FEASIBILITY STUDY INTO THE USE OF 
COCONUT OIL FUEL IN EPC POWER GENERATION

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The **CocoGen Team** consists of: Dr Vincent Bowry (Lipid Chemical Specialist), Chris Cheatham (Power Economist), Jan Cloin (Project Manager), Dr Wolf Forstreuter (GIS Forestry/Coconut Resource Specialist); and Dr Gilles Vaitilingom (Biofuel Specialist).

**ACKNOWLEDGEMENT**

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“SOPAC Community Lifelines Programme acknowledges the opportunity given by EPC and UNDP to contribute to the recent biofuel developments in Samoa, as it has a great potential for replicability throughout the Pacific region. As countries are feeling the impact of the rising oil prices in the last years, it is high time to seek sustainable alternatives.”
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<td>Meaning</td>
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<td>----------------------</td>
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<td></td>
</tr>
<tr>
<td>ASTM</td>
<td>American Product Standard</td>
<td></td>
</tr>
<tr>
<td>CIF</td>
<td>Cost, Insurance, Freight</td>
<td></td>
</tr>
<tr>
<td>CIRAD</td>
<td>French Institute for Agricultural Research in Developing Countries</td>
<td></td>
</tr>
<tr>
<td>COME</td>
<td>Coconut Oil Methyl Ester</td>
<td></td>
</tr>
<tr>
<td>COPS</td>
<td>Copra Oil Production Samoa <em>(Owned by Elan Trading)</em></td>
<td></td>
</tr>
<tr>
<td>DI</td>
<td>Direct Injection</td>
<td></td>
</tr>
<tr>
<td>DME</td>
<td>Direct Micro Expelling</td>
<td></td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
<td></td>
</tr>
<tr>
<td>EIRR</td>
<td>Economic Internal Rate of Return</td>
<td></td>
</tr>
<tr>
<td>EMA</td>
<td>Engine Manufacturers Association</td>
<td></td>
</tr>
<tr>
<td>EN</td>
<td>European Product Standard</td>
<td></td>
</tr>
<tr>
<td>EPC</td>
<td>Electric Power Corporation</td>
<td></td>
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<tr>
<td>FAME</td>
<td>Fatty Acid Methyl Ester</td>
<td></td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organisation</td>
<td></td>
</tr>
<tr>
<td>FFA</td>
<td>Free Fatty Acid</td>
<td></td>
</tr>
<tr>
<td>FIRR</td>
<td>Financial Internal Rate of Return</td>
<td></td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environment Facility</td>
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</tr>
<tr>
<td>GIS</td>
<td>Global Information System</td>
<td></td>
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<tr>
<td>IDI</td>
<td>Indirect Injection</td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>Financial Internal Rate of Return</td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>Mega litre</td>
<td></td>
</tr>
<tr>
<td>MJ</td>
<td>Mega Joule</td>
<td></td>
</tr>
<tr>
<td>MW</td>
<td>Mega Watt</td>
<td></td>
</tr>
<tr>
<td>MNRE</td>
<td>Ministry of Natural Resources and Environment</td>
<td></td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
<td></td>
</tr>
<tr>
<td>PEAR</td>
<td>Preliminary Environmental Impact Assessment Report</td>
<td></td>
</tr>
<tr>
<td>Ppm</td>
<td>Parts per million</td>
<td></td>
</tr>
<tr>
<td>PUMA</td>
<td>Planning and Urban Management Agency</td>
<td></td>
</tr>
<tr>
<td>PV</td>
<td>PhotoVoltaic</td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>PolyVinylChloride</td>
<td></td>
</tr>
<tr>
<td>SPC</td>
<td>Secretariat of the South Pacific</td>
<td></td>
</tr>
<tr>
<td>SOPAC</td>
<td>South Pacific Applied Geoscience Commission</td>
<td></td>
</tr>
<tr>
<td>ST$</td>
<td>Samoan Tala</td>
<td></td>
</tr>
<tr>
<td>STEC</td>
<td>Samoan Government Coconut Plantation</td>
<td></td>
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<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
<td></td>
</tr>
<tr>
<td>VAGST</td>
<td>Value Added Goods Tax</td>
<td></td>
</tr>
<tr>
<td>VOME</td>
<td>Vegetable Oil Methyl Ester</td>
<td></td>
</tr>
<tr>
<td>Conversion Factor</td>
<td>Value</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------------------</td>
<td></td>
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<tr>
<td>ST$ per US$</td>
<td>2.63 (Source: <a href="http://www.xe.com">www.xe.com</a>, June 2005)</td>
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<tr>
<td>Energy Content Coconut/Diesel (volume)</td>
<td>1.08</td>
<td></td>
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<tr>
<td>Density of copra oil [kg/l]</td>
<td>0.915</td>
<td></td>
</tr>
<tr>
<td>Extraction rate of copra oil mill [%]</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

### Coconut Conversion Factors (1,000 Coconuts)

<table>
<thead>
<tr>
<th>Coconut Product</th>
<th>Weight [tonnes]</th>
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<tbody>
<tr>
<td>Coconut</td>
<td>1.2</td>
</tr>
<tr>
<td>Husks</td>
<td>0.39</td>
</tr>
<tr>
<td>Shells</td>
<td>0.17</td>
</tr>
<tr>
<td>Cocowater</td>
<td>0.24</td>
</tr>
<tr>
<td>Green Copra</td>
<td>0.37</td>
</tr>
<tr>
<td>Dry Copra</td>
<td>0.2</td>
</tr>
<tr>
<td>Copra Meal</td>
<td>0.08</td>
</tr>
<tr>
<td>Copra Oil</td>
<td>0.12</td>
</tr>
<tr>
<td>1 m$^3$ copra</td>
<td>0.53</td>
</tr>
<tr>
<td>1 m$^3$ copra meal</td>
<td>0.47</td>
</tr>
</tbody>
</table>

All tonnes in this report are metric, equalling 1,000 kilograms.
EXECUTIVE SUMMARY

Samoa is currently dependent on the import of diesel fuel for a significant part of its power generation. Samoa’s utility Electric Power Corporation (EPC) is looking into viable and cleaner alternatives that make use of an abundant local resource: the coconut. As coconut-based exporting agro industries are struggling, it is also very timely to develop a new domestic market for coconuts. Traditional copra oil production has almost ceased due to the low returns for labour.

Coconut oil can replace diesel fuel using blends, 100% coconut oil, or by converting it into biodiesel (esterification). If blends with less than 10% coconut oil are used, no adaptations to the engine are required, provided it runs in the upper part of the load curve. If a higher percentage of coconut oil is used, alterations to engines are required. For biodiesel made from coconut oil, no alterations to engines are necessary. The production cost of biodiesel from coconut oil is found to be costly. Biodiesel might become a viable option with production based on lower-cost waste vegetable oil.

At this point, the economically most feasible option is using low blends of coconut oil with no engine adaptations. Using higher blends with adapted engines requires additional investment. Because of the problems in the traditional copra oil sector, the only large mill, Copra Oil Production Samoa (COPS) on the island of Upolu, is currently unable to produce sufficient supply of fuel grade oil. It is therefore proposed that EPC produce its own fuel straight from coconuts. This dedicated Coconut Oil Fuel (COF) plant avoids the traditional copra method; instead, it uses a highly-mechanised production process. Having the oil production under EPC management, gives control over quality and quantity, but it comes at a premium price.

The potential resource of coconuts has been assessed using GIS technology. A total harvest of 126 million coconuts per year was estimated, using a custom-built database in operation at the Ministry of Natural Resources and Environment. The coconuts available and accessible for COF have been estimated at 16 million in 2006 climbing to 50 million in 2010. This will require EPC operating a collection system with trucks on the island of Savai’i and farmers receiving a premium return of at least 13 sene per nut.

Technically, it is possible to produce fuel-grade coconut oil at the power station in Savai’i, which can be blended with diesel. It is also possible to adapt a dedicated engine to run on pure coconut oil. The COF plant is envisaged to collect nuts throughout Savai’i and give farmers a cash voucher for their coconuts. A two-phase approach is suggested, in which first a 660,000-litre plant is built. After proof of concept and indications that further coconut supply exists, an expansion to a 1.8 million-litre plant is suggested. The report includes recommendations for the use of by-products such as husks, shells and coconut water. This Renewable Energy source will be in addition to the proposed 1.8 MW run-of-river hydropower dam in Savai’i.

Economically, both phases will be very beneficial for Samoa as a whole. For EPC however, the financial feasibility of phase I is very tight. If Phase II is implemented, greater financial benefits for EPC are foreseen. The financial benefits for EPC are very dependent on the world market developments of diesel fuel price, but even more so on the price per coconut. Therefore, before the project is implemented, a thorough market research including the smallholder farms is suggested.

The real beneficiaries of the proposed Coconut Oil Fuel production project are the farmers and plantation holders in Savai’i through the re-creation of a stable local market for coconuts. Second beneficiary will be EPC through cutting of generation costs that in time might be passed on to the Samoan customers. Finally, the project will have great benefits to the environment of Samoa through a significant reduction of emissions.
1. INTRODUCTION

During the last few years, the Samoan Electric Power Corporation (EPC), together with UNDP-Samoa have been looking into alternatives for diesel fuel electricity generation, e.g. biofuels, solar and wind. At the end of 2004, funding was secured for a feasibility study and project proposal development into the use of coconut oil as a fuel in compression ignition engines by EPC. At the beginning of 2005, a SOPAC-led team was selected to carry out the work for these preparatory activities for EPC and UNDP-Samoa.

The feasibility study was carried out in a number of steps: first, an inception mission was carried out to identify the stakeholders and to gather the first data. This mission resulted in an inception report, which is attached in Annex II (SOPAC Trip Report 372). Secondly, a series of missions was undertaken by the various experts in when the majority of the fieldwork was carried out. The fieldwork consisted of interviews with key stakeholders, “action research” in which a pilot of 10% coconut oil blend at the power station in Savai’i was carried out and the setting up of a GIS database for the coconut resource assessment. The main findings of the fieldwork were recorded in a debriefing report, which is attached in Annex III (SOPAC Preliminary Report 142).

This feasibility study is a document to describe to EPC a resource, technical, institutional, regulatory, economic and financial viable approach to make its way into the use of the local resource of coconut oil as a biofuel. It takes into account and builds upon the inception and debriefing reports and describes, in detail, where opportunities lie in use of coconut oil as a biofuel in Samoa – in what way this can be implemented – and what the sensitivities are in terms of economic viability.

SOPAC acknowledges the opportunity given to be contributing to the recent biofuel developments in Samoa, as it has a great potential for replicability throughout the Pacific region. As countries are feeling the impact of rising oil prices in the last few years, it is high time sustainable alternatives are sought. These alternatives can be found in the form of hydropower as Samoa is currently expanding its installed capacity in Upolu as well as Savai’i. EPC in Samoa is also promoting the use of PV solar technology and is preparing to explore of wind energy as an opportunity. Other biofuel options include the production of ethanol, to blend with petrol and biogas gasification.

As technologies further develop, each technology is expected to fill its own niche in a palette of energy supplies, each being used where it is most appropriate and economically viable. The opportunity to develop a biofuel replacement for diesel at EPC is timely as while the fuel prices are still moderate, there is time for investing in Samoa’s sustainable future.

This feasibility study explores options for the use of coconut oil in the power sector of Samoa, through a technical exploration, an economic analysis, followed by a more detailed technical feasibility of an oil processing plant. The oil processing plant will be subject to a financial and economic analysis and an environmental impact assessment.
2. OVERVIEW OF THE POWER AND COCONUT SECTORS IN SAMOA

2.1 Overview of Samoa

The independent state of Samoa is situated\(^1\) roughly between Australia and the US in the Pacific Ocean. It consists of two main islands (see Figure 1) and 5 smaller islands. The total land area is 2,934 km\(^2\) and its exclusive economic zone is roughly 120, 000 km\(^2\).

![Map of Samoa](image)

Figure 1: Map of Samoa.

The capital, Apia which has about 35,000 inhabitants, is located on the Island of Upolu and is the commercial center of the country. Samoa as a whole is home to a population of 180,000 people (2004). Population growth is 0.5% per annum\(^2\).

The climate is tropical and most of the year the temperature ranges between 20 and 30\(^\circ\)C at an average humidity of 80%. The annual rainfall is 2.88 meters with lows of 2.5 in the west of Savai’i and Upolu and highs in the uplands of up to 6 metres\(^3\).

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\(^1\) 13-14 degrees South Latitude and 171-172 degrees West Longitude
\(^2\) Source: Census Reports, Government of Samoa
\(^3\) Source: Government of Samoa

[SOPAC Technical Report 393 – Cloin]
Samoa is prone to cyclones that can lead to serious damage. Especially because this study considers a vulnerable source of biomass such as coconuts, this is an important consideration.

Samoa’s National Currency is the Tala (ST$) with an exchange rate of 2.6 to the US$ (June 2005).

### 2.2 Samoan Energy Sector

Total energy supply in Samoa in 2000 was around 150 kToe. Biomass for cooking and agricultural drying remains significant and is estimated at nearly half of the total energy supply. The percentage of supply by biomass has been falling over the past two decades with petroleum imports rising annually to the present level of about 80 Ml per year with Automotive Diesel Oil (ADO) used for power generation and transport. Unleaded Petrol (ULP) is mostly used for land transport and outboard engine operation. These fuels each account for about 15% of total energy supply. The biomass resource can be considered renewable under specific circumstances, together with hydro-powered electricity (8%).

Biomass plays an important traditional role, e.g. wood is used for produce drying and cooking as experienced on Sundays where cooking is normally in an *Umu*, a Samoan traditional earth oven.

### 2.2.1 Energy Policy in Samoa

The Government of Samoa’s draft energy policy objectives include aims to meet growing demand for energy by maximising the use of indigenous renewable energy resources and minimising the import of fuel. Specifically, it spells out a strategy to: “Promote alternative fuels to substitute petroleum products to reduce dependency of the economy on fossil fuels”.

Specific renewable energy resource assessment has been limited, but has been the subject of exploration in the Pacific Islands Renewable Energy Project (PIREP) Samoa national report (2004) and the Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA) draft report (2004). Both these reports indicated a great potential for the use of biofuels such as coconut oil. The barriers to using these mostly renewable energy resources are of technical and educational nature.

---

4 Since the start of this study there have been three cyclone warnings, fortunately none of which have actually lead to loss of life, damage capital goods or loss of biomass resources.

5 Source: Adapted from “Upolu Wind Resource Assessment Project” (first draft) UNDP- Samoa (2005)

2.2.2 Samoan Power Sector

The Government-owned Electric Power Corporation (EPC) has the monopoly to generate and distribute grid-connected electricity on the islands of Samoa. Table 1 shows the main islands of Samoa with its population and its electricity supply.

<table>
<thead>
<tr>
<th>Island</th>
<th>Area [km²]</th>
<th>Population (2001)</th>
<th>Electricity Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savai‘i</td>
<td>1,708</td>
<td>42,824</td>
<td>Diesel Generation, Grid connected</td>
</tr>
<tr>
<td>Upolu</td>
<td>1,123</td>
<td>134,024</td>
<td>Diesel and Hydro, Grid Connected</td>
</tr>
<tr>
<td>Manono</td>
<td>3</td>
<td>1500</td>
<td>Connected to Upolu</td>
</tr>
<tr>
<td>Apolima</td>
<td>1</td>
<td>150</td>
<td>Diesel mini-grid</td>
</tr>
<tr>
<td>All others</td>
<td>1</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Total sales of electricity by EPC are given in Figure 3 below. It can be seen that in the last 5 years there has been a steady increase of total production that is projected to further stabilise in the current financial year.

![Figure 3: EPC Generation 1998 - 2005 (Source: EPC, incl. 2005 estimates).](image)

Figure 4 (below) shows the composition of EPC generation by source. EPC has traditionally made use of hydro stations in Upolu that generate on average half of the electricity produced. The share of diesel installed capacity and production has been increasing slowly but steadily to keep up with growing demand and unpredictable hydro capacity.
From these two graphs, it can be seen that diesel generation is a fact of life in the Samoan power supply. There are advanced plans to further develop hydro resources on both Savai’i and Upolu, however these will not replace all diesel capacity in the medium term. There will remain a need for additional electricity generation by sources other than hydro.

EPC’s outlook is a further increase of 6% annually in the next 5 years in both peak demand and capacity.  

EPC aims to utilise alternative fuels to diesel e.g. coconut oil through a combination of cost savings and environmental considerations. Increasing dependence on imported fossil fuels is one of the main reasons for carrying out a feasibility study into the use of alternative fuels in EPC generators.

During discussions with EPC management, it was learned that EPC had carried out some trials with alternative fuels in the early 1980s. However, no records or results from these trials are available today. Technical risks associated with using fuels that are not recommended by the manufacturer of the generating units have stopped any further trials.
During the last century, the export of coconut products was a stronghold of the Samoan national economy. It is also an integral part of the way of life for most Samoans, providing food, shelter, fuel, home comfort and cash\textsuperscript{11}. The coconut is often referred to as “The tree of Life”.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Coconut_Export_Volume_1997-2003}
\caption{Coconut Export Volume (Source: Coconut Industry Review).}
\end{figure}

Through a combination of fluctuating prices, weak management, limited re-investment, cyclones and pest damage, the coconut industry came to a virtual halt in 2002. Figure 6 shows the coconut export volume in recent years. The industry is getting back on its feet slowly, as can be seen for example from increased output from the COPS copra mill and the recent re-opening of Desico, a factory for Desiccated Coconut products in February 2005. Other coconut-based exports include copra, copra meal, and coconut cream. The world market for coconut products has been proven very volatile, with strong competition between both competing coconut producers and other producers such as palm oil.

Samoa plays an insignificant role in the global coconut industry. As a small isolated country, it will be dependent on further price developments for major coconut products on the world market. During the last decade, the price of coconut oil Cost, Insurance, Freight (CIF) Rotterdam fluctuated between US$ 350 and US$ 750 per metric tonne. The medium-term price development of products such as coconut oil is not expected to fluctuate greatly. In the current market arrangements with heavy interdependencies with other vegetable oil products, it is expected the volatility is limited.

\textsuperscript{11} Adapted from “Coconut Industry Review” (2004)
The price of coconut oil CIF Rotterdam in June 2005 was US$ 640 per metric tonne, while transport cost from Samoa, including storage, terminal costs, financing and insurance result in a net benefit of roughly US$ 510 per tonne.

The current potential of the coconut resource will be described in Chapter 5. It has become clear from various discussions in the Ministry of Agriculture, with the COPS mill and through site visits in Upolu (STEC plantation, hybrid coconut seedlings gene pool) and Savai’i that if the reward to harvest coconut products is increased, new supply will emerge.

During the field visits, it appeared that the current supply chain with copra production by small-scale farmers and even on the STEC plantation is not viable. The rewards for the hard work of coconut collection, copra cutting and drying are low and payments in recent years have not been reliable and prompt, so that labourers tend to see it as an income of “last resort”. To revive the coconut sector in a sustainable manner a higher and promptly paid reward per coconut combined with fewer inputs from the farmers are required. It is widely expected that new supply will emerge if these requirements are met. This decreases the likelihood of COPS as a future supplier of coconut oil unless the industry will be restructured (including taking both whole nuts and copra).

The second issue to the use of COPS as a future supplier of coconut oil fuel is the fact that the quality and quantity might not be fully controllable by EPC. It was clear during the recent trial of 10% coconut oil to diesel blend where 1,000 litres of coconut oil was supplied by COPS, that this was a good start for EPC to get more experience with using coconut oil as a fuel. Further discussions between COPS and EPC look promising, creating the foundations for a possible supply contract to the benefit of both companies.
3. THEORETIC BACKGROUND ON BIOFUELS AS REPLACEMENT OF DIESEL

The use of biofuels is nearly as old as the diesel engine itself, as Mr. Diesel designed his original engine running on peanut oil. During periods in history when regular diesel supply was hampered seriously such as WW-II, throughout the world vegetable alternatives from different sources and in different forms have been used.

**Figure 8: Biofuel Options for Compression Engines.**

In the Pacific, only recently has there been renewed interest in the use of coconut oil as a biofuel. The need to substitute for diesel imports, safeguard the local agricultural industry and reduce the impact of diesel exhaust on the environment, has led to a range of initiatives using coconut oil as a biofuel in the past 10 years.

In this chapter, an overview will be presented of worldwide research and experience using vegetable oils, including coconut oil.

### 3.1 Coconut Oil in Standard Engines

Many studies involving the use of un-modified vegetable oils (including copra\textsuperscript{12} oil) were conducted in the early 1980s. Short-term engine testing indicated that vegetable oils can readily be used as a fuel or in a range of blends with diesel fuel. Long-term engine research however shows that engine durability is questionable when fuel blends contain more than 20% vegetable oil\textsuperscript{13}.

The lower iodine value of coconut oil compared to other vegetable oils works favourably for its lower carbon deposits, however not many successful long-term experiences have been found. Especially deposits on the pistons, valves, combustion chambers and injectors can cause severe loss of output power, engine lubricant deterioration and even catastrophic failure to engines.

Under specific circumstances, unmodified engines have been running on 100% copra oil. Key variables for successful operation on raw copra oil include:

1) Stable and controlled copra drying / milling process;

\textsuperscript{12} Copra Oil is coconut oil produced in the traditional manner of husking, shelling coconuts, drying on a smoky fire and finally pressing the oil out by means of an expeller. The bulk of coconut oil is still produced in this way, however in the last 10 years other ways to produce oil have been explored, including Direct Micro Expelling (DME) in which the copra is grated, dried and expelled batch-wise in a metal cylinder. This process, even though more labour-intensive, produces higher quality oil with less Free Fatty Acids.

\textsuperscript{13} See also “Coconut Oil as a biofuel in Pacific Islands – Challenges and Opportunities” (SOPAC, 2004)
2) Removal of water, Free Fatty Acids (FFA) and solids;
3) Filtration up to 1 micron;
4) Pre-heating of copra oil up to 70 °C;
5) Blending with regular diesel or kerosene for better viscosity;
6) Application of engine in upper load curve (>60%);
7) Use in Direct Injection (DI) system.

A blend of up to 10 % of coconut oil in diesel fuel can be used in non-modified DI engines. However, many experiments have shown that at low loads, unburnt coconut oil finally coked injectors tips and pistons rings. It is therefore highly recommended to use coconut oil blends in engines that run at high load only in RI systems.

Risks of technical failure with this option are dependent on the engine design. Some DI engines can tolerate a 10% coconut oil blend from 30% of their rated power, while other engines require to be loaded more than 60%. It is therefore highly recommended that extensive tests be conducted before going into everyday operation.

### 3.2 Pure Coconut Oil in Adapted Engines

A number of successfully adapted diesel engines have run on both mixtures of vegetable oil and diesel as well as 100% vegetable oil. There are mainly two types of adaptations to an engine: firstly to add an extra fuel supply system to the existing diesel supply, and secondly to adapt the fuel supply system and injectors.

As coconut oil has up to 30 times higher viscosity and slightly lower energy content than regular diesel at room temperature, most engine modifications include a fuel heater (1.08 litre of coconut oil is equivalent to 1 litre of diesel). The fuel heater heats the fuel up to 70-80 °C before injection, using the engine coolant to cross-flow with the fuel in a heat exchanger. By heating up the coconut oil, the resulting oil viscosity will approximate the viscosity of diesel.

#### 3.2.1 Dual Fuel systems

These systems start and stop on regular diesel. As soon as the engine is at rated operating temperature, the fuel supply is switched to vegetable oil and just before shutting down, the supply is switched back to diesel to ensure that the fuel system has diesel ready for a cold start and to avoid residues in the fuel system.

