Coconut oil as a Biofuel Resource for Fiji – History, Current Status and Future Prospects

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Project

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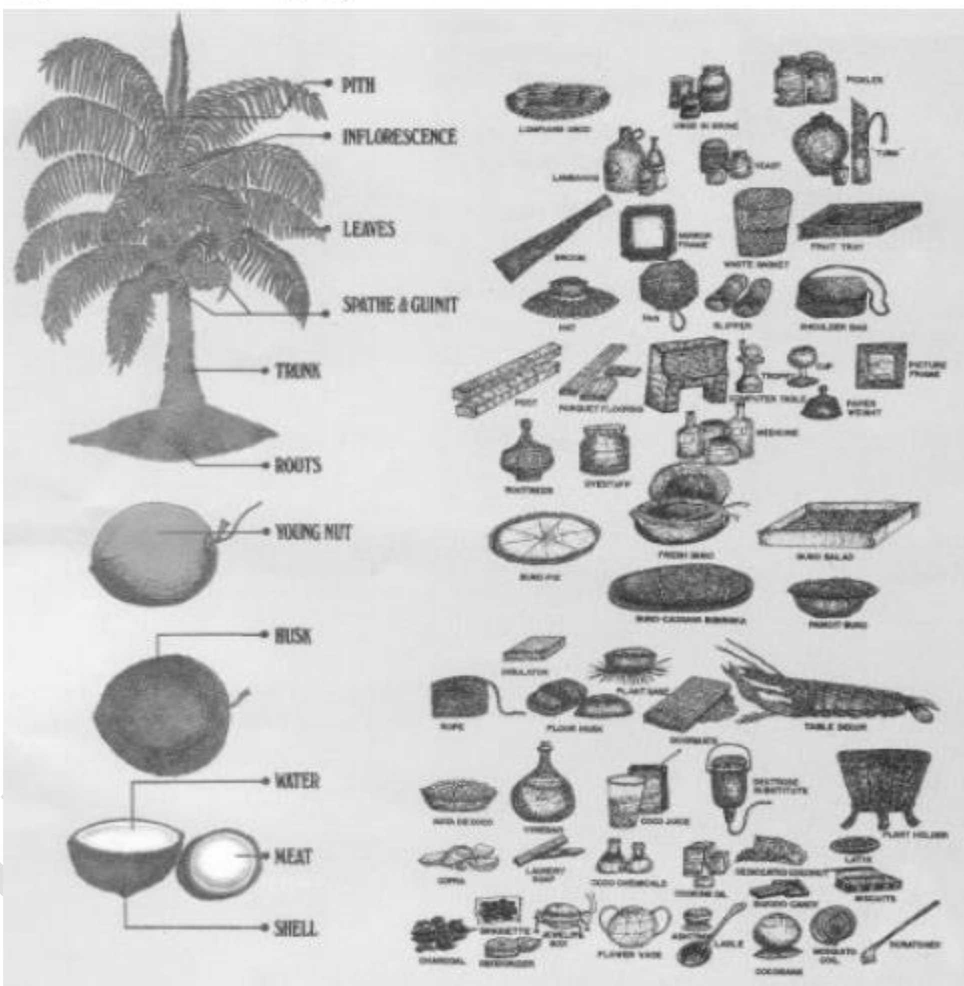

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Abstract

To do a literature survey on the topic Coconut oil as a biofuel resource for Fiji – history, current status and future prospects. In this research the status of coconut production in the world is compared together with the Pacific Island Countries. The major survey is concentrated on the Fiji Islands. Although village biofuel systems have been applied with various degrees of success in other Pacific island countries, there is not a lot of experience with this technology in Fiji. The places where the coconut oil gen-sets are placed in Fiji together with the Pacific Island countries are discussed in this research.

1. <u>Introduction</u>

Biofuels are any fuel derived from biomass. These are renewable sources of fuel, unlike other natural resources such as petroleum, coal and nuclear fuels. Used as motor fuels, these can be used in compression-ignition and spark ignition engines with no major modifications. Bio fuels are also biodegradable, nontoxic and free of sulfur and aromatics. These are also inexhaustible and can be produced from locally available agricultural resources. Typically, biofuels are burned to release its stored chemical energy. The carbon from biofuels however is extracted from the atmosphere by growing plants, so burning does not increase the average amount of carbon dioxide. Bio Fuels are not a new energy source. It was used in Germany and France way back in 1894 by the then developing industry of internal combustion engines. Brazil utilized ethanol as fuel since 1925. Over the years, however, petroleum became difficult to beat, being considered as a limitless and cheaper resource. The difficulty with petroleum, however, was that very few countries were endowed with this resource. Some countries in the Middle East led in the huge concentration of reserve. Instability of supply always created a series of petroleum crisis. When oil supply is disrupted, it is always accompanied by a rapid increase in oil prices which threaten a country's economic and national security. Crude oil prices behave like any commodity with wide swings in times of shortage or over supply. Demand is dependent on the nature of society, technical development, economic cycles and political conditions. Since 1998, global demand for oil rose by two percent every year. The US Energy Information Administration forecasted that worldwide demand for oil would increase to 60 percent by 2020. In 1994, the Wall Street Journal reported that at current rates of production, proven reserves in 2002 40.6 years of consumption, beyond this point, we are looking at unprecedented supply-demand imbalances. Recent events such as the war with Iraq, violence in Nigeria and terrorist attacks have raised doubts about the sufficiency of oil supplies in the near future[1].

The use of coconut oil in engines is not new. It was used, for example, in the Philippines during the Second World War when diesel was in short supply. Since then the wide availability of diesel throughout the world and difficulties in running engines on coconut oil in cooler weather had virtually ended its use for this purpose. Recently, in Vanuatu and elsewhere, pure coconut oil has been used successfully as an alternative to petroleum in automotive diesel engines and the result is both environmentally friendly and good for the local economy. Coconut oil is extracted in high-pressure presses from copra, the dried flesh of the coconut. The better grades of copra – those that have been dried in a hot-air drier, rather than sun or smoke dried – are best for producing coconut oil for fuel. The main drawback with using coconut fuel oil in engines is that it starts to solidify at a temperature below 22°C. And even in tropical countries, temperatures fall below 22°C on a significant number of nights throughout the year, and sometimes during the day in the cooler season. One remedy is to fit a heat exchanger in the fuel line, which warms up the fuel sufficiently within a minute of starting the engine. Another option is to mix the coconut oil with another fuel, such as diesel or kerosene[2].

2. Overview of Coconut Oil used as a Biofuel Resources in the Pacific

In the Pacific, only recently has there been renewed interest in the use of coconut oil as a biofuel. The need to substitute for diesel imports, safeguard the local agricultural industry and reduce the impact of diesel exhaust on the environment, has led to a range of initiatives using coconut oil as a biofuel in the past 10 years[3]. The use of biofuel in the Pacific Islands Countries is picking up quickly, below is an overview of the main experiences in seven Pacific Islands Countries.

2.1 Marshall Islands

The Marshall Islands are characterised by a relatively high volume of diesel usage per person for both power generation and transport. The Marshall Islands pays an above average amount for diesel compared to other Pacific Islands Countries. This combined with significant fuel taxes results in one of the higher diesel prices in the Pacific. As part of a highly subsided industry to keep income levels maintained on the outer islands, the country produces and exports about 3,000 tonnes of coconut oil per annum. With the increase of fuel prices, the Marshall Islands oil mill has started retailing various biofuel blends in the capital Majuro and investigations are on-going to utilise biofuels for power generation on some outer islands[4].

Biofuel retail in Majuro

The copra mill, run by Tobolar is retailing fuel based on coconut oil. It consists of coconut oil, which is de-watered and filtered to 5 micron. At the bowser, there is a 50/50 blend with diesel and a pure coconut oil product available. The coconut oil fuel is cheaper than diesel and this has led to a number of people trying the fuel in their cars and boats. Given the uncertainties around the increased maintenance costs of using coconut oil as compared to diesel, SOPAC, through its PIEPSAP project has supervised a MSc. Mechanical Engineering student to study this subject[4].

Review of the effects of using Coconut oil as a diesel replacement

In April 2006, an indirect injection 2.9 litre Mazda truck (Figure 1) running on pure coconut oil for a period of three years and 60,000 km was partly disassembled. It was found that no serious detrimental effects that could lead to premature engine failure were present. However, the study did report increased fuel filter changes, deposits on piston rings, deposits on injectors and a 10% decrease in power. The highest risk to future operation by the use of coconut oil were the deposits on the valve stems, which could lead to sticking valves, and hence loss of compression.

The major finding of the MSc study was that coconut oil could be used in indirect injection engines with the right injector equipment, provided that vegetable oil fuel quality standards such as DIN 51 605 are respected. Even then, additional maintenance costs as compared to operation on regular diesel fuel should be expected[4].

