MAURITIUS RESEARCH COUNCIL

Final Report

Feasibility Study on Use of Coconut Oil (CNO) and Waste Vegetable Oil (WVO) for Electricity Generation

December 2011

Content

List of Abbreviations

CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CO	Carbon Monoxide
CNO	Coconut Oil
CWA	Central Water Authority
LPG	Liquid Petroleum Gas
KVA	Kilovolt Ampere
MJ	Mega Joules
MPI	Ministry of Public Infrastructure, National Development Unit & Land Transport & Shipping
MRC	Mauritius Research Council
MSB	Mauritius Standards Bureau
NOx	Nitrogen Oxides
OIDC	Outer Islands Development Corporation
OIML	International Organization of Legal Metrology
O_2	Oxygen
PV	Photovoltaic
WVO	Waste Vegetable Oil
UOM	University of Mauritius
MoTESRT	Ministry of Tertiary Education, Science, Research and Technology

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Acknowledgement

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- CWA for providing an existing generator of 60 kVA situated at Ebene pumping station
- OIDC for providing coconut oil for the study
- Ministry of Health & Quality of Life for providing waste vegetable oil
- Indian Oil (Mauritius) Ltd for providing diesel for the study

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- Mr Z Kodabuckus, Ms T Marie-Jeanne, Mr M Ramloll, Mr G Boodhun, Mr M Apajee (Ministry of Public Infrastructure, NDU & LT & S)
- Mr S Ghoorun (Mauritius Standards Bureau)
- Mr M Chan (Auto Check Ltd.)

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EXECUTIVE SUMMARY

In line with the Maurice Ile Durable Project, the Mauritius Research Council (MRC) under the aegis of the Ministry of Tertiary Education, Science, Research and Technology (MoTESRT) in collaboration with Outer Islands Development Corporation (OIDC) initiated a project on the use of Coconut Oil and Waste Vegetable Oil as substitutes to Diesel for transportation. The aim of the project was to transform Agalega into an "Ile Durable" with regards to its energy requirement and propose environment friendly solution for disposal of waste vegetable oil in Mauritius

Phase I of this project, completed in 2009, constituted of a feasibility study and a pilot implementation carried out in Agalega and Mauritius whereby it was shown that Coconut Oil and Waste Vegetable Oil are very good substitutes to diesel for transportation. As a result, currently, there is one tractor running on Coconut Oil in Agalega and some hotels in Mauritius are running a few 4X4 on Waste Vegetable Oil.

The second phase focused on the use of Coconut Oil and Waste Vegetable Oil in diesel generators to produce electricity was launched in September 2010 and ended in December 2010.

The ultimate goal of this initiative is to reduce the dependency of Agalega on Diesel and use locally produced Coconut Oil to generate their electricity. This study led by the MRC, was carried out in collaboration with Central Water Authority, University of Mauritius, Ministry of Public Infrastructure, NDU, Land and Shipping, Mauritius Standards Bureau and Auto Check Ltd. The OIDC, Ministry of Health and Quality of Life and Indian Oil (Mauritius) Ltd. sponsored the project through the kind provision of Coconut Oil, Waste Vegetable Oil and diesel respectively.

The study entailed converting the Central Water Authority's 60 kVA generator situated at Ebene Pumping Station to run on Coconut Oil, Waste Vegetable Oil and diesel, filtering/cleaning of coconut oil and waste vegetable oil, running the generator on coconut oil, waste vegetable oil and diesel, demonstrating the results, assessing the generator's performance, engine investigation and handing over the generator to CWA in good running condition.

The engine's performance while running on Coconut Oil, Waste Vegetable Oil or Diesel was assessed through a number of parameters including:

i. *quantification of toxic gases like Carbon monoxide and Nitrogen Oxide from the exhaust emissions*
ii. *assessment of the opacity of the exhaust gases and evaluation of the engine wear & tear through lube oil analysis*
iii. *evaluation of the effectiveness of Coconut Oil and Waste Vegetable Oil compared to Diesel for electricity generation.*

It was found that by installing manually operated conversion kit to the generator engine and running the generator on full load on coconut oil, waste vegetable oil and diesel, it can be concluded that –

1. *Coconut Oil is a better substitute fuel than diesel in terms of emissions, opacity and wear and tear*
2. *The fuel consumption of coconut oil is slightly higher with similar performance*
3. *Coconut Oil was found to be suitable for electricity generation and it is recommended to transfer the technology to Agalega*
4. *Waste Vegetable Oil was not found to be suitable for electricity generation due to high opacity and suspected high fatty acid contents*

This is the first time that such a study has been carried out in the region and it might prove to be a cornerstone for reducing the dependency of Agalega on diesel for electricity production and hence gearing Agalega into an 'Ile Durable' vision.

1 COCONUT OIL AND WASTE VEGETABLE OIL AS SUBSTITUTES FOR DIESEL IN AGALEGA AND MAURITIUS

1.1 Introduction to Agalega

The atoll of Agalega is situated at around 1000 km North of Mauritius and comprises two islands (North and South Islands). Agalega has a population of about 300 persons. The Outer Islands Development Corporation (OIDC) is responsible for the management and development of Agalega.

