

Feasibility study for the collection of wasted vegetable oils in the Canton of Baños De Agua Santa and proposal for the incorporation of a biodiesel production plant as a strategy for sustainable urban development

*Radharani Alzate Luna*¹, *Alfredo Mena*², and *Rukuh Setiadi*^{3*}

¹Master Program in Urban and Regional Planning, Engineering Faculty, Diponegoro University

²Managing Director at Corporación Investigación Energética, CIE. Ecuador

³Department of Urban and Regional Planning, Engineering Faculty, Diponegoro University. Semarang, Indonesia 50275

Abstract. In Ecuador, there is 51.78% of renewable energy from which 1.55% is biomass. The development of technologies regarding Waste-to-Energy is clearly an urge. This study seeks to promote the implementation of this type of technology, in concordance with the SDGs. Baños de Agua Santa, is one of the most visited tourist locations in Latin America and does not have a waste recycling plan. The objective of this project was to evaluate the feasibility of recycling vegetable oil and to provide a solution for the existing environmental problems that would incorporate a biodiesel production plant. Therefore, an informational survey of the amount of oil discarded daily by restaurants was collected and data was evaluated to determine the adequate capacity of a biodiesel plant. In addition, the amount of CO₂ that could be reduced if biofuel was incorporated in the same county or in places of ecosystems conservation, like the Galapagos Islands, was calculated. The implementation of a biodiesel production plant would definitely play a significant role in order to promote a sustainable development in the city of Baños de Agua Santa. Cash flow made for 5 years show a NPV of \$50,314.89, with a decrease of 1,923,902.16 g of CO₂.

1 Introduction

Worldwide, there is a need to promote affordable and clean energy, as well as sustainable cities, those are some of the main Sustainable Development Goals according to the United Nations. In Ecuador there are some biodiesel plants whose raw material in most cases is residual from palm production, for example; The company La Fabril has 2 plants, with an installed capacity of 170,000,000 litres/year. Unfortunately, these last years, only a few and

* Corresponding author: rukuh.setiadi@pwk.undip.ac.id

not representative amount of production has been exported, due to the lack of government incentives for exporting [1].

There are several scale biofuel generation projects, most financed by foreign entities. According to [2] the production of biodiesel in Ecuador, assuming that it stopped exporting, covered approximately 30% of the total demand. In other words, to meet Petroecuador's requirements for a 5% mixture in diesel, 240,000,000 liters of biodiesel are needed per year, a value that increases if the mixture percentage increases also.

Therefore, Ecuador has a need to produce and improve biofuels and technologies waste-to-energy. Not only to be accurate and achieve the SDGs related to this matter, but also because it has to promote the economic autonomy of the cities in a sustainable way. Which lately, has being seen as a huge problem, due to the fact of the fluctuating prices of oil that since the covid pandemic have achieved very high levels. Besides this, it has been observed that there is lack of clear regulations. For instance, there is the Executive Decree 1303, which does not completely and specifically establish a regulation that allows the adequate replacement of diesel by biodiesel in its entirety.

Nonetheless, through the association of GSEP, the UN and the Ecuadorian Government, projects have been carried out that promote renewable energies. With the implementations carried out, the reduction of 21,000 tons of CO₂ emissions has been achieved. There is a national public policy of Zero Fossil Fuels for Galapagos. For this reason, the present study proposes the use of biodiesel produced in a Transesterification Plant, in the automobile fleet of the Islands [3].

If measures such the one proposed in this study are not taken, it can carry out several environmental problematics. When used cooking oils are dumped into drains or directly into the soil or water bodies, they are a source of contamination, causing environmental sanitation problems and cost overruns in water treatment plants.

A single liter of used vegetable oil has approximately 5,000 times more contaminant load than the residual water that circulates through the sewers. It can contaminate 40,000 liters of water, an amount that is equivalent to the annual water consumption of a person in their home [4].

In addition, there are industries that use burned vegetable cooking oil, incorporating this waste as an additive in the production of feed for livestock. This increases bad cholesterol in animals and consequently produces serious effects on their health and when ingested by humans it has been proven that they produce free radicals in the bodies, which leads to carcinogenic diagnoses. Many of the inhabitants of the Canton under study, usually mix the burned vegetable oil with the rest of the food prepared for the consumption of their cattle [5].

