# Supply Chain Analysis of Coconut Biofuel: Findings from Fiji

Conan Hales, CFA

Consultant to the World Bank

# Introduction

- Island locations in the Pacific are heavily dependent on fossil fuel imports, which are exposed to increased global oil prices
- In 2011, I undertook research in the field of coconut oil used as biofuel as part of a postgraduate thesis for the Imperial College London
- This was sponsored by the World Bank and with the co-operation with the department of energy of Fiji
  - Focus on the pilot operation on the remote island of Koro

# About the Research

- Purpose of the study is to examine the economic aspect of the entire supply chain for coconut oil biofuel production
- Identify how value is shared by the actors involved in the production of biofuel
- Research may be used to form policy recommendations
- We are looking to answer the question:
  - Does it make sense to replace diesel fuel with coconut oil?

# Outline

Context of mini-mills on remote islands

Technical feasibility of coconut oil as a fuel

Supply-chain analysis

Financing the mill

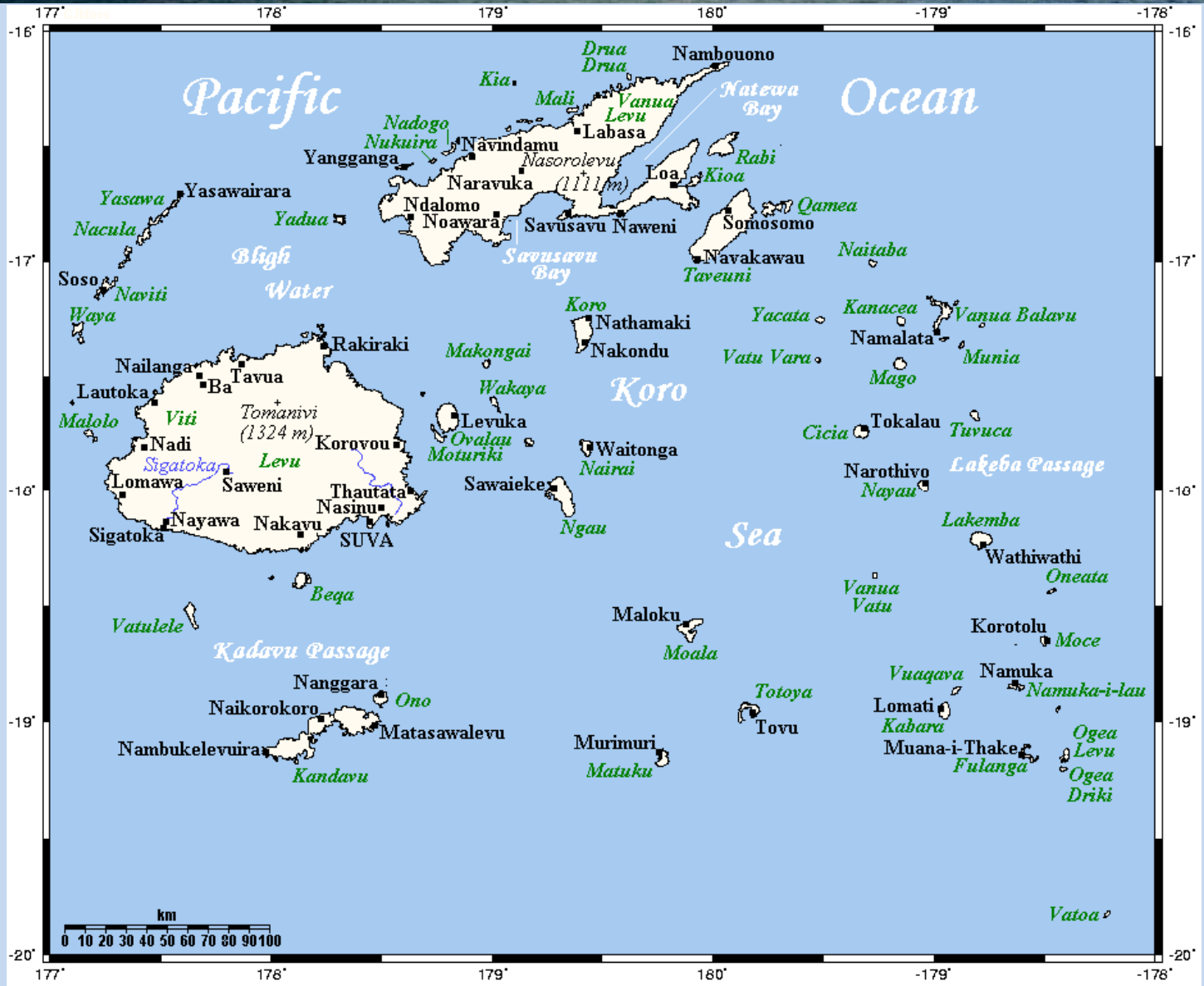
Summary

Setting the context

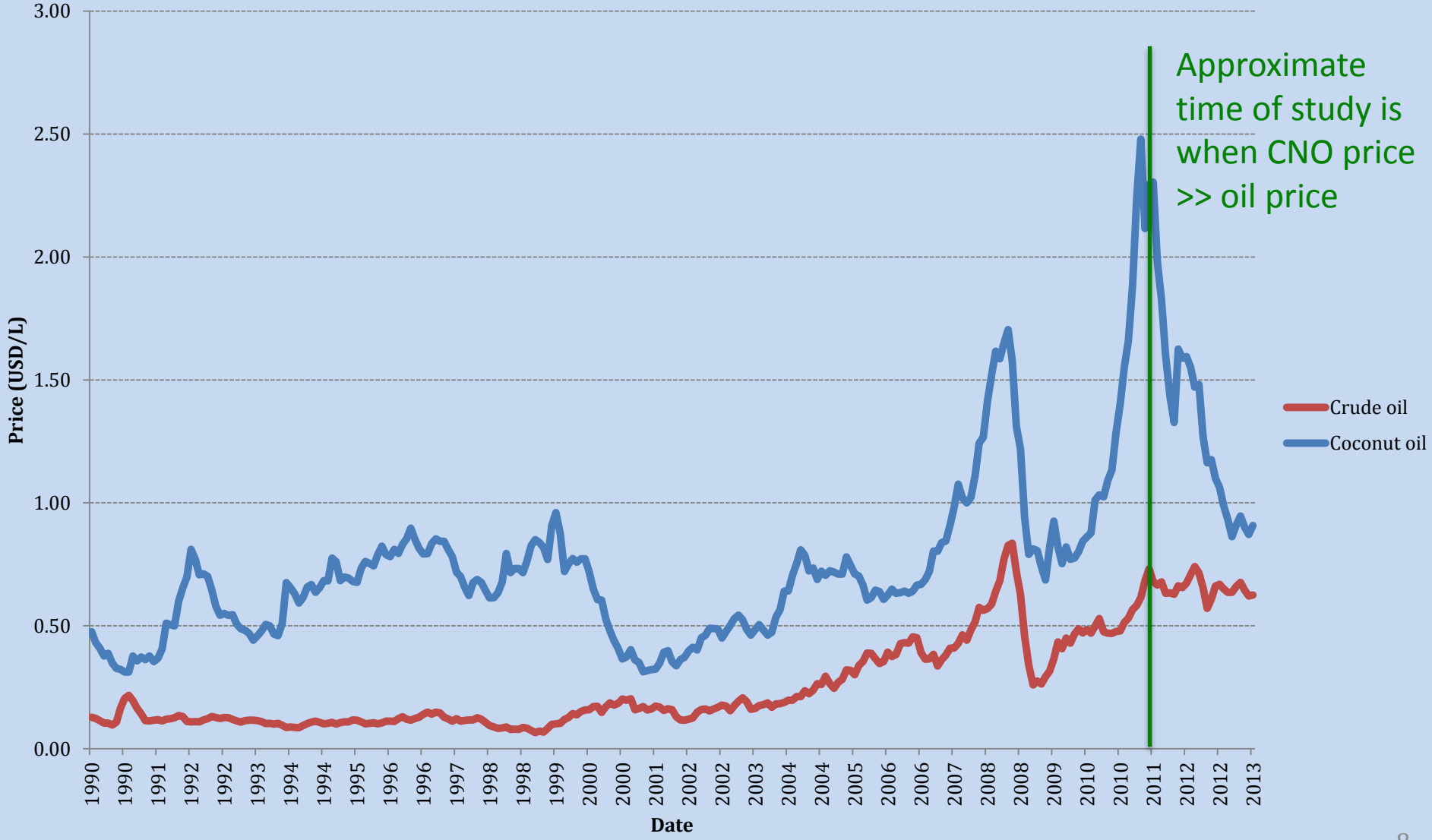
# MINI-MILLS ON REMOTE ISLAND AND GLOBAL PRICES

# What is a Mini-mill?

# Where is Koro island?



# Global Price Comparison of Coconut Oil and Crude Oil



# Question

- Does it make sense to use coconut oil to replace diesel fuel on the remote islands?
- Answer depends on:
  - Total coconut resources available after food consumption needs
  - The cost of coconut oil production
  - The landed cost of diesel on the remote island
  - Non-economic costs or benefits associated with coconut oil production

Fuel characteristics and engine modification options

# FEASIBILITY OF COCONUT OIL (“CNO”) AS A FUEL

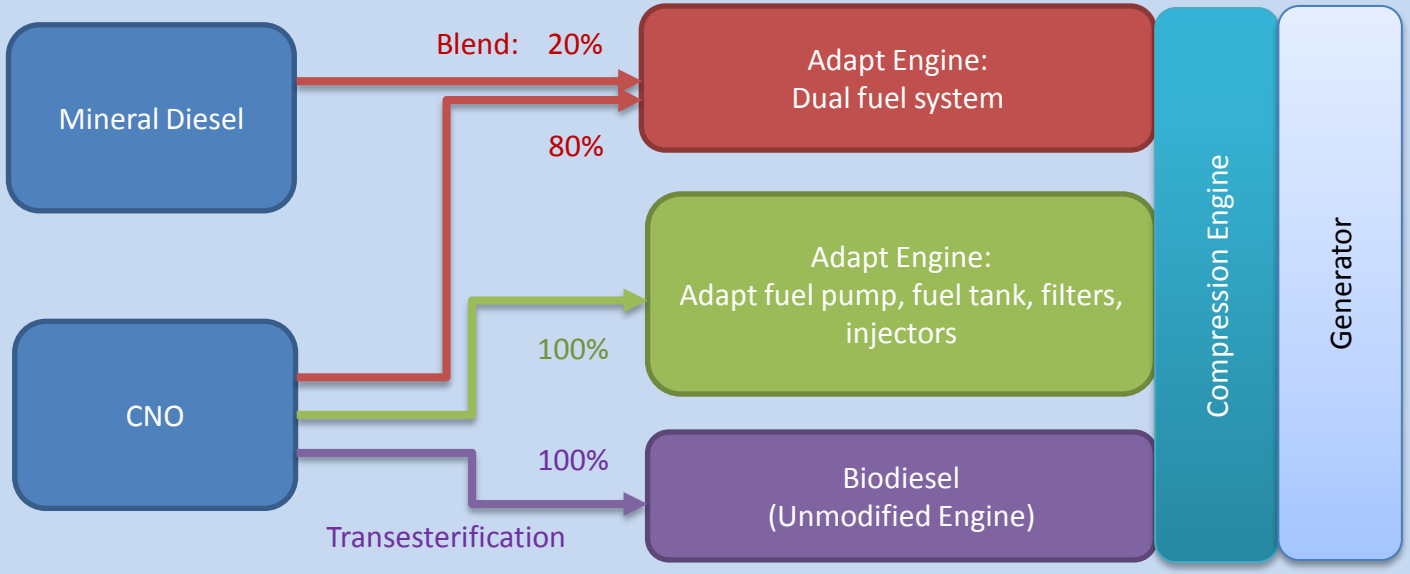
# Technical Feasibility of Coconut oil as a fuel