All the goods for needs and requirements for Agalega are shipped from Mauritius. An item of expenditure, which is escalating year after year is fuel, not only the price, but also the cost of transport to and delivery at Agalega is on the upward trend. The inhabitants rely on generators to have their electricity round the clock. The OIDC also has a fleet of vehicles, machinery, plant and equipment, which consume fuel (Action Plan, OIDC, 2005).

1.2 Energy Use Scenario in Agalega

Agalega is totally dependent on fossil fuels (mostly diesel) imported from Mauritius for its energy requirement, that is, electricity and transportation. In 2009, the volume of diesel shipped to Agalega increased by four times between 2000 and 2009 (reaching ~187,271 L in 2009), while the total cost of fuel soared by 12 times to reach Rs 7.5 million in 2009 as shown in Figure 1.

In 2010, the volume of diesel shipped to Agalega decreased first time in last 10 years to 127,800 L and the total cost of fuel reduced to Rs 5.08 million. It is anticipated that one of the reasons could be due to **one tractor** successfully running on Coconut Oil in Agalega since November 2009.

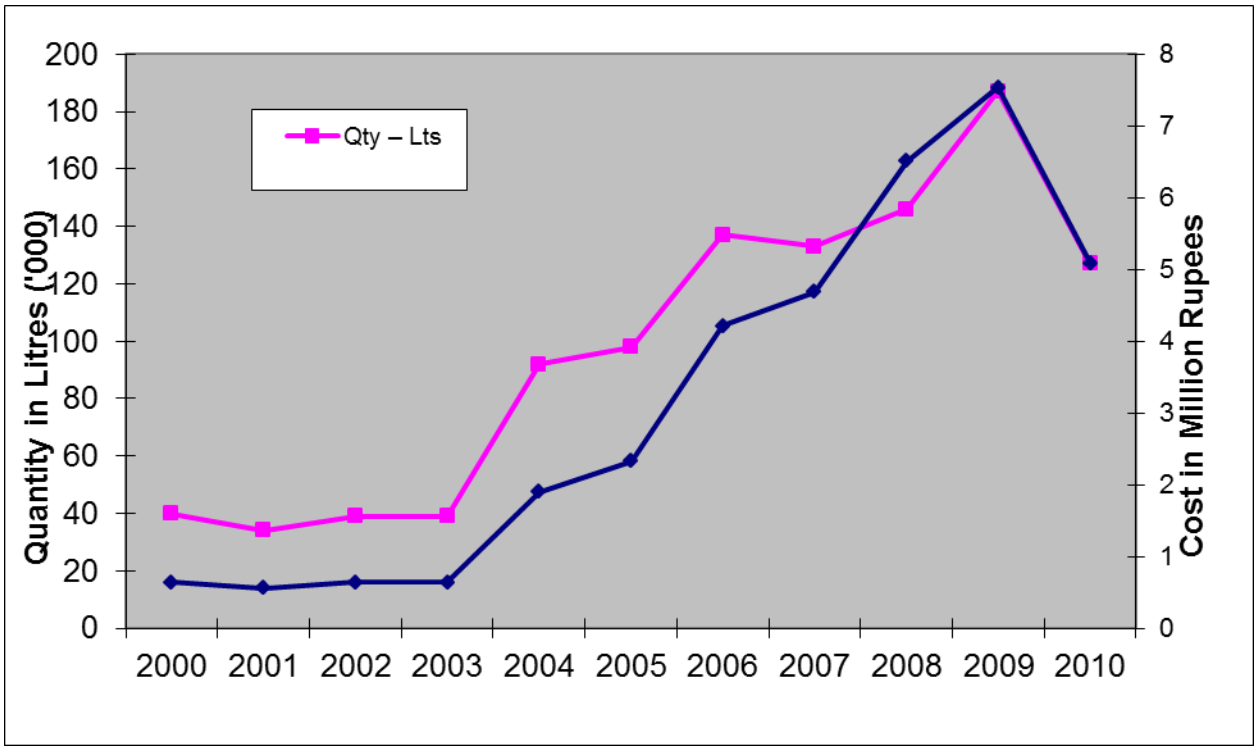

Figure 1: Quantity and cost of diesel shipped to Agalega, 2000-2010 (source; OIDC)

1.3 Problems Due to import of diesel fuel in Agalega

Agalega has a frail ecosystem with shallow water tables. The disposal of diesel drums in the open and runoff mineral oil is not only an eyesore but also a threat to the quality of underground water that is used by the inhabitants (MRC, 2008).

In the past, empty diesel drums were shipped back to Island of Mauritius. However, this practice was recently abandoned due to its high costs. Now empty drums are stacked in the open and no special precaution is taken to prevent residual diesel fuel from leaking into the ground (MRC, 2008).

There is also a risk of oil-spill during transportation of diesel from Mauritius to Agalega causing an adverse impact on our marine resources.

1.4 Coconut Oil Production in Agalega

Agalega, with its two islets has a total surface area of 2,600 hectares and has presently 20,000 standing coconut trees, which are distributed over an area of 800 hectares or around 30% of the total area. Mature coconuts are harvested

and the coconut meat also known as the kernel is removed and dried. The dried kernel is called copra. The copra is cut into small chips in a copra cutter for greater efficiency of oil extraction. The copra chips are than pressed in expeller (mechanical extraction) to produce coconut oil. This oil is **NOT** hydrogenated, and contains **NO** Trans fatty acids.