Moreover, Ecuador is totally dependent for its development on the import of processed hydrocarbons, despite the fact that it is a country where its economy is based mainly on the extraction of crude oil. The biodiesel produced in Ecuador cannot compete with the oil derivative, since the State subsidy for this product is high, approximately \$5,966.86 million per year. This is why the production of biodiesel can be competitive in an international environment, when the price of a barrel of oil exceeds \$80, which is far from the costs associated with this last year, 2017.

The highest costs of biodiesel production are generally attributed to the corresponding cost of raw material, approximately 76.3%. In the specific case of this study, the raw material factor would not have the highest production cost, since a waste valued at 0.10 cents per liter would be used.

2 Methodology

The research carried out in this project includes inductive and experimental scientific methods, since the data collection was taken at strategic points, that is, the restaurants and

cafeterias of the Canton of Baños de Agua Santa, in order to guarantee a general analysis overview of the situation of discarded wasted frying oil in this place. The data collected has been statistically analyzed.

This project has been developed from a current urban environmental problem, which seriously affects the ecosystem of the city, mainly its aquifers. The preliminary investigation of this project involves activities of field visits, interviews with stakeholders and entities representatives involved in the subject, such as the Ministry of the Environment, the Secretariat of the Environment in Quito, the Mayor's Office of the Canton, the Ministry of Transport and Public Works, Tecnopolis Yachai, University of Ibarra, technology providers and various producers.

The gathering of information in the places where food was dispatched (restaurants) was carried out with the help of the environmental engineering interns from the Baños Environment Headquarters. During 3 consecutive days, visits were made to each establishment in the sector under study.

2.1 Sampling Statistical Study for Preliminary Data Collection

2.1.1 Sample size choice

All the pre-established food centers in the matrix of the restaurant registry have been considered for this study. This matrix was developed by the Environmental Headquarters of Baños city. Using the following data, the sample size was calculated;

- Size of the Population: 197 establishments.
- Margin of error: 9.4%.
- Confidence level: 95%.

$$\text{Sample size} = \frac{\frac{z^2(p(1-p))}{e^2}}{1 + \left(\frac{z^2(p(1-p))}{e^2N}\right)} \quad (1)$$

It was determined that the sample size for a population of 197 restaurants and cafeterias is 71 number of samples, the same number of surveys carried out. The design of the wastes oil collection model is based on the evaluation of statistical data and according to the logistic convenience and mobility that exists in Baños de Agua Santa.

The proposed solution to this environmental problem is based on real data determined throughout the present study. Likewise, the economic data has been taken in a real way, through market rates.

3 Data and Information Collected

3.1 Study Area Characterization

Canton of Baños de Agua Santa, is a constituent territory of 31.5% of the Province of Tunguragua, with an area of 1066 km². It is an important tourist center in the country, so its economic source is based in this activity. This has caused an increase in the production of solid and liquid waste, which until now has no added value. This study is a contribution that serves as a baseline to improve the disposal of oily liquid waste from the food production and marketing sector in the canton.

Baños de Agua Santa does not currently have Authorized Agents in charge of the proper final disposal of used vegetable oil. Proposals have been made related to the solution of the problem, for example, in 2015, the collection of burned oil was proposed to the Municipal GAD. This consisted of the sale of the oil to a manager, for the amount of 0.10 cents of a dollar per collected liter, which would send this material by boat to the Netherlands, where biodiesel is made with the waste from developing countries. The project could not be carried out, since, during the negotiation, said manager asked the GAD for at least 10,000 liters of oil per month. Amount that the canton is unable to produce. The second proposal was to deliver the oil to a manager dedicated to the preparation of balanced for the livestock industry. The process would consist of mixing the discarded oil with the food manufactured for the animals [6]. It is known that this type of procedure causes a problem in the food chain, since free radicals are produced by the burning of the oil, which cannot be easily eliminated and consequently alterations in the health due to the appearance of various types of cancer.

3.2 Average daily oil usage

It was determined that on average, a restaurant uses 3.19 liters per day of vegetable oil. The total sum of the population sample to which the survey was carried out was 223.46 liters/day.

3.3 Oil type

The following figure shows the origins of the type of oil used commonly in the city of Baños de Agua Santa.

