

Biodiesel Production in Karkar Island of PNG - Learning from a Success Story



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1. Background

Located 60 kilometers north (4°39 'S, 145°58' E) of the beautiful town of Madang, the volcanic island of Karkar, is a home to about 50,000 people. The island is about 26 kilometers in length and 20 kilometers wide. It is administered by the Kinim Local level Government (Kinim LLG).

Karkar Island is known to have some well established coconut plantations that were planted some 70 to 80 years ago by some Australian and German settlers. Those who still operate as original owners and those that bought off plantations from the original owners. The likes of the original owners that still operate the plantations are the Middleton Family, originally from Australia. Other large plantations are owned by Noel Goodyear and Ken Fairweather (the current local member of the PNG Parliament).

These coconut plantations had been producing copra for decades. Copra from these plantations were dried and sold to local buyers in Madang for export. The Middleton Family had diversified its production by venturing into producing biodiesel from its copra, in 2006. After going through so many trials on different processing equipments, the Kulili Plantations Estate, owned by the Middleton Family had found the “secret” recipe to the production of the “right” biodiesel.

Pacific Island countries are realizing the importance of energy since all economic activities in these small island states need fuel for electricity and transportation. With the adverse impacts of climate change, one cannot rely on the continual consumption of fossil fuel, as it is an individual commitment by each island states to reduce their use of fossil fuel and increase on their renewable energy uptake and put more emphasis on energy efficiency practices. This is a way to tell the rest of the world that these small islands stated are more vulnerable to the adverse effects of climate change but they emit less than 0.03% of the global total of greenhouse gas (GHG). Not only is that, but the volatility of the world oil prices show negative effects on the economies of the small island states in the Pacific. These island state Governments are pursuing opportunities to increase economic development via a more sustainable mean.

This document serves to present experiences lessons learnt from coconut plantation owners in Karkar islands with specific attention to biodiesel production for power generation and as fuel for transportation. This is in the context of GHG emission and sustainable energy production and consumption.

2. Field Survey

The field survey involved interviews and site inspections. Interview involved questions asked to the management and other technical personnel in the establishments visited, whilst site inspection involved seeing the actual process in producing biodiesel from the coconut picking to

the consumption of biodiesel for power generation and as a fuel for transportation in motor vehicles and engine-powered boats.

The field survey in Karkar Island was done in one day with the following establishments visited:

- Kulili Estates and PNG Biofuels (Copra production and Biodiesel production)
- Inter-Island Produce (Cooperatives) – Copra buyer
- Karkar High School (Biodiesel-powered electricity generator)

Other establishments visited and information gathered on biodiesel production is:

- Department of Mechanical Engineering at University of Technology
- Bogia Biodiesel Producer (Leo Bambia)

2.1. Kulili Estate and PNG Biofuels

The Kulili Estate is owned by the Middleton Family and there are four plantations. These are:

- (i) Kulili Plantation;
- (ii) Kaviak Plantation;
- (iii) Wadau Plantation and
- (iv) Bulu Plantation

These plantations range from 5 – 10 hectares and they can produce on average 300-400 tones of copra in a month. This is about 3-4% of the total Karkar Island copra production per month. Kulili Estate has its own estate laborers that collect and dry the copra. It has been producing copra for the past 6 to 7 decades through 3 generations of the Middleton Family. The Estate has been selling most of its copra to Madang at a cost of K1100 per metric ton. The market price in Karkar is K100 per 100 kilogram bag.

PNG Biofuel is a set up within the Kulili Estate and is located at the Kulili. It was established after some discussion between the Middleton family and an Australian chemical engineer (Stephen Welsh) in 2006. For some years there had been uncertain prices for copra and steadily increasing prices for petroleum diesel fuel. All the operations in the Kulili Estate were diesel-powered, ranging from electricity for offices, residential houses, plantation machineries (tractors and Ute) to cargo boats and game fishing boats.

Lots of resources had been invested by Kulili Estates on biodiesel work since 2006. In PNG, number of people had tried to go into this biodiesel production but have not been successful due to numerous factors ranging from machineries; correct processing procedures and pricing of the final product in the open market compared to the price of copra and diesel.