Each year, about 15,000 litres of coconut oil was sent to Mauritius for sale. The volume of CNO shipped to Mauritius over the last seven year is shown in figure 2.

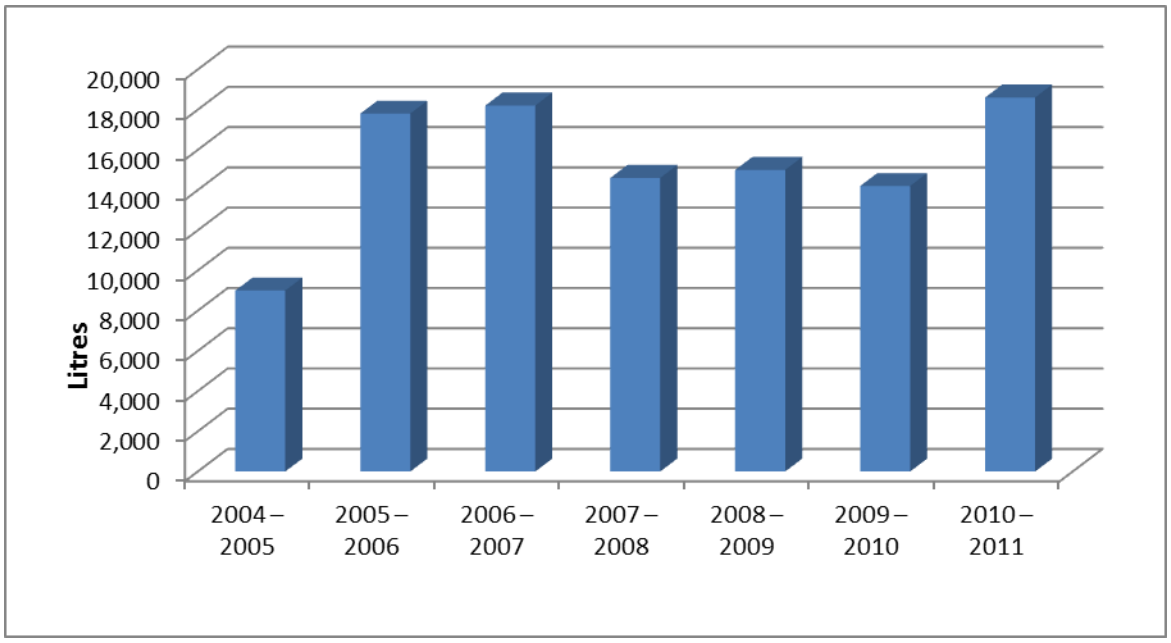

Figure 2: CNO Production in Agalega (source; OIDC)

In future, the OIDC is planning to embark on a project, which aims at expanding the existing coconut plantation over an area of 1,500 hectares at the end of a five-year period. The aim is to produce more coconut oil and thus, increase revenue for the Island of Agalega, while making use of the oil as an alterative to diesel.

1.5 Rationale for Using Coconut Oil as Substitute for Diesel in Agalega

The use of coconut oil in engines is not new. It was used in the Philippines during the Second World War when diesel was in short supply.

In 1912, Dr Rudolf Diesel stated, “the use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in the course of time as important as petroleum and the coal tar products of the present time.”

In recent years, due to fuel price fluctuation, there has been a revival of interest in the use of renewable energy. A number of countries, such as, Thailand, India, Philippines and some Pacific island states are moving towards bio fuel.

Recently, in Vanuatu (A Pacific Island State), 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.

Being given that Agalega has a vast potential for coconut oil production, it was interesting to explore whether the experiences of the Pacific Islands in field of coconut biofuels could be replicated in Agalega.

1.6 Rationale for Using Waste Vegetable Oil as Substitute for Diesel in Mauritius

In Mauritius, hotels and holiday resorts, fast food outlets, and hospitals produce a large amount of waste vegetable oils. Currently they have to pay for collection and disposal of their WVO to oil-recycling company, or sell it to WVO users which use it as a fuel for furnaces. The generation of WVO by households is virtually zero in Mauritius. The general practice at household level is for oil to be recycled during cooking.

A study undertaken by MRC on the usage and disposal of vegetable oil by large consumers, including hotels, fast food chains and hospitals in 2006-2007 had shown that between 35-40% of oil is disposed of, and that the consumers of oil also have fleets of diesel vehicles and generators. WVO can potentially be used as a substitute for diesel to decrease their fuel expenses while saving the environment.

1.7 Study on use of Coconut Oil (CNO) and Waste Vegetable Oil for Transportation

During Phase I, a feasibility study and pilot implementation was carried out by the MRC in collaboration with OIDC in Agalega and Mauritius on the use of Coconut Oil (CNO) and Waste Vegetable Oil (WVO) as substitutes to diesel for transportation whereby it was shown that Coconut Oil and Waste Vegetable Oil are very good substitutes to diesel for transportation.