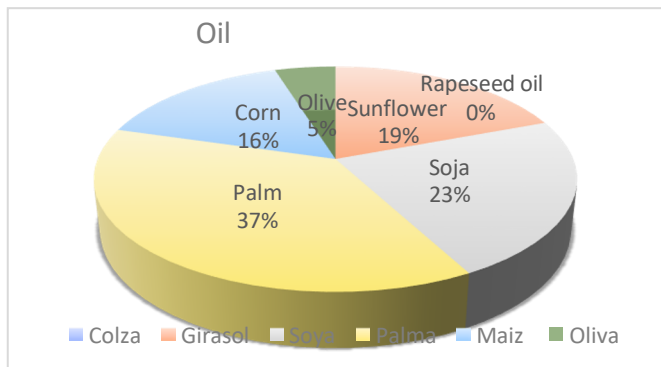


Fig. 1. Use of oil by type.

3.4 Final disposal of the oil

The final disposition of the oil made by the people living in the study area is the following;

- Flushes it down the drain 19%
- Picks it up in a container 30%
- Gives it to an authorized manager 2%
- Throws it on the grass 3%
- Incorporates it into the food of the pigs 22%
- Throws it straight in the trash 20%
- Uses it as fuel 2%
- Consumes everything 2%
- Sells it 2%

3.5 Willingness of the Population to recycle wasted oil & Willingness of the Population to deliver the oil to an authorized manager

82% of the population is willing to recycle oil, compared to 18% who do not agree. 84% of the population is willing to deliver the used oil to an authorized manager, the remaining 16% oppose this measure.

3.6 Amount of oil discarded

Table 1. Data obtained from discarded oil.

Data	Amount
Restaurant sample size (n)	71
Average oil discarded litter/day (X_o)	1.40
Total Universe = Total number of Restaurants	197
Standard Deviation (s)	1.68
Variance (σ^2)	2.82
Total sum of wasted oil from the sample litter/day	99.18
Total sum of wasted oil from the sample litter/month	2975.53
Approximation of waste oil in the universe litter/day	275.20
Approximation of wasted oil in the universe litter/month	8256.05

3.7 Resource estimation

This evaluation was enhanced by Weibull Distribution statistics. (Form Factor k: 0.818926 and Scale Factor C: 1.253243).

D. Weibull = (% Oil discarded per day; Form Factor; Scale Factor; False)

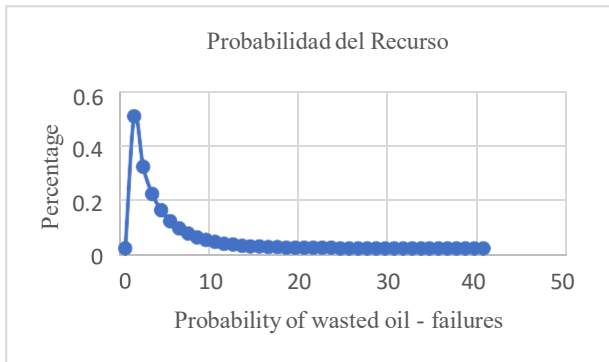


Fig. 2. Chance of obtaining the resource.

The figure above shows that from 3 l/day of oil burned, the probability that there will be more waste decreases. There is zero probability that a restaurant can generate more than 15 l/day of burned oil, since, from this point on, the distribution curve remains at zero.

3.8 Density of the burned oil

The relative density of most oils is known to be between 0.84 and 0.96, with an approximate average of 0.90; assuming that the ambient temperature was 20 °C and its relative density was 998.30 kg/m³.

$$\text{Absolute density of the oil} = (\text{Relative density of burned oil}) * (\text{Density of water at } 20^{\circ}\text{C}) \quad (2)$$

The absolute density of the oil is 898.47 kg/m³.

