Case study: Lifecycle Assessment and CBios Emission Factor for biodiesel production with variation of the biomass and eligibility criteria

Thaisa Calvo Fugineri Moreti, Alexandre Garbosa, Ricardo Alan Verdú Ramos, Paulo Sérgio Barbosa dos Santos
São Paulo State University
Brazil

Abstract

The Brazilian National Biofuels Policy (RenovaBio) has as its main purpose to promote the growth of the biofuels chain in Brazil, from more efficient and sustainable production models, culminating in the reduction of greenhouse gas (GHG) emissions, as well as contributing to the fulfillment of the commitments assumed by the country at COP-21. RenovaCalc is a tool from RenovaBio that is capable of analyzing lifecycle inventory data of background processes, added to the technical parameters of agricultural and industrial production that is informed by the biofuel producer. The final product is given through an Energy-Environmental Efficiency Grade (NEEA). In this context, NEEA, together with raw material eligibility values, will serve as the basis for the calculation of decarbonization credits (CBios). Given this context, the present study sought to investigate three scenarios: S1: excluded agricultural phase; S2: 100% eligible soy combined with the use of beef tallow, and S3: production of biodiesel with 100% soybean oil. The study compared two biodiesel producing national industries to NEEA certified by the Brazilian National Office of Petroleum, Natural Gas and Biofuels (ANP). It can be concluded that NEEA does not have a direct influence on the quantity of CBios to be traded, that is, the highest ratio is given from the eligibility (%) of the raw material chosen for the production of the fuel. Thus, scenario 2, which relied on the use of waste, proved to be 10 times more profitable compared to the other scenarios, in both analyses, due to its high eligibility. However, in terms of NEEA, it was noted that the exclusion of the agricultural phase (scenario 1) was the one that was most efficient in terms of gCO$_2$ eq./MJ. It is relevant to emphasize the importance of proper handling and practices that guarantee the traceability of the grain so that the eligibility indexes are optimized.

Keywords: Biofuel; Energy-Environmental Efficiency; National Biofuels Policy; RenovaBio; RenovaCalc; GHG.

1. Introduction

Biodiesel increasingly attracts worldwide attention as a component for mixing fuels or as direct substitutions for diesel in engines (MOURA et al., 2016; MORETI, 2018). It is a fuel similar to petroleum diesel in terms of energy content and, therefore, can be used in compression ignition engines without any adaptation (XING PENG, 2015; DELALIBERA et al., 2017).

Raw materials for the production of biodiesel are primarily categorized into four major groups: vegetable oil (edible or not); animal fat; residual oil, and algae oil (GHAZALI et al., 2015). In this sense, according to Almeida et al. (2016), in the manufacturing process of this fuel, it is essential to consider the raw material to be used as a source of oil, as this can represent up to 85% of the final price of the product.

Oils from plant sources are composed of triglycerides and belong to the lipid class. Considering the biofuels present in the energy matrix, biodiesel is a fuel obtained through renewable sources in a chemical process called transesterification (ANP, 2021).

Under the Paris Agreement, Brazil is committed to implementing measures and actions that support the achievement of the goal of reducing the greenhouse gas emissions by 37% in 2025, with reference to 2005, as well as promoting the participation of sustainable bioenergy in the Brazilian energy matrix to approximately 18% by 2030 (UBRABIO, 2018).

The creation of a National Biofuels Policy (RenovaBio), Law no. 13,576, December 2017, with the objective of stimulating the production of biofuels, such as ethanol, biodiesel, and biogas, as well as providing tax incentives based on targets for reducing the emission of greenhouse gases (GHG), fostered the need for the recognition of biofuel producing units active in reducing GHG emissions. Thus, one of the main instruments of the program is the certification of the production of biofuels, in which Energy-Environmental Efficiency Grades (NEEA) are attributed to each producing agent (primary issuer / power plant) (BRASIL, 2017).

NEEAs will reflect the association of the producer individual contribution in terms of GHG emissions in the production lifecycle, in relation to their fossil substitute and consequent mitigation of the country's total emissions. The accounting of individual contributions is made by calculating the intensity of biofuels carbon based on their lifecycle assessment (LCA) (MME, 2016).

