BIOFUEL FEASIBILITY STUDY
Kiritimati Island

FINAL DRAFT

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Contents

Abbreviations and Acronyms

AC	Alternate Current
ADB	Asian Development Bank
ADO	Automotive diesel oil
Ah	Ampere hours
AusAID	Australian Agency for International Development
BOOT	Build Own Operate Transfer
CA	Concession Agreement
CDM	Clean Development Mechanism
CNO	Coconut Oil
CPI	Consumer Price Index
DLUP	Detailed Land Use Plan
DME	Direct Micro Expelling (of Coconut oil) also referred to as ‘virgin CNO production’
DSM	Demand-side management
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EU	European Union
FIRR	Financial Internal Rate of Return
FOB	Freight On Board
GIS	Geographical Information Systems
GoK	Government of Kiribati
IC	Internal Combustion (engine)
IEC	International Electrotechnical Commission
IRR	Internal Rate of Return
IPP	Independent Power Producer
IUCN	International Union for Conservation of Nature
kV	Kilo Volts (thousands of volts)
KCCS	Kiribati Copra Cooperative Society
kW	Kilowatt
KOIL	Kiribati Oil Company
KCML	Kiribati Copra Mill Ltd
kWh	Kilowatt Hour
kWp	Kilowatt Hour peak for PV panels under standard conditions
KSEC	Kiribati Solar Energy Company
MoF	Ministry of Finance
MJ	Megajoule
MWh	Megawatt hour (1000 kWh)

MFED	Ministry of Finance and Economic Development
MLPI	Ministry of Line and Phoenix Islands
MELAD	Ministry of Environment, Lands and Economic Development
MoU	Memorandum of Understanding
NPV	Net Present Value
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PUB	Public Utility Board
SME	Small and Medium Scale Enterprise
SPC/SOPAC	Pacific Community / Pacific Islands Applied Geoscience Commission
ToR	Terms of Reference
UNDP	United Nations Development Programme
VCNO	Virgin Coconut Oil
Wh	Watt hours

Assumptions CNO-Diesel Comparison			
Parameter	**Unit**	**CNO**	**Diesel (ADO)**
Density	Kg/Litre 25C	0.92	0.83
Specific Volume	Litre/ton	1087	1205
Lower Calorific Value	Mj/kg	37.5	45.8
Lower Cal Value by Volume	Mj/litre	34.50	38.014
Substitution		1.10	1
Cetane		>60	>40
Flash Point	C	>62	>200

Executive Summary

Background

Kiribati is one of the poorest Pacific island nations and faces many constraints to sustained economic, social and environmental development including (i) limited natural resources including freshwater and usable land (ii) minimal potential for economies of scale given the small size of the domestic market (iii) small and fledgling private sector development (iv) widely scattered, physically remote and sparsely populated islands (v) limited cash opportunities outside central and local government employment and the small private sector which exists only in South Tarawa and Kiritimati Island. (vi) irregular shipping and plane access to outer islands and international markets (vii) limited education levels and high youth unemployment (viii) socio cultural constraints to the development of land including State lands on Kiritimati Island and (ix) declining public infrastructure and asset maintenance.

This general constraints are clearly visible in the serious problems both in the country's energy and coconut sectors: Power and transport sectors are plagued by high supply cost for fuel and a small scale of operation leading to a heavy burden on fuel users and one of the highest electricity tariffs in the world. At the same time energy security is vulnerable to supply interruptions and in case of a global energy crisis it is save to assume that Kiribati will be one of the first countries cut off from regular supply. At the same time the copra and coconut oil industries suffers from an inefficient and expensive transport system both for copra from the outer islands to Tarawa and from Tarawa's coconut oil mill to the world market. Large quantities of copra are left to deteriorate on the islands of production. At a heavily subsidized prize for copra (A$ 0.80 per kg) this practice leads to significant losses for the government and the economy as a whole. With a distance of 4,000 km from Tarawa, the Line Islands copra industry is affected worst by unreliable and expensive transport for copra.

Objectives

The objective of this study is to determine the available coconut resources in the Line group and analyse the technical, economic, social, institutional and environmental feasibility of producing coconut oil (CNO) on Kiritimati Island and use it as a fuel substitute in power generation and transport. Our analysis has shown that the introduction of CNO as a diesel substitute could be an economically sound investment. It should view power generation as the main market for CNO. At current copra production levels in the Line Group (1,500 tons p.a.), the production of CNO equivalent to 750,000 litre of diesel would be possible. This is less than currently used in power generation. An increase in copra and CNO production is possible, but required serious rehabilitation of the coconut resource which is in rather poor and unproductive shape.

CNO Resource Base

At present, the Line Islands produce approximately 1,500 tons of copra per annum, equivalent of approximately 750,000 litres of diesel fuel. Maximum copra production since 2005 was 2,400 tons in 2009 and these levels could be expected to be realistic in the future. Sustaining copra production levels, however, would require support for the industry, in particular at the beginning of the supply chain. With existing stocks aged around 50 years, palms are approaching the end of their economic life and need to be replaced by new high quality palms if the copra industry is to be sustained over the next 20 years. Presently there is no program that aims at integrated support for the industry starting with agricultural extension, nurseries and replacement of senile stocks or expanding coconut production areas. Rehabilitation initiatives needed to start with an inventory and classification of existing stocks which would form the basis of a long term management program including agricultural research, stock improvement, nurseries, and a replanting program. In addition, an extension service that upgrades farmers' capacity to produce high quality copra needs to be established.

Project Cost

CNO should be introduced in Kiritimati's power generation as part of a major up-grading and integration of the current power supply. Such an upgrade would involve a backbone 33 kV supply from London to Cassidy with low voltage distribution covering all current and future settlement areas. Project cost for this power system upgrade would be A$ 2 million. The equipment to use CNO in dual fuel mode at the new power plant would cost an additional A$ 103,000. Investment cost for the CNO mill having a capacity of 4,200 L per 8 hour shift would be A$ 800,000. It is assumed that the CNO mill would have access to copra at a price close to world market value i.e. A$ 400 per ton. Under this scenario a CNO mill could make a profit of A$ 0.15 per Litre of CNO. The power plant operator would be able to reduce its fuel cost. The incremental investment cost of A$ 103,000 and assumed incremental operating cost of A$ 10,000 p.a. would still yield a robust FIRR of 23%.

Technical Feasibility of CNO as a Substitute Fuel

Experience of the power utilities of New Caledonia, Solomon Islands and Vanuatu has clearly shown that the use of high quality CNO is technically feasible in well engineered equipment operated by properly trained staff. Production of high quality CNO requires high quality copra as feedstock and good working hygiene in the oil extraction processes. It's successful use in diesel engines requires strict adherence to operation protocols. Maintaining CNO temperatures in storage well above the clouding point of approximately 25^{o}C is essential to avoid fuel line and filter clogging. While Kiritimati's ambient temperatures are usually high, nighttime temperatures regularly fall to levels low enough to cause problems with unheated fuel systems. Multiple filtration down to 2 – 5 micron and removal of residual water are essential for trouble free operation of the engines and avoidance of unacceptable engine wear related to the contamination by ash and organic solids. CNO use in standard engines is only sustainable under high engine loadings and the associated high combustion temperatures. CNO use also requires consistent monitoring of parameters such as fuel quality, engine performance, emission characteristics and sump oil qualities.

Financial Viability

An analysis of commodity price developments suggest that the world energy-equivalent price per litre of CNO has at all times from 1986 to the present exceeded the world price of diesel fuel From 1986 to about 2001, the world price of CNO was not highly correlated with that of diesel fuel, in the period thereafter to the present, the two prices appear to be closely linked. After 2001, the price of CNO rises and falls closely inline with the price of diesel fuel. Recently, the prices for CNO and diesel have been gradually rising since mid-2009 and are now at a level last seen in 2008. Changes in nominal CNO prices have matched changes in nominal diesel prices very closely in this later period also. The linkage between CNO prices and diesel prices in recent years undoubtedly reflects CNO's increasing importance as a bio-fuel. CNO energy equivalent prices have been consistently higher over this period as CNO and other vegetable oils also have primary, non-fuel uses (as foods and chemical feedstocks), and competition by those uses has driven the price higher than its use as a fuel could do alone. In addition, it should be noted that any introduction and promotion of biofuel in the Western world has enjoyed (and still enjoys) some form of government subsidy. These subsidies obviously increase demand for biofuel feedstocks including vegetable oils. The world market price for vegetable oils including CNO is supported by the commodity price for fossil fuels. While prices can easily move above the energy equivalent of fossil fuels they have rarely fallen below it.

The financial advantage that indigenous CNO has over imported diesel is that it avoids international and local shipping costs from remote supply markets, since it is produced and used locally. As shown in the table below, FIRR in the range between 93 and 1% can be achieved for incremental investments in CNO equipment. Clearly, the viability of CNO as a substitute fuel mostly hinges on the copra supply cost to a local mill. The calculation is based on a scenario where commodity prices for diesel and copra move in lockstep and local productions cost for CNO (labour etc) are kept constant.

Initial Copra Cost (A$/kg)	0.30	0.35	0.4	0.42	0.44
FIRR	93%	48%	23%	16%	1%

Economic Considerations

The coconut industry offers one of the few proven options to create rural employment and income in Kiribati Rehabilitation of the industry to its former role in rural areas has obvious economic benefits. Additional economic benefits would accrue if value were added in Kiritimati by milling copra locally instead of exporting crude copra. There are also environmental benefits both on the local and on the global scale. CNO involves less risk with regard to water and soil contamination in case of spillage. CNO produced from local resources can also enhance energy security for outer island locations that are have experienced fuel shortages and supply interruptions in the past. Burning CNO is nearly carbon neutral as long as the coconut production does not have to rely on significant inputs of mineral fertilizer and does not involve the need to clear indigenous forests for the establishment of palm plantations. The government would also save – in the order of A$ 300,000 p.a. particularly by avoiding both transport cost for copra to Tarawa and diesel transport cost.

Environmental Impacts

Mostly, environmental impacts would be positive in a well managed CNO biofuel project. CNO itself is significantly less problematic as a pollutant than diesel oil and spills – though best avoided through appropriate technology and processes – would be less threatening to a very fragile environment where clean drinking water is perhaps the most critical resource. Using CNO would reduce carbon emissions by 2,000 – 2,500 tons of CO_2 per annum. A power plant using CNO would, however, produce more waste than a conventional diesel fired unit. It can be assumed that both the quantities of waste oil and the quantities of discarded fuel and oil filters would double as a consequence of not using a standard fuel.

Carbon Finance

For CNO to become financially even more attractive, an additional revenue stream reflecting global environmental benefits would be highly desirable. As the Kiritimati baseline is almost 100 % diesel, calculating emission reductions from renewable energy contribution is straightforward. The UNEP CDM guidebook suggests a emission co-efficient for small diesel grids of 0.8 kg CO_2/kWh generated by renewables. Biofuel crop plantations are now eligible for carbon credits under the Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nations, following approval of a new methodology in August 2009. However, conditions are restrictive and it is not clear if the use of coconuts for energy purposes would qualify under the new rules. The biofuel will only be eligible for carbon credits if it is produced from waste oil or fat, or vegetable oil that is "produced with oil seeds from plants that are cultivated on dedicated plantations established on lands that are degraded or degrading at the start of the project activity". The application of this condition is not clear-cut in the case of biofuel projects based on CNO. Eligibility needed to be confirmed.

1. Introduction

1.1 Background

Kiribati is one of the poorest Pacific island nations and according to a general analysis of the ADB faces many constraints to sustained economic, social and environmental development including (i) limited natural resources including freshwater and usable land (ii) minimal potential for economies of scale given the small size of the domestic market (iii) small and fledgling private sector development (iv) widely scattered, physically remote and sparsely populated islands (v) limited cash opportunities outside central and local government employment and the small private sector which exists only in South Tarawa and Kiritimati Island (vi) irregular shipping and plane access to outer islands and international markets (vii) limited education levels and high youth unemployment (viii) socio cultural constraints to the development of land including State lands on Kiritimati Island and (ix) declining public infrastructure and asset maintenance.

This general constraints are clearly visible in the serious problems both in the country's energy and coconut sectors: Power and transport sectors are plagued by high supply cost for fuel and a small scale of operation leading to a heavy burden on fuel users and one of the highest electricity tariffs in the world. At the same time energy security is vulnerable to supply interruptions and in case of a global energy crisis it is save to assume that Kiribati will be one of the first countries cut off from regular supply. At the same time the copra and coconut oil industries suffers from an inefficient and expensive transport system both for copra from the outer islands to Tarawa and from Tarawa's coconut oil mill to the world market. Large quantities of copra are left to deteriorate on the islands of production. At a heavily subsidized prize for copra (A$ 0.80 per kg) this practice leads to significant losses for the government and the economy as a whole. With a distance of 4,000 km from Tarawa, the Line Islands copra industry is affected worst by unreliable and expensive transport for copra.

Against this background, the future development of Kiritimati Island (KI) is a high priority for the Government of Kirbati (GoK). It presents GoK with the major challenge of planning and managing natural resource use in which a rapid population growth without appropriate management structures, vision and strategy would risk unchecked social, environmental and economic problems. This includes demand for infrastructure and services, an orderly land supply, inclusive social structures and sound environmental and natural resource management. One of the main challenges in the infrastructure sector is sustainable supply of energy for power generation and transport.

Recent increases in world market prices for fossil fuels have renewed interests in the opportunities to utilise copra oil and other vegetable oils as a fuel for transport and electricity generation. Technologies do exist to combust neat coconut oil (CNO) or blends of CNO and diesel in adapted compression ignition engines (diesel engines) or by means of esterification into biodiesel, using standard diesel engines.

The initiatives undertaken in Kiribati and a number of other Pacific Island Countries - in particular to utilise CNO as a fuel in generators and possibly in vehicles - have shown some promising results but have also indicated a need for a more scientific approach supported by sound technical information and co-ordination of activities across the region. The Kiribati Government has therefore requested SPREP to fund a biofuel study for Kiritimati Island with regard to biofuel production and usage in Kiritimati to enable the formulation of a strategy on the way forward. Funding has been provided by the GEF funded PIGGAREP programme.

1.2 Problems and Objectives

The Kiribati economy has had significant exposure to fluctuations of world market prices for copra and coconut oil. While large and ambitious biofuel targets in major markets such as the

EU have supported CNO prices in recent years and helped to stabilize prices, it remains costly and logistically difficult to bring copra or CNO from remote island production facilities to the world market. Thus, the Government of Kiribati recognises that remote area CNO milling may represent an opportunity to develop and expand the capabilities to use CNO as a diesel substitute as a local, reliable and environmentally friendly source of electricity. This is seen as an alternative to petroleum imports while stimulating revitalisation of local markets for the copra.

This study seeks to establish the feasibility of a larger biofuel project that would allow stakeholders in both the public and private sectors to answer key questions critical to the development of a local biofuel and renewable energy industry: What are appropriate quality standards for locally produced fuel substitutes, which end use technologies are adequate given the capacity of local users, how best to establish sustainable supply chains for biofuels, and are renewable energy options and biofuels in particular financially viable and commercially feasible? To answer these questions, a project template is needed that offers not only technological solutions for CNO use but also integrated solutions that address resource constraints that stem from a stagnation of Kiribati's coconut industry, institutional and financing arrangements that ensure a sustainable supply of alternative fuels and continuous support for operation and maintenance at all points of the supply chain.

The overall objective of this project supported by PIGGAREP/SPREP' is to develop alternative energy sources for electricity generation, in particular CNO fuel on Kiritimati Island. The use of these resources is expected to improve reliability and financial viability of energy supply, allowing expansion of electrification services to un-served communities. At the same time, local biofuel production is expected to increase income generation that would stimulate local cash economies and render the uptake of electricity supply more affordable for the local communities.

1.3 Structure of Report

This Report summarizes issues, options and constraints related to the introduction of a CNO based biofuel on Kiritimati (Christmas Island) of Kiribati's Line Island group. The report is based on the analysis of available documentation, on-site surveys, broad stakeholder and community consultations, and preliminary analysis of electricity demand in the major settlement areas of Kiritimati. Section 2 briefly outlines the methodology used for consultation and analysis. It also discusses availability and quality of data used in this report. Section 3 briefly summarizes the general context, in which a biofuel project would take place, both at national and at local levels. It examines demographics and the prospects for economic growth in the target area. Section 4 contains a resource assessment, starting with an overview of Kiribati's coconut industry followed by the situation found on Kiritimati where detailed investigations were undertaken. The section also provides an assessment of supply chain issues and of production cost for copra, the feedstock for CNO biofuel production.

Section 5 assesses the technical feasibility of CNO use in the type of standard diesel engines currently in used in the small power grids operated by the MLPI. The section also presents an evaluation of international experiences with vegetable oil use and the insights of CNO based biofuel projects in New Caledonia, Vanuatu and Solomon Islands where the respective power utilities have gained significant experience with the use of CNO for power generation. Section 6 contains an assessment of Kiritimati's energy sector and determines the market for a CNO based biofuel. Section 7 describes the design of a project that would consist of the establishment of a local CNO mill, the rehabilitation and integration of the Kiritimati power supply system and the of providing the requirements for straight CNO use in power generation. Section 8 examines the financial and economic viability of a CNO based biofuel for power generation in Kiritimati. It addresses the issues associated with the competitiveness of CNO versus conventional diesel fuel and then analyses world market price developments for the two competing commodities on the world market and assesses if there is a cost advantage for the GoK in using locally produced coconut oil as a substitute fuel. Supply costs for CNO are calculated based on current prices for equipment and copra. The section also analyses non-financial benefits of CNO use.

Section 9 presents an analysis of environmental and social impacts of CNO production and use. The food-versus fuel issue is discussed against the background of the characteristics of Kiribati's agricultural sector and its future prospects. The section also tests if and under which market conditions the sale of emission reduction certificates (carbon finance) could create an additional revenue stream that would be able to enhance the competitiveness of CNO use as a fuel. Section 10 summarizes findings and outlines recommendations on how to approach biofuel introduction on Kiritimati. Additional information is provided in the Annex, which contains also a more detailed description of CNO biofuel experiences in the Pacific region.

2. Methodology

2.1 Review of Knowledge Base

In order to create a firm knowledge base prior to the field mission, a number of relevant studies and documents on experiences with CNO production and use for energy purpose have been reviewed and appraised by the consultant. This included reports on CoCogen (Samoa) Rotuma CNO electrification project (Fiji) implemented by SOPAC, the analysis of the failure of two village scale CNO projects in Fiji, a recent ASTAE/Worldbank publication (Coconut Oil Power Generation, A how-to guide for small stationary engines) and a general study commissioned by the World Bank on the risks associated with competition between fuel and food. In addition, ongoing work on CNO use in Solomon Islands by GHD consultants (commissioned by Asian Development Bank) as well as the UNDP supported CNO conversion of all generators in Tokelau have been analyzed with respect to their relevance for Kiribati. In addition, general studies on the economics of biofuel production and use in developing countries have been reviewed and considered.

2.2 Stakeholder Consultations

Initial meetings where held in Tarawa with representatives of the Ministry of Public Works and Energy, the Public Utility Board, the Kiribati Copra Cooperative Society and the Copra discussions included (i) the consultant's ToR and preliminary work schedule, (ii) local regulations and planning standards, (iii) details on existing information and data bases (iv) existing experiences with pre-payment meter and systems, (v) financial status of the copra production system, (vi) current fuel, operation costs, and tariffs, (vii) current management structures, and (viii) existing operational procedures and reporting templates. In addition consultations were held with relevant stakeholders to make preparations and schedule the site visits to Kiritimati to confirm arrangements for the proposed tour, and facilitate the exchange of information. Information on historic copra and CNO production, use, and export was collected and reviewed including available information on the copra mill operations.

2.3 Field Missions

On-site studies on Kiritimati consisted of broadly based stakeholder consultations (see Annex 1 for list of contacts), detailed surveys of power supply infrastructure, assessment of existing coconut resources and copra processing facilities, and specific community consultations and individual interviews on relevant subjects such as copra production and pricing, and possible community participations in power system expansion projects.

The results of these surveys and consultations were used to develop both energy demand and load forecast over a 20 year planning horizon for Kiritimati. In forecasting loads and energy consumption, the total demand in the area regarded as serviceable through expansions of the Kiritimati power system has been taken into consideration. Based on a base-case load forecast, generation and distribution system expansion was designed using standard planning criteria such as N-1 generation reliability. Subsequently fuel demand for the systems was determined using standard practice values for specific fuel consumption and system losses. Based on these design parameters, resource requirements (copra/CNO and diesel) were determined.

2.4 Data Availability and Data Quality

The 2010 census data have been used as a basis for population projections and energy demand forecasts. In general, data availability and quality has been very poor at all levels. Essential power supply statistics have been analysed for the Kiritimati government supply systems but both generation data and financial records show serious inconsistencies. Records of essential generation parameters such as total engine hours, service histories, and fuel consumption are either not available and if available often not credible; plausibility checks of generation data for a particular system shows discrepancies that cannot be explained.

The consultant attempted to analyse original power station log sheets in order to establish daily load curves and load development trends. Unfortunately practically most the log sheets are incomplete, typically missing hourly loads and fuel consumption entries. More critically, no billing data could be obtained form MPLI, despite several attempts to do so. Therefore it is actually not possible to analyse the performance and efficiency of the current government operated power systems, nor is it possible to base load forecasts for Kiritimati on units currently sold.

Petroleum products supply data are available both at national and Kiritimati island level, but demand data are sketchy and require some interpretation and estimates to draw a consitent picture of the demand side of the energy balance.

Time series for copra production are available from the KCCS, disaggregated for the copra producing islands. However, there are no accurate data on supply chain losses for copra. Anecdotal evidence suggests that not all copra that is bought by KCCS is actually transported to Tarawa, mainly due to the lack of adequate and reliable shipping. The KCCS production figures, however, provide a good indication for the feedstock potential currently available for biofuel. Unfortunately, KCML was not able to provide disaggregated data on their production cost and no data at all could be obtained with regard to their revenue, i.e. the export value of CNO ex Tarawa. This somewhat limits the depth of the analysis of this report as generic data had to be used to fill the gaps.

3. General Context of Kiribati and Line Group

3.1 General

This section describes and analyses the economic and demographic conditions in which CNO based biofuel production and use would take place both on a national scale and on Kiritimati in the Line Group.

Kiribati consists of 33 low-lying atolls, which total 726 square kilometers (km^2) of land surface. Picture 3.1 shows the spread of these small islands over one of the world's largest exclusive economic zones in the Pacific Ocean measuring 3.5 million km^2. The islands are separated in three groups: the Gilbert Islands lie to the West and host the capital of Tarawa. Kiritimati or Christmas Island lies in the Line Group approx 4,000 km East of Tarawa. The Phoenix Group of is located half way between Tarawa and Kiritimati. Only 23 of the 33 islands are inhabited and almost half of the of the nation's population is concentrated in the capital, Tarawa.

One of the challenges for the Government of Kiribati (GoK) is the logistics involved in managing and supplying a country that is spread over such a vast expanse of ocean. The lack of regular, reliable and affordable transports links for passengers and goods to remote parts such as the Line Group is a major constraints to economic and social development underlined by the fact that flights between Tarawa and Kiritimati are offered by Air Pacific, a Fijian airline and is not even direct but through Fiji's international airport of Nadi.

Picture 3.1 Map of Kiribati and Location of Line Group

http://www.worldatlas.com/webimage/countrys/oceania/kinewz.gif

The climate of Kitribati is maritime equatorial with stable temperatures in the 20ies and low 30ies. Rainfall varies from North to South. The Phoenix group in the South is particularly dry with only around 800mm per year. Some islands of the Line and Gilbert Groups receive as much as 3,000 mm/year, the long term average rainfall for Kiritimati is 950 mm/year. All of Kiribati, but especially the Line Islands, are affected by the El Niño/El Niña cycle (ENSO) and suffer cyclic droughts and related problems in drinking water supply. In general winds throughout Kiribati are moderate, seasonal and variable. However, observation on Kiritimati suggests that this particular island may have an economically exploitable wind regime[1].

Kiribati is not in the cyclone belt with extended droughts the primary natural hazard. This Rainwater is the main source of potable water with brackish atoll lens water often used for washing. As is typical of atolls, the agricultural base is narrow with coconuts, breadfruit, pandanus and giant taro the only significant land based food resources. The sea is the main local food source and around 80% of households consider fishing as their main economic activity.

3.2 The Kiribati Economy

Kiribati has a per capita GDP of US$ 1,500, one of the lowest in the Pacific. The government sector dominates Kiribati's economy. It provides more than 60% of all formal sector employment and accounts for almost 50% of gross domestic product (GDP). Phosphate, once the leading source of income, was mined out in 1979, though some income from a phosphate reserve fund established in 1956 is still present. The country's economy relies heavily on the sale of fishing licenses, remittances, and earnings from the Revenue Equalization Reserve Fund (RERF). Additional export revenue is generated from the export of copra, seaweed and ornamental fish.

The Kiribati economy grew by a modest 0.5% in 2010 following 2 years of contraction. However, it is yet to fully recover from the impact of the global economic crisis. Remittances from seafarers, (a significant social safety net) fell by an estimated 13% in 2010. The value of the RERF, the main source of deficit financing, recovered slightly in 2010 but is unlikely to perform more strongly while there is uncertainty in international financial markets. The significant strength of the Australian dollar also continues to reduce the value of Kiribati's external revenue (as most external revenue, such as fisheries license fees, are denominated in US dollars)[2].

3.3 Energy Sector of Kiribati

Kiribati's energy sector is guided by a comprehensive energy policy which was adopted by the government in 2009. The Kiribati National Energy Policy (KNEP) builds on the theme and vision of the Kiribati Development Plan (KDP 2008 – 2011): "enhancing economic growth for sustainable development – a vibrant economy for the people of Kiribati", with the focus on "available, accessible, reliable, affordable, clean and sustainable energy options for the enhancement of economic growth and improvement of livelihoods in Kiribati".

This policy incorporates important contemporary energy issues, issues that Kiribati people, as well as regional and international communities perceive as of great importance, such as poverty (hardship) reduction, sustainable development through vigilant environmental regulation monitoring, and good governance. The policy is linked to the policies and action plans of other Government Ministries and emphasizes the need to reduce Kiribati's vulnerability through the development of renewable, indigenous energy sources and enhanced efficiency in the use of energy. The policy states that the heavy reliance on fossil fuel coupled with increasing demand, limited storage capacity and high oil prices are impeding factors to the availability and affordability of much needed energy services for sustainable development. The need for strategic planning, development of appropriate policies and legislations, efficient end-use, and the development of locally available energy resources to ensure a sustainable supply of energy are of utmost importance.

[1] The Energy Planning Unit currently conducts a hot spot wind measuring program with a 30 meter mast located next to the headquarters of the Ministry for Phoenix and Line Islands. Results have not been published. A feasibility study for wind is also planned for Kiritimati

[2] ADB Country Partnership Strategy 2010-2014

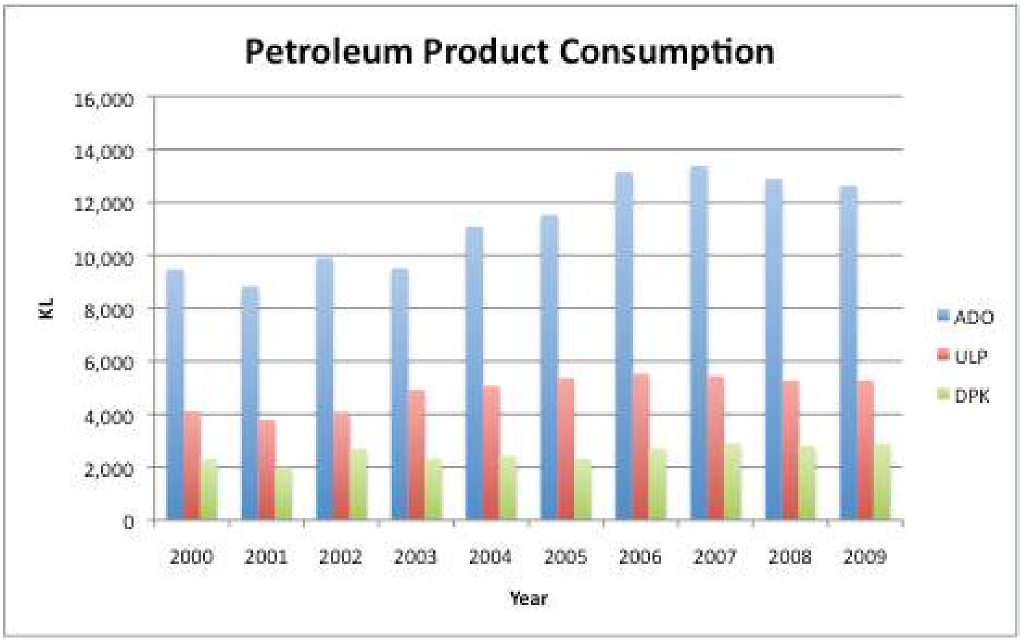
In the traditional part of the energy sector biomass used for cooking and crop drying provides around 25% of national energy supply. In its modern sector Kiribati is highly dependent on petroleum imports for electricity generation for urban areas and transport.