3.9 Recycled Oil Storage Tank Design

This section was carried out considering the standards ATEX, DIN 4119, ASME VIII, MIE APQ-1,-6, y-10. [7]:

- a. Design Volume = Total Volume * 1.15
- b. Design temperature = For safety, normal room temperature has been used; 20°C
- c. Design material= It is proposed to use stainless steel AISI 304, AISI 316L or at ends.
- d. Tank sizing= The tool used is based on the formula; $Volume = \pi (ratio^2) (height)$
- e. A radius of 1.15 m and a tank height of 2.5 m have been established for ease of cutting and assembly during tank construction.
- f. Minimum Trading Volume MOV=

$$MOV = design\ height + height\ (10\%) - height \quad (3)$$

- Design volume for the entire universe Vd (m³/día): 0,316
- Design volume for the entire universe Vd (m³/mes): 9,494
- Storage tank cylinder volume radius (m): 1.15
- Storage tank cylinder height (m): 2.5
- Storage tank cylinder volume (m³): 10.39

3.10 Raw material pretreatment

The characterization analyzes of the collected oil must be carried out by means of the INEN-ISO 660:2013, INEN-ISO 3657:2013 and related standards.

Another advantage of this project is that these analyzes can be carried out in the BIOTEC laboratory of the Corporation for Energy Research, the host entity for the development of this work, which is willing to promote the implementation of the biodiesel plant.

Being renewable energies an alternative to reduce the consumption of fossil fuels and to be friendly to the environment, the CIE requires the official support of entities such as the Ministry of Electricity and Renewable Energies and the like to endorse the management of raw material collection. in the sources of production and the purchase of biodiesel by Petroecuador.

3.11 Incorporation of a Biodiesel production plant

3.11.1 Wasted Oil collection

A collection process is proposed, where all the citizens of Baños are involved, especially the following entities;

- Food establishments
- The Municipal GAD with its Environment Headquarters.
- The entity who would be in charge of the transesterification process.



Fig. 3. Wasted oil management process.

3.11.2 Collection points

- Sector Ulba: -1.3949016-78.3939516
- Calle Juan Montalvo, Jefatura Ambiental: -1.3997055-78.4210419,3
- Sector Runtun: -1.3998978-78.414553
- Sector Río Verde: -1.4048531-78.3007292
- Sector El Salado: -1.398477-78.4291648

3.11.3 Use of reactants in the transesterification process

The use of two reagents is essential; Sodium Hydroxide NaOH and Methanol CH₄O. These two substances are considered toxic. In Ecuador, the National Council for the Control of Narcotic and Psychotropic Substances - CONSEP, is the body in charge of controlling the use of the NaOH catalyst, that is, to use this substance, a permit granted by said entity is necessary, methanol does not require this permission.

3.11.4 Transesterification process diagram

In general, there are three types of transesterification: homogeneous, heterogeneous and enzymatic, depending on the catalyst used. In this case, the use of sodium hydroxide as a catalyst is proposed.

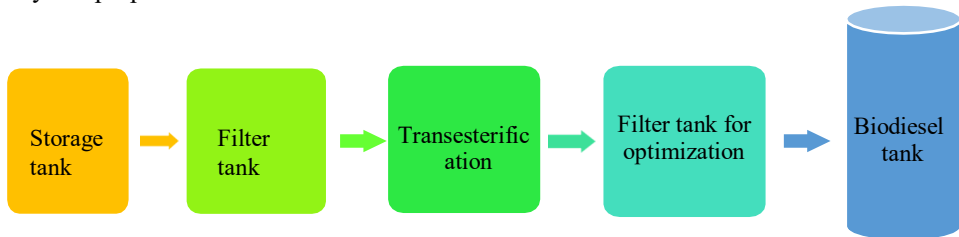


Fig. 4. Oil transformation process.

3.11.5 Biodiesel Plant Proposal

Proposal 1: Reactor: Central BioDiesel BIO800

- Capacity 800 Liters (216 Gallons) per batch
- Width: 1.5 meters; Length 3.5 meters; Height: 2.1 meters; Weight: 600Kg.
- Consumption: 40-60 watts per liter
- Average Batch Time: 3 hours

5. Reaction temperature: 90 °C
6. Recommended Pressure: 1 Atm.
7. Settling time: 7 hours

Proposal 2: Reactor: Bioenergy BIOE 200

1. Capacity 200 Liters (53 Gallons) per batch
2. Width: 0.6 meters; Height: 0.8 meters. ; Weight: Kg.
3. Average Batch Time: 3 - 5 hours
4. Reaction temperature: 90 °C
5. Recommended Pressure: 2 Bar.
6. Settling time: 8 -12 hours

3.12 Transportation and distribution of biodiesel

The biodiesel produced can be sold in various ways, but in this particular case the sale is promoted in protected areas, as is the case of the Galapagos Islands, and even in the canton of Baños itself.