From an LCA analysis, it is possible to identify the environmental impacts of biofuels during their lifecycle through consecutive and linked stages of a product system that encompasses from raw material (or from its generation from natural resources) until the final disposition. Then, there is a need to deepen industrial knowledge about the origin of the product (ABNT, 2014).

After analyzing the product used as raw material to manufacture the biofuel until its distribution, different grades are assigned to each producer, also called the primary emitter. The grade is higher for the producer who produces the greatest amount of liquid energy, with lower CO_2 emissions, in the lifecycle. This grade will reflect the individual contribution of each producing agent to mitigate an established amount of greenhouse gases in relation to its fossil substitute in terms of tons of CO_2 equivalent (CO_2 eq.).

The connection of these two instruments will take place with the creation of Decarbonization Credit (CBIO). In short, CBio is a financial asset, traded on stock exchange, issued by the primary emitter from the sale of biofuel. Fuel distributors will meet the target by demonstrating ownership of CBios in their portfolio.

Thus, this study sought to account for the energy and environmental efficiency of the production of soy biofuel, in gCO_2 eq./MJ, from two industrial complexes for the production of biodiesel under three different scenarios: (1) where the soy production agricultural phase is discarded; (2) where there is the use of beef tallow as well as 100% eligible soy in the production of biodiesel, and (3) where the production of biodiesel is made from 100% of crushed soy in the industrial power plant itself. From the three proposed scenarios, the Factor for issuing CBios (Fact CBios) for each primary issuer was established.

2. Material and methods

2.1 Identification of the study sites

The industrial complexes chosen to conduct the research are located in different Brazilian states and have manufacturing processes that also differ from each other. The primary emitter named (A) received authorization from the Brazilian National Office of Petroleum, Natural Gas and Biofuels (ANP) to increase the capacity of the power plant to 372 million liters per year, becoming the first Brazilian plant to surpass the milestone of one million liters per day in production capacity. This unit has a soybean bulk carrier with a capacity of 72,000 tons and a receiving sector with a capacity of 300 t / h, capable of filling soy oil in 900 ml PET bottles.

In 2018, Primary Emitter (A) processed 164,073.23 tons of soybean oil (of their own production) and 23,383.52 tons of animal fat. In addition to these raw materials, the following processes were processed to produce biodiesel: soybean oil (produced by third parties), palm oil, cotton oil, and used frying oil. The biodiesel production of that same year was 324,585.74 m^3, while the production of crude and purified glycerin was 20,206.72 tons and 20,510.24 tons, respectively.

On that same year, the primary emitter (B) manufactured 85,100 m^3 of biodiesel, with raw material inputs of 43,841.10 tons of soybean oil (of their own production); 17,443, 40 tons of soybean oil (produced by third parties); 1,956.25 tons of palm oil; 494.60 tons of cotton oil, and 4,549.73 tons of animal fat. This industrial unit is located in the northern region of the country, whose biome belongs to the Brazilian savannah, which is the protagonist of the national soy plantations.

2.2 Used tools

RenovaCalc is the tool that counts the carbon intensity of a biofuel (in gCO2eq./MJ), comparing it with the equivalent fossil fuel. Currently, it corresponds to a set of spreadsheets on the Excel® software, containing a database and a specific calculation structure for each type of biofuel.

For each biofuel route, RenovaCalc requests general identification data for the Producing Unit, information on the fulfillment of the program's eligibility criteria (related to control measures to avoid the suppression of native vegetation) and data on the production process, distributed in phases: a) Agricultural phase (when applicable); b) Industrial phase, distinguished in b.1) extraction of oil and b.2) extraction of biodiesel; and c) Distribution phase.

2.3 Data analysis

Lifecycle Analysis (LCA) consists of consecutive and linked stages of a product system, from the acquisition of raw material or its generation from natural resources to final disposal (ABNT NBR ISO 14040 : 2009). The tool will mention, in a clear and punctual way, the main contributors so that air pollution, environmental degradation, and the imbalance in the ecosystem are gradually increasing over the years and, thus, it will present the relevance of the tool to assess what are the harms caused by chemical or physical agents that are present in agriculture at national and global levels. At the end of this analysis, it will be possible to consolidate an inventory of GHG emissions generated through the association of incoming flows with GHG emissions data upstream and downstream of the process.