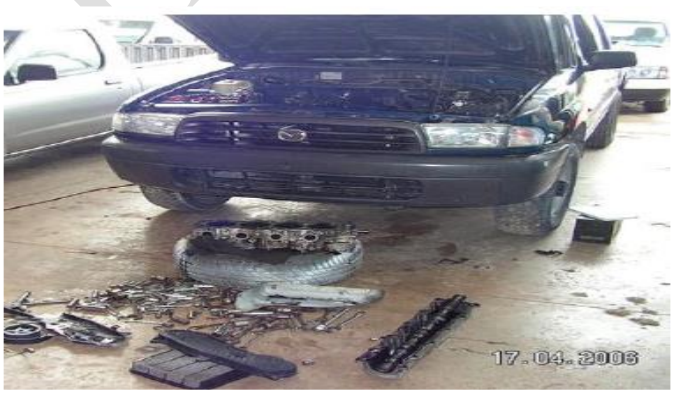

Figure 1

2.2 Vanuatu

Vanuatu has been a leader in the use of coconut oil as a fuel in the Pacific. It has been active in the area for years, driven by keen entrepreneurs and a high diesel fuel price. Vanuatu has the highest landed cost for diesel of the seven Pacific Islands Countries. “Island Fuel 80”, a blend of filtered 80% coconut oil and 20% kerosene is retailing in Vila for about US$ 0.30 per litre less than regular diesel. Nevertheless, it is still serving a niche market, as the customers require a pre-heater to be installed in their vehicles. The Government of Vanuatu is the only country in the Pacific that has a reduced excise tariff in place for biofuels (0.05US$ instead of 0.28 US$ per litre)[4] .

UNELCO coconut oil fuel trials

Vanuatu’s power utility UNELCO has been experimenting with highly filtered coconut oil for about 1 year, with encouraging results. It has been running one of their 4MW MAN 9L32/40 generators on a blend of 5% coconut oil, utilising over 1,000 litres of locally-produced fuel per day (Figure 2). After an overhaul with MAN experts, no signs of detrimental effects were found and consequently the trial was broadened by involving another machine at 5% and increasing the first to a 10% coconut oil blend[4].

Figure 2: UNELCO Generators in Port Vila running on coconut oil fuelblend (Source: UNELCO).

The machine could best be called a ‘dual fuel’ engine as the coconut oil is added into the fuel lines at 50 oC just before the injection pump, during times that the load is higher than 60% of rated power. The long-term aim of UNELCO is to ‘industrialise’ the use of coconut oil fuel by making it part of their aim of cost reduction, environmental awareness and assistance in improving the balance of payments[4].

TORBA biofuel electrification pre-feasibility study

At the request of the Vanuatu Government, SOPAC carried out a pre-feasibility study together with UNELCO on the use of coconut oil fuel on the remote island of Vanua Lava in TORBA province. The study found a great potential of copra that is currently being transported at great cost to Santo for milling. In addition, the current diesel-powered electricity grid is very inefficient because of low loading, however could be extended to include additional load and hence more efficient generation[4].

Given future load increases to be expected through the building of a hospital and an ice making facility, there is good potential to add an adapted generator that can run on coconut oil fuel. The villagers could use part of the copra produced to be milled and filtered for fuel as well as utilise oil for local value adding such as soap, body and cooking oil production. The greatest challenge has been identified to be the management of such a production unit and Renewable Energy Service Company (RESCO), with limited capacity on the island[5].

2.3 Samoa

Samoa slowly lost its copra oil exports in the last 6 years; trials to keep the copra sector alive through Government intervention, and later corporatisation, failed with Coconut Oil Production Samoa (COPS) going into receivership in 2006. The local price for copra was too low for farmers to go through the trouble of even picking up nuts and the subsequent volumes that COPS was able to produce were too small to keep the operation viable. A similar situation has arisen for Samoa Niu Products Limited (SNPL), which mainly produced desiccated coconut. Indications are that with existing equipment it could produce a high quality coconut oil at a premium price of US$ 0.90 per litre. Even at this higher level, it would be competitive with retail diesel and bulk supply to power utility EPC. However, no concrete plans for SNPL to produce oil on a large scale currently exist. Other small-scale initiatives involving organic certification and virgin oil production appear to be quite successful and will keep a small remainder of the coconut sector going through high added value niches[4].

EPC Truck running on Coco-Kero Blend

A new unmodified Toyota Hilux EPC service truck (Figure 3) has been running on an 80% coconut oil 20% kerosene21 blend for the last year with no problems reported. It is a showcase to the people of Samoa that EPC takes biofuels as a serious option for the islands' energy challenges. The truck drives on the remaining COPS copra oil stocks.

Figure 3: EPC service truck running on coconut oil fuel blend (Source: EPC).

Cocogen Blending Trials continue

At the power station in Savai'i, a 250 kW generator22 is currently running on a 20% blend of coconut oil with diesel. The coconut oil here used is also the remaining stock of COPS. Continued testing of the engine oil contamination by vegetable oil and close monitoring of the quality of the coconut oil fuel support the continued use of the 80-20 blend. During the recent overhaul of the engine, it was revealed that no adverse effects caused by the use of coconut oil could be found. As part of UNDP-Samoa/SOPAC continued assistance to Samoa's Power utility EPC, "CocoGen", an investment plan will be developed to build a coconut-based power unit as part of the new Savai'i power station. It will make use of an estimated 15 million coconuts per year, with copra milled for coconut oil fuel while the shells will be used in a gasifier for co-generation of heat and power. Copra will be dried on site with the power plant excess heat and the combustion of coconut husks. Activities under the project include the identification of appropriate technology, calculation of the heat balance and a detailed Environmental Impact Assessment[4].

2.4 Solomon Islands

The relatively high landed costs of diesel and the high cost of exporting coconut oil from Solomon Islands paved the way for the establishment of a biofuel industry in Solomon Islands. While there are a number of buses running on Solomon Tropical Products (STP) "Cocoline" which is a blend of 80% coconut oil and 20% kerosene, there are investigations to venture into biodiesel production from palm and coconut oil. In addition, the local power utility SIEA is looking into the use of a coconut oil blend to be utilised in the main power generators of the capital Honiara[4].

Honiara Biofuel Production and Retail

STP has been endeavouring to produce of biofuels after the period of ethnic tension. Building on the "Island Fuel" experience in Vanuatu, it is now retailing this biofuel in Honiara. Copra oil is cold pressed and filtered in 3-micron aviation fuel filters, before being mixed with Aviation Kerosene and a proprietary additive. In addition, the company is preparing biodiesel production together with a foreign partner and the Solomon Islands Government as stakeholders. The feedstock for this biodiesel can be coconut oil or palm oil and the output could be used as a nation-wide blend with diesel for land and sea transport[4].

Coconut fuel for isolated areas

SOPAC is assisting with the supervision of a USP MSc student in his research for applications of remote area coconut oil milling and its residues for adding value into the production of biofuels and other related products. The research will undertake a) coconut production per village in selected communities; b) visit farmers for copra and residue production potential; c) take samples of CNO for analysis; d) design appropriate power generation systems and e) identify an appropriate biomass system to use coconut residues. The research will include a cost-benefit analysis a socio-economic and environmental impact analysis[4].

2.5 Kiribati

The Kiribati copra sector is currently highly subsidised through high transport cost to the outer islands, highly subsidised copra beach prices (US$ 0.46 per kg versus slightly subsidised US$ 0.29 per kg in Fiji, and un-subsidised US$ 0.18 per kg in Solomon Islands). In addition, there are high costs of exports through handling of the oil in containers with flexi bags as opposed to bulk transport. It was estimated the copra sector costs the Kiribati government up to 1.5 Million AU$ per year at an output volume of 3,500 tonnes. The social benefits of these expenses are income generation on the outer islands; in addition, coconut oil is the only significant export product on the island[4].

National Task Force on Biofuel

Kiribati has established a national task force on biofuels, consisting of the Ministry of Works and Energy, the copra mill KCMC and the national oil company KOIL, to lead the way in establishing a national biofuel industry. The country's sole copra milling company, Kiribati Copra Millers Company Ltd (KCMC) has embarked on utilising its own product as a fuel. In addition to a number of government vehicles, it has its own truck running at a 50-50 blend with diesel and is considering expanding these experiments. In addition, KCMC identified their production boiler is working well at a 60% coconut oil 40% kerosene blend and is using this mix as part of normal operations (Figure 4). In order to be able to utilise coconut oil, the product is treated and filtered in a separate section of the production plant to make the oil fuel-grade. Recent tests of KCMC filtered oil at USP has pointed out that the oil can be used as a fuel if all moisture is removed[4].

Figure 4: KCMC copra mill in Kiribati uses coconut oil blended with kerosene in their production boilers (Source: SOPAC).

2.6 Papua New Guinea

Country Overview

Papua New Guinea (PNG) is the region's largest exporter of coconut oil and in addition has a large potential for production of ethanol from starchy crops. Even though PNG produces crude oil and has a refinery, it is still partly dependent on petroleum product imports. Actors in the field of biofuel include various initiatives under the PNG Sustainable Development activities to start rural electrification with copra oil as a biofuel[4].