The biodiesel story began with Kulili Estates purchasing the needed biodiesel equipment from India. For a good number of months it works but started to perform unexpectedly bad so a biodiesel processing equipment supplier from China was contacted and a 20ft container installed with processing equipment purchased. This was even worst as it did not worked well, resulting in Kulili opting to a smaller unit from the same company in China which operated fairly well since then until now. With this equipment, roughly 50,000 liters of biodiesel is produced per month. The biodiesel produced is used for all the fuel needs at the Kulili Estates (electricity and vehicles) including two (2) cargo boats; two (2) game fishing boats. Some are sold to Karkar High School and Karkar LLG (Local Level Government Office) gensets and vehicles and some private motor vehicles in Karkar Island.



Photo 1: Game Fishing Boat- uses Biodiesel



Photo 2: Biodiesel-powered electricity generator

2.1.1, Biodiesel Processing at Kulili Estate (PNG Biodiesel)

The biofuel processing set up at the PNG Biofuel is no different from any basic set up, that comprises of a crusher; expellers; A pump to the sedimentation tanks; Sedimentation tanks; A pump to the holding tanks; Holding tank; a mixing tank; a centrifuge; filters; Second storage tank; 1 micron filter and a third storage tank (for dispatching final product - Biodiesel). The basic process-line is given in Chart1.

Step 1: The Crusher.

Crushing of copra into smaller size for the Expeller



Step 2: The Expeller

The Expeller: An expeller press is a screw-type machine that presses copra through a caged barrel-like cavity. Raw materials enter one side of the press and copra mill exit the other side. The machine uses friction and continuous pressure from the screw drives to move and compress the copra. The oil seeps through small openings that do not allow copra mill (solids) to pass through and the oil is collected by the collecting vessel at the bottom. The coconut mill (by-product) are sold for pig and chicken farmers



Step 3: Sedimentation Tanks

Oil from the expeller is pump to these holding tanks and left for 3 to 4 days for the debris to settle to the bottom before transferred to the holding tank 1



Step 4: Holding Tank 1

This tank collect oil from the sedimentation tanks after the debris settles to the bottom of the tanks.



Step 6: Centrifuge

The raw biodiesel is transferred to the centrifuge, where the heavy particle in the mixture are removed during the centrifuging process, whilst the lighter biodiesel is transferred into a holding tank, ready to be filtered



Step 5: Mixing Tank

This is the container where all the substance (CNO, methanol and potassium hydroxide -KOH). The mixing process will take about 1 ½ hours to enable the reaction to complete



Step 8: Filtration Tank

From the Ion Exchange Filter the biodiesel is transferred to this tank ready to be passed through a 1-micron filter



Step 7: Ion Exchange Filter

This filtering system filters out Soap (glycerol) molecules. The system consists of bead coated with resin. ION exchange resins are high tech man made resins that are capable of trapping soap molecules on the surface of a resin bead. Different ION exchange resins work in different ways and use different techniques to clean the biodiesel. All of them generate a new waste stream, the spent beads.



Step 9: 1-Micron Filtration

This filter filters the biodiesel down to 1-micron. That is anything above 1 micron is being filtered out.



Step 10: Storage Tanks

These two storage tank stores the final biodiesel product, ready to be use



Step 11: Dispatching

Estate's own use: Power generation; trucks and boats

Sell to Karkar High School and Karkar Local Level Gov't

Sold to general local vehicle owners and generator owners in Karkar Island



Chart 1: Biodiesel Production Process

2.1.2. Power Generating Units at Kulili Estate

The Kulili Estate has its power-house located next to the PNG Biofuels plant. There are three (3) gensets (all Cummins). Two (2) of these are new whilst the third one is an old one. The two (2) new ones are rated at 150 kVA and 250 kVA. The old one is rated at 80 kVA. All three (3) units were running on biodiesel and we noted that gas released at the exhaust pipes was very clear. The power output during the time (1 pm on a normal working day) of the visit was 70 kVA from one of the new Cummins gensets.