As a result, currently, there is **one tractor** successfully running on Coconut Oil in Agalega since November 2009. In Mauritius, a few hotels, such as - “Hilton Resorts & Spa”, SUN Resorts”, “Naiade Resort” have adopted the idea and are currently running their 4X4 vehicles on Waste Vegetable Oil generated by the Hotel having an annual Savings of about Rs. 300,000 per vehicle each year on fuel costs for the Hotel.

2 ELECTRICITY GENERATION FROM COCONUT OIL AND WASTE VEGETABLE OIL

As a way forward the MRC in collaboration with its project partners undertook the study on “Electricity Generation from Coconut Oil and Waste Vegetable Oil”. The focus in second phase was to investigate the use of Coconut Oil (CNO) and Waste Vegetable Oil (WVO) as substitutes to diesel for Electricity Generation. The project was launched in September 2010 and ended in December 2010.

The Central Water Authority kindly agreed to collaborate in this project and made available one standby generator normally used in the Ebene Pumping station. The generator was to be run on diesel, CNO and WVO respectively for about eight hours daily on full load to simulate the conditions in Agalega.

The MRC contacted the University of Mauritius to carry out exhaust emissions tests arising from diesel, coconut oil and waste vegetable oil, and to determine the consumption of Diesel, Coconut oil and waste vegetable oil. The Mauritius Standards Bureau (MSB) carried out tests on lubricants, and the Ministry of Public Infrastructure (MPI) measured the opacity of the exhaust gases.

The study entailed converting the Central Water Authority’s 60 kVA generator situated at Ebene Pumping Station to run on Coconut Oil, Waste Vegetable Oil and diesel, filtering/cleaning of coconut oil and waste vegetable oil, running the generator on coconut oil, waste vegetable oil and diesel, demonstrating the results, assessing the generator’s performance, engine investigation and handing over the generator to CWA in good running condition.

3 PROJECT TEAM AND PARTNERS

This study led by the MRC, was carried out in collaboration with Central Water Authority (CWA), University of Mauritius (UoM), Ministry of Public Infrastructure, NDU, LT and Shipping, Mauritius Standards Bureau and Auto Check Ltd.

The Outer Islands Development Corporation (OIDC), Ministry of Health and Quality of Life and Indian Oil (Mauritius) Ltd. sponsored the project through the kind provision of Coconut Oil, Waste Vegetable Oil and diesel respectively.

4 AIM OF THE STUDY

The aim of the study was to demonstrate the technical feasibility of using Coconut Oil (CNO) and Waste Vegetable Oil (WVO) as substitutes to diesel for Electricity Generation

5 OBJECTIVES OF THE STUDY

The objectives of the study were as follows:

- To carry out exhaust emissions tests (Carbon monoxide (CO), Carbon dioxide (CO_2), Nitrogen Oxides (NO_x), Oxygen (O_2) arising from diesel, Coconut Oil and Waste Vegetable Oil)
- To measure the opacity of the exhaust gases arising from diesel, Coconut Oil and Waste Vegetable Oil)
- To perform Lube oil analysis to detect any deterioration of the engine wears and tears.
- To determine the fuel consumption of Diesel, Coconut Oil and Waste Vegetable Oil.

6 PROJECT SCHEDULE

The duration of the project was four weeks as below; the detailed schedule is given in Annex 1:

Week	**Fuel Type**
Week 1	Diesel
Week 2	Coconut Oil
Week 3	Coconut Oil
Week 4	Waste Vegetable Oil

7 FILTERING AND CLEANING OF COCONUT OIL AND WASTE VEGETABLE OIL FOR ELECTRICITY GENERATION

Ideally any plant oil need to be filtered in a centrifuge to remove all suspended solids before using it as fuel. However, in this study CNO & WVO were filtered manually through filter socks using gravity.

7.1 Filtering and Cleaning of Coconut Oil

The most important step in using coconut oil as fuel is filtration and cleaning. The filtration process is the removal of all suspended solids from the press oil. These particles must be removed to prevent blockage in the fuel delivery system, especially the fuel injector. The safety filtration limit is 10 microns.

Coconut oil has a low freezing point and is most of the time available in solid state as shown in Figure 3.

Figure 3: Coconut oil in solid state

It was therefore needed to be heated and then filtered before being used as a fuel for the Perkin generator (Figure 4). For this experiment, triple filtration method was used; the coconut oil was first filtrated to 50 micron, then filtrated to 25 micron and finally to 10 micron.

Figure 4: Heating and filtration of coconut oil

7.2 Filtering and Cleaning of Waste Vegetable Oil

Waste vegetables oils were collected from hotels. The viscosity of waste oils varies from hard crystalline solids to light oils at room temperature. In most cases, these oils are actually a complex mixture of various fatty acids triglycerides, often with the various components having widely varying melting points. This may give the oil or fat a temperature range over which solidification occurs, with the oil gradually thickening from a thin liquid, through to a thick liquid, then a semi-solid and finally to a solid.

WVO therefore need to be cleaned and filtrated before being used as fuel. The WVO was filtered four times before using as fuel, that is, from 100 micron - 50 micron - 25 micron - 10 micron.

8 GENERATOR USED FOR THE STUDY

The Central Water Authority (CWA) had made available one standby generator (Figure 5) normally used for pumping of water from a borehole situated in the Ebene region in case of power shut down.