Petroleum Products

In 2009, the last year for which the Energy Unit holds a complete data set, a total of 21,000 KL of the main petroleum products automotive diesel (ADO), unleaded petrol (ULP) and dual purpose kerosene (DPK) was consumed in Kiribati. In addition 15 KL of aviation gasoline and 136 KL of LPG were consumed. Small coastal tankers from Fiji supply petroleum products. The following graph 3.1 shows the growth in petroleum products consumption from 2000 – 2009. It is interesting to note that ADO consumption actually decreased from 2007 while DPK showed a moderate growth. The share of DPK used as household fuel is relatively high and accounts for approximately 50% of petroleum product use.

Small storage volumes (approximately 30 days worth of consumption) on Tarawa and a long supply chain have caused shortages of petroleum products in Tarawa. The latest shortage occurred in February 2012 and the state owned oil company KOIL that manages petroleum product supply in Kiribati had to ration fuel. This recent event clearly underlines the extreme vulnerability of Kiribati's energy sector, which relies practically to 100% on importet petroleum products.

Graph 3.1:Petroleum Product Consumption Kiribati



Source: Energy Unit, Ministry of Public Works and Energy

Power Supply Tarawa

The Public Utility Board operates the power system on Tarawa together with the water and sewerage systems. Power supply on Kiritimati is supplied by the MLPI. In Tarawa until 2003, power was supplied from an old station close to the harbour in Betio. This plant was decommissioned after a new plant with a total capacity of 5.5 MW was built in Bikenibeu. The backbone transmission voltage from the sole power station in Bikenibeu is 33 kV, distribution voltage is 11 kV. In 2010, total generation was 21,600 MWh. Total number of PUB accounts was 8,300. Maximum and minimum demand were 5.3 and 2 MW indicating a critically low reserve margin during peak times. Power quality is regulated following Australian and New Zealand standards AS/NZS 3000:2007.

A recent benchmarking study performed by the Pacific Power Association with funding from PRIF (Pacific Regional Infrastructure Facility) shows PUB's technical performance to be in line with other small power utilities in the Pacific. Its specific fuel consumption is 3.8 kWh per litre of fuel, which is exactly the average in the region. The capacity factor of 55% is below average and the power plants own consumption is 6% and significantly higher than the regional average of 4.8%.

Solar Energy

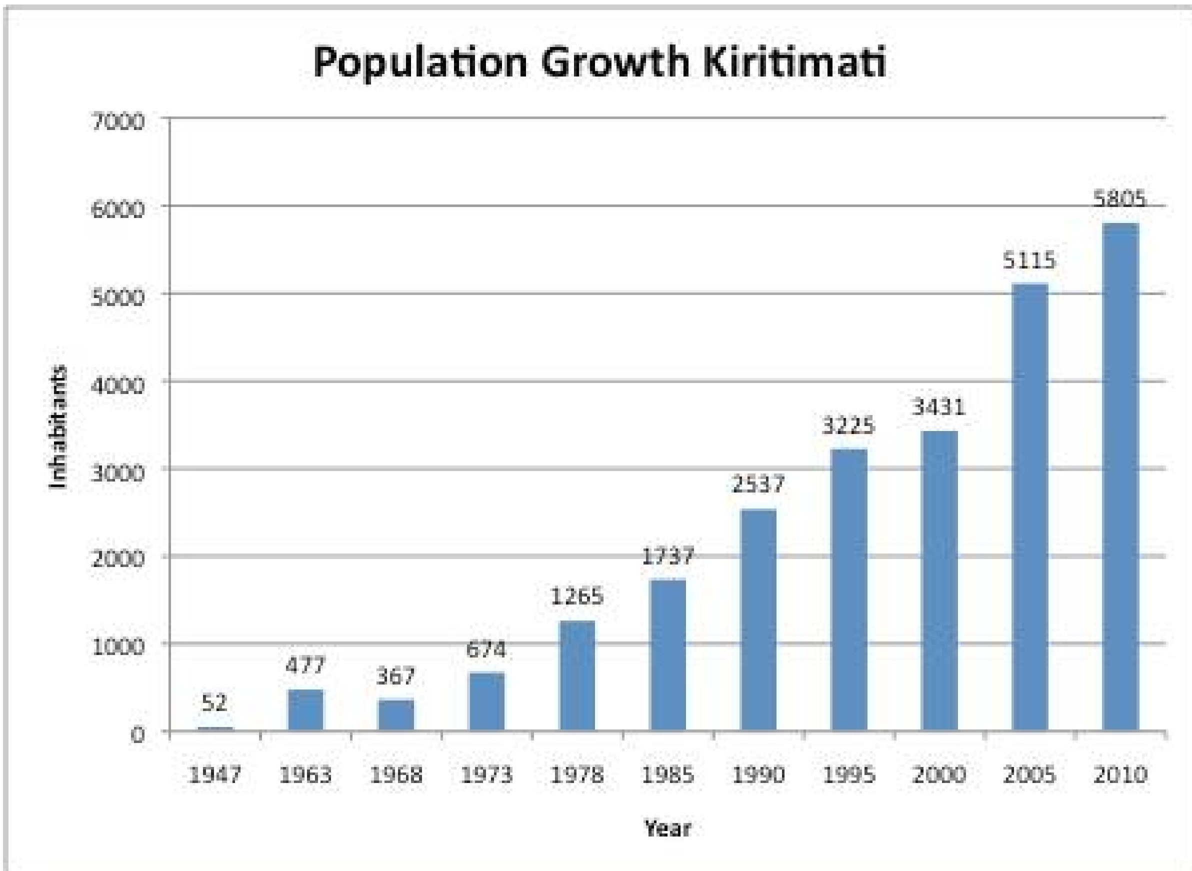
Solar power is a significant energy source for the outer islands. Its quantitative importance in Kiribati's energy balance is, however, small providing less than 2% of the total energy used in Kiribati. Solar energy projects have been traditionally funded by donors (mostly European Union). A third EDF project is currently under preparation with the Kiribati Solar Energy Company, a SOE. Unfortunately, the KSEC is financially in a very precarious situation and still suffers from serious shortfalls in the collection of the monthly subscription fee from users of solar home systems provided by KSEC. A recent evaluation of its performance indicated that commercial viability could not be achieved, even after substantial injection of assets from grant aid. The evaluation report also states that problems with collection of subscription fees is probably due to the perception of many beneficiaries that services provided under a grant funded project should be for free.

A detailed description of Kiritimati's energy sector is provided in Section 6.

3.4 History and Demographics of Kiritimati

Captain Cook discovered Kritimati Island on Christmas Eve 1799. Permanent population commenced on Kiritimati Island in 1882, six years before the atoll was formally annexed to Great Britain from the jurisdiction of the United States. During the 1900's, economic activity was limited to developing coconut plantations and accommodating copra cutters. During the Second World War, Kiritimati Island was used as a base for the Allied Pacific Air Command. In 1957, the British military used Kiritimati Island to conduct nuclear bombing tests, subsequently followed by US bomb testing. By 1962, all testing had been completed and by 1964, the extensive military presence had ended. In 1979, the British Government as part of the independence agreement gave Kiritimati Island to the newly formed Republic of Kiribati. Government policy restricted entry to Kiritimati Island through a permit system until late 1994 when Government decided to promote Kiritimati as a destination for migration from Tarawa.

Graph 3.1: Population Growth on Kiritimati Island



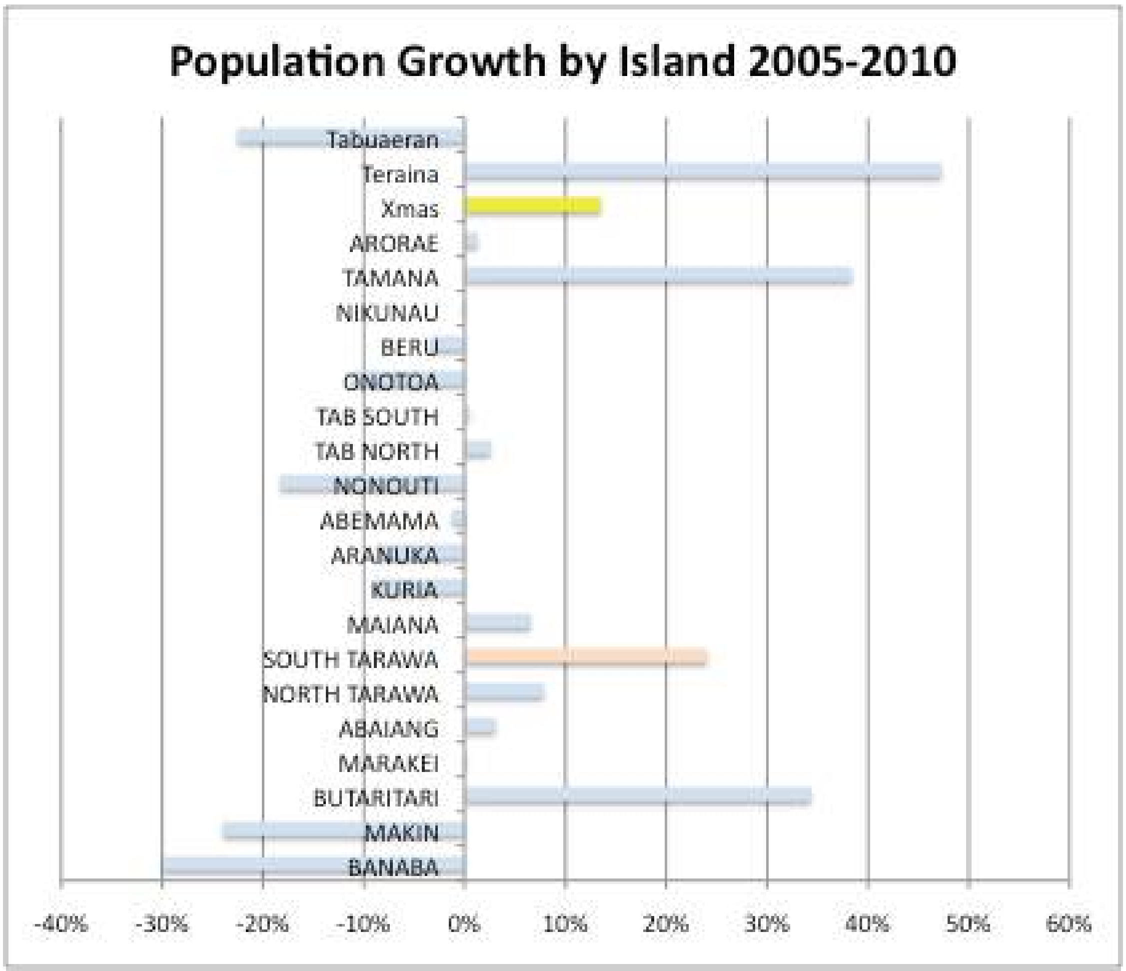
Graph 3.1 above shows population development on Kiritimati from 1947 until 2010, the year when the last census was held in Kiribati. Unlike numerous other inhabited islands of Kiribati, which have lost population due to rural – urban drift, growth on Kiritimati Island was steady and in 2010, total population was nearly 6,000. It should be noted however, that real growth was lower than reports on Kiritimati as a potential growth center have projected. SKM for instance projected the 2010 population of Kiritimati[3] to be 7,600. Aparently, there are obstacles that have prevented the Kiritimati population to grow in line with government development plans.

It is also not clear to which extend population growth on Kiritimati is due to inward migration from Tarawa. Graph 3.2 below shows population developments for all the major islands of Kiribati between 2005 and 2010. It is interesting to note that while Kiritimati showed an increase of 13% over five years whereas Tabuaeran (also in the Line Group) lost more than 20% in the same period. Teraina, the third inhabited island of the group grew by over 40% between 2005 and 2010, the highest growth rate in Kiribati and well above growth rates for Tarawa. It is not entirely clear what triggered such massive differences in the demographics of the three Line Group Islands. Taken together, however, their combined population grew from 8,809 in 2005 to 9,472 in 2010. With 8% growth in five years, the Line Group population growth falls short of the country's average rate, which was 12 % for the same period.

What is clear, however, is that South Tarawa has become even more overcrowded and pressures on water, sanitation and other infrastructure services keep mounting. Between 2005 and 2010, the population grew by 24% from 40,300 to 50,000 inhabitants. In other words, any measures to relieve population pressures in Tarawa still have to show convincing outcomes.

Graph 3.2: Population developments for all the major islands of Kiribati 2005 and 2010

[3] Preparring the Growth Center Project, SKM/ADB Inception Report October 2007



The GoK announced in 2004 a strategic emphasis on promoting Kiritimati as the main outer island growth center, in order to address the imbalance of social and economic development between the Gilbert Group to the west and the Line Islands to the east. Represenatives of the Ministry for Phoenix and Line Islands suggested that inward migration is negatively impacted by delays in the land allocation program of MELAD. The cancelling of Kiritimati as a regular stop over of a Norwegian cruise liner may have had some impacts as well. For the purpose of this study, a scenario analysis will be used to determine the impacts of different population growth scenarios on the feasibility of a biofuel project for Kiritimati. 5% annual growth is considered a base case scenario, which assumes that promotion of Kiritimati as a growth center will show some positive results over the next 20 years. A low case of 2% would reflect a continuation of past growth and an 8% growth would be a high case scenario.

3.5 Infrastructure

Kiritimati Island is some 1 metre higher on average than atolls in the Gilbert Group to the west and thus the impact from climate change, sea level rise and coastal errosion is not as threatening to infrastructure. Kiritimati Island is connected to Tarawa via an Air Pacific air link with one flight a week from Nadi, Fiji. The flight has a capacity of 130 passengers and continues to Honolulu, returning the same day to Fiji via Cassidy.

Runway and apron of the Cassidy international airport is currently re-surfaced thus removing the constraint of a sub-standard runway. However, cost of reaching Kiritimati Island via air through Fiji remains an obstacle to inward migration. There is port north of Tennessee village. This KPA port at Moumou was opened in 2002 to allow larger ships to berth on Kiritimati Island. However, the size of the wharf and lack of landing facilities constrains small to medium freight vessels. It also prohibits cruise ships stopping at Kiritimati Island. The area around the jetty is allocated for commercial use. Shipping services, however, are not reliable and transport cost between Tarawa and Kiritimati are high. At present the government owned shipping line charges approx A$ 200 per ton of freight.

Kiritimati Island has a well-developed road infrastruture with a sealed network covering a large area of the island. This road infrastructure has been developed during colonial times and upgrading and repair will be needed in the future in order to maintain acceptable standards for a growth center. Apart from sealed roads, there is an extensive network of gravel roads and tracks which criss-cross most parts of the island and provide access to the coconut resources.

Picture 3.1: Wind and Solar Water Pumping Kiritimati

Wind powered water supply

Solar Pump

The ADB assisted the GoK in planning infrastructure and economic development under a series of technical assistance assignments[4]. The studies performed under this TA identified constraints and opportunities for the development of the Kiritimati economy. One of the critical infrastructure constraints on Kiritimati is insufficient water from the piped systems to feed the current major population centres. This situation is caused by several factors including insufficient pumping capacity (for example, for the London - Tabwakea population), and major leakage from piped systems (such as Banana). At the time of visit, piped water supply was unreliable and a water bowser had to operate in the London – Tabweka corridor to ensure a minimum supply of water. Recently, a new renewable energy powered pumping station has been installed with Australian assistance (Picture 3.1). While the solar and wind pumps were functional, the reticulation from the large overhead tanks to the consumers did not seem to work and water trucks were operating.

There is no fresh surface water on Kiritimati, all lagoons contain salty or brackisch water. Groundwater is limited to freshwater which floats on the salt water that permeates the islands calcium based surface. The protection of the environment in order to safeguard the water lens, maximise sustainable water resources and promote the health of the ecosystem generally, will make it necessary to manage the major groundwater reserves outside of existing and planned villages free of settlements and polluting activities.

Rainwater collection and storage systems are small and tend to be confined to middle and upper income households. Shallow wells are the traditional source of supply particularly for low-income households. However, due to contamination of ground water, water is not considered safe in the main village of London on Kiritimati Island. Ground water wells are still being used extensively in both the urban and outer island areas and indicators show that the population is exposed to serious health risks from water-borne diseases especially in the more densly populated areas. There are however, freshwater resources in the northern peninsula, which could support an island population of approximately 13-15,000 persons if properly planned and

[4] Preparing the Outer Island Growth Centers Project including preparation of a Kiribati Island Development Plan (KIDP).

managed. There are additional substantial freshwater resources in the south and southwest but these are within a major environmental protection area and outside the main northern peninsula development corridor[5].

There is no centralised reticulation and waste treatment system in any of the villages on Kiritimati Island. Sanitation is predominantly by septic tanks. There are many continuing issues with septic tanks including lack of maintenance and leakages into the groundwater. Compost toilets have been introduced in the London/Tabweka area.

There are four formal waste disposal sites on Kiritimati Island managed by the Public Works/Civil Engineering section of MLPI: a the waste management site located south of Captain Cook Hotel serving Banana and Main Camp; a site east of Tabwakea village serving London, Tennessee and Tabwakea; a dysfunctional medical and hospital waste disposal site approximately 2 kilometres and from Cassidy Airport and a waste disposal site at Poland.

Kiritimati Island has the ususal social infrastructure including several schools, a hospital, community centers and churches. There is a Japanese satellite tracking station close to the Captain Cook Hotel, the only accommodation on the island with modern facilities. There is also a full size oil terminal at London. As all the land is State owned, it is not subject to conflicts between customary landowners over ownership and boundaries issues.

3.6 Economic Activities and Growth Prospects

As for Kiribati as a whole, the Kiritimati Island economy has a narrow base. Economic activity on Kiritimati Island can be divided into 6 sectors, namely, marine resources; agriculture resources; tourism sector; informal activities; service and Government sector. The marine resources, tourism and service sectors are at an early stage of development while others such as agriculture are characterized by low efficiencies and protection by subsidized prices (copra as well as seaweed). With little or no formal employment outside the government sector it is no surprise that a large share of the Kiritimati population is involved in the informal sector. Many services are small scale, part time and informal.

All the sectors have their own constraints and opportunities, stemming from the island's key features, namely:

- Lack of economies of scale in the provision of infrastructure and services resulting in high unit costs;
- High degree of vulnerability against external shocks because of the openness of the economy and the narrowness of its base;
- Long distances to markets and high transport costs
- Unreliable transport links and poor market access for both exports and imports
- Limited independence in Government policy and decision-making, delays and uncertainties, with decisions and approvals being made in Tarawa; and
- Little internal linkages between the various economic activities on the island.

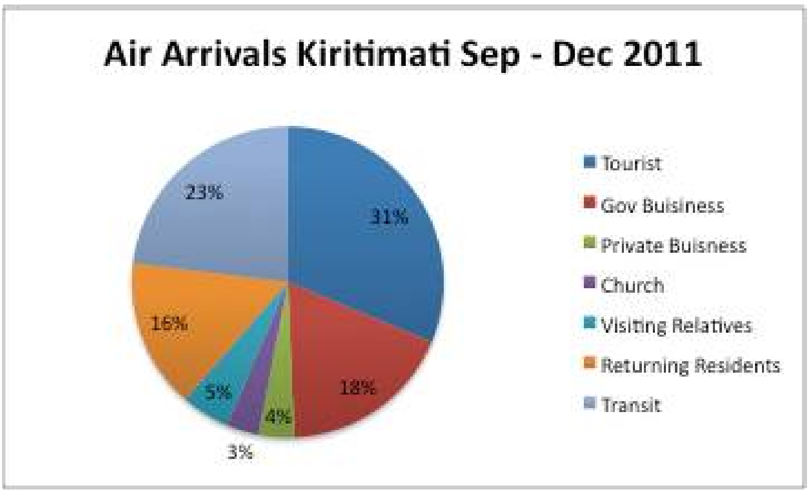
Assessment of the economic potential of Kiritimati Island by ADB have nominated tourism, high value marine products, land and the housing sector as the 3 most likely drivers of economic development to underpin Kiritimati Island as a growth center. The National Development Strategy, 2004-2007 on the other hand identifies a number of potential opportunities for Kiritimati Island including ecotourism, agriculture (primarily) copra, fishing and space

[5] SKM/ADB "Preparing the Outer Island Growth Center Project 2005'

telecommunications.

There are marine and fish resources, which if managed properly may have further potential for increasing island wealth and livelihoods if the right enabling environment for development is created. Tourism potential and economic development opportunities depend on retaining and enhancing the island's unique environment which, amongst other matters, includes a world class reputation for fishing, especially light tackle bone and trevally fishing. Recreational diving and spectacular seabird colonies could also attract special interest tourist. Kiritimati is reported to have one of the largest numbers of breeding seabirds of any coral atoll island in the world and is the destination for a number of long distance migratory birds.

Graph 3.3: Air Arrivals Kiritimati



At present tourism is, however, in a very early stage of development. The air arrival summary for the last quarter of 2011 shows a total of 594 arrivals of which only 31% or 186 arrivals were actually tourists. A comparison with arrival numbers ten years ago suggest that the sector is flat and has shown little growth. Government and private business visitors accounted for 22% of the arrivals. Tourism development is constraint by the fragility of the Kiritimati environment and availability of key resources such as fresh water. Tourism development would also require significant improvements in internet services, communications and air travel.

A resettlement program involving significant numbers of citizens to migrate from Tarawa to Kiritimati would trigger substantial growth in the construction sector, both for private residences and infrastructure such as roads, water supplies, schools, hospitals etc. Given that these activities would have time limits, the development of an industrial sector such as copra processing would be desirable.

Currently, there are some piggeries on Kiritimati that produce pigs for local consumption. The sector is still small but definitely has growth potential, particularly when the local population is increased through a resettlement program. No other animal husbandry has been identified, chicken meat and beef is imported. A biofuel program, however, would produce a very significant quantity of press cake whose value would probably be too low to be exported. This by-product has a high nutritional value for domestic animals and could be the basis for a significant increase in pork production. Chicken production could also be introduced as a replacement for imported chicken.

4. Resource Base for Substitute Fuel CNO

This section reviews the historic and current supply of copra and coconut oil (CNO) for the country as a whole and the three Line Group Islands selected for feasibility analysis. Coconut palm stocks and their current productivity are also assessed. Supply chain issues associated with a biofuel program are analysed.

4.1 The Coconut Industry in Kiribati

Commercial copra production started under British colonial rule in the 30ies. Plantations were established on many islands and operated by European copra trading companies. Today the production of copra remains the main source of income for the population of Kiribati's outer islands. Average annual production during the last six years have been in the order of 8,500 tons per annum, however, there are significant fluctuations with a peak production of over 12,000 tons in 2006 and a low of 6,800 in 2005.

In principle, there should be a strong incentive to boost copra production, as Kiribati is the only country where copra receives a subsidy of 100% of its world market value. This is done through the Kiribati Copra Cooperative Society KCCS whose buying agents in the outer islands currently pay A$ 0.8 per kg of dry copra. The current world market price for copra is in the vicinity of A$ 0.3 – 0.4 per kg. Transport cost from the place of origin to the copra mill is also carried by the KCCS which adds up to A$ 0.25 – 0.35 per kg to the subsidy. In total, current subsidy levels are therefore in the order of A$ 800 per ton. At this level of subsidy, it is actually surprising that Kiribati farmers do not produce more copra. In the Solomon Islands for instance, any government support for copra has been removed in 2001 leaving copra producer totally exposed to the world market. Nevertheless, Solomon Islands produces currently approx three times the amount of copra that Kiribati produces with local copra prices on the islands in the vicinity of A$ 0.25 per kg.

In Kiribati, the Government paid out approximately A$ 7 million in copra subsidies in 2011. Copra subsidy is politically one of the hottest topics in Kiribati as outer islands completely depend on copra as a cash crop. The opposition party campaigned for last elections with an even high subsidy and promised to pay A$ 1.00 for a kg. It is beyond the scope of this study to determine if subsidizing copra is economically efficient or sustainable. Thus, it is assumed that the practice will continue but will not trigger a major boost in copra production.

Graph 4.1: Copra production total and Line Islands 2005 – 2011

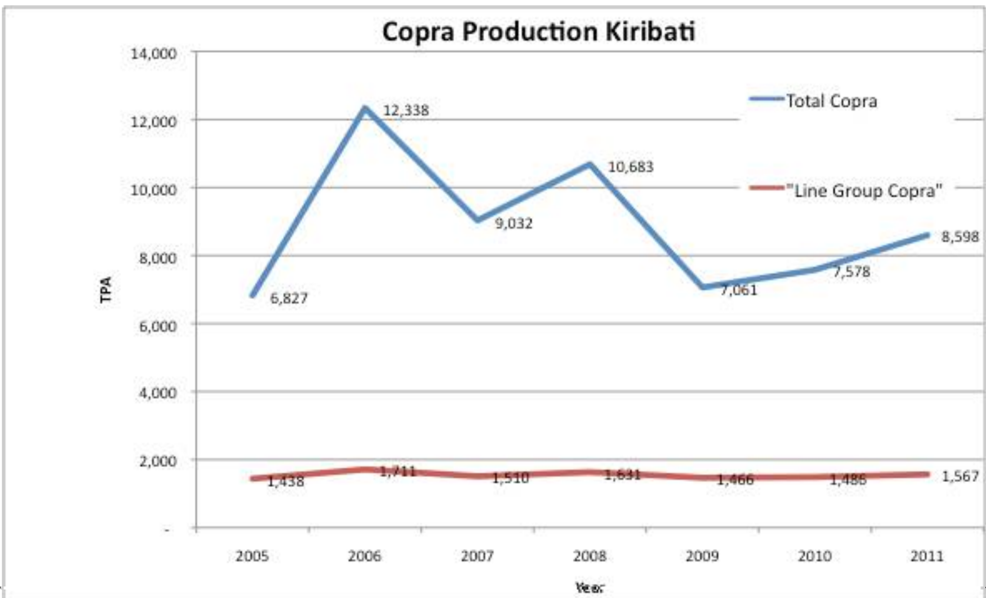


Table 4.1 displays the copra production by island from 2005 unil 2011. It is clear that the relative importance of the Line Islands as a copra producer has diminished considerably. While in 2005 27% of all copra bought by KCCS originated in the Line Islands, this share has dropped to 14% in 2011.