2.1.3. Copra production & biodiesel pricing

About 10,000 tons of copra is produced on Karkar Island. Out of those 300 tons is produced by Kulili Estates alone. Kulili Estate do not normally buy copra from local small holder as it produces its own copra, but on occasion that it buys copra from individual holder, the price it uses is K100 per bag on Karkar Island. The selling price of copra in Madang is K1100 per ton (or K110 per bag). The price of biodiesel on Karkar Island is 15 toea lower than the current price of normal diesel which is. Transport costs to Madang will increase the price. Transporting of goods between Karkar Island and Madang is a great problem. There are no Government shipping services to the island. Kulili has two boats but the cost is too high to run them. It will help the Karkar Island greatly if the shipping difficulties are reduced through Government support.

During the discussions Mr Middleton mentioned that PNG Biofuels can provide training to individuals or PICs interested in venturing into biodiesel work. They can provide consultancies in certain areas only.

2.1.4. Basic Chemical Process

Most of the work on coconut oil (CNO) used as fuel in the Pacific region are either 100% CNO or a blend with diesel oil (could be B5, B10, B15 and B20). Some biofuel producer, including PNG Biofuels alluded that the use of pure coconut oil or straight vegetable oil (SVO) as a bio-fuel is corrosive to the piston wall linings and fuel injector nozzles because it does not have the ideal properties for combustion in a diesel engine. SVO might need a dual fuel system or a modified engine to have it used. Chemical properties of coconut oils are enhanced when it is converted to biodiesel. CNO or any other vegetable are triglycerides (TGs), composed of three chains of fatty acids bound together by a glycerine (glycerol) molecule, as shown schematically in figure 1.

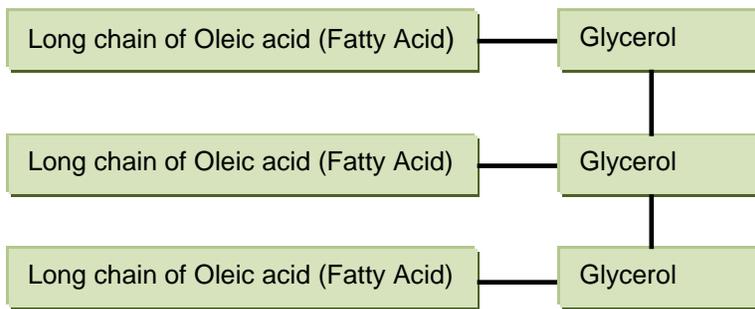


Figure 1: Triglyceride molecule

Triglycerides are esters. Esters are acids, such as fatty acids, combined with an alcohol, such as glycerine (glycerol) which is a heavy alcohol. The trans-esterification process converts triglyceride esters into mono-alkyl esters (biodiesel) by means of a catalyst (Potassium hydroxide - KOH) and an alcohol reagent, usually methanol, to give methyl esters biodiesel - the methanol replaces the glycerol.

In trans-esterification the triglyceride molecule is broken into three separate methyl ester molecules plus glycerin (glycerol) as a by-product. The KOH breaks the bond holding the fatty acid chains to the glycerin, the glycerin falls away, and each fatty acid chain then bonds with a methanol molecule. The reaction is as shown by the follow chemical equation:



It happens in three stages (this has nothing to do with the single-stage or two-stage processes). First, one fatty acid chain is broken off the triglyceride molecule and bonds with methanol to form a methyl ester molecule, leaving a diglyceride molecule (DG) -- two chains of fatty acids bound by glycerin. Then a second fatty acid chain is broken off the diglyceride molecule and bonded with methanol to form another methyl ester molecule, leaving a monoglyceride molecule (MG).