In some areas there is also an electrical heater incorporated into the fuel tank, to ensure that the fuel remains liquid, even at ambient temperatures below 22 °C. A technical challenge is to ensure that the return line of the alternative fuel does not cause contamination of the regular diesel. This can be done through using a third “day”-tank that assembles the excess mixture fuel during switching, or to short-circuit the return line and using an extra pump during operation on vegetable oil.

A good example of a dual fuel system is the village electrification system in Welagi, Taveuni, Fiji Islands (Figure 8), that uses a dual-fuel system for both diesel and copra oil fed into a 55 kVA diesel generator. Technically this system has proven to operate with little problems.
Because the generator has often only been used for a small portion of its design load (as low as 17%), excessive carbon deposits have been found on the exhaust gaskets of the generator. This can cause engine failure in the long term. It can be solved by connecting a useful extra load such as water pumping or street lighting, when the generator is running at low load. In a utility environment, this situation does not have to occur as the load on the generator can be actively controlled.

3.2.2 Adapted Fuel System

Engines with adapted fuel systems can run on pure coconut oil and use no fossil fuels. Mostly, they feature adapted fuel injectors, special pumps and extra filters. If the coconut oil is manufactured on a small scale locally, the quality will not always be stable; therefore, regular quality control and a number of filtering stages are essential to ensure long service of this type of system. Often an electrical operated fuel heating system is incorporated for ambient temperatures below 25°C. A good example of this is the pilot plant in Ouvéa, New Caledonia implemented by the South Pacific Community (SPC) and the French International Agricultural Co-operation Research Institute CIRAD in the 1990’s

3.3 Biodiesel in standard engines

Biodiesel is a standardised fuel that consists of vegetable oil Methyl Ester. Biodiesel is a product of vegetable oil, an alcohol and a catalyst such as sodium hydroxide. This process generates two products: glycerine, which can be used in soap production, and Vegetable Oil Methyl Ester\(^{14}\) (VOME), also called biodiesel.

There are two fully developed standards of biodiesel, ASTM-D 6751 in the United States and EN14214 in the European Union. If these standards are followed, the manufacturer guarantees remain valid if used up to 5% biodiesel, depending on the manufacturer. Certain manufacturers have declared certain models can be run with up to 30% and some even 100%\(^{15}\). Positive impacts on engines include increased lubricity and a reduction of visible particles in the exhaust. Some engines require replacement of rubber hoses and O-rings, due to the vulnerability of PVC (polyvinyl chloride)-based material to biodiesel.

When using pure biodiesel, some manufacturers have modified their engines (piston top ring) to achieve greater efficiency. In some cases, fuel-feeding lines have to be changed. In small engines, some problems with small rotary pumps have been found.

Therefore, even though biodiesel is a standardised fuel, engine manufacturers will have to be contacted for checking potential operational issues for higher blends.

The major disadvantage of biodiesel is that it has to be prepared in a chemical facility, contributing significantly to the cost. If the biodiesel is produced from waste vegetable oil or beef tallow in larger volumes, the price of feedstock will be lower than coconut oil and the production of a competitive fuel might be possible.

\(^{14}\) If the basis for biodiesel has been coconut oil, often the abbreviation COME, Coconut Oil Methyl Ester, is used. With waste vegetable oil as the basis for biodiesel, Fatty Acid Methyl Ester (FAME) is used.

3.4 Conclusion

Table 2 gives an overview of the different fuel options as described above.

<table>
<thead>
<tr>
<th>Biofuel Option</th>
<th>Engine Adaptation</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Blend Coconut Oil /</td>
<td>No engine adaptation</td>
<td>If blend used at low load:</td>
</tr>
<tr>
<td>Diesel</td>
<td>Coconut Oil is mixed up to 10% with diesel in tank</td>
<td>Bad combustion leads to carbon deposit in combustion chamber</td>
</tr>
<tr>
<td>2. Coconut Oil/ Diesel</td>
<td>Second Fuel Tank</td>
<td>Non filtered or polluted coconut oil</td>
</tr>
<tr>
<td>Dual Fuel System</td>
<td>Second Fuel Pump</td>
<td>Storage spoiled by bacteria</td>
</tr>
<tr>
<td></td>
<td>Fuel Tank Heater</td>
<td>Coconut oil in fuel tank</td>
</tr>
<tr>
<td></td>
<td>Fuel line heater</td>
<td>Non filtered or polluted coconut oil</td>
</tr>
<tr>
<td></td>
<td>Engine modifications</td>
<td>Storage spoiled by bacteria</td>
</tr>
<tr>
<td>3. Pure Coconut Oil Only</td>
<td>Fuel Tank Heater,</td>
<td>If blend used at low load:</td>
</tr>
<tr>
<td></td>
<td>Fuel line heater</td>
<td>Bad combustion leads to carbon deposit in combustion chamber</td>
</tr>
<tr>
<td></td>
<td>Engine modifications</td>
<td>Occupational Health and Safety (OHS) Biodiesel production</td>
</tr>
<tr>
<td>4. Biodiesel</td>
<td>Separate Production of Biodiesel</td>
<td>Vulnerability of Polyvinyl Chloride material (seals, gaskets, paints)</td>
</tr>
<tr>
<td></td>
<td>Biodiesel can be blended up to 5% with guarantee- higher blends require</td>
<td>Occupational Health and Safety (OHS) Biodiesel production</td>
</tr>
<tr>
<td></td>
<td>consultation with manufacturer</td>
<td>Vulnerability of Polyvinyl Chloride material (seals, gaskets, paints)</td>
</tr>
</tbody>
</table>

From the above we can conclude that there are a number of different biofuel options to replace diesel fuel in EPC gensets in Samoa. These technical options will be considered in the next chapters.

3.5 Technical Risks

A general risk of coconut oil use is bacterial contamination, bad filtration and contamination with water. These factors cause the quality of the fuel to deteriorate until it is unfit for a compression ignition engine. With the proper fuel handling guidelines, these risks can be significantly reduced.

When using coconut oil blends in compression ignition engines, the load needs to be kept above a threshold, to avoid carbon build up in the compression chamber and its components. This risk can be mitigated by following an active dispatch strategy for engines running on a coconut fuel blend. Regular lube-oil analysis, looking into fuel contamination (unburnt coconut oil) will indicate the minimum loading of the engine.

In all fuel options, it will still be possible to use pure diesel regardless of the adaptations. Therefore, the risk for a shortage in coconut oil can be mitigated by replacement with regular diesel.

---

16 Only climates where coconut can solidify (temp at any time < 20°C)
17 Direct Injection engines only
4. ECONOMIC FEASIBILITY OF FUEL OPTIONS

The options identified in Chapter 3 are all technically feasible in the Samoan context for power generation at EPC. We will now look at the economic feasibility of the fuel options. The prices per litre of fuel and the investment required for the fuel option to be used will be the basis of the cost-benefit analysis of the fuel options.

4.1 Cost of Fuel Options

4.1.1 Cost of Diesel in Samoa

The cost of diesel in Samoa is regulated by the Government. Through a competitive tendering system in which the storage facilities are owned by the Government and the oil companies bid for a delivery contract over a limited time, Samoa has one of the lowest fuel prices in the Pacific region.\(^\text{18}\)

Both the wholesale and retail fuel price in Samoa are determined using a fuel price template. Table 3 shows the different components with values at June 2005. The prices indicated are maximum prices; large-scale customers like EPC obtain fuel slightly below wholesale prices as determined by the template.

<table>
<thead>
<tr>
<th>Retail Price [ST$/litre]</th>
<th>Wholesale Price [ST$/litre]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landed Cost</td>
<td>1.19</td>
</tr>
<tr>
<td>Petroleum Levy</td>
<td>0.02</td>
</tr>
<tr>
<td>Excise Tax</td>
<td>0.40</td>
</tr>
<tr>
<td>Retail Margin</td>
<td>0.08</td>
</tr>
<tr>
<td>Subtotal</td>
<td>1.69</td>
</tr>
<tr>
<td>VAGST (12.5%)</td>
<td>0.21</td>
</tr>
<tr>
<td>Total</td>
<td>1.90</td>
</tr>
</tbody>
</table>

It appears that EPC received a 3.6% discount on the standard wholesale price, paying effectively ST$ 1.747/litre\(^\text{19}\) of diesel for delivery in both Savai’i and Upolu.

4.1.2 Cost of Coconut Oil in Samoa

The cost of coconut oil is dependent on world coconut oil market price. It is therefore more appropriate to talk about “opportunity cost” of coconut oil, as the real production cost in Samoa does not matter in the determining of the price. It is more the world market price of the commodity coconut oil minus the cost to get the oil to that market. The most quoted price for coconut oil is the Rotterdam price, from which it is used in the food and the cosmetic industry.

\(^{18}\) Source: Pacific Island Fuel Price Monitor, various issues, Pacific Island Forum Secretariat, Fiji.

\(^{19}\) Source: EPC fuel bill July 2005
Table 4: Samoa local Coconut Oil Cost Composition
Source: COPS (July 2005)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotterdam Price</td>
<td>640</td>
<td></td>
</tr>
<tr>
<td>Transport, Freight, Insurance</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Terminal Charges</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Samoa Opportunity Cost</td>
<td>510</td>
<td></td>
</tr>
<tr>
<td><strong>Translates to:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAGST (12.5%)</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.48</td>
</tr>
<tr>
<td>Diesel Equivalent (1.08)</td>
<td></td>
<td>1.60</td>
</tr>
</tbody>
</table>

Table 4 starts off with the price of coconut oil paid in Rotterdam. Subtracting the costs of getting the commodity to its market, a net value of US$510 remains. This translates to ST$ 1.23 per litre. Taking into account the taxes payable and the lower energy content of coconut oil results in a price of **ST$ 1.60 per litre**.

4.1.3 Cost of Biodiesel in Samoa

Because there is no biodiesel operation in Samoa, the cost of biodiesel has been estimated based on international experience. The International Energy Agency recently carried a survey over European and American biodiesel producers. The production cost per litre was estimated at US$ 0.15 to US$0.38, depending on type of feedstock and size. Depending on the sale of the glycerine that is produced with the process, prices could be suppressed by US$0.10 per litre.

Because of the restricted size of a biodiesel operation in Samoa and the non-existent market for glycerine, it is deemed reasonable to take the upper figure as a proxy for biodiesel production in Samoa.

Table 5: Biodiesel Production Cost Composition
Source: IEA

<table>
<thead>
<tr>
<th></th>
<th>Cost [ST$/litre]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock (coconut oil)</td>
<td>1.48</td>
</tr>
<tr>
<td>Production Cost</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>2.48</td>
</tr>
<tr>
<td>Diesel Equivalent (1.10)</td>
<td>2.73</td>
</tr>
</tbody>
</table>

The cost of biodiesel is determined to be **ST$ 2.73 per litre**. This price could go down if there are other vegetable oils used as feedstock (such as waste vegetable oil or beef tallow); if markets for glycerine can be found; and if larger-size plants (for example including production for transportation fuels) are considered. This however is beyond the scope of this study.

4.2 Fuel Option Cost Variation

Of course, all the prices as calculated above are changing continuously and it is important to look at their variability over time. Figure 9 shows the wholesale price of fuel for 2004-2005, together with the price of coconut oil fuel equivalent. The total volume used by EPC last year was roughly 17 Million litres of diesel in 2004, resulting in a total fuel bill of ST$ 24 Million. This includes 6.8 Million ST$ in duty minus ST$ 1 Million (15%) refunded by the Government of Samoa to EPC.

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20 Based on: “Biofuels for Transport; An international perspective” IEA (2005)
The green line in Figure 9 indicates the opportunity cost for a litre of coconut oil to be used for fuel locally versus being exported at current world market prices. It includes the lower energy content of a litre of coconut oil versus a litre diesel (92.5%), the cost to export the coconut oil (CIF plus financing) and the VAGST (Value Added Goods Tax) payable on coconut purchased from COPS.

![Price Development of EPC Diesel and Coconut Oil Fuel Cost 2004-2005](image)

It can be clearly seen that the current competitive price for coconut oil has not always existed. It can also be concluded that biodiesel cannot compete with diesel or coconut oil fuel as the cost per litre is roughly one Tala per litre higher than coconut oil.

4.3 Coconut Oil and Diesel Commodity Prices

To better understand the price development and the economic impact of the remaining fuel options: diesel and coconut oil, we will look at the development of the commodity prices. The prices we will look at are the local prices, based on the international commodity prices. To rule out the effect of inflation and variation of exchange rates, we will convert to constant US$ of the year 2000.

The United Nations Conference for Trade and Development (UNCTAD) has a valuable database that fits the purpose of our analysis. From 1960 onwards, commodity prices are recorded. These prices are in constant US$ and do not include any taxes, duties or excise. Figure 10 shows the landed price of diesel fuel and the opportunity cost for coconut oil exported from Samoa.
Figure 11a: Commodity Price Development of diesel and coconut oil (1960 - 2005) (Source: http://www.unctad.org commodity price bulletin)

Figure 12 depicts a blow-up of the circle in Figure 10 for a closer look at the recent historical developments of commodity prices. Only recently, at US$60 per barrel has coconut oil become competitive with diesel fuel.

Figure 11b: Commodity Price Development of diesel and coconut oil (1998 - 2005) (Source: http://www.unctad.org commodity price bulletin)
The commodities are both highly volatile in nature with historically lower prices for diesel fuel. Due to the nature of the coconut oil market and its available replacements, it appears unlikely that spikes above 0.6 US$/litre will re-occur\textsuperscript{21}. Similarly, prices below 0.2 US$/litre seem unlikely for extended periods. The diesel price has increased because of a much more powerful market development: the fossil fuel market prices. At the time of writing, it seems fair to assume a price range between US$30 and US$120 per barrel for the coming 10 years, resulting in a landed cost range of 0.2–0.81 US$/litre.

The price comparison does not necessarily reflect EPC’s opportunity cost, as duties have not been included in the diesel price equivalent. In addition, the exchange rate development has not been taken into account.

For EPC to be able to use both fuels, a dual fuel system is preferred over adaptations to engines that leave them only operational on pure coconut oil, to cater for flexible fuel feedstock. There are no guarantees for either coconut oil fuel or diesel fuel to be more competitive; given the market developments of the last years, it makes economic sense to have an alternative to diesel fuel available.

Table 6 shows the price ranges of fuel expected in the coming 10 years, based on the analysis above, assuming the taxation of diesel is not altered and coconut oil.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>1.22</td>
<td>1.74</td>
<td>3.15</td>
</tr>
<tr>
<td>Coconut Oil from COPS</td>
<td>0.64</td>
<td>1.48</td>
<td>1.91</td>
</tr>
<tr>
<td>Coconut Oil Biodiesel</td>
<td>1.85</td>
<td>2.73</td>
<td>3.27</td>
</tr>
</tbody>
</table>

### 4.4 Coconut Oil Fuel Supply

The first alternative to diesel is buying coconut oil fuel from COPS. This mill has a potential output of several thousand tonnes per annum, all of which is currently exported. The quality of the oil cannot be controlled by EPC and the output cannot be scaled up if wanted, as the oil mill would need to be refurbished for that. At the same time, it is unclear whether COPS has the financial resources for such an operation. The price is currently competitive with diesel fuel but all the production factors are beyond EPC’s influence. The oil from COPS would have to be supplied under a strict delivery contract with clauses on oil quality. Given the current state of the oil mill, this might not lead to a long-term fuel solution for EPC.

An alternative is producing coconut oil under EPC management, dedicated for use as fuel. The mill based on Savai’i would produce coconut oil from whole, unhusked coconuts and utilise all components of the coconut to offset production costs of the fuel. During periods of low diesel prices, this plant could still produce high quality oil for export. The venture would include trucks collecting nuts and processing the unhusked nuts using machinery. The mill would generate electricity through a small steam generator or gasifier and produce the amount of coconut oil fuel required by EPC. This option, although more expensive than buying oil from COPS, might be more reliable in terms of quantity and quality.

The third alternative is for EPC to produce biodiesel. The feedstock could be coconut oil or other (waste) vegetable oil. During the fieldwork however, no significant potential stream of waste

\textsuperscript{21} Coconut oil has sometimes been very precious in the past; this is due to its high contents of lauric oil (together with palm oil) that is the basis for high-quality soaps. Because of genetic manipulation, it appears rapeseed oil has taken over part of this market, which might dampen these price spikes in the future.
vegetable oil was identified. The cost of converting the vegetable oils into biodiesel are relatively high since they rely on large investment and require methanol as an input.

4.5 Fuel Option Economics Conclusions

Based on the above paragraphs, it can be concluded that coconut oil in certain cases is competitive with diesel fuel. This competitiveness hinges on the following factors that are beyond EPC’s control: international coconut oil commodity prices, international fossil fuel prices and exchange rate fluctuations.

It is proposed to study the feasibility for EPC to invest in a dedicated Coconut Oil Fuel processing plant that can produce 3-10% of EPC’s current fuel consumption. In addition, it is currently competitive to use coconut oil from the COPS mill, if the right quality and quantities are available.

The production of biodiesel is currently not considered an interesting opportunity as no large quantities of waste vegetable oil have been identified. Converting coconut oil into biodiesel does not make economic sense as the coconut oil, in case of sufficient quality, can be used straight into the compression ignition engines of EPC.

By aiming for a partial displacement of diesel fuel, EPC can gain valuable experience based on which further substitution can be considered. The price volatility on both the coconut oil market and the fossil fuel market do not support the complete switch to coconut oil fuel.

5. RESOURCE FEASIBILITY OF COCONUT OIL FUEL

While carrying out the fieldwork for this feasibility study, it was found that the coconut sector in Samoa is at a crossroads. Either efficient agro-industries utilise the remaining coconut resources producing competitive (export) products, encouraging replanting of the diminishing coconut resources, or the coconut industry will soon fall back to subsistence level.

The currently available resource for producing coconut oil fuel consists of coconuts that are:
1. harvestable in Samoa;
2. available for coconut oil fuel production; and
3. collectable and bought at an acceptable price.

On the basis of these requirements, the potential supply of coconut oil fuel will be analysed and estimated in the following paragraphs.

5.1 Potential Production of Coconuts in Samoa

The first requirement of the list – determining the coconut resource gave rise to a GIS inventory study during the fieldwork. Figure 12 gives an overview of the result of this inventory and indicates the different areas where the coconut resources are located. Table 7 indicates the distribution over the islands.

<table>
<thead>
<tr>
<th>Island</th>
<th>Surface [Hectare]</th>
<th>Share of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apolima</td>
<td>30</td>
<td>0.1 %</td>
</tr>
<tr>
<td>Manono</td>
<td>162</td>
<td>0.7 %</td>
</tr>
<tr>
<td>Sava'i</td>
<td>33,657</td>
<td>53 %</td>
</tr>
<tr>
<td>Upolu</td>
<td>28,651</td>
<td>46 %</td>
</tr>
<tr>
<td>Total</td>
<td>62,500</td>
<td>100 %</td>
</tr>
</tbody>
</table>

[Table 7: Coconut Area Distribution Samoa (Source: CocoGen Study)]

[SOPAC Technical Report 393 – Cloin]
The GIS database was set up first with support from the Food and Agriculture Organisation (FAO) and has been set up at the Forestry Department. It was customised as part of the CocoGen activities, and distinguishes between different categories of coconut-producing areas. The classification stratifies areas stocked with vegetation, where coconut palms make up a part, into 16 different strata. The Forestry Department knows all these classes from the field checks and estimated the **number of trees (palms) per hectare**, which is the first important parameter.

The **yield (number of coconuts) per year per palm** is the second important parameter. Yield differs between the **coconut varieties**; however, at this point it is unknown which varieties have been planted in the different areas. Until further data is available, variety Samoan Tall, at 30 years of age, is used as the default value.

The **ages** of plantations are also not known at this point, as more detailed investigations have to be carried out. As soon as the average age for a plantation or an area is known the GIS database programme will use this more exact age classification to increase or reduce the yield per tree.
Figure 12: GIS display of different coconut strata. The dominant stratum "Coconut plantation with secondary forest", which covers 69% of the total coconut area, is distributed over both islands. (Source: CocoGen fieldwork)
The yield is also influenced by the soil and a soil map is available for Samoa. The soil has not been taken into consideration; however, the database is capable of incorporating the soil information later.

The Access Basic code calculates the potential yield for each of the 594 areas separately. Areas are classified into categories where coconut trees are at least part of the vegetation to calculate the total yield of coconuts per year. The formula used is:

\[
\text{Total Yield [coconuts/year]} = (\text{Yield/Tree}) \times (\text{Trees/Hectare}) \times (\text{Area Size})
\]

Where:
- **Yield/Tree** is a function of Coconut Variety, Age and Soil
- **Trees/Hectare** is a function of Stratum Type
- **Area Size** as calculated by MapInfo (GIS software)

<table>
<thead>
<tr>
<th>Description</th>
<th>Area [hectare]</th>
<th>Yield Total [nuts/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut plantation with secondary forest</td>
<td>42,837</td>
<td>72,823,682</td>
</tr>
<tr>
<td>Coconut plantation with mixed crops</td>
<td>6,509</td>
<td>17,704,233</td>
</tr>
<tr>
<td>Secondary forest logged over with coconut</td>
<td>3,595</td>
<td>7,334,166</td>
</tr>
<tr>
<td>Secondary forest with coconut</td>
<td>3,166</td>
<td>5,919,778</td>
</tr>
<tr>
<td>Coconut plantation</td>
<td>2,504</td>
<td>13,449,338</td>
</tr>
<tr>
<td>Grassland with coconut and livestock production</td>
<td>959</td>
<td>2,281,943</td>
</tr>
<tr>
<td>Mixed crops with coconut and secondary forest</td>
<td>712</td>
<td>1,089,819</td>
</tr>
<tr>
<td>Coconut plantation with livestock production</td>
<td>606</td>
<td>2,471,339</td>
</tr>
<tr>
<td>Open Forest with coconut and secondary forest</td>
<td>469</td>
<td>797,861</td>
</tr>
<tr>
<td>Mixed crops with coconut</td>
<td>459</td>
<td>936,646</td>
</tr>
<tr>
<td>Secondary forest with coconut and merinium</td>
<td>377</td>
<td>1,025,576</td>
</tr>
<tr>
<td>Secondary forest with albizia and coconut</td>
<td>107</td>
<td>200,895</td>
</tr>
<tr>
<td>Secondary forest with coconut and secondary forest</td>
<td>84</td>
<td>157,192</td>
</tr>
<tr>
<td>Mixed crops with coconut and logged over forest</td>
<td>62</td>
<td>105,774</td>
</tr>
<tr>
<td>Coconut plantation with cocoa</td>
<td>41</td>
<td>222,400</td>
</tr>
<tr>
<td>Coconut plantation with grassland</td>
<td>19</td>
<td>88,346</td>
</tr>
</tbody>
</table>

|                                                | 62,507         | 126,608,988            |

The GIS coconut resource assessment (Table 8) indicates that Samoa at present can produce some **126 million coconuts per year**. This rough estimate is based on a custom-designed database, installed at the Ministry of Natural Resources and Environment. Future inclusion of variables such as soil type, age and a distribution of coconut variety will result in a more accurate estimation, however, not necessarily decrease or increase this potential.


### 5.2 Coconuts Available for use as Coconut Oil Fuel

Of all the coconuts produced in Samoa, only a limited share will be available for use as coconut oil fuel. First, there are the coconut-based agro-industries that are currently struggling for survival. Secondly, there are a great variety of traditional uses of coconut, including human food and animal food.
Agro-Industrial Consumption of Coconuts

If the industrial players were to revive to their 1997 production levels, they would require the inputs given in Table 9.