Table 4.1 Copra Productions by Island

Island/Year	2005	2006	2007	2008	2009	2010	2011
Makin	348	480	529	386	420	259	184
Butaritari	81	338	259	185	249	147	134
Marakei	251	503	435	382	191	368	186
Abaiang	134	521	483	341	125	444	281
Nth Tarawa	26	193	122	141	40	162	129
Maiana	308	676	349	526	176	394	519
Kuria	268	632	421	465	376	393	590
Aranuka	271	664	379	453	241	252	255
Abemama	723	1409	1042	1068	732	1111	1136
Nonouti	416	1033	523	733	288	544	649
Tab North	491	979	513	930	442	499	612
Tab South	243	477	603	510	278	195	264
Onotoa	153	529	194	324	110	116	332
Beru	311	672	374	672	428	352	417
Nikunau	593	884	549	843	408	555	893
Tamana	180	338	132	259	96	221	322
Arorae	158	493	134	313	72	298	455
X-Mas	292	282	335	210	287	385	575
Teraina	988	936	1040	1108	1107	803	537
Tabuaeran	591	299	616	832	995	83	127
Total	**6827**	**12338**	**9032**	**10683**	**7061**	**7578**	**8598**

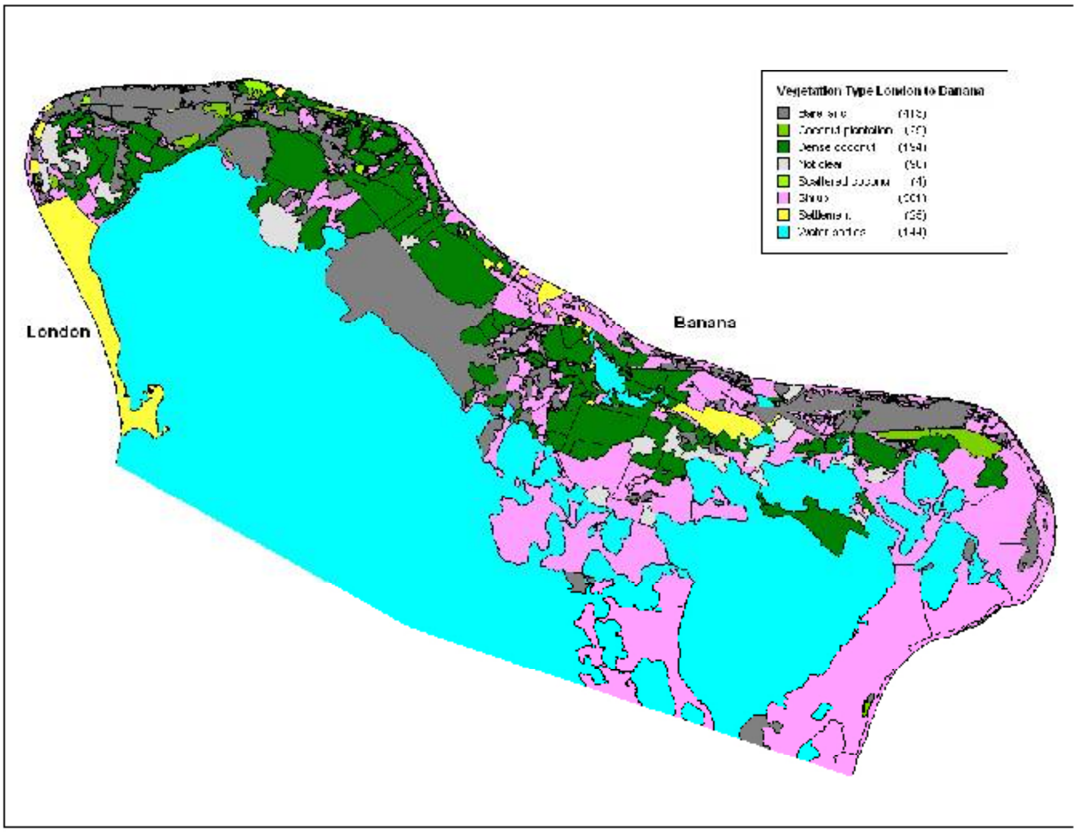
4.2 Coconut Resources in the Line Island Group

There are two independent sources to assess coconut resources in the Line Islands: Firstly, there are the actual production figures recorded by the copra co-operative KCCS described in the section above. Secondly, there is an assessment of the coconut stands by Kataebati Bataua of SPC/SOPAC. This is a recent FAO supported analysis of land cover and coconut stands based on high-resolution satellite imagery. This analysis has been performed for all copra-producing islands of Kiribati and provides an excellent basis for further analysis. The SOPAC assessment has stratified and mapped coconut cover into three density classes. All mapping is based on visual interpretation at 1:5,000 working scale. The mapping is based on geo-coded very high-resolution image data (pan-sharpened QuickBird). While KCCS data are historical, the SOPAC assessment allows some forward-looking analysis, i.e. it can be used to determine the future production potential.

Kiritimati Island

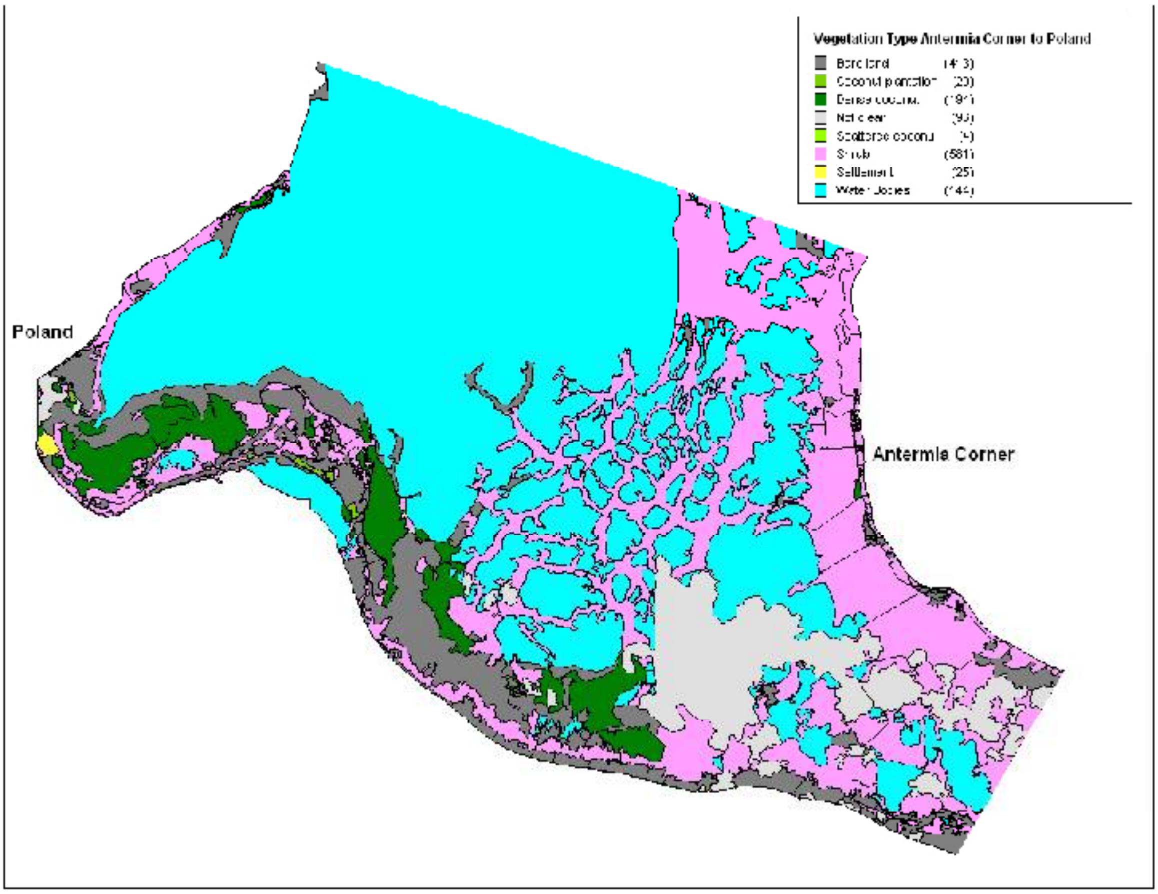
For Kiritimati Island, SOPAC's remote sensing based resource assessment could be checked with some ground thruthing work. The following two graphs show the mapping of the Northern part of Kiritimati Island. On the island, which has a total surface area of 64,000 ha only the Northern part has exploitable coconut stands, essentially the old coconut plantations established during colonial administration. The Southern part is uninhabited and is dominated by scrub, bare land and lagoons.

Graph 4.1: Coconut Stands in the London to Cassidi Airport Corridor



Source: SOPAC

Graph 4.2: Coconut Stands in the Poland to Antermia Corner Corridor



Source: SOPAC

Coconuts stands are mainly found in the London to Cassidy airport corridor in the North and in the Poland to Antermia Corner corridor in the mid section of the island. The plantations near Poland used to be a major producer of copra until the early eighties and evidence of industrial scale copra drying on sliding trays can still be found in the area. The southernmost part of Kiritimati does not hold any significant coconut stands.

Satellite image interpretation revealed eight classes of surface area, namely bare land, scrub, settlement, water body, undetermined, scattered coconut, coconut plantation and dense coconut. The most productive area is 168 ha of coconut plantation with a plantation density of approx 100 palms per ha equivalent to a palm spacing of approx 10 meters. These plantations are found to the south of the Cassidy airport and in smaller stands along the London to Banana road. It appears that these stands are on land for which owners hold titles and therefore have a strong incentive to maintain the plantations.

Scattered coconut (average 40 Palms per ha) stands cover an area of 20 ha, while dense coconuts have the largest share of 3,700 ha. These stands are almost all unmanaged plantations where natural regeneration (seeding) has increased the density of palms to an average of approx 300 – 350 palms per ha. For these areas, no land titles have been allocated, they are effectively on public land. The conditions of these stands are not uniform as the SOPAC stratification may suggest. There are areas where lower densities (250 Palms per ha) and clustering of Palms allow easy access for harvesting. Other areas have regenerated to a very dense growth with many young palms making access and harvesting quite difficult.

In total, the number of coconut palms on Kiritimati is estimated at 1.1 million palms. While all of the plantations and scattered coconut stands are harvested, dense coconut stands are only harvested to a degree, due to limited accessibility and low productivity. Ground observations suggest that approx 10 % of those stands are currently harvested. Spot checks suggest that productivity of dense coconuts is significantly lower with an average of 15 nuts per palm as opposed to 45 for plantations. The table below shows the current resource base of coconuts on the island. It is assumed that the situation on the other two coconut producing islands of the Line group is similar to Kiritimati.

Table 4.1: Coconut Resources Kiritimati Island

		Surface ha	Palms/ha	Total Palms	Nuts per palm and year	Total Nuts	Harvested Nuts	Total Dry Copra kg
Scattered Coconut		20	40	800	45	36,000	36,000	7,200
Coconut Plantation		168	100	16,800	45	756,000	756,000	151,200
Dense Coconut		3,703	300	1,110,900	15	16,663,500	1,333,080	266,616
Total		3,891		1,128,500		17,455,500	2,125,080	425,016

It should be noted that annual production of palms would vary in line with the age class of the individual trees, soil conditions and fertilization. Also, the size of nuts can vary significantly in response to these parameters. Measurements in the field have indicated that on average a nut would yield approximately 0.2 kg of dry copra. This figure is low in comparison to managed plantations, but on Kiritimati there is little sign of any management of the stands. Even the most productive more recent plantations of hybrid varieties along the road East of the Cassidy airport already show significant signs of bush encroachment. Older plantations show significant natural regeneration which leads to the class that SOPAC has identified as dense coconuts (See Picture 4.1. below).

In total the above assessment shows a production of 425 tons of dried copra per year which is consistent with KCCS most recent production figures in the order of 380 tons of copra per year. It should be noted that not all copra produced is actually bought by KCCS. In remoter locations such as the Poland area in Kiritimati, copra production is interrupted when storage facilities are full and no transport is available to get the product to the buying agents.

Picture 4.1: Typical Coconut Stands Kiritimati Island

Encroached Recent Plantation

Dense Natural Regeneration

Ground observation also suggest that a considerable share of existing plantation stocks are aged around 50+ years, the palms are approaching the end of their economic life and need to be replaced by new high quality palms if the copra industry is to be sustained over the next 20 years. In recent years, there were some efforts of MLPI's agricultural division in re-planting of palms. There is, however, no sign of an integrated support for the industry such as an inventory of stocks, agricultural extension, nurseries and replacement of senile stocks.

Terania and Tabuaeran

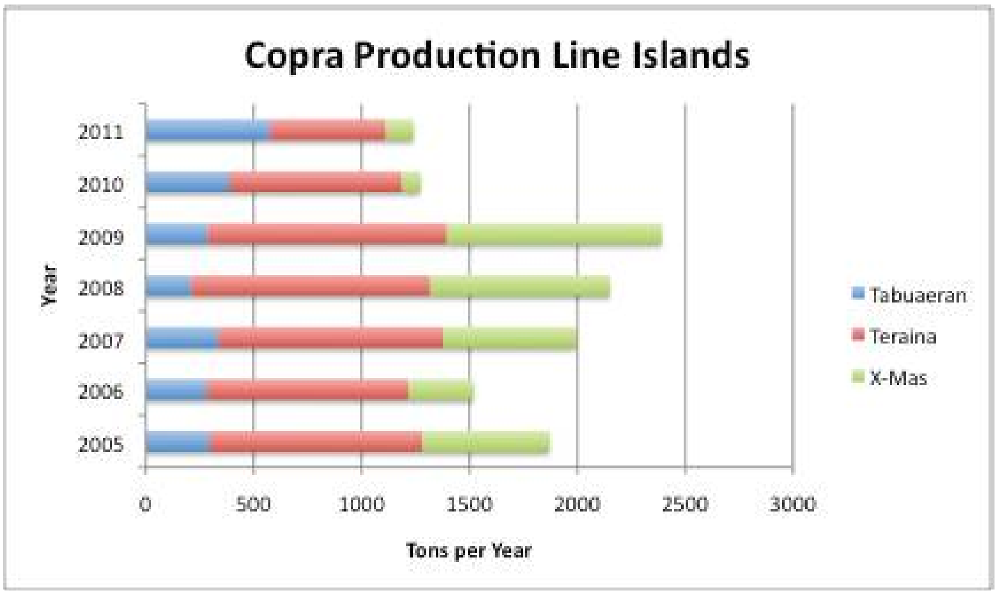
It was logistically not possible to visit the other two islands in the Line Group, namely Tabuaeran and Terainia (Fanning and Washington). It can, however, be assumed that coconut stands on these islands have a similar characteristic as observed on the ground on Kiritimati. The table belwow summarises the number of palms and their productivity based on density and productivity figures on Kiritimati. The following table summarises the results of SOPAC's resource assessment for all three Line Group Islands.

Table 4.2: Surface Area Classification Line Group

Surface Area ha	Kiritimati	Tabuaeran	Teraina	Total
Forest	0	228	47	275
Settlement	424	269	132	825
Shrub	16,707	485	45	17,237
Water Body	31,193	1,456	276	32,925
Bare Land	6,998	434	71	7,503
Undetermined	4,712	44	180	4,936
Coconut	3,891	1,230	685	5,806
Total	**63,925**	**4,146**	**1,436**	**69,507**

A break down of the coconut classification together with productivity estimates based on observations on Kiritimati is provided in table 4.3. It should be noted that the KCCS copra production figures of 2011 do provide a good match for Tabuaeran Island when assumed that 2% of the category "dense coconuts" are actually harvested. To achieve the KCCS production figures for Terania, however, it must be assumed that at least 90 % of the category 'dense coconuts' is harvested. Another explanation would be a higher productivity (either nuts per palm or copra yield per nut) of the stands. Checking historic production figures indicates that the Terania copra production has significantly decreased (Graph 4.3) together with a significant loss in population.

Graph 4.3: Copra Production Line Islands



Source: KCCS

The discrepancy between actual production figures and remote sensing data clearly suggests that ground surveys on all three Line Islands are required in order to determine where the copra on these islands is actually produced and what the future prospects of the copra industry on the three islands are.

Table 4.3: Coconut Resources Tabuaeran and Teraina

Tabuaeran	Surface ha	Palms/ha	Total Palms	Nuts per palm and year	Total Nuts	Harvested Nuts	Total Dry Copra kg
Scattered Coconut	166	40	6,640	45	298,800	298,800	59,760
Coconut Plantation	72	100	7,200	45	324,000	324,000	64,800
Dense Coconut	992	300	297,600	15	4,464,000	89,280	17,856
Total	1,230		311,440		5,086,800	712,080	142,416
Teraina	Surface ha	Palms/ha	Total Palms	Nuts per palm and year	Total Nuts	Harvested Nuts	Total Dry Copra kg
Scattered Coconut	4	40	160	45	7,200	7,200	1,440
Coconut Plantation	7	100	700	45	31,500	31,500	6,300
Dense Coconut	674	300	202,200	15	3,033,000	2,729,700	545,940
Total	685		203,060		3,071,700	2,768,400	553,680

For the purpose of this study, it is assumed that in the foreseeable future, copra production in the Line Island group will on average not fall below the average levels experienced in the last seven years. I.e. for a local biofuel production, a total of 1,500 tons of copra would be available for CNO milling on Kiritimati. This production level can most probably be sustained for 20 years with minimum efforts in re-planting and plantation management.

The maximum production level, achievable in the mid term through planting of hybrid species and a better management of existing stands (cutting of undergrowth, mulching) is estimated to be 3,000 – 3,500 tons per year. It appears, however, that major investments in enhancing the productivity of coconut plantations can only be achieved through allocation of land titles or long term leases. It is extremely unlikely that copra cutters who have no long term rights to land will invest in plantation management, despite the high, government subsidised prices for copra.

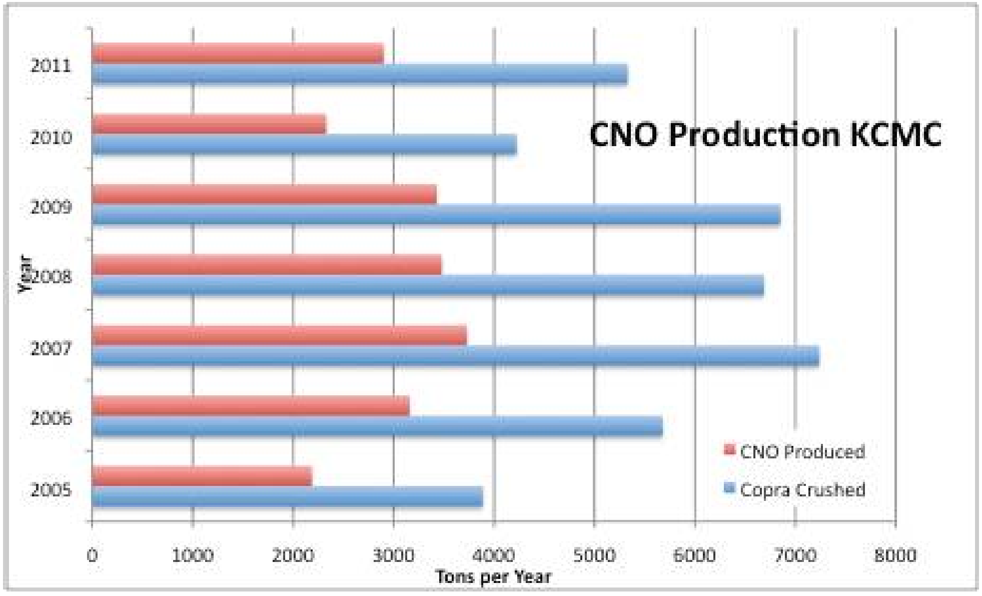
4.3 CNO Production in Kiribati

The Tarawa copra mill (KCMC) is the only CNO production facility in Kiribati. This means that all copra needs to be shipped from the producing islands to Tarawa where a mill with a maximum production capacity of approx 4,000 tons of CNO was built in 2002 at a cost of A$ 2 million. The mill employs modern steam extraction and double press technology. Most of its CNO production is exported in lined 20' standard containers. A small quantity is used in local manufacturing of soap.

KCMC buys copra at or near world market prices, presently around A$ 300 per metric ton. Over the last seven years, the mill has achieved an average extraction yield of 0.53 kg of CNO per kg of copra or 580 litre of CNO per ton of copra. These values are below best practice levels for the industry, but poor copra quality (high water and contamination content) is most likely one of the main reasons. The copra mill also suffers from shut downs, when insufficient quantities of copra are made available by KCCS.

Graph 4.4 displays input and output of the KCMC copra mill. The production level peaked in 2007, at a time when commodity prices including CNO reached an all time high of approximately A$ 1700 per ton. CNO production thereafter dropped together with CNO world market price and started to recover only in 2011, again coinciding with another peak in world market prices for CNO reaching more than A$ 2,000 pr ton (see also Graph 9.1).

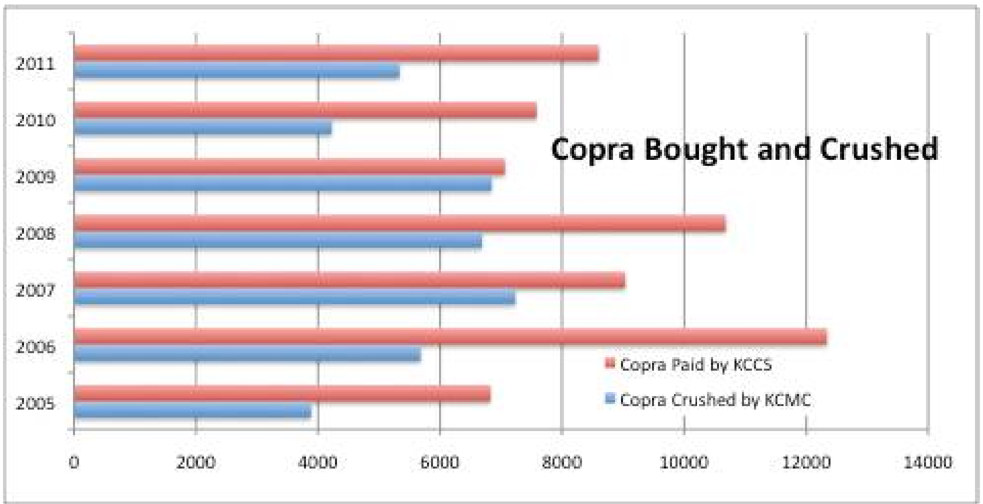
Graph 4.4: CNO Production Tarawa Copra Mill (KCMC)



Source: KCMC

KCMC Production records show that milling operations have to stop frequently due to shortages of copra. This is surprising, as the copra buying society KCCS consistently buys significantly more copra than is processed at KCMC. While discrepancies in a single year can often be explained by stock changes, such discrepancies should balance out when a longer time series is analysed. For the last seven years, however, there was always a significant mismatch of these figures as Graph 4.5 shows.

Graph 4.5: Copra Bought versus Copra Crushed



Source: KCCS and KCMC

The most extreme year was 2006 when KCCS bought more than twice as much copra then processed by KCMC. Over the time horizon analysed, i.e. for the period from 2005 – 2011 the KCCS apparently bought 22,000 tons more copra than was processed in Tarawa. At current copra prices of A$ 0.8 per kg this amounts to a total value of nearly A$ 18 million which is essentially unaccounted for.

It seems necessary to investigate this issue further but anecdotal evidence suggests that most of this copra has actually never existed. With copra sheds bursting due to lack of land transport and shipping and a very low level of security around copra storage, it does not seem too difficult to ‘sell’ the same bag of copra to KCCS several times. The picture below shows a KCCS store on Kiritimati. Local residents complained at the time of visit that copra had not been collected for several months.

Picture 4.1: KCCS Copra Storage Poland, Kiritimati

It is obvious that such issues if remained unresolved would negatively impact on a local biofuel production. <u>It is therefore suggested to conduct a full audit of both the KCCS and the KCML prior to any investment in a biofuel project on Kiritimati.</u>

4.4 Supply Chain Issues

Agricultural Extension and Replanting

For settlers arriving from Tarawa or other Kiribati islands, copra cutting is often the only chance to earn an income. Other opportunities are limited to government employment or a post in one of the state owned enterprises. At present, coconuts are not high on the agenda of Kiribati’s Ministry of Agriculture. With existing stocks aged around 50 years, the palms approach the end of their economic life and need to be replaced by new high quality palms if the copra industry is to be sustained as a major source of income over the next 20 years.

The supply chain for copra still capitalizes from extension and planting efforts undertaken 40 – 50 years ago and it is obvious that without extension efforts, the production potential in the Line Group cannot be sustained. It is difficult to assess the state of existing plantations but field observations and discussions with those familiar with the copra industry in Kiritimati suggest that the industry requires considerable support at the beginning of the supply chain for it to be sustainable over the medium and long term.

Such an initiative needs to start with an inventory and classification of existing stocks which would form the basis of a long term management program including agricultural research, stock improvement, nurseries, and a replanting program. In addition, an extension service that upgrades farmers’ capacity to produce high quality copra needs to be established.

Copra Extraction and Transport

Copra cutting is subject to licensing by MELAD. Licences are issued for limited periods (up to three months). Given the widespread occurrence of coconut palms, enforcing the licensing scheme appears to be difficult. On Kiritimati, like elsewhere in Kiribati, numerous techniques and processes are being used in the production of copra. Some copra cutters harvest nuts and cut them directly underneath the palm it was from. Green copra is filled in bags and either transported to the home of the cutter and dried or sold to middlemen who drive around in trucks and buy green copra at prices around A$ 0.25 per kg. For the copra cutter, this process has the advantage to receive cash quickly. The risk of losses in the drying process is transferred to a trader. The only investment a copra cutter need is a pole (to harvest nuts) and a knife to cut copra. It has also been observed that whole nuts are harvested and then transported on charts and trucks to residences where copra is cut and dried. This has the advantage that the owners of copra can easily survey their stocks.

Copra Drying

Unlike in other Pacific island countries where copra is often forced dried using firewood, husks and shells as fuel, in Kiribati, practically all copra is sun dried. The product is spread out either on the ground or on some old iron sheets of hessian bags, often directly in front of the copra cutters house. There are also remnants of industrial copra drying: copra is dried on elevated wheeled trays that sit on rails. This allows the copra to be moved under a roof when it starts raining, thus shortening the required drying time as well as contamination.

Picture 4.2: Copra Drying

Ground Drying

Industrial Drying Trays

Soil Contamination

The practice of sun drying can result in good quality copra provided that the product does not come in contact with rainwater and that a good working hygiene is maintained[6]. Observations in the field suggest, however, that this is not always the case and a biofuel production facility had to ensure that high quality copra is used for CNO.

Production Cost of Copra

Biofuel experiences in the Pacific region and elsewhere have clearly shown that a sustainable supply of good quality feedstock is the most critical parameter. Discussions with local copra producers and agricultural officers indicate that copra production responds very strongly to the price that farmers can achieve and to the time delay between producing copra and getting paid. At A$ 0.8 per kg, clearly the cost of producing copra can be easily recovered. In fact, observations suggest that copra cutters on Kiritimati can produce about 6 to 8 kg of green copra per hour. This translates into a dried copra value of A$ 2.40 – 3.00 per hour and is well above the going rate for casual labour (approx A$ 1 – 1.5 per hour).

[6] Forced drying involves the risk of spoiling copra through 'overcooking'

Feedstock Quality

Fuel grade CNO production is best achieved with high quality copra as a feedstock. Quality appears to vary considerably throughout the Kiribati mainly as a function of time in storage. Copra of all grades has been observed in Tarawa and on Kiritimati and stakeholder consultations suggest that the quality of copra received from KCCS has been relatively poor. There is no incentive to produce a high quality copra in Kiribati. In most copra producing countries copra is graded and sold in three grades, which rewarded the producer of high quality copra. Since the KCCS price is uniform, there is no price incentive to produce high-grade copra as all grades of copra are purchased at the going price of A$ 0.8 per kg irrespective of quality. Poor copra quality is also related to the infrequency of shipping to the outer islands and long storage times for copra. Some farmers seem to lack knowledge regarding the operation of copra driers and particularly the need to move the copra around on the screen to ensure even drying. The dilapidated condition of driers in some areas also undermines quality.

Expeller Technology

The yield of oil from dried copra varies not only with the quality and source of the copra but with the expeller equipment type used. Typical yields in litre of CNO per kg copra are displayed below.

Hand operated DME	0.40
Tinytech or similar expeller	0.50
Double pressing Tinytech	0.55
Multiple action expeller	0.55 - 0.65

Given the size of the operation required to process all copra produced in the Line Group, double pressing technology would be the minimum choice. It should be noted, however, that the nutritional value of the press cake increases when lower yield technologies are being used.

4.5 Risk and Risk Management

The greatest risk to a consistent supply of CNO for biofuel operations is the potential lack of high quality copra generated. While the risk of a hurricane destroying the crop is low in the Line Islands, the coconut stands are exposed to pests such as the coconut beetle and leaf miners[7]. In general, unmanaged plantations, where palm trees survive under marginal conditions in competition with each other and a number of encroaching weeds, the risk of plant disease is higher than in healthy, well-managed plantations. To mitigate the risk of pests further a better understanding of the dynamics of these diseases is necessary.

Perhaps the most significant risk for a biofuel operation in Kiritimati is a lack of good quality copra, which is an important consideration when the product is to be used as fuel. Currently the KCCS has no incentive to grade copra or insist in a certain quality standard. In case a CNO mill is installed on Kiritimati for biofuel production, the CNO mill itself would have a strong incentive to purchase high quality copra as poor quality copra would always result in a poor quality oil which in turn had to be rejected by the users/buyers of this oil.

The risks associated with operating on poor quality oil could be addressed by:

- Direct purchases of copra by the CNO mill. Suppliers would be required to produce copra to a set standard (moisture content and contamination being the main parameters to be checked).
- Extension and education program for copra producer who sell copra to the CNO mill.

[7] A leaf miner outbreak devastated the coconut crop of Temoto province in Solomon Islands in 2009

5. Technical Feasibility of CNO Use in Diesel Engines

The assessments in this section reviews experiences with the use of CNO as a substitute fuel and outlines the technical requirements of operating standard diesel engines using CNO or blends of CNO and diesel. The success of any biofuel use depends on three critical parameters: i) securing a sustainable supply of the feedstock for biofuel production, ii) the suitability of the technology package employed using a fuel outside the range of standard specifications and iii) the competitiveness of the substitute fuel in comparison with its conventional fossil rivals.

5.1 CNO as a Substitute Fuel

The use of vegetable oils for fuel in general and the specifics of CNO use in diesel engines are well documented in a large body of relevant literature. Most compression ignition (CI) engines will run on coconut oil or other vegetable oils provided that ambient temperatures are high enough to prevent solidification of these oils. CNO is one of the easiest vegetable oils to burn in a diesel engine as its Cetane number is even higher than that specified for normal ADO[8]. Unfortunately, however, chemical and physical characteristics of CNO and other vegetable oils differ significantly from diesel, the fuel that standard compression ignition engines, have been designed for. Assuming that clean oil is available (water-free oil, filtered to 2 micron or less) there are some characteristics that provide challenges to trouble-free operation in an unmodified engine and these are discussed below.