Figure 5: CWA Generator

8.1 Specifications of the CWA Generator

The specifications of the generator used for the experiment are tabulated in Table 1:

Table 1: Specifications of the generator

Make	Perkins 1000 series
Number of cylinders	4
Rated Power	60kVA
Cylinder arrangement	In line
Cycle	Four stroke
Combustion system	Direct injection
Valve tip Clearance • Inlet • Exhaust	 0.64 mm 0.64 mm
Lubricating oil pressure	345kN/m^3
Typical coolant capacity (engine only)	12.8 L
Direction of rotation	Clockwise from front

8.2 Conversion Kit Used on the CWA Generator

Different conversion kits are available ranging from manually operated to automatic and electronically controlled heavy duty kits.

For the purpose of the study a Manually Operated Standard Duty CNO/ WVO Conversion Kit was used on the CWA Generator to propose a simple technology for Agalega which could be easily managed by the local technicians. The Kit comprised of the following components –

- Tank Heater (built-in)
- Tank Stand
- CNO Filter Assembly x1
- Valves x4
- In-line Heating Assembly
- Heater Hose
- CNO Hose
- Set Clamps (standard)
- Set Fittings (standard)

8.3 Operation of the Generator

The generator is normally operated using diesel as fuel. For the experiment, modifications were made to fuel supply systems as shown in Figure 6. A parallel supply line for coconut oil or waste vegetable oil was connected to the generator via a 3 way valve and a heat exchanger was used as shown in Figure 7 to preheat the coconut oil or waste vegetable oil before injection.

The generator was first operated on diesel till the temperature of the coconut oil or waste vegetable oil attained the required temperature, that is 70^{o}C, then by the way of the 3 way valve, the generator was run using either coconut oil or waste vegetable oil.

