Republic Of Kiribati
Ministry of Public Works and Energy

Feasibility of Coconut Oil as a Diesel Substitute in Kiribati

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DRAFT for DISCUSSION

July 2005

PIEPSAP
PACFIC ISLANDS ENERGY POLICY AND STRATEGIC ACTION PLANING

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Background

In a request addressed to the South Pacific Applied Geoscience Commission (SOPAC) dated 10 November 2004, the Kiribati Ministry of Works and Energy requested SOPAC's assistance under its PIEPSAP project. The request included a feasibility study on coconut oil use and a feasibility study on alternative supply arrangements for petroleum fuels. In parallel the Kiribati Oil Company Limited (KOIL) requested technical assistance from the Pacific Islands Forum Secretariat (PIFS) to review options available to KOIL to meet the national priorities and plans, and to prepare a strategy for the negotiation and rollover of the current agreement with Mobil Oil. In order to avoid duplication of efforts the PIFS and SOPAC have combined their resources to address future liquid fuel supply for Kiribati taking a holistic view that considers both conventional fuels and renewable biofuels in an integrated manner. This inception report describes the main parameters that determine the feasibility of coconut oil as a substitute fuel. The report also considers experiences made in other PIC and lays out the way forward to a full feasibility analysis.

Rationale

Kiribati is extremely vulnerable to fluctuations of commodity prices on the world market. The country is at present 100% dependent on imported fuels. At the same time world market prices dictate the earnings for Kiribati's main export product coconut oil. As a remote and small producer of coconut oil (CNO) and a small consumer of fuel Kiribati is penalised twice by high transport and transaction cost. This has lead to a cross over of diesel supply cost and net earnings for CNO. A ton of CNO is now worth less than its energy equivalent in diesel supplied to Tarawa, i.e. the supply of CNO to the local fuel market makes commercial sense for Kiribati's CNO producer KCMC. In the following the main aspects of the feasibility of CNO use under current market conditions is briefly examined.

The Copra Industry in Kiribati

World coconut oil production is approx 3.5 million tons and represents 3 % of the world production of edible oils. In Kiribati the coconut is by far the most important crop. For more than a century, the income derived from copra sustains the rural economies on the atolls where smallholders produce practically all copra. Copra and CNO are also the most important export commodities currently generating approximately US$ 1.4 million in annual import earning. The dispersed nature of the islands puts shipping in the

centre of the copra industry and irregular shipping schedules frequently constrains market access for the rural copra producer. In recent years unfavourable world market prices for copra and CNO have required substantial government subsidies to keep the copra industry alive. At present buying price of copra is approx US$ 400 per ton. The beach1 value measured in KCMC's current net earnings for a ton of CNO is approximately US$ 155 per ton, i.e. there is a government subsidy of approx US$ 245 per ton of copra.

Production Potential

Kiribati's annual production of copra used to be in the order of 12,000 tons per annum. At an oil extraction ratio of 0.55 kg of coconut oil (CNO) per kg of copra this translates into a CNO production potential of 6,500 tons per year. In 2005 the new Betio copra mill KCMC produced approx 3000 tons of CNO equivalent of 6500 tons of copra. Some copra was exported in 2004, but it is save to assume that current production for CNO is somewhat constraint by copra supply as in recent years senile trees have not been replanted. This may be the result of price deteriorations for copra and CNO on the world market experienced in the mid 80ies. Government subsidies should, however, still provide a substantial incentive to maintain production potential. It is not entirely clear whether inadequate inter island transport or declining productivity of the coconut stocks are responsible for the constraint supply.

The issue of current production potential merits further research. A comprehensive assessment of the current state of outer island smallholder plantations and their productivity is beyond the scope of PIEPSAP support. If such an assessment were to be carried out under an agricultural program, PIEPSAP would, however, be able to assist. For the purpose of this study it is assumed that KCMC will be in the position to maintain its 2004 output level in the order of 3000 tons of CNO.

Removing shipping constraints and replanting of senile stock could over a period of 10 years probably re-establish historic peak productions of 12,000 tons of copra per annum. Removing shipping constraints could increase the current total potential of copra production in the order of 8500 tons, or approx 4000 tons of CNO. This matches the milling capacity of KCMC that is between 4000 and 5000 tons of oil per annum. At current consumption levels of 9000 tons of diesel oil per annum and an energy equivalent of 1.2 tons of CNO per ton of diesel, coconut oil could substitute for approx 37 % of Kiribati's diesel supply. If historic peak production levels were re-established a homegrown fuel could replace nearly all of Kiribati's diesel fuel demand.

[1] beach value is the copra value at pick-up point in an copra producing island

Edible oil market

While the petroleum fuel market is driven by futures and thus highly speculative, the market for edible oils is characterized by a complex interrelationship between the various vegetable oil markets. There is a strong correlation between price movements of the various edible oils and the prices in each country the are determined in relation to world markets that reflect not only market forces but also distorting interventions including subsidies, tariffs, quotas, and export taxes[2.] CNO prices over the last 25 years have seen significant volatility and a sharp downward trend in the mid 80ies and late 90ies. In recent years prices have recovered and there is less volatility in the market. The general expansion of world trade in vegetable oil is a contributing factor to more favourable recent prices and further reform of the EU agricultural policy (CAP) will probably work in favour of CNO prices.