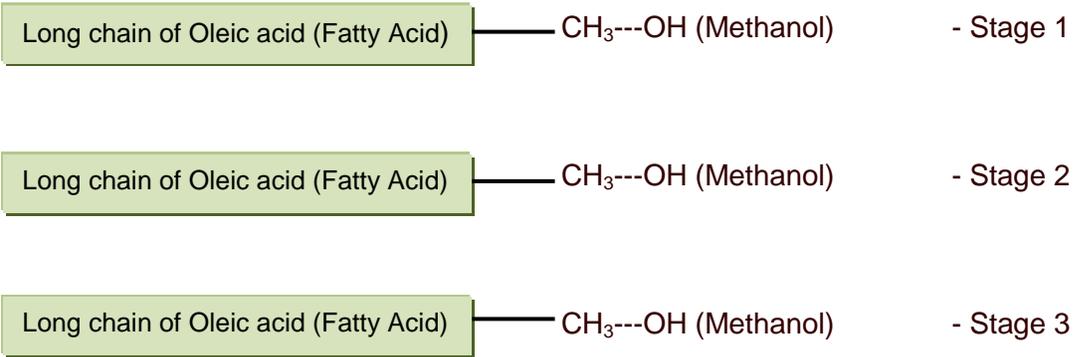


Figure 2a: Methyl Ester molecules (Biodiesel)

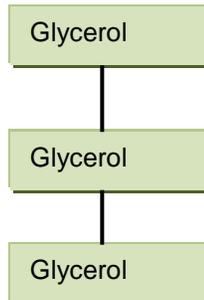


Figure 2b: The Glycerin molecule (by-product)

However, the process can run out of reagent or catalyst before it gets as far as completion, or the agitation, temperature or processing time may not be adequate.

The result is some unconverted or partly converted material remaining in the biodiesel. Diglycerides and monoglycerides are fuel pollutants: diglycerides don't combust well and lead to coking problems, monoglycerides can lead to corrosion and other problems resulting in engine failure.

2.2. Inter-Island Produce Cooperative

An interview was made with the general manager of Inter-Island Produce (IIP); Mr. Joe Bannick at the IIP Office is located next to the Kinim LLG Office in Karkar Island. IPP is a Cooperative within the island and it supports the local small holder coconut growers to sell their copra produces. Out of 15 registered cooperatives in the island, only 11 are in operation. IIP buys copra from members and other farmers are sold to Copra Products Limited, based in Madang town. Member of the IPP and others that sells their copra to IPP are from half of the Karkar Island and a monthly sales (profit) of copra by IPP is about K50,000 (50,000 kina) at a price of K900 per ton. IPP, on average can sell 400 tons of copra per month to Madang, less K15.00 per

bag or 100 kilograms, for boat freight. IIP does not produce biodiesel there are potential in branching off to that stream, but some technical support could be sought for a start.



Photo 3: IIP Copra shed

Thoughts of expanding and improving the operation were made by the management but since there are limited external assistances from the LLG another other Government bodies in PNG, these plans cannot be implemented.

Like any other entrepreneurship, IPP faces its fair share of problem and difficulties as stated by the General Manager. These are some of the problems given:

- Local small holders having logistics problems in transporting bags of copra to the IPP shed.
- The current copra bought from the farmers is of low quality
- There is borer (beetle) problem with the coconut
- Hot air driers require modification and do away with smoked-air driers
- Coconut & Cocoa Research Institute (CCRI) has technical expertise but cannot render assistance to the communities due to financial constrain.
- There is lack of proper management in the part of the small holder coconut farmers
- Market problems exist for downstream processing

2.3. Karkar High School Biodiesel Generator

Karkar High School has two (2) power generating units. One is an old one whilst the new one is a Cummins that was purchased from Cummins in January 2011, and it ran on diesel for a couple of months before switching to biodiesel bought from PNG Biodiesel of Kulili Estate.

The new genset is rated at 65 kVA x 3-phase and it is normally operated from 0900am to 1500pm and then from 1830pm to 2200pm. It supplies the School buildings, workshops and teacher's house to power all the regular appliances and workshop equipment. There is a mini grid that distributes power from the genset to the load centers.



Photo 4: Karkar High School 65kVA Cummins genset

Karkar High School buys six (6) x 200 liter biodiesel every week from PNG Biodiesel. One (1) drum is for the School truck and the other five (5) drums are for the genset. The cost of these 6 x 200 liters is K2000. One (1) drum of biodiesel cost K600 in 2011 and in 2012, the cost increased to K800.