The duel fuel system allowed engine start/stop on diesel as follows -

- Start on diesel
- Run on Coconut Oil or Waste Vegetable Oil
- Stop on diesel

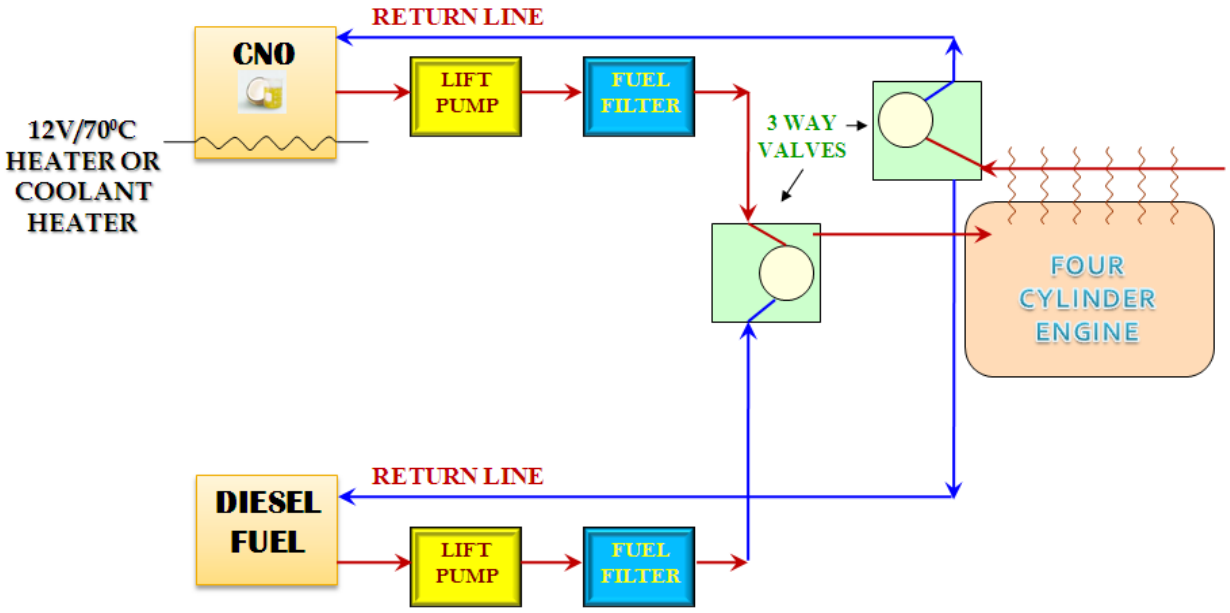

Figure 6: Fuel Supply System

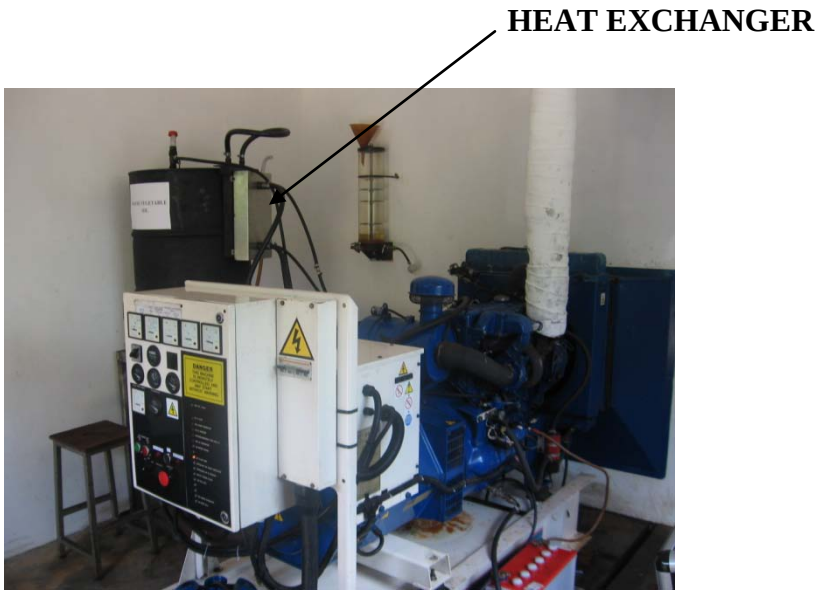

Figure 7: Heat Exchanger Kit

9 EQUIPMENT USED FOR THE STUDY

9.1 Emissions

A Kane portable gas analyzer (Figure 8) was used for measuring the exhaust emissions by inserting its probe into the exhaust pipe of the engine. The Kane analyzer has been designed to be used on gasoline, diesel, LPG or CNG. The analyzer measured the concentration of CO (vol. %)), CO2 (vol. %), NO_x (vol.%) and O2 (vol. %). It also equipped to measure oil temperature and engine speed in RPM.

The exhaust gas analyzer meets the accuracy and functionality of the OIML (R99) class 1 approval standard.

Figure 8: Portable Gas Analyser

9.2 Consumption of Fuel - Diesel, CNO and WVO

Two separate measuring cylinders (Figure 9 and Figure 10) were used for determining the consumption of the fuel. The first measuring cylinder was used to feed the engine with fuel, whereas the second one is used to store return fuel from the engine.

Figure 9: Measuring cylinder

Figure 10: Measuring cylinder(return)

The fuel consumption was measured using the constant volume time method wherein the fuel flow rate was measured from the volume change in the measuring cylinders.

9.3 Opacity

A Bosh Smoker Meter (Figure 11) was used to measure the opacity of the exhaust gases. This equipment was operated by Officers of the Ministry of Public Infrastructure. The latter is the owner of the equipment.

Figure 11: Bosh Smoke Meter

10 PRELIMINARY TESTS ON CRUDE COCONUT OIL, FILTERED COCONUT OIL AND WASTE VEGETABLE OIL

Preliminary tests were performed on crude coconut oil, filtered coconut oil and waste vegetable oil at the Mauritius Standard Bureau. The results are tabulated in as follows:

Table 2: Preliminary Tests

Parameter	Diesel	Coconut oil		Waste Vegetable Oil
		Crude	Filtered	
Flash point, ^{o}C	62.7	175	104	166
Viscosity at 40^{o}C, mm^{2}/s	3.26	26.48	17.47	34.02
Water content, %	N/D	Not detected	Not detected	Not detected

11 Results and Discussions

11.1 Emissions: Emission tests were carried out as per agreed schedule.

The emissions were **on average** as follows:

Table 3: Exhaust Emissions

	Carbon dioxide $C0_2$(% vol)	Carbon monoxide CO(% vol)	Nitogen oxides NO_x(ppm)	Oxygen O_2(% vol)
Diesel	6.4	0.18	329	12.80
CNO	6.2	0.12	Not detected	12.82
WVO	6.7	0.42	400	12.47

Carbon monoxide (CO) is formed when the fuel flame temperature drops and the progression to carbon dioxide (CO_2) is not complete. This happens when the flame front approaches the relatively cool cylinder liner and combustion slows or stops. It also happens in the crevice volume that is between the outer diameter of the piston and the cylinder wall, where flame front is extinguished. The other source of CO is when the engine is being operated on too rich fuel air ratio and there is insufficient oxygen for complete combustion.

The CO emission level, when the generator was operated on CNO as fuel, was lower to that of diesel and WVO as shown in Table 4. This is because the percentage of oxygen content in the CNO was higher than that of diesel or WVO.

Oxides of nitrogen (NO_x) are formed when nitrogen in the air react with oxygen at the high temperature and pressure inside the engine. NO_x is a precursor to smog and acid rain. It is a mixture of nitrogen oxide and nitrogen dioxide. The latter destroys resistance to respiratory infections.

Moreover, the emissions of oxides of nitrogen (NO_x) were practically negligible when CNO used as fuel as compared to that of diesel and WVO. The heat release rate when CNO was used as fuel was lower during premixed combustion phase, which would lead to lower peak temperatures. Nitrogen oxide formation strongly depends on peak temperature, which explains the observed phenomenon.

11.2 Opacity: The opacity of the exhaust gases was on average as follows (Table 5):

Table 4: Opacity of the Exhaust Gases

DIESEL	CNO	WVO
42.9%	24.8%	57.6%

The opacity of the exhaust gases when the generator run on CNO was much less than that of diesel and WVO. The higher the content of unburned gases, that is, carbon monoxide, the higher will be the opacity. Therefore, due to higher oxygen content in the coconut oil, there will more combustion of the fuel in the cylinder of the engine, hence less carbon monoxides formed in the exhaust gases. Furthermore, the opacity measured when the generator run on WVO were very high (acceptable limit<50%). This is because of the low oxygen content present in the WVO.