The information collected for the LCA will have general information of the producing unit (total area; planting system; collected straw; concealer; seeds; moisture; synthetic fertilizers; organic or organo-mineral fertilizers; fuels, and electricity), so that the carbon footprint corresponding to the impact of the production is obtained. Accordingly, the scenarios evaluated in the survey are shown in Table 1, below.

Table 1. Description of the scenarios used for evaluation.

	Primary Emitter (A)	Primary Emitter (B)
Certification	Data obtained from the original certification process	
Scenario 1	Exclusion of the agricultural phase	
Scenario 2	Soy 100% eligible + use of beef tallow	
Scenario 3	Not applicable	Biodiesel production with 100% soy oil

For the two industrial units, the agricultural and industrial data used to fill RenovaCalc can be found under the supplementary material section of this article.
The CBios emission factor is calculated according to Equation (1).

(1) $$f = NEEA * (felegible/100) * \rho * LCV * 10-6$$

where f is the factor for emission of CBios; NEEA is the Energy-Environmental Efficiency Grade (in gCO2eq./MJ); $felegible$ is the fraction of the volume of eligible biofuel (in %); ρ is the specific mass of the biofuel (t / m3); LCV is the lower calorific value of the biofuel (MJ / kg).
The CBios emission factor may be multiplied by the volume (in liters) sold by the biofuel producer in order to obtain the quantity of CBios that each invoice will be entitled to issue.

3. Results and Discussion

When observing the NEEA of Primary Emitter (A), if the agricultural phase of the process is excluded, there is a significant increase in the Energy-Environmental Efficiency Grade of 49.6 gCO2eq./MJ (certified) to 79.6 gCO2eq./MJ. According to Matsuura et al. (2018), the agricultural stage contributes significantly, in a negative way, to GHG emissions from biofuels, which are mainly related to the production and use of agricultural inputs. In this sense, the most important GHGs generated in agricultural activity are methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O). Also, according to the authors, the main practices that impact GHG emissions in the agricultural phase are the use of limestone, the use of nitrogen inputs, the burning of agricultural residues, and the consumption of fossil fuel in mechanized operations, in addition to land use, land-use change, and forestry (LULUCF).
In contrast, when disregarding the agricultural phase, the portion of eligible soy is discarded, causing Total Eligibility to decrease from 18.8% to 7.30% and, consequently, the CBios Emission Factor is 1.926768 x 10-4, which is less than the previous of 3.091954 x 10-4, (a 62.32% decrease). Thus, it can be noted that it is not recommended to exclude the agricultural phase from the scope of the LCA for the purposes of the RenovaBio Program since Total Eligibility is lost, even with the NEEA increase, causing the CBios

Emission Factor to decrease.

The decrease in CBios emission factor even with the increase in NEEA can also be observed in Primary Emitter (B). In a simulation in which the agricultural phase was removed from scope, NEEA increased from 50.9 gCO2eq./MJ to 76.9 gCO2eq./MJ. However, in terms of Total Eligibility, there was a decrease from 17.05% to 6.57%, thus making the Emission Factor lower, from 2.877635 x 10-4 to 1.675272 x 10-4 (down 58.21%).

Another important evaluation to be analyzed through comparisons between Primary Emitters (A) and (B) is in relation to the use of bovine tallow for the production of biodiesel (Scenario 2). In this case, all ineligible soybeans were replaced by eligible soybeans (100%) and all ineligible oils (third party soy oil, palm oil, cotton oil, corn oil) were replaced with beef tallow (100% eligible). It can be concluded, from this analysis, that in relation to the certified grade (49.60 gCO2eq./MJ), Primary Emitter (A) would have, in this proposed scenario, an increase in NEEA due to the increase in the eligibility of raw materials (56.10 gCO2eq./MJ). However, it can also be noted, with this simulation, that although the NEEA was higher when disregarding the Agricultural Phase (79.6 gCO2eq./MJ), the CBios Emission Factor was lower (Scenario 1).

Still regarding the Primary Emitter (A), when comparing Scenario 2 to the other analyses, the CBios Emission Factor went from 10-4 (certificate - Scenario 1) to 10-3. In other words, due to the high percentage of eligibility, the CBios Emission Factor became 10 times bigger in this second scenario.