Genset maintenance is done by a village handyman every 3-4 weeks. This involves simple jobs like cleaning filters, changing oil and general checks on the overall operation. The School requires someone who can really maintain the gensets. The school was advised to seek arrangement with Kulili Estates as their (Kulili Estates) gensets are from Cummins and since the School buys biodiesel from Kulili Estates, to have the maintenance personnel from Madang to attend to the maintenance of the Karkar School genset.

2.4. Biodiesel Project at the Department of Mechanical Engineering, University of Technology

A visit to the University of Technology (Unitech) in Lae, Morobe Province was only for a couple of hours. A brief discussion was made with Professor John Pumwa in which a briefing on the Universities biodiesel research work was outline. His work is mainly research on the effect of biodiesel on engines component, mainly the fuel supply system, the filters, the injector and the combustion chambers including the pistons. This research work is supported financial by the Office of Higher Education (OHE) of the Ministry of Education (PNG). Coconut oil (CNO) from of Bogia (further west of Lae) is used for the research work. Waste vegetable oil (WVO) from the student mess was also used for the research work. There are plans to collect waste cooking oil from hotels in Lae town. This research work is on halt as there were no post-graduate student to do the work as required and the department is in a process securing personnel for the research work.



Photo 5: A Biodiesel Processor



Photo 6: Biodiesel testing geneset

The department has a simple laboratory set up that house a processor for the transesterification process and titration apparatus. The laboratory uses the following ratio for their biodiesel production:

- 1 liter of coconut oil
- 60 grams of sodium hydroxide (or potassium hydroxide). This is a catalyst that helps the reaction to proceed effectively
- 600 milliliters of methanol.

This will produce 1 liter of biodiesel

2.5. Bogia Biodiesel

Bogia is a district in the northern coastline part of PNG's mainland, and is located 60 km west of Madang, Bogia Biodiesel has a mini biodiesel processing plant. Feedstock (copra) for the processing plant are bought from copra farmers in and around Bogia district at a price which is the same as Madang mill prices to produce virgin coconut oil for bio-soap making and biodiesel.

The biodiesel plant of a hammer mill (like a crusher) and an oil press (like an expeller). The hammer mill is capable of taking one ton every two hours while the oil press is capable of taking five hundred (500kg) in one hour. The oil press (expeller) takes crushed copra from hammer mill and produces oil and milled copra for stock feed (chicken and pig feed). The oil is then settled in the storage tanks for three to seven days for the sediments or oil dust to settle before it can be used to produce virgin cooking oil and bio diesel.

The bio diesel processor is control by a timer and produces one hundred and eighty (180) liters of biodiesel and twenty (20) liters of biosoap (glycerin) as a bye product of biodiesel every hour.

Bogia Biodiesel's current production cost for biodiesel is K2.40 per liter and biosoap is K6.50 per kilo. These prices vary according to the prices of chemicals (catalyst and methanol) used for producing biodiesel.

The above plants are all powered by our 75 kVA and 25 kVA generators. These generators together with Bogia Biodiesel's vehicles are all running on biodiesel. The copra mills are sold as stock feeds also to local piggeries and chicken farmers. This really demonstrates a downstream processing and a self supporting initiative for Bogia Biodiesel.

The Bogia landing cost for diesel is expensive. This is the main reason for Bogia Biodiesel to venture into biodiesel production as a measure to produce power for its business operation and to sell for local users. PNG Power Ltd still has a long way to go in connecting electrical power to the Bogia district. It could be another ten (10) to twenty (20) years.

Most diesel engine users in Bogia district are yet to fully accept the fact that biodiesel works well and does not cause any problems to the engines. Bogia Biodiesel used its vehicles to advocate the benefit of using biodiesel. It has been using biodiesel in its vehicles since 2010 and there were no problems encountered, except the need to change the fuel filter a couple of times for a start as the biodiesel cleans off the fuel system and the fungal residue associated with diesel clogs the fuel filter – hence the need to change filters.

3. Summary

The highlight of this report is the production and marketing mechanism employed by Kulili Estate in PNG Biodiesel Ltd, and the potential that exists for Inter-Island Produce (IIP) Cooperative in venturing or branching off to production.