- Much research published that indicated coconut oil ("CNO") is a viable alternative to diesel fuel
  - "Coconut Oil Power Generation: A how-to guide for small stationary engines", World Bank, 2009

| Fuel | Specific energy (MJ/kg) | Density (kg/m$^3$) | Cetane number | Kinematic Viscosity (cSt 40°C) | Solidification Temp. (°C) | Flash point (°C) |
|---|---|---|---|---|---|---|
| Diesel fuel | 42.6 | 828 | 40–55 | 2–4 | -9 | >62 |
| CNO | 35.8 | 915 | 60–70 | 27 | 22–25 | 200–285 |

# Modification options of using CNO in diesel engines

- At least 3 options considered for using CNO as a fuel in diesel engines:
  - Adapting Engines for 80% CNO and 20% Mineral Diesel
  - Adapting Engines for 100% CNO Use
  - Biodiesel
- *First option most suited to remote island setting due to simplicity and cost*




Reference: Jan Cloin, "Cocogen: Feasibility Study Into The Use Of Coconut Oil Fuel In Epc Power Generation" 2008

# Solutions to the challenges of CNO biofuel

| Situation | Problem that will arise | Associated solution |
|---|---|---|
| High moisture content in copra (greater than 6%). | • Production rate of CNO drops.<br>• Moisture content in biofuel. This has a high chance of affecting the power output of engine. | • Ensure moisture content in copra is decreased by re-drying copra. |
| Large particles in settling tank entering the CNO filter. | • CNO filter clogs and shuts down.<br>• Frequent shut downs and washing of filters occur delaying oil production time. | • Ensure one or two days are allocated for settling to allow the large particles in the CNO to settle to the bottom.<br>• Avoid sudden movement of the settling tank or stirring of the settled CNO during decanting for filtering.<br>• Frequent cleaning of the settling tank. |
| CNO in settling tank has high viscosity (or solidifies) in the colder months. | • CNO filter clogs and shuts down. | • Use heater installed in the settling tank to heat CNO. (Care must be taken not to overheat CNO, which may result in a fire hazard) |
| Large particle sizes in biofuel | • The large particles will quickly clog the generator fuel filters. Clogged fuel filters result in reducing the flow of fuel to the combustion chamber in the biofuel engine resulting in a breakdown or 'choking'. | • Ensure that the CNO filter is frequently cleaned.<br>• Biofuel blending tanks are covered at all times.<br>• Avoid any dust/particles entering exposed/open areas in storage and blending tanks. |

Reference: Singh, R. (2010) Economic Feasibility Of The SOPAC-CATD Biofuel Project, Nadave, Tailevu, Fiji Islands.

# Sustainability of Feedstock

- Total resource assessment crucial to ensure feedstock sustainability after existing consumption
- Satellite imagery technique may be used to count trees
  - E.g. On Rotuma island the estimated production is 7.5 million nuts per year using this technique, of which the harvestable number is 5 million and after consumption of 1.5 million leaves 3.5 million for biofuel stock or about 690,000 litres of biofuel. This is about 3x the diesel consumption
- Coconut palms typically intercropped with other food sources, reducing competition for land

Reference: Gerhard Zieroth with Leba Gaunavinaka and Wolf Forstreuter "Biofuel from Coconut Resources in Rotuma"