Buka Coconut Diesel

An entrepreneur in Buka, East New Britain has established coconut oil fuel filtering for retail of a coconut-diesel blend. Mr Horn has a series of four tanks where the oil goes through a step-by-step process for use in engines. Apart from a fuel for diesel engines, the oil is also used for home-made lamps, chainsaw bar lubrication, cosmetic oils and high-grade cooking oil. The University of Papua New Guinea is assisting with oil analysis. In past years, the province of Bougainville was already using coconut oil fuel successfully during its period of political tensions when diesel deliveries had come to a standstill[4].

Coconut Fuel Trials at Unitech

The Technical University in Lae, has been a regional leader in establishing the efficiencies and operational characteristics of various derivatives of coconut oil [29]. The findings suggest the use of up to 40% coconut oil blends with diesel, above which the use of biodiesel is recommended.

Papua New Guinea Sustainable Development Programme (PNG SDP), in collaboration with Hydro Tasmania Consulting has been looking into the use of coconut oil for rural electrification, mainly for the western provinces. As part of these activities, a direct injection generator has been trial run with coconut oil at a varying load pattern, which led to early engine failure. The findings provide further evidence that a generator run on coconut oil fuel must be of the indirect injection engine type for long-term viable operation, or have a dual-fuel system to switch back to diesel at low loads[4].

National Fisheries College Coconut Oil Fuel experiments

The principal objective of the project is to undertake a detailed assessment of the feasibility of commercial production of coconut oil as an alternative fuel for diesel in both fisheries and community applications. This will be achieved through the establishment of an oil production base in the National Fisheries College engineering workshop. The facility will be equipped to produce up to 2,500 litres of fuel per day requiring up to 4,000 kilograms of dried copra. Production operational details will be recorded and analysed in regard to operational economics. Coconut oil will be tested in both small and large vessels and compared with diesel in regard to cost and potential effects on engines. This will include a review of the newly available coconut oil powered outboards. The project also includes a study of village level oil production and applications. This will be undertaken by the deployment of a number of hand presses for oil production. Training will be provided to operators and production details recorded and analysed in regard to cost benefits. This will include analysis of the use of coconut oil for village lighting and the trial operation of community operated vehicles on coconut oil fuel[4].

3. History of Coconut Used as a Biofuel in Fiji

The coconut tree is found throughout the pacific with the windward islands of the Fiji group particularly well suited to its cultivation. The coconut is known as 'the tree of life' because of its ubiquity and its utility – every part of the tree can be used to produce something of subsistence or commercial value.

The tree is used for a multitude of local purposes in village situations in Fiji but historically the dominant (and generally only) commercial product has been copra. Copra is cut and dried near to the growing site, whether in villages or plantations, then transported to large industrial millers. Originally copra was exported to millers in Europe and Australia but latterly milling has been done within Fiji at sites in Savusavu and Lautoka (CIDA 1960-2003). Thus crude CNO has replaced copra as the export crop for the country, although the average planter or village is still selling dried copra [5].

The Fiji Coconut Industry Development Authority was formed under the Coconut Industry Development Authority Act of 1998 as the successor to the Coconut Board. But on the 19th of April 2010 Fijis Interim Government Cabinet approves Coconut Industry Decree 2010 .The Decree repeals the Coconut Industry Development Authority Act 1998 thus dissolving the Coconut Industry Development Authority (CIDA), and transferring its powers, functions assets and liabilities to the Ministry of Agriculture. Cabinet based its decision on a submission by the Honourable Attorney-General, Mr Aiyaz Sayed-Khaiyum. The Attorney-General explained that the CIDA Act established the CIDA, which was assigned the function of overseeing the development of the coconut industry in Fiji. "CIDA also has the power to licence the exportation of coconut products from Fiji." The Attorney-Generals aid that with the reforms that are taking place, amalgamation of functions and powers upon a central authority has become important, to ensure that Government resources are used efficiently for the discharge of public duties. He said that the transfer of power, functions and assets of CIDA to the Ministry of Agriculture will give Government the ability to drive the coconut industry not only from a policy perspective, but also on an operational basis. He added that this control by the Ministry of Agriculture will enable it to further the development in the coconut industry to a level that will ensure maximum returns to the economy[6].

The total area under coconuts (*Cocos nucifera*) in Fiji is estimated to be approximately 58,900 ha planted at an average of 115 trees per ha. (6.8 million trees). 80% of Fiji's copra production is in the hand of smallholders. The families that rely on copra production earn less than F$ 500 p.a. and are considered amongst the poorest households in the country. CIDA estimates that a total of 100,000 people in Fiji still depend on income from copra and coconuts. Historically, copra production in Fiji peaked in the 1950ies when more than 40,000 mt of copra were being exported. 60 % of this production originated in private estates. During the last decade production peaked in 2002 when the national total was above 15,000 mt. Today 80% of copra production originates from smallholders. In 2003 when hurricane Ami devastated a large portion of the crop, production fell to 9,500. Since then production has gradually increased to 11,300 mt in 2005.CIDA forecasts 2006 production to be 14,000 mt. Fiji's largest copra producer is the island of Vanua Levu where approximately 50% of all copra originates. The following Figure 9 displays the annual production of Fiji's largest producers. Rotuma is the fourth largest, after Taveuni[7].

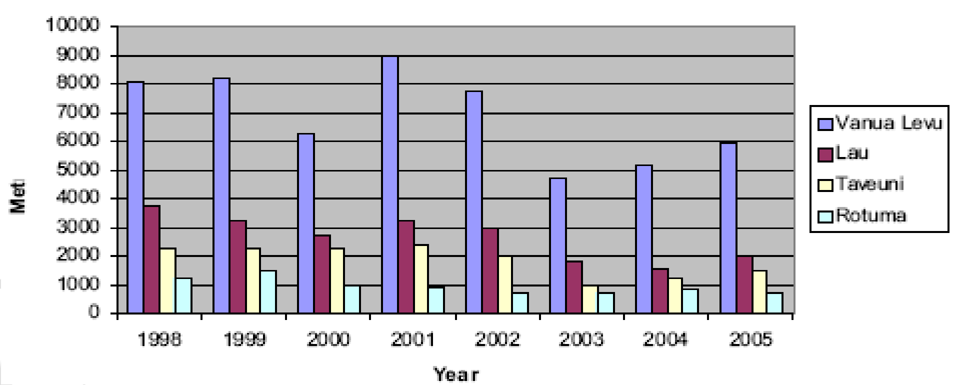

Figure 5: Annual Copra Production for Fiji in Tonnes: 1998 – 2005

Fiji's coconut industry has been declining over the last 40 years because of low productivity, low prices and competition from other edible oils sold on the world market. The soybean industry in the US contributed to this by spreading a lot of misinformation about the ill effects of using coconut oil for cooking, on cholesterol levels. Although there have been some efforts in the last four decades to revive the industry, the lack of a sustained long-term national policy for development of the coconut sector has made it difficult to reverse the decline. In the early 1960s, copra production was over 40,000 tons/yr; now it is less than 15,000 tons/yr. Moreover, about two-thirds of the trees will go out of production over the next 20 years. The older trees need to be replaced soon otherwise the industry will decline further and the rural people dependent on the industry will migrate to urban areas looking for alternative livelihoods adding more pressure on the limited resources of the urban centers. The rural population could also react by resorting to more unsustainable use of natural resources for livelihood such as "slash and burn".

In response to this problem, the Fijian Government created the Coconut Industry Development Authority (CIDA) under an Act of parliament, in November 1998, with a mandate to revitalize the industry. CIDA has drawn up a 25-year Coconut Industry Master Development Plan that includes a Nationwide Coconut Industry Promotions Program (NCIPP). CIDA aims to restructure the coconut industry, register 20,000 coconut growers and establish a network of Coconut Planters Associations throughout the coconut growing areas. This will assist the Extension and Research and Development Divisions to achieve their targets for the planting of six million trees and the rehabilitation of another two million trees. The Taveuni Coconut Center, with its four seed gardens, will be provided financial, manpower and logistical support to play a key role in this campaign. A manpower development plan and increasing public awareness through posters in schools, restaurants, hotels, public markets and government offices, etc., are also being planned.

CIDA aims to increase the production of copra, coconut oil and tender nuts for the local and export markets. Product diversification, intercropping practices, wholenut purchase centers and a centralized copra drying facility are envisaged together with a large number of mini-mills and two big coconut oil (CNO) mills. CIDA wants to improve the quality of life of 100,000 rural people involved in the coconut sector, empower women, reduce poverty and improve the education rural children. Other ambitious targets of CIDA include export of coconut timber and production of biodiesel to replace 10% of imported diesel.