CNO as a Fuel

There are numerous ways to replace imported diesel by CNO or CNO derived products. Essentially, there are three options:

- Use of straight oil
- Use of diesel/CNO blends
- Chemical adaptation of CNO (Esterification into “Biodiesel”)

The first two options require the production of water free oil that is filtered to 5-micron mesh or better. The smaller the filter the better the fuel quality. As CNO and other vegetable oils readily mix with diesel filtered, water free CNO can be either used straight (neat) or in blends with diesel3. Numerous studies and tests involving the use of un-modified vegetable oils (including CNO) have been conducted since the early 1980s. From the considerable body of relevant scientific literature it must be concluded that while short-term operation of diesel engines on vegetable oils or vegetable oil/diesel fuel is possible, long-term use of vegetable oils in unmodified, standard engines results in operational problems, reduced engine life, increased maintenance, and possibly in catastrophic engine failure. There are a large number of parameters that influence performance and durability of engines fuelled by CNO. Engine type, speed, injection method, engine age, ambient temperature and loading all influence tolerance towards CNO. It is safe to assume that the characteristics of vegetable oils including CNO differ substantially from diesel oil and as a consequence the use of CNO

[2] The EU and the USA have a number of distorting interventions in place that are being examined in international trade negotiations such as the Doha Round

[3] CNO solidifies at around 25 C, and the use of neat CNO in Kiribati is only possible because of the high ambient temperatures that occur all year.

will result in additional operation and maintenance cost[4]. Investments in fuel heating systems and the use of specific types of diesel engines such as the pre-chamber design will reduce the risk of operational problems and downstream cost. Operational problems also decrease with decrease in CNO content in a blended fuel. Low-level blends up to 20% CNO will probably not impact much on engine life and operation. Close monitoring of combustion performance is nevertheless recommended. Constant high loads on the respective diesel engine will also reduce operational problems. It should be noted that use of any CNO/diesel fuel blend voids engine manufacturers warrantees.

Producing "Biodiesel"

From an operational point of view the safest option to use CNO as a diesel substitute is the esterification that involves an alcohol (typically methanol) and a catalyst (typically sodium hydroxide). Through this process both viscosity and ignition properties (cetane numbers) are brought closer to regular diesel fuel and the resulting "biodiesel" can be safely used under most operating conditions and in most engines. There are now standards for vegetable oil esters (such as the EN 14214 in Europe and the ASTM D 6751 in the USA) accepted by most engine manufactures. Some engine manufacturers allow only biodiesel blends up to certain percentages; others allow 100 % biodiesel use without voiding of warrantees. The esterification adds cost of approx US$ 200 per ton of fuel for a plant size of 1,000 tons per annum. The esterification process also yields by-products (glycerol and fatty acids); their value, however, is inadequate to completely offset the additional cost. CNO esters can be either used as neat fuel or blended with diesel fuel. Blending is a common strategy in European countries such as France.

Economics of CNO as a Fuel in Kiribati

Perhaps for the first time in history supply cost for diesel to Kiribati (Betio) exceeds the net earnings that can be achieved form export of the energy equivalent of CNO. The following considerations take KCMC's financial viewpoint i.e. it is assumed that government subsidies for copra will continue. In mid 2005 world market price for CNO is approx US$ 600 per ton. As a small-scale exporter KCMC incurs comparatively high cost for packaging, insurance, freight and agency fees. There is also a penalty of approx 5% for higher than standard free fatty acid content of the oil produced in Micronesia. In total KCMC pays currently approx US$ 150 to bring a ton of CNO to the world market. The net value of 1 ton of CNO to KCMC is thus in the order of US$ 450. Current (mid 2005) supply cost of diesel to Kiribati is approx US$ 600 per ton. The

[4] The viscosity of CNO is approximately 10 times greater than that of diesel. The high viscosity with resulting poor atomisation prior to combustion is a major cause of engine problems such as nozzle coking and piston ring deposits

energy value of 1 ton of CNO measured against landed fuel cost is US$ 500[5]. This simple calculation shows that the use of neat CNO as fuel is currently a commercially interesting proposition if no downstream costs are being considered. The US$ 50 differential even leaves some room for additional cost such as storage, handling and filtration to 5 micron or better. Esterification is not a viable option at present, as additional cost of US$ 200 per ton of biodiesel would result in fuel cost US$ 100 in excess of landed diesel cost.

