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USO DO BIODIESEL EM MOTORES DE COMBUSTÃO: ANÁLISE DO IMPACTO AMBIENTAL E ECONÔMICO

USE OF BIODIESEL IN COMBUSTION ENGINES: ANALYSIS OF THE ENVIRONMENTAL AND ECONOMIC IMPACT

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Resumo:. Este artigo apresenta uma proposta de modelo de simulação computacional para diminuir os gastos, poluição da água e emissão de CO2, relativos a coleta de resíduos sólidos urbanos na região central do estado do Rio Grande do Sul. Será utilizando diversas porcentagens de biodiesel, que junto a porcentagens de diesel formará um combustível com menor impacto ao meio ambiente. Para a definição de variáveis e suas inter-relações utilizou-se por base teórica as pesquisas bibliográficas e observações do processo da geração dos resíduos pós-uso do óleo de cozinha. Para avaliar a possibilidade de geração de um novo combustível, que poderá ser utilizado pelos veículos responsáveis pela coleta de resíduos total de municípios na região central do estado, foram gerados dois cenários: um cenário baseado na situação atual de coleta dos resíduos e, outro, denominado cenário proposto, com melhores práticas de reaproveitamento. Os resultados obtidos através da simulação demonstram que além da grande redução do impacto ambiental, o processo de reciclagem traz um significativo ganho econômico em função da redução de custos com a aquisição de combustível. O horizonte de tempo simulado foi de 10 (dez) anos e foi utilizado o software Vensim para o desenvolvimento da simulação.

Palavras-chave:. Biodiesel; Dinâmica de Sistemas; Meio Ambiente e Sustentabilidade Econômica; Sustentabilidade; Estudo de caso.

Abstract:. This paper presents a proposal for a computer simulation model to reduce costs, water pollution and CO2 emissions, including the collection of urban waste in the central region of Rio Grande do Sul state. Will use various percentages of biodiesel, which together diesel percentages will form a fuel with less impact on the environment. To define variables and their interrelationships used by theoretical bases such as bibliographic research and applications of the cooking oil post-use waste generation process. To evaluate the possibility of generating a new fuel that can be used by vehicles used for total waste collection in the central region of the state, two scenarios were generated: one scenario based on the current situation of waste collection and another; proposed scenario, with best reapproval practices. The results obtained through simulation show that besides the great reduction of environmental impact, the recycling process brings a significant economic

gain due to the reduction of costs with fuel acquisition. The simulated time horizon was 10 (ten) years and was used by Vensim software for the development of the simulation.

Keywords:. Biodiesel; Systems Dynamics; Environment and Economical Sustainability; Sustainability; Case study.

1. INTRODUÇÃO

One concern that has received much attention is the disposal of waste because of all their environmental implication that affects the quality of life of the population. The is a big concern for the proper disposal of solid waste. According to Oliveira and Sommerlatte (2009), this destination is the largest problems of modern society, due to the urban waste composition have been modified in last year and their production increased expressively.

According to Brazilian Association Vegetable Oil Industry, are produced nearly 3 billionof oil liters by year in Brazil, but only 2,5% of all oil is recycled and reused in the productive range. In the sometime that the cooking oil is a dangerous product against the environment when it is discarded by inadequate way, also is on excellent sub product to the productive range (OLIVEIRA AND SOMMERLATTE, 2009).

According to the focus the fried oil resting represents a big potential after this input. This raw material can be purchased in cafeterias and industrial kitchens, where companies are frying food products in sewers where the supernatant cream is rich in fatty matter and wastewater of food industry processes. Thus, the recycling of solid waste, such as cooking oil, generates energy economy, creates jobs and increases public awareness of environmental issues.

In this scenario, to be an excellent byproduct, post-use cooking oil can receive a correct destination through its reuse and recycling. The production of biofuels from cooking oil would provide numerous benefits to society as there would be a decrease of several problems related to their disposal, but in addition to these benefits, there would still be the possibility of increasing the production and use of biofuels, contributing to the environment by reducing the emission of greenhouse gases (BARBOSA and PASQUALETTO, 2015).

