A FEASIBILITY STUDY OF A BIODIESEL PLANT IN CARTAGO, COSTA RICA

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Abstract

The Reventazón River in Cartago, Costa Rica has become polluted by waste oil. COMCURE, an environmental management agency, and five municipalities within Cartago wish to build a plant to process this waste oil into biodiesel. We investigated economic, social and environmental impacts the plant may have through a cost-benefit analysis, site assessments, and research. From our investigation, we concluded that the plant will be profitable, accepted by the public, and should be implemented at a site in Oreamuno.

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Executive Summary

The Lower Reventazón River basin in Cartago, Costa Rica is being contaminated by the disposal of waste oil from communities in the surrounding area. The upper part of the river basin supplies San Jose, the country's capital, with half of its drinking water and is also in danger of being contaminated. To address this problem, COMCURE and five municipalities wish to collect this waste oil and construct a biodiesel plant to convert it into biodiesel. In order to provide the municipalities and COMCURE with recommendations, this project investigated the economic feasibility, possible social and environmental effects, and potential locations for the plant.

We used five distinct methods to formulate our recommendations for the plant. First, we conducted a cost-benefit analysis to verify that the plant would be profitable. The data for this analysis was gathered from an interview with a local biodiesel plant, consultation with local experts in the biodiesel field, and research of current market prices. The analysis showed that the plant will be cost-effective and will pay its initial investment back after 20 years through the sale of biodiesel and the process's main byproduct, crude glycerine. Research showed that the glycerine can be processed into soap, providing a second revenue stream that would reduce the plant's payback period to 3 years. We highly recommend that this process be included in the plant design.

Once we determined the economic feasibility of the plant, we identified and assessed locations where the plant could be built. One site was proposed by the municipality of Oreamuno. We used a Center of Gravity method to find another site that would minimize transportation costs. This method resulted in a location in Eastern Cartago. Site assessments were conducted on these two sites to identify available infrastructure and compare site characteristics.

Through these site assessments, we rated factors that directly affected the cost of construction, annual cost of operation, environmental impact, and plant safety. As some factors were more important than others, we weighted different factors to give them a greater impact on the final score. The final comparison values were then statistically analyzed to determine if there was a significant difference between the ratings of the two sites. The results showed that both sites were comparable in infrastructure and positive features and that both sites were suitable for a biodiesel plant.

In order to inhibit negative environmental impact, site features were evaluated on their ability to negatively affect the surrounding ecosystems. We evaluated features such as proximity to bodies of water, source of electricity and wastewater treatment options The Oreamuno site was located further from bodies of water, had better wastewater treatment options and was predicted to have a smaller impact on the surrounding environment.

In addition to investigating the environmental impact, we surveyed members of the local communities to assess the potential social impact. After analyzing the results, we found that residents near both sites are willing to accept a moderately sized biodiesel plant that will reduce the amount of oil deposited into the river and economically benefit the local municipalities. We also found that the district of Oreamuno is marginally more supportive than the community of Cartago, and recommended that the municipalities complete a more comprehensive study to confirm this data.

After considering the data we obtained through the site assessments, environmental evaluation and surveys, we concluded that the plant should be built in Oreamuno, a location that will minimize the impact on the surrounding communities and ecosystems. The site in Oreamuno is further from residential areas than Cartago site. It will have treated wastewater, and the land is free of cost. Furthermore, this site has many of the same benefits as the Cartago site: it uses renewable electricity source and has access to all required infrastructure. We also highly recommend that the glycerin produced by the plant be processed into soap because the sale of the soap products is predicted to increase the profit of the plant by a factor of four. In conclusion, the construction of this plant and the collection of waste oil will reduce the magnitude of oil pollution in the Reventazón Basin and aid in the protection of San Jose’s drinking water supply.

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Background

As the second largest river in Costa Rica, the Reventazón provides fifty percent of the water used by San Jose, the country's capital, from its upper basin (Muñoz, 2000). Unfortunately, this river is also the second most damaged in the nation due to pollution (Antonio & Salazar, 1998). Illicit disposal of waste oil from local communities in this river has led to further contamination of the watershed. In an effort to counter this problem, the Committee of Operation and Regulation of the Upper Basin of the River Reventazón (COMCURE) and five cooperating municipalities would like to build a plant to process the oil into biodiesel. This project investigated the economic feasibility, possible social and environmental effects and potential locations for this biodiesel plant within the province of Cartago.

Our project sponsor, COMCURE, was established in 2000 to focus on environmental preservation in the Reventazón river basin. The organization's mission is to create a healthy and ecologically balanced environment for the area's inhabitants by implementing the national environmental management plan created by MINAET, Costa Rica's Ministry of Environment. This plan contains regulations concerning water conservation and natural resources of the Upper River Reventazón (COMCURE, 2009). COMCURE has already been successful in reducing fecal contamination in the basin, and has turned its attention to other sources of pollution in the river, in this case, residual cooking oil from restaurants, factories, and other sources within the community. COMCURE has begun working with five neighboring municipalities, Cartago, Alvarado, El Guarco, Jimenez and Oreamuno, who are willing to initiate a waste oil collection program. COMCURE and the five cooperating municipalities hope that these efforts will help decrease the pollution of the Reventazón River and in the future, allow it to be used for agriculture or recreation.

In order to understand the possible consequences this pollution may have, we looked at other rivers that have been treated in the same manner as the Reventazón. One example of such a river is the Cuyahoga River, located in the northeastern part of Ohio. This river was continuously polluted by industrial waste, which would ignite with the passing of a car. These fires burned for days, causing significant damage on each occasion. With environmental regulations and initiatives, the government of Costa Rica hopes to avoid ever having environmental problems as severe as those of the Cuyahoga River. This project is an example of these initiatives; the collection of waste oil at the source and the production of biodiesel with the collected waste oil. The biodiesel process was chosen for this project because it can be created directly from the waste cooking oil currently being dumped in the river.

In order to convert this waste oil into biodiesel, the oil must be refined to remove unwanted solids and contaminants (Moser, 2009). After this removal process a catalyst, such as methanol, is added to the solution. The mix is then fed into a reactor where biodiesel is produced (Chavalparit, Ongwandee, & Raghareutai, 2010). The process that occurs in the reactor is called transesterification. This is a chemical reaction between the vegetable oil and the alcohol that lowers the viscosity of the biodiesel (Demirbas, 2008; Knothe, 2010; Moser, 2009). After the reaction takes place, excess methanol is removed via distillation and can be reused. Any remaining water is removed from the final product before storage to prevent degradation of the fuel. The main byproduct of this process, crude glycerine, is separated and stored for sale or processing.

While not very valuable in its crude form, glycerine is used in many industrial processes and can be sold in bulk for use or processing by a third-party. Refining glycerine into a pure form allows it to be sold into the pharmaceutical and food industries at a significantly higher price. However, glycerine processing can be difficult for small or medium size plants due to the high initial investments required for the refining equipment (Chavalparit et al., 2010). A more feasible option for these plants is the sale of the crude, or unprocessed, glycerine. It is also possible to create soap products from crude glycerine. Through contact with an industry expert, we found that there are companies that specialize in processing crude glycerine from biodiesel into soap products, and the sale of these soap products can generate triple the profit of the sale of biodiesel (Personal Communication, November 2011). Most importantly it is necessary to develop an outlet for this waste byproduct so that it is not simply dumped into the ecosystem as this could damage that which this plant aims to help.

It is not only the glycerine byproduct that has potential to harm the environment but also the biodiesel this plant will produce. Although biodiesel is less toxic than diesel produced from crude oil, known a petrodiesel, it can still negatively impact the environment. In particular, biodiesel depletes water’s available oxygen content when it degrades and can suffocate aquatic life as shown by one biodiesel plant that improperly disposed 135,000 gallons of oil into a local stream, killing hundreds of fish (Siles 2011). Research showed that the majority of pollution caused by biodiesel plants is due to either improper execution or disregard of safety protocols. For instance, in Moundville, Alabama, the oil and grease found 2 miles downstream from the biodiesel plant was 450 times higher than what is permitted by the state (Goodman, 2008). In addition, a recent study looking at biodiesel plants in Iowa found in a 7-year span (2000-2007) there were over 394 health violations and over 276 sewage violations (Beeman, 2007). It was determined that in many of these instances, the facilities either failed to acquire proper permits for waste regulation equipment, or the facilities failed to construct their plants as outlined in their permits. However, due to this study, many Iowan plants have made significant efforts to improve their environmental controls. It is imperative that plants maintain process control and remember that while renewable, biodiesel is still a hazardous chemical.

While biodiesel has the potential to cause pollution, it is a very good alternative to petrodiesel. It can be burned in diesel engines in its pure form or mixed with petrodiesel in any ratio (Demirbas, 2008; Moser, 2009). The emissions from recovered biodiesel fuels have lower levels of carbon monoxide and unburned hydrocarbons than those of petrodiesel, causing less air pollution (Demirbas, 2008). The fatty acids in biodiesel give it exceptional lubrication properties that help prolong engine life and decrease wear on critical engine components. It is also less volatile than petrodiesel which makes it less likely to explode during storage (Moser, 2009; Al-Zuhair, 2011). Aside from its main use as a fuel source for engines, it can also be used as an alternative to petroleum in heating oil or as a commercial scale solvent.

In addition to biodiesel's performance advantages, it is also more environmentally friendly. One of the main environmental benefits of biodiesel is that it is biodegradable. When biodiesel is released into soil it degrades quickly into non-toxic organic compounds. It will also degrade in water, although water and biodiesel are insoluble and the degradation rate is slower than in soil. Petrodiesel spills require costly human intervention, and can remain in ecosystems for many years after the initial pollution occurs. Biodiesel spills cause less damage than those of petrodiesel, and have fewer lasting effects.

After comparing biodiesel and petrodiesel we found biodiesel to be a better alternative, and that a biodiesel plant could help reduce the oil pollution in the basin. We then found that there is already a commercial biodiesel plant in Cartago which can process waste oil. However, this is not a feasible option as the municipalities do not receive any profits from it, and are not capturing this significant source of income. A new plant will economically benefit the municipalities and aid in the reduction of waste oil disposal in the Reventazón.

Methodology

The goal of this project was to examine the feasibility of establishing a biodiesel plant in the district of Cartago, Costa Rica. Within the Cartago province, the major stakeholders of this project are the participating municipalities, COMCURE, the abutting communities, and the local restaurants. In order to produce recommendations for our sponsor and participating municipalities, we established the following research goals:

1. Investigate the economic feasibility of the plant with a cost-benefit analysis.
2. Determine a second potential location for a biodiesel plant.
3. Compare the two potential locations using site assessments.
4. Evaluate the environmental impact of plant implementation at each site.
5. Analyze community attitudes towards the project through a survey.

Study 1 – Cost-Benefit Analysis

The implementation of a biodiesel plant involves major economic risks such as the uncertainty of the raw material supply and fluctuation of the biodiesel price. One way to limit these risks prior to implementation is to assess the feasibility of the project. To determine this, we utilized a Cost-Benefit analysis (CBA) which is the most comprehensive method for evaluating projects. This method creates a common monetary value as a measurement for all costs and benefits (DeSpiegelaere, 2006; Williams, 2008). Due to limited government funds, this project needed to be economically justified in order to proceed towards implementation. We researched possible ways to increase the profitability of the plant. We found that glycerine, the main byproduct of biodiesel production, could be processed into soap, providing the plant with a second source of revenue. To analyze the profitability of glycerine treatment alternatives, calculations were performed on two glycerine sale options: the sale of crude glycerine, and the sale of glycerine soap products.