CNO is therefore a better fuel in terms of emissions and opacity to that of Diesel and Waste Vegetable oil.

11.3 Fuel Consumption: The fuel consumption of the generator is tabulated in below:

Table 5: Fuel Consumption

	Fuel Consumption		Fuel Return		Actual Fuel Consumption		Time / s	Rate of Fuel Consumption/ L/hr	Remarks
	c.c	L	c.c	L	c.c	L			
Diesel	100	0.10	20	0.020	80	0.080	127.38	2.26	No load
	100	0.10	25	0.025	75	0.075	128.91	2.09	
	100	0.10	20	0.020	80	0.080	121.65	2.37	
	100	0.10	15	0.015	85	0.085	50.16	**6.10**	**On load**
	100	0.10	12	0.012	88	0.088	52.50	**6.03**	
	100	0.10	12	0.012	88	0.088	50.09	**6.32**	
Coconut oil	200	0.20	35	0.035	165	0.165	90.40	6.57	No load
	200	0.20	34	0.034	166	0.166	89.00	6.71	
	200	0.20	6	0.06	194	0.194	95.00	**7.35**	**On load**
	200	0.20	6	0.06	194	0.194	94.00	**7.43**	
WVO	200	0.20	2	0.02	198	0.198	102	6.99	on load
	200	0.20	2	0.02	198	0.198	100	7.13	
	200	0.20	3	0.03	197	0.197	99	7.16	

The average consumption was as follows (Table 6):

Table 6: Average Consumption

Diesel	CNO	WVO
6.15L/hr	7.39L/hr	7.07L/hr

The fuel consumption of coconut oil and waste vegetable oil were slightly higher than that of diesel on load as shown in Table 6. This is mainly due to the lower gross calorific value of coconut oil (35.8MJ/kg) than that of diesel (45.5MJ/kg).

11.4 Lube Oil Analysis: The lubricating oil analysis was performed by the Mauritius Standard Bureau to detect wear and tear. The results are tabulated in Table 7.

Table 7: Results of lubricant oil analysis

Parameter	control	DIESEL	CNO	WVO
1.Wear metals' contents, additives and contaminants, mg/kg				
a) Silver	N/D	N/D	N/D	N/D
b) Aluminium	N/D	N/D	N/D	N/D
c) Barium	N/D	N/D	N/D	N/D
d) Calcium	3198.22	3474.69	3225.83	3071.09
e) Cadmium	N/D	N/D	N/D	N/D
f) Copper	N/D	N/D	N/D	N/D
g) Iron	N/D	4.26	2.67	6.47
h) Magnesium	6.28	3.15	3.99	2.52
i) Manganese	N/D	N/D	N/D	N/D
j) Molybdenum	5.15	11.55	8.89	8.14
k) Sodium	N/D	N/D	N/D	N/D
l) Nickel	N/D	N/D	N/D	N/D
m) Phosphorus	780.39	797.87	736.84	719.10
n) Lead	N/D	N/D	N/D	N/D
o) Silicon	2.19	1.11	N/D	N/D
p) Tin	N/D	N/D	N/D	N/D
q) Titanium	N/D	N/D	N/D	N/D
r) Vanadium	N/D	N/D	N/D	N/D
s) Zinc	1078.09	1180.18	1101.96	1050.48

Note: 1) N/D-Not detectable

Lubricant was drained and replaced whenever there was a change of fuel. From Table 6, iron, molybdenum and silicon are higher in the case of diesel to that of CNO and WVO. Iron and silicon are indications of wear and tear in the engine parts such as cylinder walls, pistons, rings, liners and crank shaft. The others parameters are more or less the same.

Therefore, CNO and WVO are better fuel than diesel in terms of wear and tear.

11.5 Problems faced during the study due to Coconut Oil

At the start of the project in August 2010, when the engine ran on coconut oil, various problems cropped up such engine misfiring and clogging of the filter. A technical committee comprising of members of MPI, CWA, UOM, MSB, Auto Check and MRC was set up to address these problems.

The committee discussed on the possible causes for the filter clogging. It was felt that the quality of Coconut Oil could be the reason for clogging due to the following reasons -

- High water content in Coconut Oil
- Inappropriate temperature of the coconut oil to be used as fuel (The ideal temperature range is about 70-80^{o}C)
- Impurities in the Coconut Oil

Samples of the coconut oil were analysed by the MSB and no impurities/water content were detected. It was therefore decided to use an additional heat exchanger as shown in Figure 12 to ensure that the temperature of the oil was maintained at 70^{0}C. A new fuel filter was also fitted in the generator bypassing the direct filter. After the modifications, the generator ran successfully on coconut oil.