In this context, this paper presents a proposed reuse model of cooking oil for the generation of biodiesel to replace totally or partially the diesel used in the collection trucks in a region.

2. BIODIESEL

Biodiesel has been used in several parts of the world, as it has characteristics similar to those of diesel oil, mainly in the composition of docet. Typically it is derived from vegetable oils through mixing, emulsification, thermal cracking and transesterification methods, this process causes the transesterification of vegetable oil with alcohol leading to the production of Fatty Acid Methyl Esters. (VALENTINO ET AL, 2011)

However, biodiesel is presented with five components of methyl esters characterized by a longer carbon length than conventional diesel, which is the increase in the viscosity of the product, leading to difficulties in the functioning of the filter. It is also noted that biodiesel degrades up to four times faster than diesel (CHIU ET AL, 2004).

Due to the negative factors, it is worth mentioning that biodiesel is renewable and the oxygen content reaches about 10% more by weight than diesel, causing the reduction of emissions from unburned hydrocarbons (UHC), carbon monoxide (CO) and particles (PM) in modern engines (ZENG ET AL., 2008).

The performance, combustion characteristics and emission of biodiesel engines, reveal that the lower heating value of biodiesel produces less release of liquid heat, lower emissions of exhaust gases such as HC, CO and PM and greater CO 2 and NOx were produced, due to enriched oxygen and a higher number of cetane that improve the combustion and performance of biodiesel as a fuel (TAMILSELVAN ET AL., 2017).

2.1 PNPB: PROGRAMA NACIONAL DE PRODUÇÃO E USO DE BIODIESEL (NATIONAL BIODIESEL PRODUCTION AND USE PROGRAM)

The National Institute of Technology (INT), in Rio de Janeiro, has been carrying out its studies and tests with alternative and renewable fuels since the 1920s, but only in the 1970s INT in partnership with IPT (Institute of Technological Research) and CEPLA (Executive Committee of the Cocoa Crop Plan), developed vegetable oil projects as fuels individually (MENDES, 2015).

On January 13, 2005, Law 11,097 was created, which mandates the minimum addition of a percentage of biodiesel to diesel oil sold to consumers, the percentage nowadays is 5%. Industrial development demonstrates mobilization in the private sector, since the government

is struggling to adapt to this marked increase in capacity, proof of this is the biodiesel auctions (BIODIESELBR, 2007/2008).

The National Program for the Production and Use of Biodiesel (PNPB) was launched by the Federal Government in 2004, with the objective of stimulating the production of biodiesel in a sustainable manner, promoting social inclusion, competitive prices, quality and supply. Figure 7 shows the minimum percentages of biodiesel added to diesel from the creation of the PNPB until 2010. On November 1, 2014, the National Congress approved a minimum mixture of 7% biodiesel, this measure was approved by the president of the Brazil in March 2016. In 2020 the mandatory percentage is 12 percent according to the Ministry of Mines and Energy.

The PNPB is a public policy built on the combination of laws, decrees and other legal and regulatory documents that together make up the program. It focuses on the diversity among the government involved, requiring the participation of several actors, whether public or private.

The main guiding guidelines of the program can be described as follows:

- The main guiding guidelines of the pro • Introduction of biodiesel in the energy matrix in a sustainable manner, diversifying national energy sources, increasing the participation of renewable sources and contributing to energy security; gram can be described as follows:
- Employment and income generation, due to the production of oilseed raw materials, mainly for family farming;
- Reduction of regional economic and social disparities, enabling greater development in the North and Northeast regions and in the country's semiarid region;
- Decrease in pollutant emissions and health expenses related to pollution;
- Savings on foreign exchange by reducing diesel imports;
- Concession of tax incentives and implementation of public policies that provide sustainability to the production of biodiesel;
- Flexible regulation, allowing the use of raw materials and diversified technological production routes.