Table 2. Biodiesel demand.

Place	Diesel vehicles	Of which buses	Approximation of diesel demand per day
Baños de Agua Santa	183	30	1.524,39 diesel liters diesel/day
Galápagos	1.962	50	16.343,46 liters of diesel/day

Adapted from the Provincial Commission of Land Transport, Transit and Road Safety of Tungurahua (2017) and [8].

3.13 CO₂ emissions into the atmosphere

On the Baños – Mera route there are 47 km, while on the Riobamba – Baños route there are approximately 39 km. This means that the amount of fuel per liter required to travel these distances would be 3.91 liters of diesel and 3.25 liters of diesel respectively.

It is known that for every liter of gasoline consumed, 2.32 kg of CO₂ and 2.61 kg of CO₂ are emitted into the environment due to the use of diesel [9]. A vehicle traveling along the Baños – Mera section would be emitting 9.07 kg of CO₂ into the atmosphere and 7.54 kg of CO₂ on the Riobamba – Baños section. Due to this specific situation, in Baños de Agua Santa they would be emitting in the environment for each car that travels the mentioned sections. Therefore, if an example were to be considered where the 183 vehicles registered in Baños traveled these sections every day, it would mean an emission of 3,039.84 kg of CO₂/day.

Assuming that the same kilometers are covered by a vehicle in Galapagos, this would mean that the atmosphere is polluted with 14,061 kg CO₂ / day for the 1962 vehicles on the islands.

If 214,8 liters of biodiesel B2 were added each day to the estimate of the total number of buses belonging to the Canton of Baños de Agua Santa (30 buses), assuming that 15 buses travel the section Baños – Mera and another 15 the section Riobamba – Baños, could have a total savings of 104.77 kg CO₂ / day or 3,143.1 CO₂ / month.

Transportation from Baltra airport to Puerto Ayora on Santa Cruz Island is one of the most frequent routes in Galapagos. If 116.1 liters of biodiesel were incorporated into 30 buses that make this journey, there could be a decrease in 61,9 kg of CO₂ / day, which means; 1.857 kg CO₂ / month. In addition, if 500 liters of biodiesel were added to the fleet in general, it could be reduced by approximately 266.58 kg of CO₂ / day.

4 Feasibility Analysis

Deeping into the economic analysis, an annual project cash flow has been created. For it, an equipment tabulation and calculation were done. Taken into consideration the prices of the biodiesel plant, the operation of the plant and its management, and the staff required to work on it. The annual cash flow of the project is made considering the production of biodiesel, not its transportation to different places.

Expenditures from workforce (drives, administrative staff, technicians' staff, transport and marketing) were analysed summing a quantity of \$ 17,955.60 per year. Assuming a depreciation of the plant in 5 years, the results of the annual cost of raw material, supplies and workforce of the (WtE) biodiesel plant is \$ 12,5498.72.

The sale price of biodiesel, was fixed, according to the regulations and decrees in the (Executive Decree 338). The sale of biodiesel with an international price was established. That is, currently \$3.50 per gallon of biodiesel. The economic analysis has been carried out, assuming the minimum production of biodiesel is 800 litres per day.

A 5-year investment is proposed, where it is invested with bank financing of 80% and co-financing with another entity of the remaining 20%, all this at an inflation update rate of 15%. It should be remembered that the sale price per gallon would be \$3.50, which will generate profits of approximately \$ 42,501.28.

The analyses of the cash flow done on excel gave as a result a Net Present Value of \$50,314.89, with an Internal Rate of Return (IRR) of 29%. This means that the implementation is definitely an accurate option that can generate profits with years, with which Baños de Agua Santa will benefit from.

5 Conclusions

If waste-to-energy technologies are developed in Ecuador, there will be a reduction of capital outflows from the country, by replacing the importation of diesel and consequently the production of biodiesel. With the implementation of a transesterification technology for the wasted oil resulted from the commercialization activities of the Canton of Baños, the productive matrix can be improved, because a product with greater added value is generated and investments are made in industrialization.

Since fuels are regulated by the Ecuadorian state, without the support of a regulatory entity, the biofuel market would be non-existent, since the price of biodiesel is higher than diesel. Laws of Ecuador need to establish and deepen the legislation regarding renewable energies, specifically regarding the production of biodiesel through recycled oils.