Downstream Cost of CNO Use

Downstream cost of CNO use does mainly accrue to the user. They include cost of engine modifications, higher maintenance and lowered durability of engines. These cost are extremely difficult if not impossible to quantify, especially if CNO or a CNO blend was to be introduced as a regular fuel. Different engine types have different tolerances towards fuel quality variations, loading of the individual engine has a significant impact on tolerance and so has engine age and general maintenance routines. Downstream cost could also accrue to the supplier of the CNO fuel if liability claims were made due to engine malfunctions or failure as a result of selling a non-specified fuel to the general public. In order to avoid the risk of creating downstream liabilities a strategy has to be found which allows to control and manage these risk at least cost. At the same time capacity to deal with technical problems associated with CNO use in diesel engines has to be developed.

Biofuel Strategy for Kiribati

The major objective of a biofuel strategy should be to reduce vulnerability of Kiribati against volatility in the fuel and edible oil markets. Introducing edible oil that is traded on the world market, as a fuel substitute requires an effective strategy that allows to manage and mitigate associated risks and to maximise economic benefits. As assumptions with respect to future market developments for CNO and diesel fuel are fraught with uncertainty, a strategy that allows Kiribati as a CNO producer a high degree of flexibility is preferable. I.e. the national biofuel strategy should be reversible and enable a re-direction of CNO to the edible oil market when this is more beneficial to Kiribati. The requirement of reversibility and avoidance of sunk cost weigh against the production of biodiesel. Biodiesel esterification requires investment in a dedicated chemical processing facility that may be obsolete when markets move in favour of CNO, against diesel or both. It also required the import of methanol, a toxic substance that needs careful handling. At current market prices, biodiesel production in Kiribati is financially not viable. Thus esterification is not recommended at this point in time.

[5] Energy content diesel: 46 GJ/ton, CNO: 38.4 GJ/ton

Introduction of Neat CNO

Having excluded esterification Kiribati's biofuel strategy should concentrate on neat CNO. Full feasibility of CNO use should be determined during phase 1 of this strategy. PIEPSAP will be able to assist throughout this process that should include the following measures:

1. Agreement with KCMC that CNO fuel prices will be based on forgone export earnings (currently 0.65 A$/liter)
2. Government decision not to impose taxes, duties or levies on CNO that is used as a diesel substitute for a period of at least 5 years.
3. Test applications where operating parameters can be controlled and monitored such as PUB's power generation, KCMC's steam boiler, boats and the diesel powered part of the KCMC and government vehicle fleet.
4. Closely monitor CNO fuel use and document operational experiences rigorously in order to build a body of empirical data under Kiribati environmental conditions
5. Train operators and technicians in maintenance routines and in detection and restoration of CNO induced operational problems.
6. Closely observe market movements for fuel and CNO.
7. Network with and learn from other users of CNO fuel in the region that have already practical experiences[6].
8. Educate the public on the CNO fuel issue as a preparation for the introduction of CNO fuel to the general diesel market

This strategy allows short-term absorption (phase 1) of 500 tons per annum of CNO with a potential to expand over two to three years to 1500 – 2000 tons per annum in phase 2 of a biofuel introduction strategy. With growing experience in controlled use CNO a decision can be taken to introduce CNO blends into the general diesel market.

Priorities

Priority uses in the feasibility phase should be determined under risk management and economic criteria. Firstly, all applications where CNO substitutes for diesel as a boiler fuel should be considered a first priority as the risk of operational problem is very low. Risk is also minimised in applications where qualified technicians are available on site and where loading patterns are conducive to CNO use. PUB's generator sets fulfil this

[6] SOPAC is setting up a mailing list for CNO fuel users and other interested parties

criteria and a fuel blend should be tested immediately following the routines established in a pilot project recently implemented by the Samoan power company EPC and SOPAC[7]. Economic criteria include transport and storage cost as well as potential cost that accrue from maintenance. The following table lists the recommended applications for phase 1 and estimated quantities for phase 2 in priority order together with a brief assessment of risks and risk management.

Priority	**Application**	**Quantity t/year**		**Risk**	**Risk Management**
		Phase 1	Phase 2		
1	KCMC steam boiler, no adjustments or modifications, 100 % CNO	50	50	Low risk of increased maintenance	Monitoring of performance, Preventive maintenance
2	PUB Betio initially as 10 % blend, increased to 20 % after positive results and expanded to main power station	400	1500	Risk of reduced power output, increased maintence (fuel filtration), low risk of engine damage	Quality control of fuels, regular lube oil testing, monitoring of performance, exhaust and engine parameters (temperatures and pressures)
3	Dedicated government vehicles - blends and neat CNO use	50	150	Risk of increased maintence, low risk of engine failure	Monitoring of performance and exhaust, Preventive maintenance such as increased frequency of lube oil change

[7] Feasibility Study into the use of Coconut Oil Fuel in EPC Power Generation, SOPAC, June 2005

In phase 1 it will be important to develop a monitoring and documentation schedule that is rigorously followed. The results of phase 1 will determine the feasibility of CNO use and the design of phase 2. As CNO activities in Kiribati start it is suggested to establish a scientific network of all CNO users in the Pacific and link this to the other international networks that exchange data and information on biofuel use.