2.2 USE OF BIODIESEL IN COMBUSTION MOTORS

In mixtures of diesel oil and biodiesel at proportion until 10% occurred a reduction of fuel consumption and in bigger proportions than this occurred an increase consumption reaching to 4.77%. When the biodiesel is used pure. This increase in consumption is justified by the difference into warmful power of biodiesel, that in general it is presents the lowerwarmful power diesel oil.

Agarval and Das(2001) observed that the use of fuel B20, resting in a diesel motor, had the better performance between all analysedmistures, with 2,5% benefit into maximum thermic efficiency and a significative reduction in the theor of smoke.Dorado et al (2002) conclude that the diesel motor, analysed without modification functioned satisfactionaly with 10% of biodiesel from frying oil and 90% diesel oil Ferrari et al (2005) accomplished tests using 25% biodiesel and 95% conventional diesel (B5) during a year, having roamed about 19.240km at normal working conditions and observed the vehicle presented normal performance with reduction of smoke issuing. Moreover, in the period of tests were not did repairs in motor,so the researchers conclude the transesterificade vegetable oils adopted perfectly to the motor.

2.3 EMISSION OF NITROGEN OXIDE AND EFFECTS AT HUMAN HEALTH

More than 95% of NO_2 emissions (nitrogen dioxide) are as nitric oxide form, the gas which is introduced in the environment mainly by gases from muffler cars. Is shapped, above all, due to the hight temperature into combustion chamber motors and does not present damage to the health but reacting with oxygen(O_2) form dioxide of nitrogen(NO_2).NO_2 is a poison gas once the attacked person feels burning eyes, nose and mucous membrane in general. In the presence of expressive reduction from different gases emission, which motivate greenhouse effect, like carbon dioxide, the biodiesel is already one of the main fuel of renovating source. Used by several countries.It fasten oneself in the production stage around 80% dioxide of carbon emitted in the combustion (NOGUEIRA andDARBELLO 2009).The advantage from reduction of CO_2, due to burn a cleaner fuel can be estimated around two ton and half of CO_2 by tons of biodiesel. At European market,the carbon credits are negociated for about u$ 9.25 for ton according Nogueira and Darbello (2009).

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2.5 IMPACTS CREATED BY COOKING OILIN THE ENVIRONMENT AND THE IMPORTANCE AS SOURCE TO BIODIESEL PRODUCTION

The discard of cooking oil into comum garbage causes a strong problem to the world, respecting the oil decomposition generates a hightmetane emission in the atmosphere, that contributes to the worldly warmfull, this negligence in the discard, can have hight cost to mankind. Other problems occasioned by the discard in bottons of a sieve is derivated from oil and organic substance mixture, causing this way, choking at grease boxes and daming the flowing off other solid rests throughtsanitaries and pluvial drains.

The cooking oil when is thrown out wrongly(usually on the sink) can cause large environmental impacts normally his oil dropps to drain net but also water table.Also corroborating with these authors, many person and shops put these used oil into drains, due to the unknowledge about the damage that this kind of posture can cause to the environment. The same can be used as an alternative source to biodiesel production, because any grease acid can supply as raw material to it is. Although, neither these sources enable the industrial process that equilibrates its productions economicaly. To Freitas et al (2010), the biodiesel production through the cooking oil adds hight value to the companies that use this process and for the community, because everybody make use some oil to cooking or make other activities, is important highlights the environmental impacts will be avoid.

3. RESEARCH METHOD

The research method for the model development is based on the methodology for modelling and simulation presented by Law (2015), which consists of the following steps: (1) exploratory studies in technical articles, technical reports and observations of the environment where data were collected and through these data, the research problem is defined and

structured; (2), solution development through the construction of formal models capable of representing the problem (variables and their relationships); (3) implementation of the computational solution, using the simulator Vensim (Ventana Systems, 2016); (4) the verification and validation (V&V) of the solution through the lab testing and analysis of historical behaviour (with the data that were available).