The relationship between the CBios Emission Factor and eligibility was observed by Sabonaro, Sabonaro and Carmo (2019), who affirmed the importance of Biofuel Producers in fulfilling the three eligibility criteria[1] , in addition to joining the program, in order to be entitled to commercialization of CBios. In short, Moreira et al. (2018) explain that the eligibility proposal is based on the legitimation of risk management tools, with a focus on controlling the direct conversion of native vegetation areas and the expansion of biofuels to environmentally sensitive areas, through national land use planning instruments that are already in place, without the need for direct or indirect LULUCF quantification.

From the carried-out simulations, it is possible to state that NEEA is related to three main processes related to the production of biodiesel: 1) the agricultural exploration of the raw material;

2) oil extraction, and 3) the production of biodiesel, specifically. However, as already shown in the previous results, the eligibility of the raw material directly influences the grade. Thus, the increase in the eligibility of the raw material influences NEEA, which, in turn, does not have as much influence on the CBios Emission Factor. That is, the financial gain from the commercialization of decarbonization credits comes with the increase in eligibility.

According to the Brazilian Energy Research Company (EPE, 2018), through Technical Note n. 26, which deals with the socioenvironmental analysis of energy sources, it is worth highlighting the importance of producing biodiesel from the reuse of waste such as beef tallow and used frying oil. Through this process, value is added to these tailings, in addition to offering a more suitable destination for the product, once waste starts to be used as raw material for the production of biofuel. In this sense, Ramos et al. (2019)

[1] All certified production must come from an area without deforestation after the date of promulgation of the RenovaBio law (December 26, 2017); 2. The entire area must comply with the Forest Code, through the regularization of the Rural Environmental Registry (CAR); 3. Sugarcane and palm production areas must comply with the agro-ecological zoning of sugar cane and oil palm, defined by Federal Decrees 6,961 and 7,172, respectively.

evaluated the case of a hypothetical power plant in which there was an exchange of biomass used as raw material, from soy to beef tallow, and noted that NEEA received an efficiency increase of 68%.

The same Scenario 2 previously described (100% eligible soy + use of beef tallow) was calculated for Primary Emitter (B). In this case, the exchange of raw materials resulted in an increase in NEEA, in addition to the great increase in the eligibility of this case (from 17.05% to 98.58%), also caused the CBios Emission Factor to increase from 10-4 to 10-3, similar to what happened in the case of Primary Emitter (A) (Figure 1).