Firstly, the viscosity of the oil is twenty times higher than the viscosity of diesel fuel. This leads to sub-optimal atomisation in the spray that is injected into the combustion chamber. Poor fuel atomisation results in incomplete combustion and the formation of carbon deposits at injector nozzles and in the combustion chamber (see Picture 5.1)

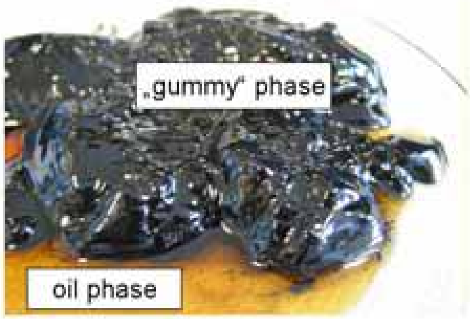
Picture 5.1: Carbon Deposits at Injector Nozzle and at Piston Rings

Source: D. Fuerstenwerth "Potential of CNO as Diesel Substitute for Pacific Island Countries" 2008

[8] An empirical measure of a diesel fuel's ignition quality that indicates the readiness of the fuel to ignite spontaneously under the temperature and pressure conditions in the engine's combustion chamber. Adding cetane improvement additives can increase the cetane number.

Secondly, the high flashpoint of CNO and other vegetable oils and their tendency to polymerise also leads to the formation of deposits on the injector nozzles and piston rings. Sticking piston rings allow unburned fuel to contaminate the lubricating oil which then degrades. Probably the most critical effect of using vegetable oils is polymerisation occurring in the lubricant oil that leads to a phase separation. A polymerised, gummy phase settles on the bottom of the oil sump and on any part the lubricant oil circulates around. This event can trigger a total failure of the lubrication system and as a consequence catastrophic engine failure. Unfortunately both viscosity and flashpoint related problems have the potential to be self-enforcing, i.e. once the building of deposits on critical parts of the engine sets in, combustion quality is further reduced and more deposits are formed.

Picture 5.2: Polymerisation and Phase Separation of Engine Oil



Source: D. Fuerstenwerth “Potential of CNO as Diesel Substitute for Pacific Island Countries” 2008

Thirdly, CNO solidifies at approximately 24°C and combined with the high viscosity, even temperatures above this can cause fuel line blockage and prevent a cold start of an engine. It should be noted that minimum temperatures recorded at Kiritimati only occasionally fall below 24°C but this is sufficient to require controlled heating of CNO fuel systems. Other problems have been encountered in trials using vegetable oils as a diesel substitute. Amongst them is the potentially high acidity that causes engine corrosion, especially at parts of the injection system.

Modifications of fuel systems and engines may be required to allow medium- and long-term operation of a diesel engine on CNO. Modifications include fuel heating, additional filtration, installation of dual-tank systems, replacement of injector nozzles and injector pumps. CNO use also requires additional operation cost such as more frequent service of engines and more frequent replacement of fuel and oil filters and monitoring of engine oil quality. Best results can be expected for applications where engines are consistently operated under high loads and high operating temperatures.[9] These conditions are best achieved with stationary diesel generators where trained operators who are capable of reading the signs of engine problems can control loading and fuel use. These early signs include frequent filter clogging, loss in engine power, unusual exhaust fume colour, overheating of engine, loss or undue increase in oil pressure, fuel leaks, carbon deposits at injector nozzles and cold start difficulties. When these signs are read, understood and acted upon, serious damage to the respective engine can normally be avoided.

[9] Some references include: Croezen, H., et al.; “The road to pure plant oil? - The Technical, Environment, Hygienic and Cost-related Aspects of Pure Plant Oil as a Fuel”; Senternovem; study commissioned by the GAVE Programme, Dutch Ministry for Spatial Planning, Housing and the Environment; Delft, Netherlands, 2005. Bannikov, M., et al.;“Investigation of the Characterisitics of the Fuel Injection Pump of a Diesel Engine Fuelled with Viscous Vegetable Oil-Diesel Oil Blends“; Proceedings of the Institution of Mechanical Engineers, Vol. 216. Part D: J Automobile Engineering, p. 787-792. 2006, Zieroth, G., et al:”Biofuels for Developing Countries, Promissiong Option or Dead End” GTZ Publication 1985, ISBN3-88085-261-8.

5.2 CNO as a Transport Fuel

Unlike stationary generators with known specifications and technical characteristics, a fleet of diesel powered transport vehicles is diverse and typically consists of a variety of engine designs, of different ages and different state of repair. As a response biofuel programs in Europe, USA Australia and New Zealand have taken the route to produce vegetable oil esters that have characteristics very close to diesel oil. Many attempts have, however, be made to use straight vegetable oils in diesel powered vehicles. Depending of the type of engine and its fuel injection system adaptation of engines can involve a number of measures. The most common being the fitting of a dual-tank system with switches and the pre-combustion heating of CNO via heat exchanger. Other measures include but are not necessarily limited to the following:

- Replacement of seals and hoses of the fuel-supply system that are not vegetable oil compatible.
- Fuel hoses which are replaced with larger diameter hoses, to reduce resistance to the flow of fuel.
- Exchange of fuel pump for a model with higher volumetric yield or an additional fuel pump.
- Installation of cleanable fuel pre-filters to reduce the need for fuel filter replacements.
- Installation of parallel fuel filter with a switching device.
- A heat exchanger is added before or at the fuel filter to reduce viscosity of the oil in the filter.
- Installation of an additional electrical pre-heater in one-tank systems to assist in cold starting.
- Replacement of glow plugs with a model of higher heating capacity (hotter start up).
- Replacement of glow plug control to allow a longer glow time.
- Installation of electrical resistance heating of the injection nozzle.
- Advance of injection timing to provide more time for good air/fuel mixture.
- Increase of opening pressure of the injection nozzles to improve the spray pattern and atomisation
- Thermal isolation of piston to achieve higher combustion-chamber temperatures (direct injection only).
- Reduction of oil change and fuel filter change intervals.

These modifications can reduce fuel-related problems but hardly completely avoids them. The use of a vegetable oil in a vehicle also immediately voids all manufacturer or suppliers warrantees for the vehicle.

There are some experiences with the use of straight CNO or with blends of CNO and diesel in cars and trucks in the Pacific region including Kiribati where KCMC has operated a truck on CNO. Unfortunately, very few trials have been properly documented. Anecdotal evidence, however, suggests that sooner or later trails were given up when engines started to develop troubles. In most cases blends were used to reduce the risk of breakdowns, a strategy that could be employed in Kiritimati as well.

There are a considerable variety of diesel engines on Kiritimati island and a CNO – diesel blend may reduce technical problems considerably in certain engines whose design and operating mode are not conducive to CNO use. It is difficult to advise on blending ratios, but a relatively safe approach is to start tests for a certain application with a low level blend i.e. 10 – 20 % CNO and test it. Depending on results the content of CNO can then be gradually increased. It should be noted that blending of diesel and CNO requires the CNO to be water free. Even small contaminations with water that would be tolerated when used as straight CNO are known to cause filter clogging through the formation of a gel like substance.

5.3 CNO Power Generation Experiences in the Region

ENERCAL and UNELCO

The technical feasibility of using CNO as a fuel for power generation has been proven beyond any doubt in Pacific Island countries. Two different approaches have been successfully used: the use of 90 % CNO in a dual fuel configuration in New Caledonia and as a fuel blend containing up to 30% CNO used by UNELCO in Vanuatu. Both ENERCAL and UNELCO are using high quality engineering developed in close co-operation with engine suppliers. Both operations use CNO only when the respective engines are working under loads higher than 75% of their rated capacity in order to minimize impacts from incomplete combustion and the resulting carbon deposits on injector nozzles and piston rings.

Both operations show that successful CNO use starts with good quality feedstock (copra) having moisture content of not more than 5 – 6 %. Good working hygiene and consistent control of key CNO production parameters are also essential. Both operations achieve a high quality of CNO through multiple stage filtrations and dewatering through vacuum separator and/or centrifuge. Operational problems related to high viscosity and pipe blockages caused by solidification of CNO is avoided through consistent control of temperatures of storage and transfer systems. Both operations use a combination of cooling water heat (heat exchangers) and electrical heating.

While the UNELCO operation appears to be financially viable at today's supply costs for diesel fuel, ENERCAL considers its CNO use as a corporate contribution to rural development on the Island of Ouvéa. Both operations share a common problem: fluctuations in oil production due to unavailability of copra. ENERCAL does not seem to contemplate an expansion of their CNO use. UNELCO on the other hand is currently expanding its CNO milling capability in Port Vila and is installing two new duel fuel generators of 100 kVA each as a power source for a small rural grid on the Island of Malecula.

SIEA Solomon Islands

In 2011, the Solomon Island Electricity Authority SIEA started a CNO biofuel project in one of their outstations in Auki, the provincial capital of Malaita. The project is supported under the "Improving Access to Renewable Energy" initiative of the Asian Development Bank. The pilot project's objective is to provide a solid base of technical and financial data that would allow SIEA to assess if CNO is a viable alternative to diesel in remote outer island power stations. As Kiritimati these islands suffer from the high transport cost and the vulnerability of long supply chains for both fuel to and copra from the islands. Solomon Islands currently produce 20,000 tons of copra per year, down from a peak production of 50,000 tons in the early 80ies.

In Solomon Islands the biofuel pilot project engages the entire supply chain starting with the copra producers. A local CNO mill has established quality standards that are necessary to produce a high quality CNO. The mill rejects any copra whose moisture content exceeds 6% and/or is contaminated by dirt. The CNO mill itself is a Tinytec installation consiting of copra cutter, screw press and press filter. The capacity of the mill is approx 500 liter of CNO per day. Cost of the CNO mill is approximately US$ 10,000.

SIEA has imposed quality standards on the mill operator and tests each consignment received for water content, free fatty acid content and total contamination (sediment) at an on-side laboratory. CNO is held in an unheated bulk tank from where it is pumped through a conditioning unit, consisting of multistage filtration and vacuum separator. From this unit CNO is pumped into a day tank which is heated by an electrical immersion heater. The generator (see pictures below) is a standard Cummins 340 kW high-speed unit with two addional features: a low load warning sound and a second fuel filter. These additions cost less than US$ 1,000.

Although the SIEA installation is low tec, the set up provides high operational flexibility and allows the use of blends (various blending ratios have been tested) as well as operation in dual fuel mode (90% CNO 10% Diesel).

Picture 5.3: Biofuel Installation Solomon Islands

Biofuel Project Auki, Solomons

Biofuel Generator Installation Solomons

Fiji Islands

Following positive results with CNO use in New Caledonia, two CNO biofuel projects were started in Fiji in the 90ies on the islands of Taveuni and Vanuabalavu. After a relatively short period of operation, the projects failed for two reasons: First, the opportunity cost for farmers to produce copra and CNO had been too high: Growing taro and buying diesel for the community generator has been financially more attractive for farmers. A second reason has been the disruption of the supply chain for CNO when a commercial CNO mill ceased operation. Although there were minor technical issues with generation equipment, the main constraint has been the lack of copra for CNO production. This situation is unlikely to occur in Kiribati as copra producers enjoy a price that is subsidized to a level 200% above world market price. This strong incentive together with a lack of other income opportunities in Kiribati's outer islands will guarantee a flow of feedstock for a biofuel operation – at least in the medium term.

A second generation of CNO based biofuel projects have been implemented in Fiji in the last three years. These projects on islands such as Rotuma and Koro provide village electrification via small scale copra mills and small diesel generator sets operating in dual fuel mode. So far, they seem to be sustainable. Annex 3 provides a detailed description of current CNO based biofuel activities in the region.

The power utility of Samoa (EPC) has also run a series of trials using CNO as a diesel subsitute.

5.4 Technical Options for Kiritimati

There are four different technical approaches to the introduction of CNO based biofuels for power generation in the Kiribati:

- Production of a CNO methyl ester and use in standard engines;
- Use of 100 % high quality CNO in adapted power plants and engines;
- Use of up to 90% high quality CNO in a dual fuel mode in slightly modified standard generators;
- Use of low level blends of high quality CNO and ADO in standard equipment.

The first approach is not considered suitable for a Kiritimati biofuel project. The production of methyl esters adds considerably to the final cost of the biofuel and is dependent on significant scale economies and low feedstock cost to be financially viable at present supply cost for conventional ADO. The production process involves imported methanol, which is highly toxic. Methanol is known to consumed as a substitute for drinking alcohol (ethanol) and has caused many death around the world. For a small-scale operation such as a biofuel project in Kiritimati, esterification would add at least A$ 0.5 – 0.8 to the cost of a litre of locally produced biofuel.

As esterification should be ruled out for Kiritimati, the option of using strait CNO remains. The approach requires high-quality, water free CNO filtered to 2 micron. High loading of the engine that uses such blends or strait CNO is also required to ensure trouble free operation.

Strait CNO can be used in three ways: 100% CNO use requires a high quality CNO and an engine that is designed for vegetable oil use or as a multifuel engine[10]. Such engines are significantly more expensive than standard diesel engines and are typically only available in sizes too large to match the power demand of Kiritimati, even if an integrated power grid would be established covering the London to Cassidy corridor.

The third option is the so called 'dual fuel mode' and replaces approximately 90% of the diesel fuel. This can be either achieved through a fully automated dual-fuel operation or through a manual dual fuel mode. The 300 kVA installation in Ouvea, New Caledonia has is a fully automated installation and has incurred cost of more than 400,000 US$ including engineering, heated main storage tank and heated day tank, heat exchangers, automatic controls of fuel switching and electrical integration, installation and commissioning. The unit starts and stops using ADO and allows CNO use only at high loads. CNO use is controlled through exhaust gas temperature probe set at 460^{o} C. The concept requires considerable skills and – despite its automatic fuel switching - consistent attention by the operators.

Picture 5.4: Biofuel Installation Ovea, New Caledonia

A more appropriate and more affordable option for Kiritimati would be an installation similar to the ADB supported unit in Solomon Islands. As described above, the SIEA installation in Auki used a low tec/low cost set up whith manual fuel switching. This type of operation requires a permanent presence of an operator. Currently all government operated power systems on Kiritimati have permanent operator presence. I.e. a biofuel operation would not require additional staff.

The fourth approach involves the blending of CNO and ADO. Tolerance of engine types varies for this fuel type and the introduction should be gradual and accompanied by close monitoring. Given the fact that copra resources in the Line Group are sufficient to allow dual fuel mode operation this is the recommended approach. In section 7 a full flow diagram of the recommended set up is displayed. The set up could be used in each of the current power supply stations or in a central power station that supplies the entire London – Cassidy corridor.

[10] MAK Caterpillar produces such engines in various sizes

6. Kiritimati's Energy Sector

6.1 Current Fuel Supply and Demand on Kiritimati Island

KOIL, the state owned petroleum company currently imports and distributes three petroleum products, namely unleaded petrol (ULP), automotive diesel (ADO) and dual purpose kerosene (DPK), aviation gasoline (AVGAS) and liquid petrol gas (LPG). Except for LPG, all products are supplied via coastal tanker from Fiji. Products are delivered to an oil terminal (see Picture 6.1), which has a total storage capacity of 530,000 litre of petrol, 1,200,000 of diesel and 660,000 litre of DPK. There is no bulk storage or LPG decanting in Kiritimati. The product is sourced from Tarawa in 18 and 40 kg bottles which arrive on the normal supply boat. Current retail prices are A$ 1.30 for ULP and A$ 1.50 for diesel.

The two other islands in the Line Group, Fanning and Washington are supplied with all petroleum products from Kiritimati. The following table shows the supply for 2010, the last year with a complete statistic.

Table 6.1: Petroleum Product Supply Line Group

Customer	ULP	ADO	DPK	AVGAS	LPG
International	17,600	119,873	588,799	1,878	-
Kiritimati Island	359,990	1,204,193	103,718	2,872	2,245
Fanning Island	20,300	11,100	5,500	-	-
Washington Island	71,245	180,022	79,501	-	5
Year Total	**469,135**	**1,515,188**	**777,518**	**4,750**	**2,250**

Source: KOIL, International sales of product refers to sales to aircraft and boats.

The transport sector (ships and land transport) consumes 27% of the ADO supplied. There are two operating fuel pumps on Kiritimati that supply fuel to a total fleet of 380 registered vehicles. 130 of these vehicles are equipped with diesel engines (buses, minibuses, pick-up trucks and lorries). 190 vehicles are motorcycles using ULP and the rest are saloon cars equipped with spark ignition (petrol) engines (Source: Kiritimati Town Council).

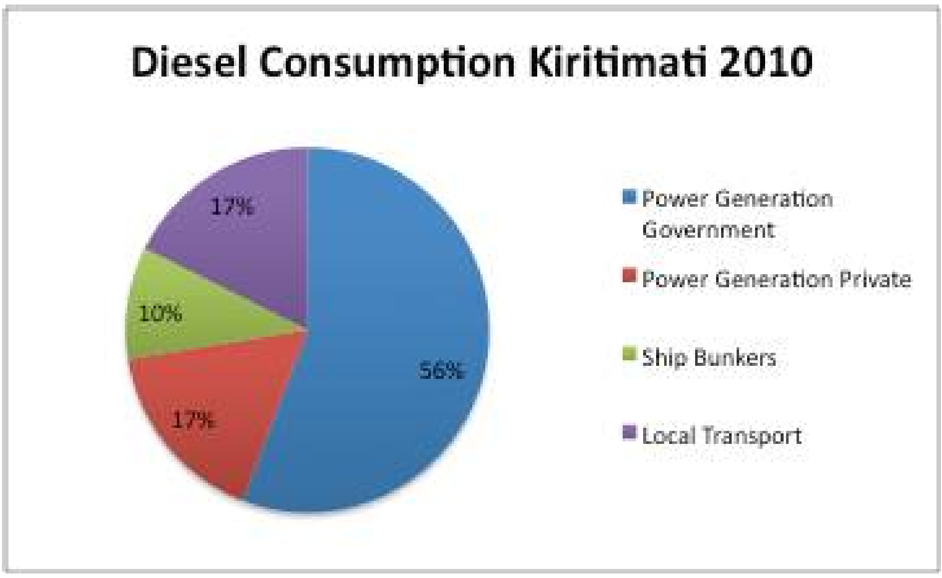
Current prices that KOIL charges to consumers in Kiritimati are listed in the table below. The listed wholesale price is reflective of supply cost plus KOIL's cost, which the depot manager estimates at approximately A$ 0.20 per litre of product. It should be noted that KOIL does not adjust its prices in line with the actual landed cost for a particular shipment. The aim of the SOE is to buffer fluctuations and keep the prices stable, at least for a couple of months. Taxation levels are extremely low in Kiribati. DPK, which is mostly used as aviation fuel but also as a lighting and cooking fuel in households is not taxed at all.

Table 6.2: Petroleum Product Prices KOIL February 2012 (A$/Litre)

	Wholesale	Retail	Tax
ULP	1.08	1.3	0.07
ADO	1.33	1.5	0.06
DPK	0.85	1	0

In total Kiritimati Island consumes approx 1.2 million litres of ADO per year, the entire Line Group approx 1.5 million litres. The following Graph shows a break down of diesel use in Kiritimati. Clearly, power generation in both private installation and the government-operated mini-grids dominate diesel use with more than 70% being consumed in this sub-sector.

Graph 6.1: Diesel consumption on Kiritimati



This analysis leads to an important conclusion: The total diesel consumption in the Line group (1.5 million litres) exceeds the production potential of CNO (900,000 litres p.a.) by a significant margin. A potential biofuel project should therefore focus on the use of CNO in power generation and in a first implementation phase should **not** allocate resources to the transport sector. Technically, the use of CNO in power generation is significantly easier than in a variety of vehicles with a variety of different diesel engine designs. In power generation the operator can ensure that CNO is only used under optimal conditions, i.e. under high engine loads and with optimal engine temperatures. Also, trained generator operators can read signs of engine trouble related to a non-spec fuel and act accordingly.

Picture 6.1: KOIL Terminal Kiritimati

6.2 The Kiritimati Power Supply

Currently, there is no integrated power system on Kiritimati. Power is generated in a variety of locations by both the government and private users. Distribution is limited to small 415 V grids with limited reach. The following table displays the key data for the government operated power systems in five villages on Kiritimati.

Table 6.1: Government Power Systems

London	**Generator 1**	**Generator 2**
Generator Make	Cummins	Cummins
Capacity kW	250	250
Average Fuel Use l/h	42	42
Year of Instalation	2000	2000
Estimated hours	52560	50000
Remarks	Operational, but requires replacement	Operational, but requires replacement
Tennessee		
Generator Make	Denyo	Nippon Sharyo
Capacity kW	60	48
Average Fuel Use l/h	7	
Year of Instalation	2008	2000
Estimated hours	33580	n.a.
Remarks	Generates at 60 Hz	Water pump defective, not operational
Banana		
Generator Make	J. Deere	Nippon Sharyo
Capacity kW	180	100
Average Fuel Use l/h	10	
Year of Instalation	2001	n.a.
Estimated hours	83950	n.a.
Remarks		Not operational, beyond repair
Poland		
Generator Make	Denyo	
Capacity kW	60	
Average Fuel Use l/h	4.5	
Year of Instalation	2005	
Estimated hours	28105	
Remarks	Operated from 6pm to 6 am only	
Tabwakea		
Generator Make	J. Deere	
Capacity kW	180	
Average Fuel Use l/h	15	
Year of Instalation	2001	
Estimated hours	83950	
Remarks	Bay for 2nd generator in powerhouse	

Only the power supply of the Kiritimati capital of London has currently two operational generators, the rest of the systems rely on a single unit, although the systems of Banana, Tabweka and Tennessee used to have second generators. Except for the small Poland system, where power is on from 6 p.m to 6 a.m., power is normally supplied 24 hours a day. Stakeholder consultations however revealed that supply is unreliable with frequent interruptions caused by planned and non-planned outages.

Most generators are due for replacement. The London power system in particular, urgently requires an upgrade, new generators and a major clean up. Given the fragility of Kiritimati's fresh water supply and the high risk of contaminating the freshwater lens with engine oil or fuel spills, the power operations badly require upgrades including bunded storage and spill management procedures. The London powerhouse for instance is littered with more than 10 old disused generators oozing engine oils and coolants into the ground. This scrap also hinders a proper operation of the facility. It has been reported that a new 500 kW generator has been ordered for the system, but documentation on this project could be identified.

Picture 6.1: Power Generation Kiritimati

London Generator

Banana Generator

Recording of generation data is very limited and only London and Tennessee record hourly loads. There is no recording of daily fuel consumption or kWh send out. However, aggregated annual fuel supply to the powerhouses is logged. Unfortunately, sales or billing data could not be obtained from the electricity department of MPLI. The only information obtained was total generation for each of the stations for 2007. This lack of data makes a thorough analysis of the power systems' performance impossible[11].

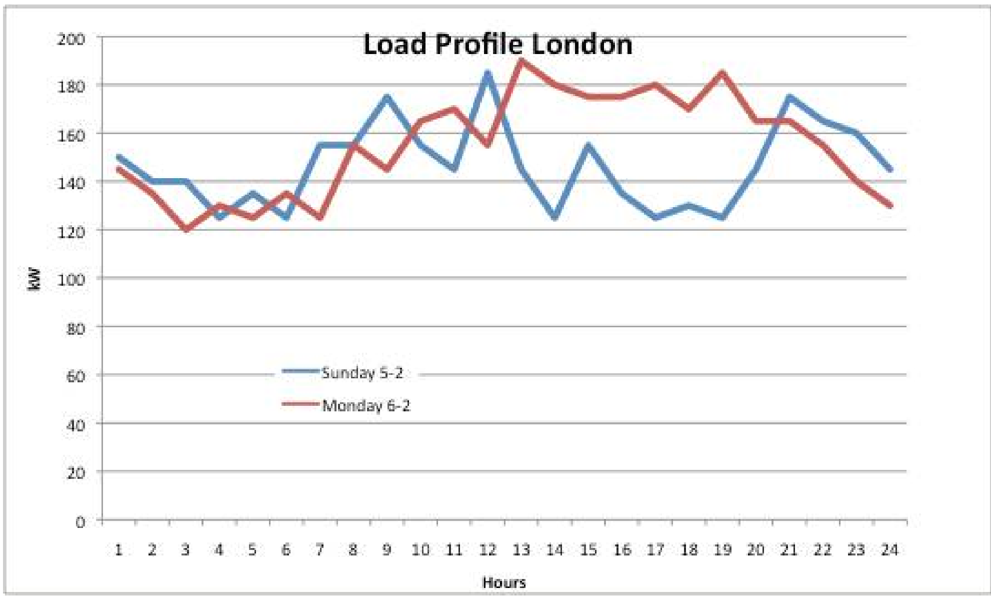
Power tariffs on Kiritimati are lower than on Tarawa (A$ 0.33 for government and A$ 0.30 for all other consumers). This is not reflective of a higher effieiency or lower cost involved in supplying power on Kiritimati. It is the result of the government providing another subsidy through the MLPI.

The following graph shows the current load profile of the London system for both a weekend and a weekday. Midday load for a Sunday is significantly lower than for a working day which clearly shows the impact of office air conditioning and other commercial loads. The peak of 190 kW is reached at noon on a weekday. The London powerhouse has no synchronizing facility, i.e. only one generator can be operated at a time. With a nominal capacity of 250 kW and a temperature and age de-rating of at least 20 % to 200 kW, it is obvious that the generators in London struggle to maintain load on a hot day.

It can be assumed that the other mini grids show similar load characteristics with a base/minimum load occurring during the night (1 a.m. – 5 a.m.) and a peak that is approximately 50% higher than the base load. The peak loads occur both during midday (air conditioning) and again towards 8-9 p.m. in the evening (household demand).

[11] MPLI staff promised to provide financial data but despite repeated calls, no data could be obtained

Graph 6.2: Load Curves London Power System



All other government generators seem to operate significantly below their rated capacity. Tennessee, the only other system where hourly load is displayed and recorded has a rated capacity of 60 kW, but an average load of 13 kW and a peak of 18 kW. This results in high specific fuel consumptions. It is also interesting to note that there is no standardization of the power supply in Kiritimati. Supply systems of 130 V/60 Hz run parallel to 240V/50 Hz. The systems of Tennessee generates at a frequency of 60 Hz suggesting that this generator was provided under an US aid program.

A comparison of kWh sold and fuel used is pending as the latest electricity sales data obtainable from the Electricity Distribution Unit of the Ministry of Line and Phoenix Islands was for the year 2007. For this year, however, no break down of KOIL sales data is available. The following table shows a summary of the 2007 electricity sales records[12].

Table 6.2: Electricity Sales Records 2007

Electrcity Consumption						
Total kWh						
	London	**Tennessee**	**Tabwakea**	**Banana**	**Poland**	**Total**
Commercial	1,119,803	62,965	-	17,342	-	1,200,110
Business	383,164	26,413	18,455	12,266	-	440,298
Domestic	222,894	24,889	403,726	68,604	8,660	728,773
Total	**1,725,861**	**114,267**	**422,181**	**98,212**	**8,660**	**2,369,181**
Number of Accounts						
	London	**Tennessee**	**Tabwakea**	**Banana**	**Poland**	**Total**
Commercial	44	3	0	6	0	53
Business	68	14	8	12	0	102
Domestic	187	19	186	92	41	525
Total	**299**	**36**	**194**	**110**	**41**	**680**

[12] The Electricity Unit has promised to e-mail the 2011 records as soon as their computer has been fixed.

In 2007 a total of 680 customers consumed 2,369 MWh with the commercial/government sector clearly dominating. As supply areas and consumption patters have not changed in any significant way since 2007, it can be assumed that current power sales are in the vicinity of the figures recorded for 2007.

For the four power supply of London, Banana, Tabweka and Tennesse, the poor state of repair of the existing power systems and the mix of US and Australian standards suggest that a biofuel project should go hand in hand with an overall rehabilitation and upgrading of the entire Kiritimati power supply. If government plans of a significant resettlement are to materialize and economic development of Kiritimati is to follow it seems prudent to establish a central power plant and a 11,000 V distribution system ranging from London to the Cassidi airport, similar to the supply in Tarawa. This would not only allow establishing a generation facility that is designed for the use of CNO and the integration of other renewable energies such as wind and solar but at the same time open opportunities for settlement in the Banana-London corridor. At present there are a significant number of households and other consumers in this corridor that cannot be supplied due to the technical limitations of the existing low voltage power systems.