Kulili Estate operates the PNG Biodiesel within the Estates Kulili Plantation. The Plantation is some 70 to 80 years old and the current Middleton family that operates the estate is the third generation. Prior to 2006 the Estate was producing copra for export and there was little or no attention to coconut oil production, until then. Kulili Estate had been operating the following plantations: i) Kulili Plantation; ii) Kaviak Plantation; iii) Wadau Plantation and iv) Bulu Plantation.

Kulili Estate manages its own plantation and commands its workforce from the local communities in Kakar, but houses them within the Estate labourers' quarters. The estate houses all the workers, ranging from the managing director to the dry coconut fruit pickers. It's like a mini-town of its own.

In its operation the Estate can produce on average a total of 300 tons (an estimate of 300 bags) in a month compared to an average output from Karkar Island of 10,000 tons. From this production an estimate of 40,000 – 50,000 liters of oil is produced per month for biodiesel, indicating that an estimated 70 - 80 tons of copra are being used for biodiesel production. This saw the remaining 200 plus tons being exported.

Hot air dryers built by the company, operated by the company and managed by the company are used for drying purposes and there are quality controls in place to ensure the copra are properly dried. This is one other factor that contributes to the quality of biodiesel produced. Properly dried copra means less water content, no 'smoked air odour', resulting in good quality oil for biodiesel production.

PNG Biodiesel of the Kulili Estate produces about 40,000 to 50,000 liters of biodiesel per month. From these production more than 10,000 liters is used for power generation; about 15,000 liters for powering its cargo and game fishing boats and an estimated 10,000 liters for its trucks and other machineries. The remaining 15,000 liters are up for sale. The main buyers are the Karkar Local Level Government (LLG) for its vehicles; the Karkar High School and the general public from Karkar and Madang.

To maintain its market, PNG Biodiesel sells a liter of biodiesel at a price which is K0.15 (15 toea) less than the landing retailing cost of diesel in Karkar Island and the surrounding Madang Province. The landing prices range from K3.06 to K3.16 per liter. The pump price of diesel in Port Moresby in March is K2.98 per liter. The Estate's usage of its own biodiesel for the past 5 or more years saw no apparent problems with the engines. This has consolidated public confidence in biodiesel resulting in an increasing number of customers opting to use biodiesel from PNG Biodiesels.

On the aspect of biodiesel price, PNG Biodiesel sets its biodiesel price K0.15 lower than the landed cost of diesel. The price of copra in Madang is K110 per 100kg and K90 in Karkar Island. 1 bag of copra can produce an average of 60 liters of coconut oil. Strictly speaking, this in effect means the cost of 1 liter of oil is K1.50 in Karkar and K1.83 in Madang town. By selling biodiesel within this range is not commercially viable as production cost (including cost of methanol and potassium hydroxide) is yet to be factored in. The price of biodiesel was set to be around K0.15 less than the cost of landed diesel, which should be around K3.01. When these production costs of biodiesel are factored in, the selling price would be the range of K2 to K3 per liter. So a set price of K3.01 falls above the supposed selling price and thankfully below the landed price of diesel (K3.06 – K3.16) which is good as a small margin is made and the price is less than diesel price, which in a long term means more turnovers – profitable.

Inter-Island Produce (IIP) Cooperative has been in operation for quite a while now and it is buying copra from its members, who form small village cooperatives and are registered to IIP. IIP buys and sells its copra to Copra Products Limited (CPI) in Madang. It buys its copra from the local cooperative or small holder farmer at K900 per metric ton and sells in Madang at K1100 per metric ton, making a margin of K200 per metric ton. This is the sole business of IIP. There were discussions done with IIP of the possibility in diversifying its operation into biodiesel production

for sale in Karkar Island and Madang Province and even beyond. IIP had shown interest in investigating such option as a mean to diversity it business operation under the notion of clean and green business entrepreneurship. This is a good opportunity for PIGGAREP and other similar project to render assistance in helping such set ups realize their dreams in biodiesel production for local sales.