<table>
<thead>
<tr>
<th>Export Commodity</th>
<th>Amount Produced [tonnes]</th>
<th>Coconuts per tonne</th>
<th>Coconuts Required [Millions]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut Oil Export</td>
<td>5,800</td>
<td>8,333</td>
<td>48.14</td>
</tr>
<tr>
<td>Copra Export</td>
<td>8,500</td>
<td>5,000</td>
<td>42.50</td>
</tr>
<tr>
<td>Desiccated Coconut</td>
<td>1,000</td>
<td>8,333</td>
<td>8.33</td>
</tr>
<tr>
<td>Coconut Cream</td>
<td>1,280</td>
<td>7,500</td>
<td>9.60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>108.57</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assuming that the local production of copra is not viable in the current Samoan context through high inputs of labour for low return, it can be concluded that the revival of copra-based industries (copra exports and copra oil) is very unlikely.

It is assumed that both desiccated coconut and coconut cream will rise slowly to consume a maximum of 20 million nuts per annum in the coming 5 years. In addition to this, there is a slowly emerging organic virgin coconut oil production based on small-holder DME production methods. This potential market is not expected to exceed 6 million nuts by 2010.

Together, the agro-industrial uses of coconut are expected to consume a maximum of 26 million nuts per year by 2010.

Domestic Production and Consumption of Coconuts

Table 10 indicates the role of households in the coconut sector. Of the nearly 14,000 households, 30% indicated that they regularly sell their coconuts.

<table>
<thead>
<tr>
<th></th>
<th>Upolu</th>
<th>%</th>
<th>Savai'i</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Home Consumption Only</td>
<td>6,585</td>
<td>73</td>
<td>3,169</td>
<td>65</td>
<td>9,754</td>
</tr>
<tr>
<td>For Sale Only</td>
<td>123</td>
<td>1</td>
<td>98</td>
<td>2</td>
<td>221</td>
</tr>
<tr>
<td>For Both Home and for Sale</td>
<td>2,298</td>
<td>26</td>
<td>1,616</td>
<td>33</td>
<td>3,914</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,006</strong></td>
<td><strong>4,883</strong></td>
<td></td>
<td><strong>13,889</strong></td>
<td></td>
</tr>
</tbody>
</table>

One of the trading places for small-holder produce is the Fugalei Domestic Market, Apia. Since 1997, between 6.5 and 10 tonnes per month were traded. The price per coconut in this period varied between 10 and 17 sene. The other part of small-holder production was consumed by the agro-industries.

Coconuts Available

Whereas previously plantations and small holders were consuming some 90 million nuts per year on copra (see 1997 Corpa Oil Export and Copra Export), in the near future they are not expected to exceed 23 million due to a sharp decline in the coconut product export industry.

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22 Based on: 50 organically certified farms producing 200 litres per week, equalling 460 tonnes of DME Virgin oil; 12 nuts per litre of virgin oil.
23 This equates 5,400 – 8,333 nuts.
24 Based on the annual export of 3,000 tonnes of coconut oil by COPS (Source: discussions with COPS management)
Production to fill the gap between these two figures of 67 million nuts per year cannot be readily resumed due to loss of rural labour, and transporting equipment. In addition, since the decline of the coconut-based industries, large parts of the plantations have been overgrown and have become inaccessible, or lost to diseases and cyclones. This can be seen from the production figures of the STEC plantation (Figure 13). Next to STEC, the major churches in Samoa produce significant amounts of coconuts.

![Coconut Production STEC Plantation](image)

*Figure 13: STEC production figures 1997-2004 (Source: STEC)*

However, resumption of local harvesting would provide a badly-needed source of rural income. It is assumed that **25% of the 1997 potential can become available within a year**, as households would be willing to supply coconuts if a steady demand for them were to develop. Moreover, through an outreach campaign, serious replanting of both hybrid and local varieties, cleaning and building of infrastructure – 75% of that gap can be closed within 5 years. Table 11 outlines these estimates.\(^{25}\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Nuts per year</th>
<th>% Of 1997 availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>16.75</td>
<td>25.0</td>
</tr>
<tr>
<td>2007</td>
<td>25.13</td>
<td>37.5</td>
</tr>
<tr>
<td>2008</td>
<td>33.50</td>
<td>50.0</td>
</tr>
<tr>
<td>2009</td>
<td>45.23</td>
<td>67.5</td>
</tr>
<tr>
<td>2010</td>
<td>50.25</td>
<td>75.0</td>
</tr>
</tbody>
</table>

**5.3 Price of coconuts for Oil Production**

During the fieldwork the prices per coconut were collected for different purposes. The prices tended to reflect the amount of labour and equipment required to produce the form traded (Table 9). For example, Desico pays 3 sene per nut more if the coconuts are delivered to the factory.

\(^{25}\) The estimates will require a significant revitalisation of the STEC plantations and the replanting of hybrid varieties throughout plantations and small-holder farms in Samoa.
Table 12: Prices per Coconut for different purposes
(Source: “Coconut Industry Review”, site visits, stakeholder meetings)

<table>
<thead>
<tr>
<th></th>
<th>Current Price^26 per nut [sene]</th>
<th>Labour input</th>
<th>Market Opportunities/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copra</td>
<td>11 – 13</td>
<td>Gather, Dehusk, Cut Copra, Dry Copra</td>
<td>Unlimited market opportunities in Upolu. Limited opportunities in Savai’i through transport costs. Farmers have to be patient with payment.</td>
</tr>
<tr>
<td>Desico</td>
<td>15</td>
<td>Gather, Dehusk, bring to Plant</td>
<td>Currently limited market, some growth opportunities.</td>
</tr>
<tr>
<td>Desico Collected</td>
<td>12</td>
<td>Gather, Dehusk</td>
<td>Currently limited market, some growth opportunities.</td>
</tr>
<tr>
<td>Coconut Cream</td>
<td>12</td>
<td>Gather, Dehusk</td>
<td>Limited market opportunities, some growth opportunities.</td>
</tr>
<tr>
<td>Roadside Sale</td>
<td>10-15</td>
<td>Gather</td>
<td>Currently oversupply, moderate growth opportunities.</td>
</tr>
<tr>
<td>Virgin Coconut Oil</td>
<td>30-50</td>
<td>Gather, Dehusk, Shell, Grate, Dry, Press Oil</td>
<td>Limited market. Moderate export growth opportunities.</td>
</tr>
<tr>
<td>Drinking Nut</td>
<td>25 - 100</td>
<td>Climb Tree, Gather, Transport to Market, Pay Stall</td>
<td>Only green nut. Limited market.</td>
</tr>
</tbody>
</table>

The market for coconuts in Samoa can be characterised by limited and virtually unlimited markets. The limited markets, comprising roadside sale, green drinking nuts and virgin coconut oil have high rewards, however low total volume.

The more or less unlimited markets, being the agro-industrial players, convert into a value of 11 to 13 sene per nut, excluding transport.

From the above, and given that the local agro-industrial players are hampered through limited supply, it can be concluded that the local price of coconuts, collected for coconut oil at farm gates in great quantities has to exceed 12 sene per nut. Test market surveys will have to indicate what the long-term price is, for delivering sufficient coconuts to the proposed coconut oil fuel plant.

The feasibility study will therefore adopt a rate of 13 sene per nut.

^26 Source: Coconut Industry Review (2004), site visits, stakeholder meetings. Prices quoted are Farm Gate Prices
6. TECHNICAL FEASIBILITY OF COCONUT OIL FUEL USE BY EPC

In Chapter 4 – Economic Feasibility of Fuel Options – it was observed that the most reliable supply of quality oil to be used by EPC as a fuel would be from a dedicated plant. This plant will have to produce a certain quality of Coconut Oil Fuel (COF) and some engine adaptations are required to use this fuel. The technical feasibility of such an operation will be explored in this section.

6.1 Coconut Oil Fuel Quality Standards

For any fuel to be used in a compression ignition engine, certain minimum standards need to be met. Table 13 outlines the requirements for both coconut oil and diesel fuel.

<table>
<thead>
<tr>
<th></th>
<th>Density At 20 °C</th>
<th>Water content Max (ppm)</th>
<th>Carbon residues %</th>
<th>Pour Point (°C)</th>
<th>Cetane number</th>
<th>Lower calorific value MJ/kg</th>
<th>Free Fatty Acids %</th>
<th>Filtration grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Fuel</td>
<td>0.836</td>
<td>100</td>
<td>&lt; 0.01</td>
<td>–18</td>
<td>50</td>
<td>43.8</td>
<td>–</td>
<td>10 µm</td>
</tr>
<tr>
<td>Coconut Oil Fuel</td>
<td>0.915</td>
<td>100</td>
<td>–</td>
<td>23/26</td>
<td>43</td>
<td>37.1</td>
<td>Max. 10</td>
<td>10 µm</td>
</tr>
</tbody>
</table>

Coconut oil and diesel fuel mix (blend) easily in any percentage and the mixture remains stable under Samoan climatic conditions. As the COF will be produced from copra, it will be heavily dependent on the quality of copra. It should be noted that coconut oil used in compression ignition engines has to be of a higher quality than regular edible (cooking) oil. Therefore, quality control will be an important element of the coconut fuel production plant.

Since the envisaged COF plant will be under EPC management and the throughput time of copra will be limited to a maximum of a few weeks, it is expected that the plant would produce exceptionally good quality oil. Once this oil is filtered below 10 µm, it is a suitable fuel for the EPC compression ignition engines.

In case “bad quality” coconut oil, i.e. that does not meet the above standards is produced, it will have to be treated by conditioning equipment before it is used in the day-tanks of the engines. Therefore, regular fuel quality checks will be required during the normal operation of the COF plant.

6.2 Coconut Oil Fuel Plant Operation

The COF plant is envisaged to be built next to, or as part of the planned new EPC power station in Savai’i. Other locations might be viable, however it was thought to be the best location because of:

- high rural unemployment in Savai’i;
- good coconut resource and limited commercial coconut market;
- higher landed cost of fuel for EPC in Savai’i;
- good fit into the plans to build a new power station; and
- good infrastructure (ring road) for collection of nuts.

The operation of the COF plant is shown in Figure 14. The process has distinguished inputs, process steps and by-products. The potential uses of the by-products are also indicated.
Figure 14: Coconut Oil Fuel Plant Operation
6.3 Coconut Oil Plant Logistics

The logistics for the Coconut Oil Production facility requires attention since it will consume a significant amount of biomass (coconuts). Please find below in Figure 15 a diagrammatic layout of the proposed COF Plant.

After collection, coconuts are stored in a shed. The coconuts are then de-husked and de-shelled. The coconut water is collected separately. The copra is then dried and stored in bulk. The copra is cut and expelled, with the end-products copra meal and copra oil. After purification, the oil is stored in tanks. The required blend is achieved through mixing with diesel fuel in a blending tank. The heat from the cooling systems of the EPC compression ignition engines will be fed to the dryer for additional overall efficiency.
Figure 16 depicts the logistics associated with the production of phase I volumes. The volumes in this figure are given per week. In Annex IV, an overview is given for both phases per year.

**Figure 16: Coconut Oil Processing Plant Product Streams per week – Phase I.**
As mentioned earlier, the production of 660,000 litres of coconut fuel is equivalent to 606 tonnes COF and requires 1,011 tonnes of copra or 5 million nuts.

This translates into 11 trucks collecting coconuts weekly, or just over two truckloads per day. Another truckload of coconut meal will have to be transported to Apia Harbour or be collected by local buyers. The volume of a week’s worth of copra meal will take up a volume of 15m$^3$ for which storage needs to be built. The manpower required is estimated at 15 labourers and 1 supervisor. This position might be combined with the position of plant manager at Saleloga.

The electrical energy required is mainly consisting of fans, and motors for the de-husk and de-shelling machines and is estimated at 1,400 kWh per month. Since it will be generated on-site, this can be at cost price.

Weekly, there will be 20,000 litres of coconut water, for which a market needs to be sought. This can be transported in two truckloads a week by using an edible-grade stainless steel tank truck. It might need to be refrigerated for future use. The husks are assumed to be required for the drying of the copra.

The shells will form a good feedstock for a 120 kW gasifier. This gasifier technology with stable feedstock can be considered proven technology with proper technical support and attention. At an investment of US$ 300,000, this equipment will earn back its investment in just over 2 years, generating an annual 1 GWh of electricity.

The feasibility of the use of side products (shell, husks, water) has not been included in the study. It will be a source for a variety of applications on the local markets. The volumes appear to be too small to export.

### 6.4 Training and Technical Assistance Needs

For the coconut oil processing plant to be operating efficiently and effectively over its intended lifetime, there will be the need for building human capacity locally.

Through the already existing industries in Samoa, human capacity is expected to be widely available for the tasks of truck driving, copra drying, coconut oil expelling, maintenance of coconut expellers. In addition, no training needs can be identified in the field of general logistics, coconut or copra handling.

As identified in the earlier paragraph on Fuel Quality, Coconut Oil and Fuel Characteristics Testing might be a task where external assistance and training is required.

Operators of the EPC gensets that run on (a blend of) coconut oil must be instructed thoroughly to load the machines in the upper range of the load curve, however through efficiency measures it can be assumed that this was already part of normal operating procedures.

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27 For a list of assumptions and used conversion factors, refer to Annex 2.
7. ECONOMIC AND FINANCIAL FEASIBILITY OF COCONUT OIL FUEL

7.1 Coconut Oil Fuel in Samoa: SWOT-Analysis

The potential production of coconut oil as a substitute for diesel fuel for electricity generation is an opportunity for Samoa to replace imported fuel – the price of which has nearly doubled in the last five years and is likely to stay permanently high – with a lower-cost indigenous fuel. In addition to bringing financial and environmental benefits, the development could help to revive the once important but now moribund coconut industry, with a significant positive impact on rural incomes. The pros and cons and risks of coconut oil for fuel are discussed below in a Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis.

7.1.1 Strengths

*Spare capacity in the coconut industry:* As discussed in Chapter 4 of this feasibility study, the coconut industry in Samoa has declined precipitously in the last ten years, with the production of coconut oil declining from nearly 6,000 tonnes in 1997 to close to zero in 2001, despite an estimated potential harvest of some 126 million nuts annually. The reasons for the decline, cited in a 2004 *Coconut Industry Review* prepared by the Ministry of Agriculture, include fluctuating world prices, weak management, insufficient investment, and natural disasters. All but the last of these causes ultimately relate to poor market conditions in the sector, and thus poor incentives to improve and re-build.

Production of coconut oil for fuel would establish a firm local demand for coconuts for power generation, a vital activity that faces high costs for substitute imported fuel. The demand for coconuts for fuel could easily be met from the under-utilised coconut production capacity of Samoa, with no increase in acreage. The labour and equipment required are the same as were employed in Samoa when the coconut industry was much stronger than it is now, and could be re-employed at minimal cost.

*Financial savings:* Calculations carried out for this study show that, over a range of realistic prices for local coconuts supplied to the market, coconut oil can be produced to fuel-quality standard at a cost less than that of the imported diesel fuel that the coconut oil would replace, resulting in financial savings in the cost of producing electricity. These calculations are discussed further below.

*Environmental benefits:* The use of coconut oil as a diesel fuel substitute would result in less air pollution, less risk of damaging fuel spillages, and reduced net greenhouse gas emissions. These benefits are discussed in detail elsewhere in this report.

7.1.2 Weaknesses

*Dispersed small holdings in Savai’i:* The proposed site for the project is Savai’i, which is less populated and less developed commercially than Upolu. Agriculture in Savai’i, including coconut cultivation, is largely by small holders, who are generally less efficient as producers than are commercial plantation operators. A pattern of small-holder ownership of coconut-growing land may permit only a limited mechanisation of coconut harvesting and collection. This limits the potential for investment in the upstream end of the industry in Savai’i. It is therefore not known at this time whether the volume of coconuts required for the project in Savai’i can be sustainably supplied by small holders at the roadside coconut prices assumed in the economic analysis. It is recommended that market testing be carried out to confirm this.
7.1.3 Opportunities

Revival of rural employment: The collection and sale of coconuts to EPC by small holders (households) in Savai’i represents an opportunity for Samoa to redistribute income to rural areas, and thus reduce poverty. Current estimates of increased aggregate rural income value in Savai’i range from ST$750,000 to more than ST$2 million per year, depending on the price paid per coconut and the size of the oil production plant ultimately chosen by EPC. These estimates are discussed further below.

Stabilisation of fuel input costs in the power sector: Imported diesel fuel prices have risen substantially in recent years and remain volatile. Substitution of a portion of diesel fuel imports by local coconut oil production would contribute to stabilising the costs of the fuel input to power generation, as local coconut oil costs are highly unlikely to fluctuate significantly after the production facility is built (except in cases of major natural disasters wiping out a high portion of the coconut crop).

Potential new electricity generation source through combustion of coconut wastes: The production of coconut oil for fuel will result in the generation of considerable volumes of shell and husk, only a portion (about half) of which will be burned for drying copra. The leftover shell and husk is an available fuel source that could be used for additional power generation, through either gasification or a steam turbine. The capital and operating costs of power generation using coconut wastes have not been analysed in this report.

7.1.4 Threats (risks)

Build up and disposal of coconut waste: If burning coconut waste for electricity generation is found to not be feasible for technical, financial, or other reasons, a considerable volume of such waste will build up over time at the coconut oil plant. (Husk and shell represent about half of the material in a coconut by weight.) Unless an economic and environmentally acceptable use for this waste can be found, the accumulation of waste could become a serious environmental and storage issue.

Possibly unsustainable supply by small holders: As the ‘import’ of coconuts from Upolu to Savai’i is likely to be cost-prohibitive, the production of coconut oil for fuel under the project requires a sustained supply of nuts grown in Savai’i, largely by small holders. As mentioned, it is not known whether, over the long term, the small holders in Savai’i are willing, or able, to supply the sustained volume of coconuts required by the project. This key consideration needs to be market tested prior to investment in a coconut oil producing facility in Savai’i.

Possible fall in diesel price after investment: An unforeseen decline in the price of imported diesel fuel may make the continued production of coconut oil for fuel uneconomic or, what is the same thing; prevent EPC from gaining the benefits of cheaper indigenous fuel. In this case, the value of the investment in a coconut oil plant for fuel will be undermined. This risk, however, is mitigated by the potential to switch output of the plant away from fuel to the export of high-quality coconut oil, depending on market conditions.

7.2 Potential Economic and Fiscal Impacts of Coconut Oil Fuel on Samoa

7.2.1 Potential Economic Impacts

Between 1998 and 2008, diesel fuel imported for electricity generation is projected to rise from about 12 million litres per annum (or approximately 35 percent of total diesel fuel imports in 1998 – the balance largely consumed by the transport sector) to about 25 million litres (or approximately 46 percent of total diesel fuel imports in 2008). The respective annual fuel volumes
for electricity generation represented 16.4% (1998) and 24.6% (2008) of total petroleum imports. Given these volumes, the scale of coconut oil production for fuel for electricity generation envisaged for the near and medium terms (0.67 million litres per annum and 1.8 million litres per annum respectively, as discussed below) will not make much of a dent in Samoa’s petroleum imports. The project’s potential for import substitution and its impact on the balance of payments are small.

A far more significant macroeconomic impact of the project is expected in the form of a redirection of resources away from expenditure on imported fuel and toward incomes to small holder coconut farmers in Savai’i. According to a recent ADB study of poverty in Samoa, widespread hardship in Savai’i is largely due to a “limited market for agricultural crops” and “poor access to basic services”; lack of access to markets caused “…81% of rural respondents [to] give away the excess produce from their plantations. Five out of six communities on Savai’i rated market access as poor…” The coconut oil project for power generation in Savai’i would provide a steady market for coconuts to the rural poor of Savai’i, representing a potential for increased aggregate rural income on the island of between ST$0.7 million and ST$1.8 million per annum, depending on the scale of operations. This is the principal potential source of economic benefit of the project to the country.

7.2.2 Potential Fiscal Impacts

EPC pays 42 sene of excise duty on each litre of fuel, ST$ 6.8 million in 2004 of which ST$1 million annually is reimbursed by the Government. At the current price of diesel fuel to EPC of ST$1.74 and a volume of about 17 million litres (2004), total duty paid after reimbursement will be approximately ST$8.2 million in 2005. The initial phase of the coconut oil project, designed to produce 0.66 million litres of coconut oil and displace 0.61 million litres of imported diesel fuel, will thus represent a loss of about ST$293,000 in excise duty annually to the Government. Three times as much, however, will go to the rural farmers on Savai’i. Phase II will lead to a Government loss in revenue of ST$ 0.8 million annually. It is imperative for the feasibility of the project that Government does not decide to levy the lost revenue on the Coconut Oil Fuel. This would greatly jeopardise the viability of the COF plant.

The economic and financial analysis, presented and discussed in detail below, indicates a substantial economic benefit of the project to the country as a whole (largely in the form of rural incomes) but, at least in the initial stages, a marginal financial benefit to EPC. It is recommended, therefore, that any consideration of taxing the production of coconut oil for fuel to recoup the losses in fuel duty be indefinitely deferred, at least until the fuel production facility has become well established and the financial impact of coconut-oil fuel on EPC is well understood.

7.3 Economic and Financial Analysis of Coconut Oil Fuel use by EPC

The project to produce coconut oil for fuel, by EPC for use in their own generators in Savai’i, is envisaged on two alternative scales, which in practice may be implemented in two consecutive phases. The first phase would be a relatively small-scale plant producing about 660,000 litres of coconut oil per annum and displacing about 610,000 litres of diesel fuel, or about 20 percent of the annual consumption of diesel fuel by EPC in Savai’i. As it is recommended that a maximum blend of one part coconut oil to nine parts diesel fuel be used in a non-modified diesel engine, in order to utilise 660,000 litres of coconut oil; at least one of the larger engines in the Savai’i power house would require modification to allow higher concentration of coconut oil in the blended fuel.

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29 Priorities of the People: Hardship in Samoa, Asian Development Bank, November 2002
30 See the technical feasibility section of this report.
The first-phase project would require the annual purchase and processing of 5.0 million coconuts on Savai'i.

A second phase of the project, which would follow successful implementation of the first phase, would expand oil production capacity to 1.8 million litres of coconut oil per annum, requiring the purchase and processing of 13.65 million coconuts per annum. This facility would displace about 1.67 million litres of diesel fuel annually, or more than 50 percent of EPC’s annual fuel use on Savai'i. This volume of oil could be utilised either by suitably modifying a 1-MW baseload engine in Savai'i to burn 100% coconut oil, or by shipping some of the coconut oil fuel to Upolu for use there. For this analysis, it is assumed that all of the fuel is used in a dedicated 1-MW engine in Savai'i.

Assuming prior success of the first phase, expansion of coconut oil output in the second phase is estimated to result in a reduction of production costs per litre, due to economies of scale. However, there are significant resource factors that may limit the feasibility of phase II, as discussed below.

Economic and financial analyses of the proposed phase I and phase II plants have been carried out with sensitivity analyses of key parameters and are summarised below. The detailed tabulated calculations for each phase are presented in Annex I.

A discount rate of 5% is used to evaluate the present values of future benefits and costs, which is somewhat lower than the discount rate normally used for commercial investments (8%-12%). The lower discount rate was selected to reflect a relatively high value for the future environmental and poverty-reducing benefits expected from the project. It is further assumed that, as there will be no taxes or duties payable on coconut oil production inputs, economic prices and financial prices of the project are equivalent on the input side. Duties, however, are removed from the economic (but not financial) valuation of diesel fuel savings on the output side.

### 7.4 Phase I of the Coconut Oil Fuel Production Project: 0.65ML

The input parameters (capital and operating costs, throughput assumptions, and the production of coconut by-products) are summarised below for the proposed phase I plant.