Methodology

Estimation of Plant Size

To calculate economic costs and revenues for the proposed biodiesel plant, we needed to estimate its expected size. We calculated the amount of waste oil that would be available for the new plant to process for the estimation. To do so we collected lists of the licensed restaurants and businesses from four of the five cooperating municipalities: Alvarado, Cartago, Oreamuno, and Jimenez. From this data we established five categories of waste oil production: bars, sodas (small restaurants run by local families), restaurants, fast food restaurants, and industrial sources.

The district of Alvarado provided us with average waste oil production data for each established category. We separated the provided data into the different categories and averaged it to obtain a value for oil production per month for each category. We multiplied the average waste oil production of each category by the number present in each district. The industrial sources were not estimated in this manner due to magnitude of variance expected from each source. We instead contacted the individual plants and acquired the waste oil production data directly. We then summed the total available waste oil from bars, sodas, restaurants, fast food restaurants and industry for the four districts. Unfortunately, the municipality of El Guarco did not have a list of local businesses for the district. Therefore, the waste oil production for El Guarco was estimated per capita based on the results from the other four districts. After all the data had been gathered, the total amount of waste oil available within the five participating municipalities was summed and used to estimate the size of the proposed plant.

Economic Costs

Once the size of the plant was established, economic costs were calculated. Economic costs consist of initial and annual expenditures. The initial expenses of this plant include the cost of land, construction and equipment. The cost of land was acquired from the municipalities. The expected price of equipment was obtained from an interview with the owner of the pre-existing biodiesel plant in Cartago. We also gathered the values for annual expenses (employee salaries, utilities, logistics and transportation, and maintenance fees) from this biodiesel plant. Taxes are typically figured into annual expenses; however, since this is a government project it is exempt from taxes.

Calculation of Revenue

The revenue is the total income from the sale of biodiesel its main byproduct, glycerine. We acquired local market pricing information for biodiesel and crude (unrefined) glycerine from the biodiesel plant in Cartago. We estimated the expected revenue from biodiesel and crude glycerine by multiplying the annual production of each in liters by the market price. To determine additional means for acquiring income from glycerine, we contacted a local company that specializes in processing crude glycerine into soap products. This company provided us with estimated costs and potential market value for soap products.

Results and Discussions

Estimation of Plant Size

The estimation of the plant size is based on the waste oil production data provided by the local municipalities. The new plant is expected to process 26,413 liters of waste oil per month, which will require a small sized biodiesel plant. See Appendix A for full calculations. This data is reliant on the assumption that the municipalities will be able to collect 100% of the expected waste oil from the five districts, a goal that an industry expert noted would be difficult to achieve. Even so, this number represents the maximum availability of waste oil to the potential plant.

Economic Costs

As illustrated below in Table 1, many costs were obtained from an interview with the owner of the Cartago Biodiesel Plant. The Cartago plant currently produces 10,000 liters of biodiesel per month, and has a maximum capacity of 100,000 liters. According to an industry expert, the Cartago plant is currently operating at a level far below capacity (Personal Communication, November 2011). However, since the new plant will have a higher monthly production volume, having the maximum capacity of 100,000 liters is more justifiable. Additionally, local municipalities stated the possibility to expand waste oil collection plan to include households or even neighboring municipalities. This plan has potential to double the monthly capacity of the proposed plant. Therefore, the initial equipment cost and construction cost for the proposed plant were acquired directly from the Cartago Biodiesel Plant with modification.

Type of Cost	Monetary Value	Source of Raw Information
Cost of Construction	$ 250000	Cartago Biodiesel Plant
Initial Equipment Cost	$ 1300000	Cartago Biodiesel Plant
Glycerine Soap Equipment Cost	$ 50000	Industry Expert
Waste Oil Collection Cost	$ 151200 per year	Cartago Biodiesel Plant
Labor Cost	$ 111600 per year	Cartago Biodiesel Plant
Energy Cost	$ 3672 per year	JASEC Electricity

Table 1 - Specific Economic Costs and Sources

The largest cost component for this biodiesel plant will be the purchase of equipment. Pumps, reactors, distillation piping, and storage containers are the most significant pieces of equipment that will be required for startup. The estimated cost for each category can be seen in Table 1 and a detailed list of costs can be found in Appendix B.

To calculate the cost of utilities and employees we looked at the difference of biodiesel production between the proposed plant and the biodiesel plant in Cartago currently in operation. The proposed biodiesel plant is expected to produce approximately 26,000 liters per month; a factor of 2.6 more than the 10,000 produced by the Cartago Biodiesel plant. We therefore multiplied energy consumption and waste oil collection cost by 2.6 to account for the difference between the two plants. We increased the number of workers from 5 to 13 to account for additional monthly production, and added an additional 2 workers to run the process for glycerine soap production. We did not increase the number of on-site professionals, because the Cartago plant currently has 3. It is only necessary to have one professional on-site at a time for running chemical tests (Personal Communication, November 2011). Therefore, we determined 3 would still be a sufficient number to assure quality control and operate the laboratory. The energy consumption per month for the Cartago Biodiesel Plant was 600 kilowatt hours, allowing us to estimate the production of the new plant to be 1560 kilowatt hours. According to data collected from JASEC Electricity Company (see Appendix C), the cost for producing 3000 kilowatt hours or fewer will be $306.00 per month. The electricity cost is low because the plant will be able to use biodiesel for heating in chemical processes.

Expected Revenue

We next calculated expected revenue of the proposed biodiesel plant. The unit prices of both biodiesel and crude glycerine were acquired from the Cartago biodiesel plant. These prices are $1.30 per liter and $0.40 per kilogram respectively. Market information was also gathered for glycerine soap production from a company that specializes in that industry. From this data we were able to calculate the expected revenue from biodiesel, crude glycerine sale and glycerine soap sale. Complete calculations can be found in Appendix E.

Expected Annual Income from Biodiesel: $ 412,042.80

Expected Annual Income from Crude Glycerine Sale: $ 19,017.36.00

Expected Annual Income from Glycerine Soap Sale: $ 1,118,668.24

The above calculations assume that all oil collected is processed and that the production of glycerine is 15% the volume of biodiesel production. It also assumes that a consistent demand for the biodiesel and glycerine products will exist. This estimate will fluctuate based on the sources of oil, the price of biodiesel, and inflation.

Analysis of Economic Feasibility

Using the above values, we calculated the total expected revenue of biodiesel and glycerine in addition to the initial and annual costs. These values are listed below:

Annual Revenue for Sale of Biodiesel and Crude Glycerine: $ 431,060.16

Annual Revenue for Sale of Biodiesel and Glycerine Soap: $ 1,530,711.04

Total Initial Cost for Sale of Crude Glycerine: $ 1,550,000.00

Total Initial Cost for Sale of Glycerine Soap: $ 1,600,000.00

Total Annual Cost for Crude Glycerine Sale: $ 248,393.52

Total Annual Cost for Glycerine Soap Sale: $ 723,827.52

According to the results, the annual revenue is larger than the annual cost for both the sale of crude glycerine and glycerine soap products. This indicates that the new plant has profit generating potential. The initial cost is quite high due to the high cost of chemical production equipment; however, further calculations below show that the plant will quickly pay off this investment.

Another set of calculations used to determine economic feasibility is the Present Worth Method (PW), Annual Worth Method (AW) and Payback Period Method. Present Worth (PW) and Annual Worth (AW) methods are common engineering economic methods that are applied to projects to determine if the outcome will be justified financially. Although looking at the expected annual revenue versus the initial cost can provide a rough estimate of profitability, these methods offer an in-depth analysis of the project (Koelling, Sullivan &Wicks, 2010). The following terms have been defined to clarify the calculation process:

Cash flow: the change in capita over a period of time, considering annual income and expenditures

Time value of money: the change in the worth of an amount of money over a period of time due to investment opportunities and/or interest rates.

The interest rate that was used in the calculation of comparison indicators is the Minimum Attractive Rate of Return (MARR). It is the lowest rate of return for a project to be economically justified. More specifically, this rate compares the expected profits of a proposed project with other investment options. If the project could not achieve the same amount of profit as these other options, such as investment in the stock market, then this project would not be economically justified. MARR takes the following factors into consideration: amount of available funding, investment options, risk of projects and the type of organization (Koelling et al., 2010). In our project, the investing organizations are the local municipalities. Therefore, we utilized the highest interest rate of investing in Costa Rican bank bonds as the MARR in this project.

The PW method exemplifies the total amount of money that will be generated throughout the expected life span of the plant considering the time value of money. The AW method illustrates the annual profit over a steady useful life of the project. Detailed calculations for these methods can be found in Appendix F.

PW for Crude Glycerine Sale: $ 108,065.090
PW for Glycerine Soap Sale: $ 5,724,081.67

AW for Crude Glycerine Sale: $ 11,856.00
AW for Glycerine Soap Sale: $ 630,523.52

As shown above, both the PW and AW are greater than zero, indicating that the biodiesel plant will eventually generate a profit, reinforcing the feasibility of this proposed plant. For the above calculations we used an expected plant life span of 25 years to calculate all comparison indicators. This life span represents the approximate number of years the plant will be able to run without a major reinvestment and was determined using standardized depreciation data published by the IRS (Internal Revenue Service, 2010).

Another method that helped to determine the economic feasibility of the plant is the Payback Period method, or the amount of time it will take the biodiesel plant to pay off the initial costs. The detailed calculation for this method can be found in Appendix G.

Payback Period for Crude Glycerine Sale: 20 years

Payback Period for Glycerine Soap Sale: 3 years

This calculation considers the interest rate of the initial investment, in addition to projected inflation rates. A shorter Payback Period is desirable because it represents the length of time required to achieve a return on initial investment. However, with an expected life-span of 25 years, both Payback Periods are reasonable.

Break-even Analysis

In order to further support the results of the three above methods, we also completed a break-even analysis. This analysis determines the point at which the monthly revenue of a business equals the monthly expenditure – the Break-even point. The Break-even analysis differs from the Payback Period method because it does not determine the amount of time it will take the plant to acquire a return on investment. Instead, this analysis calculates the minimum quantity of product that must be sold monthly in order for the plant to not lose money. Major components of this analysis include the costs to run the plant and the income generated by the plant (Foltz & Wilson, 2008). The detailed calculation can be found in the Appendix H.

Break-even Point (Sale of Crude Glycerine): 10,223 Liters

Break-even Point (Sale of Glycerine Soap): 3,533 Liters

The Break-even analysis illustrated that the plant must sell 2.9 times the amount of biodiesel if glycerine is sold in crude form to be profitable. However, as the plant is expected to process 26,413 liters of biodiesel per month, even if glycerine is sold in crude form, the plant will still only need to sell half of its monthly production. A representative from the Cartago Biodiesel Plant estimated that 250,000 liters of petrodiesel fuel are consumed in Costa Rica per month, thus the Break-even point will be possible to reach for both glycerine sale options, although the sale of glycerine soap is the more profitable option (Personal Communication, December 2011).