The System Dynamics methodology, developed by Jay Forrester in the 1950´s, is a technique that combines flows and stocks for decisions' makers to assess the consequence their decision before taking them (Daelenbach and McNickle, 2005). Ford (2009) defines the systems dynamics as a method that combines flows and stocks in a computational structure to be simulated. Several authors use this methodology for the analysis of issues related to the Environment (FORD, 2009; GOLROUDBARY and ZAHRAEE, 2015). With respect to the use of Systems Dynamics for assessment of remanufacturing, the model developed by Poles and Cheong (2009) evaluates which possible improvements are in the phases components of the remanufacturing process so as to reduce the total cost of production. The model of Vlachos et al. (2007) uses this methodology for the capacity planning of the supply chain to the remanufacturing, taking into account not only the economic aspects, but also the environmental aspects inherent to the process.

4. VARIABLES AND THE SIMULATING MODEL.

Having as basement the importance from cited process to environment preservation also environmental earnings caused to these, in that research seeks the development of a simulating model, which will allow as much the environmental managers as that from rest areas, evaluate recycled/reusing policies of cooking oil, where evaluated the environmental earnings, aiming the sustainable development, create by this, as well as the economic benefit from process.

In the model, the environmental earnings that will be evaluate in the future, will the reduction of water pollution also CO_2 emission and relative to financial advantage, the cost-cutting with the whole collect in the central region of state.The model was developed searching simply the user- computer interaction, in order that this kind of analyses(what-if) usual at simulating models, be faster and simple execution.

To the definitions of variable from simulating model, were accomplished interviews with expert area, where examined all systematic from studied issue, academic and governmental papers of resting area. BNDES (2004), CONAMA (2011), Oliveira et Filho

(2014) e Zucatto et al (2013) complementedthisstage.The selected variables, which, influence on total values from reusing of cooking at biodiesel production and using as fuel are:

(1) Oil to recycle=Total collect
(2) Reduction of water pollution=18400*Oil to recycle
(3) Total diesel=Diesel by year
(4) Generate biodiesel=Oil to recycle *Rate use oil
(5) Glicerinageneration=0,1 * Generated biodiesel
(6) Generation CO_2= (2.669 *total diesel)-(2.669*0.85) * Generated biodiesel
(7) Economy=(Medium biodiesel intake *Generated biodiesel)+(Diesel cost*Total diesel)/(Medium Diesel intake)-Biodiesel cost

Picture 1-Math formulating of developing simulating model.

- The oil to recycle variable achieved from total collect variable, is the variable that has the amount of oil collected for about 10 years with the necessary variations to produce the wanted biodiesel, it will present at equation(1) present at equation model from picture 1;
- The reduction of water pollution variable is achieved by the product of residual oil quantity by polluter potential from each liter poured unadequately, so, 18400 water liters by oil liters. Thevariable is described at equation(2) of equation model presented at picture 1;
- The total diesel variable is achieved by the variation of diesel by year variable, where will be simulated different values this fuel in a period of 10 years. The equation(3) of equation model represents the described variable;
- The generate biodiesel variable is achieved by the product of oil to recycled variable by rate use oil variable, which represents how much we take advantage of recycling the residual oil. The described variables are represented at equation(4) of equation model;
- The generation Glycerin variable represents the total of glycerin generate by the biodiesel production from recycled cooking oil. The rate of generation is 10% of total produced biodiesel. Is important highlight, that variable was not the main purpose of this research, but from glycerin can be produced other products. This fact demonstrates the importance of reusing oil not by environmental earnings only, but also financial gains.The variable is described at equation(5) of equation model represented at picture 1.
- The generation CO_2 variable is achieved by the subtract from the quantity of diesel liters for 2.669 by the product of biodiesel quantity generates by quantity of CO_2

emission for common diesel liter (2.66kg/CO_2). The equation (6) of the equation model describes the variable;

- The economy variable represents the financial gains from reusing of cooking oil is achieved making use the medium biodiesel consumption variables(that represents the estimated cost by produced biodiesel liter).Generation biodiesel, diesel cost and total diesel.The variable is described at equation(7) of the equation model presented at the picture1.