The economics of the biofuel

# SUPPLY CHAIN ANALYSIS OF CNO FUEL PRODUCTION

# Electricity Generation on a Remote Island

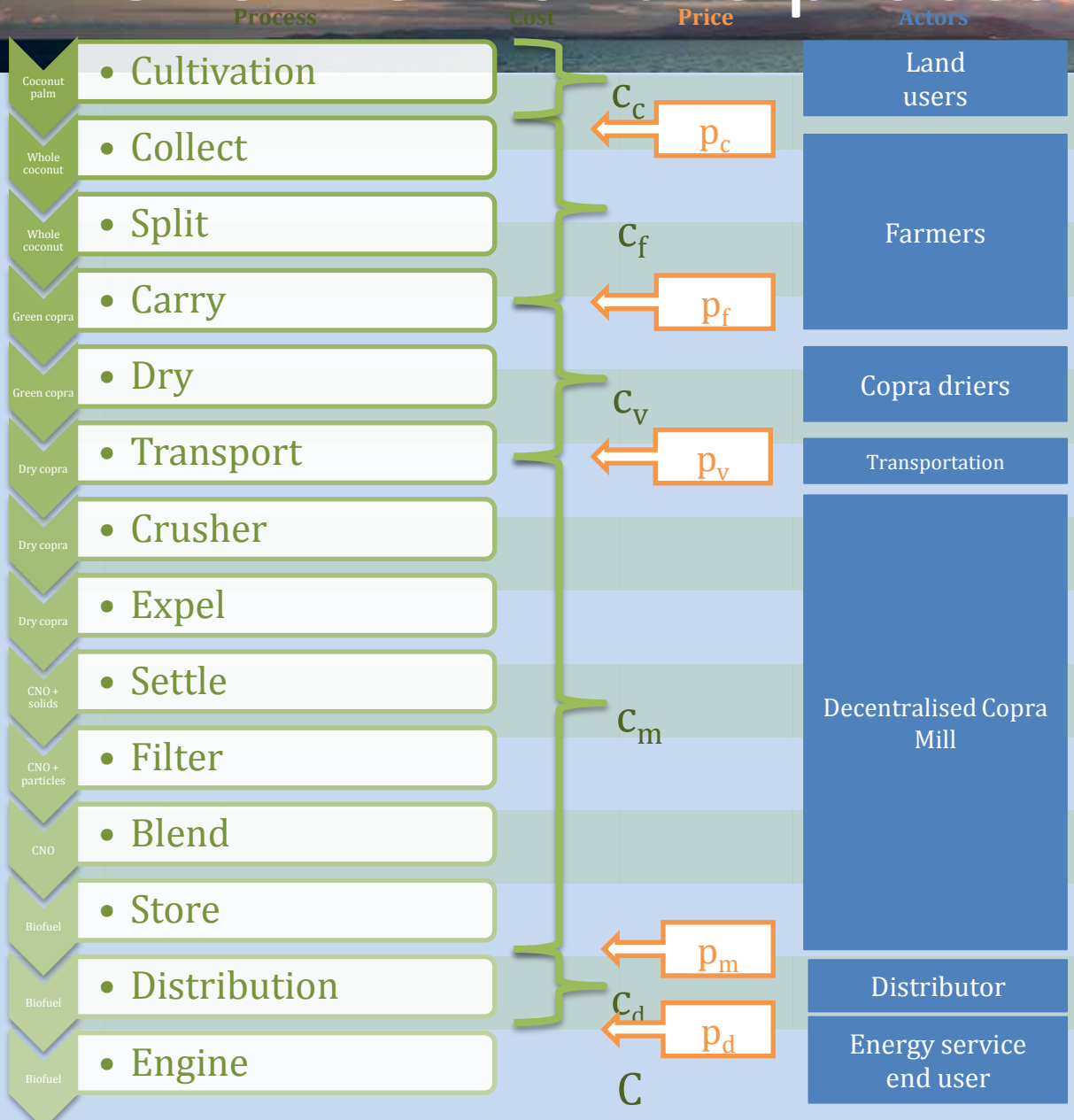

**Farmer**
- Cultivates
- Collects
- Cuts

**Dryer**
- Transports
- Dries

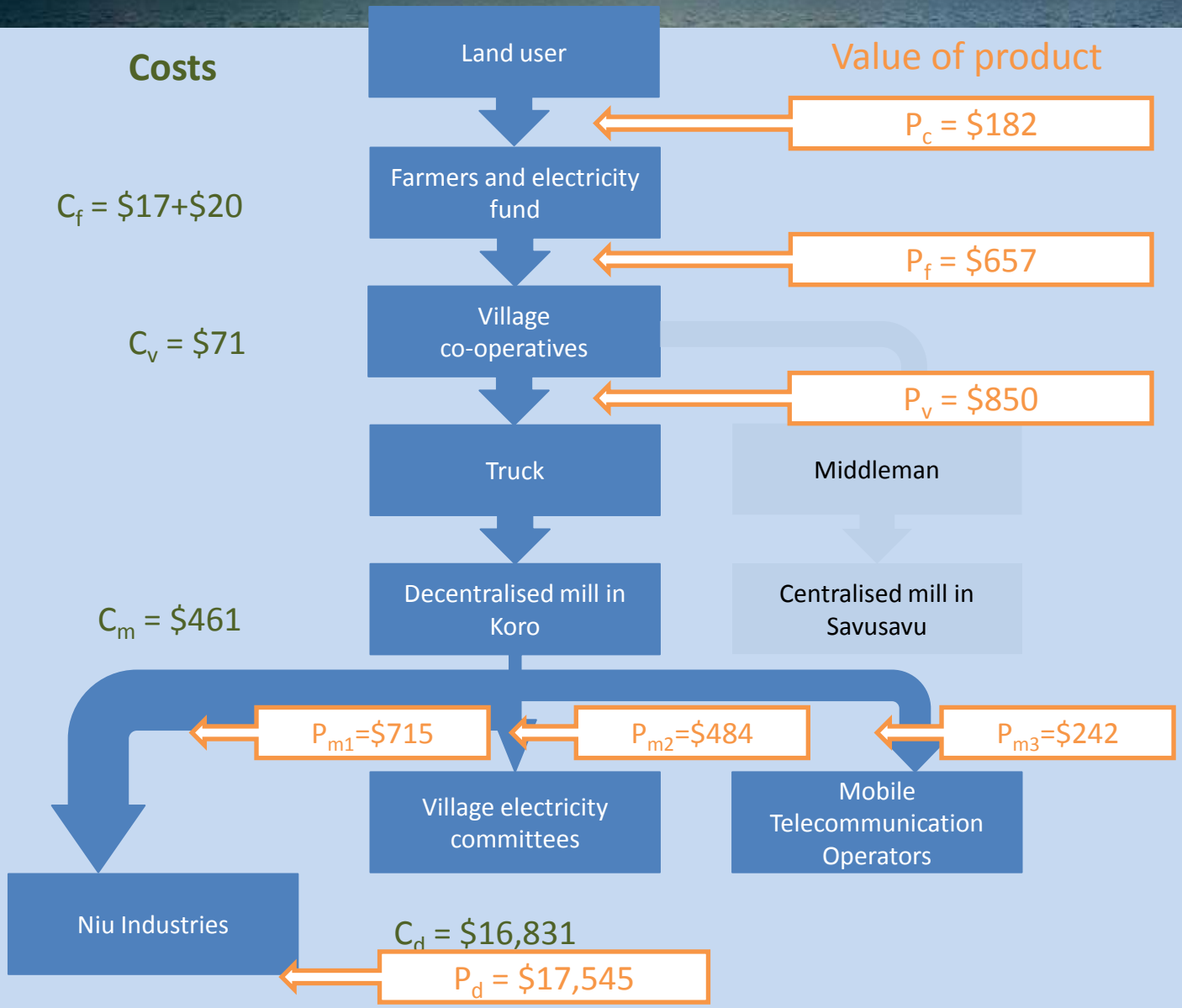
**Mill**
- Crushes
- Expels
- Filters
- Settles