Study 2 – Identifying a Second Site

After establishing that the proposed biodiesel plant was economically feasible, we set out to determine a location for the implementation of the plant. The municipality of Oreamuno proposed a site for the construction of the plant. Past research has looked at the traits of successful biodiesel plants. This research shows that low transportation costs are a significant factor in successful biodiesel production and are important in minimizing the plant's annual costs (DeSpiegelaere, 2006; Sabrsula, 2007). Therefore, we set out to determine a second potential site that will have low transportation costs. The second site will provide a comparison against the site proposed by the Oreamuno municipality. We used a Center of Gravity method to find a site with the lowest possible transportation costs.

Methodology

Center of Gravity Method

To identify a site that would minimize the costs of transportation, we used the Center of Gravity method. To conduct this method, we first plotted the geographical coordinates of the municipalities using mapping software. We then assigned them the volumes calculated in the estimation of plant size, located in Appendix A. Using the monthly oil volumes as a numerical "mass", we calculated the Center of Gravity of the points with the equations detailed in Appendix I. This produced a set of coordinates corresponding to a site that is as close as possible to all waste oil sources.

Results and Discussion

The Center of Gravity method determined the site that will minimize transportation costs is located in Eastern Cartago, as seen below in Figure 1. The green marker represents this new location, the blue markers represent the municipalities and the red marker represents the proposed site in Oreamuno.

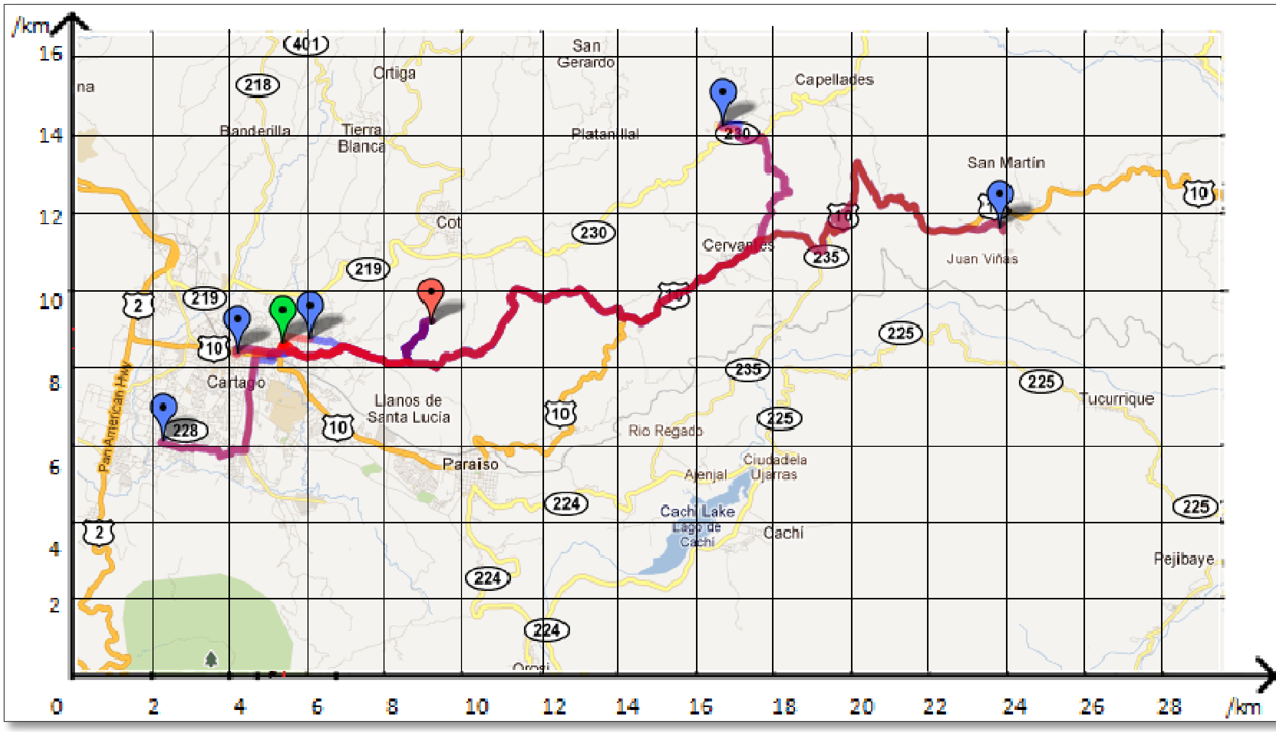

Figure 1 -- Center of Gravity Point

One limitation of this analysis is that the calculation of the volume of waste oil for each district does not include the waste oil produced by individual households. There are over 263,000 people living within the five participating municipalities and municipal representative estimated that a family of five produces one liter of waste oil per month (Personal Communications, November 2011). Thus household waste oil is a significant factor that is currently unaccounted for as collection programs for individual residences do not yet exist. Future research should consider implementing such programs and recalculating the total available waste oil for each region rather than focusing only on businesses.

The second limitation of this method is the small district used for calculation. The calculated site in Cartago is located only 3.8 kilometers from the proposed site. The transportation costs for an additional distance of almost two miles are small compared to the other annual costs calculated in the CBA. However, despite these limitations, this analysis provided a strong, second site to compare with the proposed location in Oreamuno.

Study 3 - Site Assessments of Oreamuno and Eastern Cartago

The implementation of the proposed biodiesel plant will require a significant investment from the five cooperating municipalities. Although the plant is expected to be profitable, the economic justification relies on the assumption that the plant will operate effectively. The selection of a proper site is considered one of the most important attributes of project development (Clean Fuels Development Coalition, 2006). Site features and available infrastructure greatly affect the level of efficiency at which a plant operates (Sabrsula, 2007). Therefore, it is important that the plant be built in a location that will assist in the overall success of the plant. To determine this location, we compared the site proposed by the Oreamuno municipality, with the second location in Eastern Cartago. We then compared the results of both assessments to illustrate any differences between the two sites.

Methodology

Site Evaluation Factors

We began the site assessment by assessing each individual location using factors that are common to biodiesel plant feasibility studies (Despiegelaere, 2007; Illinois Environmental Protection Agency, 2008). We then created a site assessment table (see Appendix L). In this table, the first two columns list the factors under consideration. Each factor was rated on a scale of 0 to 10. A score of 0 indicated that the factor was un-ideal, whereas a score of 10 indicated that the site was exceptionally ideal for this particular factor. The following sections explain the factors we chose in detail and the scale we used to rate each one.

Accessibility Factors:

In order to ensure efficient transportation to and from the plant, and to minimize infrastructure construction (e.g. resurfacing poor quality roads) we looked at the following factors:

- **High-Speed and Rural Road Access:** To determine the availability of high speed and rural roads, we obtained maps from ProDUS (El Programa de Investigación en Desarrollo Urbano Sostenible) of the two sites under consideration and examined the proximity of the roads to the sites. If the access roads were further away (i.e., more than 10 kilometers) then the site was rated 0; whereas, if the access roads were nearby (i.e., within 1 kilometer of the site), then the site was rated a 10. Other scores were determined by subtracting 1 point from 10 for every kilometer further the road was from the site.

- **Quality of Nearby Roads:** Another factor that plays a role in efficient transportation is the quality of the roads. In addition, poor roads will require road reconstruction, and this will add to the total construction cost. To determine the quality of the nearby roads, four observers visited the nearby roads and made visual observations. Each observer evaluated the road quality based on a scale of 0-10. If the road was impassable, then the road quality was assessed as a 0; a 2 represented a dirt road with large ruts and stones that made the road barely traversable; a 4 is a degraded tarmac road; a 6 is a well maintained dirt road or single lane paved road; an 8 represented a double lane paved road; and a 10 is a pristine two-lane highway. After each observer made their individual assessments, the average of these assessments was taken and used as the overall quality score.
- **Traffic Load**: We created this factor to ensure that effective transportation to and from the plant would be possible. We obtained maps from ProDUS that illustrated the traffic load of the nearby high-speed roads. These maps can be found in Appendix M. The maps used a scale of 1-6 to rate traffic at each point. A 6 was assigned for minimal traffic conditions and a 1 for non-moving traffic jams at all times. To maintain consistency between factors, we normalized the 1-6 scale to a 0-10 scale. We achieved this by dividing the score each site received by 6 so the score would be in a percentage. We then multiplied the score by 10 to create the final score.

Energy Factors:

To ensure that the plant is using environmentally friendly energy sources, and to minimize the annual energy operation cost, we looked at the following factors:

- **Type of Power Source:** To determine whether the available power source at each location was environmentally friendly, we contacted the local power company. This factor was rated on a 3-point scale, though to maintain consistency with the other rating scales the possible values were 0, 5, and 10. A 0 was given for non-renewable, non-clean energy sources such as a coal plant. A 5 was given to clean non-renewable energy sources or non-clean renewable energy sources such as clean coal with CO_2 sequestration or wood chip burning facilities. A 10 rating was given for clean, renewable energy sources such as wind or hydro-energy.

- **Cost of Electricity:** We acquired the cost of electricity (per kilowatt hour) from the regional electricity company for each site. The scores were determined relative to the other site in question. The site with less expensive electricity cost was assigned a 10 because it would result in lower overall operational costs. The other site's score was determined by subtracting 1 point for every 10% increase in expense. If the cost per kilowatt hour was equal, both sites were given a score of 10.

Water Factors:

When choosing a site for this plant, it is important to take into consideration the effects it may cause on the nearby watershed. To maintain low annual and initial costs as well as minimize environmental impact, we analyzed the following factors:

- **Proximity to Bodies of Water:** This is a rating that determines the plant's potential for water pollution. We used maps provided by ProDUS to determine the distance of the plant to the nearest body of water. A 0 was given if a body of water existed nearby (i.e., within 100 meters of the site). A score of 10 was assigned when there were no bodies of water nearby the site (i.e., within 1 kilometer). Other scores were determined by subtracting 1 for each 100 meters closer the plant was to the body of water.
- **Accessibility to Industrial Water:** We used maps acquired from ProDUS of city water lines and available water resources to measure the proximity of industrial water connections to the site. We graded the availability of the water source using the following scale: A 0 represented the need to build a well, or connect pipes to a source that was more than 1 kilometer away. A rating of 10 represented a nearby connection (i.e., within 100 meters of the site). Other scores were determined by deducting a point from the score for each additional 100 meters away from the site.
- **Cost of Water:** We acquired the cost information for water from the municipalities of each site. The scores for this detail were determined relative to the other site in question. The site with less expensive water source was assigned a 10. The other site's score was determined by subtracting 1 point for every 10% increase in expense. If the monthly cost for water was equal, the two sites were given the same score of 10.