At present, there are numerous generators operated outside the government village supply systems. The major installation are listed below:

Table 6.3: Generation outside Government Systems

Location	Size (kW)
JASCA	100
Spivey Highschool	40
San Francis Highschool	40
JOC	18
Captain Cook Hotel	120
	85
	75
	40
Total	**518**

The largest power producer outside the government systems is clearly the Captain Cook Hotel, which has four generators with a total installed capacity of 320 kW. In addition, all commercial operations such as Telecoms (TKSL) and the fishing company operate stand-by generators to allow continuous operation during outages of the government supply system. In the following section a biofuel project for the Line Island Group will be outlined based on the assumption that a backbone power supply will be installed in the London to Cassidy corridor. From 2010 KOIL sales data for diesel fuel, total diesel consumption for power generation can be approximated using generic specific fuel consumption figures[13].

6.3 Future Demand for Power and Diesel Fuel

Based on current estimated levels of power generation and diesel consumption, future demand for fuel on Kiritimati can be projected. Table 6.4 depicts the current diesel consumption and electricity generation on Kiritimati broken down by location. In total approx 872,000 liters of diesel are being consumed for power generation of which 200,000 litres are used outside the five government-operated systems. At a conversion rate of 3 kWh per litre of diesel, the total electricity generation for 2012 is estimated at 2.6 GWh.

[13] No consistent data set for power generation and fuel consumption is currently available

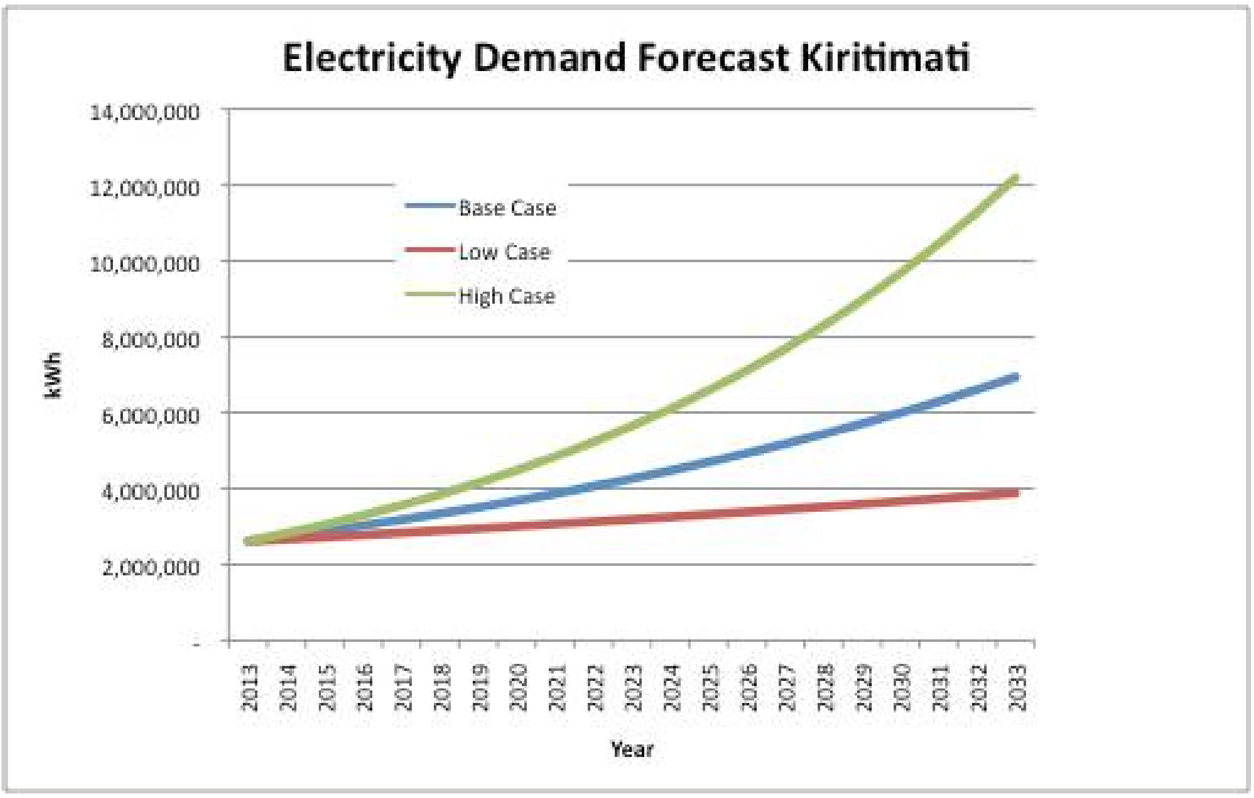
Table 6.4: Current Power Generation and Diesel Consumption

Location	Diesel (l)	Electrcity (kWh)
London	420,000	1,260,000
Tabweka	140,000	420,000
Banana	12,000	36,000
Poland	20,000	60,000
Tennessee	80,000	240,000
Private	200,000	600,000
Total	**872,000**	2,616,000

Future demand is expected to grow in line with population growth and economic development on Kiritimati. As a base case scenario it is assumed that electricity demand will grow at 5%, a low case would be a 2% growth and 8% is considered a high growth scenario. Some adjustments needed to be made when future demand is projected. Firstly, the diesel generation for Poland is soon to be replaced by a solar powered mini grid funded under the European Union's EDF 10.

Secondly, better specific fuel consumption can be expected when the old generator sets powering the current government grids are being replaced by new, more efficient equipment. However, part of these efficiency gains will be off-set by higher distribution losses which will occur when a single power plant supplies the entire London – Cassidy corridor. The net efficiency gain is therefore estimated at 8% resulting in a specific fuel consumption of 3.24 kWh per litre of diesel. When projecting CNO demand, adjustments have to be made for the lower volumetric calorific value. It is assumed that 1.1 litre of CNO replace one litre of diesel. The following Graph 6.3 shows the resulting electricity generation forecast which in turn would drive fuel demand.

Graph 6.3: Electricity Demand Forecast Kiritimati



From the electricity demand projected above diesel and CNO demand forecast can be developed for the three different scenarios. It should be noted that in the so called 'Dual Fuel" mode only approximately 90% of diesel can be replaced by CNO. For start up and stopping of generators as well as in low load operation diesel is still needed for safe operation. The following Table 6.5 depicts the forecast for diesel fuel and CNO for a 20 years planning horizon. It is clear that a the entire current copra production of the Line Group (1,500 tons per year – equivalent of approx 800,000 litre of CNO) could be absorbed immediately if an integrated electricity grid powered by generators in dual fuel mode was installed on Kiritimati. As mentioned earlier, current and future electricity generation on Kiritimati offers a large enough market to absorb all

Table 6.5: Fuel Demand Forecast Electricity Generation

Year	Base Case		Low Case		High Case	
	Diesel	CNO	Diesel	CNO	Diesel	CNO
2013	80,741	799,333	80,741	799,333	80,741	799,333
2014	84,778	839,300	82,356	815,320	87,200	863,280
2015	89,017	881,265	84,003	831,626	94,176	932,342
2016	93,468	925,328	85,683	848,259	101,710	1,006,930
2017	98,141	971,595	87,396	865,224	109,847	1,087,484
2018	103,048	1,020,174	89,144	882,529	118,635	1,174,483
2019	108,200	1,071,183	90,927	900,179	128,125	1,268,442
2020	113,610	1,124,742	92,746	918,183	138,375	1,369,917
2021	119,291	1,180,979	94,601	936,546	149,445	1,479,510
2022	125,255	1,240,028	96,493	955,277	161,401	1,597,871
2023	131,518	1,302,030	98,423	974,383	174,313	1,725,701
2024	138,094	1,367,131	100,391	993,871	188,258	1,863,757
2025	144,999	1,435,488	102,399	1,013,748	203,319	2,012,857
2026	152,249	1,507,262	104,447	1,034,023	219,584	2,173,886
2027	159,861	1,582,625	106,536	1,054,703	237,151	2,347,797
2028	167,854	1,661,757	108,666	1,075,797	256,123	2,535,621
2029	176,247	1,744,844	110,840	1,097,313	276,613	2,738,470
2030	185,059	1,832,087	113,057	1,119,260	298,742	2,957,548
2031	194,312	1,923,691	115,318	1,141,645	322,642	3,194,152
2032	204,028	2,019,876	117,624	1,164,478	348,453	3,449,684
2033	214,229	2,120,869	119,976	1,187,767	376,329	3,725,658

Even the low growth scenario, which assumes only 2% demand growth, would be sufficient to absorb all CNO production. These forecasts also show that there is substantial room to expand copra and CNO production beyond the current levels of 1,500 tons of copra. Assuming the base case scenario materialized, a doubling of copra production between now and 2033 could be absorbed in Kiritimati's power sector. This analysis shows that a local biofuel market could still absorb substantial increases in copra production, which could be triggered by a rehabilitation of the Line Islands coconut industry.

7. Designing the Kiritimati Biofuel Project

7.1 Design Objectives

Biofuel production and use on Kiritimati has several objectives. Firstly, it aims at reducing the cost to the government by avoiding shipping cost for copra from the line islands to Tarawa. Secondly, it will save KOIL transport cost for shipping fuel from Fiji to Kiritimati. Thirdly, the projects will improve Kirimati's energy security and at the same time create a local industry. At the same time, the project will significantly reduce the risk of environmental damage that stems from the spillage and mishandling of fossil fuels. With respect to copra production, the objective is to achieve some economies of scale through milling the entire copra production of the Line Group. Based on average production figures of 1,500 tons of copra p.a. for the entire Line Group, a CNO mill with a production capacity of approx 800,000 to 1 million litres p.a. would be required. The CNO produced would replace 90% of all diesel used in power generation on Kiritimati. It is assumed that fuel demand would increase in line with the base case scenario described in the previous section.

Based on an assessment of available technology, discussions with hardware suppliers and based on documented experiences with CNO fuel use in the Pacific region and elsewhere, a low risk, low cost, multi phase strategy is recommended for the introduction of a CNO based biofuel in the Line Group and on Kiritimati in particular. Major design objective is to produce a CNO based fuel substitute as efficiently as possible. Emphasis is put on the production of a high quality CNO and strict quality control.

7.2 CNO Production

A conventional CNO mill that uses dried copra as a feedstock is suggested for Kiritimati. The technology is well understood and the supply chain for copra is well established. The mill would have a capacity of about 4,200 litre of CNO per shift equivalent to approximately 1,000,000 litres p.a. with 240 production days per year. This capacity is sufficient to process all of the current Line Islands copra production of 1,500 tons per year. Higher production volumes (which could be achieved through a rehabilitation of the Line islands copra industry) are possible through the introduction of a second shift boosting production volumes to 2 million litres per annum.

The mill would require a new building and would be equipped with copra storage capable of holding a minimum of 20 days of feedstock. A higher storage capacity may be needed if shipping traffic between Tabuaeran, Teraina and Kiritimati proves to be less frequent. The mill would have standard copra cutters and multiple action screw presses. Steam extraction is not recommended. Although steam extraction can boost yields (up to 0.65 litre of CNO per kg of copra) it adds complexity and cost to the operation and diminishes the value of the press cake as an animal fodder. For the Kiritimati CNO production a yield of 0.55 litre of CNO per kg of copra is assumed. Feedstock transport inside the mill (copra to cutters and cut copra to expellers would be on conveyor belts. The mill would also have settling tanks and a first stage press filter unit capable of filtration to 5 micron and 50 mg/kg total sediment.

The mill can be established in one year and would ramp up production from 400,000 litre of CNO during the first to full production level thereafter. Ideally the CNO mill would be established next to the new power plant. In this configuration CNO could be transferred via a short pipeline from the mill to the power plant. This minimizes supply cost of biofuel.

CNO Quality and Operational Aspects

Quality control needs to begin with influencing copra producers to produce high quality copra. It is recommended that the CNO mill measures moisture of copra received and rejects copra with more than 6.5 % moisture. It is also recommendable for the milling operation to check for general contamination (dirt, dust, foreign objects) and colour. It is, however, not realistic to expect small and medium scale copra mills to consistently produce fuel grade quality copra. Experience in New Caledonia and Vanuatu have clearly shown that responsibility for final quality control rests with the CNO user, i.e. the power plant operator. What can be expected, however, is that CNO received for use in a power station meets a minimum quality standard in order to facilitate final conditioning at the power plant. Table 7.1 summarizes suggested standards for both crude CNO (as received by the biofuel user) and CNO prior to injection into engine or mixing into day tank.

Table 7.1: Suggested Fuel Quality Parameters for CNO

CNO	Water Content Max (mass %) max	Total Sediment (mg/kg) max	Phosphorous (mg/kg) max	Lower Calorific Value MJ/kg min	Acid Value mg KOH/g max	Ash (mass %) max	Filtration Grade
Crude CNO	0.5	50	30	35	5	0.1	5 µm
CNO Fuel	0.1	25	30	36	5	0.05	2µm

It has been suggested that the European vegetable oil fuel quality standard be adopted for CNO used in biofuel operations in Kiritimati. Whilst it is agreed that a formal quality criteria should be adopted for fuel grade CNO it probably impractical to expect remote island CNO producers to measure the majority of these parameters. Parameters such as solid contamination (inorganic and organic) on a 2µm filter, water content, and acidity (free fatty acid) are easily measured with the minimum of equipment and training and will provide a good indication of the suitability of the CNO produced for use as fuel. Annex 5 lists the laboratory equipment needed for basic CNO quality tests (water content, total sediment/contamination and free fatty acids).

Phosphorous is associated with the occurrence of gums which increase the tendency to form deposits. The phosphorous content appears to be naturally associated with coconut oil and while methods to remove phosphorous are available they are unlikely to be cost effective for small to medium scale CNO for fuel production. Phosphorous content would have to be checked occasionally by an external lab.

Experience shows that copra quality, transport and storage time make it difficult for larger mills to produce CNO at acidities less than 7mg KOH/g. Processing good quality copra within a week of the copra production does enable acidity levels of less than 5mg KOH/g to be achieved. A CNO ash content of 0.05% has been recommended as it matches the Caterpillar standard and has been shown to be possible to produce in the larger mills in the Pacific.

Free Fatty Acids

Using poor quality copra that has been stored for extended periods can result in CNO that may have unacceptably high levels of free fatty acids (FFA). A high FFA content could lead to corrosion in the fuel supply systems and require premature replacement of expensive engine parts such as injection pumps. It is obvious that the quality of copra in Kiribati varies and high FFA content can occur in CNO several strategies can be employed in biofuel operations to ensure that CNO suitable for fuel will be available. These include:

1. The CNO mill needs to maintain a quality copra supply from local producers. The copra is measured for moisture content and is evaluated for colour and cleanliness on delivery. Copra not meeting specifications (clean white and a moisture content < 6.5%) is rejected. Other CNO producers in other provincial centres would need to establish a similar system of quality control.
2. Investigation of larger CNO mills in PNG indicates that oil is commonly produced at FFA levels of less than 3% from the available copra supply which is highly variable in quality. These mills mix the various grades of copra and most importantly pre-dry the copra prior to expelling the oil. A small mill (700L/day) on Buka also uses this pre-

drying technique to maintain CNO quality. Oil produced in this mill is used to power a genset on site and sold for fuel after settling and filtration. Should FFA levels in locally produced oil become an issue then producers would be encouraged to develop an effective pre-drying system for the copra.

3. Should the levels of FFA in the locally produced oil be unacceptable due to poor copra then the FFA can be removed by a simple treatment process. This process has been used in small mill production at Kavieng, PNG. This process involves intimately mixing small quantities of water and caustic soda into the CNO. The treated oil is then left to settle and the FFA's which have coagulated settle to the bottom of the container. The overlying oil can then be decanted off and further processed through the CNO conditioning unit. It is envisaged that this process would be undertaken by the local CNO producer with the CNO delivered to the power station then meeting specifications for FFA.

7.3 Upgrading of the Kiritimati Power System

A reliable and efficient power supply is a necessary precondition for economic development and expanded settlement activity on Kiritimati. At present the five power systems operated by the MLPI is in very poor conditions. The small low voltage grids are powered by old, inefficient generators and the low voltage distribution systems do not allow expanding the electricity supply beyond the small service areas supplied at present. The development of a biofuel project should therefore go hand in hand with an upgrade of the entire power system. It should be noted that the Poland power supply system is already earmarked for conversion to solar power with funding from the EU. What remains to be integrated are the government systems of London, Tennesse, Tabweka and Banana. As these areas will also be the main settlement corridors for the future, several options available for such an upgrade have been considered:

a) Replacement of generators in the four MLPI systems with redundant generation following N-1[14] planning criteria.
b) Upgrading of the London power station, installation of three new generation sets (following N-1) and establishment of a high voltage (11 kV) distribution system ranging from London to Tabweka
c) Establishment of a 33 kV transmission/distribution system of 25 km spanning from London to Cassidy airport and providing supply to all current and future electricity users in this corridor.

Option a) is not recommendable. While it would improve reliability of the existing systems and would allow converting the existing systems to biofuel, this option does not allow any significant expansion of the supply areas. I.e. new settlers moving from Tarawa to Kiritimati would not be able to enjoy access to a modern power system. This option would also not allow the development of businesses.

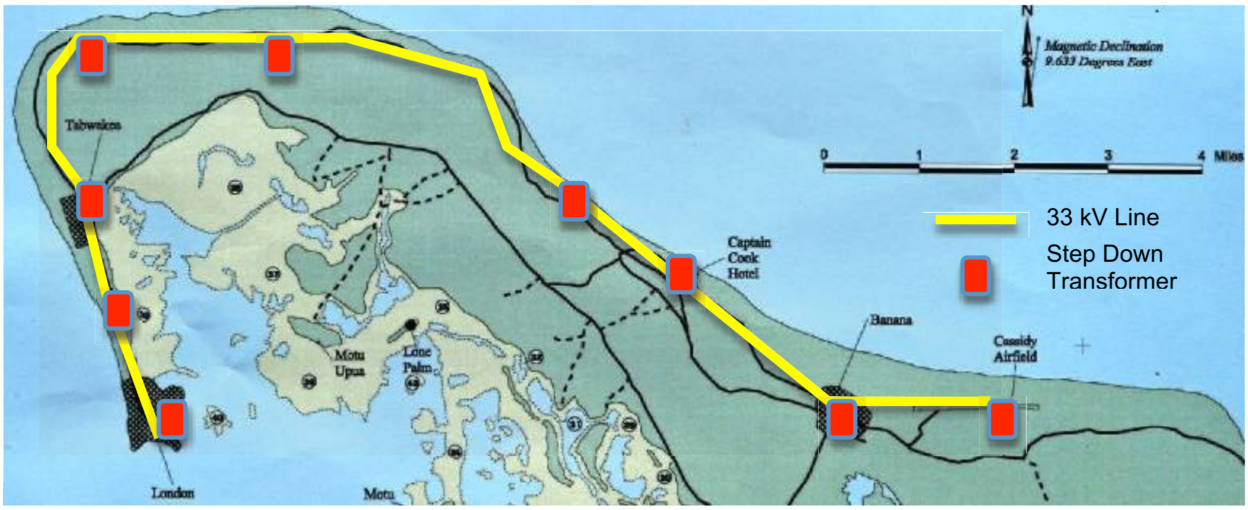
Option b) is an acceptable solution as a few new settlement areas could be supplied between London and Tabweka. The Banana station would continue to operate as an isolated grid and numerous private and public electricity consumers in the London – Cassidy corridor could not be supplied from the main grid. Option c) in contrast would allow full development of the entire London to Cassidy corridor as shown in Picture 7.1. It would be integrating the two colleges north of Tabweka (Spivey and San Francis) and the Satellite station JASCA.

[14] N-1 generation planning means that a power station can still supply total load when the largest generator set of this station experiences an unplanned outage

This upgrade would normally require a 33 kV transmission line as the total distance from London to Cassidy in 26 km. 11 kV could still be used but line losses would increase significantly with little reduction in construction cost gained (some savings would be achieved through lower step down transformer cost). The system would require at least 9 step down transformer stations from where 415 V distribution lines would supply consumers in the corridor. Building this system would face no obstacles; the routing would all be along the main road and construction would be easy and cost effective.

The transformers would be 500 kVA for London and 300 kVA for the other locations. From the substations a network of 30 km of 415 V distribution lines would allow supplying power to a significant corridor extending up to 1.5 km each side of the main road. The existing low voltage underground supply systems for London, Banana, Tenessee and Tabweka could be maintained. For these systems a step down transformer would simply replace the existing powerhouses as a source of electricity. Some up-grades may, however, be desirable in order to expand supply areas and allow the development of new settlements.

Picture 7.1: Map London to Cassidy

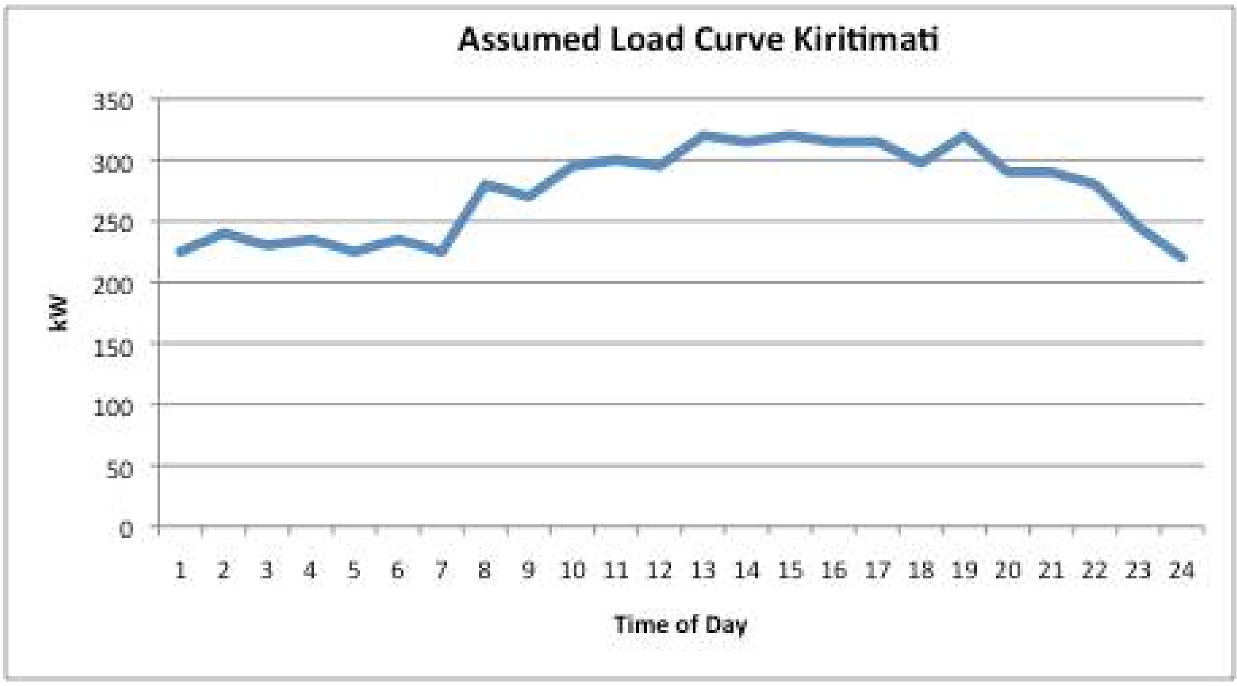


The rehabilitation of Kiritimati's power supply would also create the opportunity to move the current powerhouse out of the centre of London. The building is dilapidated anyway and residents complain about the noise emitted by this plant. The most efficient set up would be to build a new powerhouse in the Tabweka area and establish the CNO mill next to it. This set up would minimize transport cost for the CNO (it could be send via pipeline to the powerhouse).

7.4 Power Generation

It is assumed that an integrated power system will be established to supply the combined load within the London to Cassidy corridor. The base-case load growth scenario of 5% annual increase of load and energy output is the basis for power plant design. The required power plant capacity and the size of individual generator sets are normally based on load recorded load curves. In the case of Kiritimati, however, there is load curve for an integrated system available because such an integrated system does not yet exist. Thus, on the basis of the load curves recorded by MLPI for the London system, a likely load curve that would emerge for an integrated system can be constructed. It is assumed that initially, the combined load of an integrated system would follow the load shape of London but would initially be 75% higher than the loads recorded in London. This estimate is based on the actual size of both the government and private installations outside the London system. Graph 7.1 shows the anticipated weekday load shape. Initial (2013) peak loads would be in the vicinity of 320 kW with low loads in the order of 220 kW.

Graph 7.1: Anticipated Load Curve Kiritimati



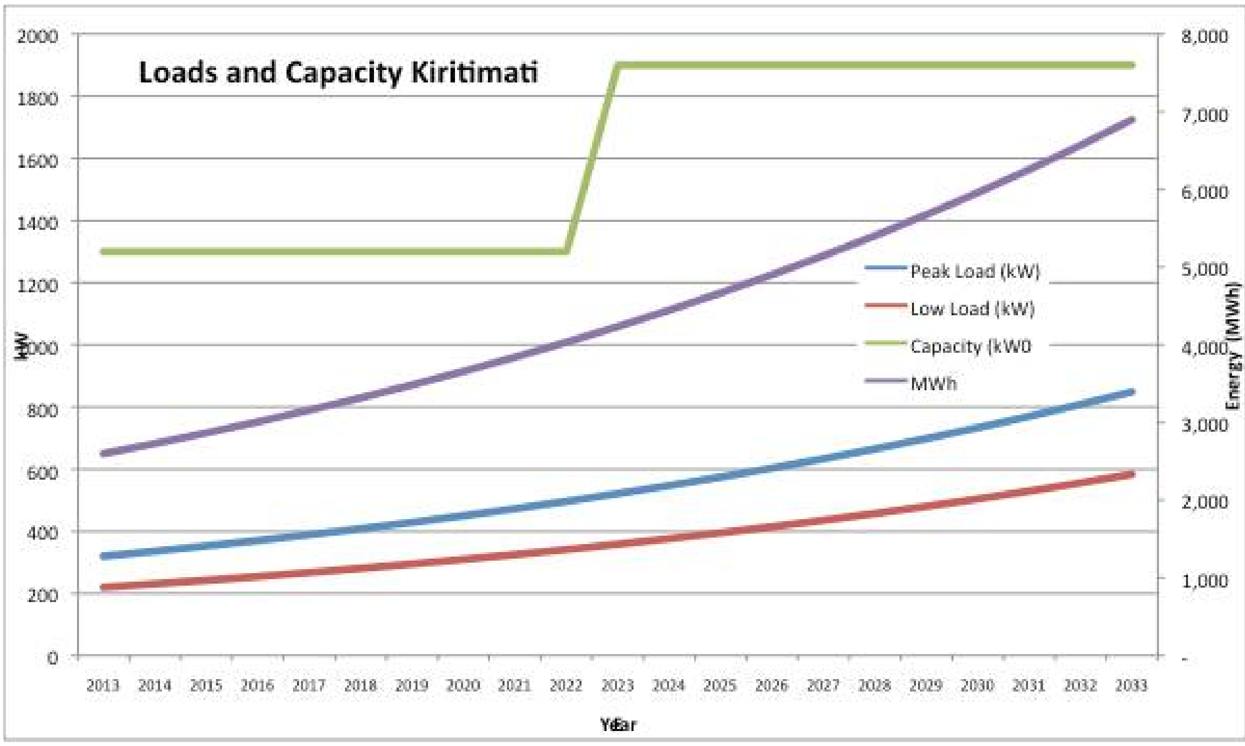
Expansion Planning

To efficiently supply the load depicted in Graph 7.1, in an N-1 configuration requires three generators. It is assumed that load (both peak and low load) and energy will grow in line with the base case scenario described above i.e. at 5% p.a. Further it is assumed that high speed generators are being employed that have a technical lifetime of approx 40,000 hours requiring replacement after approximately 10 years.

The powerhouse would also have the ability to synchronize the individual generators. For the first 10 project years a configuration of 2 x 500 and 1x300 kW would be a solution that a) allows an operation of generators at high loads (>65%) in both high and load situations. The 500 kW set could carry the load from 8 a.m. until 10 p.m, initially the 300 kW set would carry low night loads. Towards the end of the first 10 project years, peak loads would require operating two generators in parallel (300+500kW) and in 2023, the power house would receive three new generators (2x700 and 1x500 kW). The replacement generators would operate in a similar fashion then the first generation of generators. The smaller unit would cover low load situations during the night, the large generators would cover daytime loads. From about 2029 onwards, meeting peak demand would require synchronized operation of a 700 and a 500 kW unit.

The following Graph 7.2 shows the assumed load development (Base Case Scenario) and the capacities required to maintain generator loading and N-1 reliability criteria. A power plant with two generator sizes offers more flexibility to respond to load situations. The downside of using generators of different sizes is a more complex spare part management for two different generators. However, the new central powerhouse would replace variety of generators used at present, thus reducing complexity. Power system expansion should always be based on a thorough review of historical experiences. I.e. after 5-6 years of operation the load growth assumptions made in this study should be assessed against the background of the development of the actual loads.