Moreover, Copra Millers Fiji Limited (CMFL) is another company responsible for production of coconut oil. This company was established on 14th October, 1983 under the companies Act. The Copra Milling operation of Copra Millers of Fiji Limited is situated on the island of Vanua Levu about 5 kilometers to the North of Savusavu town at Balaga bay, Savusavu. CMFL is one of the two larger local manufacturers of Crude Coconut Oil from Copra. 94% of the sales was exported to Europe and 6% sold locally. The by-product of Copra is Coconut meal which is sold locally[2]. This company produces coconut oil in two forms refined coconut oil and virgin coconut oil. Refined coconut oil is extracted from the kernel or meat of matured coconut harvested from the coconut palm. Throughout the tropical world it has provided the primary source of fat in the diets of millions of people for generations. It has various applications in food, medicine, and industry. What make coconut oil different from most other dietary are the basic building blocks or fatty acids making up the oil. Coconut oil is composed predominately of a special group of fat molecules known as medium chain fatty acids (MCFA). The majority of fats in the human diet are composed almost entirely of long chain fatty acids (LCFA). The coconut palm is an integral part of the Pacific identity; it is also the source of one of our greatest natural products– virgin coconut oil. Virgin coconut oil is becoming recognised both locally and internationally for its wonderful natural health benefits and its ability to generate meaningful employment for our rural island communities. Virgin coconut oil is the most natural form of coconut oil; it is extracted from the coconut flesh with the minimal amount of processing i.e. no high heat or pressure and no harsh chemical solvents, bleaching agents etc. Virgin coconut oil is completely unrefined; this ensures that the oil retains all the natural goodness of the coconut itself[8].

4. Current Status of Biofuel in Fiji

In April 1998 Fiji department of Energy through its rural electrification program did two feasibility studies on two community based biofuel projects in Vanua Balavu (villages of Lomaloma, Naqara and Sawana) and Welagi in Taveuni. The study was to investigate the relevance, feasibility and sustainability of the sites. A thorough investigation was taken of the socio-economic environment and a technical assessment was also undertaken for the justification for the site selection. In early 2000, a joint agreement for implementation of Renewable Energy Project was signed by the FDOE and the Secretariat of the Pacific Community (SPC). The objective of this agreement was to promote activities of scientific and technical co-operation in favour of Rural Energy Development. Under the agreement, FDOE took all responsibilities for local costs of project implementation while SPC provided for the transfer of the new technology (bio-diesel generator) for electricity generation. This was through CIRAD-AMIS – France that provided the technology. Additional funding was provided by the French Embassy. The Vanua Balavu Biofuel Project was installed in April 2000 and the Welagi Biofuel Project was installed in July 2001. The uniqueness of the project was the, specificity of the modified biofuel generator, which was able to use coconut oil to generate electrical power for the homes in the village. The dual fuel tanks contain diesel oil and coconut oil respectively. The diesel oil is used to start the engine and when the engine is heated, the coconut oil takes over as the sole fuel source to run the engine for the duration of its intended purpose. The switch over from diesel to coconut oil is automatic. Just before switch off, the engine has to be turned off on diesel[9].

4.1 Descriptions of Pilot Projects

A. The Lomaloma Copra Biofuel Project

This project is located at Sawana, Vanua Balavu; Lau Group and is the first biofuel project site in Fiji. After socio- economical and technical feasibility, one 90 kVA generating set was installed in Vanuabalavu to electrify three villages (Sawana, Lomaloma, and Naqara), 198 households and an oil-mill with a 150-200kg/h copra milled capacity. Initially the kWh rate for the 115 customers was around $0.90 per kWh. This electricity generating plant was able to use crude coconut oil as fuel. A Hospital, Adi Moape Junior/primary School and other government quarters were also electrified[3]. Since 2003 the Biofuel generator is operating only on diesel fuel with no technical or managerial problems. The local production of coconut oil has never taken place here since the closure of the existing Oil Mill that had been proposed as a source of fuel supply[13]. Currently, the three villages have not had access to electricity since March 2005 due to mechanical problems with the community biofuel gen-set except for those who have their own small gen-sets. These families reported currently spend between F$30 – F$50 per week on fuel which might have been increased due to rise in fuel cost about a month ago. Given the delay in repairing the engine the village of Lomaloma (and Sawana) is (are) exploring options of obtaining their own gen-sets. A load survey was carried out by DOE in October 2005. DOE on the other hand has not totally ruled-out the biofuel gen-set thus the need for the evaluation exercise to lay out the options[10].

On the social aspects, information gathered seems to indicate a very weak cooperation and institutional structure between the villages. This rules-out the opportunity for any communal organised task to be carried out successfully, including the effective operation of the community's electricity supply[10].

The current status of the projects has raised questions on whether the technology failed due to its inability to adapt to local conditions and/or due to the communities' lack of capacity to manage its operation. There are certainly additional factors such as the quality of fuel (coconut oil) used and the design.

Figure 6:95kVA biofuel gen-set at Sawana, Vanua Balavu

B .The Welagi Copra Biofuel Project

Another such technology was the introduction of a mini oil mill in Welagi. The screw press with an input capacity of 30 kg/hour of crushed copra was considered suitable. Technical analysis at the time of project design showed an energy consumption of 180 kWh/day. The mini oil mill in Taveuni produces 52% oil from dried copra. This needed about 60 kg (34 litres) of coconut oil per day which requires the village to produce 2 tonnes of dried copra per month. Note that at present the energy consumption is below 180 kWh/day – and more likely to be 85 kWh/day based on the current fuel. 57

households were electrified to the underground mini-grid system linked to the newly constructed power house. Each house was fitted with two tube lights and a power point. The powerhouse consists of a work shed, a processing room and the generator room. The bio-gen set is currently operating on coconut oil and diesel, but more often on diesel. There have been technical problems with the generator during 2004. With the gen-sets currently not in operation as planned (i.e. to run on coconut oil) there still remains the issue of whether the biofuel component was the main cause of problems. In Welagi, the response during the site visit indicated that the community would have preferred that the gen-set continue to run on diesel only. The community has the perception that coconut oil will lead to mechanical problems thus, disruption in the electricity supply. The 45kVA bio-genset runs only at less then 17% efficiency. The bio-gen set is oversized for the site. Initially, it was thought that spin off efforts and new demand arising from electricity in the households would lead to increased usage but this has been minimal. Thus the low load has caused problems with the bio-gen set. This again has led to more maintenance for the FDOE and unreliable power supply for the community.

Figure 7: Current state of the Crusher in Welagi, Taveuni

4.2 Feasibility study in Rotuma

Rotuma is located at Located 640 km North North West of Fiji’s capital Suva, Rotuma is Fiji’s remotest island. Disruptions in fuel supply and high supply cost for fuel have triggered interest to develop local coconut resources and other renewable energies.

Energy Demand of Rotuma

Rotumas energy demand as the report prepared on October, 2007 states that currently consumes a total of 300,000 litres of liquid fuels per annum. Diesel accounts for 185,000 litres alone followed by 45,600 litres of Multi-Purpose Kerosene and 36,000 litres of premix. All fuel is imported in 200 Litre drums with local prices in 2007 being well above F$ 2 per litre of product. Demand is expected to increase moderately over the next 10 years. Electricity generation consumes 85% of the diesel on the island with water pumping being the single most important use. Electricity generation capacity is approximately 480 kVA with water pumping accounting for approximately. 150 KVA and 330 KVA are distributed in numerous small size generators that power village mini grids. Electricity generation is plagued by high specific fuel consumption, frequent breakdowns of generation equipment and logistical difficulties to maintain and repair generators[11].According to CIDA the average weight per nut of more than 2 kg demonstrates that the Tall variety in Rotuma grows significantly larger nuts than found elsewhere. In fact the average weight is approximately 30 % higher than experienced in other locations around the Pacific. The average green copra yield per nut was established as 0.59 kg. These high averages are most likely attributable to the excellent soil qualities found on Rotuma. In theory, the 3.5 million nuts currently available in Rotuma could produce 2100 mt of wet copra or 1155 mt dry copra (at moisture content of 45% of green copra wet basis). This corresponds with the copra production of 1999 and represents a CNO production potential of 635 metric tons or 690,000 litres of oil. This represents a diesel equivalent of approximately 635,000 litres or more than three times the estimated annual diesel fuel consumption of 184,000 litres[11].

Feasibility of CNO as a Diesel Substitute

General Considerations

Most Rotumans feel that the island required a small-scale industry that provides stable income for low-income families and creates some added value on the island. At present this local source of income is copra. Although this opportunity will continue to exist provided that there is no fundamental change in government policy with respect to transport subsidies and price support for copra, more economic activities could be created on Rotuma if copra or coconuts were further processed on island. Even without the

launch of a fuel substitution programme or biofuel programme, processing of coconuts into marketable products could increase the total income made on the island. Virgin coconut oil as an ingredient for high-quality cosmetics currently fetches prices in the vicinity of F$ 5.00 per litre12 and could thus be a viable proposition. High-quality CNO that fulfils US purity standards (Food and Drug Administration
Certification) fetches a wholesale price of approximately F$ 3000 a ton. This is considerably more than the F$ 400 the local copra cutters currently get per ton of CNO equivalent. On the other hand the income that could be obtained from the export of high quality oil typically exceeds the value of a litre of pure, good quality CNO as a fuel substitute. In any event, there is a strong case to be made for the local production of a high-quality CNO rather than relying on the export of raw or tried copra at comparatively low prices. As it happens, the specification required for a viable diesel substitute are very similar to those required for high-quality CNO applications in both the cosmetics and food industries (total contamination, phosphorous, acid value, ash)[11].