Wastewater Factors:

It is important to ensure that wastewater created by the plant is treated and will not harm the environment, or the plant's profitability. With this in mind, we rated the following factors on effectiveness and cost:

- **Wastewater Treatment Type:** It is a requirement of Costa Rican law that all wastewater be treated. We rated each site on the available treatment options. We used a 3-point scale, where possible values were 0, 5, and 10 to maintain consistency between factors. A 0 was given if no treatment option was available. A 5 was given to a process that abides by all waste disposal laws. A 10 was reserved for a treatment process without environmental impact such as a large scale wastewater treatment facility.
- **Distance to Sewage Line:** The distance that a sewer line must be built can affect the initial cost of the plant. To keep this low, we rated each site on its proximity to sewer connection. A 0 represented the need to build a pipes 1 or more kilometers long; a rating of 10 was for a nearby sewage connection (i.e., within 100 meters of the site). Other scores were determined by deducting a point from the score for each additional 100 meters away from the site.
- **Cost:** Cost information for sewage treatment was acquired from the municipalities for each site. The scores determined for this factor were determined relative to the other site in question. The site with less expensive sewage service was assigned a 10. The other site's score was determined by subtracting 1 point for every 10% increase in expense. If the monthly cost for sewage was equal, the two sites were given the same score of 10.

Communications Factors:

For daily and emergency use, it is important that there be open communication lines between the plant and the surrounding area. To determine the ability of plant employees to contact emergency services we rated the following factors:

- **Mobile Network Coverage:** While not absolutely essential to the operation of the plant, it is very valuable to have cell phone service in the event of an emergency. It can decrease the time before a response can reach the plant. To determine cell tower coverage, four observers using Kolbi and Fullmovile cell phones rated the network. As each phone used an indicator with 5 bars, each bar of service was given a value of two points on the 0 to 10 scale. If no service was found a 0 was recorded. For every bar of service observed, 2 points were added. A 10 represented full reception or 5 bars of reception. The scores of the observers were decided upon separately and averaged to create the final score.

- **Landline Cost:** Both sites considered had available landline service, eliminating the need to measure the accessibility. We assessed the cost of a landline to keep annual costs low. The cost information for landline services was acquired from the regional telecommunications provider, ICE. The score for this factor was determined relative to the other site in question. The site with a lower monthly cost received a score of 10. The other site's score was determined by subtracting 1 point for each 10% increase in expense. If the monthly cost for landline use was equal, the two sites were given the same score of 10.

Emergency Services Factors:

- **Fire, Police and Health Services Response:** While we applied the same methodology for each type of emergency service (i.e., fire, police, and health services), we considered them as separate factors in our assessment. To determine the estimated response time of each emergency service, we used a GPS to mark the location of the nearest station which contained a response vehicle such as an ambulance, fire truck or police automobile. From this point we measured the distance by road to the site. A 0 was assigned when there was no emergency service station within 10 kilometers because this would require a longer response time. A score of 10 was given for an emergency service station that was located within 1 km of the site because it should require shorter response time. Other scores were determined by deducting 1 for each additional kilometer.

Glycerine Factors:

Glycerine is a byproduct of the biodiesel process which may have negative environmental impact if not treated in a proper manner. Disposal of crude glycerine into the surrounding ecosystems could lead to serious environmental damage. We rated the following factors to ensure that negative environmental impacts did not occur, and any profitable treatment options were investigated:

- **Glycerine Treatment Type:** Due to the negative environmental impact of untreated crude glycerine, the sites were rated on treatment availability. This factor showed the efficacy of the available treatment options, and was rated on a 3-point scale. To maintain consistency between factors the possible values were 0, 5, and 10. A 0 was given if no treatment option was available and the crude glycerine would be disposal directly into the environment. A 5 was given to a process that abides by all chemical waste disposal laws which may still cause certain pollution or negative impact for local ecological system. A 10 was reserved for a treatment process without environmental impact such as one that transfers glycerine into biodiesel.

- **Distance to Treatment Site:** Another factor that can affect annual costs is transportation to the glycerine treatment plant. To minimize this, we measured the distance from the site to the glycerine treatment plant. A 0 was given if the treatment option was further away (i.e., 10 or more kilometers from the site). Other scores were determined by subtracting 1 point for each additional kilometer to the treatment plant. A 10 score was reserved for a treatment center that was nearby (i.e., within 1 kilometer) or onsite.
- **Cost/Value of Glycerine Treatment:** It is possible for glycerin to add significant value to the biodiesel plant. Outside glycerine treatment can also be expensive if performed by a third-party company. We obtained product pricing information of local options from the local Cartago biodiesel plant and from a company that aids in glycerine processing. Even though the process for the new plant has not yet been decided upon, we still need to evaluate the economic information of the possible local options. A 0 represented a treatment that caused a significant cost to the plant, such as paying to dispose the glycerine. A 5 represented a treatment that had no cost or profit to the plant. A 10 was reserved for a treatment that produced a final product that added profit to the biodiesel plant such as sale of refined glycerin products.

Location Factors:

When building a biodiesel plant, it is important to consider the location the plant will be built on and its relation to the surrounding area because these surrounding areas can also be affected by the construction of this plant. To ensure lower transportation and construction costs, we rated the following factors:

- **Property Constructability:** The current state of the property the plant will be built on can greatly affect the initial cost. This factor is a rating of how much work will be required before plant construction can begin at the site. This factor was rated on a 3-point scale, with the possible ratings being 0, 5, and 10. A 0 was assigned if the lot required both demolition and land reconfiguration. A 5 represented the need for the land to excavated or a building be demolished before construction could be started. A 10 represented a site that was ready for construction and required no landscaping or demolition.

- **Distance from Center of Gravity Point:** The cost of transportation of waste oil directly increases with distance from the optimum Center of Gravity point. We measured the distance of the site in question from the Center of Gravity point determined by Study 1. A 0 was assigned if the plant was more than 10 kilometers away. A score of 10 was assigned for any plant site within 1 kilometer of the Center of Gravity site. A point was deducted for each additional kilometer from the optimal point.
- **Residential Area:** To understand the potential impact the plant may have on the surrounding community, we measure the distance to the nearest residential area. The score for this factor was based on the distance from an urban area using maps provided by ProDUS. A 0 was assigned if there was a residential area within 100 meters of the site. A 10 was assigned if there was no residential area within a 1 kilometer radius. Every additional 100 meters closer to the nearest residential area led to 1 point being deducted from the rating.
- **Zoning:** Zoning is a city ordinance that defines permissible construction in certain areas. We analyzed maps provided by ProDUS to determine if the site fell into the industrial zoning category. A 0 or 10 scale was used for this factor. A rating of 0 was assigned if the construction of the plant at the site did not follow zoning guidelines. A rating of 10 was given the sites followed the guidelines.
- **Frequency of Other Potential Hazards:** Another important factor to consider when building a biodiesel plant is the safety of the building, the workers, and the surrounding community both in terms of protecting the residents and the environment. The sites have equal frequency to a major hazard, as both are located within 15 kilometers of Volcano Irazú. However, there are other possible hazards that exist, such as mudslide-prone slopes, rivers which flood, or areas prone to other natural disasters. Therefore, we assessed the number of hazards (other than Volcano Irazú) that were within 15 kilometers of the site. A point was reduced from 10 for each potential hazard that existed within 15 kilometers.

Weighting Factors

In order to compare the assessment results of Oreamuno and Eastern Cartago, we researched weighting systems for biodiesel plant site assessments, as some factors were more important than others. There was very little literature on the subject, and no weighting systems for biodiesel plant site assessments currently exist. We thus created our own system to compare the two sites using a Pair-wise comparison matrix. To create this weighting system, opinions on the importance of each factor were gathered from the four researchers and two experts in biodiesel plant production. The ratings from these six individuals were then averaged to create a weighting factor for each factor within the site assessment. More specifically, a Pair-wise Comparison uses a matrix to compare each site assessment factor against the others on a 3-point scale: more importance (1), equal importance (0.5), or less importance (0). After the six participants filled out the matrix, the responses were averaged and summed. These average sums were then normalized to equal 1. A step-by-step process and an example of a Pairwise Comparison matrix can be seen below.

Step 1: List all factors in columns and rows in the same order.

Step 2: Place an X where a factor would be compared against itself (see Table 2).

	A	B	C	D	Score	Weighting Factor
A	x					
B		x				
C			x			
D				x		

Table 2 - Example Matrix 1

Step 3: Complete the matrix by considering each cell to the right of the X's. To do this, consider if the factor in the row is more important than the factor listed in the column; if so, input a 1; if not, input a 0; if the factors are equally important then input 0.5. See Table 3 for clarification.

	A	B	C	D	Score	Weighting Factor
A	x					
B		x				
C		1	x			
D				x		

If A is more important than B, put a 1 here. If B is more important than A, put a 0. If equal, use 0.5.

Table 3 - Example Matrix 2

	A	B	C	D	Score	Weighting Factor
A	x	1	1	0		
B		x	0	1		
C		1	x	0.5		
D				x		

Table 4 - Example Matrix 3; all data has been inputted

Step 4: Transpose the data that is to right of the X to cells below it. To preserve the pattern in the data, the data below the X must be inverted (1's will become 0's and vice versa). See Table 5 for an example.

	A	B	C	D	Score	Weighting Factor
A	x	1	1	0		
B	0	x	0	1		
C	0	1	x	0.5		
D	1	0	0.5	x		

Table 5 - Example Matrix 4; Note the symmetry across the diagonal line of X's

Step 5: Sum all rows and normalize values to 1. See Table 6.

	A	B	C	D	Score	Weighting Factor
A	x	1	1	0	2	0.333333333
B	0	x	0	1	1	0.166666667
C	0	1	x	0.5	1.5	0.25
D	1	0	0.5	x	1.5	0.25
				Sums:	6	1

Table 6 - Final Example Matrix

Results and Discussion

Illustrated below in Table 7 are the final scores for the site assessment factors of each site. Complete tables with detailed descriptions can be found in Appendix L.

Site factors		Oreamuno Site	Cartago Site
Accessibility	High Speed Road Accessibility	4	8
	Rural Road Accessibility	10	10
	Quality of Nearby Roads	1	7
	Traffic Load	6	5
Energy	Type of Power Source	10	10
	Cost of Electricity	10	10
Water	Proximity to Bodies of Water	3	0
	Accessibility to Industrial Water	9	10
	Cost of Water	10	10
Wastewater	Wastewater Treatment Type	10	0
	Distance to Sewage Line	10	10
	Cost of Sewage	5	10
Communications	Mobile Network Coverage	8	10
	Landline Cost	10	10
Emergency Services	Fire Coverage	4	9
	Police Coverage	4	9
	Health Services Coverage	4	9
GlycerineManagement	Glycerine Treatment Type	10	10
	Distance to Treatment Site	10	10
	Cost/Value of Glycerine Treatment	10	10
Location:	Distance from Waste Oil Sources	4	10
	Residential Area	9	0
	Zoning	0	0
	Property Constructability	10	10
	Frequency of Hazardous Items	9	10

Table 7- Final Site Assessment Chart

The Eastern Cartago site received high scores in several categories, notably high speed road accessibility, emergency services, and distance to waste oil sources. However, this is primarily due to the Center of Gravity method used to identify this site to minimize transportation costs. Meanwhile, Oreamuno received notably higher scores in its distance from residential areas and proximity to bodies of water..While the site assessment was useful for comparing single factors, we relied on the weighting system to compare the two sites.

Weighting Factors

We then averaged the results of the Pair-wise comparison matrix from the four researchers and two experts to obtain the results shown below in Table 8. The highest rated factors were rural road accessibility, quality of nearby roads, cost/value of glycerin treatment and proximity to bodies of water. The lowest rated factors were the distance and cost of sewage, mobile network coverage, traffic load, and the cost of water.