This document sets out the proposal for the use of biodiesel on Santa Cruz Island. The use of biodiesel B2 is proposed in buses that travel 46.6 km from Baltra Airport to Puerto Ayora. If biofuel is incorporated into 30 buses, 61.9 kg of CO₂/day would be reduced. And if 500 liters of biodiesel were incorporated into the vehicle fleet in general, 266.58 kg of CO₂/day would be reduced.

In Baños de Agua Santa there is a serious environmental problem derived from the use of vegetable oils for frying. The poor disposal of this waste has a direct impact on the rivers of the canton, since people deposit the used oil through the pipes that direct the oil to the sewers, and since there is still no wastewater treatment in the canton, the entire load of contamination is deposited directly in the aqueous bodies, destroying the ecosystem.

The amount of oil discarded by the establishments registered in the canton of Baños de Agua Santa is 275.20 liters/day of burned cooking oil, that is, 8,256.05 l/month. The design of the storage tank has been sized to contain a whole month's worth of oil, that is, 8256 m³. The height of the tank was calculated to be 2.5 m and a volume to store 10.39 m³, taking into account a 15% oversizing, recommended by ATEX standards.

Contrary to exporting used oil produced in the country, biodiesel should be produced within Ecuadorian territory, thus CO₂ emissions produced by transporting discarded vegetable oil to the Netherlands could be reduced. A decrease of 1,923,902.16 g of CO₂ was determined CO₂/ month. If the oil is used in the same canton of Baños de Agua Santa, incorporating it into 30 buses that make different routes, 104.77 kg of CO₂ / day could be reduced.

It is recommended to consider the proposal 1 for the incorporation of a biodiesel plant (Central BioDiesel BIO800), because with this plant it is possible to expand production in the future and generate more profits. This technology has an approximate cost of \$40,890 dollars, tax free. The total investment of the project is \$128,350.45 dollars.

A cash flow has been made for 5 years, with 80% bank financing and 20% co-financing, at a 14% update rate. The results show IRR data of 29% and NPV of \$50,314.89. This if a daily production of 200 gallons of biodiesel is maintained. Which means that you must have 800 liters of oil for transesterification per day. That is, the project is viable.

The creation of a (WtE) Biodiesel Plant in Baños de Agua Santa is the respond to several problems related to waste management in the city. It improves the energy transition, environment, economy and live quality of the people living in the urban and rural areas of this municipality. It is an accurate strategy to develop a sustainable city and fulfils the requirements to achieve the 11th Goal of Sustainable Cities and Communities of the SDGs.

Future studies should be considered to be done based on the approach that the touristic sector can benefit by the implementation of WtE technologies. Future researches can be done based on the results of this study, focusing on Energy Transition, Renewable Energies, Environment and Urban Planning.

References

1. H. Santana, Vocero La Fabril. Biodiesel. (2017) Retrieved from; <https://www.lahora.com.ec/noticia/1101310430/falta-de-normativa-limita-al-biodic3a9sel>
2. Pro Ecuador, Biocombustibles, (2015)
3. Chatham, Energía Renovable en Las Islas Galápagos (2017). Retrieved from; <http://grandhotelchatham.com.ec/2017/04/08/>
4. I. González & J. González, Aceites usados de cocina. Problemática Ambiental, incidencias en redes de saneamiento y coste del tratamiento en depuradoras. Consorcio de Aguas Bilbao Bizkaia (2017).
5. L. Márquez, Diseño de un sistema para la gestión de aceites vegetales usados en cañete para producir biodiesel. (2013) Retrieved from; https://pirhua.udep.edu.pe/bitstream/handle/11042/2015/ING-L_003.pdf?sequence=1
6. Jefatura Ambiental- GAD de Baños de Agua Santa., Propuestas para la gestión del aceite vegetal desechado. (2017)
7. UAB – Universitat Autònoma de Barcelona, Manual de cálculos (2020)
8. D. Dueñas, Emisiones Reguladas: estudio y clasificación base a la metodología Network for Transport and the Environment (NTM) en el sistema de transporte vehicular de las islas Santa Cruz y San Cristóbal (2014)
9. OCU, Información general sobre la emisión de CO₂ de los vehículos y los objetivos de reducción fijados por la UE (2016)