While this study's terms does not include an investigation into the supply chain management and marketing of high-quality oils for other purposes than fuel, it is argued that whatever effort will be made in these areas will be extremely beneficial if a project could demonstrate that a local production of CNO is feasible. A local CNO production would then offer a higher energy security for the island and at the same time provide the opportunity to supply other markets if and when this is more profitable than burning the oil in internal combustion engines[11].

4.3 CNO as a Diesel Substitute

After the detailed resource assessment done by **Gerhard Zieroth with Leba Gaunavinaka and Wolf Forstreuter** it clearly shows that CNO could be produced in sufficient quantities to meet Rotuma's demand for diesel in vehicles, pumps and power generation. There are two methods to produce CNO in an island community such as Rotuma: Firstly, there is the conventional Mini Mill (expeller) that uses copra as an input. The copra needs to be sufficiently dry to minimise moisture content in the oil. Residual moisture content of 5 % is desirable. This is achievable by the traditional copra drying process or through solar drying. Dried copra is cut and then sent through an expeller, typically a continuous screw press. Thereafter, the oil settles in a tank and is then filtered. Centrifuge, press filters, bag filters or a combination are typically used to achieve the required filtration. Cooking the oil drives out residual water content. The oil quality obtained in such processes depends mainly on the quality of the copra input. Contaminated copra yields high total contamination values of the oil (standard according to DIN V 51605 max. 24 mg/kg). If copra is left lying around its surface oxidizes and the oil extracted from such copra becomes rancid. This result in high acid values that easily exceed acceptable values. While sub-standard oils will still burn in diesel engines, additional cost of maintence and repair will increase significantly.

Figure 8: Mini Expeller and Filter Press with approximately 15 l/hour capacity (Oekotec Germany)

Second method recommended by them is the Direct Micro Expeller (DME) process that uses grated wet copra. The product is also called virgin oil (VCO) and is typically used for cosmetic and food purposes. The oil is clear and has little odour. Good filtration, sometimes in centrifuges and fermentation are also common steps in the process of producing VCO. Both methods are suitable for producing a diesel substitute. However, the DME process is labour intensive and – given a good quality control – produces oil that fetches wholesale prices in the order of F$5-10 per litre. In principle both options could be used in Rotuma. The low labour productivity of the DME process may, however, not be suitable for Rotuma where labour is not abundant. The labour productivity of a simple DME process would be in the order of 1 litre per worker per hour. This does not seem to make much economic sense if a diesel substitute is being produced whose value is F$2 per litre. As our copra harvesting trials have clearly shown, a copra cutter who only needs a cane knife can earn F$3-5 an hour by cutting copra. Although there are more mechanised ways to produce VCO from freshly ground copra, the investment requirements increase accordingly[11].

Although both the Mini Mill and the DME plant could be used to produce coconut oil on a remote island a Mini Mill seems to be a more appropriate route if fuel is the main product. While the Mini Mill is more efficient and less labour-intensive it requires at least one skilled operator who can maintain the mill and train other staff. Although we consider the mini-mill option as more appropriate if fuel is the main product a DME oil extraction unit could still be a sensible project for Rotuma but it should aim for the cosmetics market where wholesale prices in the order of F$ 5 are achievable if the workforce is devoted to maintaining high quality standards of its product. Given the demand of researches demand projections for diesel, an initial oil production should not exceed 100,000 – 120,000 litres per annum, (at 200 working days approximately 500 – 600 litres per day or 60 – 70 litres per hour). Mills that can produce these quantities are readily available from a number of sources (China, Germany, Malaysia, and India). A production of 100,000 litres per annum would not be sufficient to substitute all diesel currently consumed on Rotuma. It is however, unlikely that a full substitution of all diesel is technically feasible. There will be numerous applications that require blending of CNO with diesel in order to avoid damage to the respective engines[15].Should a CNO production facility aiming to substitute diesel be established in Rotuma, there is a need to enforce a serious quality control and to check oil quality regularly. The most critical parameters include: Acidity, total contamination and water content.

Biofuel mill will benefit copra farmers

The opening of a new Rotuma biofuel mill at Ahau government station will herald in a new era for copra production on the island. For long time copra production has been the mainstay of the island’s economy. The biofuel mill will certainly boost copra production to the next level as it represents a new market that the 2500- odd population can capitalise on. The mill opened by the President Ratu Epeli Nailatikau. The project, which costs $640,000, was initiated by Government as part of an overall drive to save the copra industry. Mill manager Mr. Fuata Faktaufon believes such a project has been a long time coming for islanders. “The people on the island have been waiting for so long for this project,” he said. “The opening of this new biofuel mill will help farmers. This will encourage farmers to cut their copra and bring it over to the mill so that we pay them.” The mill will buy copra from farmers at 70 cents per kilogram. At the moment, there are six workers at the mill and more will be employed later depending on the progress of production.

Figure 9 :(Writer: Source: MINISTRY OF INFORMATION)

4.4 Biofuel Project in Nadave, Tailevu

Under the Fiji Rural Electrification Policy, Government will contribute up to 95 per cent of project cost whilst the community/village provides the remaining 5 per cent. Rural electrification also faces a great number of challenges due to transportation difficulties and lack of income-generating opportunities. SOPAC and CTA [The Technical Centre for Agricultural and Rural Cooperation, based in the [Netherlands] in July 2009 jointly funded a biofuel (coconut oil) project in Fiji. Using local copra supply as biofuel for rural electrification is perceived as a potentially viable and sustainable option. Under this biofuel project, a package of compatible components were provided to a local community, including a mini oil mill, settling tanks, other accessories to blend the coconut oil with diesel and an 18-kVA indirect injection diesel engine. These components were installed and commissioned at the Centre for Appropriate Technology and Development (CATD) in Nadave, Tailevu, Fiji Islands. CATD is a Government training centre that provides training to Fijian nationals from rural and remote island communities in a wide range of disciplines such as carpentry, small engine repair, and energy and small/micro business management skills to facilitate community development. The operation of the biofuel project – particularly the performance of the biofuel generator – is being monitored by SOPAC and CATD for the first five years after installation, which is currently on its way[12].

The process of the mini mill at the site

The coconut oil processing system comprises a copra cutter and coconut oil mill, biofuel blending unit and storage tanks, a power generator and the production of value adding products is shown in the figure below:

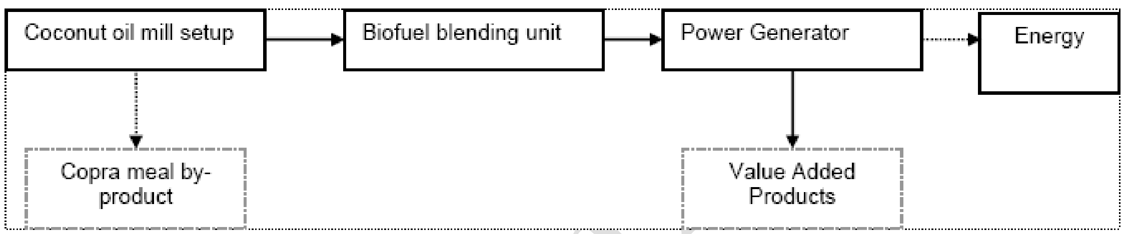

Figure 10: Coconut oil processing system.

Description of the Process

Coconut oil mill

The coconut oil mill consists of a copra cutter to cut dried copra (preferably with a moisture content of less than 6 per cent) into small pieces that are then passed through a cold press which squeezes coconut oil from the copra, producing a by-product of copra meal which can be used as pig fodder or as manure. The expelled coconut oil is then stored in a settling tank for 1-2 days, allowing the big particles in the oil to settle and fall to the bottom of the settling tank.

Ideally after settling, the top layer should not contain any particles greater in size than 100 microns. The oil is then passed through a filter which removes any remaining particles larger than 1 micron in size. The filtered oil is then stored in 200 litre tanks for future use. The coconut oil mill is designed to produce on average an output of around 15 to 18 litres of coconut oil per hour. Around 12-15 coconuts are required to produce 1 litre of oil. The moisture content of the copra is a determining factor in the output/production rate of the oil mill, such that the higher the moisture contents – the lower the coconut oil yield. The expeller used in the coconut oil mill is a cold press expeller, meaning that virgin coconut oil can also be produced by the coconut oil mill if green copra is used. The filtered coconut oil can be used later for a variety of purposes[12].

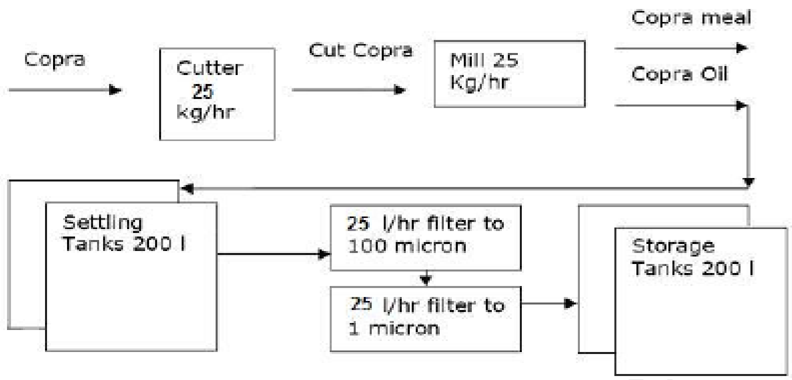

Figure 11: Oil mill with 3-stage inline filtration.