#### Initial Costs and Assumptions

**Capital Costs**

<table>
<thead>
<tr>
<th>Buildings and Design</th>
<th>Estimated Cost (S$)</th>
<th>Estimated Cost (US$)</th>
<th>Estimated Useful Life (years)</th>
<th>Annual Depreciation Cost (S$)</th>
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<tbody>
<tr>
<td>Dryers, Dehusking and Deshelling Equipment</td>
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<td>$ 95,000 $</td>
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<td>Expellers</td>
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<td>Fuel Tanks</td>
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<td>$ 38,000 $</td>
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<td>$ 5,000 $</td>
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<tr>
<td>Piping, Belts, Infrastructure</td>
<td>$ 250,000 $</td>
<td>$ 95,000 $</td>
<td>15</td>
<td>$ 16,667 $</td>
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<tr>
<td>Total</td>
<td>$ 1,350,000 $</td>
<td>$ 589,000 $</td>
<td></td>
<td>$ 105,000 $</td>
</tr>
</tbody>
</table>

Cost of modifying a 1–MW genset to burn >10% oil/diesel blended fuel (up to 100%) | $ 65,789 $ | $ 25,000 $ |

Total Capital Costs | $ 1,815,789 $ | $ 614,000 $ |

The total annual throughput of the plant begins with 5,000,000 coconuts supplied and delivered to the plant each year, with production implications as follows:
Throughput Assumptions

Initial operations use
5,000,000 nuts annually
or
416,667 nuts/month
Plantations provide
50,000 nuts/month
500 households provide
368,667 nuts/month
or
733 nuts/household/month
or
183 nuts/household/week

Efficiency of Conversion of Nuts to Oil
Dry copra yield per coconut (kg) 0.20
Yield of oil by weight from dry copra 60%
Density of coconut oil (kg/ltr) 0.91
Nuts required to produce 1 litre of fuel 7.58

Annual and Daily Throughput
Total copra produced 1,000 tonnes/year
Workdays available per year 240
Copra processing rate 4.17 tonnes/day
Workdays required per year to process 240
Percent days worked 100%
Number of nuts processed per day 20,833
Number of deshelling machines at 360 nuts/hr 8
Coconut oil produced 2.50 tonnes/day
or 2,747 litres/day
or 659,341 litres/year

Here it is assumed that at least 500 households in Savai‘i are continuously active in supplying an average of 183 nuts per household per week, supplemented by plantations, which provide an additional 50,000 nuts per month. The nuts would be sold to EPC at the roadside; EPC would use its own 10-tonne trucks to collect the nuts and transport them to the mill. The mill is assumed to operate an average of 240 days/year (20 days/month), processing about 21,000 coconuts yielding 4.2 tonnes of copra per working day. This will result in an output of 2.5 tonnes of coconut oil per working day.

Operating Cost Assumptions and Estimates

Price paid per coconut collected
$ 0.1300
Transport Costs (10-tonne truck(s) assumed available)
Number of nuts per tonne transported 450
Truckloads per month 93
Distance per truck per load 60 km
Cost per truck-km $ 1.50 per km
Additional cost of maintaining a modified genset (above usual maintenance costs) $ -
Labour
Management
1 $ 2,000
Labourers employed fulltime at the Mill
15 $ 375

Operating Cost Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Annual Cost ($)</th>
<th>Estimated Annual Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of Coconuts (roadside)</td>
<td>$ 650,000</td>
<td>$ 247,000</td>
</tr>
<tr>
<td>Delivery of Coconuts to Mill</td>
<td>$ 100,000</td>
<td>$ 38,000</td>
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<tr>
<td>Labour</td>
<td>$ 91,500</td>
<td>$ 34,770</td>
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<td>Annual Maintenance</td>
<td>$ 21,930</td>
<td>$ 8,333</td>
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<tr>
<td>Consumables</td>
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<td>$ 9,500</td>
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<td>Fuel</td>
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<td>Electricity</td>
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<td>Water</td>
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<tr>
<td>Other</td>
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<td>$ 4,560</td>
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<tr>
<td>Consumption of Capital</td>
<td>$ 105,000</td>
<td>$ 39,900</td>
</tr>
<tr>
<td>Total Operating Costs</td>
<td>$ 993,430</td>
<td>$ 377,303</td>
</tr>
</tbody>
</table>
The last of the basic input assumptions concerns the production and sale value of coconut by-products. The total volume of by-products consists of coconut shell, husk, coconut water and meal, of which only meal is assumed to have a market value (although an assumption of some value for shell can be easily incorporated). It is assumed that coconut meal can be sold by EPC, chiefly to farmers as livestock feed, at ST$200/tonne.31

Volume and Value of Coconut By-Products

<table>
<thead>
<tr>
<th>By-Product</th>
<th>Volume</th>
<th>Revenue/Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal produced as by-product</td>
<td>400 tonnes/year</td>
<td>$200/tonne</td>
</tr>
<tr>
<td>Shell produced as waste product</td>
<td>960 tonnes/year</td>
<td>-$ per tonne</td>
</tr>
</tbody>
</table>

Revenue from meal sold (net of marketing and distribution costs) $200/tonne
Benefits from sale of meal $80,000/year

Annual Benefit of Coconut Oil Fuel Operations

It is understood that the current price of imported diesel fuel paid by EPC is approximately ST$1.81/litre, inclusive of duty. Since, in terms of energy value, 1 litre of diesel fuel is equivalent to 1.08 litres of coconut oil, the price of coconut oil per litre at which oil has the same energy cost as diesel fuel is ST$1.81/1.08, or ST$1.68.

The output of 659,341 litres of coconut oil from the processing of 5 million coconuts per year will displace 610,500 litres of diesel fuel valued at ST$1.105 million. To this is added ST$80,000 per year as the assumed value of sales of the by-product coconut meal, to give a gross annual financial benefit of operating the coconut oil plant of ST$1.158 million.

Against this gross financial benefit, the financial costs of operating the plant, inclusive of energy costs, maintenance and depreciation of the building and processing equipment, purchase and transportation of nuts to the mill, labour, and financing charges (in the present case, assumed to be nil) total ST$0.993 million per year. At the given costs, the cost of coconut oil produced is ST$1.51 per litre, equivalent to a cost of ST$1.63 per litre of diesel fuel displaced, compared to the current cost of diesel fuel (ST$1.81/litre). This yields a net financial benefit of coconut oil operations to EPC at the phase I level of output of about ST$192,000 per year. These values are summarised for 2007 (the assumed first year of operations) below.

31 COPS have reportedly sold meal at ST$250/tonne in the past.
32 See the Chapter 3 for technical background.
Annual Benefits and Costs of Coconut Oil Operations (Phase I)

Oil Mill Operating Benefits to EPC
- Production of coconut oil (litres) 659,341
- Displacement of equivalent diesel fuel (litres) 610,501
- Value of displaced diesel fuel $1,105,006
- Sale of coconut byproducts $80,000
- Total Operating Benefits to EPC $1,185,006

Oil Mill Operating Costs
- Purchase of Coconuts (roadside) $650,000
- Delivery of Coconuts to Mill $100,000
- Labour $91,500
- Annual Maintenance $21,930
- Consumables (electricity, fuel, water, other) $25,000
- Depreciation of equipment $105,000
- Financing Charges $-
- Total Operating Costs $993,430

Cost per litre of coconut oil produced $1.51
Cost per litre of diesel fuel displaced $1.63

Net Financial Benefit of Oil Mill Operations to EPC $191,576
Interest from cash balances due to project $-
Net Financial Benefit of Project to EPC $191,576

It can be seen from the above that the chief component of annual operating costs is the cost of purchasing coconuts at the roadside from households and plantations in Savai‘i, under the initial assumption of a roadside purchase price of 13 sene per coconut. The financial benefit of coconut oil operations to EPC is extremely sensitive to the price per coconut paid to the growers.

7.5 Long-Term Financial Impact of the Project on EPC

It is assumed that the initial capital cost of the plant will be 75% financed by external grant and 25% by internal contribution from EPC or the Government. All other costs including annual operating costs and capital replacement costs as required are assumed to be met by EPC as production proceeds, financed chiefly from savings in expenditure on diesel fuel and from the sale of coconut by-products (coconut meal). It is also assumed that EPC will add the value of net savings and the proceeds of coconut meal sales to corporate cash balances that, at a 1% real interest rate, earn a minor amount of interest income.

Over the 20-year planning period for the project, EPC will have to provide for capital replacement of the various components of the coconut oil plant as they wear out, in accordance with the assumed duration of useful life as indicated in the above table “Capital Costs” (See section 7.4). In view of the capital replacement costs, assumed to be entirely financed by EPC from the net annual savings of the project, the project is a marginally favourable financial proposition for EPC over the long term, as shown below in the calculation of the financial internal rate of return (FIRR) of the project.

33 The discount rate at which the present value of financial costs equals the present value of financial benefits over the planning period of the project (in this case, 20 years).
that are not felt at all or are felt differently by EPC, i.e., with regard to: specification of benefits is quite different. The country as a whole benefits from the project in ways oil project, the costs measured are the same in the financial and economic analyses, but the economic analysis of the project assesses its impact on the country as a whole. For the coconut In contrast with the financial analysis of the project’s impact on the owner of the assets (EPC), the 7.6 Long-Term Economic Impact of the Project on Samoa

The FIRR of less than 6 percent and the small positive net present value (NPV) of the project indicate that, at a purchase price per coconut at the roadside of 13 sene/nut and a competing diesel price of fuel of ST$1.81/litre, EPC is recovering slightly more than the life-cycle financial costs of the project. Reducing the purchase price of coconuts at the roadside, however, has a dramatic effect on the financial attractiveness of the project to EPC: a purchase price of 12 sene/nut results in an FIRR of 11.13% and a positive NPV of ST$710,000. For further results, please see the sensitivity analysis in section 7.9.

The other factor of great significance is the financial (duty inclusive) price of imported diesel fuel: as the diesel fuel price increases, the financial savings that come from substituting coconut oil of a given cost also rise. At a coconut purchase price of 13 sene per nut, the FIRR of less than 6 percent and a small positive NPV when the financial cost of diesel is ST$1.81/litre rises to 16.79% and ST$1.56 million respectively, if the diesel price is ST$2.00/litre.

At the ‘base case’ diesel price of ST$1.81 and coconut purchase price of 13 sene, however, the project is of marginal financial attractiveness to EPC, with associated high risk that increases in cost, either in capital or operating costs above the base case estimates indicated in the tables above, will make the project financially unsustainable.

7.6 Long-Term Economic Impact of the Project on Samoa

In contrast with the financial analysis of the project’s impact on the owner of the assets (EPC), the economic analysis of the project assesses its impact on the country as a whole. For the coconut oil project, the costs measured are the same in the financial and economic analyses, but the specification of benefits is quite different. The country as a whole benefits from the project in ways that are not felt at all or are felt differently by EPC, i.e., with regard to:

i) The benefit of rural employment in the collection and sale of coconuts to support the project – a value that results from diverting some expenditure on imported fuel to expenditure on making indigenous poor, rural, and presently unemployed labour productive (though this benefit does not accrue to EPC);

ii) The value of reducing greenhouse gas (GHG) emissions by substituting coconut oil for a petroleum fuel (a value which likewise does not accrue to EPC); and

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil Mill Initial and Replacement Costs</th>
<th>Engine Modification Costs</th>
<th>Oil Mill Operating Costs</th>
<th>Interest Cost</th>
<th>Total Costs</th>
<th>Diesel Fuel Costs Avoided</th>
<th>Coconut By Products</th>
<th>Interest Earnings</th>
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FIRR 5.76%
NPV (5%) $74,269

[SOPAC Technical Report 393 – Cloin]
iii) The valuation of savings in diesel fuel costs (import duty is eliminated from the financial
diesel fuel price in the economic analysis, as duty is a tax rather than an economic cost,
despite it being a substantial financial cost to EPC).

Estimation of Benefit from Reduced GHG Emissions

The GHG benefit is estimated on the basis of reduced CO₂ emissions from the generation of
electricity by diesel fuel, valued at the current international credit for reduced emissions (10 USD
per tonne). The calculation of the benefit for the phase I project is summarised as follows.

- CO₂ produced per diesel-generated kWh: 1.00 kg
- Diesel fuel displaced by project: 610,501 litres/year
- Diesel conversion efficiency: 3.63 kWh/litre
- Diesel-generated kWh displaced by project: 2,215,593 kWh/year
- Total reduction in CO₂ emissions: 2,216 tonnes/year
- International value of reduced emission: 10.00 USD/tonne
- Total Carbon Credit from project: 58,305$ per year
- or: 26.32$ ST$/tonne

Though not terribly significant in the present analysis, the value of GHG reduction could become
an important factor in the economic worth of a larger-scale project.

With the project benefits specified as above, the economic internal rate of return (EIRR) of the
phase I project is calculated as follows.

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil Mill Initial and Replacement Costs</th>
<th>Engine Modification Costs</th>
<th>Oil Mill Operating Costs</th>
<th>Total Costs</th>
<th>Diesel Fuel Costs Avoided</th>
<th>Value of Coconut By Products</th>
<th>Value of Rural Employment</th>
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<td>$650,000</td>
<td>$58,305</td>
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</tbody>
</table>

The EIRR of the project in the base case is high at 35%, and the NPV using a 5% discount rate
totals about ST$4.6 million. The economic benefits of the project to the country as a whole are
substantially greater than the financial benefits of the project to EPC largely because of the
project’s notable contribution to rural employment.

Savai’i is an economically depressed area, with high unemployment and low productivity, a prime
reason being the lack of access of small-holder growers to agricultural markets. The project
represents an opportunity to transform a portion of the coconut output in Savai’i, which at present
is largely left to rot, into an important source of rural income. In valuing this benefit, it is assumed
that the labour that would be involved in collecting coconuts for the oil mill is presently
unemployed and that coconuts are available for sale without increasing the areas under

[SOPAC Technical Report 393 – Cloin]
cultivation; i.e., that there are no opportunity costs associated with making the coconuts available to the mill.

In contrast with the financial analysis, in the economic analysis the returns to the project are entirely insensitive to the price paid for coconuts at the roadside. The price per coconut is simultaneously an input cost to the production of coconut oil and a determinant of the value of the benefit of rural employment — as both costs and benefits change equally in response to a change in the coconut price, the economic return to the project remains unchanged. What does happen when the coconut price changes is that the distribution of project benefits between EPC and the involved rural population changes: a higher price directs more of the project benefit to the rural workers while a lower price directs more of the benefit to EPC. The key to realising any of the economic benefits of the project, given that EPC is the agent implementing the project, is to allow the distribution of benefits to EPC to be such as to give them sufficient incentive to remain in the game, i.e., to ensure that the coconut price is low enough to benefit EPC financially.

The economic analysis of the project is ‘robust’ to changes in input costs: the returns to the project are insensitive to changes in the price of coconuts. If the capital cost of the oil mill increased by as much as 100%, the EIRR would fall to a still-acceptable 10%, although EPC couldn’t afford to produce oil due to financial losses. If operating costs apart from the coconut price increased by as much as 100%, the EIRR would fall only to 18%, although, again, EPC wouldn’t produce oil at such costs. Detailed sensitivity analysis for the economic evaluation is tabulated in Annex I.

7.8 Phase II Coconut Oil Fuel Production Project: 1.8 ML

A financial and economic analysis identical to that described above was carried out on the proposed phase II coconut oil project, which would produce 1.8 million litres of coconut oil and displace 1.67 million litres of diesel fuel. The resulting price per litre at this scale of production is ST$1.43 per litre, equivalent to ST$1.55 per litre of diesel fuel displaced.

The economic and financial performance of the phase II project is substantially better than the phase I project, as the average unit costs of production are lower due to economies of scale. Fixed costs (capital and labour) in the larger project rise in lesser proportion to the increase in oil production. In particular, given the key base case parameters as in the previous case (coconut purchase price of 13 sene/nut and a diesel fuel financial price of ST$1.81/litre), the phase II project provides an FIRR to EPC of an attractive 14.45% and a positive NPV of about ST$2.5 million, in contrast to the marginally viable performance of the phase I project under similar conditions.

The difficulty in implementing the larger project consists in the uncertainty in obtaining the necessary raw materials in Savai’i on a sustained basis, which are summarised as follows:
### Throughput Parameters, Phase II Project

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial operations use</td>
<td>13,650,000 nuts annually</td>
</tr>
<tr>
<td>or</td>
<td>1,137,500 nuts/month</td>
</tr>
<tr>
<td>Plantations provide</td>
<td>200,000 nuts/month</td>
</tr>
<tr>
<td>1000 households provide</td>
<td>937,500 nuts/month</td>
</tr>
<tr>
<td>or</td>
<td>938 nuts/household/month</td>
</tr>
<tr>
<td>or</td>
<td>234 nuts/household/week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Efficiency of Conversion of Nuts to Oil</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry copra yield per coconut (kg)</td>
<td>0.20</td>
</tr>
<tr>
<td>Yield of oil by weight from dry copra</td>
<td>60%</td>
</tr>
<tr>
<td>Density of coconut oil (kg/ltr)</td>
<td>0.91</td>
</tr>
<tr>
<td>Nuts required to produce 1 litre of fuel</td>
<td>7.58</td>
</tr>
</tbody>
</table>

### Annual and Daily Throughput

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total copra produced</td>
<td>2,730 tonnes/year</td>
</tr>
<tr>
<td>Workdays available per year</td>
<td>240</td>
</tr>
<tr>
<td>Copra processing rate</td>
<td>11.38 tonnes/day</td>
</tr>
<tr>
<td>Workdays required per year to process</td>
<td>240</td>
</tr>
<tr>
<td>Percent days worked</td>
<td>100%</td>
</tr>
<tr>
<td>Number of nuts processed per day</td>
<td>56,875</td>
</tr>
<tr>
<td>Number of deshelling machines at 360 nuts/hr</td>
<td>20</td>
</tr>
<tr>
<td>Coconut oil produced</td>
<td>6.83 tonnes/day</td>
</tr>
<tr>
<td>or</td>
<td>7,500 litres/day</td>
</tr>
<tr>
<td>or</td>
<td>1,800,000 litres/year</td>
</tr>
</tbody>
</table>

As noted, farmers in Savai’i consists mainly of small holders. There is a high degree of uncertainty whether the sector in Savai’i can supply the greatly increased volume of coconuts needed for the phase II project. For example, in order to make the average contribution of coconuts per household per week feasible, it is assumed that 1,000 households in Savai’i choose to enter the market on a sustained basis, compared to 500 households required for the phase I project, and that plantations quadruple their contribution from 50,000 to 200,000 nuts per month. It is not presently known whether these assumptions are reasonable.

However, if the potential constraints in the primary supply in Savai’i can be addressed, the larger project would provide greater financial security to EPC, due to overall lower average costs. The higher volume of coconut oil fuel would require EPC to dedicate at least one 1–MW engine (by technical modification) to operate on 100% coconut oil.
7.9 Sensitivity Analysis of Financial Analysis

As indicated above, the result of the financial analysis are very much dependent on the assumptions. Figure 17 shows the results of a sensitivity analysis of the main parameters on the Financial Internal Rate of Return.

Figure 17 shows that the viability of the investment increases significantly with a rising diesel price. Rising prices for coconuts, capital expenditure and operational cost result in a negative Net Present Value. The investment is most sensitive to diesel prices; after that – coconut prices; and relatively insensitive to changes in operational and capital investment.

A 10% increase in diesel prices will more than offset a 10% rise in coconut prices.

Because of the significance of the coconuts as an input cost, a separate graph has been compiled in Figure 18.

Figure 18 indicates the Financial Internal Rate of Return as a function of the coconut price in sene.
Figure 18: FIRR as a function of the coconut price [Phase-I] (Source: CocoGen study).

It is clear from the graph above that the FIRR is highly sensitive to the price of coconuts and that a small increase (even to 14 sene) leads to a negative outcome for EPC. Even though the economic benefits for the farmers will be higher in the case of higher coconut prices, a thorough coconut market research in Savai'i is recommended.

The sensitivity analysis of Phase II indicates slightly less vulnerability to the price of coconuts, the investment or the operational cost through economies of scale; nevertheless, the same conclusions can be drawn as on Phase I.

The biggest threat to the viability of the Phase II operations is a lack of coconuts supplied to the Coconut Oil Fuel plant. If the coconuts are not supplied by the farmers, the plant cannot operate and will lose through low output. If during Phase I only 2.5 million coconuts can be supplied instead of the projected 5 million, the price of a litre of fuel produced increases by 25%. It is therefore imperative that a detailed coconut market survey on Savai'i be carried out.

The project, once established, will remain exposed to the risk of not receiving feedstock at a price that is viable for EPC.
8. PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT OF COCONUT OIL FUEL USE AT EPC

8.1 Legal framework Environmental Impact Assessment in Samoa

For any major development in Samoa, the Government requires a “Development Consent”. This is a legal document that gives permission for a use or development on a particular piece of land in Samoa. It contains written conditions and usually an endorsed plan that shows what is to be built and how the land can be used. The proposed use or development must satisfy all the conditions on the development consent of the proposed activity if consent has been granted (MNRE, 2005).

The procedure includes a “Development Consent Application Form” that gives the Ministry of Natural Resources and Environment the opportunity to approve of the plans as part of the PUMA-Act (1998), subject to conditions. This procedure entails a checklist with details on applicant, the development, proposed land and environmental impact; it has to be submitted for any development. Developments with a total value of over ST$ 1 Million have to be approved by a special committee. The procedure usually takes 28 working days. During initial discussions with MNRE officials, no major hurdles have been identified in this legislative requirement for the CocoGen plant.

Under the Government of Samoa, Ministry of Natural Resources and Environment (MNRE) definition, Environmental Impact Assessment is “An examination, analysis and assessment of planned activities with a view of ensuring environmentally sound and sustainable development”. This chapter is a first exploration into the regulatory requirements that a coconut oil fuel production facility and what the proposed use of coconut oil fuel by EPC might entail.

EPC, or its contractor, will be responsible for obtaining a scoping document from the Planning and Urban Management Agency (PUMA), which outlines the Environmental Impact Assessment (EIA) requirements for the work. Usually, specialised consultants are hired for this work and MNRE has a number of guidelines for setting up the Terms of Reference for such work. These guidelines can be obtained free from MNRE.

The role of PUMA in the EIA is limited to deciding which project requires an EIA, reviewing the EIA, making recommendations to minimise environmental impacts; and monitoring/enforcing the environmental requirements resulting from the EIA. Under the EIA draft regulations (part of the PUMA-Act (1998)), there are two stages identified:

1) Preliminary Environmental Impact Assessment Report (PEAR)
2) Full Environmental Impact Assessment (EIA)

This feasibility study will be limited to a Preliminary Environmental Impact Assessment for Phase II (being the largest imaginable impact for the whole proposed operation) of the coconut oil processing plant. During the full implementation, the EIA guidelines for power projects of the ADB (1993) will also be a good reference and checklist.

8.2 Preliminary Environmental Impact Assessment

Description of the Development Proposal

A coconut oil production plant in Savai’i is proposed – the plant will produce coconut oil for use as a fuel by EPC for power generation. It is envisaged the coconut oil production facility will be

incorporated into the proposed new Saleloga power station. It includes a collection system of trucks collecting nuts from plantations and small-holder farms and store these on site. The whole coconuts will then be processed into dried copra and subsequently oil will be produced. By-products include coconut water, husk, shell and copra meal that will all be sold to third parties.

**Area to be affected and the nature of the proposed change of the area**

The area that will be affected by the proposed coconut oil processing plant will include the whole of Savai'i, through its collection system. Therefore, it is proposed to define a:

a) Primary Area (immediate vicinity of 1 kilometre around the plant)

b) Secondary Area (the remains of Savai'i).

The Primary Area would otherwise have contained a power station owned by EPC and now there will be an additional coconut oil processing plant. The Secondary Area will be impacted through the removal of biomass (coconuts) and the use of trucks.

**Resources required by the project**

The full-size proposed project would require no special resources during its construction other than regular construction materials. The specialised machinery for coconut processing will be imported through Apia Harbour.