5. AUTHENTICATE AND EXPERIMENT OF MODEL

The model was authenticated on different stages, firstly were used data took from scientific article studies, technical manuals concern to the solid resting management area , also, achieved with the resting management expert, here is pointed out the nominal validate, for as much will make use experts to determine the important variables in the propose pattern.

Next, in the second validate stage, as the introduction of Vensim simulate (VENTANASYSTENS, 2011), will make use current data about the RSU collect in the central region of RS, with the purpose to verify the integration between all variables composed in model, as well as ,the generate results, since will evaluate the exits produced by simulating model from real data.

In the last stage of validate, to the experiment structure, will make use data and real rates concerning to biodiesel using, moreover rates concerning to the increase of diesel value according the site oglobo.com in order to, will generate scenery to be simulate at the model. The detailment and quantification of rates for each simulated scenery are following present at subsection 5.1.

5.1 SIMULATED SCENERIES IN MODEL

The reason of transformation from cooking oil to diesel, by methanol inserction is 80% (OLIVEIRA and SOMMERLATE, 2009), although other references present divergences in this value (ZUCATTO et al 2013). As subproduct in the process there is also the glycerin generation, corresponding for about 10% (YANG et al 2012).

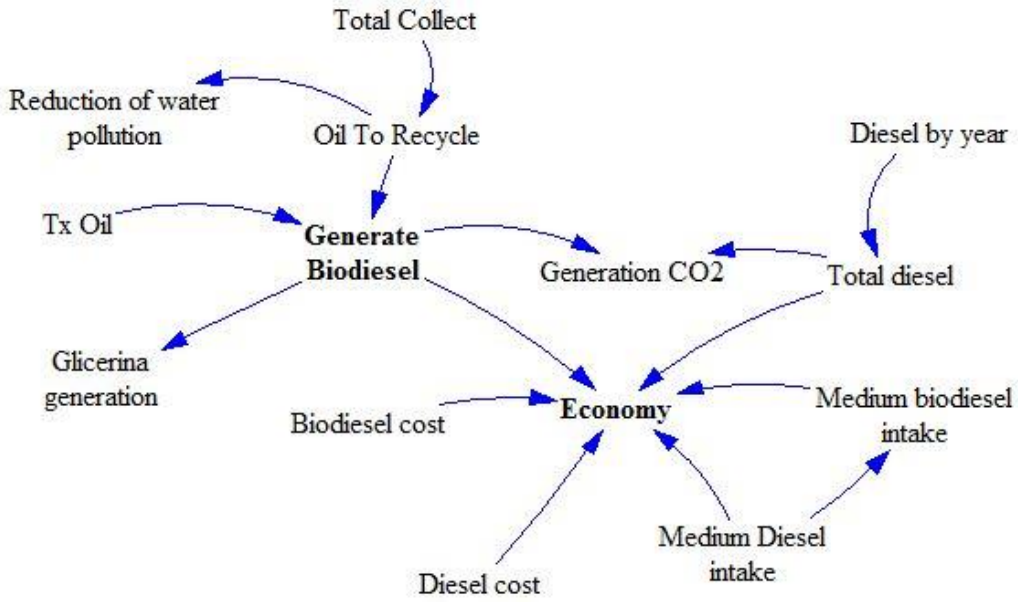
In Brazil, the legislation establishes since 2013 that common diesel must be present 5% of biodiesel, from this mixture would be add up to 20% of biodiesel or B20, that is the maximum mixture endured by diesel motors without adaptation. This way, to each B5 diesel liter, would be add 190ml produced biodiesel. Further the generate economy by reduction

from biodiesel purchase, there are other supplement advantages which would be achieve for biodiesel using , one of them is the environmental impact resulting from inappropriate discard, once the using of biodiesel helps on decrease of carbon dioxide emission in the atmosphere.