**Generator**
Electrification

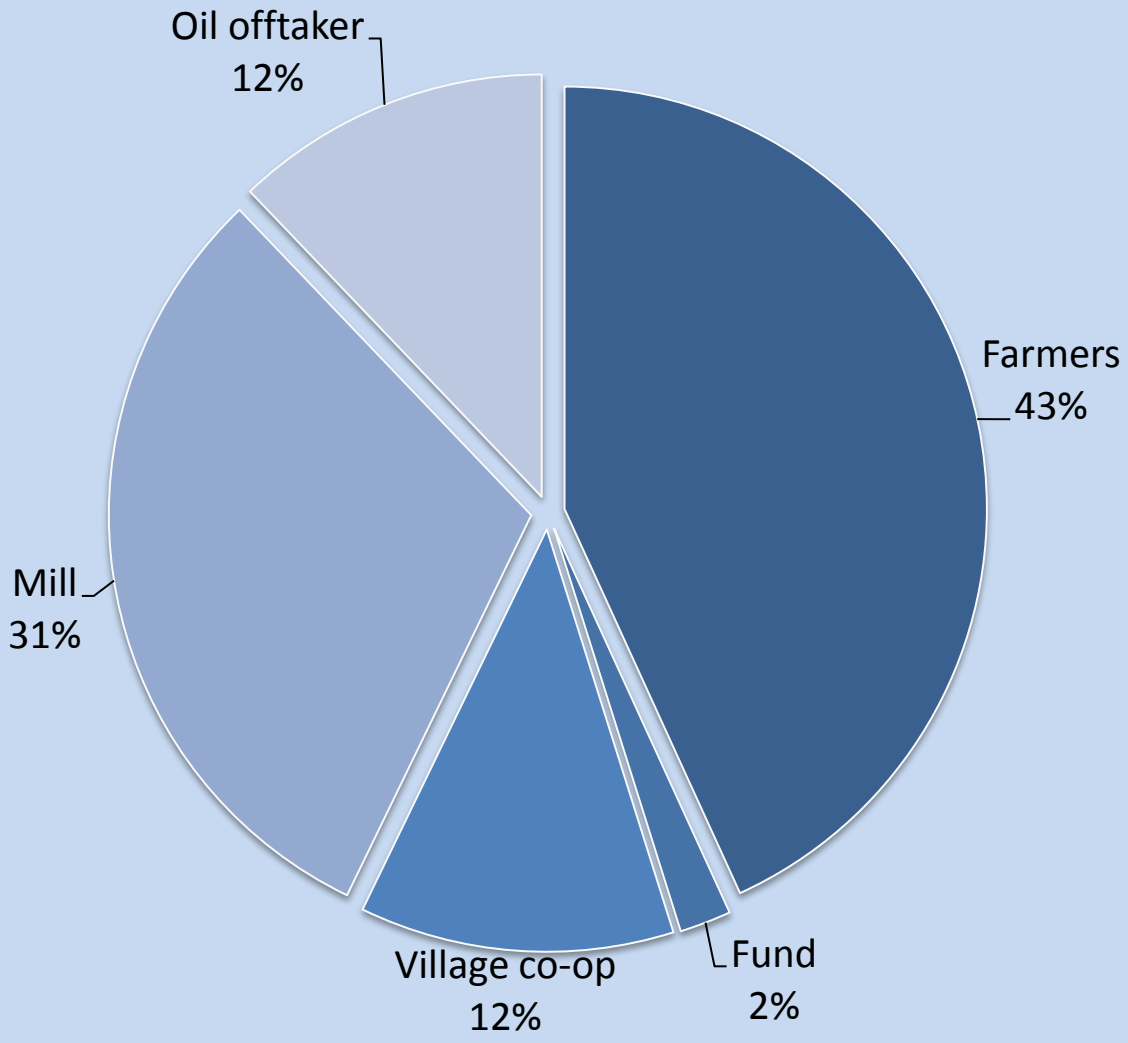
# Overview of the process and prices



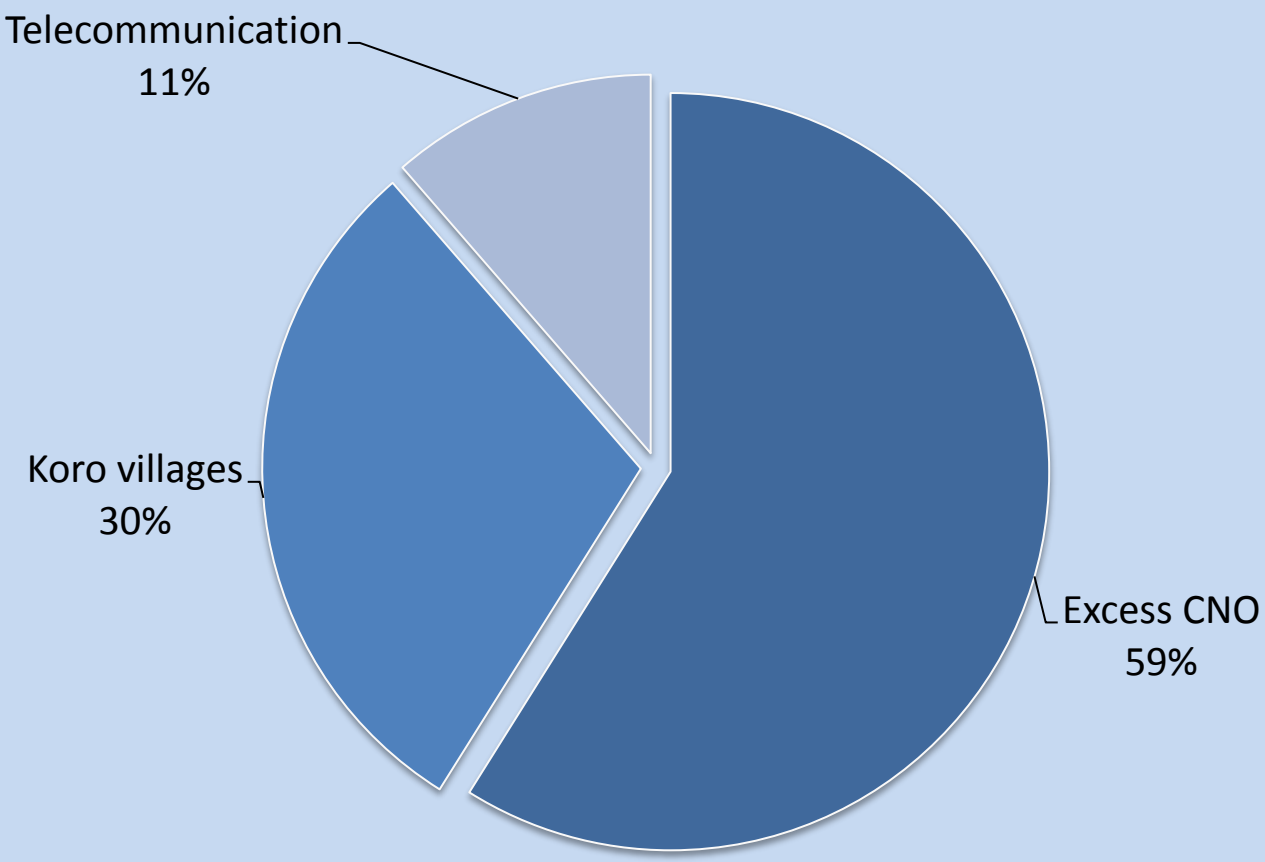
# Supply chain of Koro Mill



# Share of estimated profits (/T of dry copra)



# Estimated Market Share of Biofuel End-users



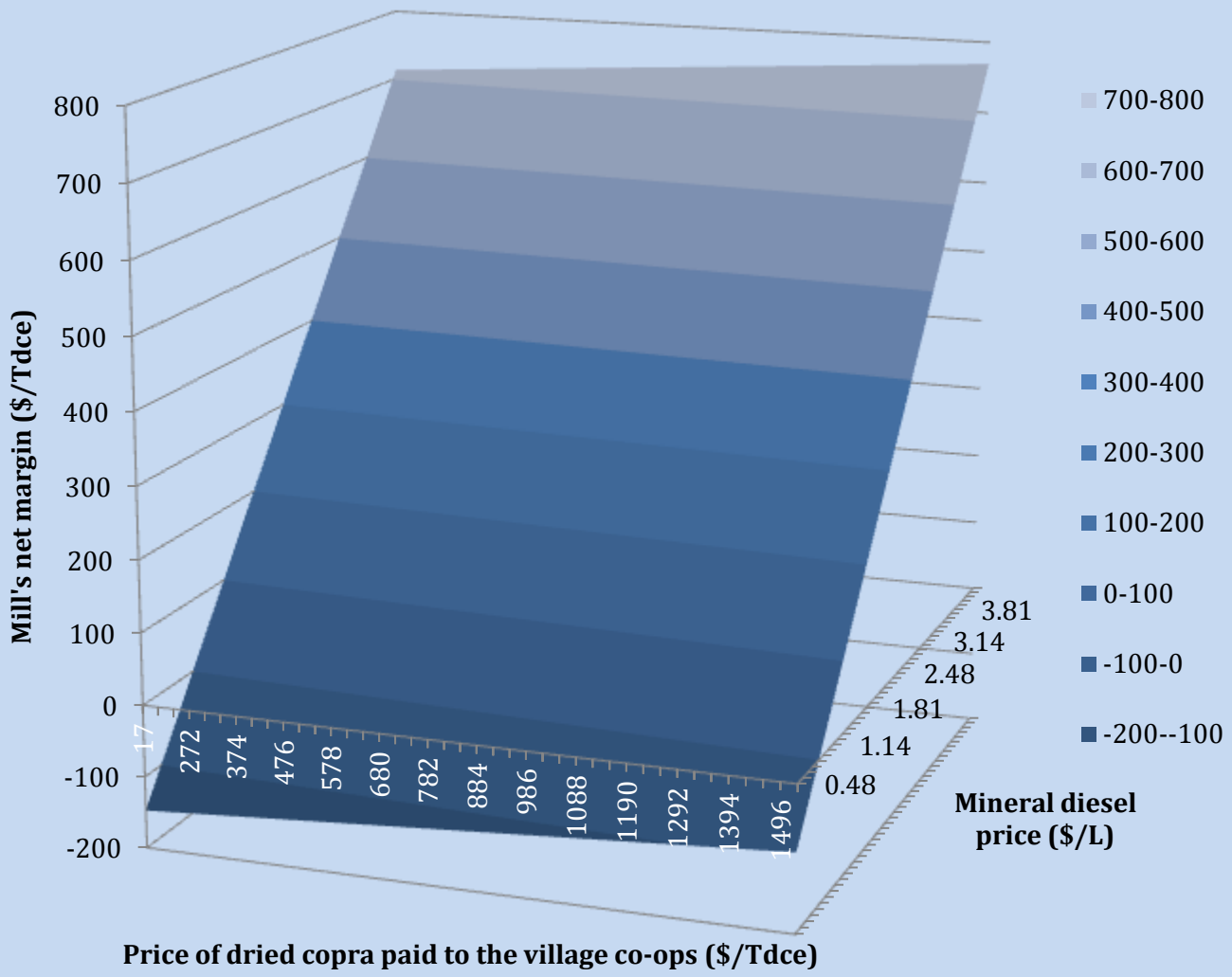
Cost of production of CNO fuel

# FINANCIAL ANALYSIS OF THE MINI-MILL

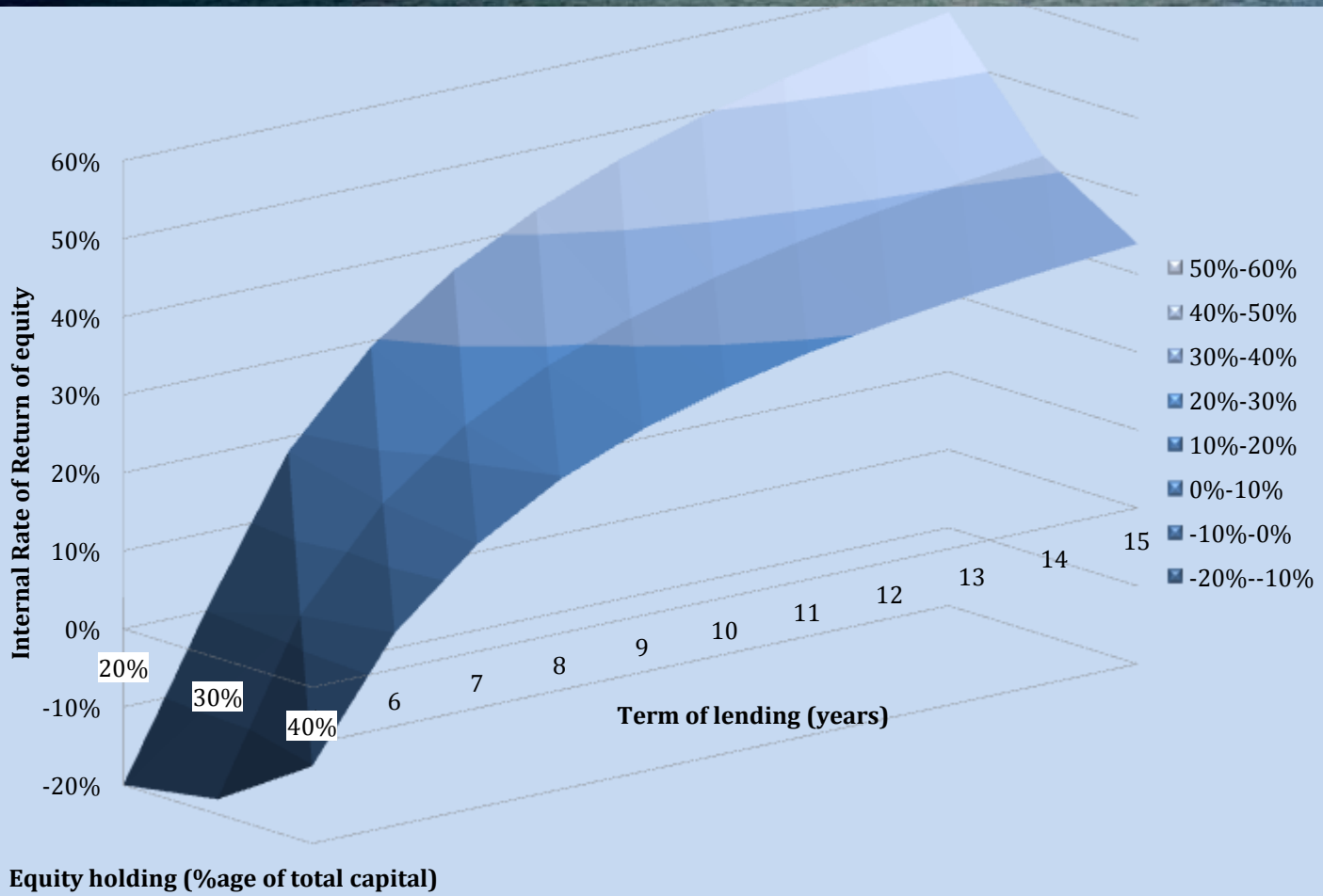
# Economics of the decentralised mill

| | Copra (kg) | Diesel (L) | 70% Bf (L) | 80% Bf (L) | CNO (L) | Meal (kg) | Costs | Rebate |
|---|---|---|---|---|---|---|---|---|
| Production (CNO vol) | | | 74 | 176 | 397 | | | |
| Input | 1,000 | 76 | | | | | | |
| Daily production | | | 105 | 220 | 397 | 350 | | |
| Price | $850.00 | $2.38 | $2.30 | $2.20 | $1.80 | $0.52 | | |
| Wages | | | | | | | $148.75 | |
| Catalyst | | | | | | | $40.73 | |
| Overheads | | | | | | | $69.72 | |
| Truck | | | | | | | $32.17 | |
| 0.13c on diesel (/L) | | | | | | | | $9.82 |
| Subtotal | -$850 | -$180 | $242 | $484 | $715 | $182 | -$291 | $10 |
| | | | | | | | | |
| Profit/Loss | $311 | /day | or | | | $6,738 | /month | |
| | | | | | | | | |
| Cost of production (/L) | | | $2.03 | $1.96 | $1.70 | | | |