During the operational life of the coconut oil fuel processing plant, resources as listed in Table 11 will be consumed by the proposed plant.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount/yr</th>
<th>Availability</th>
<th>Other users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconuts</td>
<td>15 million</td>
<td>Resource Locally Available</td>
<td>Farmers, Households, Dessico, moderate competition</td>
</tr>
<tr>
<td>Electricity</td>
<td>1,000 MWh</td>
<td>Locally available</td>
<td>No competition</td>
</tr>
<tr>
<td>Water</td>
<td>10,000 m³</td>
<td>Locally available</td>
<td>No competition</td>
</tr>
<tr>
<td>Human</td>
<td>31 Full Time Employment</td>
<td>Locally available</td>
<td>Great unemployment, No competition</td>
</tr>
</tbody>
</table>

**Justification for the development proposal**

The coconut oil production facility will enable Samoa and especially the small-holder farms in Savai'i to regain livelihoods by producing a renewable crop that will be used for electricity generation. It will mitigate the use of hundreds of thousands of litres of diesel fuel in Savai'i, decreasing Samoa’s dependence on this imported commodity. The burning of coconut oil fuel as opposed to diesel fuel is CO$_2$ neutral and has therefore no net contribution to GHG emissions. In addition, the burning of coconut oil fuel blends that is partly the result of this project is cleaner than straight diesel fuel oil through coconut oil’s high oxygen content.

**Possible adverse and positive impacts**

An inventory of the positive and adverse impacts, including long-term and short-term, primary and secondary consequences are listed below.
Effect on other users of resources

The only effect on other users of the resources, listed in Table 11 are slightly higher prices for coconuts on Savai‘i. This competition is perceived to be healthy for the sector that is currently in disarray. The use of local labour will have a positive effect on the economy of Savai‘i. Moreover, the project will create a market for coconuts that are currently rotting and unused in plantations. This project will enable households willing and able to harvest coconuts, to revive their pastures and grow more coconuts.

Sustainability

The sustainability of the resources used by the project will be safeguarded only when the farmers and plantation holders decide to replant (hybrid) coconut trees during the first years of operation. If this does not occur, the supply of coconuts might be hampered in the medium term. It is expected from the newly emerging market for coconuts; that this project will trigger new replanting by coconut growers.

Waste Product by the Project

The full-size project will produce the side products listed in Table 12.

<p>| Table 15: Side products created by Coconut Oil Processing Plant |
|----------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>By Product</th>
<th>Amount</th>
<th>Potential use</th>
<th>Potential Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut Water</td>
<td>2,280 m³</td>
<td>Tourist drink, vinegar</td>
<td>Agro-industrial industry</td>
</tr>
<tr>
<td>Coconut Husk</td>
<td>2,700 tonnes</td>
<td>Coir mats, rope</td>
<td>Agro-industrial industry</td>
</tr>
<tr>
<td>Coconut Shell</td>
<td>1,185 tonnes</td>
<td>Activated carbon</td>
<td>Chemical Industry, export</td>
</tr>
<tr>
<td>Copra Meal</td>
<td>1,080 tonnes</td>
<td>Pig feed</td>
<td>Farmers, export</td>
</tr>
</tbody>
</table>

The figures for coconut husk and shell as listed in Table 12 assume a 50% burning during the copra-drying process. If EPC decides to do so, a steam engine or a gasifier might be built at the site in addition, to make electricity from this waste stream. The result would be that only the coconut water and copra meal would be by-products of this plant. There are ready markets for these products.

Waste Pollution

The waste is not expected to cause any pollution or have any impact on ground-water quality.

Air Pollution

The coconut oil processing plant is envisaged to produce steam, smoke from coconut shell and husk fires. The air pollution will be have to be subject to a more detailed study based on similar operations. The overall emissions of electricity production will be lower than the baseline with diesel. This is a positive impact.

The factory will also create smells downwind similar to a copra processing plant, which is assumed to be acceptable in an area where EPC is allowed to set up a power plant.
Solid Waste

Assuming all the by-products from the coconut oil fuel processing plant either will be used for electricity or be sold to third parties, there will be no solid waste. Therefore, either concrete plans for use of the biomass streams of coconut shell and husk are required, or an indication by means of Memorandum of Understanding between interested parties with EPC. Such an agreement should prepare the sale of by-products prior to the start of the operation of the plant. If these uses or sales of by-products do not materialise, the husks and shells have to be burnt, otherwise, the plant will create an unacceptable amount of organic solid waste.

Noise

The coconut oil processing plant will create noise comparable to a medium-sized copra mill. This noise is not expected to exceed the operation of a multi-megawatt diesel power plant. Therefore, it should be acceptable to its location. More in-depth study will be required on the actual dB emitted by the coconut oil processing plant.

Changes in land use

The re-creation of a market for coconuts for plantations and small-holder farms is expected to result in significant replanting of (hybrid) coconut trees. It is also expected that currently overgrown plantations will be cleaned and roads will be re-constructed. This is perceived to be a positive development to the agricultural inventory of Samoa.

Effects on the Natural Environment

The effects on the natural environment of the coconut oil processing plant (primary area) are assumed minimal and negligible.

In the secondary area, there will be the removal of biomass (15 million coconuts) that was previously partly used for other purposes, or not harvested at all. Instead of rotting and providing soil nutrients, the coconuts will now be centrally processed, removed and/or burned. The ashes from the coconut oil processing plant will partly provide fertiliser for Savai‘i, however more research is required into the long-term nutrient balance of the coconut pastures soil and the potential need for chemical fertiliser.

Effects on the Human Environment

The social effects of the proposed coconut oil processing plant are expected to be strongly beneficial. Apart from creating livelihoods for small farmers that will have a market for coconuts that was previously unavailable, the plantations are expected to require more labour for harvesting more nuts and replanting, creating local long-term jobs. During construction there will be a significant requirement for construction labour and during operation – as many as 31 full time employment positions can be created.

Since there are very few jobs created through the provision of diesel in Savai‘i, the displacement of these jobs are expected to be non-existent, as diesel will still be required in significant quantities.
Consultations

There have been no consultations with local farmers and plantation owners, or with the immediate surrounding households. The first consultation with the major stakeholders took place during July 2005, in Apia. Further stakeholder consultations will be part of the full environmental impact assessment.

8.3 Preliminary Environmental Impact Assessment Conclusions

Based on the preliminary environmental impact assessment, a full environmental impact assessment is proposed. This study should focus on the following points:

- alternative uses of by-products;
- air pollution;
- noise production; and
- nutrient balance of coconut-producing soil.

Generally, there seems to be no adverse impacts that cannot be resolved easily. The positive benefits of the proposed coconut oil fuel processing plant will generally outweigh the negative.
9. CONCLUSIONS AND RECOMMENDATIONS

The CocoGen feasibility study has found that both Phase I and II of the oil processing plant are technically, financially, economically and environmentally feasible.

It has also identified some significant financial risks that need to be addressed. These are the oil price, the local price of coconuts, and the willingness and ability of the households to deliver the nuts.

The CocoGen Team therefore recommends the following EPC:

- Conduct a thorough market survey for coconuts on Savai’i.
- Develop an initial Memorandum of Understanding with existing plantation holders that can easily be transformed into supply contracts for coconuts.
- Perform a full Environmental Impact Assessment of the coconut oil production plant.
- Negotiate a contract with for COPS for defining quantity and quality of oil for at least 1 year, using the world coconut oil price minus transport costs. This coconut fuel oil can be used as a blend in both Savai’i and Upolu.
- Develop a proposal for both Phase I and II for submission to donors to access co-financing in addition to EPC’s own investment.
- Develop a detailed design for the oil production plant.
- Seek further clarification on gasification opportunities for waste streams of husk and shells.

The proposed Phase I and II are viable investments, provided the oil and coconut prices develop favourable. We therefore recommend EPC to seek opportunities to invest in coconut oil fuel production for use in its compression ignition engines.
LITERATURE LIST


“Biofuels for Developing Countries: Promising Strategy or dead end?” Ziero et al, (1985) GTZ.

“Biofuels for Transport; An international perspective” IEA (2005).


Samoa Observer, various dates.
ANNEX I

CocoGen Economic Analysis
Calculation of the Cost of Producing Coconut Fuel for Diesel Generation in Samoa
(All values are in Samoan Tala except where indicated)

S$1 = 0.38 USD

I. Capital Costs of Proposed Mill (adjacent to new power plant on Savai'i)

<table>
<thead>
<tr>
<th>Estimated Cost (S$)</th>
<th>Estimated Cost (US$)</th>
<th>Estimated Useful Life (years)</th>
<th>Annual Depreciation Cost (S$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings and Design</td>
<td>550,000</td>
<td>299,000</td>
<td>30</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryers, Dehusking and Deshelling Equipment</td>
<td>250,000</td>
<td>95,000</td>
<td>30</td>
</tr>
<tr>
<td>Expellers</td>
<td>400,000</td>
<td>152,000</td>
<td>10</td>
</tr>
<tr>
<td>Fuel Tanks</td>
<td>100,000</td>
<td>38,000</td>
<td>20</td>
</tr>
<tr>
<td>Piping, Belts, Infrastructure</td>
<td>250,000</td>
<td>95,000</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,550,000</td>
<td>589,000</td>
<td></td>
</tr>
</tbody>
</table>

Cost of modifying a 1 MW genset to burn >10% oil/diesel blended fuel (up to 100%) | 65,789 | 25,000 |

**Total Capital Costs** | 1,615,789 | 614,000 |

II. Throughput Parameters

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial operations use 5,000,000 nuts annually or 416,667 nuts/month</td>
</tr>
<tr>
<td>Plantations provide 50,000 nuts/month or 366,667 nuts/month</td>
</tr>
<tr>
<td>500 households provide 733 nuts/household/month or 183 nuts/household/week</td>
</tr>
</tbody>
</table>

Efficiency of Conversion of Nuts to Oil

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry copra yield per coconut (kg)</td>
</tr>
<tr>
<td>Yield of oil by weight from dry copra</td>
</tr>
<tr>
<td>Density of coconut oil (kg/ltr)</td>
</tr>
<tr>
<td>Nuts required to produce 1 litre of fuel</td>
</tr>
</tbody>
</table>

Annual and Daily Throughput

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total copra produced 1,000 tonnes/year</td>
</tr>
<tr>
<td>Workdays available per year</td>
</tr>
<tr>
<td>Copra processing rate</td>
</tr>
<tr>
<td>Workdays required per year to process 240</td>
</tr>
<tr>
<td>Percent days worked</td>
</tr>
<tr>
<td>Number of nuts processed per day</td>
</tr>
<tr>
<td>Number of deshelling machines at 360 nuts/hr</td>
</tr>
<tr>
<td>Coconut oil produced 2.50 tonnes/day or 2,747 litres/day or 659,341 litres/year</td>
</tr>
</tbody>
</table>

III. Operating Cost Assumptions

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Price paid per coconut collected</td>
</tr>
<tr>
<td>Transport Costs (10 tonne truck(s) assumed available)</td>
</tr>
<tr>
<td>Number of nuts per tonne transported</td>
</tr>
<tr>
<td>Truckloads per month</td>
</tr>
<tr>
<td>Distance per truck per load</td>
</tr>
<tr>
<td>Cost per truck-km</td>
</tr>
<tr>
<td>Additional cost of maintaining a modified genset (above usual maintenance costs)</td>
</tr>
</tbody>
</table>

Labour

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor</td>
</tr>
<tr>
<td>Labourers employed fulltime at the Mill</td>
</tr>
</tbody>
</table>

Operating Cost Summary

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of Coconuts (roadside)</td>
</tr>
<tr>
<td>Delivery of Coconuts to Mill</td>
</tr>
<tr>
<td>Labour</td>
</tr>
<tr>
<td>Annual Maintenance</td>
</tr>
<tr>
<td>Consumables</td>
</tr>
<tr>
<td>Fuel</td>
</tr>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Consumption of Capital</td>
</tr>
<tr>
<td><strong>Total Operating Costs</strong></td>
</tr>
</tbody>
</table>

IV. Benefits of Coconut Oil By-Products

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal produced as by-product</td>
</tr>
<tr>
<td>Revenue from meal sold (net of marketing and distribution costs)</td>
</tr>
<tr>
<td>Benefits from sale of meal</td>
</tr>
<tr>
<td>Shell produced as waste product</td>
</tr>
<tr>
<td>Revenue from shell sold</td>
</tr>
<tr>
<td>Benefits from sale of shell</td>
</tr>
<tr>
<td><strong>Total output (litres of coconut oil fuel)</strong></td>
</tr>
</tbody>
</table>

Input costs per litre | $ 1.51 | $ 0.57 |

V. Total output (litres of coconut oil fuel) | 659,341 | 0.9 reliability | 0.5 ST$/kWh
I. Capital Costs of Proposed Mill (adjacent to new power plant on Savai‘i)

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Cost (S$)</th>
<th>Estimated Cost (US$)</th>
<th>Estimated Useful Life (years)</th>
<th>Annual Depreciation Cost (S$)</th>
<th>Capital Cost Sensitivity Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings and Design</td>
<td>$825,000</td>
<td>$313,500</td>
<td>20</td>
<td>$27,500</td>
<td>0%</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryers, Dehusking and Deshelling Equipment</td>
<td>$750,000</td>
<td>$285,000</td>
<td>10</td>
<td>$75,000</td>
<td></td>
</tr>
<tr>
<td>Expellers</td>
<td>$1,200,000</td>
<td>$450,000</td>
<td>10</td>
<td>$120,000</td>
<td></td>
</tr>
<tr>
<td>Fuel Tanks</td>
<td>$300,000</td>
<td>$114,000</td>
<td>20</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td>Piping, Belts, Infrastructure</td>
<td>$500,000</td>
<td>$190,000</td>
<td>15</td>
<td>$33,333</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$3,575,000</td>
<td>$1,358,500</td>
<td></td>
<td>$270,833</td>
<td></td>
</tr>
</tbody>
</table>

Cost of modifying a 1 MW genset to burn >10% oil/diesel blended fuel (up to 100%) | $65,789 | $25,000 |

Total Capital Costs | $3,640,789 | $1,383,500 |

II. Throughput Parameters

Initial operations use | 13,650,000 nuts annually or 1,137,500 nuts/month |
Plantations provide | 200,000 nuts/month or 937,500 nuts/month |
1000 households provide | 938 nuts/month or 234 nuts/household/week |

Efficiency of Conversion of Nuts to Oil
- Dry copra yield per coconut (kg) | 0.20 |
- Yield of oil by weight from dry copra | 60% |
- Density of coconut oil (kg/ltr) | 0.91 |
- Nuts required to produce 1 litre of fuel | 7.58 |

Annual and Daily Throughput
- Total copra produced | 2,730 tonnes/year or 2,730 tonnes/11.38 tonnes/day |
- Workdays available per year | 240 |
- Copra processing rate | 11.38 tonnes/day |
- Workdays required per year to process | 240 |
- Percent days worked | 100% |
- Number of nuts processed per day | 56,875 |
- Number of deshelling machines at 360 nuts/hr | 20 |
- Coconut oil produced | 6.83 tonnes/day or 7,500 litres/day or 1,800,000 litres/year |

III. Operating Cost Assumptions

Price paid per coconut collected | $0.1400 |

Transport Costs (10 tonne truck(s) assumed available)
- Number of nuts per tonne transported | 469 |
- Truckloads per month | 253 |
- Distance per truck per load | 60 km |
- Cost per truck-km | $1.50 per km |

Additional cost of maintaining a modified genset (above usual maintenance costs) | $ - |

Labour
- Number of Staff | 1 |
- Monthly Wage per Person | $2,000 |
- Labourers employed fulltime at the Mill | 25 |
- Monthly Wage per Person | $375 |

Operating Cost Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Annual Cost (S$)</th>
<th>Estimated Annual Cost (US$)</th>
<th>Capital Cost Sensitivity Factor*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of Coconuts (roadside)</td>
<td>$1,911,000</td>
<td>$726,180</td>
<td>0%</td>
</tr>
<tr>
<td>Delivery of Coconuts to Mill</td>
<td>$273,000</td>
<td>$103,740</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>$136,500</td>
<td>$51,870</td>
<td></td>
</tr>
<tr>
<td>Annual Maintenance</td>
<td>$59,868</td>
<td>$22,750</td>
<td></td>
</tr>
<tr>
<td>Consumables</td>
<td>$68,250</td>
<td>$25,935</td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>$ -</td>
<td>$ -</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>$35,490</td>
<td>$13,486</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>$ -</td>
<td>$ -</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>$32,760</td>
<td>$12,449</td>
<td></td>
</tr>
<tr>
<td>Consumption of Capital</td>
<td>$1,911,000</td>
<td>$726,180</td>
<td></td>
</tr>
<tr>
<td>Total Operating Costs</td>
<td>$2,719,452</td>
<td>$1,033,392</td>
<td></td>
</tr>
</tbody>
</table>

IV. Benefits of Coconut Oil By-Products

Meal produced as by-product | 1,092 tonnes/year |
Revenue from meal sold (net of marketing and distribution costs) | $200 per tonne |
Benefits from sale of meal | $216,400 per year |
Shell produced as waste product | 2,621 tonnes/year |
Revenue from shell sold | $ - per tonne |
Benefits from sale of shell | $ - per year |

V. Total output (litres of coconut oil fuel) | 1,800,000 |

Input costs per litre | $1.51 | $0.57 |
### Initial Assumptions

- **EPC Annual Fuel Consumption (ltrs):**
  - Upolu: 10,000,000

- **Financial Fuel Cost per Litre:** $1.810
- **Duty component (per litre):** $0.520
- **Economic Fuel Cost per Litre (exclusive of duty):** $1.290
- **Equivalent price per litre of coconut oil (duty paid):** $1.676

### Financing Cost Parameters

- **Project Initial Cost partly funded by loan:** $1,000,000
- **Grace Period (years):** 3
- **Loan Interest Rate:** 7.0%
- **Real Interest Rate earned on cash balances:** 1.0%
- **Economic discount rate:** 5.0%

### 2006 - 2026 Financial Analysis

#### Initial Investment Costs

<table>
<thead>
<tr>
<th>Year</th>
<th>Coconut Oil Mill</th>
<th>Engine modification for min 30% oil/diesel blend</th>
<th>Total Initial Investment Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>$3,575,000</td>
<td>$65,789</td>
<td>$3,640,789</td>
</tr>
</tbody>
</table>

#### Oil Mill Operating Benefits to EPC

<table>
<thead>
<tr>
<th>Year</th>
<th>Production of coconut oil (litres)</th>
<th>Value of displaced diesel fuel</th>
<th>Total Operating Benefits to EPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1,800,000</td>
<td>$3,016,667</td>
<td>$3,235,067</td>
</tr>
</tbody>
</table>

#### Oil Mill Operating Costs

<table>
<thead>
<tr>
<th>Year</th>
<th>Delivery of Coconuts to Mill</th>
<th>Consumables (electricity, fuel, water, other)</th>
<th>Depreciation of equipment</th>
<th>Financing Charges</th>
<th>Total Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>$273,000</td>
<td>$68,250</td>
<td>$270,833</td>
<td></td>
<td>$2,719,452</td>
</tr>
</tbody>
</table>

#### Cost per litre of diesel fuel displaced

- $1.63

#### Net Financial Benefit of Oil Mill Operations to EPC

- $515,615

#### Memo Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal contribution to project cost</td>
<td>$910,197</td>
</tr>
<tr>
<td>Retained savings</td>
<td>$515,615</td>
</tr>
</tbody>
</table>

#### Total Outflows

<table>
<thead>
<tr>
<th>Year</th>
<th>Buildings and Design</th>
<th>Expellers</th>
<th>Fuel Tanks</th>
<th>Piping, Bld, Infrastructure</th>
<th>Total Outflows</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>$1,200,000</td>
<td></td>
<td>$300,000</td>
<td></td>
<td>$2,250,000</td>
</tr>
</tbody>
</table>

### International Value of Reduced Emissions

- **CO₂ produced per diesel-generated kWh:** 1.00 kg
- **Diesel conversion efficiency:** 3.63 kWh/litre
- **Diesel-generated kWh displaced by project:** 6,048,568 kWh/year
- **Total reduction in CO₂ emissions:** 6,049 tonnes

### Carbon Credit Value

- **International value of reduced emission:** $19.00 USD/tonne

### Total Carbon Credit from project

- $114,036
### Calculation of the EIRR and Economic NPV of the Project

#### Reduced Value of Diesel Fuel

<table>
<thead>
<tr>
<th>Year</th>
<th>Initial and Replacement Costs</th>
<th>Engine Modification Costs</th>
<th>Oil Mill Operating Costs</th>
<th>Total Costs</th>
<th>Diesel Fuel Cost Avoided</th>
<th>Value of Coconut By-Products</th>
<th>Value of Avoided GHG Emissions</th>
<th>Total Benefits</th>
<th>Cognitive EIRR</th>
<th>Net Benefits</th>
<th>FIRR</th>
<th>NPV (5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>$2,719,452</td>
<td>$3,016,667</td>
<td>$2,719,452</td>
<td>$5,438,573</td>
<td>$4,669,452</td>
<td>$2,719,452</td>
<td>$2,150,000</td>
<td>$1,911,000</td>
<td>$159,173</td>
<td>$1,719,121</td>
<td>46.62%</td>
<td>$14,759,636</td>
</tr>
<tr>
<td>2008</td>
<td>$3,016,667</td>
<td>$2,719,452</td>
<td>$2,719,452</td>
<td>$5,438,573</td>
<td>$2,150,000</td>
<td>$1,911,000</td>
<td>$159,173</td>
<td>$1,719,121</td>
<td>$159,173</td>
<td>$1,719,121</td>
<td>46.62%</td>
<td>$14,759,636</td>
</tr>
<tr>
<td>2009</td>
<td>$500,000</td>
<td>$2,719,452</td>
<td>$2,719,452</td>
<td>$5,438,573</td>
<td>$3,219,452</td>
<td>$2,719,452</td>
<td>$1,911,000</td>
<td>$1,719,121</td>
<td>$548,887</td>
<td>$1,219,121</td>
<td>46.62%</td>
<td>$14,759,636</td>
</tr>
<tr>
<td>2010</td>
<td>$2,250,000</td>
<td>$2,719,452</td>
<td>$2,719,452</td>
<td>$5,438,573</td>
<td>$4,969,452</td>
<td>$2,719,452</td>
<td>$1,911,000</td>
<td>$1,719,121</td>
<td>$1,397,082</td>
<td>$1,719,121</td>
<td>46.62%</td>
<td>$14,759,636</td>
</tr>
</tbody>
</table>

#### Sensitivity Analyses

<table>
<thead>
<tr>
<th>Diesel Fuel Price ($/ltr)</th>
<th>Cognitive EIRR</th>
<th>Net Benefits</th>
<th>FIRR</th>
<th>NPV (5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>45.62%</td>
<td>$14,759,636</td>
<td>14.76%</td>
<td>$764,816</td>
</tr>
<tr>
<td>0.105</td>
<td>46.62%</td>
<td>$14,759,636</td>
<td>26.12%</td>
<td>$764,816</td>
</tr>
<tr>
<td>0.12</td>
<td>46.62%</td>
<td>$14,759,636</td>
<td>19.42%</td>
<td>$764,816</td>
</tr>
<tr>
<td>0.125</td>
<td>46.62%</td>
<td>$14,759,636</td>
<td>17.01%</td>
<td>$764,816</td>
</tr>
<tr>
<td>0.13</td>
<td>46.62%</td>
<td>$14,759,636</td>
<td>14.45%</td>
<td>$764,816</td>
</tr>
<tr>
<td>0.14</td>
<td>46.62%</td>
<td>$14,759,636</td>
<td>8.44%</td>
<td>$764,816</td>
</tr>
<tr>
<td>0.145</td>
<td>Not defined</td>
<td>Not defined</td>
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<td>Not defined</td>
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<tr>
<td>0.155</td>
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<tr>
<td>0.16</td>
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<tr>
<td>0.18</td>
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<td>Not defined</td>
</tr>
<tr>
<td>0.185</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
</tr>
<tr>
<td>0.19</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
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<tr>
<td>0.195</td>
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<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
</tr>
<tr>
<td>0.20</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
</tr>
</tbody>
</table>