According data from CONAMA resolution (2011), is admitted until 50 mg/l of vegetable oils and animal grease at efluents. The recommended density to cooking oil is 0,920 according ANVISA. From these data, we cancalculate the environmental impact caused by oil liter wrongly discard in the environment. From this relation realize that each liter oil needs 18400 water liters to dispersion.

This value is inferior to indicated values at Oliveira and Sommerlatte (2009) andZucatto et al (2013), but, do not identify support to cited values into such references.In the pattern which will be develop, the variable of larger impact to the sensibility model is the Economy.

This is affected by variation in the resting collect directly, at once will be done a cost collect study during 10 years, changing the rates such as diesel quantity and biodiesel quantity used on the collect. The picture 2 shows graphly the propose pattern, that is, the variable parts of the system, as well as, their interrelations.



Picture 2. Proposed simulation model Source:
Authors (2019)

The production cost of, biodiesel is largely influenced by the used raw material cost. The comprehended costs concerned to the process also other products necessary to chemistry reaction are estimated for about R$ 0,30 for oil lit, that is nearly by R$ 1,05 for biofuel liter B 100.

It`s know the common diesel discharges 2.669 kg/CO_2 for liter of burned fuel, the diesel B5, that is, the pattern diesel availables in Brazil currently presents a pollution reduction for about 15,28%. This way is possible mensurate the CO_2 reduction, one of the main gases of greenhouse effect, in relation to decrease of common diesel oil using we study also, the fuel B10, which will be composed by 10% of biodiesel. Based on some information were projected two sceneries: one called current scenery with rates. Where is represented the nowadays collect using diesel, applying the increase rates diesel during the proposed ten years, whereas in the scenery proposed with rates, will use the biodiesel and diesel mixture also the reduction rate of diesel using.

The proposal is decrease the environmental impact caused by generate restings. That can be achieved through a more efficient transformation process or else the generation reduction these restings, situation present in this scenery.

5.1.1 CURRENT SCENERY WITH CURRENT RATES VARIATION.

To do simulating in this scenery were used data and rates observed during 2015, although it is considering the variation (increase or decrease) these in a period of years. In this scenery was simulated the collect using diesel only during ten years, with the fuel having 5% biodiesel in it is composition. At table 1 are showed the values that aid to construction of simulating model.

5.1.2 SCENERY B10

To do simulating in this way it made use data and rates observed in 2015. Although considered the using of 10% biodiesel mixed to diesel structuring this way the B10 fuel. In this way was simulated using this mixture for about ten years.

5.1.3. SCENERY B20

To do simulating in this way made use data and rates observed in 2015, although it considered the using of 20% biodiesel mixed to diesel, structuring this way the B20 fuel. In this way was simulated the collect using the mixture during ten years.

Variable	SimulatedScenery
Utilization Rate Of the oil in the process Recycling	Fixedat 80%.
Diesel Cpst	R $ 2.89 in year 1, year 2 to 10, increase of 2.7% per year.
ProductionCost (Biodiesel)	R $ 1.03 in year 1, year 2 to 10 increase of 4.5% per year.
Yield Biodiesel(B20)	94% of ordinary diesel oil yield.
Diesel OilConsumption	3,03 Km/l.
GenerationofGlycerin	Fixedat 10%.
PollutionCO_2 Diesel Oil	2,669 Kg / CO_2.
ReductionCO_2 (B20)	15.38% in relation to Diesel Oil. 18400 liters of water.

Table 1: Variables and Values Used in Scenarios
Source: Authors (2019)

6.2 EXPERIMENT

After the way definition to accomplish the experiment using the model will execute the simulations. As cited before, the data used on three ways were collected from a company that makes a collect of the cities as São Martinho da Serra, Agudo, RestingaSeca e Faxinal. Located at central region of Rio Grande do Sul, whole collect is conducted to sanitarium embankment of Santa Maria city. To executesimulatings was used the vensim simulate (VENTANA SYSTEMS, 2011) in a worksatation with intel core processor (i5) e 8gb with memory RAM.