| Implied CNO price (/L) | | | $2.27 | $2.16 | | | | |

# Sensitivity of Mill's Profit to Diesel and Copra Prices



# Return on Equity for Mill Financing




| | Equity holding | | |
|---|---|---|---|
| Term (yr) | 20% | 30% | 40% |
| 5 | -42% | -18% | -10% |
| 6 | 0% | 3% | 5% |
| 7 | 18% | 15% | 14% |
| 8 | 29% | 23% | 20% |
| 9 | 37% | 28% | 24% |
| 10 | 42% | 32% | 27% |
| 11 | 46% | 35% | 29% |
| 12 | 50% | 37% | 31% |
| 13 | 52% | 39% | 32% |
| 14 | 54% | 40% | 33% |
| 15 | 56% | 41% | 34% |

IRRs for various tenors and leverage were calculated assuming debt can be financed at 9%
All the profit goes to equity as excess cash-flow after paying interest on debt

# Supply-chain analysis of larger mills

- Centralised milling operations exist in some Pacific island countries (E.g. Fiji, Vanuatu)
- Centralised mills benefit from economies of scale for CNO production, however, fuel prices may be expensive if cost of delivery is expensive to remote locations.
- Needs further investigation on a case-by-case basis

# SUMMARY OF FINDINGS

# Summary of Findings

- Remoteness of the island is a key factor for high diesel prices and lower costs of production
- Farmers are significant beneficiaries in the supply chain