**EIRR** 46.62%

**NPV (5%)** $14,759,636
### Capital Costs

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>ENPV (millions)</th>
<th>FISAR (millions)</th>
<th>Costs of coconut oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>14.76 $</td>
<td>14.45%</td>
<td>1.435 $</td>
</tr>
<tr>
<td>5%</td>
<td>14.32 $</td>
<td>12.69%</td>
<td>1.442 $</td>
</tr>
<tr>
<td>10%</td>
<td>13.88 $</td>
<td>10.99%</td>
<td>1.450 $</td>
</tr>
<tr>
<td>15%</td>
<td>13.44 $</td>
<td>9.29%</td>
<td>1.458 $</td>
</tr>
<tr>
<td>20%</td>
<td>13.00 $</td>
<td>7.59%</td>
<td>1.465 $</td>
</tr>
<tr>
<td>25%</td>
<td>12.56 $</td>
<td>5.82%</td>
<td>1.473 $</td>
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<td>30%</td>
<td>12.12 $</td>
<td>3.91%</td>
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<td>35%</td>
<td>11.68 $</td>
<td>1.69%</td>
<td>1.488 $</td>
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<tr>
<td>40%</td>
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<td>1.503 $</td>
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<tr>
<td>50%</td>
<td>10.36 $</td>
<td>Not defined</td>
<td>1.510 $</td>
</tr>
<tr>
<td>55%</td>
<td>9.92 $</td>
<td>Not defined</td>
<td>1.518 $</td>
</tr>
<tr>
<td>60%</td>
<td>9.48 $</td>
<td>Not defined</td>
<td>1.525 $</td>
</tr>
<tr>
<td>65%</td>
<td>9.04 $</td>
<td>Not defined</td>
<td>1.533 $</td>
</tr>
<tr>
<td>70%</td>
<td>8.60 $</td>
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<td>1.540 $</td>
</tr>
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<td>75%</td>
<td>8.16 $</td>
<td>Not defined</td>
<td>1.548 $</td>
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<td>80%</td>
<td>7.72 $</td>
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<td>1.555 $</td>
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<td>85%</td>
<td>7.28 $</td>
<td>Not defined</td>
<td>1.563 $</td>
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<tr>
<td>90%</td>
<td>6.84 $</td>
<td>Not defined</td>
<td>1.570 $</td>
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<tr>
<td>95%</td>
<td>6.40 $</td>
<td>Not defined</td>
<td>1.578 $</td>
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<tr>
<td>100%</td>
<td>5.96 $</td>
<td>Not defined</td>
<td>1.585 $</td>
</tr>
</tbody>
</table>

### Sensitivity Analyses (continued)

<table>
<thead>
<tr>
<th>Diesel Fuel Price</th>
<th>ENPV (millions)</th>
<th>FISAR (millions)</th>
<th>Costs of coconut oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.50$</td>
<td>31.66%</td>
<td>8.63 $</td>
<td>4.03 $</td>
</tr>
<tr>
<td>1.55$</td>
<td>34.13%</td>
<td>9.62 $</td>
<td>3.02 $</td>
</tr>
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<td>1.60$</td>
<td>36.57%</td>
<td>10.61 $</td>
<td>1.97 $</td>
</tr>
<tr>
<td>1.70$</td>
<td>41.39%</td>
<td>12.58 $</td>
<td>5.83% 0.17 $</td>
</tr>
<tr>
<td>1.75$</td>
<td>43.77%</td>
<td>13.57 $</td>
<td>10.22% 1.23 $</td>
</tr>
<tr>
<td>1.80$</td>
<td>46.15%</td>
<td>14.56 $</td>
<td>13.79% 2.30 $</td>
</tr>
<tr>
<td>1.85$</td>
<td>48.50%</td>
<td>15.55 $</td>
<td>16.96% 3.36 $</td>
</tr>
<tr>
<td>1.90$</td>
<td>50.86%</td>
<td>16.54 $</td>
<td>19.89% 4.43 $</td>
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<tr>
<td>1.95$</td>
<td>53.20%</td>
<td>17.53 $</td>
<td>22.67% 5.50 $</td>
</tr>
<tr>
<td>2.00$</td>
<td>55.53%</td>
<td>18.52 $</td>
<td>25.34% 6.57 $</td>
</tr>
<tr>
<td>2.05$</td>
<td>57.86%</td>
<td>19.51 $</td>
<td>27.94% 7.63 $</td>
</tr>
<tr>
<td>2.10$</td>
<td>60.19%</td>
<td>20.50 $</td>
<td>30.48% 8.70 $</td>
</tr>
<tr>
<td>2.15$</td>
<td>62.51%</td>
<td>21.49 $</td>
<td>32.98% 9.77 $</td>
</tr>
<tr>
<td>2.25$</td>
<td>67.14%</td>
<td>23.46 $</td>
<td>37.88% 11.90 $</td>
</tr>
<tr>
<td>2.35$</td>
<td>71.76%</td>
<td>25.44 $</td>
<td>42.69% 14.04 $</td>
</tr>
<tr>
<td>2.45$</td>
<td>76.37%</td>
<td>27.42 $</td>
<td>47.44% 16.17 $</td>
</tr>
</tbody>
</table>

### Operating Costs (except coconut purchase price and consumption of capital)

<table>
<thead>
<tr>
<th>Operating Costs</th>
<th>ENPV (millions)</th>
<th>FISAR (millions)</th>
<th>Costs of coconut oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>14.12 $</td>
<td>12.26%</td>
<td>1.465 $</td>
</tr>
<tr>
<td>15%</td>
<td>13.80 $</td>
<td>11.10%</td>
<td>1.480 $</td>
</tr>
<tr>
<td>20%</td>
<td>13.48 $</td>
<td>9.87%</td>
<td>1.495 $</td>
</tr>
<tr>
<td>25%</td>
<td>13.16 $</td>
<td>8.55%</td>
<td>1.510 $</td>
</tr>
<tr>
<td>30%</td>
<td>12.85 $</td>
<td>7.12%</td>
<td>1.525 $</td>
</tr>
<tr>
<td>35%</td>
<td>12.53 $</td>
<td>5.52%</td>
<td>1.540 $</td>
</tr>
<tr>
<td>40%</td>
<td>12.21 $</td>
<td>3.67%</td>
<td>1.554 $</td>
</tr>
<tr>
<td>45%</td>
<td>11.89 $</td>
<td>1.33%</td>
<td>1.569 $</td>
</tr>
<tr>
<td>50%</td>
<td>11.57 $</td>
<td>-2.65%</td>
<td>1.584 $</td>
</tr>
<tr>
<td>55%</td>
<td>11.25 $</td>
<td>Not defined</td>
<td>1.599 $</td>
</tr>
<tr>
<td>60%</td>
<td>10.93 $</td>
<td>Not defined</td>
<td>1.614 $</td>
</tr>
<tr>
<td>65%</td>
<td>10.61 $</td>
<td>Not defined</td>
<td>1.629 $</td>
</tr>
<tr>
<td>70%</td>
<td>10.29 $</td>
<td>Not defined</td>
<td>1.644 $</td>
</tr>
<tr>
<td>80%</td>
<td>9.65 $</td>
<td>Not defined</td>
<td>1.674 $</td>
</tr>
<tr>
<td>85%</td>
<td>9.36 $</td>
<td>Not defined</td>
<td>1.689 $</td>
</tr>
<tr>
<td>90%</td>
<td>9.03 $</td>
<td>Not defined</td>
<td>1.704 $</td>
</tr>
<tr>
<td>95%</td>
<td>8.70 $</td>
<td>Not defined</td>
<td>1.719 $</td>
</tr>
<tr>
<td>100%</td>
<td>8.38 $</td>
<td>Not defined</td>
<td>1.734 $</td>
</tr>
</tbody>
</table>
### Fuel Use and Production in Savai'i, 2004
(EPC Data)

<table>
<thead>
<tr>
<th></th>
<th>Litres of Fuel</th>
<th>kWh</th>
<th>kWh/ltr</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>203,354</td>
<td>738,175</td>
<td>3.63</td>
</tr>
<tr>
<td>February</td>
<td>207,440</td>
<td>799,335</td>
<td>3.85</td>
</tr>
<tr>
<td>March</td>
<td>219,025</td>
<td>849,017</td>
<td>3.88</td>
</tr>
<tr>
<td>April</td>
<td>205,322</td>
<td>876,383</td>
<td>4.27</td>
</tr>
<tr>
<td>May</td>
<td>226,239</td>
<td>880,363</td>
<td>3.89</td>
</tr>
<tr>
<td>June</td>
<td>249,899</td>
<td>863,433</td>
<td>3.46</td>
</tr>
<tr>
<td>July</td>
<td>258,900</td>
<td>884,923</td>
<td>3.42</td>
</tr>
<tr>
<td>August</td>
<td>265,128</td>
<td>915,346</td>
<td>3.45</td>
</tr>
<tr>
<td>September</td>
<td>254,126</td>
<td>896,076</td>
<td>3.53</td>
</tr>
<tr>
<td>October</td>
<td>263,364</td>
<td>922,353</td>
<td>3.50</td>
</tr>
<tr>
<td>November</td>
<td>245,971</td>
<td>858,987</td>
<td>3.49</td>
</tr>
<tr>
<td>December</td>
<td>272,547</td>
<td>936,015</td>
<td>3.43</td>
</tr>
<tr>
<td>Average</td>
<td>239,276</td>
<td>868,367</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,871,315</td>
<td>10,420,406</td>
<td>3.63</td>
</tr>
</tbody>
</table>
ANNEX II

CocoGen Inception Report
(SOPAC Trip Report 372)
Cocogen Inception Report

March 2005
SOPAC, Community Lifelines Programme

Prepared for: EPC Samoa, UNDP Samoa
Acknowledgements:

Thanks to Mr. Thomas Jensen for excellent in-country support and to Mr. Herb Wade for sharing his technological experience and cooperation. Thanks to Joseph Walter for providing logistical support and information. Also thanks to colleagues at SOPAC for their support.

*Picture front page: Sunrise in North Savai’i (Herb Wade)*
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1. Introduction

In the first week of February 2005, the SOPAC Cocogen-team was officially awarded the consultancy contract for the UNDP-Samoa funded study on the use of biofuels in EPC Generators.

In this same week, literature study commenced as a preparation to the consultancy work. Travel arrangements and meetings were scheduled for the first inception mission.

During the week of 7 to 11th of February 2005, a mission was undertaken to Samoa by Jan Cloin with the aim of first fact-finding for the preparation of the Cocogen consultancy with EPC.

This inception report is an overview of the findings of the mission to Samoa and aims to formulate recommendations for the focus of the consultancy objectives, its planning and its approach.

2. Objective

This inception report has two main objectives; the first objective is to create an overview of the status of the coconut sector and the electricity sector in Samoa with relation to biofuel use by EPC. The second objective of this report is to adapt and refine the Terms Of Reference for the Cocogen consultancy in line with the findings of the first objective.

3. Methodology

The data in this inception report are the result of meetings with people, literature research and site visits to various actors of the coconut sector. These data will be compiled and analysed for their impact on the potential future use of biofuels by EPC, focusing on coconut oil. After conclusions on the data analysis, recommendations will be made for the adaptation of the ToR, the planning and the consultancy approach.

4. Findings

4.1 Samoa Country Specifics

The Independent state of Samoa is situated\(^1\) between Australia and the US in the Pacific Ocean. It consists of two main islands (see figure 1) and a number of smaller islands. The total land area is 2,934 km\(^2\) and its economic zone roughly 120,000 km\(^2\).

\(^1\) 13-14 degrees South Latitude and 171-172 degrees West Longitude
The capital, Apia has about 35,000 inhabitants, is located on the Island of Upolu and is the commercial center of the country. Samoa as a whole is home for some 180,000 people (2004) that is growing only slightly at 0.5%\(^2\).

The climate is temperate and most of the year the temperature ranges between 20 – 30°C at an average humidity of 80%. The annual rainfall is 2.88 meters with lows of 2.5 in the west of Savai'i and Upolu and highs in the uplands of up to 6 meters\(^3\).

The country is prone to be hit by cyclones that have shown in recent years to potentially lead to serious damage. Especially because this study considers a vulnerable source of biomass such as coconuts, this is an important consideration\(^4\).

Samoa’s National Currency is the Tala (ST$) with a rate of 2.6 to the US$ (March 2005).

### 4.2 Samoan Electricity Sector

Energy is central in the lives of Samoans and the potential for development in the future. The main sources of energy comprise of imported petroleum products (35%), biomass (60%) and hydro electricity (5%)\(^5\). The important role of biomass is found as wood is used for produce drying, cooking and the Samoan traditional earth oven, Umu.

Table 1 shows the Main Islands of Samoa with its population and its electricity supply.

---

\(^2\) Source: Census Reports, Government of Samoa  
\(^3\) Source: Government of Samoa  
\(^4\) Since the start of this study there have been three cyclone warnings already in 2005, fortunately none of which have actually lead to damage or loss of biomass resources.  
\(^5\) Source: Pacific Regional Energy Assessment (1992)
Table 1: Island Areas, Population and Power Supply
Source: adapted from PIREP Samoan National Report (2005)

<table>
<thead>
<tr>
<th>Island</th>
<th>Area [km²]</th>
<th>Population (2001)</th>
<th>Electricity Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savai’i</td>
<td>1,708</td>
<td>42,824</td>
<td>Diesel Generation, Grid connected</td>
</tr>
<tr>
<td>Upolu</td>
<td>1,123</td>
<td>134,024</td>
<td>Diesel and Hydro, Grid Connected</td>
</tr>
<tr>
<td>Manono</td>
<td>3</td>
<td>1500</td>
<td>Connected to Upolu</td>
</tr>
<tr>
<td>Apolima</td>
<td>1</td>
<td>150</td>
<td>Diesel mini-grid</td>
</tr>
<tr>
<td>All others</td>
<td>1</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Total sales of electricity by the government owned and only power utility Electric Power Corporation (EPC) are given in figure 2 below. It can be seen that in the last 5 years there has been a steady increase of total production that is projected to further stabilise in the current financial year.

![Figure 2: EPC Generation 1998 - 2005 (Source: EPC, incl. 2005 estimates)](image)

Figure 3 (below) shows the composition of the generation by source. EPC has traditionally made use of a hydro station in Upolu that generates on average half of the electricity produced, depending on rainfall patterns.
The share of diesel installed capacity and production has been increasing to keep up with growing demand and unpredictable hydro capacity.

EPC Production by Source

![EPC Production by Source](image)

**Figure 3: EPC Generation by source (Source: EPC)**

From these two graphs, it can be seen that diesel generation is a fact of life in the Samoan power supply. There are advanced plans to develop further hydro resources, however these will not replace all diesel capacity in the medium term.

EPC’s outlook is a further increase of 6% annually in the coming 5 years in both peak demand and capacity.

Through a combination of cost savings and environmental considerations, EPC aims to utilise alternative fuels from diesel will be a part. In addition, the increasing dependence on imported fossil fuels is another main reason to carry out a feasibility study into the use of alternative fuels in the EPC generators.

During discussions with EPC management it became clear that EPC has carried out some trials with alternative fuels in the early 1980s. From

---

7 Source: Chairman's remarks in "EPC Corporate Plan 2004-2007" -
8 see Annex I, list of meetings during country mission February 2005
these trials however, no records or results are available today. Because of the technical risks associated with using fuels that are not recommended by the manufacturer of the generating units, there have been no further trials.

It is felt that during the feasibility study, the economic cost-benefit analysis should be taking into account the decrease of direct fuel costs, however also including likely increase in maintenance costs. Therefore, a similar cost-benefit analysis as the use of heavy fuel instead of distillate in the generators should be carried out.

The importance of the Cocogen consultancy to not only focus on a desk study but also increase the capacity of EPC personnel through training on the use of biofuels was re-iterated.

### 4.3 Samoan Coconut Sector

Samoa has been a major exporter of a range of coconut products in the past century and has been the backbone of the national economy. It is also an integral part of the way of life for most Samoans, providing food, shelter, fuel, home comfort and cash\(^{10}\).

Through a combination of fluctuating prices, weak management, limited re-investment, cyclones and pest damage, the coconut industry came to a virtual halt in 2000. This is illustrated in Figure 5, showing the coconut export volume in recent years. The industry is getting back on its feet slowly, as can be seen for example from increased output.

*Figure 5: Coconut Export Volume (Source: Coconut Industry Review)*

---

\(^9\) "EPC has held a six-month trial using coconut oil as a substitute for diesel in engine operation and expects to carry out further trials" – please refer to Western Samoa: Issues and Options in the Energy Sector, June 1985, p. iv, joint UNDP/World Bank Energy Sector Assessment Program. This publication we forwarded today in electronic version.

\(^{10}\) Adapted from "Coconut Industry Review" (2004)
from the COPS copra mill and the recent re-opening of Desico, a factory for Desiccated Coconut products in February 2005.

Other coconut-based exports include Copra, Copra Meal, and Coconut Cream.

The world market for coconut products has been proven to be very volatile, with strong competition both between competing coconut producers and also other producers such as palm oil.

Samoa plays a small role in the global coconut industry and will be dependent on further price developments for major coconut products on the world market. During the last decade, the price of coconut oil CIF Rotterdam fluctuated between US$ 350 and US$ 750 per metric tonne. The medium-term price development of products such as coconut oil is not expected to fluctuate greatly. In the current market arrangements with heavy interdependencies with other vegetable oil products, it is expected the volatility is limited.

The current price of coconut oil CIF Rotterdam is US$ 620 per metric tonne, while transport cost from Samoa, including storage, financing and insurance result in a net benefit of roughly US$ 500 per tonne. The February 2005 opportunity costs for raw coconut oil from the only copra mill in Samoa (COPS, owned by Elan Trading Pty Ltd) are thus\(^\text{11}\) ST$ 1.18 per litre\(^\text{12}\).

The size of the coconut resource has been subject to a number of studies and it is expected that the Cocogen consultancy will add a degree of confidence to the available data. It has become clear from various discussions in the Ministry of Agriculture, with the COPS mill and through site visits in Upolu (STEC plantation, hybrid coconut seedlings gene pool) and Savai’i that if the reward to harvest coconut products is increased, new supply will emerge.

\(^{11}\) See Also “Copra Oil, Challenges and Opportunities”, South Pacific Applied Geoscience Commission (2004)

\(^{12}\) Rate Feb 2005: 2.6 Tala/ US$
5. Analysis

5.1 Supply Chain Analysis of coconut oil

It will be a major effort during the feasibility study to assess the impact of an increased demand for coconuts through biofuel usage by EPC, the required price increase and the resulting supply of coconuts, given the other actors in the coconut industry. Table 2 indicates the prices farmers obtain for different purposes of coconut use.

It can be seen that the limited markets such as drinking nuts and virgin coconut oil have relatively high rewards of 25 to 50 senes per nut. The more or less unlimited markets (for example COPS is craving for copra) have a value of 10 – 15 senes per nut. Copra production will only increase when:

1) Higher price is paid per kg of copra;
2) Rural and inter-island transport systems improve;
3) Payment becomes more reliable.

The coconut industry review recommends the study of a value-added analysis of the coconut produce supply chain; therefore we assume this has not been done previously. The Cocogen Feasibility study will therefore aim to assess the elasticity of prices and the potential supply for copra in the coming 3 years.
Table 2: Prices per Coconut for different purposes

<table>
<thead>
<tr>
<th>Product</th>
<th>Current Price(^{13}) per nut [$sene]</th>
<th>Labour</th>
<th>Market Opportunities/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copra</td>
<td>10 – 14</td>
<td>Gather, Dehusk, Cut Copra, Dry Copra, Transport</td>
<td>Unlimited market opportunities in Upolu, Limited opportunities in Savai‘i through transport costs. Farmers have to be patient with payment.</td>
</tr>
<tr>
<td>Desico</td>
<td>15</td>
<td>Gather, Dehusk, bring to Plant</td>
<td>Currently limited market, significant growth opportunities</td>
</tr>
<tr>
<td>Desico Collected</td>
<td>12</td>
<td>Gather, Dehusk</td>
<td>Currently limited market, moderate growth opportunities</td>
</tr>
<tr>
<td>Coconut Cream</td>
<td>12</td>
<td>Gather, Dehusk</td>
<td>Limited Market opportunities, Moderate growth opportunities</td>
</tr>
<tr>
<td>Roadside Sale</td>
<td>10-15</td>
<td>Gather</td>
<td>Currently oversupply, moderate growth opportunities</td>
</tr>
<tr>
<td>Drinking Nut</td>
<td>25</td>
<td>Climb Tree, Gather, Transport to Market, Pay Stall</td>
<td>Only Green nut Limited market</td>
</tr>
<tr>
<td>Virgin Coconut Oil</td>
<td>30-50</td>
<td>Gather, Dehusk, Shell, Grate, Dry, Press Oil</td>
<td>Limited Market, Moderate export growth opportunities</td>
</tr>
</tbody>
</table>

5.2 Resource Assessment

Following interviews with the Ministry of Agriculture, the Ministry of Finance and the visit to the STEC plantation, it was found that there is a lot of data available on the resource potential of coconuts. However, this information does not seem to be available in a ready-to-process form.

During the same period as this consultancy will be carried out, SOPAC will perform a training session in Samoa on the use of spatial databases and GIS at amongst others the Ministry of Agriculture.

Given the large amount of data already available at the Ministry of Agriculture, it is proposed to carry out the resource assessment in close collaboration with the Ministry of Agriculture, the Ministry of Natural Resources and Environment and the SOPAC in-country GIS intern.

\(^{13}\) Source: Coconut Industry Review (2004), site visits, stakeholder meetings.
5.3 Cost-benefit analysis Fuel Options

In the Quotation for Services Cocogen, submitted by the SOPAC team, 5 fuel options have been described. Table 3 lists these fuel options again with estimated prices per litre.

Table 3: Prices of Fuel Options per liter

<table>
<thead>
<tr>
<th>Source: Ministry of Finance, site visits, stakeholder meetings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price per Litre</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Diesel (baseline)</td>
</tr>
<tr>
<td>Pure Coconut Oil</td>
</tr>
<tr>
<td>Dual Fuel System</td>
</tr>
<tr>
<td>Blend Diesel Coconut Oil</td>
</tr>
<tr>
<td>Blend Diesel Biodiesel</td>
</tr>
<tr>
<td>Pure Biodiesel</td>
</tr>
</tbody>
</table>

Figure 7 shows the wholesale price of fuel for the year. EPC pays the wholesale price as determined by the Government of Samoa. As EPC

\[\text{Cost estimate based on data from Biodiesel operations in Hawaii; requires further investigation.}\]
required roughly 17 Million litres of diesel in 2004, their fuel bill was around 24 Million ST$. This includes 6.8 Million ST$ in duty\textsuperscript{15}.

In order to make sufficient copra oil available to consider it as a significant fuel option it is proposed to aim for at least 5% of the current diesel fuel to be replaced. This is equal to an annual supply of 850,000 litres or 765 tonnes\textsuperscript{16}. This will require a rough 4-5 Million nuts to be collected, de-husked, dried and milled. In comparison, Desico is currently absorbing 1 million nuts per annum and says it can boost up productivity to 8 million per annum, if the export market materialises.

On the basis of an overall 5% replacement, EPC can gain valuable experience on the basis of which further diesel substitution can be considered.