Site Assessment Factors	Final Weighting Percent
High Speed Road Accessibility	4.08
Rural Road Accessibility	5.19
Quality of Nearby Roads	5.28
Traffic Load	2.64
Type of Power Source	3.78
Cost of Electricity	3.03
Proximity to Bodies of Water	6.47
Accessibility to Industrial Water	4.42
Cost of Water	2.81
Wastewater Treatment	4.61
Distance to Sewage Line	1.00
Cost of Sewage	2.61
Mobile Network Coverage	1.61
Landline Cost	3.11
Fire Coverage	3.97
Police Coverage	3.83
Health Services Coverage	4.67
Type of Treatment	4.47
Distance to Treatment Site	3.61
Cost/Value of Glycerine Treatment	5.69
Distance from Waste Oil Sources	4.69
Residential Area	5.03
Zoning	3.64
Property Constructability	5.44
Frequency of Hazardous Items	4.31

Table 8 - Weighting Factors

Final Site Comparison Values

We applied this weighting system to the final site assessment. The complete results can be found in Appendix L. The score for each factor was multiplied by its respective weighting factor value and these products were summed for each site. This determined final site comparison values for the two locations (see Appendix F for complete calculation) and this can be seen below in Table 9.

Site	Score
Oreamuno	**7.027**
Cartago	**7.098**

Table 9 -– Final Site Comparisons

To determine the statistical significance of our results, we conducted a dependent means T-test on the weighted scores for each site. This analysis showed that both the Oreamuno (M = 0.25; SD = 0.17) and the Cartago (M = 0.29; SD = 0.21) were equally suitable for the biodiesel plant, t (24) = 0.811, p = 0.43.

Study 4 – Environmental Impact

According to Costa Rican law, any "human activities that alter or destroy elements of the environment or generate waste, toxic or hazardous material" require an environmental impact assessment (EIA) by the National Environmental Technical Secretariat (Secretaria Tecnica Nacional Ambiental, 1994). Thus, in order to minimize the overall affect this project has on the environment and the degree of the necessary EIA, an investigation of the environmental impact was completed. It is also important that we compile this data to inform municipal policymakers on the environmental impact that this plant may have. We used data and observations gathered during the site assessments to determine the factors that may have such an impact. We compared the two sites on these factors.

Methodology

Environmental Impact

To start this study, we examined the factors in the site assessment for possible environmental impact. A column specific to environmental impact was added to the site assessment tables as can be seen in Appendix L. While visiting the sites, we rated each factor on the impact it could have on the surrounding area. If it was determined that it was not possible for the factor to have an environmental effect, then a N/A was placed in the environmental impact column. If the data collected on the specific factors showed a direct effect on the environment, such as pollution into a river, a "yes" was inputted. For example, at the Oreamuno site, it was determined that the rural road would require resurfacing before plant operation could begin. This construction could cause erosion and possibly require excavation. Thus, it could have negative effect on the environment.

If it was deemed that there was a possibility of environmental impact, "potential" was placed in the cell. For example, at the Cartago site, there is a stream that runs directly through the property. Therefore for the Proximity to Bodies of Water factor a "potential" was inputted because if there was ever a spill of biodiesel or waste oil at the facility, it could pollute this stream.

If the data showed no possible environmental impact, "none" was inputted into the cell. This indicates that although the factor has the potential to negatively impact the environment, the data reflected that it would not occur in this location. For example, at both sites it was determined that the energy provider uses hydro-electricity. This type of power generation produces minimal environmental impact and therefore it was appropriate to place “none” in the cells that represented the type of power source at both sites. Once the data for these factors was collected, we were able to qualitatively compare the two sites.

Results and Discussion

Environmental Impact

The factors with the most significant potential to impact the environment are listed below in Table 10. The complete table of all factors can be found in Appendix L.

Factor	Oreamuno	Cartago
Road Construction	Yes - Will require resurfacing before operation	None – Road requires no construction
Water Treatment	None - Septic Field provides complete treatment	Yes – Sewer offers no treatment
Possibility of Water Pollution	Potential – Stream approx. 200 meters from build site	Potential – Stream runs through property
Source of Electricity	None – Hydroelectric	None – Hydroelectric
Ease of Utility Connection	Yes – Minimal distance to connections	Yes – Minimal distance to connections
Distance to Optimal Location	Yes - Some air pollution caused	Yes - Minimal air pollution caused

Table 10 -– Environmental Impact Results

Before examining the environmental impact factors that differentiate the two sites, we looked at the impacts that the two sites shared, both positive and negative. Factors such as glycerine treatment type and type of power source were rated “none” at both sites. As previously mentioned, the power source of both sites is hydroelectric power. In addition, both sites will implement a glycerine treatment process that will completely treat all glycerine byproduct produced.

After looking at the factors that were similar at each site, we compared the other factors. First, we looked at the factors in which the Cartago site is better than the Oreamuno site. The Cartago site is closer to the optimal location and will cause less air pollution during transportation. Although this is advantageous for this site, it has a minimal influence overall as the direct distance between the proposed site in Oreamuno and the site in Cartago is only 3.8 kilometers. The site located in Cartago has other benefits: the site will require no road resurfacing; it is also located closer to a fire station, which will minimize damage caused by a fire in or around the plant.

Even with these positive attributes, the site in Cartago suffers from one major negative: it has no wastewater treatment. Even though wastewater is not a major factor in the biodiesel process, the biodiesel plant will produce wastewater from bathrooms and sinks. In Cartago, an industry expert has informed us that there is currently no treatment for wastewater. The city sewers empty directly into local rivers, thus contradicting the nature of this project.

Similar to Cartago, Oreamuno offers no wastewater treatment options. However, the Oreamuno site has enough open land to allow the construction of a septic tank. Both sites were rated a "potential" under Possibility of Water Pollution. However, the Oreamuno site showed a slight advantage in this category because there is a larger distance from the site to the nearest body of water. This increased distance created a larger buffer zone from the water source. Lastly, in case of a fire, the site in Oreamuno is not near any other structures or residential areas. Although, a fire here may be more devastating to the plant due to the greater distance from the fire department, it will have a lower effect on the surrounding area.

In general, the potential negative aspects of the Oreamuno site are significantly less than those expected from the Cartago site. The Oreamuno site will require resurfacing on the rural roads before the plant can be operational. However, the roads are gravel and resurfacing will require minimal work. The property will also require light clearing of trees and leveling of land before the site can be constructed on. Alternatively, the Cartago site is located very close to residential areas, and a fire or other accident in the area could be catastrophic.

We concluded that implementation of the biodiesel plant at the Oreamuno site will result in lower environmental impact. Although, the site will require some minor work before construction, it will allow for the treatment of wastewater and is less likely to cause water pollution.

Study 5 - Social Impact

An important consideration in determining the level of public support for a plant's development, is accurately measuring public opinion (Deller & Fortenbery, 2008). The implementation of this plant will have an effect on the lives of residents within the neighboring communities and the extent of this impact is worthy of investigation (Deller et al., 2008). The support of the community is important to maintain a steady waste oil source and for the potential expansion of the sources to private households (Personal Communication, November, 2011). Furthermore, as this plant's main purpose is to improve the local environment, it should not influence the residents in a negative way. To gather the community attitude, we conducted a short survey and statistically analyzed the results to determine the general opinion of the local community about the proposed biodiesel plant.

Methodology

Participants:

To assess the opinions of the local citizens regarding the implementation of the proposed biodiesel plant, we surveyed 42 individuals (23 Males, 19 Females) with an average age of 30. 20 individuals resided in the Cartago municipality (8 Males; 12 Females) and 22 resided in Oreamuno (15 Males; 7 Females). Most of the participants worked in small businesses within the two districts.

Procedure:

These surveys were conducted in downtown Cartago and in San Rafael in Oreamuno. The survey assessed the willingness of each individual to accept the proposed plant under the assumption that the plant will decrease oil pollution in the river basin or that the plant will give an economic benefit to their municipality. We also asked the participants to indicate what size plant they would be most willing to accept, and their overall opinion pertaining to the proposed plant. The survey used a 7-point Likert-Type scale (1 = strongly disagree; 7 = strongly agree). The survey ended with a free response question where the respondents were asked to indicate any general concerns they had about the overall implementation of the plant. The full survey is located in Appendix N.

Results and Discussion

The results of the survey were analyzed using an analysis of variance (ANOVA) with Gender (male, female) and Location (Oreamuno, Cartago) as factors. According to this analysis, both districts were most willing to accept a plant size of 4 on the Likert-scale, or more specifically, a moderately sized plant. This is evident from the statistical data, Cartago (M=4.40, SD=2.13) and Oreamuno (M=4.14, SD=1.52). This data illustrates that there is no significant difference in opinion on plant size between the two districts (p=0.828). The two districts were also in agreement that they would be more likely to support the implementation of a biodiesel plant if it helped to prevent waste oil from being discarded into the river (Cartago M=6.45, Oreamuno M=6.5, p=0.928). The data also suggests that both districts would be more likely to show support if the plant generated a profit for the municipalities and local economy (Cartago M=6.10, Oreamuno M=6.59, p=0.392).

Regarding overall opinion of implementation, the statistical data illustrated that Cartago citizens were in support of the plant (M=5.35) and the Oreamuno district was also supportive (M=6.18). The data analysis indicated that the Oreamuno site was only marginally close to being more in favor of the proposed plant (p=0.123). We therefore assessed the results from the free response question. Of the 20 members surveyed within the Cartago district, 35% expressed concerns about further contaminating and adding additional infrastructure to an already heavily industrialized city. Of the 22 members surveyed within the Oreamuno district, 5% of the respondents expressed similar concerns. A chi-squared analysis illustrated that the concerns of the Cartago citizens were more prevalent than the concerns of Oreamuno citizens, χ^2 (1, N = 42) = 22.5, $p < .00$.

Final Discussion

This project set out to determine the feasibility of implementing a biodiesel processing plant in Cartago, Costa Rica. The results of the Cost-Benefit analysis demonstrated that the proposed plant was economically feasible. The site determined from the Center of Gravity method, Eastern Cartago, was then compared with the proposed site in Oreamuno using the site assessment chart. A statistical analysis of the final comparison values showed that both sites were equally suitable for implementation. The survey of the local community established that both sites were willing to accept a biodiesel plant. However, Cartago residents reported being more concerned than the residents in Oreamuno about pollution from the plant and about building additional infrastructure in the already heavily industrialized city. Also, the environmental assessment illustrated that negative impacts were more significant at the Cartago site. Thus, we recommend the Oreamuno site as the better site for implementation of the proposed plant.

While biodiesel is environmentally friendly and the processing will divert waste oil from the Reventazón, the plant will not be able to function without sufficient profit. We found that one possible way to increase profit is through the sale of glycerine soap. Our CBA showed that this sale, along with biodiesel, would increase the profitability of the plant by a factor of 3. In addition to selling glycerine products, another option for increasing profits is creating contracts with local businesses for biodiesel sale. For instance, we learned in our interview with the biodiesel plant currently operating in Cartago that they have contract with a local bus company to ensure the sale of their biodiesel. We recommend that the municipalities look for other businesses with which they can partner to increase demand and potentially create joint marketing campaigns.