Biofuel blending unit

A biofuel blending unit was included as part of the project to produce and store biofuel. The unit comprises a stirrer fitted into the 200 litre tank where coconut oil and diesel are blended in a ratio of 80 % coconut oil to 20 per cent diesel fuel.3 The blended biofuel is then stored in a biofuel storage tank (200 litre tank). The biofuel as produced has a low freezing point, where pure coconut oil will solidify during the colder months when the temperature is 18 degrees Celsius or less. The 80:20 blend biofuel will remain in liquid state and at a fairly constant viscosity level at this optimal mix ratio. In mixing the 80 % to 20 % (CNO: ADO) biofuel blends, an additive (cetane additive) was also included in a number of cases to facilitate proper mixing and combustion. When introducing coconut oil and diesel biofuel blends for the first time in diesel engines, it is advisable that biofuel blends should contain around 20% coconut oil and slowly increase the coconut oil percentage in the blends over time.[12]

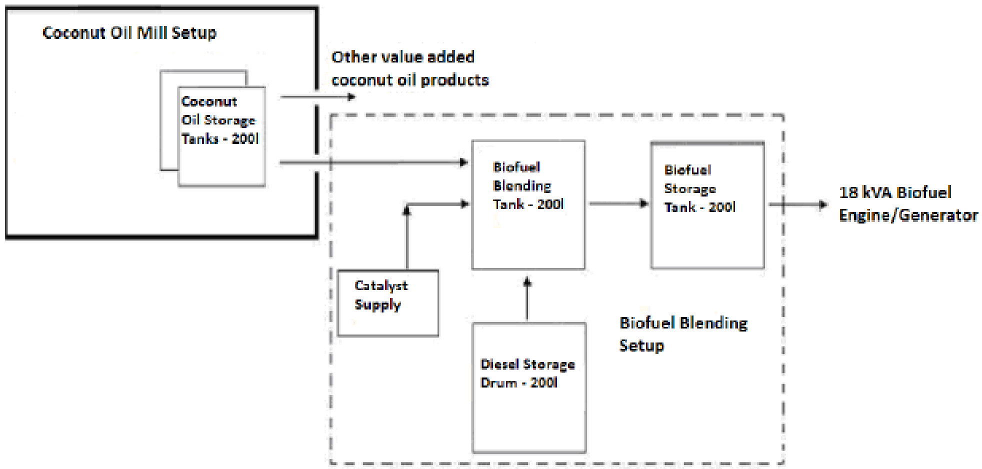

Figure 12: Coconut oil mill and biofuel blending unit.

Diesel engine/generator

The diesel engine/generator comprises an indirect injection engine where the generator is rated at 18 kVA (14.4 kW) under standard (prime) operation. In theory "indirect injection" diesel engines are recommended for use with biofuels as they have the capability to burn practically any heavy fuel oil including straight (100 %) vegetable oil; this is provided the oil has a low level of viscosity which can be achieved by including a heat exchanger in the system or using a biofuel mixture such as that produced in the CATD biofuel blending process[12].

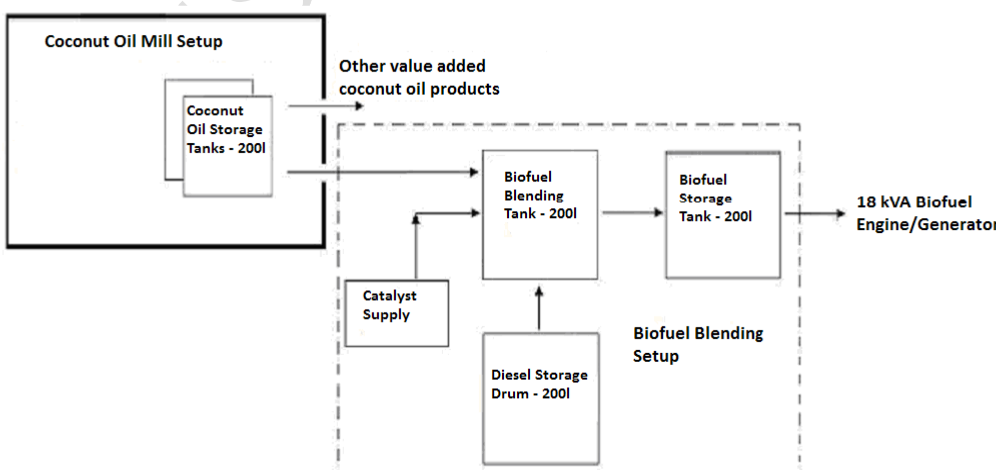

Figure 13: Coconut oil mill and biofuel blending unit

Final Products Out of the Project

The production of value added products requires additional/alternative processing activities and costs, such as:

- Coconut Oil Biofuel – consisting of a blended ratio of 80 % coconut oil and 20 % diesel fuel.
-Coconut Soap – involving coconut oil, mixed with caustic soda (sodium hydroxide), water, essential oils and incenses consisting of native flowers. Soap produced is for washing, bathing and as souvenirs.
-Body Oil – involving a traditional process of oil making where the refined coconut oil is heated with incense consisting of native flowers and adding essential oils.
- Body Lotion – involving a mixture process of blending emulsifying wax (bees wax), coconut oil, water, essential oil and fragrances consisting of native flowers[12].

Load demand for the biofuel demonstration project

The total demand for all the equipment used for the coconut oil mill and crusher, the biofuel blending unit including the pumps, heater and inline filtration system is around 7.1 kW. At present the 18-kVA (14.4 kW) biofuel engine in the project is running at less than 50 % load meeting only the biofuel production needs. The inclusion of other value adding activities (coconut soap, lotion and body oil making) and other equipment and appliances will see the biofuel engine operating at the recommended 75 % load or more which is optimal for better efficiency and performance. For backup power to CATD, the 18-kVA biofuel engine/generator will provide power to the important areas in CATD (refrigeration in the kitchen premises, the water pumps and around the main office premises) [12].

Production capacity and operation of the biofuel demonstration project

The actual production rate from the coconut mill was 10 to 15 litres of coconut oil per hour, capable of producing around 460 litres of coconut oil from 1 tonne of copra or 2.17 kg to produce 1 litre of coconut oil. Oil produced is filtered to 1 micron particle size and is stored in a 200 litre drum. To begin initial production and operation, 51 litres of diesel fuel is needed to generate power (from the 18-kVA generator for 13 hours at 75 % load) to meet the coconut oil mill and biofuel blending unit load of 7.1 kW. The oil mill produced 128 litres of filtered coconut oil in 13 hours, fractionally under the lower specified production rate of 10 litres per hour. When the 128 litres of coconut oil is blended with 32 litres of diesel, 160 litres of coconut biofuel will be produced. This amount of coconut biofuel (80:20 blends) is capable of running the 18-kVA generator for 41 hours when operated at the recommended 75 % load. According to supplier specification, the fuel consumption is 3.9 litres/hour. The biofuel system as operating can provide fuel for the biofuel engine and production of value adding products[12].

4.5 Fiji Electricity Authority's Project

Harvie Probert from Fiji (Pacific) writes: Currently the Fiji Electricity Authority in Fiji are testing a larger 3.3Mw Cat engine running on coconut oil at their Sigatoka power station and are looking at that and other biofuels (fuels from biological materials such as crops, animal wastes) as an alternative to diesel. With diesel at over $900/ tonne, biofuels at up to $700 are a workable replacement. On a recent survey to one of the remotest Fiji islands, Rotuma, it was observed that the island had the potential to use the coconuts lying around to displace almost entirely the need to import diesel, as the production available locally was estimated at about 2,000 tonnes per year of copra, which would produce around 1,600 tonnes of coconut oil, and if refined into biodiesel would produce around 1,500 tonnes[13].

4.7. Opportunities for Biofuel Applications in Rural Electrification on Koro Island

Pre-Feasibility Study in Nacamaki Village

Copra is the main income earner for Nacamaki, next to farming and fishing. Currently, Koro has an average annual production of about 86 tonnes of dry copra that is sold at a net value of FJ$ 460 per tonne. Wet copra is produced by individual farmers, sold communally through the village co-operative, dried, bagged and stored for onwards shipping. 5% of the value of the green copra is taken by the co-operative to go towards the village electrification system. Through higher margins on product, it appears to be economically interesting for the co-operative to engage in milling part of the copra into oil. The demand for oil in the village, considering bio-fuel demand and other uses is estimated between 4.5 and 14 kl per year. Small-scale oil presses with a capacity of 20 litres per hour are available on the market for this purpose. It is proposed to have a 30 kVA biofuel-adapted generator installed in the village and to introduce electricity metering, ensuring proper revenue collection for electricity generation[15].