Such market developments will however undoubtedly lead to an increase in price per nut to an estimated 17-20 sene per nut, or ST$ 36-40 per 100 pounds\textsuperscript{17}. At the ministry of Agriculture this price is perceived to be sufficient for farmers to start replanting their coconut resources. This price increase will also cover for the collecting time, dehusking and drying process associated with copra production, that currently limit the amount of copra produced.

Such prices enable the Savai’i coconut resources to again participate in the copra supply as currently low prices of the commodity lead to inhibitive transport costs.

This observation re-iterates the recommendation from paragraph 5.1 to carry out an in-depth investigation into the current value added / supply chain of coconut products and the logistics involved.

5.4 Collaboration Cocogen – ADB REEP

During meetings with ADB REEP consultants and the ADB Steering Committee meeting the 2005, it has become clear that the Cocogen consultancy and the Asian Development Bank (ADB) Renewable Energy and Energy Efficiency Programme for the Pacific (REEP) have very much linked focuses of work. One of the priorities during the steering group meeting is that the REEP consultants prepare a feasibility study for a combined heat and power plant that is to be built in the Government STEC plantation for generation of up to 2 MW heat and 5 MW electricity.

Especially the resource assessment component of Cocogen could provide essential input for this REEP feasibility study. Furthermore, the REEP consultants have agreed to co-fund the travel of a consultant to the Pacific to contribute to the Cocogen work and share his experiences during

\textsuperscript{15} EPC is reimbursed ST$1M per annum for the duties on fuel
\textsuperscript{16} This is 16% of the annual theoretical capacity of the COPS mill
\textsuperscript{17} This implies an price increase for copra of 148%
a SOPAC Biofuel national workshop in Fiji. This collaboration strengthens the regional links of both projects and creates the opportunity for EPC personnel to learn from experiences in Fiji.

Because the time frame for implementation of ADB REEP projects is up to three years in the future, whereas Cocogen was designed to look at the current opportunities, it is therefore proposed to collaborate closely with the ADB – REEP project on findings and to keep the Cocogen consultancy focused on the opportunities of the current situation and near future (0-3 year).

### 5.5 Team Composition

Due to unforeseen organisational and personal circumstances, the technical consultant originally proposed to work as part of the SOPAC team, Mr. Timothy Kopial from PNG has been replaced by a biofuel specialist from France, Dr. Gilles Vaitilingom. As Dr. Vaitilingom is more experienced and therefore has a higher consultancy rate per day, it is proposed to decrease the amount of days designated for the technical consultancy from 40 to 15, keeping the costs within the original budget.

**It is therefore proposed to change the budget line for Technical Consultant (US$6,000) from 40 days at US$150 to 15 days at US$400.**

This will have an impact of the approach of the technical feasibility, limiting the opportunities to carry out physical testing at EPC generators. **In consultation with EPC, the SOPAC team proposes to carry out only one (1) fuel test with the most likely feasible fuel option.**
6. Recommendations

6.1 General
It is recommended to delay the project implementation in line with EPC requirements to prepare and organise their contribution to the technical component of the Cocogen consultancy. Please find the newly proposed planning for the implementation of the Cocogen consultancy in Annex III.

6.2 Feasibility Study Approach
From the analysis, a number of points are recommended for the continuation of the Cocogen consultancy. It is firstly recommended that the activities and the approach as described in the Cocogen Quotation of Services. There are several issues that need slight adaptation in the approach. These adaptations in focus are listed below:

- Cocogen to assess in detail the value-added chain of coconut oil, the price elasticity and a resulting supply estimate;
- Cocogen to carry out the resource assessment in close collaboration with the Ministry of Agriculture and the Ministry of Natural Resources and Environment and the SOPAC in-country intern for spatial databases and GIS;
- Cocogen to collaborate closely with ADB-REEP consultants;
- Cocogen to focus on applications between now and three years ahead;
- Cocogen technical feasibility study to be carried out by Dr. Gilles Vaitilingom;
- Cocogen in consultation with EPC to carry out one of the most likely feasible fuel test;
- Environmental impact assessment to be carried out along the lines of PUMA’s Environmental Management Plan (EMP).
Literature List


“Pacific Regional Energy Assessment – Volume 1”. Overview, WB, ADB and the UNDP/ESCAP Pacific Energy Development Programme, August (1992)


Samoa Observer, various dates


“Copro Oil as a biofuel in Pacific Islands – Challenges and Opportunities” (2004) South Pacific Applied Geoscience Commission


### Annex I - List of Meetings during country mission February 2005

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name</th>
<th>Subject of Meeting</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNDP – Samoa</td>
<td>Mr. Thomas Jensen</td>
<td>General preparation and inception meeting, kindly made office available for the preparation of meetings during the week, email and telephone calls.</td>
</tr>
<tr>
<td>Ministry of Finance</td>
<td>Mr. Iulai Lavea</td>
<td>Courtesy visit to update on the status of the Cocogen Project and general SOPAC assistance to the Samoan Government. The Cocogen project was again endorsed by Ministry of Finance</td>
</tr>
<tr>
<td>Ministry of Finance</td>
<td>Ms. Hieremoni Suapaia</td>
<td>General assistance on meetings with Government, general status of energy in Samoan Government was discussed as well as the status of the Energy Policy, which is still in Draft. Ms. Suapaia kindly made available macro-economic data on Samoa that will be used in the feasibility study. Also obtained the latest draft of the energy policy and a press release on fuel prices</td>
</tr>
<tr>
<td>JICA</td>
<td>Mr. Hisaharu Okuda</td>
<td>Discussed the current JICA assistance to the Samoan Government and how this overlaps or has links with Cocogen. JICA has three volunteers working in the energy sector, one on HV transmission lines (reducing losses for EPC) one is working on maintenance for the Savai diesel generators and one is assisting EPC in increasing the capacity of the hydro dam construction.</td>
</tr>
<tr>
<td>STEC</td>
<td></td>
<td>Mission to observe the state of the Government Plantation and to see the Gene Pool where new hybrid seedlings are produced for a government coconut planting scheme.</td>
</tr>
<tr>
<td>Desico</td>
<td>Mr. Taimang Jensen</td>
<td>Observe the operations of the newly refurbished Dessicated Coconut production facility as a gauge for the revitalisation potential of the Samoan Coconut market. Also learn about their collection system as this seems to be a major challenge in the industry.</td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>Mr. Frank Fong</td>
<td>Discuss the Samoan Coconut Sector as a whole, prepare the resource assessment exercise at the Forestry Division in the Ministry of Agriculture, Discuss subsidy scheme that was in place for copra, STEC state of affairs, perceived difference between hybrid trees and Samoan Talls</td>
</tr>
<tr>
<td>COPS/Elan Trading</td>
<td>Mr. Rodney Parker</td>
<td>Discuss the current copra oil sector. Recently COPS has milled 1,500 tonnes of oil from Kiribati (mouldy, relatively low quality). COPS has difficulties paying the copra farmers up front through cash flow problems. Expected to improve in the coming 6 months. Transport system to collect copra is another major challenge, especially to get Savai involved in the production.</td>
</tr>
<tr>
<td>AusAid</td>
<td>Mr. Anthony Gill</td>
<td>Courtesy visit to AusAid and gave an update on the activities by SOPAC in the field of energy. AusAid gave an overview of possible linkages with projects however no obvious overlaps were identified.</td>
</tr>
<tr>
<td>Ministry of Natural Resources and Environment</td>
<td>Mr. Faafetai Sagapolutele</td>
<td>Discuss the situation on waste oil in Samoa; Discuss the requirements of the Government of Samoa to any large-scale development, With regard to the development consent, if procedures are followed, the “Development Consent” should form no problem.</td>
</tr>
<tr>
<td>Ministry of Natural Resources and Environment</td>
<td>Mr. Sunny Seuseu</td>
<td>Discuss the guidelines as formulated by the government of Samoa on carrying out an environmental impact assessment. Planning and Urban Management Authority will further provide the Planning and Urban Act (2004) which includes guidelines for Environmental Management Plan (EMP)</td>
</tr>
<tr>
<td>REEP Meeting</td>
<td>Mr. Tommy Scanlan</td>
<td>Attended the Asian Development Bank (ADB) Renewable Energy and Energy Efficiency (REEP) project meeting. During the meeting, the potential links between the project and Cocogen were discussed. Decided was that the priority projects in RE were going to be 1) Biomass/Biofuel for EPC on the basis of the STEC plantation revitalisation and Hydro Resource Assessment in Upolu. The Cocogen project was presented to the participants. It was decided that the Cocogen would act as a feasibility study for the current options; especially the resource assessment will provide input to the REEP project.</td>
</tr>
<tr>
<td>EPC</td>
<td>Mr. Muaausa Joseph</td>
<td>Presented the Cocogen approach. Possible machines for testing were</td>
</tr>
<tr>
<td>Topic</td>
<td>Participants</td>
<td>Details</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>---------</td>
</tr>
<tr>
<td>Walter Mr. Tile Tuimalealiifano Mr. Tiotio Taulealeausumai</td>
<td>discussed. The technical risks and the actual revival of the coconut industry are perceived to be the main barriers towards implementation of alternative fuels. Training is perceived to be very important component of the consultancy.</td>
<td></td>
</tr>
<tr>
<td>Savaii Mr. Thomas Jensen Mr. Herb Wade</td>
<td>Visit to the Island of Savaii to obtain an impression of the local coconut sector. Unhusked coconuts are for sale along the road for 10 to 15 Tala per 100. There are a number of smaller plantations that have relatively well maintained pastures. Most smallholders seem to farm coconuts as part of subsistence agriculture and only haphazardly sell their coconuts on the market.</td>
<td></td>
</tr>
<tr>
<td>REEP-Cocogen Wrap-up meeting Mr. Thomas Jensen Mr. Herb Wade</td>
<td>REEP will perform a feasibility study into the construction of a coconut oil power plant based in STEC. The plant would consist of a CoGen unit of 1 MW running on shells, husks and woody biomass from cleaning the plantation and old coconut trees. The heat of the Cogen unit will be used to dry copra. A second unit would be comprised of a separate unit of 2-3 MW compression generator running (partly or fully) on coconut oil fuel. The Power plant is envisaged for the short-to medium term, i.e. roughly 3 years from now, if found feasible. It was agreed that Cocogen will look into the current options, whereas REEP will look at the options of 3 years and onwards.</td>
<td></td>
</tr>
</tbody>
</table>
## Annex II - EPC Diesel Generating Capacity Installed

<table>
<thead>
<tr>
<th>Power Station18</th>
<th>Unit Number</th>
<th>Make</th>
<th>Rated Power [MW]</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tanugamanono (Upolu)</strong></td>
<td>4 A</td>
<td>Mirrlees K8 MK1</td>
<td>2.2</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>5 A</td>
<td>Mirrlees K8 MK3</td>
<td>4.2</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7 A</td>
<td>Mirrlees K8 MK3</td>
<td>4.2</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>9 A</td>
<td>Mirrlees K8 MK3</td>
<td>4.2</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Mirrlees K8 MK2</td>
<td>3.5</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Saleloga (Savai’i)</strong></td>
<td>1A</td>
<td>Cummins</td>
<td>0.8</td>
<td>No (Overhaul)</td>
</tr>
<tr>
<td></td>
<td>2A</td>
<td>Cummins</td>
<td>0.4</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>3A</td>
<td>Cummins</td>
<td>0.8</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>5A</td>
<td>Caterpillar</td>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Caterpillar</td>
<td>1.4</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Caterpillar</td>
<td>1.4</td>
<td>Yes</td>
</tr>
</tbody>
</table>

18 Sources: email communication with EPC Generation Manager and Greenpeace "Towards Energy Independence in Western Samoa" (1995), site visits.
Annex III - Updated Planning Sheet
ANNEX III

CocoGen Debriefing Report
(SOPAC Preliminary Report 142)
CocoGen
Debriefing Report

June 2005
Prepared by: SOPAC CocoGen Team
Prepared for: EPC Samoa and UNDP Samoa
Acknowledgements:

Thanks to Mr. Thomas Jensen for excellent in-country support and to Mr. Muaausa Joseph Walter for providing logistical support and information and Tiafau Magele Tafu for his generous support during the Coconut Oil Blend Pilot in Saleloga Power Station. Also thanks to colleagues at SOPAC for their office support.

The CocoGen team consists of: Dr. Vincent Bowry (Lipid Chemical Specialist), Chris Cheatham (Power Economist), Jan Cloin, (Project Manager), Dr. Wolf Forstreuter (GIS Forestry/Coconut Resource Specialist) Dr. Gilles Valtilingom (Biofuel Specialist).

Photo on the front page: EPC Saleloga (Savai’i) Power Station engine #2 that has been successfully tested on the use of 10% coconut oil.
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   Appendix IX - Cost of Coconut Fuel Production in Samoa 54
1. **Introduction**

After the inception mission and the inception report, the CocoGen team has prepared a second mission to Samoa during the weeks of 20-26 March and 27 March to 5 April 2005. The mission was undertaken by Dr. Gilles Vaitilingom, technical consultant, and Mr. Jan Cloin, project manager.

Between 19 and 26 April, Dr. Wolf Forstreuter has visited Samoa to carry out his tasks as agreed under the resource assessment of coconuts. During these activities, Dr. Forstreuter has met with various stakeholders from the Department of Agriculture and the Department of Forestry to use the currently available data with several digital technologies, to assess the amounts of coconuts that can be produced in Samoa. His findings can be found in Chapter 7 of this report.

This debriefing report is an overview of the preliminary findings and achievements of these missions to Samoa.

2. **Objective**

This debriefing report has the objective to update both UNDP-Samoa and EPC on project progress after the fieldwork has been carried out. It will serve as a basis for the feasibility study as well as indicate where work still needs to be undertaken to obtain more clarity about the feasibility of coconut oil as a fuel in Samoa.

3. **Methodology**

The data in this debriefing report are the result of meetings with people, literature research and site visits to various actors of the coconut and power sector. This data will be used in the feasibility study, part of the CocoGen assignment.
4. Findings

4.1 Electricity Sector in Samoa

4.1.1 Increase Electricity Rates
During the mission to Samoa EPC announced a tariff increase to its costumers. Reasons are a combination over the last few years of rising fuel prices and an increasing exchange rate for the New Zealand and Australian Dollar versus the Samoan Tala. The revised tariffs (See also Annex II) are as follows:

<table>
<thead>
<tr>
<th>Rate Structure</th>
<th>Existing Tariff [Sene/kWh]</th>
<th>New Tariff [Sene/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifeline (&lt;50 kWh/month)</td>
<td>50</td>
<td>58</td>
</tr>
<tr>
<td>50-200 kWh / month</td>
<td>60</td>
<td>69</td>
</tr>
<tr>
<td>&gt; 200 kWh / month</td>
<td>72</td>
<td>83</td>
</tr>
</tbody>
</table>

The price per litre of diesel fuel for EPC in Upolu and Savai’i was reported to be ST$1.71 (EPC Wholesale Prices April 2005). This corresponds with US$ 0.64/litre.

*This development indicates that EPC is committed to rational power rate structure. The rising price of diesel is an important variable in the feasibility study of using alternative fuel sources for EPC generation.*

4.1.2 Hydro Power Station in Savai’i

During the mission to Samoa, informal talks (See Annex I, list of meetings) were held with Asian Development Bank (ADB) and EPC staff on the implementation of the Hydro dam in Savai’i. It appeared that chances are high that land issues can be sorted out and the run-of-river hydro station can be built, in a village close to the one that was identified 10 years ago. The power station will have an estimated capacity of 2 MW during the wet season and lower power output during the rest of the year, depending on precipitation patterns.

*This development indicates that the total dependency on diesel for EPC could be reduced by some 5-10% in about 3 years time from now, however this is a one-off reduction and there will still be a need for compression ignition generation by either diesel or alternative fuels.*
4.2 Coconut Sector in Samoa

4.2.1 Coconut products exports

There were many indications that the coconut manufacturers were continuing to struggle with lower volumes and lower market prices. There was unconfirmed talk that Desico was for sale and an independent consultant was asked to look into the finances of the coconut cream manufacturer. Furthermore tender proposals were requested in newspapers for the lease of land, buildings and operating plant, equipment and other assets to an investor for the operation of Desico coconut processing and export business.

The Rotterdam price of coconut oil fell since the beginning of the year to about 610 US$/tonne, resulting in a local spot price of 515 US$/tonne to COPS. This reflects a price of 1,375 ST$/tonne or 1.27 ST$/litre. The current retail price of diesel is ST$1.82/litre, a difference of 55 sene. The difference with the effective price that EPC pays, ST$1.71/litre, is still 44 sene.

The current price difference between the opportunity costs of coconut oil and the effective EPC diesel price of 44 sene/litre shows a positive sign for the feasibility study of using coconut as an alternative fuel. Further research into the sensitivity of price changes is required.

4.2.2 Coconut Market Savai’i

During a small sample survey along the main road in Savaii, it was found that de-husked coconuts were for sale in bags of 30 for ST$5, leading to a price of 16,67 sene per nut. On the market in Saleloga the prices were slightly higher. Heaps of 100 un-husked coconuts were being sold for ST$15.

<table>
<thead>
<tr>
<th>Table 1: Coconut Products in Savai’i</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source: Own Sample Survey</td>
</tr>
<tr>
<td>Type of Nut Product</td>
</tr>
<tr>
<td>Unhusked, 100 pieces, roadside</td>
</tr>
<tr>
<td>Husked, 30 pieces, roadside</td>
</tr>
<tr>
<td>Husked 10 pieces, market</td>
</tr>
<tr>
<td>Husked, green nut, roadside</td>
</tr>
</tbody>
</table>

The manager of the power station, Mr. Tiafau Magele Tafu felt that regular income from coconuts for farmers might be an incentive for them to start re-plant and harvest more than currently is the case. Of the roughly 10,000 households that live on Savai’i, some 5% are expected to have access to coconuts. If these households were to produce one heap of 100 coconuts a week, theoretically, an estimated 50,000 coconuts/week could be produced.

It is unclear whether copra is currently transported from Savai’i to Upolu. If it is, then it is not in great quantities, implying that there is currently a very limited market to produced coconuts in Savai’i. Some report small quantities through local shop owners who trade copra in return for groceries, other claim there is no copra removed from Savai’i.

There seems to be ample supply of coconuts on Savai’i at a price of 15 sene per nut.

---

1 Source: Samoa Observer 20/3/’05 “Down, Down: Exports drop. So do prices for coconut oil and copra”
2 Source: Samoa Observer 27/03/05
5. Pre-Feasibility of an Oil Mill on Savai’i

During the mission, EPC has indicated to be interested in setting up its own coconut oil milling operation. Below is a short exploration of that option.

5.1 Oil Mill Operation

Local Resource

If 500 households have access to 100 nuts per week and collect that on the road (see paragraph 4.2.2), there are 50,000 unhusked coconuts available, or 200,000 per month. Assuming 5 small plantations in Savai’i can contribute another 50,000, this will result in a total supply of 250,000 nuts per month.

The nuts will have to be collected by EPC trucks, driving along the main road of Savai’i and exchanging nuts for cash. Based on 10-tonne trucks, 50 truckloads are to be delivered to the power station. This translates in 2-3 truckloads per day, at an average distance of 60 km at a cost of ST$2/km.

The mill will employ an estimated 15 low-skilled labourers at ST$375/month and a supervisor at ST$2,000/month.

<table>
<thead>
<tr>
<th>Table 2: Monthly Recurring Cost Components Savai’i Coconut Oil Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Coconuts</td>
</tr>
<tr>
<td>Transport</td>
</tr>
<tr>
<td>Labour</td>
</tr>
<tr>
<td>Manager</td>
</tr>
<tr>
<td>Consumables</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

5.2 Oil Mill Investment

The mill is envisaged to be built in combination with the new power plant in Savai’i, to reduce infrastructure costs. Furthermore, the excess heat from the generators can be used to dry copra, in addition to heat from the husks.

<table>
<thead>
<tr>
<th>Table 2: Monthly Investment Cost Components Savai’i Coconut Oil Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Storage / Milling Hall, Design</td>
</tr>
<tr>
<td>Dryer</td>
</tr>
<tr>
<td>Expellers</td>
</tr>
<tr>
<td>Fuel Tanks</td>
</tr>
<tr>
<td>Piping, belts, infrastructure</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

The total write-off costs add up to ST$145,000 per year. It is assumed EPC will finance the operation itself or receive a grant (hence there are no financing costs associated with the investment). Please refer to Appendix IX for a copy of the initial calculations. These calculations will be further refined during the feasibility study.

---

3 The numbers that follow are assumptions; feedback on these assumptions is highly appreciated to make this study more concrete.
5.3 Coconut Oil Fuel Costs

Table 3 below gives an overview of the expected operating costs of the plant.

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Yearly Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of Coconuts (roadside)</td>
<td>ST$ 450,000</td>
</tr>
<tr>
<td>Delivery Coconuts to mill</td>
<td>ST$ 72,000</td>
</tr>
<tr>
<td>Labour</td>
<td>ST$ 91,500</td>
</tr>
<tr>
<td>Consumables (Fuel, electricity, water, etc.)</td>
<td>ST$ 60,000</td>
</tr>
<tr>
<td>Consumption of Capital</td>
<td>ST$ 145,000</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td><strong>ST$ 818,500</strong></td>
</tr>
</tbody>
</table>

Input costs per litre: 1.36 ST$/litre

Table 3 shows that the first indications of price per litre, taking a 25% inaccuracy factor, are in the range of **ST$ 1.02 – ST$ 1.70** per litre of coconut oil fuel.

The result is very sensitive with regard to the weight of copra per nut and the price per nut. This will need to be further addressed in the feasibility study, together with the market for by-products of the coconut oil extraction process.

The initial calculations on the feasibility of a dedicated EPC oil mill in Savai’i seems feasible at a diesel cost to EPC higher than ST$1.36 per litre.
6. Machine Selection Pilot

6.1 Site visit to Tanugamanono (Upolu) Power station

The visit started with a short introduction of the technical consultant to the generation manager (Tile Tuimalealifano), two EPC technical support staff (Ailao and Menu) and a brief presentation of the objectives of the project. Thomas Jensen and the project manager were also present during part of the visit.

Briefly discussed was the likeliness of coconut oil to solidify in Apia. From the meteorological data this will be very rare, especially close to the power station. If a storage tank is to be built far away from the power station, the solidification of the coconut oil feeding line might be an issue in the early morning but can be easily overcome.

The maintenance arising from the use of coconut oil as compared to regular diesel can be expected to be the same. The same time interval for changing of the lubricant is to be expected and no extra wear on the engine has been reported in earlier use of coconut oil as a fuel.

In terms of fuel usage, it can be expected that there will be an increase of 5-6% in volume, as the energy density of coconut oil is slightly lower.

EPC indicated not to be satisfied with the performance of the Mirrlees machines through various problems in the control of the machines, a cracked fuel pump and positive crankcase pressure. This has lead to discussions with the manufacturer that have not been resolved yet. It is therefore felt by EPC management that it is not appropriate to carry out pilots with alternative fuel in the machines currently under discussion.

There have also been discussions with the MAN-B&W sales office in Australia on the use of heavy fuel, which has discouraged EPC to utilise this fuel in their current machine park. Even though the heavy fuel costs are significantly lower, there are a number of issues that keeps EPC from using it in the short term.

Firstly, there is a need for a dedicated storage tank on the wharf as well as on the power station site. Secondly, the current supplier of fuel, Shell PPS has indicated that the volume of heavy fuel use by EPC is not sufficient to start delivering to Samoa now. There will be a need for further market development for heavy fuel, such as reselling heavy fuel to ships from the wharf in combination with delivery to EPC. Thirdly, there will be a need to invest in Fuel heaters, Filters, Centrifugal treatment of the fuel, a more expensive lubricant (through higher content of sulphur in the fuel) and an increased frequency of cleaning the exhaust deposits.