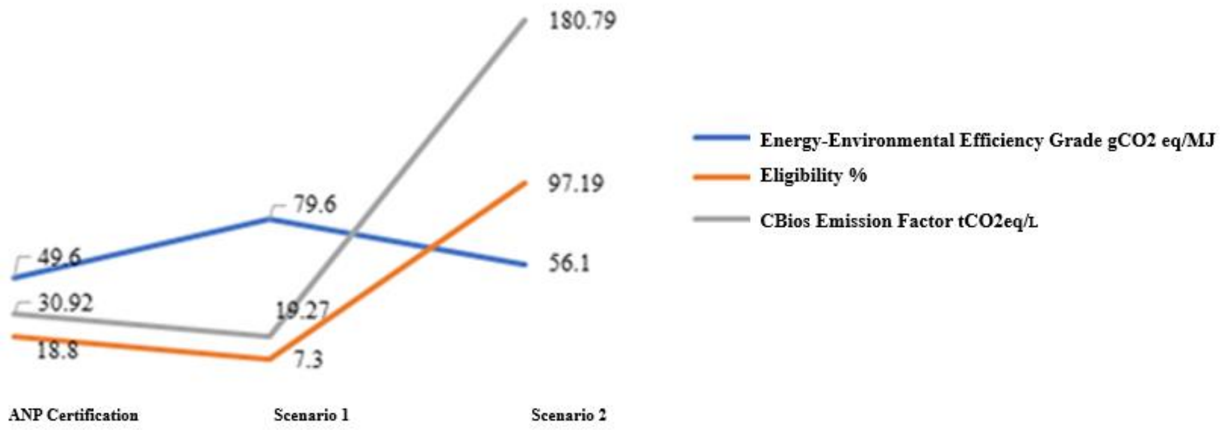


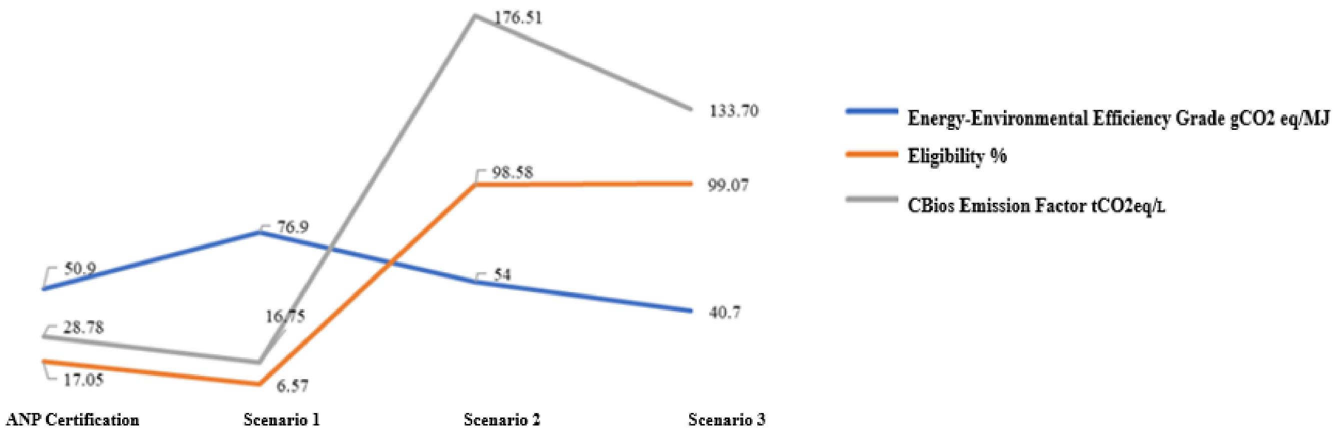
Figure 1. Analysis of the scenarios proposed for the Primary Emitter (A)[2].

Knowing that the highest eligibility (%) presented in Scenario 2 provided the highest CBios Emission Factor for the Primary Emitter (A), Resolution ANP 758/2018 (more specifically, Annex I, Item 3.2) states that bovine tallow is a material considered as waste for RenovaBio purposes. Therefore, waste, by its definition, is exempt from environmental load and, in the LCA, only emissions that occur after the generation of the waste are considered, from the stages of collection and transportation. This means that waste, as a raw material for biodiesel production, may have its eligibility set at 100%.

For Primary Emitter (B) (Figure 2), it was also possible to simulate a scenario where biodiesel was only produced from soybean oil from the crushing of the plant itself. For this scenario, it was considered that the plant was in industrial activity 300 days / year, crushing 2,500 tons of soybeans per day, and considering that soybeans would be 100% eligible. It can be observed, in this case, that the NEEA was lower than the grade of the referred certified unit, since the NEEA of the certification was 50.9, whereas that of this scenario was 40.7. However, in the certified NEEA, the eligibility achieved was of 17.05% and, considering the 100% eligibility of the soy proposed in this scenario, the Total Eligibility of this situation would be 99.07%, providing a CBios Emission Factor of 1.336996 x 10-3, much higher than what was certified (2.877635 x 10-4).

When analyzing Figures 1 and 2, it is possible to notice that companies looking for more energy-efficient ways of producing biomass and biofuels will have a greater NEEA and, consequently, more CBios if it is possible for them to reach high eligibility indexes.

[2] Emission Factors were multiplied by 100,000 to simulate the graphs.



4. Final Remarks

It is possible to conclude that the Energy-Environmental Efficiency Grade (NEEA) is an important product of the Brazilian National Biofuels Policy and is capable of translating the efficiency of a company's agricultural and industrial processes. However, what has the greatest impact on the CBios Emission Factor is the Eligibility of the raw material, that is, the greater the quantity of eligible raw material submitted to the process, the greater the return obtained through decarbonization credits. It is also worth pointing out that the use of soy has a direct impact on NEEA and that the greater the quantity of soy used in the process, the lower the Efficiency Grade of the producing industry. Thus, it is suggested to invest in waste as a source of raw material for the production of biodiesel, such as used frying oil as well as beef tallow, free of environmental burden