6.3 RESULTS

In this section will present the modeling results concern to simulation applied in this research,it accomplished a proposal creation to reusing the burning cooking oil as raw material. To consummate the analyses from generating results by simulating model it took into account the combination of biodiesel using and diesel, with the purpose be used on seven

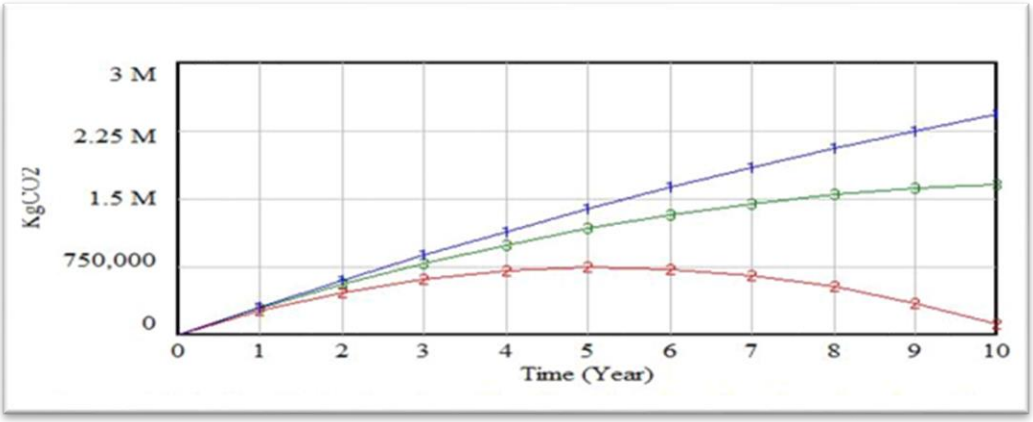
vehicles which make the resting urban collect at some districts of central region in Rio Grande do Sul, the table 2 represents the monthly and annual values of compounds used at simulating.

	AnnualOil	AnnualDiesel	MonthlyOil	MonthlyDiesel
Currentscenario (liters)	7.500	114.000	625	9.500
ScenarioB10(liters)	15.000	108.000	1.250	9.000
ScenarioB20(liters)	30.000	96.000	2.500	8.000

Table 2: Scenario Values
Source: Authors (2019)

At simulating period it observed a large difference on CO_2 emission, the picture 3 presents the results of 3 simulating sceneries, the current scenery generates for about 1,448 ton of CO_2 per year, whereas the positive scenery to environment, the B20 scenery generates for about 672 ton of CO_2 per year, a difference nearby 53,36% in the year ten. The B10 scenery has a polluter potential about 32,75% lesser when compared to current scenery, once that the B10 scenery emits on average about 974 tons per year.

Picture 3.CO_2Emission

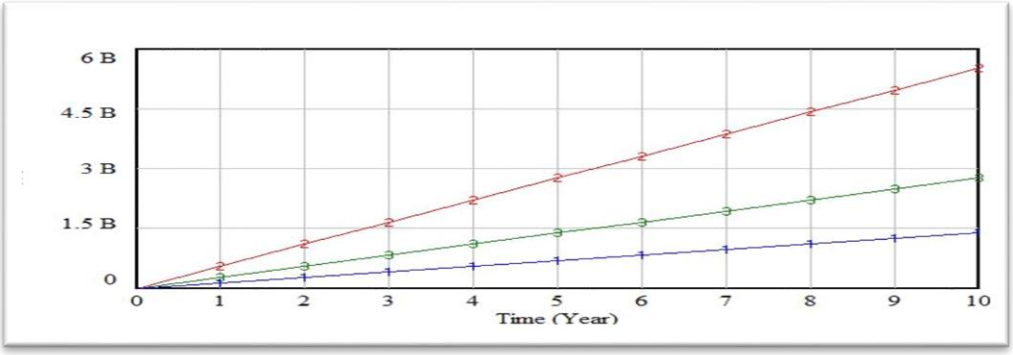


***Note:** Blue represents the current scenario; Green represents the scenarioB10; Red represents the scenarioB20.

At patterned sceneries it took into account the cooking oil recycling, observing its environmental impact. The picture 4 presents the water pollution variable, an event resulted by inappropriate discard of burning oil normally, in view of the best scenery to the