A marketing campaign initiated by the municipality and one its partners could have numerous benefits on the operation of the plant. It has been shown that greater profits are generated from effectively marketed products (Johnson, 2011). We recommend that the municipalities find businesses that they can cooperate with and therefore broaden the audience that they can reach. This will increase public knowledge of the plant throughout the surrounding area and attract more buyers for both the biodiesel and glycerine soap.

The marketing campaign will also help the plant acquire sufficient oil per month. An expert in the biodiesel field stated that the foremost reason biodiesel plants fail is due to an inconsistent feed supply (Personal Communication, November 2011). Therefore, future research should investigate methods for maintaining a consistent supply chain. One way to accomplish this could be to establish a collection program prior to the start of construction. This program could help to create a functional supply chain before the plant begins production and demonstrate the exact amount of available feedstock, ensuring that a correctly sized biodiesel plant is built.

In order to increase the willingness of the community to participate in such a collection program, we recommend that education programs are implemented within the community and schools. Prior research has shown that environmental education programs have the ability to affect the actions of community members (Hungerford & Volk, 1990). COMCURE has previously succeeded in educating the community on the environmental benefits of changing their waste disposal practices (Alvarado, Portuguez, & Salas, 2008). Therefore, we recommend that these education programs be implemented and run by COMCURE.

One limitation on the success of the plant, as noted by an industry expert, is the difficulty in maintaining effective cooperation between the five participating municipalities (Personal Communication, December 2011). To overcome this limitation, we recommend that the municipalities create and agree upon a plan for the distribution of funding for the plant. The main problem with the initial implementation is that Costa Rican law forbids a municipality from spending funds on construction in other districts. Therefore, the municipality of Oreamuno will be responsible for all construction costs of the plant. Yet, the other municipalities will still be able to contribute to the equipment costs, which will be much higher than that of construction. If the initial investment is too expensive for the municipalities, we recommend that they begin by organizing the waste oil collection program. The oil can be transported to the Cartago biodiesel plant, and if it is sold at a reasonable price, this program may even be profitable.

In conclusion, our research showed this plant to be economically feasible and found a suitable site for implementation. This initiative will help reduce the disposal of waste oil into the river and benefit the canton of Cartago economically, socially, and environmentally. In addition, the revenue created from this plant will benefit the municipalities and could be reinvested into other initiatives to continue to clean the Reventazón River. Thus, reducing this pollution by processing the waste oil into biodiesel will aid in the clean-up of Costa Rica’s second most polluted river.

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Appendices

Appendix A - Estimation of Plant Size

The following waste oil data from Alvarado was used to estimate the average oil production from sodas, bars, fast food establishments and restaurants:

	Sodas	Bars	Fast Food	Restaurant
Number	34	2	1	6
Sum	469	12	60	360
Average (liters)	13.79411765	6	60	60

Table 11 -- Waste oil data from Alvarado

This data was then used to approximate the amount of oil produced at these types of establishments in Cartago, Oreamuno, Alvarado and Jimenez.

Type	Bars	Sodas	Restaurants	Fast food	Total without industry	Industry	Total
Waste oil production of Cartago							
Number	80	269	161	14	524	3	527
Volume (Liters)	480	3709.51	9660	840	14689.51	1200	15889.51
Waste oil production of Oreamuno							
Number	10	46	22	6	84	2	86
Volume (Liters)	60	634.34	1320	360	2314.34	1600	3914.34
Waste oil production of Alvarado							
Number	3	47	16	2	68	3	71
Volume (Liters)	18	648.3235	960	120	1746.329	640	2386.324
Waste oil production of Jimenez							
Number	8	7	11	0	26	0	26
Volume (Liters)	48	96.53	660	0	804.53	0	804.53
Total Volume	**606**	**5088.704**	**12600**	**1320**	**19554.73**	**3440**	**22994.7**

Table 12 -- Waste Oil Production without El Guarco

The municipality of El Guarco lacked a list of waste oil producing establishments. Thus, the waste oil production from El Guarco was estimated using per capita data. In order to obtain this data, the total amount of waste oil that is produced in the first four municipalities was divided by the combined population of these districts. This calculation resulted in the average amount of waste oil produced per person. This number was then multiplied by the average population in El Guarco to estimate the waste oil production of this district per capita.

Municipalities	**Population**	**Monthly Waste Oil**
Eastern Cartago	156600	15889.51
Oreamuno	39000	3914.34
Jimenez	15000	804.53
Alvarado	14000	2386.323529
Total without El Guarco	**224600**	**22994.703**
	Per Capita	0.10012

Table 13 - Per Capita Data

Total Waste Oil Production	**Monthly**	**Annually**
	26413.36398	316960.3678

Table 14 - Total Waste Oil Production

$$\boldsymbol{El\ Guarco\ Monthly\ Waste\ Oil} = 39223\ people\ x\ 0.10012\ \frac{liters}{person} = 3418.66\ \frac{liters}{month}$$

Appendix B - Data from Cartago Biodiesel Plant

The following data was obtained from an interview with the owner of the Cartago Biodiesel Plant:

Cost Information			**Cost Information Continued**		
Cost of Waste oil (collected)	₡ 150.00	Liter	**Production Maximum Capacity**	100000	Liter
Cost of Waste oil (dropped off)	₡ 210.00	Liter	**Real Capacity**	10000	Liter
Price of Biodiesel	₡ 650.00	Liter	**Daily Diesel consumption in Costa Rica**	3000000	Liter
Monthly Energy Cost	₡ 60,000.00	Month	**Start of the plant**	2004	
Monthly Salary for workers	₡ 210,000.00	Month	**Total Monthly energy need**	500-600	Kwh
Monthly Salary for professionals	₡ 500,000.00	Month	**Number of employees**	8	
Crude Glycerine Sale	$ 0.40	Kilogram	**Life Span of Tanks**	50	years
Initial Equipment Cost	$ 1,300,000.00		**Average Life Span of Equipment**	8 to 10	years
Construction Cost	$ 250,000.00		**Transport of waste oil**	daily	
			Storage room possible	100	ton

Table 15 -- Plant Operation Data

Appendix C - Power Costs from JASEC

New Rates 2011					
	DETAILS OF CURRENT RATES			SEASON:	NA
	FORCE	Friday, May 13, 2011	to the (*)	New price-setting	
	PUBLISHED:	Date:	Friday, May 13, 2011	Gazette:	92
RATE TYPE					
ARESEP	JASEC	DESCRIPTION	Rank	Energy, kWh	DEMAND, KW
T-RE	A, C	Residential Services, dedicated to housing.	First 30 KWh , Colones	1710.00	
			More than 30 to 200kWh, ¢ / kWh	57.00	
			More than 200 KWh , ¢ / kWh	70.00	
T-CS	D, E	Services charities and pumping water	First 30 KWh , Colones	2130.00	
			Over 30KWh, ¢ / kWh	71.00	
T-GE	B, P, F, G, H	Business services, small industry and irrigation water pumping.	First 30 KWh , Colones	2580.00	
			Over 30KWh, ¢ / kWh	86.00	
	T-1 and T-3	Industries and Commerce, with monthly consumption less than 3000KWh and 8 KW.	First 3000KWh, Colones	153,000.00	
			Over 3000KWh, ¢ / kWh	51.00	
			First 8 KW, Colones		64008.00
			Over 8KW, ¢ / KW		8001.00
	T-2 and T-4	Industries and Commerce, with monthly consumption less than 20000KWh and 55KW	First 20000KWh, Colones	153,000.00	
			Over 20000KWh, ¢ / kWh	51.00	
			First 55 KW, Colones		64008.00
			More than 55KW, ¢ / KW		8001.00
	T-7	Services charities and pumping water, with consumption equal to or greater than 3000KWh and 8KW	First 3000KWh, Colones	123,000.00	
			Over 3000KWh, ¢ / kWh	41.00	
			First 8 KW, Colones		49232.00
			Over 8KW, ¢ / KW		6154.00
	TMT	Service with consumption equal to or greater than 240 000KWh/año	Punta, 10 to12:30 and 17:30 to 20 hours, ¢ / kWh or ¢ / KW	43.00	7638.00
			Valle, 06 to10 hours and 12:30 to 17:30, ¢ / kWh or ¢ / KW	22.00	5477.00
			Night 20 to 06 hours, ¢ / kWh or ¢ / KW	15.00	3746.00
(*) ... The effective date may be varied by a new publication fee.					

Table 16 - Power Costs from JASEC

Appendix D - Economic Costs

According to JASEC Electricity Company, the cost for producing 3000 kilowatt hours or fewer will be \$306.00 per month.

$$\boldsymbol{Annual\ Energy\ Cost} = Monthly\ Cost\ \times 12\ \frac{months}{year}$$

$$= \$306 \times 12 \frac{months}{year}\ = \$3672$$

$$\boldsymbol{Labor\ Cost} = Workers\ Salary + Professionals\ Salary$$

$$\$420.00 \times 15 workers \times 12 \frac{months}{year} + \$1000.00 \times 3 professionals \times 12 \frac{months}{year}$$

$$= 111600.00$$

$$\boldsymbol{Waste\ Oil\ Collection\ Cost} = Waste\ Oil\ Collection\ Cost/liter \times 30000$$

$$= \$0.42 \times 26{,}413.00\ liters\ \times 12\ months = \$133121.50$$

Appendix E - Expected Revenue

The market price for biodiesel is \$1.30 per liter according to the San Jose Biodiesel Plant.

Biodiesel Revenue

$$= \$1.30 \times 26413 \frac{liters}{months} \times 12 \frac{months}{year} = \$412042.80$$

The production process of biodiesel will also produce crude glycerine. For every one liter of biodiesel product, 0.15 liters of crude glycerine is produced. This component can be sold as crude product for \$0.40 per kilogram and the density of the crude glycerine is 1 kg/liter. This allowed us to calculate the expected revenue from the direct sale of crude glycerine

Direct Sale Glycerine Revenue

$$= \$0.40 \times 26413\, litersbiodiesel \times 0.15 \frac{glycerine}{biodiesel} \times 1 \frac{kg}{liter} \times 12\, months = \ \$19017.36$$

Another option for the sale of glycerine is to process it into soap products. We acquired information on this from a local company that specializes in processing crude glycerine into soap products for biodiesel plants.