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Appendix

	Unit of measurement	Primary Issuer(A)	Primary Issuer (B)
General information			
Total area	**hectare**	101,636.80	23,561.38
Total production (wet base)	**ton soy**	353,692.59	73,865.09
Quantity of soy purchased by the plant	**ton soy**	173,870.35	32,866.90
Correctives			
Dolomitic limestone	**kg/ton soy**	546.60	546.60
Plaster	**kg/ton soy**	90.60	90.60
Seeds			
Seeds	**kg/ton soy**	39.16	39.16
Synthetic Fertilezers			
Urea	**kg N/ton soy**	5.55	5.55
Simple Super Phosphate (SSP)	**Kg K2O/ton soy**	58.77	58.77
Potassium Chloride (KCL)	**Kg K2O/ton soy**	51.80	51.80
Fuels and electricity			
Diesel (B10)	**L/ton de soy**	17.36	17.36
Effective Soybean Processing	**ton**	809,162.16	198,396.93
Soybean transport distance	**km**	23.55	9.84
Oil yield	**Kg/ton soy**	203.94	220.98
Bran yield	**Kg/ton soy**	762.74	758.93
Fuels and electricity			
Mains electricity-mix	**KWh/ton soy**	33.26	13.18
Diesel -B8	**L/ton soy**	0.08	N/A
Diesel -B10	**L/ton soy**	0.31	0.02
Fuel oil	**L/ton soy**	0.56	N/A
Wood chip			
Quantity (wet base)	**Kg/ton soy**	39.40	233.09
Moisture	**%**	35	35
Transport Distance	**km**	159.89	345.00
Firewood			
Quantity (wet base)	**Kg/ton soy**	27.91	8.87
Moisture	**%**	45.00	45.00
Transport Distance	**km**	49.83	110.26

Own soy oil			
Quantity of processed soy oil	**ton oil/year**	164,073.23	43,841.10
Transport distance	**km**	-	-
Are any fractions eligible?	**Yes/No**	No	Yes
Third party soy oil			
Quantity of processed soy oil	**ton oil/year**	99,697.70	17,443.40
Transport distance	**km**	361.31	963.76
Are any fractions eligible?	**Yes/No**	No	No
Palm oil			
Quantity of processed palm oil	**ton óleo/ano**	4,660.98	1,956.25
Transport distance	**km**	1,809.28	1,244.79
Are any fractions eligible?	**Yes/ No**	No	No
Cotton oil			
Quantity of processed cotton oil	**ton oil/ year**	7,204.00	494.60
Transport distance	**km**	660.89	1,338.40
Are any fractions eligible?	**Yes/ No**	No	No
Other vegetable oils			
Quantity of processed other vegetable oils	**ton oil/year**	5,342.81	N/A
Transport distance	**km**	1,093.98	N/A
Are any fractions eligible?	**Yes/No**	Não	N/A
Used frying oil			
Total input of used frying oil	**ton oil/year**	67.67	N/A
Transport distance	**km**	-	-
Animal fat			
Total input of animal fat	**ton fat/year**	23,383.52	4,549.73
Transport distance	**km**	167.37	555.57
General information			
Production route	**N/A**	Methyl	Methyl
Biodiesel production	**m^3/year**	324,585.74	85,100.71
Purified glycerin production	**ton/year**	20,510.24	N/A
Crude glycerin production	**ton/year**	20,206.72	10,370.32
Inputs			
Methanol	**ton/year**	38,010.94	8,632.29
Sodium methylate	**ton/year**	6,255.84	1,463.95
Sodium hydroxide	**ton/year**	381.01	18,299.50
Fuels and electricity			
Mains electricity-mix	**MWh**	25,167.21	1,518.53
Diesel -B8	**m^3/year**	55.58	0.23

Diesel -B10	**m^3/year**	206.37	1.27
Fuel oil	**m^3/year**	372.27	37.11
Wood chip			
Quantity (wet base)	**ton/year**	25,996.14	18,727.11
Moisture	**%**	35.00%	35.00%
Transport Distance	**km**	159.89	345.00
Firewood			
Quantity (wet base)	**ton/year**	11,278.14	1,271.00
Moisture	**%**	45	45.00
Transport Distance	**km**	49.83	110.26
Sugarcane bagasse			
Quantity (wet base)	**ton/year**	27,667.34	N/A
Moisture	**%**	50.00%	N/A
Transport Distance	**km**	185.31	N/A
Fuel transport mode			
Truck	**%**	100	100