Graph 7.2: Load Forecast and Capacity Requirement



7.5 CNO Use in Electricity Generation

Introduction of CNO as a fuel should focus on power generation and start with the use of fuel blends having a CNO content of not more than 30 %. As operator knowledge and confidence builds, CNO use can be increased up to 90%. In this so called dual fuel mode, the objective is to replace as much diesel as possible and operate the respective engines on diesel only for start up and shut down or in exceptional low load situations. This low risk strategy is suggested for the following reasons:

- Investment in an upgrade of the MPLI power supply system is required anyway;
- Gradual introduction of low risk blends would allow to build technical capacity over time;
- No expensive high tech special design systems would be required;
- Production of a high grade CNO is a highly marketable commodity, i.e. even in the event of diverting CNO to the world market instead of using it locally, a local CNO production could still be a viable option.

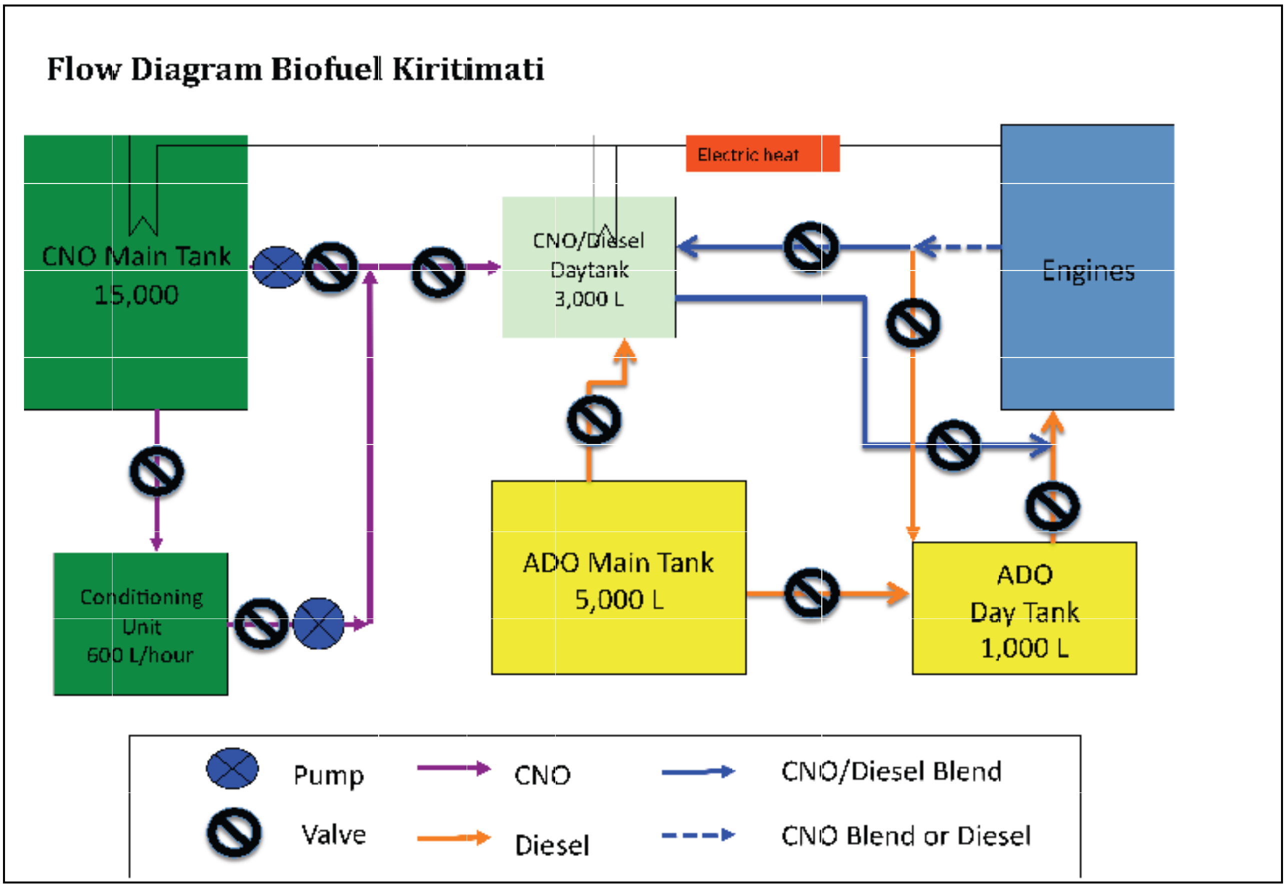
The introduction of biofuel should be accompanied by a comprehensive training program for both copra production, CNO milling and CNO use in power generation. A comprehensive monitoring and documentation of operating parameters of the generators that use CNO blends should accompany the introduction of fuel blends. Once confidence and experience with low level blends are achieved and a price level for fuel grade CNO has been established, after a pilot and training phase of six to 12 months, operation can shift to 90 % CNO in dual fuel units in order to make full use of the local CNO production capacity. This phasing in of CNO would also allow the CNO mill to ramp up their production gradually over its first year of operation.

It is assumed that in dual fuel mode (90%), both of the main CNO tank (15,000 litre) and the day tank (3,000 Litre capacity) have to be heated as night-time temperatures on Kiritimati drop below clouding point for CNO on a regular basis. Temperatures below 24°C would lead to blockage in the fuel system and stop dual fuel operations. The main CNO tank is sized to hold sufficient CNO to sustain 5 days of operation (15,000 L). Prior to transfer of CNO from the main tank into the day tank CNO is processed through a conditioning unit. The day tank would be heated electrically with thermostat control in order to ensure that the CNO is injected at 50°C. Start and stop of a generator would always be on 100% diesel and the valves would be adjusted manually. The generators would be equipped with either an exhaust temperature probe placed in the exhaust manifold or a load sensor that measures the actual load under which the generator is operating. Any drop of either values (about 450 °C for exhaust temperature or 65% load) would sound an alarm. In response the operator would have to switch operation back to diesel until the minimum values for safe CNO have been reached again.

The power station also requires main diesel tank (5,000 L) and a day tank for diesel (2,000L) . Excess fuel is returned either into the CNO or the diesel day tanks in order to avoid contamination of the two separate fuel cycles. The engine would be equipped with an additional fuel filter (2 micron cartridge type) in order to ensure that most impurities remaining in the CNO are removed prior to injection. Experience in the Solomon Islands have shown that fuel filter replacement frequencies have to be higher in comparison with straight diesel use. The SIEA project replaces fuel filters every two weeks as opposed to once a month when diesel is being used.

The following Graph 7.3 displays the recommended lay out for CNO based, dual fuel power generation on Kiritimati.

Graph 7.3: Biofuel Diagram Suggested for Kiritimati Power Generation



The set up shown is suitable for installations of one or more diesel generators and would allow replacing 90% of diesel. Only during start up, shut down and under low load, the fuel supply has to be switched back to diesel by operating the valves shown in the lay out. Automatic operation is possible through the addition of solenoid valves that are controlled either by a load or exhaust temperature signal. Retrofitting a manual operation to automatic dual fuel mode is possible any time. The manual operation facilitates the training program for operators as they are forced to understand the issues involved in the use of CNO as a diesel substitute rather than operators relying on the trouble free functioning of a fully automated system.

7.6 Training Program and ADO/CNO Blend

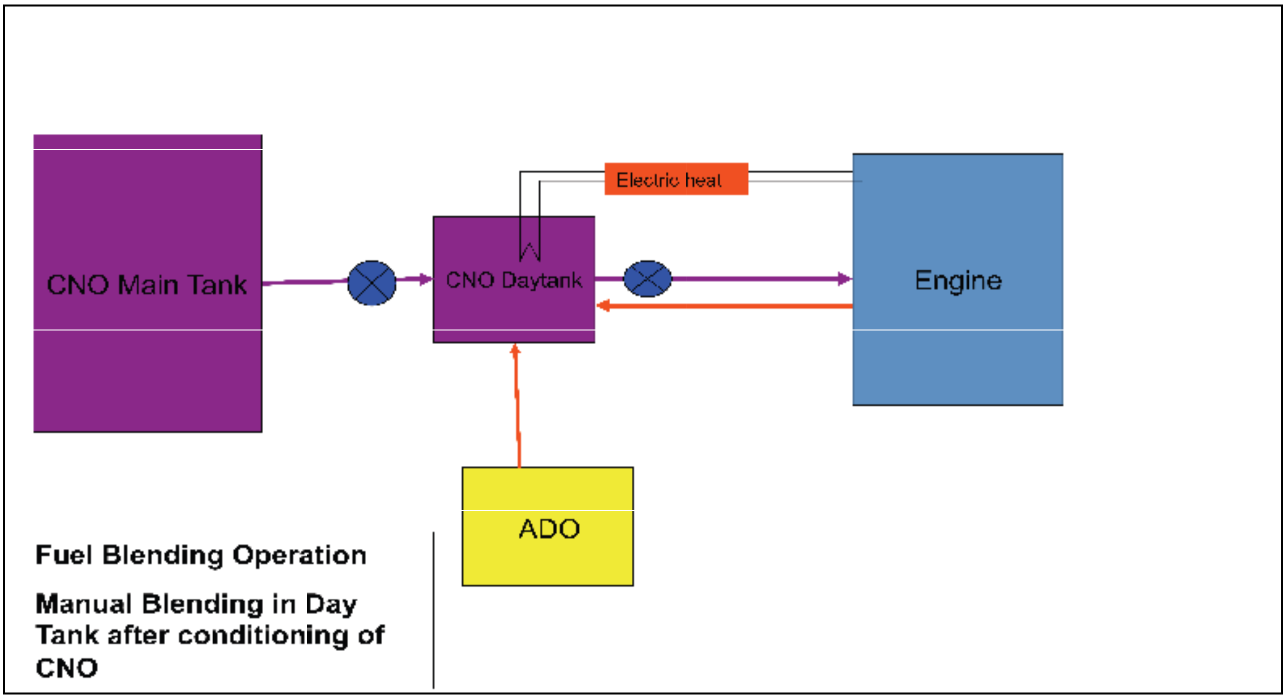
It would be beyond the scope of a Kiritimati biofuel programme to reach out to copra farmers/cutters and enhance their capability of producing high quality copra. It would have to be the task of dedicated agricultural extension programme to work closely with their copra suppliers to ensure that copra quality is adequate. It is also assumed that the CNO milling operation is performed by a competent organisation that is capable of handling the production and refinement of CNO. Training of the powerhouse operators will be a priority task should biofuel projects proceed. Operations protocols would have to be established to cover the following areas:

- Testing of CNO fuel quality: A small laboratory will be required on site and operators will be trained to test for water content, total sediment, acid value and filtration grade on CNO received on site. The testing protocol will ensure that all CNO is of an acceptable standard before transfer from the drums to the main CNO storage tanks.
- Regular sampling of oil after conditioning would also be required in order to maintain the fuel grade quality listed above.
- Management of the CNO storage tanks: Tanks would be heated by electrical element to 50C. Management of the storage tank will also include CNO drum transfer procedure, CNO transfer to pre-conditioning unit and regular draining of settled solids.
- Operation of the pre-conditioning system: The pre-conditioning system is a critical engine protection measure. It will consist of a series of filtration steps which will ensure all particles greater than 2 μm are removed and a vacuum separation step to remove any water remaining in the CNO.
- Operation of the generator sets. The existing operating procedures employed by MLPI are not adequate for CNO use. New operations protocols would address the level of observation of control equipment, new sump oil sampling regime, increased servicing and maintenance requirements and specific record keeping requirements.
- Operation of the power house site: This would include maintenance of the infrastructure, operation and recording of stores including fuel use, lubrication oil use, CNO use and spare parts together with an environmental management plan for the site which will address aspects such as waste oil storage, oil spills, general rubbish removal and sanitation.

Training should also address the issue of spare part management. The availability of spare parts appears to be a particular problem in all the power stations visited. Basic servicing spares such as filters are often not supplied on time (or not at all) and while operators do the best they can by cleaning and recycling the used filters this is not good practice and will certainly create problems when working with CNO. The issue of parts availability and its impact on equipment maintenance will need to be addressed. A list of the regularly required service parts and equipment will be developed and a lockable store constructed to contain at least a 3-month supply of the required materials. The powerhouse manager would operate and monitor the store and will order replacement parts as they are used. It is hoped that in this way consumption of materials can be monitored accurately and most importantly parts will be available when required by the servicing protocol.

For training purposes, initially ADO/CNO blends would be used during a training phase. The main is equipped with an electric pump and a fuel meter that records the CNO received. CNO is then processed through the fuel-conditioning unit and pumped into the day tank maintaining a set blending ratio (initially 20% than gradually increasing to 50%). The required diesel quantity is always pumped first followed by the CNO. The day tank of 3,000 l is electrically heated with thermostat controls in order to compensate for viscosity increases induced by CNO blend. It is equipped with an external gauge, a pump, and a fuel meter, which allows accurate mixing of the blend. Fuel return from the generator would be to the day tank in order to avoid changes in blending ratios over time. The following simplified flow chart shows the process when ADO/CNO blends are being used.

Graph 7.4: Flow Diagram ADO/CNO Blend during Training



7.7 Cost Estimates

In the following cost estimates and assumptions on both investment and operating cost for the biofuel production and the power system upgrade are described. Where possible, cost figures from similar projects and investments are used.

CNO Production

Table 7.2 Summarizes the cost assumptions for a CNO mill with a capacity of 4200 L per 8 hour shift. The cost estimates are based on the assumption that in line with current government policy to promote private sector investment, the CNO mill would be developed and operated by the private sector as a green field project. Unlike the KCML mill in Tarawa, the operation has to make provisions for depreciation of assets and amortisation of the capital used. It would also have to pay a lease for the land it uses.

The mill would be capable of producing up to one million litre per annum and up to 3 million L per year in a 3-shift operation. It should be noted that the estimated lifetime of individual components such as screw presses would be reduced in a multi shift operation. Table 7.3 summarizes cost assumptions for the operation of the CNO mill.

Table 7.2: Capital Cost CNO Mill

Mill Capital Costs		A$	Useful Life (years)
Initial Costs			
	Building	$250,000	30
	Dryers, dehusking & shelling equipment	$80,000	10
	Expelling systems	$160,000	10
	Settling and Storage Tanks	$60,000	20
	Pipes, conveyor belts, other infrastructur	$80,000	15
	Install & Commission	$90,000	
	Total Initial Costs	$720,000	
Engineering Study, plant design, construction supervision		$75,000	
	Total Capital Cost	**$795,000**	

Capital cost for the KCML mill in 2002/2003 were approx A$ 2 million which is consistent with our estimate for a mill with a capacity of 4,200 Litre of CNO per 8 hour shift.

Table 7.3: Operating Cost CNO Mill

Input Requirements			
Variable Costs			
	Price of Copra, delivered 2013 (A$/kg)	*$*	*0.40*
	Electricity Required per litre of CNO (kW		0.20
	Electricity Price (A$/kWh)	$	0.40
Fixed Costs			
	Manager	$	40,000
	Labour Required (FTE)		10
	Wages (A$/hr)	$	3
	Annual Wages	$	57,600
	Materials, other O&M	$	25,000
	Site Lease	$	20,000
	Depreciation (A$/year)	$	40,667
	Total Fixed Costs	$	183,267
	Capital Amortisation	$	32,268
	Expected Profit (A$/litre CNO)	$	0.15

The fixed cost of the KCML mill in Tarawa are quoted to be 324,000 per annum which is consistent with the assumptions taken here, considering that the Kiritimati mill would only be a third of size of the Tarawa mill. Based on these cost estimates, CNO production cost will be calculated in the following section 8. It should be noted that a CNO mill couldn't compete with imported diesel if the mill had to pay the full government set price for copra of A$ 0.8 per kg. A price closer to the world market value of the copra would be necessary to operate the CNO mill in a commercially viable manner. As a base case a purchase price of A$ 0.40 per kg has been assumed.

Power System Expansion

The following Table 7.4 depicts the cost associated with the upgrading and expansion of the Kiritimati power supply system. At a total cost of A$ 2 million, a backbone power supply would cover the entire London Cassidy corridor. Cost estimates are based on the assumption that a new powerhouse would be constructed in the Tabweka area. Ideally this power house would be located next to or close to the newly established CNO mill, which in turn would be one of the largest consumers of electricity. It should be noted that incremental cost related to the use of CNO are just above A$ 103,000 or 5% of the total investment. These cost would cover two CNO conditioning units (600 L/hour capacity) as well as tanks and dual fuel controls. The estimates are based on a manual operation of the dual fuel operation. In the financial analysis in Section 8, additional incremental operating cost of A$ 10,000 per year have been assumed. These cost would reflect the need for more frequent lube and filter changes as well as more frequent replacement of injector nozzles.

Table 7.4: Cost Estimates Power System Upgrades

Cost Diesel Power Plant	Units	Unit Cost A$	Total A$
Building incl 3 generator bays	1	120,000	120,000
Main Tank Diesel 5000 L incl bunding	1	6,000	6,000
Day Tank Diesel 1000L incl bunding	3	2000	6,000
Piping	1	4000	4,000
Generators 500 kW	2	120,000	240,000
Generators 300 kW	1	100,000	100,000
Control Board and Syncronizing	1	30,000	30,000
Switchgear and Busbar	1	20,000	20,000
Step up transformers 1000 kVA	1	50,000	50,000
Total			**576,000**
Cost Power Distribution			
33 kV transmission line (poles, Conductors etc)	26	30,000	780,000
Step down transformers 300 kVA	9	15,000	135,000
Step down transformers 500 kVA	1	20,000	20,000
415 V distribution system	30	10,000	300,000
Total			**1,235,000**
Incremental Capital Cost CNO Use			
Fuel Conditioning units 600 l/h	2	32,000	64,000
Heated Day tank electric heating and thermostat control 2000 l	3	3,000	9,000
Main tank incl head exchanger and piping for CNO	1	15,000	15,000
CNO dual fuel control and ancilliaries	3	2,000	6,000
Piping duel fuel feed and return	3	1,000	3,000
On site Laboratory	1	6,000	6,000
Total			**103,000**
Grand Total			**1,914,000**

7.8 Renewable Energy in Kiritimati

An integrated power supply system as described above would allow the integration of solar and wind power. At present, the options are constraint by the small systems and their low load factors. The solar regime in Kirtimati can be assumed to allow capacity factors of 12% (1050 kWh per annum and kW installed). Wind regime recordings are currently undertaken by the Energy Planning Unit, but capacity factors of 15% seem to be realistic for the rather constant trade wind pattern prevailing on Kiritimati. It is estimated that initially up to 100 kW of renewable energy could be injected into an integrated power system without risks to system stability and reliability.

8. Competitiveness of CNO as a Fuel

The financial competitiveness of coconut oil (CNO) as a substitute for diesel fuel in the on Kiritimati in the Line Group depends mainly on how the price of a volume of CNO compares with the delivered price of an energy-equivalent volume of diesel fuel to the KOIL terminal. For the purposes of this analysis, it is estimated that about 1.1 litres of CNO have an energy content equivalent to 1 litre of diesel fuel, i.e., the volume of CNO needs to be about 10 percent higher than the volume of diesel to deliver the same energy output of a standard diesel engine.

8.1 World Market Developments

A comparison of CNO and diesel costs must take into account the respective prices of the products in the world market and also international transportation and local shipping costs to the fuels' ultimate destinations. An inherent advantage that CNO has over imported diesel fuel on Kiritimati is that it avoids international transport and local shipping costs, since it is produced close to the point of use. However, for practically all of the past two decades, the nominal price of CNO as a commodity has been above that of diesel fuel on the world market, on an energy-equivalent basis. From information available from international data basis[15] combined with diesel fuel prices reported by KOIL, it is possible to compare the price history of CNO with that of diesel fuel on world markets and in Kiritimati, from June 1986 to the present.

A comparison of the world market prices of each fuel is shown below in Figure 8.1. The Figure shows the prices of CNO and diesel fuel, expressed in A$ per metric ton, as set in major world centres where the products are distributed internationally in bulk (for CNO, Rotterdam; for diesel fuel Singapore and the US West Coast). The graph clearly shows that in 25 years, only for a brief three months period in the year 2006, energy equivalent commodity prices for diesel and CNO were about the same. For the rest of the analysed time series, CNO world market prices have been significantly higher for CNO (on an energy equivalent basis).

Another feature from the comparison stands out: whereas in the period from 1986 to about 2001, the world price of CNO was not highly correlated with that of diesel fuel, in the period thereafter to the present, the two prices appear to be closely linked. After 2001, the price of CNO rises and falls in close step with the price of diesel fuel.

Related to this, another feature that stands out is the relative stability of the nominal price of diesel fuel on the world market in the period 1986-2000, following which the diesel price begins to rise, quite steeply from mid-2006 to a historic peak in mid-2008 (when the world price of crude oil reached about US$150/bbl). Thereafter, a precipitous decline occurred in late 2008 and early 2009. This volatility in petroleum product prices seemed to spill into and dominate the CNO and other vegetable oil markets as well: it is remarkable that the price of CNO rose as fast as, and remained above, the diesel price throughout that event. The diesel price has been gradually rising since about mid-2009 and is now at a level last seen in 2008. Changes in nominal CNO prices have matched changes in nominal diesel prices very closely in this later period also.

The linkage between CNO prices and diesel prices in recent years undoubtedly reflects CNO's increasing importance as a biofuel. Other vegetable oils that can be used as bio-fuels, such as palm oil and soybean oil, also exhibit the same price pattern (though the linkage appears to be most pronounced in CNO prices). From Early 2011 however, the CNO price departed significantly from the energy price. In 2011, all food commodity prices spiked in response to poor grain harvests in countries that are major producer of world food commodities. CNO price climbed above A$ 2,000 per metric ton in the first half of 2011 more than double the world

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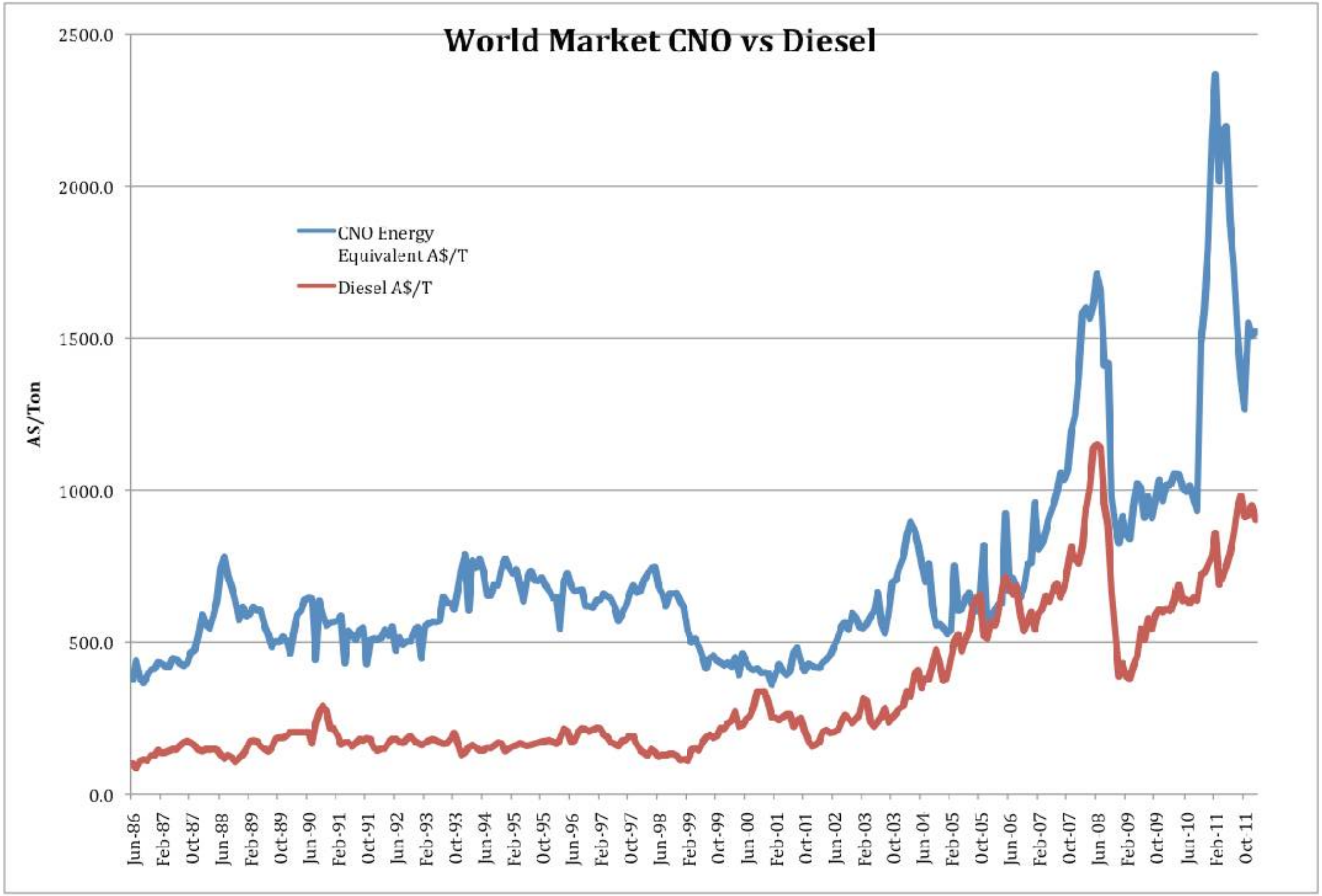
[15] http://www.indexmundi.com/commodities/?commodity=coconut-oil&months=240

Graph 8.1 World Market Prices for CNO and Diesel (Adjusted for lower energy content of CNO)



market price for diesel. Thereafter CNO price declined together with other food commodities and reached A$ 1,500 per ton in energy equivalent in January 2012.

If it is accepted that the nominal prices of diesel fuel and CNO (and other vegetable oils generally) have become strongly linked since about 2000, one might ask: why is the price of CNO significantly higher than the diesel price throughout the period? The evident explanation is that CNO and other vegetable oils also have important, indeed primary, non-fuel uses (as foods and chemical feedstock), and competition by those uses has driven the price higher than its use as a fuel could do alone.

In addition, it should be noted that any introduction and promotion of biofuel in the Western world has enjoyed (and still enjoys) some form of government subsidy. These subsidies obviously increase demand for biofuel feedstock including vegetable oils. Thus, it appears that the increasing use of vegetable oils as fuels, rather than as foods, has come to significantly influence the way that their prices change. The world market price for vegetable oils including CNO is supported by the commodity price for fossil fuels. While prices can easily move above the energy equivalent of fossil fuels they have rarely fallen below it.

From this analysis it is quite clear, that on the world market, CNO and other vegetable oils have never been competitive with diesel for any significant period of time. The question that needs to be answered, however, is what impacts transport cost for both diesel and copra/CNO have on the relative position of CNO as a fuel in Kiritimati.

8.2 Transport Cost

As mentioned, the financial advantage that indigenous CNO has over imported diesel is that it avoids international and local shipping costs from remote supply markets, since it is produced and used locally. For this reason, the price that KOIL pays for diesel fuel in Tarawa and on Kiritimati is significantly higher than the reported price ex Singapore. Assuming an average world market price for ADO of A$ 1.00 per litre for the last quarter in 2011 (approx A$ 1,100 per ton), the average transport cost from the world market to Kiritimati would be in the order of A$ 0.27 per litre.

On the other hand there is transport cost for copra from the Line Group to Tarawa and onwards to the world market either in the form of processed CNO or in the form of dried copra. Assuming average production levels for the Line Islands to continue in the future, the government would have to pay approx 2 million A$ for copra purchases and transport to Tarawa. Table 8.1. depicts the current (government regulated) transport cost for copra between the Line Islands and between the Line Islands and Tarawa. At average production levels of 500 tons for each island, transport cost to Tarawa in 2012 would be in the order of A$ 393,000. Local processing of copra would allow the government to save the Kiritimati to Tarawa component of the transport, i.e. A$ 280,000 per annum.

Table 8.1: Current Transport Cost for Copra

From	To	A$/ton	Average Cost A$
Kiritimati	Tarawa	186.2	93,100
Tabuaeran	Kiritimati	94.4	47,200
Teraina	Kiritimati	134.9	67,450
Kiritimati	Tarawa	186.2	93,100
Tabuaeran	Tarawa	280.6	140,300
Teraina	Tarawa	321.1	160,550
Total			**393,950**

Source: KCCS

On the other hand, the price of CNO ex Kiribati will continue to move in lockstep with changes in the world price of CNO. Thus, for the purposes of this analysis, it is assumed that the opportunity price of CNO is equal to the world price (with perhaps a slight time lag) less shipping costs to the US West coast, expressed in A$/litre. What is important here is the volatility of CNO prices due to their close linkage to volatile petroleum prices. In general, the more remote the station (e.g. Kiritimati), the higher the cost of delivering diesel fuel to this station, due to the cost of fuel transport. KOIL data suggest that in the third quarter of 2011 these transport cost were approx A$ 0.27 per litre.