environment, it observes the B20 scenery presenting an increase pollution for about 3 billion of liters by year, when compared to the worst scenery (current scenery), it has 75%(about 22 billions of water liters)of decreasing water pollution at the end of the ten year. It verifies the B10 scenery with a reduction of water nearby 50% smaller than the reduction contained at current scenery.

Picture 4.Waterpollution reduction



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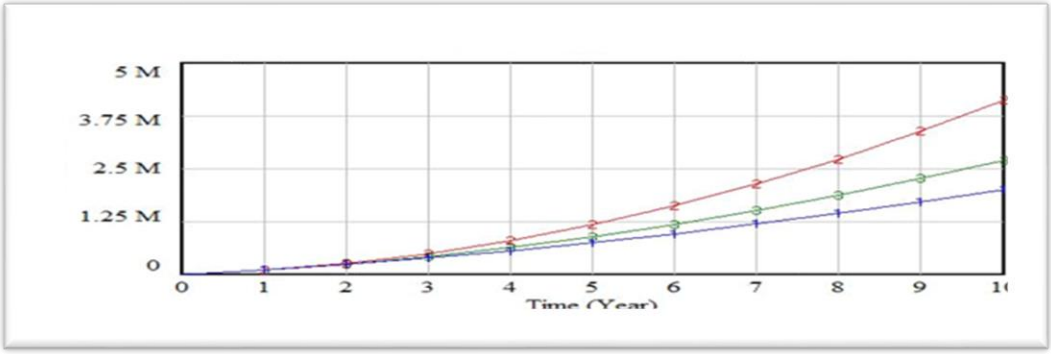
The reusing of cooking oil at B20 way, generates more than R$ 13,949 for month economy already substracted the involved costs at biodiesel production, it could observe at picture. The increase of economical difference between the B20 scenery and current scenery, adding in the tenth year a difference for about 44,41% it noticed through picture 5, the B20 scenery presenting a respectable progress at economy of 7,45% by year.

Picture5. Economy



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7. FINISHING CONSIDERATIONS

The presented results were achieved by simulations did with the vensim software but is possible assert that besides reduction the environmental impact and the generate economy to the scenery of ten years justify the application from results generate through the model.

Among main results occasioned from cooking oil recycling it has an economy more than R$ 7 million on the diesel acquisition and if the same will mixed to 20% of diesel, substract the involved costs in the biodiesel production then. In relation to environmental impacts reduction also purpose of research, it found out with the oil recycling and, with its posterior use at collect vehicles, the emission of CO_2 in the environment would reduce at 7.761.173 kg, a decreasing for about 53%, thus be used a great mixture of biodiesel as possible as.In relation to decreasing water pollution, it checked that for about 22 billion of water liters won`t be polluted, if 20% of biodiesel be mixed to fuel, which is used at urban solid resting collect. The table 3 briefs the sceneries.

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	CurrentScenario (10 years)	**ScenarioB10 (10 years)**	**ScenarioB20 (10 years)**
Economy (Real)	0	2.478.429	7.435.275,30
GenarationCO_2 (Kg)	14.488.658	9.742.911	6.727.485,00
Water Pollution ReductionÁgua (Liters)	0	7.590.000.000	22.770.000.000

Table 2: Results summarized in the scenarios studied.
Source: Authors (2019)

As future work it is intended to include in the model variables that can more accurately measure the cost of collecting cooking oil. Variables capable of analyzing the transport of residues in addition to professional costs will also be included in the model.

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