- Koro mill should be profitable, and should benefit the island's economy
- Access to the outside market for the coconut oil is important
- The current distributor is exposed to falls in diesel price, so it is important to find a more reliable oil off-taker
- New mills on other islands could be financed on commercial terms
- Regular quality control of the biofuel is important for consumer confidence and avoiding long-term technical issues
- There is potential to improve traditional copra methods in the supply chain
  - E.g. Use of solar drying instead of thermal drying which can contaminate the copra
  - Poor handling of the wet copra increases aflatoxins and FFAs
- Once a mill is established, there are potential upgrade opportunities for production of higher quality oil for human consumption and use of other parts of the nut such as the husk and shell

# Findings from Other Case Studies in the Pacific Islands

There is a consensus that *CNO used as a fuel is technically feasible* based upon Taveuni, Vanua Balavu, Koro, EPC Samoa, ENERCAL Ouvéa, Vanuatu island fuel and PNG Fisheries case studies. Despite the technical feasibility, the four categories of issues which have either prevented or caused pilot projects to fail are:

**Policy**

- Subsidies are preventing economic biofuel production in Kiribati and Rotuma
- Laws are preventing sale of biofuel for vehicles in Vanuatu

**Technical**

- Non-trivial techniques of refining fuel for transport engines in PNG fisheries and Vanuatu cases.
- There was no engineer to fix the generator in Welagi, but that was subsequent to the decision to run the generator on mineral diesel

**Feedstock**

- Competition from dalo was the primary issue in Welagi
- Supply and quality issues existed in Ouvéa
- There is also a potential feedstock risk from cyclones

**Socio-economic**

- There was a failure to understand the community structure in Vanua Balavu, and farmers sold copra for a better price to the central mill as they did not receive benefit from the local mill

# Benefits of CNO biofuel

- Potential to reduce fuel import bills
- Reduces total greenhouse gas emission balance if it displaces mineral diesel
- Compared to solar PV, the levelised cost is cheaper
  - F$0.73/kWh versus F$0.86/kWh
- Relies on basic, proven and affordable technology
- Remote islands benefit from energy security by relying less on imports

# Reference

- The research is publically available on the Linked-in profile under Conan Hales