Soap Sale Glycerine Revenue

$$= \$1.40 \times 26413\, liters\ biodiesel \times 0.15 \frac{liters}{months} \times 1 \frac{kg}{liter} \times 2 \frac{kg\ soap}{1\ kg\ gylcerine} \times 1000 \frac{g}{1\ kg} \div$$

$$120\ \frac{g}{1\ soap\ product} \times 12\, months = \$1{,}118{,}668.24$$

Appendix F - Comparison Indicators for Economic Feasibility

The PW method exemplifies the total amount of money that will be generated throughout the expected life span of the plant considering the time value of money. The AW method illustrates the annual profit over a steady useful life of the project. The equations for these methods and definitions of their variables are listed below:

$$Present\ Worth(i\%) = \sum_{k=0}^{N} \mathrm{F_k}(1+\mathrm{i})^{-\mathrm{k}}$$

$$Annual\ Worth(i\%) = R - E - I\left(\frac{A}{P}, i\%, N\right) + S\left(\frac{A}{F}, i\%, N\right)$$

A and P are two coefficients within the equations

$$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] = A\left(\frac{P}{A}, i\%, N\right)$$

$$A = P\left[\frac{i(1+i)^N}{i(1+i)^N - 1}\right] = P\left(\frac{A}{P}, i\%, N\right)$$

i%=effective interest rate

F_k=Future Cash Flow at the end of period k

k=index for each compounding period ($0 \leq k \leq N$)

R=Annual Revenues

E=Annual Expenses

I=Investment

$\frac{A}{P}$=Capital Recovery Factor

N=Project Study Period

S=Salvage (market) Value at the end of the study period

$\frac{A}{F}$=Sinking Fund Factor

θ=Simple Payback Period

(Koelling et al., 2010)

The PW and AW values were calculated using two glycerine sale alternatives

1. **Direct Glycerine Sale Option:**

$$\mathbf{PW} = \text{Total Initial Cost} + (Annual\ Revenue - Annual\ Cost) \times (\frac{P}{A}, 10\%, 25)$$

$$= \$ - 1{,}550{,}000 + (\$431{,}060.16 - \$248{,}393.5) \times 9.077$$

$$= \$108{,}065.09$$

$$\boldsymbol{AW} = Total\ Initial\ Cost \times (\frac{A}{P}, 10\%, 25) + (Annual\ Revenue - Annual\ Cost)$$

$$= \$ - 1{,}550{,}000 \times 0.1102 + (\$431{,}060.16 - \$248{,}393.5)$$

$$= \$11856.64$$

2. **Glycerine Soap Sale Option:**

$$\boldsymbol{PW} = Total\ Initial\ Cost + (Annual\ Revenue - Annual\ Cost) \times (\frac{P}{A}, 10\%, 25)$$

$$= \$ - 1{,}600{,}000 + (\$1{,}530{,}711 - \$723{,}827) \times 9.077$$

$$= \$5{,}724{,}081.67$$

$$\boldsymbol{AW} = Total\ Initial\ Cost \times (\frac{A}{P}, 10\%, 25) + (Annual\ Revenue - Annual\ Cost)$$

$$= \$ - 1{,}600{,}000 \times 0.1102 + (\$1{,}530{,}711 - \$723{,}827)$$

$$= \$630{,}523.52$$

Appendix G - Payback Period

The Payback period for this plant was calculated twice, using each of the glycerine sale options. The following equation was used to calculate this number, where θ is the Payback Period (Koelling et al., 2010).

$$k = 1\theta(R_k - E_k) - I \geq 0$$

1. Direct Glycerine Sale Option:

Year	Cumulative PW at 10%
0	$ -1,550,000.00
1	$ -1,383,937.76
2	$ -1,232,982.05
3	$ -1,095,744.60
4	$ -970,983.28
5	$ -857,565.57
6	$ -754,450.25
7	$ -660,705.73
8	$ -575,491.74
9	$ -498,022.82
10	$ -427,604.83
11	$ -363,580.17
12	$ -305,382.58
13	$ -252,464.06
14	$ -204,367.93
15	$ -160,637.54
16	$ -120,889.28
17	$ -84,757.81
18	$ -51,896.09
19	$ -22,030.09
20	**$ 5,114.17**

Table 17 - Payback Period for Direct Sale of Glycerine

We calculated the PW value for every year until we had the first positive value in Cumulative PW at 10% which is 20th year.

2. **Glycerine Soap Sale Option:**

Year	Cumulative PW at 10%
0	$ -1,600,000.00
1	$ -866,462.20
2	$ -199,653.66
3	**$ 406,557.93**

Table 18 - Payback Period for Sale of Glycerine Soap

We calculated the PW value for every year until we had the first positive value in Cumulative PW at 10% which is 3rd year.

Appendix H - Break-even Analysis

In addition to indicator calculations, we also conducted a break-even analysis. The initial investment, annual cost, and annual revenue were used in this calculation. Major components of this analysis include the annual costs and income. Costs are categorized as fixed cost and variable cost which are detailed further in the appendices.

Fixed costs, also referred to as overhead costs, are the cash outflow not directly related to the volume of production. Administrative cost, rent, interest, depreciation, and insurance are all typical overhead costs which always exist regardless of the production situation of the company. Variable costs are those costs directly related with production or sales changes. Examples of this type of cost include wage for labor, raw materials, packaging, logistics and energy costs (Foltz & Wilson, 2008).

The break-even points were determined by solving the following equations (Foltz et al., 2008):

$$TC = vQ + F$$

$$TC = TR$$

$$TR = pQ$$

TC=Total Cost

v=Variable Cost

Q=Quantity (Break-even Point)

F=Fixed Cost

TR=Total Revenue

p=Price per item

Specifically for the proposed plant, the fixed costs will be labor cost on a monthly basis. The cost of monthly oil collection and energy costs are both variable. The break-even point will illustrate the quantity of product that must be sold in order for the income to equal the monthly cost.

Break-even Point (Sale of Crude Glycerine):

$$Total\ Cost = Total\ Income$$

$$Labor\ Cost + \left(Energy\frac{Cost}{liter} + Collection\frac{Cost}{liter}\right) \times Q$$
$$= (Biodiesel\ Price + Direct\ Glycerine\ Sale\ Price) \times Q$$

$$\$9300 + (\$0.0102 + 0.42) \times Q = (\$1.3 + \$0.04) \times Q$$

$$Q = 10222.03\ liters/month$$

Break-even Point (Sale of Glycerine Soap):

$$Total\ Cost = Total\ Income$$

$$Labor\ Cost + \left(Energy\frac{Cost}{liter} + Collection\frac{Cost}{liter}\right) \times Q =$$

$$= Biodiesel\ Price \times Q + Glycerine\ Soap\ Price \times Glycerine\ Soap\ Quantity$$

$$\$9300 + (\$0.0102 + 0.42) \times Q = \$1.3 \times Q + \$11.75 \times 1 \times 15\% \times Q$$

$$Q = 3532.76\ liters/month$$

Appendix I - Center of Gravity

The locations of the municipalities were plotted using Google maps and given a weight based on the amount of oil that each produced. The following steps were used to calculate the Center of Gravity point for this project (Personal Communication, October 2011):

Step 1: Determine the X, Y coordinate points for each source and demand point, along with point volumes and linear transportation rates.

Step 2: Approximate the initial location as follows:

$$\bar{X} = \frac{\sum_i V_i R_i X_i}{\sum_i V_i R_i}; \qquad \bar{Y} = \frac{\sum_i V_i R_i Y_i}{\sum_i V_i R_i}$$

Step 3: Using $(\bar{X}, \bar{Y})$ from step 2, calculate d_i using the following equation. (The scaling factor K need not be used in this case.)

$$d_i = K\sqrt{(X_i - \bar{X})^2 + (Y_i - \bar{Y})^2}$$

Step 4: Substitute d_i into equations in Step 2, and solve for the revised $(\bar{X}, \bar{Y})$ coordinates.

Step 5: Recalculate d_i based on the revised $(\bar{X}, \bar{Y})$ coordinates.

Step 6: Repeat steps 4 and 5 until either of the $(\bar{X}, \bar{Y})$ coordinates do not change for successive iterations.

Step 7: Finally, calculate the total cost for the best location using the equation:

$$TC = \sum_i V_i R_i d_i$$

Definition of the variables: TC = total transportation cost

V_i = volume at point i

R_i = transportation rate to point i

d_i = distance to point i from the facility to be located

Revised 2 Solution										
Point #	Point *i*	Coordinate X_i	Coordinate Y_i	Volume, V_i (liter)	Tranp. Rate, R_i ($/liter/km)	V_iR_i	$V_iR_iX_i$	$V_iR_iY_i$	d_i'	V_iR_i/d_i'
1	Cartago	4.20	8.30	15889.51	0.04	635.6	2669	5275.3	1.5635543	406.4972
2	Oreamuno	6.00	8.66	3914.34	0.04	156.6	939.4	1355.9	0.27237806	574.8392
3	El Guarco	2.22	6.10	3418.66	0.04	136.7	303.6	834.15	4.31101472	31.72024
4	Alvarado	16.70	14.23	2386.324	0.04	95.45	1594	1358.3	12.3276766	7.742979
5	Jimenez	23.82	11.63	804.53	0.04	32.18	766.6	374.27	18.3374386	1.754945
Total						1057	6273	9198		1022.555
Revised 2	X¯'=Σ(ViRiXi/di')/Σ(ViRi/di')=5397.8531/1022.5546					0				
Solution:	Y¯'=Σ(ViRiYi/di')/Σ(ViRi/di')=8676.1205/1022.5546						0			

Table 19 - Center of Gravity Calculation

Appendix J - Oreamuno Site Evaluation Pictures

Below are pictures of the roads observed and rated at proposed site in Oreamuno.

Figure 2 - Oreamuno site road from Southwest (Photo by Zhang)

Figure 3 - Oreamuno site road towards Northeast (Photo by Zhang)

Appendix K - Cartago Site Evaluation Pictures

Below are pictures of the roads observed and rated at site in Cartago.

Figure 4 - Cartago site road bordering Eastern side (Photo by Zhang)

Figure 5 - Cartago site dirt road bordering Northern side (Photo by Zhang)

Appendix L - Site Evaluation Chart

Site factors		Oreamuno Site (9.872298,-83.87538)				
		Weighting Factor	Rating	Factor Product	Environmental Impact	Notes
Accessibility	High Speed Road Accessibility	0.041	4	0.163	N/A	Site is 6.3 km by rural road to Closest National (High-Speed) Road - Route 219.
	Rural Road Accessibility	0.052	10	0.519	N/A	Rural road borders property and there is a driveway into the property.
	Quality of Nearby Roads	0.053	1	0.053	Yes	Rural road available to the site will require contruction (See Appendix TBD).
	Traffic Load	0.026	6	0.158	N/A	Main Roads to Cartago and El Guarco rated as a 7 (Route 219). Main Roads to Alvarado, Cervantes and Jimenez rated as 5 (Route 230).
Energy	Type of Power Source	0.038	10	0.378	None	All Power is generated by JASEC from hydroelectric dams.
	Cost of Electricity	0.030	10	0.303	N/A	Power costs for both sites were equal coming from the same provider JASEC (See Appendix TBD).
Water	Proximity to Bodies of Water	0.065	3	0.194	Potential	River is located at 212 meters from possible build site.
	Accessibility to Industrial Water	0.044	9	0.398	Yes	Closest water connection is located at 185 meters from possible build site.
	Cost of Water	0.028	10	0.281	N/A	Cost of Water was assumed to be the same between the two sites.
Wastewater	Wastewater Treatment Type	0.046	10	0.461	None	A septic system will need to be built. Once built, the Spetic system will treat wastewater completely.
	Distance to Sewage Line	0.010	10	0.100	None	Spetic tank will require no extra sewer pipes to be implemented.
	Cost of Sewage	0.026	5	0.131	N/A	Initial cost of treatment will be expensive because a septic tank will need to be built.
Communications	Mobile Network Coverage	0.016	8	0.129	N/A	Near Perfect Coverage was noted throughout the site visit on both carriers.
	Landline Cost	0.031	10	0.311	N/A	Both sites are covered by the same service provider (ICE)
Emergency Services	Fire Coverage	0.040	4	0.159	Potential	Cartago Fire Station is 6.5 km away (9.865646,-83.923464)
	Police Coverage	0.038	4	0.153	N/A	6.8 kms to Cartago Police (9.869188,-83.923132)
	Health Services Coverage	0.047	4	0.187	N/A	Hospital of Cartago is 6.3 km away (9.861664,-83.921986)
GlycerineManagement	Glycerine Treatment Type	0.045	10	0.447	None	DieselloVerde Soapification Process
	Distance to Treatment Site	0.036	10	0.361	None	Glycerine soap production will occur on-site
	Cost/Value of Glycerine Treatment	0.057	10	0.569	N/A	Glycerine soap production will add more income to the plant than biodiesel.
Location:	Distance from Waste Oil Sources	0.047	4	0.188	Yes	The site is 3.64 km from the optimal site.
	Residential Area	0.050	9	0.453	N/A	Nearest urban area is located at 947 meters away.
	Zoning	0.036	0	0.000	N/A	Site is zoned as ZAG (Agricultural area).
	Property Constructability	0.054	10	0.544	None	Site is near ready for construction. Minor clearing of Trees and land needed.
	Frequency of Hazardous Items	0.043	9	0.388	N/A	Site is located near a steep slope that could be affected by erosion.
Overall Score				7.027		