At the low volumes of demand in Nacamaki, the costs of producing copra oil are relatively high. Income from oil sales can cover the direct production costs with some margin, but cannot cover the capital costs. Therefore, strategies need to be developed to sell more oil to achieve economies of scale. With diesel costs at FJ$1.38 per litre, direct production costs of coconut oil fuel equivalent price would be FJ$1.12 per litre.
Compared to for example wind energy or solar energy, biofuels provide much more cost-effective solutions in terms of investment cost per kWh. However, they come at a significant expense of labour input and continuous commitment by the community. If this commitment does not come with a return on time spent, it can hardly be sustainable in a Pacific context, as other experiences have shown. The case for Nacamaki looks promising as the community has indicated it has very few other options[15].

Copra Production in Nacamaki

Koro Island contains about 2,000 hectares of coconut plantation. At Nacamaki the copra production is seasonal between February to October and off season in November to January. When it’s off season, villagers plant dalo (taro) and yaqona (kava) as an alternative source of income. During this May-July, there is sometimes an overproduction of copra (i.e. more than storage can contain) and people then supply directly to the Consort Shipping agent. During November – February there is some copra collection but the yields are significantly lower (See Figure 24)[15].

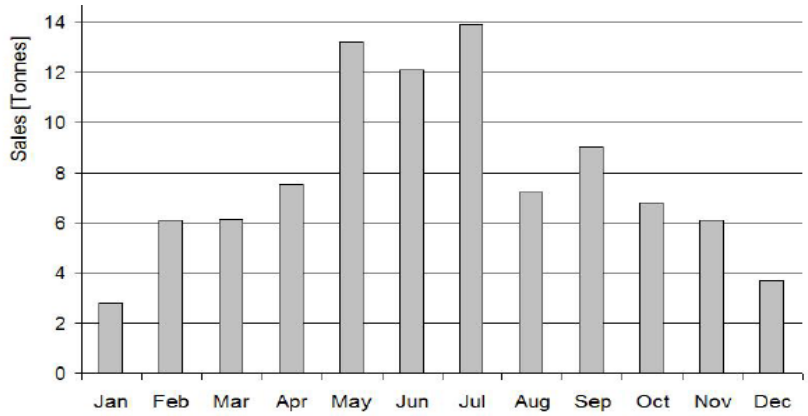

Figure 14: Copra Production Nacamaki in 2006 per month

Villagers have to collect wet copra every Friday and village cooperative buys for 20 cents per kilogram. The cooperative will deduct 1 cent for electricity and 19 cents given to villagers as cash. The cash will just stay at the cooperative but villagers are given groceries at the same value. With 150 coconut nuts, a villager can produce 40 – 60 kg of wet coconut. A man can fill 2-3 bags of wet coconut per day.

Year	Production [tonnes dry copra]
2004	93.91
2005	70.14
2006	94.58

Table 1: Copra Production in Nacamaki 2004-2006

Future sizing

Based on the sizing formula of the Department of Energy of 500 W per connection point, the village of Nacamaki would be advised to have a 43 kVA genset, if it were to be electrified today. Considering the current usage of an average of 8 kVA, this would lead to a significant Underutilisation of the generator by the village. Underutilisation results in poor efficiency and high maintenance cost, and has to be avoided. On the other hand, considering the lifetime of a generator to be at least 10 years, it should cater for any future load increase.The logbook by the technician will be very useful in further establishing the appropriate generator sizing. For the purposes of this study, a 30 kVA, 24 kW generators will be assumed as the most appropriate size.

5. <u>Future Prospective</u>

5.1. State and future of Copra Sector in Fiji

In order to better understand the copra sector in Fiji, DoE also visited a number of copra processing parties on Vanua Levu and Taveuni. Mr. Ashok, CMFL Mill manager, was interviewed about their operation. The mill opened in 1985 and has the capacity to process 24,000 tonnes/year. At the moment, their output is only about 7-8,000 tonnes copra per year because of lack of copra supply to the mill. It is nevertheless the largest copra mill in the country, with only Punja's mill in Lautoka producing coconut oil on a large scale.

The crude coconut oil produced in Savusavu is sold to European countries. The cargo ship usually arrived after 4 – 5 months and it's a very expensive for Fiji coconut oil to reach its destination. Shipping companies are charging US$130/tonne for Europe and US$45/tonne to reach Australia. On top of that, the oil needs to be 'financed' during the journey, i.e. the real payment only comes when the oil finally is delivered.

Currently there are about 10 agents who are supplying copra to the mill. In addition to these, individual farmers also supply copra directly. CMFL supply areas are around Vanua Levu, Taveuni, Lomaiviti, Cikobia, Kadavu and Lau Group. Most copra received comes from agents[15].

5.2. Fiji Copra Prices

Gradings are done at the mill using hydroprobe equipment, which check the moisture contents of the copra. For low moisture content Fiji 1 CMOF buys for FJ and for Fiji 2 CMFL buys for FJ per tonne.

Copra Source:	Fiji 1 (premium)	Fiji 2
CMFL Gate price	$524.68	$472.21
from Taveuni / Vanua Levu	$554.68	$502.21
from Lau; Lomaiviti; Kadavu; and Cikobia	$579.68	$522.25

Table 2: Copra Prices in Fiji in FJ$ per tonne in March 2007

For agents buying copra from Lau/Lomaiviti/Kadavu and Cikobia they received an additional FJ$55 premium per tonne. For those buying copra around Vanua Levu and Taveuni, they received FJ$30 premium per tonne. These premiums are added to the CMFL gate price, Fiji 1 ($524.68) and Fiji 2 ($472.21) respectively (see table 5 above).The CMFL is also facing some constraints in its production. The transport costs for export is a major constraint. Secondly, the consistency of the copra supplies to reach the mill. Third the quality of copra usually decreases in wet weather, some bags contain mixed grading (Fiji 1 and Fiji 2). It is very difficult to buy on the correct grading.The mill has started an awareness programme for the production of good copra. In addition, the biofuel production is another programme that should fully utilised the mill capacity and also generate needed revenue for the company. Lastly, the improvement in the copra production routine work should enhance the quality and quantity of the overall copra industry.

6 .Comparison of Diesel Fuel against Coconut Oil

Whether a diesel engine requires conversion to be successfully operated on coconut oil is typically determined by a few key factors relating to the engine. It steps you through the four main considerations when assessing the suitability of an engine for coconut oil and what adaptation measures are required to successfully operate an engine on coconut [16].

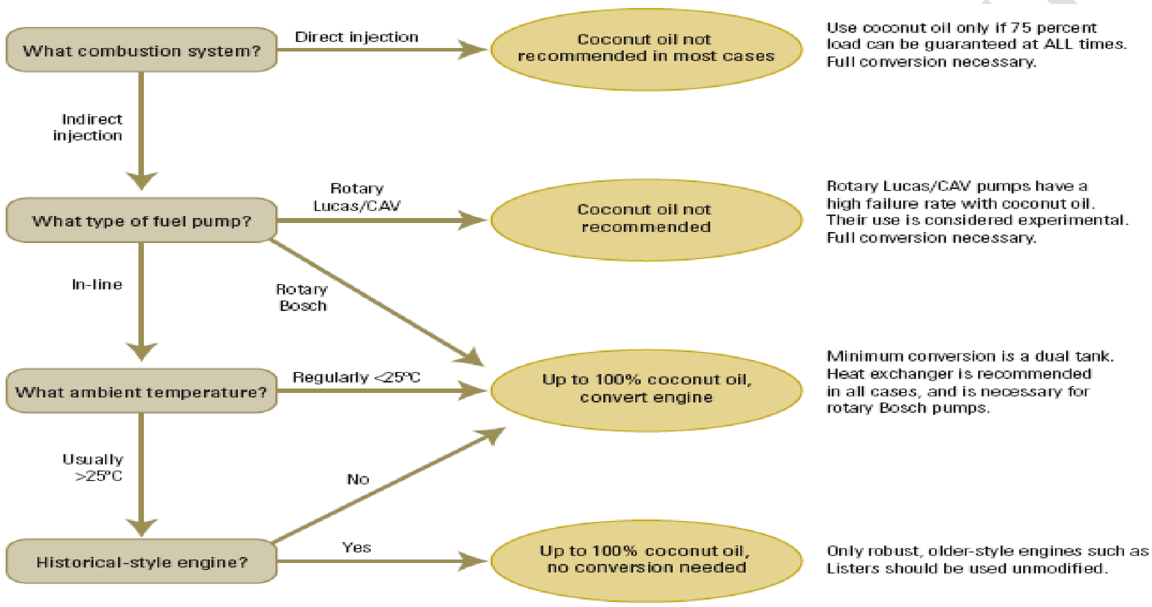

Figure 15: A diesel engine on coconut oil

6.1 Diesel Fuel versus Coconut Oil

If you physically compare diesel fuel with coconut oil or, say, the vegetable oil you cook with at home, it is easy to understand that the two have different properties. The most obvious one of these is that coconut oil is much thicker, or viscous, than diesel fuel. This factor of viscosity accounts for many of the main problems associated with using coconut oil as fuel. The other important difference between the two relates more specifically to combustion properties, in that coconut oil has a much higher ignition temperature than diesel fuel. The key physical properties are listed in table 3 below[16].