The other half of the equation is the relationship between the CNO world price (in A$/litre) and the CNO price ex Kiritimati, which will be lower than the world price due to the cost of shipping CNO from Kiribati to major world trading centres for CNO. An estimate of the average shipping costs has been made, based on the shipping costs of diesel fuel in the other direction, but assuming that the main destination for coconut industry output from the Kiritimati is the US West coast or Hawaii, and assuming that the CNO price prevailing in there is the world price[16]. On this basis, it is estimated that the cost of shipment of CNO from Kiritimati to the USA is approximately 20 percent of the CNO world price or approx A$ 300 per ton. Shipping cost for CNO to the world market is higher than shipping diesel to Kiritibati because CNO has to be shipped in lined 20' containers rather than in tankers. For this analysis it is assumed that the alternative to using CNO as a local fuel would be to ship it to Hawaii or to the US West Cost, where it could be sold at world market price.

In summary, processing 1,500 tons of copra on Kiritimati would produce 825,000 litres of CNO equivalent to 750,000 litre of diesel. Total cost savings in 2013 would be A$ 280,000 from transport cost for copra and 202,000 from transport cost for diesel. Saving nearly A$ 500,000 in transport cost seems attractive, but this calculation is only indicative. In reality savings would be less for a number of reasons: Copra is transported from the Line Islands to Kiritimati on regular supply boats that bring goods to the islands. On their return trip they take copra back to Tarawa. I.e. the government owned company loses revenue when no copra is transported back. In addition, replacing a significant quantity of diesel fuel by locally produced CNO will increase the specific landed cost for the residual diesel that is still needed on Kiritimati as all petroleum product purchase prices are dependent on volume. Thus I reality a savings figure of approximately A$ 250,000 would perhaps be more realistic.

8.3 CNO Production Costs

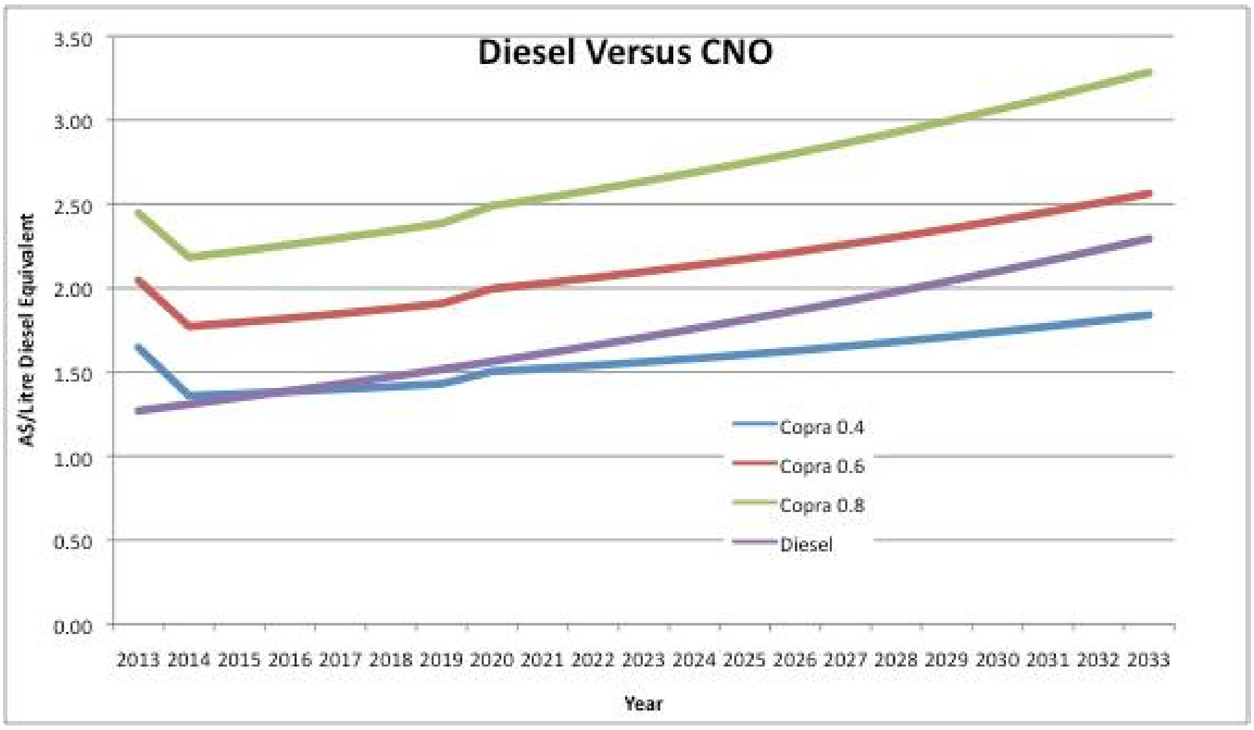
Cost estimates described in the previous section are the basis for the calculation of CNO production cost. Clearly, these costs are mostly driven by the price at which the CNO mill can procure copra. Other important cost parameters are the cost for electricity and the cost for labour. CNO production cost calculations are based on the assumption that a private investor would own and operate the plant. I.e. the calculation includes depreciation, capital amortisation as well as a profit of A$ 0.15 per litre of CNO. It is assumed that average diesel price increase is 3% p.a. the same increase has been assumed for the purchase price of copra. For 2013, the first possible year of operation, a copra purchase price of A$ 0.4 has been assumed. Thereafter, the copra price increases by 3% p.a.

Under this set of assumptions, the levelized CNO production cost (Net Present Value of all CNO production cost/Net Present Value of all Production) is A$ 1.58 per Litre of replaced diesel, i.e. lower than the levelized cost of diesel. As Graph 8.1 shows, the supply cost of CNO is higher than diesel during the first two years of operation, but then drops below the diesel equivalent where it remains throughout the planning horizon.

What Graph 8.1. also shows is the impact of higher copra purchase prices. Whilst the biofuel operation is financially viable at a base copra price of A$ 0.40 per kg, the advantage of CNO as a fuel vanishes at higher copra purchase cost. At the current government subsidised copra price of A$ 0.8 per kg, a biofuel operation would not be competitive with diesel. Even at a base price of A$ 0.6, biofuel would not be viable. In other words a commercially viable CNO production performed by a private sector operator can only work on the basis of a copra price that is equal or at least very close to the world market value of copra in Kiritimati. Annex 4 shows the full cost model for CNO production on Kiritimati.

[16] Note that no production or shipping cost, nor FoB values for CNO ex Tarawa could be obtained from KCML

Graph 8.1: Supply Cost Diesel versus Supply Cost CNO (Diesel Equivalent)



Price Adjustments and Alternative Markets for CNO

Assuming that CNO is produced by a private enterprise an arrangement would be required which protects the investor from world market fluctuations and at the same time protects the interests of the power generator who under this study's set of assumptions would be a government owned entity (MLPI or PUB). Such a protection could be achieved by adjusting CNO buying prices in line with a) the copra price the CNO miller pays and b) adjusting CNO buying prices in line with supply cost of diesel.

However, under certain world market conditions it would be more sensible to sell CNO to the world market rather than burning it as a fuel. Such conditions do occur as a look back to price developments in late 2011 underline. In February 2011, the world market price for CNO peaked above A$ 2000 per ton, whilst diesel prices were in the order of A$ 1,200 per ton or A$ 1.00 per litre. Assuming CNO production cost in the order of A$ 1,200 per ton based on a copra price of A$ 0.40 and transport cost of A$ 300 to the world market, under such conditions, it would have been more profitable to export CNO at a profit of A$ 500 per ton rather than sell it for the energy equivalent value of diesel (A$ 1,270) to a local power producer which would have resulted in a profit of A$ 70 per ton. However, as Graph 8.1 clearly shows, these conditions were short lived and it would not have been practical or even achievable to quickly redirect CNO output to the world market.

8.4 Financial Internal Rate of Return

Under conventional FIRR methodology, an FIRR is calculated for financial capital costs and expected revenues of a project, and compared to the owner's weighted average cost of capital (WACC). Projects with an FIRR exceeding the owner's WACC are financially viable to the owner. As its name implies, the WACC is an estimate of the cost of employing internal and external funds, based on a composite of internally-generated funds and external sources of grants and borrowed funds. The GoK's WACC is not presently known but is likely to be low until its debt-carrying capacity substantially improves. For present purposes, it is assumed that the GoK's implicit WACC does not exceed 5%; this is the rate used for discounting purposes in calculating NPVs.

The financial internal rate of return does not consider the cost involved in building an adequate power supply system for Kiritimati. This is a necessity and is completely independent from the type of fuel used in this power supply. What matters are the incremental costs that accrue to the power plant operator in comparison with the cost avoided by the use of CNO. The analysis considers the CNO price as a given, determined by the production cost plus profit of a private CNO miller. Obviously, this price is mostly determined by the price for which copra can be bought.

Table 8.2 displays the results of an FIRR analysis from the power plant operator's perspective.

Table 8.2: FIRR as a Function of Copra Price

Initial Copra Cost (A$/kg)	0.30	0.35	0.4	0.42	0.44
FIRR	93%	48%	23%	16%	1%

The analysis shows that a base copra price between A$ 0.35 and A$ 0.4 per kg yields acceptable FIRR's. Beyond A$ 0.42 the investment becomes marginal and above A$ 0.44 per kg, the operation started to lose money. However, there are is one potential revenue stream for the mill operator that has not yet been considered: the mill would produce approx. 750 tons of press cake per year. This represents a world market value of A$112,000. As this product does not have high enough a value to be exported, local use as animal fodder could generate considerable additional revenue for the mill.

It can thus be concluded that using CNO in the power generation would financially beneficial to the power systems operator. As discussed, the value of CNO as a fuel has become inextricably bound up in the volatility of the petroleum market, and predictions cannot be made of the future world price of CNO any more easily than they can for the petroleum market. Over the past decade, the prices of CNO and diesel fuel have moved in fairly close synchrony, and there will undoubtedly be periods in the future when one of the fuels or the other enjoys a momentary price advantage. On the ground in Kiribati, the opportunities inherent in using locally-produced CNO as fuel are constrained by the relatively poor state of the coconut industry, the heavy market distortions introduced by a massive government subsidy, the poor state of plantations, the front-end need for investment to get a new industry moving in Kiritimati and the small volumes and high unit costs that are characteristic of production in the remote locations such as Kiritimati.

8.5 Economic Considerations

A successful GoK program to to resettle people from Tarawa to Kiritimati, requires two preconditions to be met: Firstly, the island needs an infrastructure (power, water, sanitation, transport) that is attractive enough for people to move and secondly employment and income opportunities for these new settlers to survive. Under these conditions people are expected to leave Tarawa and ease the cost to provide services to an ever increasing population on Tarawa. In addition, the government or government owned entities would save the transport cost for copra from Kiritimati to Tarawa and those for diesel from Fiji to Kiritimati. At a production level of 1,500 tons of copra p.a. gross savings amount to A$ 280,000 for avoided copra and A$ 216,000 for avoided diesel transport cost. Although net savings would be less than the full amount (due to diluted diesel procurement volume and lack of copra return loads for supply ships, an estimated net impact of at least A$ 300,000 can be expected. This savings could finance the entire power system upgrade costing A$ 2,000,000 and would create an economic internal rate of return of 14% not considering avoided infrastructure cost on Tarawa. However, the government would still have to pay a subsidy of A$ 600,000 per annum for copra being purchased significantly above its world market value. I.e. economically, the copra sector would still be a loss maker, unless the copra price that farmers receive is brought in line with world market prices.

9. Environmental and Social Aspects

9.1 Potential Impacts of Fuel Switch

Large-scale production and use of biofuels as substitutes for fossil fuels can cause severe negative environmental and social impacts. Environmental groups have expressed serious concern about the practice of large-scale clear felling of indigenous forests in Asia and South America for biofuel production projects that would be hard pressed to mitigate over their entire lifetime the carbon emissions they have caused through the destruction of these forests. Additionally, there is also considerable loss in natural habitats and biodiversity.

In Kiribati, such impacts are not expected as long as coconut production levels remain within the range of historical copra quantities achieved in the 80's, i.e. 30,000 tonnes per annum of copra. equivalent or approx 18 million litres p.a. of diesel equivalent. This production quantity could be achieved again through the rehabilitation of existing plantations that have fallen into disuse. From a carbon cycle perspective, it might not make much of a difference if the plantations are brought back into operation for biofuel production or if natural forest regeneration is allowed in these plantations as the latter also has a mitigating impact of CO_2 emissions by creating carbon sinks.

Direct Local Impacts

A local CNO production would involve the construction of an industrial copra mill which would a footprint of approx 5,000 m^2 of which 2,000m^2 would be the actual building holding copra cutters and presses, the balance would be reception of trucks, car park and open storage. As there is no shortage of land at present theses impact are only small and a good industrial design can always avoid or at least mitigate negative visual impacts. The mill would create noise emissions of approx 45 -50 dBA and residential buildings should not be build closer than 100 meters from the factory. In case low quality copra is being used, there might be a strong odour of rancid copra. However, rancid copra does not make a good biofuel and there would be a strong incentive for the mill operator to use only high quality copra. As steam extraction is not recommended for the Kiritimati mill, water use of the facility would be very low, essentially confined to cleaning of the facility. This is important, as clean water is one of Kiritimati's most critical and scarce resources.

CNO when spilled, causes low level environmental damage as large quantities of oxygen are needed to decompose the oil. CNO should therefore be handled in the same way as diesel fuel, although the possible damage from a CNO spill would be significantly less than that from the same quantity of ADO. The cost calculations for all project components include environmental safeguards such as bunded storage and safe transfer pumps.

At the power plant level, CNO use would result in the production of larger quantities of pollutants than a conventional ADO fired power plant. The quantities of disused fuel and oil filters and used engine oil would double, as CNO use requires more frequent changes of filters and lubrication oil. For safe disposal of the engine oils, these should be collected in drums and shipped out for reprocessing or disposal in an incinerator.

Carbon Emissions and Sustainability

Assuming that no land is cleared for the plantation of coconut palms, theory suggests that CNO or other biofuels are carbon neutral – i.e. plant material when burnt releases the same amount of carbon back into the atmosphere as it absorbed (sequestered) during its lifetime. Thus, some proponents claim that biofuels are a suitable global solution for greenhouse gas mitigation. However, once the energy inputs into the farming system in terms of fertilisers, transportation and carbon dioxide released from the soil by tillage etc. are accounted for, the net impact is substantially reduced; varying widely according to crop and production technique. For most current production systems for biofuels (biodiesel from rapeseed oil in Europe or fuel ethanol from corn in USA or from sugar cane in Brazil) the actual reduction of carbon emissions achieved is rather small or even negative, i.e. ill-conceived biofuel projects may even result in more carbon emissions compared with their fossil competitors.

In order to deal with such issues in a scientific and unbiased way the International Energy Agency (IEA) has established Task Force 40 whose mission is to address sustainability issues in biomass trade. One possible approach to avoid ambiguity could be biomass certification according to a number of ecological and social sustainability criteria such as the energy balance, competition with food supply, deforestation, soil erosion, biodiversity, employment, wages and health care. Current certification systems, such as forestry and agricultural certification systems, as well as some first attempt for biomass certification, only cover these sustainability aspects globally. However, coverage of land-use, possible leakage effects and induced land use are critical components that need to be addressed.

In contrast to heavily mechanised large-scale agro industrial biofuel production, CNO production in Kiritimati would reduce carbon emissions. The feedstock would come from existing plantations managed traditionally with little or no use of mineral fertilisers. Copra trying is traditionally performed in the sun, i.e. using coconut husks and shells and occasionally firewood for drying is not practiced and there would be no carbon emissions in the drying process. Short transport distances for copra bought at the roadside would not add large amounts of carbon either and the vehicles could be fuelled fully or partially with CNO. The locally- produced biofuel would not only replace fossil fuels that are locally used but also reduce carbon emissions that are attributed to the transport of fossil fuels from source to the location of consumption.

In conclusion, a biofuel project on Kiritimati Island would have very little if any negative environmental impact. On the contrary the use of CNO as a diesel substitute would greatly reduce the risks associated with the spilling of diesel in an extremely fragile environment such as Kiritimati. The threat that a major diesel oil spill would pose to the economy of Kiritimati cannot be overemphasized. Such a spill would not only diminish Kiritimati's value as a potential destination for ecotourism it would also be a major threat to Kiritimati's most critical resource: Clean drinking water.

9.2 Benefits of CNO Use

The introduction of CNO as a fuel for diesel generation in Kiritimati could potentially bring substantial benefits to the country including, a local market that generates rural employment and income, more resources for rural investment, revived economic development and higher living standards in rural areas and, critically, a stronger and deeper cash economy to support the rural power sector by making uptake of power more affordable to residents of rural areas. For such rural income benefits to accrue, it is not necessary to use locally produced CNO as a fuel. Selling it on the world market would obviously have similar impacts.

Although since about 2005 there has been an apparent price advantage to CNO (ex Kiritimati) compared to diesel use in a power station energy-equivalent CNO and landed diesel prices have tracked each other closely over most of the present decade. Coupled with this, and as discussed further below, the supply of copra to a CNO producer on Kiritimati is not sensitive to the CNO world price, whilst the cost of producing CNO on Kiritimati can only be viable if the CNO producer is not forced to pay more than the world market value for copra (as is the case with the CNO producer KCML in Tarawa. CNO production cost would be relatively high on the world scale, given the small holdings and small volumes involved.

It therefore cannot be said with assurance that CNO will provide a financial advantage to a Kiritimati power supplier over the long term, in comparison with continued use of diesel in the power station. The world price of CNO is quite volatile, reflecting not only changing demand factors (as a substitute for fuel, for other food oils, and as a chemical feedstock) but also changes in short and medium term supply conditions. (An August 6th 2010 article in the journal *Philippine Star* suggests that current increases in the CNO price are related to the current global El Nino phenomenon that causes dry conditions in South East Asia's main coconut productions areas and thus reduces output.)

However, it is equally true that substituting diesel fuel with CNO in Kiritimati is not likely to become a major financial disadvantage to the electricity provider over the long term, given the probable continued close linkage between the CNO and the diesel markets and the inherent flexibility in switching between them as supply and prices fluctuate. CNO offers unambiguous advantages in terms of avoided fuel transport costs and, assuming local CNO supply contracts and arrangements are well managed and sustained, CNO offers a degree of fuel supply security in the outer islands. There, however, are also other local benefits that stem from reduced reliance on diesel fuel:

- Less chance of noxious diesel leakage into the environment;
- A diversified fuel market that increases security of supply;
- Reduced storage risks and less need for maintaining large fuel inventories.

9.3 Food Versus Fuel

Kiritimati and the other outer islands of Kiribati clearly represent a niche market situation where an under-utilised resource (coconuts and land) could be used to replace a critical and costly imported commodity (diesel fuel) while generating local employment and revenue. Local social impacts would be positive and the rehabilitation of coconut plantations would actually increase food security by a) providing additional cash income for local communities and b) allowing to re-introduce the mixed cropping pattern typical for well maintained coconut stands. However, even the outer isalands of Kiribati are not completely isolated from the world market (as was demonstrated in section 8) and thus vulnerable to terms of trade on the global markets.

With mandatory biofuel targets and/or subsidies now in place for the European Union and other industrialised countries a significant increase in demand for oilseeds and vegetable oils for biofuel production could lead to a global food crisis as raw materials are switched to bio energy output. As the global supply and demand balance of the seven major oilseeds tightens there will be a growing incentive for oil seed producers around the world to supply the global biofuel market. While price increases on the world market would initially be positive for Kiribati as a producer and exporter, there is a risk that global trade conditions could contribute to local competition between the local use of coconuts for food and export. This means the risk of negative social impacts need to be carefully monitored and managed. Development of a larger biofuel sector in Kiribati would require special government attention to environmental and food security concerns.

The Kiritimati CNO project would actually quite considerably enhance food security on the island. A mill using 1,500 tons of copra p.a. would also produce 750 tons of nutrient rich press cake. This cake cannot be exported as transport cost in the order of A$ 300 per ton would be higher than its value on the world market (Approx A$ 150 – 200 per ton). However, local used of this cake in animal husbandry could support the production of more than 1,000 pigs per year.

9.4 Carbon Finance

Given the relationship between world commodity prices for diesel and CNO and the large copra subsidy paid by the GoK described above, for CNO to become financially attractive, an additional revenue stream would be highly desirable. Carbon finance would be one option. Clean Development Mechanism (CDM) allows emission reduction projects that assist developing countries in achieving sustainable development and that generate ‘certified emission reductions’ (CER) for use by the investing countries or companies. Biofuel projects could theoretically qualify[17] for CDM and projects in Kiribati could therefore generate an additional revenue stream from the trade of certified emission reductions. This would not apply for projects that are financed using ODA funds. As the baseline is 100 % diesel, calculating emission reductions from renewable energy contribution is straightforward. The UNEP CDM guidebook suggests an emission co-efficient for small diesel grids of 0.8 kg CO_2/kWh generated by renewables. At an assumed average specific fuel consumption of 3.38 kWh per litre of diesel each litre of diesel replaced by CNO equals 2.7 kg of CO_2

Biofuel crop plantations are now eligible for carbon credits under the Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nations, following approval of a new methodology in August 2009. However, conditions are restrictive and it is not clear if the use of coconuts for energy purposes would qualify under the new rules.

[17] As a minimum Kiribati government has to establish a Dedicated National Authority (DNA) for CDM

The methodology – ACM0017 – covers the production of biodiesel for use as a fuel, both in generators and vehicles, but only if used in the country of origin. A CNO project on Kiritimati Islands would fulfill these criteria. The biofuel will only be eligible for carbon credits if it is produced from waste oil or fat, or vegetable oil that is “produced with oil seeds from plants that are cultivated on dedicated plantations established on lands that are degraded or degrading at the start of the project activity”. The application of this condition is not clear-cut in the case of biofuel projects based on CNO. While the oil contained in coconuts that are not harvested and rot on the ground could be considered as waste oil (and would thus be eligible for CDM) eligibility needs to be confirmed. The establishment of new plantings, however would have a high chance of qualifying for CMM.

In addition to CER, there is also trading in so-called "verified emission reductions" (VERs) in what is commonly referred to as the voluntary carbon market. VERs are not a standardized commodity. While they may eventually become CERs there is a risk that this may not happen and therefore buyers therefore tend to pay a discounted price for VERs, which takes the inherent regulatory risks into account. Such opportunities may also be explored.

10. Conclusions and Recommendations

10.1 Resource Base

At present, the Line Islands produce approximately 1,500 tons of copra per annum, equivalent of approximately 750,000 litres of diesel fuel. Maximum copra production since 2005 was 2,400 tons in 2009 and these levels could be expected to be realistic in the future. Sustaining copra production levels, however, would require support for the industry, in particular at the beginning of the supply chain. With existing stocks aged around 50 years, palms are approaching the end of their economic life and need to be replaced by new high quality palms if the copra industry is to be sustained over the next 20 years. Presently there is no program that aims at integrated support for the industry starting with agricultural extension, nurseries and replacement of senile stocks or expanding coconut production areas. Rehabilitation initiatives needed to start with an inventory and classification of existing stocks which would form the basis of a long term management program including agricultural research, stock improvement, nurseries, and a replanting program. In addition, an extension service that upgrades farmers' capacity to produce high quality copra needs to be established.

10.2 CNO as a Substitute Fuel

750,000 litres of diesel fuel is equivalent of 86% of the ADO currently used in MLPI's power supply. Clearly, this offers an opportunity to replace a significant share of imported ADO with locally manufactured CNO. As the CNO market in power generation would already allow the absorption of all CNO produced, it is concluded that a biofuel project should focus on CNO use in power generation, rather than on the much more difficult market for transport fuels.

Experience of the power utilities of New Caledonia, Solomon Islands and Vanuatu has clearly shown that the use of high quality CNO is technically feasible in well engineered equipment operated by properly trained staff. Production of high quality CNO requires high quality copra as feedstock and good working hygiene in the oil extraction processes. It's successful use in diesel engines requires strict adherence to operation protocols. Maintaining CNO temperatures in storage well above the clouding point of approximately 25°C is essential to avoid fuel line and filter clogging. While Kiritimati's ambient temperatures are usually high, nighttime temperatures regularly fall to levels low enough to cause problems with unheated fuel systems. Multiple filtration down to 2 – 5 micron and removal of residual water are essential for trouble free operation of the engines and avoidance of unacceptable engine wear related to the contamination by ash and organic solids. CNO use in standard engines is only sustainable under high engine loadings and the associated high combustion temperatures. CNO use also requires consistent monitoring of parameters such as fuel quality, engine performance, emission characteristics and sump oil qualities.

From the analysis provided above it can be concluded that CNO would be a diesel fuel substitute that is financially competitive in Kiritimati's power stations. CNO production on Kiritimati would not be competitive with imported ADO if a CNO mill had to pay the government fixed copra price of A$ 0.8 per kg. Under the assumption that CNO production is based on a sustainable and fair price for copra in the order of A$ 0.4 per kg, its production and use as a biofuel would provide a profitable business opportunity for a copra mill and at the same time produce a competitive fuel for the power plant operator.

10.3 Implementation Modalities

It is recommended to aim for the establishment of the CNO production as a private sector venture. Investment cost would be approximately A$ 800,000 making the project accessible to private sector funding. This would be in line with GoK's current policy of promoting a stronger role of the private sector in Kiribati's economic development. CNO mills are efficiently operated by the private sector in a large number of countries and no reason could be identified why this should not be possible in Kiritimati. It is further assumed that power supply remains a government task, possibly shifting from MLPI to PUB when a larger integrated system as recommended in this study has been established. A contractual arrangement would have to link copra price, CNO price and diesel supply cost together to protect the interests of both the private operator of the CNO mill and the off-taker of CNO. As incremental investment cost to run on CNO at the power generation would be quite low and therefore not create any significant risk for the government owned power supplier, the CNO miller should be allowed to export CNO if and when market conditions favour this strategy. In such a case, the CNO miller had to provide sufficient notice to the power plant operator in order to allow for the supply of diesel.

In the framework of a new power sector project described under in this study, significant improvements of data recording and reporting will be required. The following procedures are suggested:

- Recording of all standard power station log sheet parameters.
- Recording of ADO and CNO received.
- Recording of CNO and ADO used in the CNO generator.
- Sampling of CNO/ADO mix every 500 hours of operation.
- Sampling of sump oil at every oil change of the CNO generator.
- Recording of fuel filter cartridge use.

Fuel and sump oil samples will have to be analysed at a laboratory (sump oil contamination by CNO and fuel properties of ADO/CNO mix). The records and lab analysis require regular scrutiny by power station management and have to be actioned upon when they are out of line with normal values.

10.4 Financial Viability

It can be said with assurance that CNO will provide a significant financial advantage to CNO mill and power plant operators over the long term, in comparison with continued use of diesel in power generation. However, the world price of CNO is quite volatile, reflecting not only changing demand factors (as a substitute for fuel, for other food oils, and as a chemical feedstock) but also changes in short and medium term supply conditions. The prime driver of CNO production costs is the price paid for copra of suitable quality to local farmers. The cost of copra represents approx 65-70% of total CNO production costs. The other costs associated with CNO production (equipment operation, maintenance, depreciation, personnel, consumables, etc.) are largely fixed and 'modular' in the sense that CNO production is not subject to substantial economies of scale, at least not in the scales obtainable and practical on Kiritimati. Fluctuations in the world price of CNO translate quickly and directly into the export value for CNO and/or copra. As a rule of thumb, it can be concluded that whenever the world market price for CNO is more than A$ 700 per ton above the price for a ton of CNO, it would make more sense to sell CNO on the world market and use diesel as a local fuel. Historically these conditions were met for about three months in 2011.

The financial advantage that indigenous CNO has over imported diesel is that it avoids international and local shipping costs from remote supply markets, since it is produced and used locally. It cost approx A$ 270 per ton to bring diesel from the world market to Kiritimati and approx A$ 300 to ship a ton of CNO out to the world market. In general, the smaller and more remote the station the higher the cost of delivering diesel fuel to the outstation, due to the costs of fuel transport. In addition, there is the cost of shipping copra from Kiritimati to Tarawa that could clearly be avoided if a local CNO production was established in Kiritimati. Assuming that a CNO mill can access copra in Kiritimati at A$ 0.4 per kg, which equals approximately the world market price, then CNO could be sold to a local power producer cheaper than the equivalent ADO cost. The power producer had to make an incremental investment to equip a power plant with the gear needed to use CNO in dual fuel mode. In addition, there would be additional incremental operating cost. Considering these cost, the investment would still yield a robust 23% FIRR.