Table 20 - Site Evaluation Chart for Oreamuno

Site factors		Cartago Site - 465 meters Northeast of Basílica de Nuestra Señora de Los Ángeles (9.867499,-83.910205)				
		Weighting Factor	Rating	Factor Product	Environmental Impact	Notes
Accessibility	High Speed Road Accessibility	0.041	8	0.327	N/A	Nearest National (High Speed) road is 267 meters by paved rural road.
	Rural Road Accessibility	0.052	10	0.519	N/A	Rural road borders the property on the eastern side.
	Quality of Nearby Roads	0.053	7	0.369	None	Road that borders eastern side of property is 2 lanes paved with no defects. Dirt road on northern side is well maintianed, minimal ruts and pot holes. See pictures in appendix (TBD)
	Traffic Load	0.026	5	0.132	N/A	National Roads to the south rated as 6, to the North and East as a 5, and to the west as a 4.
Energy	Type of Power Source	0.038	10	0.378	None	All Power is generated by JASEC from hydroelectric dams.
	Cost of Electricity	0.030	10	0.303	N/A	Power costs for both sites were equal coming from the same provider JASEC - see appendix (TBD).
Water	Proximity to Bodies of Water	0.065	0	0.000	Potential	Property has a small river running through it.
	Accessibility to Industrial Water	0.044	10	0.442	None	Site is sourrounded by residences with water connections - within 100 meters.
	Cost of Water	0.028	10	0.281	N/A	Cost of Water was assumed to be the same between the two sites.
Wastewater	Wastewater Treatment Type	0.046	0	0.000	Yes	Sewage in the city of Cartago is untreated.
	Distance to Sewage Line	0.010	10	0.100	None	Site is sourrounded by residences with sewer connections - within 100 meters.
	Cost of Sewage	0.026	10	0.261	N/A	Cost of Sewage will be lower because sewage connection is cheaper than septic tank construction needed in Oreamuno.
Communications	Mobile Network Coverage	0.016	10	0.161	N/A	Group members observed full network coverage across both carriers during site visit.
	Landline Cost	0.031	10	0.311	N/A	Both sites are covered by the same service provider (ICE)
Emergency Services	Fire Coverage	0.040	9	0.358	Potential	Cartago Fire Station is 1.2 kilometers away (9.865646,-83.923464)
	Police Coverage	0.038	9	0.345	N/A	Cartago Police is 1.6 kilometers away (9.869188,-83.923132)
	Health Services Coverage	0.047	9	0.420	N/A	Hospital of Cartago is 1.3 kilometers away (9.861664,-83.921986)
GlycerineManagement	Glycerine Treatment Type	0.045	10	0.447	None	DieselloVerde Soapification Process
	Distance to Treatment Site	0.036	10	0.361	None	Glycerine soap production will occur on-site
	Cost/Value of Glycerine Treatment	0.057	10	0.569	N/A	Glycerine soap production can add as much value to the plant as biodiesel.
Location:	Distance from Waste Oil Sources	0.047	10	0.469	Yes	Site is located directly on top of Center of Gravity Point.
	Residential Area	0.050	0	0.000	N/A	Property is surrounded by urban area.
	Zoning	0.036	0	0.000	N/A	No Zoning information available but nearby zones include ZPRQ (Protected for nearby rivers) and ZPI (Institutional Public use - Cemetary)
	Property Constructability	0.054	10	0.544	None	Property is a cleared parcel of land currently used for animals to graze on.
	Frequency of Hazardous Items	0.043	10	0.431	None	The team observed no other hazardous items.
Overall Score				7.098		

Table 21- Site Evaluation Chart for Cartago

Appendix M - Average Daily Traffic Number of Vehicles

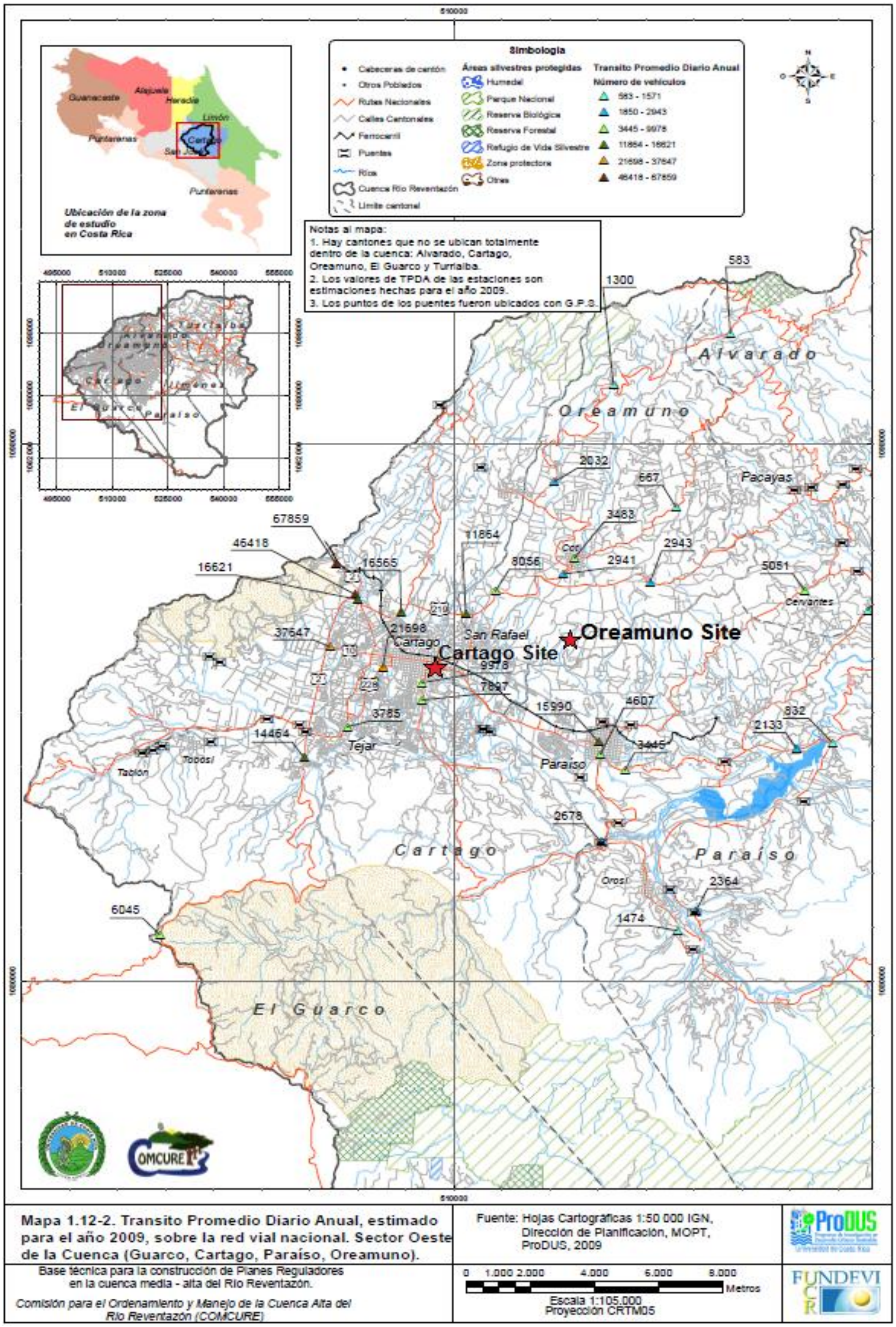

Figure 6 - ProDUS Map of Average Daily Traffic

Appendix N - Social Survey Questions

Survey of Biodiesel Plant Production

Instructions: Please answer the following questions as honestly as possible. Please circle the response that best represents your opinion.

1. Assuming that a biodiesel plant will be built in your municipality, how large of a plant do you feel would be reasonable and acceptable?

1 2 3 4 5 6 7

Very Small (e.g., a Soda) Very Large (e.g.,a Factory)

2. I would be more likely to support the biodiesel plant if it helped prevent waste-oil from being discarding into the river.

1 2 3 4 5 6 7

Strongly Disagree Strongly Agree

3. I would be more likely to support the biodiesel plant if it helped generate a profit for my municipality and improved the economy of my municipality.

1 2 3 4 5 6 7

Strongly Disagree Strongly Agree

4. Overall, I strongly support the building of and implementation of a biodiesel plant in my municipality.

1 2 3 4 5 6 7

Strongly Disagree Strongly Agree

5. Are there any other concerns or issues you have about building a biodiesel plan in your municipality?

6. Please circle your gender: Male Female

7. Please indicate your age (in years): ___________

8. Please indicate your occupation: ____

9. Please indicate your municipality _______________________________________

Encuesta de Producción de Planta Biodiesel

Instrucciones: Por favor conteste las siguientes preguntas honestamente. Encierre con un círculo la respuesta que mejor represente su opinión.

1. ¿Suponiendo que una planta de biodiesel se construirá en su municipio, cual sería es el tamaño que usted cree que sería razonable y aceptable?

1 2 3 4 5 6 7
Muy pequeñas (por ejemplo, soda) Muy Grande (por ejemplo, una fábrica)

2. ¿Apoyaría el establecimiento de una planta de biodiesel si ayudara a evitar el vertido de aceite en las aguas del Río Reventazón?

1 2 3 4 5 6 7
Totalmente en desacuerdo Totalmente de acuerdo

3. ¿Apoyaría el establecimiento de una planta de biodiesel si ayudara a generar un beneficio para mi municipio y la mejora la economía de mi comunidad?

1 2 3 4 5 6 7
Totalmente en desacuerdo Totalmente de acuerdo

4. ¿En general, apoyo firmemente la creación e implementación de una planta de biodiesel en mi municipio?

1 2 3 4 5 6 7
Totalmente en desacuerdo Totalmente de acuerdo

5. ¿Hay otras preocupaciones o problemas que usted tiene sobre la construcción de una planta de biodiesel en su municipio?
____
____
____

6. Por favor marque con un circule su género: Masculino: ____ Femenino: ____

7. Por favor, indique su edad (en años): __________

8. Por favor, indique su ocupación: ____

9. Por favor, indique el nombre de su municipio: ____