Fuel	Specific Energy (MJ/kg)	Density (kg/m^3)	Cetane Number	Kinematic Viscosity (cSt 40 °C)	Solidification Temp. °C	Flash Point (°C)	Iodine Value
Diesel Fuel	42.6	828	40-55	2-4	-9	>62	-
Coconut oil	35.8	915	60-70	27	22-25	200-285	6-12

Table 3: Characteristics of Diesel Fuel and Coconut Oil

6.2. Coconut Oil as Fuel

Most diesel engines can run on 100 percent coconut oil, at least for a short while. Tempting as it may be to simply pour coconut oil into the fuel tank of your engine, this approach will probably have shopping for a new generator in a very short space of time. However, if a person has a sound understanding of the issues of using coconut oil and effectively manage those issues, then there coconut-powered generator can run as long than a generator using diesel fuel—or even outlive it. Some of the key points regarding the type of engine were touched on in the previous section. Here we will discuss the key problems with using coconut oil and provide the necessary information about how to avoid them[16].

6.3. The Main Issues

There are two fundamental issues with using coconut oil in a diesel engine:

• Incomplete combustion

• Viscosity

Incomplete Combustion

For coconut oil to burn completely, a minimum combustion chamber temperature of 500°C is required, compared with about 250°C for diesel fuel. If this minimum is not reached, partially burned fuel will form carbon deposits (coking) on injector nozzles, cylinder walls, and elsewhere throughout the combustion system. Coked injector nozzles have a strong, self-enforcing negative effect. This is particularly the case for multiport injector nozzles found in direct-injection engines, where a finely atomized fuel-spray pattern is more critical. Deposits around the injector ports create an uneven spray pattern, producing larger fuel droplets that do not burn completely, leading to more carbon buildup and escalating the problem that will eventually lead to engine failure if left unchecked. If partially burned fuel makes contact with the cylinder walls, it will get picked up by the piston rings and can cause them to stick and malfunction. Also, very low combustion temperatures will leave unburned fuel on the cylinder walls that can be transferred to the engine sump (oil pan) either by the sweeping nature of the piston or blown through as "blowby" because of malfunctioning piston rings and lost compression[16].

To achieve complete combustion using coconut oil, it is critical that the engine is regularly and consistently loaded—a typical rule of thumb being about a 75 percent load. This will ensure that complete combustion is achieved. This factor is critical if attempting to use coconut oil in direct-injection engines: a load of 75 percent or more MUST be placed on the engine at all or nearly all times. In contrast, indirect-injection engines are more tolerant of underloading and have proven that they can successfully run on loads down to 50 percent. There are three reasons for this: the precombustion chamber retains heat, assisting combustion; any partially burned fuel lines the precombustion chamber, rather than the walls of the cylinder chamber, and gets blown out with the exhaust gases; and the single larger port of the pintail injector nozzle has a self-cleaning effect and is less susceptible to coking. (Direct-injection engines are more susceptible to problems for the opposite of these reasons).

Higher Viscosity

At 25°C, coconut oil is about 10 times more viscous than diesel fuel. This can have two detrimental effects on the engine: it produces an altered spray pattern of injected fuel, and it creates additional stresses on both the injection pump and the distribution pump. The more viscous coconut oil will not produce as fine a fuel mist as with diesel fuel, and the larger droplets do not burn as effectively. This leads to the problems of incomplete combustion and deposits of carbon throughout the combustion system, introduced above. Multiport injector nozzles in direct-injection engines are more prone to this problem because they have smaller holes than pin-type injectors. This problem is even worse in very small (about 5kVA) direct-injection engines. Experience has shown that jerk and in-line injection pumps are better able to tolerate the more viscous coconut oil than rotary pumps, particularly those of the Lucas/CAV variety.

The viscosity of coconut oil can be reduced by two methods: heating and blending. The adjacent graph indicates the overall effect on viscosity as different blends of coconut oil and diesel fuel are heated. The graph shows that at temperatures around 80°C, coconut oil has a viscosity of about 10 centistokes (cSt)—the measurement for kinematic viscosity—which is only twice the viscosity of diesel fuel at normal operational temperatures. Most diesel-engine makers specify a maximum fuel viscosity of 10–15 cSt, so coconut oil at 80°C is within the design parameters of most diesel engines at this temperature[16].

6.4. Other Issues

A number of other issues can arise from using coconut oil. These can be broken down into the following categories:

• Solidification temperature
• Filter blockage
• Carbon deposits
• Lubrication oil deterioration
• Distribution pump problems

6.5. Options for Using Coconut Oil

To operate a diesel engine on coconut oil, there are four options:

• Use an unmodified engine with 100 percent coconut oil
• Adapt the engine and use 100 percent coconut oil
• Blend coconut oil and use in either unmodified or modified engine
• Modify coconut oil chemically to produce biodiesel fuel and use in unmodified engine

Adapting an Engine for Coconut Oil

Three adaptation options are recommended:
• Dual-tank, so the engine starts and stops on diesel fuel
• Dual-tank with heat exchanger, so the coconut oil is preheated before it is injected
• Looping the fuel return to reduce stresses on the injection pump

6.6. Sustainability

The use of coconut oil to replace diesel has a range of potential environmental benefits. First, there is the decrease of emissions of poisonous gases and particulate matter as compared to diesel, through the higher oxygen content of coconut oil, although these benefits are not so evident when using straight vegetable oil in standard engines. Secondly, the use of coconut oil can be considered CO_2 neutral. The CO_2 stored in the coconuts, husks and shells are used in the process of oil production (husk and shells for drying the copra) and burning of the oil. This CO_2 is again sequestrated during the growing of new trees and nuts[17].Other advantages of coconut oil include:

- Lower emissions and toxic fumes than petroleum diesel fuel
- Smoother running and reduced engine knock
- Availability to the producer in remote areas to run machinery and generate electricity when the roads are cut off in the wet or prices are too high
- The oil is a sustainable resource.

What is more, supporting a local industry which cuts down on fuel imports will benefit fragile Pacific island countries substantially through improvements in balance of payments and job creation. Simultaneously, coconut farmers are given access to a new, potentially booming market as the difference between the cost of their product and the benchmark of the diesel price further widens. Even though there is considerable evidence of the environmental benefits of using coconut oil as a fuel, it is the local cost of petroleum fuel that is the real driver behind these developments in the Pacific island economies. Electric utilities generally suffer from great dependence on imported diesel for power generation and are seeking new ways to hedge these risks[17].

7. Conclusions/Recommendations

The high price of fossil fuels in the South Pacific, and the economic as well as the environmental hazard associated with their use, make renewable energy particularly attractive in the region. New renewable energy projects also offer an opportunity to bring electrification to isolated island communities that previously lacked proper electricity supplies. In coconut oil, Pacific islands have a renewable fuel source that is locally-produced, high-yielding, straightforward to process, and can be accommodated to a certain extent by existing diesel-based energy infrastructure. It is also environmentally friendly: not only is the burning of coconut oil carbon neutral, but its production and distribution can be done without significant emissions, if the oil is pressed locally using machinery operated by hand or powered using the oil itself. A further advantage of coconut oil in the South Pacific over other biofuels such as palm oil is that large, under-utilised areas of coconut plantation already exist in the region, so land use for coconut oil production need not compete with food production or biodiversity. Although coconut oil is not available in sufficient quantities to completely replace fossil fuel use, potential exists for it to make a substantial contribution to some Pacific countries' energy needs.

Following the success of initial trials, the addition of small quantities of coconut oil to diesel for use in electricity generation is likely to become widespread wherever the oil is available at a competitive price. However, realising the full potential of coconut oil as a fuel will require investment in oil processing infrastructure, and in specialised generators capable of handling the oil in larger concentrations. Unfortunately, investment in renewable energy in the South Pacific has historically been neglected due to a lack of awareness of the available options, lack of institutional capability, and a lack of financing opportunities. Another recurring problem has been a lack of involvement and collaboration with local stakeholders, which was evident in the partial failure of the Fijian scheme described .Further development of coconut oil as an energy source therefore requires better cooperation between governments, international donors, coconut growers and millers, and local communities, with an emphasis on long-term capacity building rather than short-term infrastructure investment. Another problem is the volatility in prices of both coconut oil and fossil-fuel alternatives, which makes the return on any investment in biofuels uncertain. Initially, overcoming this problem may require subsidy for coconut oil production, together with the elimination of any existing subsidies that favour the use of imported fuel. South Pacific governments are under little pressure to support renewable energy on environmental grounds, since the region's per capita carbon emissions are already a mere quarter of the world average. However, properly-implemented renewable energy schemes offer clear economic benefits. A greater capacity to use coconut oil as an alternative to diesel would buffer vulnerable South Pacific countries against changes in the world price of both commodities, providing them with a much-needed measure of economic stability and energy security. In addition, the prospect of reducing carbon emissions through biofuel use provides foreign donors with an incentive to help South Pacific countries invest in sustainable development of their energy resources.

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