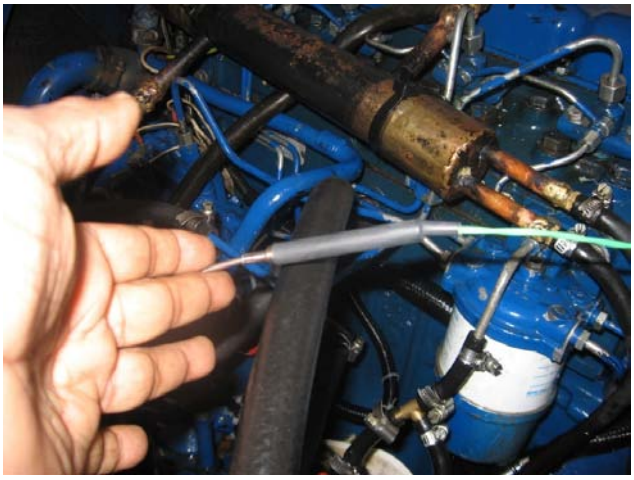

Figure 12: Additional Heat Exchanger

(Courtesy: Ministry of Public Infrastructure, NDU, L,T & S)

11.6 Problems faced due during the study due to Waste Vegetable Oil

During the last week of the experiment, when the generator was running on Waste Vegetable oil as fuel, the experiment was interrupted due to the high opacity of WVO (black smoke from exhaust). It was anticipated that fatty acid contents in the WVO could also be the reason for the problem of WVO as fuel for generator. The technical committee decided to stop the experiment and the engine was dismantled by the MPI technicians. It was found to be smoky and had excessive carbon deposits. The injector nozzles had to be changed and replaced.

11.7 Engine Investigation prior to handing over the Generator to CWA

The engine was opened and engine investigation was carried out by the technicians from MPI. The engine was cleaned and all the relevant parts, such as injector nozzle, head gasket were replaced. Thereafter, the engine was re-assembled. The generator was started in presence of all the members and handed over to CWA in good working condition.

11.8 Differing results from Phase I as regards to use of WVO as fuel

The findings of this project differ from Phase I project on ”Use of Coconut Oil and Waste Vegetable Oil for Transportation”, especially, in case of WVO as a fuel for electricity generation because of –

- Difference in operating conditions of the generator engine as compared to the motor vehicle - The generator engine runs on a constant full load for any given time unlike the engine of a motor vehicle which runs on a variable regime.
- In the case of motor vehicle the fuel injection pump gets time to be filled with fuel while in case of generator the injection pump does not get enough time to overcome any shortage of fuel especially if the filter is partially clogged.

However, it is felt that use of automated or electronic control conversion kit could have addressed the problems faced due to use of WVO for electricity generation as it would have injected diesel intermittently and led to polymerization.

12 Conclusion

The main objective of this research project was to find whether a compression ignition engine (Diesel) could run on coconut oil (CNO) and waste vegetable oil (WVO) to generate electricity.

The performance tests were done on a 4 cylinders Perkin Engine 1000 series (Diesel). The following parameters had been monitored, that is, engine temperature, oil temperature, water temperature in and out, fuel consumption, exhaust temperature and exhaust emissions control.

During the test, we noticed certain problems such as engine misfiring and smoky exhausts. The problems had been located and remedies action had been taken.

It is concluded that *results have confirmed that Coconut Oil is a better substitute fuel than diesel in terms of emissions, opacity and wear and tear. The fuel consumption of coconut oil is slightly higher with similar performance. However, Waste Vegetable Oil was not found to be suitable for electricity generation due to high opacity and suspected high fatty acid contents.*

13 Recommendation and Way Forward

As Coconut Oil was found to be suitable for electricity generation, it is recommended to transfer the technology to Agalega and convert at least one generator on a pilot basis to run on coconut oil.

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Annex 1: Project Schedule

Days	Date	Day	Fuel Type	Sampling	Lube Oil Change (MSB Samples)
Day 1	1-Nov-10	Mon	Diesel	UOM, MPI	Start on new oil
Day 2	2-Nov-10	Tue	Diesel		
Day 3	3-Nov-10	Wed	Diesel		
Day 4	4-Nov-10	Thu	Diesel		
Day 5	5-Nov-10	Fri	Diesel		sample+ top up with new
Day 6	8-Nov-10	Mon	CNO	UOM, MPI	
Day 7	9-Nov-10	Tue	CNO		
Day 8	10-Nov-10	Wed	CNO		
Day 9	11-Nov-10	Thu	CNO		
Day 10	12-Nov-10	Fri	CNO	UOM, MPI	sample+ top up with new
Day 11	15-Nov-10	Mon	CNO		
Day 12	16-Nov-10	Tue	CNO		
Day 13	17-Nov-10	Wed	CNO		
Day 14	18-Nov-10	Thu	CNO		
Day 15	19-Nov-10	Fri	CNO	UOM, MPI	
Day 16	20-Nov-10	Sat	CNO		
Day 17	22-Nov-10	Mon	CNO	UOM, MPI	
Day 18	23-Nov-10	Tue	CNO		
Day 19	24-Nov-10	Wed	CNO		
Day 20	25-Nov-10	Thu	CNO		
Day 21	26-Nov-10	Fri	CNO	UOM, MPI	sample+ top up with new
Day 22	29-Nov-10	Mon	WVO		
Day 23	30-Nov-10	Tue	WVO		
Day 24	1-Dec-10	Wed	WVO		
Day 25	2-Dec-10	Thu	WVO		
Day 26	3-Dec-10	Fri	WVO	UOM, MPI	sample+ top up with new
Day 27	4-Dec-10	Sat	Diesel		