10.5 Economic Considerations

At present, the copra industry is a heavy burden for the GoK. Subsidies include a 100% premium over the world market value of copra (currently approx A$ 400 per ton) and up to A$ 320 in transport cost from the Line Islands to Tarawa. In addition to these significant market distortions there are massive, unexplained discrepancies in the purchase of copra through KCCS and milling by KCML. Between 2005 and 2011, 22,000 tons or copra that has been bought by KCCS has not been accounted for. At present purchase price of A$ 0.80 per kg, this represents a value of A$ 18 million. It is not recommendable to invest in any new project in the copra industry unless these discrepancies can be explained. It is therefore recommended to conduct a full audit of both KCCS and KCML as a first step towards the development of a viable biofuel industry in Kiribati.

There is no doubt that milling copra on Kiritimati makes economic sense. Net transport cost savings would be approximately A$ 300,000 p.a. for diesel to Kiritimati and for copra from Kiritimati to Tarawa. The savings would reduce the subsidy burden on the GoK. CNO use will not fundamentally change a Kiritimati power supplier's financial position, if the contract price between the copra mill and the power supplier is fixed to the price of diesel. It is equally true that substituting diesel fuel with CNO is not likely to become a major financial disadvantage to the power supplier over the long term, given the probable continued close linkage between the CNO and the diesel markets and the CNO millers flexibility in supplying the world market rather than selling to the local power producer. CNO offers unambiguous advantages in terms of avoided fuel transport costs and, assuming local CNO supply contracts and arrangements are well managed and sustained, CNO offers to the power supplier a degree of fuel supply security in the outstations.

The introduction of CNO as a fuel for power generation in Kiritimati could potentially bring substantial benefits to the country including, a local market that generates rural employment and income, more resources for rural investment, revived economic development and higher living standards in rural areas and, critically, a stronger and deeper cash economy to support the rural power sector by making uptake of power more affordable to residents of rural areas. For such rural income benefits to accrue, it is not necessary to use locally produced CNO as a fuel. Selling it on the world market would obviously have similar impacts. There, however, are also other local benefits that stem from reduced reliance on diesel fuel:

- Less chance of diesel leaks contaminating the environment,
- A diversified fuel market that increases security of supply,
- Reduced storage risks and less need for maintaining large fuel inventories.

On the global level there is also the impact of a reduction in net greenhouse gas emissions, which accrues due to the low-tech method of copra production (very little mechanisation, no use of mineral fertilizers etc).

As discussed, the value of CNO as a fuel has become inextricably bound up in the volatility of the petroleum market, and predictions cannot be made of the future world price of CNO any more easily than they can for the petroleum market. Moreover, the opportunities inherent in using locally-produced CNO as fuel are constrained by the relatively moribund state of the once-vibrant coconut industry, the poor state of plantations, the front-end need for investment to get the industry moving again, and the small volumes and high unit costs that are characteristic of production in the outer islands.

10.6 Introduction of CNO in Kiritimati Power Station

It is strongly recommended to integrate and expand the Kiritimati power system to a level where the entire London Cassidy corridor can be covered. This project is considered a necessary precondition for a successful resettlement program. Such a project would be independent from the fuel the generators would use and cost approx. A$ 2 million. It would be desirable to locate a new power station and a CNO mill close together to minimize transport cost. CNO can be delivered to a central power station in Kiritimati at costs competitive with the supply cost of imported diesel. Two options exist to use CNO in such a power station: the use of a blend containing up to 30 % and the operation of generators in dual fuel mode using 90% CNO.

It is recommended to opt for a dual fuel configuration which could absorb all CNO produced from Line Island copra. Initially the use of a blend would allow the familiarisation of operators to the new fuel and allow the CNO mill to ramp up production to full capacity. Quality control and operating protocols need to be firmly established before shifting to dual fuel mode, otherwise the use of CNO as a diesel substitute could end in disappointing failure.

Annex

Annex 1: Contacts During Mission

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Annex 3 Biofuel Experiences in the Pacific Region

In the following, successful CNO biofuel operations in the electricity sector in Pacific Islands are described. The author of this study has visited these installations and is the team leader for the ADB funded biofuel project in Auki, Solomon Islands.

1. ENERCAL, New Caledonia

1.1 Oil Milling Operation

Ouvea is a low lying atoll which has been one of the major coconut producing areas of New Caledonia. The existing oil mill is has been operating for more than 15 years and is completely independent from the power utility. It is organized as a farmers' co-operative with the intention to provide local farmers with a stable income from copra. The mill buys copra at price significantly above world market price. At present the gate price is 100 XFP/kg (1.14 US$/kg). This price is subsidized by the Provincial Government of the Loyalty Islands, but despite its high level, the oil mill has difficulty to obtain a sufficient copra to use its production capacity. In 2008 no CNO was produced due to both technical problems with the milling equipment, the installation of a new production line and lack of copra. In 2009 and 2010 the mill succeeded to obtain local copra but had to import significant quantities of copra from Vanuatu. The mill supplies a soap factory which is located adjacent to the mill, excess oil is supplied to ENERCAL which can take up to 360 liter per day. A cosmetics manufacturer in Noumea also buys smaller quantities which are used for shampoo and body lotions. Oil is sold at XFP 80 per litre (0.91 US$/l) at the factory gate. Press cake is sold at 0.60 US$ per kg. According to the mill manager the mill is not able to meet a strong demand for press cake which is used locally as chicken, cattle and pig fodder. At an estimated combined total processing cost of US$ 1.30 per kg of copra the oil mill makes a loss of US$ 0.55 per kg of copra.

New fully automatic CNO mill Ouvea

CNO Storage Tanks and Oil Dispensing

The oil mill has two production lines with a combined production capacity of 1,800 litres per day (single shift). Expellers and press filter units are fit into standard 20' shipping containers. After single stage cutting of copra to approx. 5 mm size, the copra is fed into an electrically heated container (90 °C) from where it is automatically fed into a conventional screw type expeller. After the expeller the oil is fed into a settling tank from where it is pumped through a press filter. After filtration the CNO is stored in two external 15,000 l tanks (insulated and heated). The oil is dispensed to clients through a fuel pump type arrangement where a second stage filtration to 10 Micron takes place.

2.2 CNO Use Ouvéa Power Station

CNO use for power generation in Ouvéa, in New Caledonia, has started in 1995 when a first generator set of 90kVA running with 100% coconut oil was installed to power the copra mill of Ouvéa Island. CNO has also been trialled in a Toyota Hilux, water pumps driven by CI engines and, in 1999, a 200 kVA generator which supplies power to the desalination plant of the island.

The initial engines were indirect injection (IDI) dual tank engines with heating of the CNO tanks to cope with CNO solidification under 25°C a temperature that is often reached in New Caledonia. The dual fuel systems were developed with assistance from the French research and science organisation CIRAD.


Cummins Sets Power House Ouvéa


Fully Automated Power Station

In 2004, the power utility ENERCAL (co-owned by the Government of New Caledonia and two French utility companies) installed a purposely designed duel fuel 300 kVA Caterpillar generator set engineered and supplied by Energie Relais of France18. The unit is fully integrated in the Ouvéa Power Station which supplies the entire island through a distribution network of 90 km of 15 kV overhead lines and 90 km low voltage ABC power cables. The power station also holds 4 Cummins 650 kVA generators. At a peak load of 800 – 900 kW, the power station fulfils the N-1 planning criterion (not counting the CNO unit). The CNO installation is well engineered and consists of:

- a fuel reception unit with bag filter 10 Micron
- a 15,000 l heated main storage tank
- a heat exchange system that taps into the cooling water circuit of the CNO generator
- a 500 l secondary (day) tank with electrical heater and secondary bag filtration unit (5 Micron)
- a 300 kVA Caterpillar dual fuel genset with final CNO filtration to 2 Micron and automatic switching capability from diesel oil to CNO .


Fuel Reception


Bag Filter


Heated Tank

Both main tank and CNO fuel line are heavily insulated in order to avoid heat loss as Ouvéa frequently experiences temperatures below 25 °C. Operating temperature of the main tank is 60 °C. Heating water circulation is controlled by a temperature sensor in the tank which determined the quantity of cooling water required to maintain the set temperature. The fuel line is integrated into the insulation of the heating/cooling water circuit and ends in the 500 l day tank where an electrical heater maintains an operating temperature of 45 °C prior to injection into the engine.

[18] http://www.energie-relais.com/


Daytank, Fuel meter, Filter


Final filter


Filter change

The Caterpillar engine model 3406 is directly injected (DI) and is only operated on CNO at 75 % load (180 kW) or above. Given the load curve of Ouvéa, the unit is operated in parallel with one of the 650 kVA Cummins sets from 8.00 a.m. until 2 p.m. provided there is sufficient CNO available. As the load increases towards the evening peak, a second 650 Cummins is brought online and the CNO is switched off. Start and stop is strictly on diesel with an automatic switching to CNO for exhaust temperatures of 460 °C or above. At 460 °C the engine operated at 75% load or higher. Fuel return is separated, i.e. when operated on CNO excess fuel is returned to the CNO day tank, when operated on diesel, fuel is returned to diesel day tank.


3406 Engine with duel fuel lines


Cooling water circuit


Temperature sensor at exhaust

When in operation the caterpillar engine consumes 60 l of CNO per hour at 90% load which equals a specific fuel consumption of 3.6 l CNO per kWh. The CNO set uses the same lube oil as the other sets, a Shell Rimula 15 W 40 grade. Maintenance intervals are standard engine oil and oil filters are changed after 250 hours of operation. The CNO filters, however, are checked on a daily basis and exchanged as required and are an additional cost.

ENERCAL has an agreement with the oil mill to purchase CNO at the same price it pays for diesel fuel supplied to the power plant. There is no adjustment in for lower calorific value of CNO. Fuel prices in New Caledonia are regulated by the government (monthly adjustments) and ENERCAL pays the same taxes as any other diesel user and only gets a small volume discount from the fuel supplier. Currently supply cost for diesel are US$ 0.95 per l. ENERCAL quotes total cost of US$ 570,000 for the CNO facility including engineering, transport, installation, tanks, heat exchanger system, automatic fuel control and electrical integration in the fully automated power station. These cost are significantly higher than those typically quoted in studies and reports. From a financial perspective, the project does not generate any benefits for ENERCAL. Motivation for the project was a desire to support the local farming community and to perform practical research and gain experience with the technology.

2. UNELCO Vanuatu

UNELCO is a subsidiary of GDF Suez, one the leading French utility and energy concerns. In Vanuatu, CNO use as a substitute fuel dates back to the 90ies when UNELCO ran its first small generator set on coconut oil. Other initiatives include the various automotive fuel mixes (kerosene CNO and diesel CNO) encouraged by a reduced government tax on biofuels.

2.1 Oil Milling Operation

In contrast to the ENERCAL operation UNELCO Vanuatu has established CNO mill, which is dedicated to fuel production only. The decision was taken after initial CNO trials in UNELCO's medium speed generators proved successful but CNO supply from Vanuatu's largest CNO mill in Luganville on the island of Santo was inadequate both in terms of quality and quantity. The UNELCO mill is located only 100 meters from the Tagabe power station which allows transfer for CNO via an underground pipeline. UNELCO aims to buy good quality copra directly from farmers at a beach price of 25 Vatu/kg (0.26 US$/kg).

The utility then organizes transport to Port Vila costing approx 0.04 US$ per kg. The buying strategy is based on geographical diversification in order to avoid supply interruptions in case of plant disease or cyclone. Incoming copra is stored in a shed next to oil mill and processed with conventional milling equipment consisting of a copra cutter and a screw press. Milling capacity is 1,600 litres per 2 shift day.

Copra Cutter

Screw Press

Filter Press

The CNO is pumped via a small piston pump trough a press filter and then stored in a settling tank. Before transferring the CNO to an underground storage tank at the powerhouse, CNO is pumped through a conditioner which consists of a 4 stage filtration (100-80-50-10 Micron) an electrical heater and a vacuum separator. CNO is heated to 70 °C and exposed to a vacuum of 0.08 bar resulting in a reduction of water content to 0.2 %. The conditioner has a capacity of 600 l/hour.

Piston Pump

CNO Conditioner

UNELCO quotes a total electricity consumption of 0.132 kWh per litre of CNO produced including all lighting of the facility. Production cost of CNO is estimated to be US$ 0.70 per litre. CNO is thus competitive with today's supply cost for diesel (0.85 US$/l) even after adjustments for lower calorific value. UNELCO currently constructs a new oil mill, which will have a capacity of 6,000 litres a day. Components such as the CNO conditioner have already been dimensioned with this expansion in mind.

2.2 CNO Use Tagabé Power Station

CNO use in the Tagabé power station was carefully introduced in close collaboration with the manufacturer of the two medium speed 9L32/40 MAN engines of 4 MW each. The engines are designed for both heavy fuel oil and diesel use but are equipped with an injection system for diesel fuel. The engines are pre-chamber or indirect injection type. CNO fuel in the power plant is first stored in a tank that heats the CNO to 70 °C via heat exchangers using engine cooling water. The tank is connected to a 600 l/centrifuge that reduces water content to 0.1 % and reduces other contamination. The tank content is repeatedly circulated through the centrifuge.

Heating Tank 2,000 l

Centrifuge

Heat Exchangers

From the heating tank CNO is transferred to a 10,000 l main tank which is also heated through cooling water. This tank sits next to the heating tank and maintains a temperature of 40 °C. CNO leaving this tank is send through 3 parallel filters of 10 Micron and is pumped into the power house where it is send through two identical arrangements for each engine. The first step is sending CNO through a 5 Micron bag filter.

From the bag filter the CNO is pumped through a battery of 4 parallel filters of 5 Micron to a 500 l day tank, which is electrically heated to maintain a temperature of precisely 50 degrees. The day tanks are equipped with a dosimeter pump that maintains a pre-set blending ratio. The pumps are controlled by the engine loads and calculate the blend ratio by using the typical specific fuel consumption above 75% load of 200 gr/kWh.

The dosimeter pump also shuts off the CNO when the load of a generator drops below 3 MW, an event that is usually avoided as the two generators are used as base load units. Prior to mixing with diesel, CNO is send through a final fuel filter of 5 Micron. Four 800 kW containerized high speed generator sets normally pick up load fluctuations above base load.

Day Tank with Dosimeter Pump

4 MW MAN Engines

Fuel Return

Blends of up to 30% CNO have been successfully used, but due to limited availability of CNO, UNELCO currently set the blending ratio at 15%. The engine manufacturer carefully monitors both fuel quality (water, acidity, cetane number and total contamination). Sump oil samples are also regularly analysed for CNO contamination and polymerisation. Excess fuel blend is returned to the main diesel tank. UNELCO currently contemplates to pre mix a fuel in a tank in order to have better control of the actual CNO content as the fuel return into the main diesel tank leads to an accumulation of CNO in the mix.

3. SIEA Auki, Solomon Islands

3.1 Oil Milling Operation

CNO for the Auki pilot project is sourced from a local oil mill. The mill was established to produce CNO for soap manufacturing and uses a standard Tinytec mill including copra cutter, expeller and filter press. Total investment cost for the milling equipment is approximately US$ 7,500. For the pilot biofuel operation a contract to supply 5,000 l of CNO per month has been concluded between the miiler and the power utility SIEA. The supply contract has a quality clause which commits the miller to the following standards: The CNO will have a water content of no more than 0.5 per cent, a total contamination of no more than 50 milligram per kilogram and a fatty acid content of no more than 2.5 per cent.

The initial price for this contract was set at A$ 1.3 per litre which is essentially equivalent to the supply cost for diesel fuel to the provincial capital of Auki. The price is pegged to the supply cost for diesel in Auki. The oil miller only buys high quality copra at a current price of A$ 0.35 per kg.

3.2 CNO Use at Auki Power Station

CNO is supplied in 200 l drums and pumped into a CNO storage tank via an electrical drum pump. CNO received at the power plant is tested in an on site laboratory for water content, total contamination and free fatty acids. Oil that does not meet the specs described above is rejected. From the main CNO tank the oil is send through a multi stage filtration unit that also contains a vacuum separation unit. This unit produces a very clean CNO that is than pumped into a heated day tank. The CNO is blended with diesel oil and a variety of blending ratios have been tested. The generator also has a diesel day tank, which makes a ‘dual fuel operation’ possible. Unlike the ENERCAL installation in New Caledonia all switching is done manually. This reduces isnvestment cost drastically.

The biofuel project in Auki employs a standard 350 kW Cummins generator. This brand was selected because it is the standard equipment that SIEA uses in their outer island power stations. The generator can be syncronized with two other sets in the powerhouse. The diesel engine is equipped with an additional (second) fuel filter and a low low load warning horn, which alerts the operator in case the system load drops below 60% of the maximum load.

4. Conclusions

The technical feasibility of using CNO as a fuel for compression ignition engines has been proven beyond any doubt in two different approaches: the use of 100 % CNO in a dual fuel configuration in New Caledonia and as a fuel blend containing up to 30% CNO. Operations show that successful CNO use starts with good quality feedstock (copra) having a moisture content of not more than 5 – 6 %. Good working hygiene and consistent control of key parameters are also essential. Operations achieve a high quality of CNO through multiple stage filtrations and dewatering through vacuum separator and/or centrifuge. Operational problems related to high viscosity and pipe blockages caused by solidification of CNO is avoided through consistent control of temperatures of storage and transfer systems. Both operations use a combination of cooling water heat (heat exchangers) and electrical heating.

While the UNELCO operation appears to be financially viable at today’s supply costs for diesel fuel, ENERCAL considers its CNO use as a corporate contribution to rural development on the Island of Ouvéa. At the same time the CNO production there receives a very substantial subsidy from the provincial government. Both operations share a common problem: fluctuations in oil production due to unavailability of copra. ENERCAL does not seem to contemplate an expansion of their CNO use. UNELCO on the other hand is currently expanding its CNO milling capability in Port Vila and is installing two new duel fuel generators of 100 kVA each as a power source for a small rural grid on the Island of Malecula. The Auki operation is financially neutral to the SIEA. Here, the positive economic impacts of local CNO production and use are the main objective of the project.

Annex 4: Lay Out of Backbone Power Supply Kiritimati

Annex 5: CNO Production Cost Model

Input Requirements		
Variable Costs		
Price of Copra, delivered 2013 (A$/kg)	$	0.40
Electricity Required per litre of CNO (kW		0.20
Electricity Price (A$/kWh)	$	0.40
Fixed Costs		
Manager	$	40,000
Labour Required (FTE)		10
Wages (A$/hr)	$	3
Annual Wages	$	57,600
Materials, other O&M	$	25,000
Site Lease	$	20,000
Depreciation (A$/year)	$	40,667
Total Fixed Costs	$	183,287
Capital Amortisation	$	32,258
Expected Profit (A$/litre CNO)	$	0.15

Cash Flow for ~2,000,000 max litres of CNO per year

CNO Mill O&M Costs A$	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Variable O & M										
Offer Price of Copra, delivered (A$/kg)	$ 0.40	$ 0.41	$ 0.42	$ 0.44	$ 0.45	$ 0.46	$ 0.48	$ 0.49	$ 0.51	$ 0.52
Copra Required (tonnes)	727	1,526	1,602	1,682	1,767	1,855	1,948	2,045	2,147	2,255
Copra Purchase Cost	$ 290,909	$ 626,712	$ 679,952	$ 735,366	$ 785,301	$ 860,118	$ 930,217	$ 1,005,330	$ 1,088,021	$ 1,175,535
Electricity Required (MWh)	80.00	167.99	176.25	185.07	194.32	204.03	214.24	224.95	236.20	248.01
Electricity Cost	$ 32,000	$ 67,144	$ 70,501	$ 74,026	$ 77,728	$ 81,614	$ 85,695	$ 89,979	$ 94,478	$ 99,202
Total Variable Costs (A$)	$ 322,909	$ 695,856	$ 750,453	$ 809,394	$ 873,028	$ 941,732	$ 1,015,912	$ 1,095,309	$ 1,182,500	$ 1,275,337
Annual Fixed O & M Costs (A$)										
Manager	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000
Wages	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 115,200	$ 115,200	$ 115,200
Materials, other O&M	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Building Lease	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000
Depreciation	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667
Total Fixed Costs	$ 183,267	$ 183,267	$ 183,267	$ 183,267	$ 183,267	$ 183,267	$ 183,267	$ 240,867	$ 240,867	$ 240,867
Capital Amortisation	$ 32,258	$ 32,258	$ 32,258	$ 32,258	$ 32,258	$ 32,258	$ 32,258	$ 32,258	$ 32,258	$ 32,258
Expected Profit	$ 60,000	$ 125,885	$ 132,180	$ 138,789	$ 145,738	$ 153,026	$ 160,677	$ 168,711	$ 177,147	$ 186,004
Total O&M Costs (A$)	$ 598,444	$ 1,037,298	$ 1,098,178	$ 1,153,729	$ 1,234,302	$ 1,310,293	$ 1,392,124	$ 1,537,858	$ 1,632,782	$ 1,735,037
Output ('000 litres)	407	835	881	925	972	1020	1071	1125	1181	1240
Total O&M Cost per Litre at the Mill	$ 1.498	$ 1.236	$ 1.248	$ 1.258	$ 1.270	$ 1.284	$ 1.300	$ 1.367	$ 1.383	$ 1.399
Cost of CNO per litre of diesel displaced	$ 1.65	$ 1.33	$ 1.37	$ 1.39	$ 1.40	$ 1.41	$ 1.43	$ 1.50	$ 1.52	$ 1.54
Delivered Diesel Price (A$/litre)	$ 1.27	1.31	1.35	1.39	1.43	1.47	1.52	1.56	1.61	1.66
Difference (row 61 row 60)	$ (0.38)	$ (0.35)	$ (0.02)	$ 0.00	$ 0.03	$ 0.06	$ 0.09	$ 0.06	$ 0.09	$ 0.12
CNO Fuel Cost	$ 598,444	$ 1,037,298	$ 1,098,178	$ 1,153,729	$ 1,234,302	$ 1,310,293	$ 1,392,124	$ 1,537,858	$ 1,632,782	$ 1,735,037
Savings From CNO Use	$ (150,298)	$ (43,126)	$ (20,630)	$ 4,035	$ 31,051	$ 50,658	$ 93,055	$ 65,139	$ 103,886	$ 146,264
Total Diesel no Biofuel (Litres)	807,407	847,776	890,167	934,675	981,409	1,030,479	1,082,003	1,136,103	1,192,909	1,252,554
Total Diesel Cost no biofuel	$ 1,025,407	$ 1,109,979	$ 1,199,550	$ 1,297,138	$ 1,402,522	$ 1,517,152	$ 1,640,000	$ 1,774,325	$ 1,919,149	$ 2,075,559
Incremental Cost Biofuel Use	$ 103,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
Net Benefit	$ (253,258)	$ (53,126)	$ (30,630)	$ (5,965)	$ 21,051	$ 50,658	$ 83,055	$ 55,139	$ 93,895	$ 136,264
FIRR	23%									
Levelized Production Cost CNO A$/L	$ 1.43									

CNO Mill O&M Costs A$	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	203
Annual Variable O & M											
Offer Price of Copra, delivered (A$/kg)	$ 0.54	$ 0.55	$ 0.57	$ 0.59	$ 0.61	$ 0.62	$ 0.64	$ 0.66	$ 0.68	$ 0.70	$
Copra Required (tonnes)	2,367	2,486	2,610	2,740	2,878	3,021	3,172	3,331	3,498	3,673	
Copra Purchase Cost	$ 1,272,586	$ 1,375,312	$ 1,488,482	$ 1,609,753	$ 1,740,881	$ 1,882,882	$ 2,036,337	$ 2,202,258	$ 2,381,785	$ 2,575,801	$ 2,78
Electricity Required (MWh)	260.41	273.43	287.10	301.46	316.53	332.36	348.97	366.42	384.74	403.98	4
Electricity Cost	$ 104,162	$ 109,371	$ 114,839	$ 120,581	$ 126,610	$ 132,941	$ 139,588	$ 146,567	$ 153,895	$ 161,590	$ 16
Total Variable Costs (A$)	$ 1,376,758	$ 1,485,583	$ 1,603,321	$ 1,730,334	$ 1,867,601	$ 2,015,822	$ 2,175,924	$ 2,348,865	$ 2,535,681	$ 2,737,491	$ 2,95
Annual Fixed O & M Costs (A$)											
Manager	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 40,000	$ 4
Wages	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 115,200	$ 11
Materials, other O&M	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 2
Building Lease	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 2
Depreciation	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 40,667	$ 4
Total Fixed Costs	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 240,867	$ 24
Capital Amortisation	$ 32,268	$ 32,258	$ 32,268	$ 32,268	$ 32,268	$ 32,268	$ 32,268	$ 32,268	$ 32,268	$ 32,268	$ 3
Expected Profit	$ 195,304	$ 205,070	$ 215,323	$ 226,089	$ 237,394	$ 249,263	$ 261,727	$ 274,813	$ 288,554	$ 302,981	$ 31
Total O&M Costs (A$)	$ 1,845,198	$ 1,953,997	$ 2,091,779	$ 2,229,568	$ 2,378,130	$ 2,538,221	$ 2,710,788	$ 2,896,813	$ 3,097,389	$ 3,313,807	$ 3,54
Output ('000 litres)	1302	1367	1435	1507	1583	1662	1745	1832	1924	2020	
Total O&M Cost per Litre at the Mill	$ 1.417	$ 1.437	$ 1.457	$ 1.479	$ 1.503	$ 1.527	$ 1.554	$ 1.581	$ 1.610	$ 1.641	$
Cost of CNO per litre of diesel displaced	$ 1.56	$ 1.59	$ 1.60	$ 1.63	$ 1.65	$ 1.68	$ 1.71	$ 1.74	$ 1.77	$ 1.80	$
Delivered Diesel Price (A$/litre)	1.71	1.76	1.81	1.87	1.92	1.98	2.04	2.10	2.16	2.23	
Difference (row 61 row 60)	$ 0.15	$ 0.18	$ 0.21	$ 0.24	$ 0.27	$ 0.30	$ 0.33	$ 0.36	$ 0.39	$ 0.42	$
CNO Fuel Cost	$ 1,845,198	$ 1,953,997	$ 2,091,779	$ 2,229,568	$ 2,378,130	$ 2,538,221	$ 2,710,788	$ 2,896,813	$ 3,097,389	$ 3,313,807	$ 3,54
Savings From CNO Use	$ 192,583	$ 243,109	$ 288,304	$ 358,543	$ 424,263	$ 495,940	$ 574,089	$ 629,269	$ 752,087	$ 863,199	$ 96
Total Diesel no Biofuel (Litres)	1,315,182	1,380,941	1,449,988	1,522,487	1,598,611	1,678,542	1,762,469	1,850,593	1,943,122	2,040,278	2.14
Total Diesel Cost no biofuel	$ 2,244,717	$ 2,427,332	$ 2,625,516	$ 2,839,486	$ 3,070,915	$ 3,321,194	$ 3,591,872	$ 3,884,009	$ 4,201,205	$ 4,543,003	$ 4,91
Incremental Cost Biofuel Use	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 1
Net Benefit	$ 182,553	$ 233,109	$ 288,304	$ 348,543	$ 414,263	$ 485,940	$ 564,289	$ 643,259	$ 742,087	$ 843,139	$ 953

Annex 5: On Site Biofuel Laboratory

A site laboratory needs to be maintained on the powerhouse site. All necessary equipment to conduct tests on the CNO to determine free fatty acid (FFA) content, water content and total sediment have to be provided. Two reagents, AR grade sodium hydroxide and phenolphthalein indicator are classified as dangerous goods and require special arrangements when brought in by plane using a registered dangerous goods carrier.

Laboratory Equipment

The following equipment is regarded as the minimum necessary to monitor the quality of the CNO received by the power plant operator for use as fuel.

Reagents: AR grade Sodium Hydroxide granules (1000g)
Isopropanol to use as solvent 10 litres
Phenolphthalein indicator

Hardware: 3 decimal figure top loading balance 0 - 200gm
magnetic stirrer hot plate
5 X magnetic stirrer magnets
3 X thermometers to 105°C
1 X hand pump vacuum filtration system
2 X buchner funnels to fit filter papers below.
10 X packets of 2 micrometer filter papers
2 X 500ml vacuum flasks
2 X rubber stoppers to fit buchner funnels and vacuum flask
1 X burette stand and burette clamp
2 reagent spatulas
4 pairs clear safety glasses
10 boxes of large fitting latex disposable gloves

Glasswear: 10 X 75mm watchglasses
2 X glass stoppered storage vessels (1000ml capacity)
2 X 10ml measuring cylinders
2 X 50ml measuring cylinders
2 X 100ml measuring cylinders
2 X 250ml measuring cylinders
4 X 250ml conical flasks
2 X 50ml burette
2 X 10ml pipettes
1 X rubber pipette suction bulb to fit 10ml pipette
2 X 25ml pipette

1 X rubber pipette suction bulb to fit 25ml pipette

2 X 50ml pipette

1 X rubber pipette suction bulb to fit 50ml pipette

4 X 100ml pyrex beakers

4 X 250ml pyrex beakers

The total cost of all laboratory equipment including transport to Kiritimati is estimated at was A$ 6,000.