The current base load delivered by the power station is approximately 8 MW, with a morning peak of 13 and an evening peak of 17 MW. This is in addition to the power generated by the Hydro power station.

The corporate plan of EPC provides for the acquisition of another 4.2 MW genset in 2006-2007, for which the use of heavy fuel will be considered. The use of coconut oil in machines that have been designed for heavy fuel will be easier and more flexible to use coconut oil than the existing machines. There has also been an interest in the acquisition of a biomass gasifier for power production, however the investment

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4 If engines are adapted or modified and/or under specified working conditions
5 While substituting one volume of diesel, 1.05 volume of coconut oil is needed for the same power output.
involved and the premature state of the technology seem currently to be inhibiting factors.

The generators were inspected and documentation on the engines was provided to the technical consultant.

After discussions with the Generation Manager, no opportunities were identified for carrying out pilots on the machines in Upolu, as discussions continue with the manufacturer on the performance of the machines on regular fuel.

6.2 Site visit to Saleloga (Savai‘i) Power Station

The power station in Saleloga on the island of Savai‘i was visited and discussions were held with the Manager, Mr. Tiafau Magele Tafu.

He indicated that there were plans to rebuild the power station at an estimated cost of T$6 Million in the coming two years, if investment capital could be identified. The construction would include 4 times 1,000 kVA machines. It is unclear whether these plans will be implemented in the short term.

![Estimated Demand Curve Savai’i](image)

The present machines (see list in Annex III) are all in use, except for #1A, which is currently being overhauled. The Japanese Senior volunteer\(^6\) is heading this exercise with the technical staff of EPC.

The current base load is during the daytime, around 1.2 – 1.3 MW. During 7-9 pm there is a peak demand of around 2.5 up to 2.9 MW\(^7\). The current staffing is set at 1 person per engine during operating times. The machines are started, stopped and synchronised manually. During the peak hours, all the machines are used. During the day, only two machines are running. An alternating selection of engines provides for the easy maintenance of the equipment throughout the day.

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\(^6\) The mission did not meet him, as he was on leave during April 2005

\(^7\) Measured during Christmas night 2004.
The manager indicated that the power station grew slowly with some 400 kVA machines, but as load increased, engines were added. All engines at Savai’i are bought second hand and it is not clear what the exact amount of running hours per machine is.

On the basis of the available machine data and the dispatch strategy of the power station, it was suggested #2A and #5A to be considered for a pilot with coconut oil fuel.

It was considered to run a test on 10% or a 100% straight coconut oil. Central in the decision for the pilot with coconut oil was the reduction of any risk to the equipment while piloting the utilisation of coconut oil. Secondly, minimal interference with the normal operation at the power station was required. Therefore, the blending of coconut oil in the diesel day-tank was chosen as the preferred option.

In addition, there is limited stock of coconut oil available in Samoa at the moment. However, for the lubrication oil sample analysis, a minimum amount of coconut is required, with a minimum amount of running hours. These are determined by the accuracy of the sampling equipment used to determine the possible unburnt coconut oil diluted in the lubricant. A too high rate of unburnt coconut oil will be the sign of the unsuitability of the proposed blend in this engine (See Table 3).

<table>
<thead>
<tr>
<th>Table 3: Determination of Pilot Fuel Blend Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Number</td>
</tr>
<tr>
<td>Effective Capacity</td>
</tr>
<tr>
<td>Consumption (est.)</td>
</tr>
<tr>
<td>Proposed Quantity</td>
</tr>
<tr>
<td>Pilot Duration</td>
</tr>
<tr>
<td>Blend Quantity</td>
</tr>
</tbody>
</table>

After presentations of these options, the Manager of the Salelologa Power Station indicated that he was reluctant to carry out the test, unless the General Manager would decide to take responsibility for the risks. He reiterated his concern for the long-term condition of the engine. It was agreed that the team would send him some international references on experiences with using coconut oil.

If a pilot would be carried out, engine #2A would be the preferred option.

After consultation with the General Manager, it was agreed a 10% blend pilot would be carried out with engine #2A with 1,000 litres of coconut oil.

For the pilot, the following risks (with the following risk reduction strategies) were identified:

- **No Coconut oil available;** Contacted and visited COPS to request the delivery of oil from current production.
- **Bad Quality COPS oil;** Pre-filtering of oil with existing fuel filters to avoid particles in the fuel tank.
- **Carbon Deposits;** The machines have to be run above 50% of their rated capacity to avoid excessive carbon deposits. With the de-rating of the machines, this means they should run at maximum power.
- **Filter clogging;** If coconut oil is mixed with water by accident, the resulting mixture can lead to clogging of filters, therefore, good working hygiene is required.

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8 Please see Annex IV for details on the determination of lubricant contamination analysis.
Blend percentage not right: As the pilot is designed to minimise the risk for the machines, it is imperative that the operator sticks to the 10% blend of coconut oil and 90% regular diesel. For higher percentages of coconut oil in the fuel, engine adaptations may be required.

Lube oil sample not right: It is imperative that the sample of the lube oil after the test is taken according to instructions so that the analysis can be carried out correctly.

The above risks will be reduced by including them in the working instructions for the pilot. Furthermore, the technical consultant will be present for the first day(s) of the pilot and instruct the operators.

6.3 EPC Support for Pilot
EPC has kindly assisted with logistical support for the technical consultant, drums for transport of coconut oil and a technical resource person to support the preparation of the pilot. EPC further has given free access for the technical consultant to the Savai’i generation site and records of production and fuel use.

EPC support was further reassured during a meeting with the General Manager on 24th of March and during several short meetings with the Technical Consultant and the General Manager in the week from 29th March through the 1st of April.

6.4 Implementation of Pilot
Depending on the availability of coconut oil, it was planned to commence the pilot on the 31st of March 2005. Due to some logistical problems, the pilot on # 2A was only commenced on the morning of April 2, 2005. The Technical Consultant was present during the start of the Pilot and left working instructions for the Plant Manager and the personnel (Annex IV).

The pilot was expected to last less than a month, assuming an unchanged dispatch strategy of the machines.

After completion of the pilot, a lubricant sample will be sent by EPC to SOPAC and further on to France for analysis.

6.5 Results of the Pilot
Between April 2 and April 23 2005, a total of 1,018 litres of coconut oil has been blended in the day tank with 9,167 litres of diesel. This fuel was blended inside the day tank of engine # 2 in Saleloga Power Station. The overall fuel usage for the trial engine for the whole month of April was 17,162 litres. A total of 10,185 litres of blend used during the test. This is a very close approximation amount taking into consideration the volume measurement error.

In Appendix VIII, the test report of Mr. Tiafau Magele Tafu, Acting Manager of Saleloga Power Station can be found. In the report, it is indicated that the pilot were carried out successfully with no indication of problems.

Currently, the lube-oil sample after the test is sent to labs in Fiji and to France for analysis. The level of contamination of the lube-oil by unburnt coconut oil will indicate whether it is advisable to continue using a coconut oil blend in machine #2.
7. Coconut Resource Assessment

7.1 Introduction

This section provides an estimation of the available coconut resource and details how this estimation can be further improved in accuracy.

Wolf Forstreuter as part of the project team spent three working days in Apia, Samoa to evaluate existing data, set up a tabular database and links this data to the corresponding GIS layer.

The report deals with the availability and potential production of coconuts, it does however not go into great detail about the conversion of coconut to oil.

7.2 Summary, Current Status of Coconut Resource

The current area information stored in the spatial database (GIS) is based on the land use classification carried out by the Samoan Forestry Department under technical guidance from James Atherton.

The classification stratifies areas stocked with vegetation, where coconut palms are at least part of it, into 16 different strata. The Forestry Department knows all these classes from the field checks and estimated the number of trees (palms) per hectare, which is the first important parameter.

The yield (number of coconuts) per year per palm is the second important parameter. The yield differs between the coconut varieties; however, at this stage it is unknown which varieties stock in the different areas. For the time being, a variety Samoan Tall with 30 years of age is used as default value.

The ages of the plantations are not known at this status, more detailed investigations have to be carried out. As soon as the average age for plantation or area is known the program will use this more exact age to increase or reduce the yield per tree.

The yield is also influenced by the soil and a soil map is available for Samoa. For the time being soil is not taken into consideration, however, the program is capable to incorporate the soil information.

The Access Basic code is calculating for every of the 594 areas, classified as areas where coconut is at least part of the vegetation, the total yield of coconuts per year. This calculation is based on:
Total Yield \[[\text{coconuts/year}]\] = \((\text{Yield/Tree}) \times (\text{Trees/Hectare}) \times (\text{Area Size})\)

**Yield/Tree** is influenced by:
- Variety
- Age
- Soil

**Trees/Hectare**

Stratum
Treatment
The parameter “Trees/Hectare” will be determined for all major areas from aerial photographs calibrated through field measurements.

**Area Size**

MapInfo (GIS software) modules calculate the parameter “Area size”. Any change of the corresponding GIS layer will be reflected by the Access Basic code. The table has to be imported, which then allow updating the main table.

<table>
<thead>
<tr>
<th>Description</th>
<th>Area</th>
<th>Yield Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut plantation with secondary forest</td>
<td>42,837</td>
<td>72,823,682</td>
</tr>
<tr>
<td>Coconut plantation with mixed crops</td>
<td>6,509</td>
<td>17,704,233</td>
</tr>
<tr>
<td>Secondary forest logged over with coconut</td>
<td>3,595</td>
<td>7,334,166</td>
</tr>
<tr>
<td>Secondary forest with coconut</td>
<td>3,166</td>
<td>5,919,778</td>
</tr>
<tr>
<td>Coconut plantation</td>
<td>2,504</td>
<td>13,449,338</td>
</tr>
<tr>
<td>Grassland with coconut and livestock production</td>
<td>959</td>
<td>2,281,943</td>
</tr>
<tr>
<td>Mixed crops with coconut and secondary forest</td>
<td>712</td>
<td>1,089,819</td>
</tr>
<tr>
<td>Coconut plantation with livestock production</td>
<td>606</td>
<td>2,471,339</td>
</tr>
<tr>
<td>Open Forest with coconut and secondary forest</td>
<td>469</td>
<td>797,861</td>
</tr>
<tr>
<td>Mixed crops with coconut</td>
<td>459</td>
<td>936,646</td>
</tr>
<tr>
<td>Secondary forest with coconut and merinium</td>
<td>377</td>
<td>1,025,576</td>
</tr>
<tr>
<td>Secondary forest with albizia and coconut</td>
<td>107</td>
<td>200,895</td>
</tr>
<tr>
<td>Secondary forest with coconut and secondary forest</td>
<td>84</td>
<td>157,192</td>
</tr>
<tr>
<td>Mixed crops with coconut and logged over forest</td>
<td>62</td>
<td>105,774</td>
</tr>
<tr>
<td>Coconut plantation with coco</td>
<td>41</td>
<td>222,400</td>
</tr>
<tr>
<td>Coconut plantation with grassland</td>
<td>19</td>
<td>88,346</td>
</tr>
</tbody>
</table>

| 62,507 | 126,608,988 |

The table [status 30.04.05] details the area per stratum and estimated yield of coconuts per year. “Coconut plantation with secondary forest” is the dominant stratum.

The preliminary results will be permanently revised, as new information will be entered into the system.
7.3 From Global Picture to Accurate Information

It is important to have an estimation of the available resource as soon as possible, which made it necessary to work with assumptions. However, following forestry best practices taking a low value if the exact value is not known. Additional information will be gathered through:

- Screening of more available reports,
- Photo interpretation,
- Sample plot measurement in the field,
- Asking plantation manager to identify the average age of plantations.

The most important parameter is the "forest area" and this parameter is very accurately mapped by Samoa’s Forestry Department. Nevertheless, the system allows updating this parameter as soon as changes of areas are known.

The next important parameter is the “number of stems per hectare”. The Samoa Forestry Department will update this parameter for the main areas. The update will be carried out through aerial photo interpretation described in chapter “Interpretation of Aerial Photographs”. The work will be fast, accurate and statistically sound.

The parameter “Coconuts per Tree” is depending on the age, coconut variety and on the soil condition. The age cannot be estimated from aerial photographs, but for the first 20 years a correlation can be established between coconut height and age. The average height will be measured for every sample plot. In addition, land owners and plantation managers will be asked for the date of plantation establishment. The coconut palm variety will be estimated during the fieldwork. For every sample a “Bitterlich circle” will be established where the total basal area and the basal area for every coconut palm variety is measured. CROPS specialists, who are knowledgeable to recognise the 6 to 7 different varieties, will be part of the field team.

Soil information will be added at a later stage, it will be necessary to change the complete curve of coconut production per palm per year, as the influence of soil not only changes the amount of coconuts per palm, but also changes the time a palm produces coconuts.

Any new information will update the current information to a more accurate one. The main coconut areas are concentrated in the northeast part of Upolu as shown in subsection “Coconut Area and Stratification”. In this area most of the well managed plantations are established, which enables to increase the accuracy soon.

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9 Bitterlich circle is measuring the basal area, which is explained in the chapter “Field Measurements”.
10 Basal area is the theoretical area of the surface of all trees stems cut at 1.3m height, which is explained in chapter “Field Measurements”
7.3.1 The Coconut Area and Stratification

As mentioned before, the coconut area was stratified and delineated by the Samoa Forestry Department under guidance of James Atherton. Aerial photographs at 1:50,000 scale were used and the stratification is described in corresponding reports available in the Forestry Department including an interpretation key and photo material for every stratum or type.

![Coconut Strata](image)

**Figure 2:** Area of different coconut strata: A = Coconut plantation with secondary forest, B = Coconut plantation with mixed crops, C = Secondary forest logged over with coconut, D = Secondary forest with coconut, E = Coconut plantation

The stratum “Coconut plantation with secondary forest” covers 69% of the total coconut area or 42837 hectares, followed by the stratum “Coconut plantation with mixed crops” 10% of the total coconut area or 6509 hectares, “Secondary forest logged over with coconut 6% of the total coconut area or 3595 hectares, “Secondary forest with coconut” covers 5% of the total coconut area or 3165 hectares and “Coconut plantation” covers 4% of the total coconut area or 2503 hectares.

Distributing the number of sample plot with the principle parts proportional to size (PPS), 69% of all plots have to be established in the stratum “**Coconut plantation with secondary forest**”. It is essential to know exactly the number of stems per hectare for this stratum.
**Figure 3:** The figure above shows the GIS display of different coconut strata. The dominant stratum “Coconut plantation with secondary forest”, which covers 69% of the total coconut area, is distributed over both islands.

The interpretation of aerial photographs and the corresponding fieldwork will establish production figures for parameters "stems per hectare", "basal area per variety per hectare" “average stem height” and “average age”. These figures are related to the physical area, which is the polygon established during the delineation process. Again the PPS principle applies, which means that the largest areas will get the most of the sample plots. However, if the counted and measured parameters do not change with additional plots the plot establishment can be stopped. Therefore it is essential to start with the largest areas.

<table>
<thead>
<tr>
<th>Object_ID</th>
<th>Description</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1359</td>
<td>Coconut plantation with secondary forest</td>
<td>9,101</td>
</tr>
<tr>
<td>2323</td>
<td>Coconut plantation with secondary forest</td>
<td>6,398</td>
</tr>
<tr>
<td>2338</td>
<td>Coconut plantation with secondary forest</td>
<td>4,744</td>
</tr>
<tr>
<td>1471</td>
<td>Coconut plantation with secondary forest</td>
<td>4,258</td>
</tr>
<tr>
<td>2254</td>
<td>Coconut plantation with secondary forest</td>
<td>3,403</td>
</tr>
<tr>
<td>2315</td>
<td>Coconut plantation with mixed crops</td>
<td>2,169</td>
</tr>
<tr>
<td>2287</td>
<td>Secondary forest logged over with coconut</td>
<td>1,994</td>
</tr>
<tr>
<td>2310</td>
<td>Coconut plantation with secondary forest</td>
<td>1,893</td>
</tr>
<tr>
<td>2303</td>
<td>Coconut plantation with secondary forest</td>
<td>1,667</td>
</tr>
<tr>
<td>2220</td>
<td>Secondary forest logged over with coconut</td>
<td>1,434</td>
</tr>
<tr>
<td>1424</td>
<td>Coconut plantation with secondary forest</td>
<td>1,363</td>
</tr>
<tr>
<td>2266</td>
<td>Coconut plantation with mixed crops</td>
<td>1,206</td>
</tr>
<tr>
<td>2143</td>
<td>Coconut plantation with secondary forest</td>
<td>1,082</td>
</tr>
<tr>
<td>1203</td>
<td>Coconut plantation with secondary forest</td>
<td>1,081</td>
</tr>
<tr>
<td>1406</td>
<td>Coconut plantation with secondary forest</td>
<td>984</td>
</tr>
<tr>
<td>1487</td>
<td>Coconut plantation with mixed crops</td>
<td>701</td>
</tr>
</tbody>
</table>

The first two areas represent with 15,499 hectares already ¼ of the total coconut area (62,506 hectares). These two areas are located in northwest Upolu and east Savai’i as figure 4 shows.
Figure 4: The location of the two largest coconut areas of the MapInfo layer linked to the tabular database (see table 5). The first sample plots should be located in these areas.

Figure 5: The location of the five largest coconut areas of the MapInfo layer linked to the tabular database (see table 5). These five areas already represent 45% of all coconut areas. They are all belonging to stratum “Coconut plantation with secondary forest”.
7.4 Estimation of Yearly Coconut Production

Even without detailed information yield estimation is possible having the coconut area available as GIS layer. Other parameters are coconut density, coconut variety and coconut age. At a later stage soil information can be added, which additionally details the productivity.

7.4.1 Coconut Densities

The coconut areas are stratified into 16 different strata due to composition of associated vegetation. The number of stems per hectare is the main factor related to the coconut production per hectare. The figures will be determined through analysis of aerial photographs at 1:5,000 in combination with field sample plots, as described in the sub-section “Proposed Inventory of Coconut Resource”. For the time being the forestry department estimated the number of palms per hectare from their field experience. The table 03 provides the current default values.

Table 6: Estimated palms per hectare within the different coconut strata in Samoa

<table>
<thead>
<tr>
<th>Description</th>
<th>Stems/Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Forest with coconut and secondary forest</td>
<td>50</td>
</tr>
<tr>
<td>Secondary forest with albizia and coconut</td>
<td>55</td>
</tr>
<tr>
<td>Secondary forest with coconut</td>
<td>55</td>
</tr>
<tr>
<td>Secondary forest with coconut and secondary forest</td>
<td>55</td>
</tr>
<tr>
<td>Secondary forest logged over with coconut</td>
<td>60</td>
</tr>
<tr>
<td>Secondary forest with coconut and merinium</td>
<td>80</td>
</tr>
<tr>
<td>Grassland with coconut and livestock production</td>
<td>70</td>
</tr>
<tr>
<td>Mixed crops with coconut</td>
<td>60</td>
</tr>
<tr>
<td>Mixed crops with coconut and secondary forest</td>
<td>45</td>
</tr>
<tr>
<td>Mixed crops with coconut and logged over forest</td>
<td>50</td>
</tr>
<tr>
<td>Coconut plantation</td>
<td>158</td>
</tr>
<tr>
<td>Coconut plantation with coco</td>
<td>158</td>
</tr>
<tr>
<td>Coconut plantation with secondary forest</td>
<td>50</td>
</tr>
<tr>
<td>Coconut plantation with grassland</td>
<td>140</td>
</tr>
<tr>
<td>Coconut plantation with livestock production</td>
<td>120</td>
</tr>
<tr>
<td>Coconut plantation with mixed crops</td>
<td>80</td>
</tr>
</tbody>
</table>

7.4.2 Coconut Varieties

There are six main varieties of coconuts in Samoa, which have different coconut production per tree and year, but also different life span. There are two main types of coconuts world wide a) tall types such as Samoan Tall or Niu Vai Tall 20 to 30m in height and a life span of 60 to 70 years or longer and b) dwarf types such as Malayan Red Dwarf 8 to 10m in height and a life span of 30 to 40 years. In Samoa the tall types are breaded with the Malayan Red Dwarf, which results into 3 to 4 times higher production.
The coconut varieties can only be identified through field survey not through photo-interpretation. For the time being Samoan Tall variety is set as default value for all coconut areas. As soon as more information is available this can be revised for every coconut area.

7.4.3 Declining Coconut Yield due to Age
There are no exact figures available taking the factors coconut variety and coconut age into consideration. From the literature the life expectancy is known for a) tall type and b) dwarf types, which allows estimating the breeds. Furthermore the best production is known\textsuperscript{11} and it is assumed that the culmination points for tall is about 25 years of age and for breeds at 20 years. All natural processes follow more or less the shape of a normal distribution. Putting these assumptions and facts together it was possible to contract a best fit curve showing for every variety the coconut production per tree and year dependent on age. The curves have to be revised, when more accurate information is available. For the time being the current constructed curves are the basis for the table 04, which is used by the Access Basic program to adjust the production figure coconut per tree per year. See more detailed information about declining yield in relation to age in Appendix V.

| Table 7: Coconut production per year and tree in different age classes for the main varieties in Samoa. |
|-----------------|---|---|---|---|---|---|---|---|---|
| Description                                   | 05Y | 10Y | 15Y | 20Y | 30Y | 40Y | 50Y | 60Y | 70Y |
| Niu Vai Tall                                   | 2   | 7   | 16  | 26  | 28  | 17  | 9   | 4   | 0   |
| Niu Vai Tall x Malayan Red Dwarf              | 7   | 33  | 80  | 136 | 68  | 22  | 0   | 0   | 0   |
| Rennen Tall                                   | 2   | 10  | 26  | 55  | 58  | 20  | 10  | 4   | 0   |
| Rennen Tall x Malayan Red Dwarf               | 7   | 38  | 103 | 129 | 63  | 17  | 0   | 0   | 0   |
| Samoan Tall                                   | 2   | 10  | 23  | 34  | 34  | 20  | 10  | 4   | 0   |
| Samoan Tall x Malayan Red Dwarf               | 7   | 37  | 85  | 114 | 53  | 14  | 0   | 0   | 0   |

The age will be estimated during the field checks as an average age per area from available information of plantation establishment and from the average height, which will be measured. For the time being 30 years of coconut plantation establishment in 1975 will be the default value.

7.4.4 Production Difference Related to Soil Types
Coconut palms start to produce earlier and produce more on good soil compared to poor soils with low water content. The soil types are mapped and can be overlaid over the coconut areas to indicate on which soil type each plantation is established. However, currently the correlation between soil type and production is not known to the extent allowing to inbuilt a soil correction factor into the program.

7.5 Proposed Inventory of Coconut Resource
To detail available information and to increase the accuracy of information it is essential to carry out an inventory of the available coconut resource, which will be based on interpretation of aerial photographs and on field measurements.

7.5.1 Selection of Sample Plots
Currently there are no funds to carry out a nation wide inventory, which would provide sufficient accuracy for all strata. Therefore it is proposed to start with the stratum “Coconut plantation with secondary forest” covering the largest part of the total coconut area (69%) see figure 2 and figure 3.

\textsuperscript{11} Production figures are based on Project Termination Report CGRNAP Phase 1
Within the total coconut area and within the stratum “Coconut plantation with secondary forest” the five largest areas cover 28,000 hectares, which is 45% of the total area. It is recommended to start the inventory with the largest area and then continue with the next four areas in sequence of the size (see table 5 and figures 4 and 5). If there are more funds available, area 2315 of stratum “Coconut plantation with mixed crops” should be inventoried using the method proposed in the next subsections.

7.5.2 Interpretation of Aerial Photographs

There are two sets of aerial photographs. One series has a scale of 1:50,000, which do not allow estimating the number of palms per hectare. The other series is recorded at 1:5,000 scale and shows sufficient texture information to count the number of palms per hectare. To estimate the parameter “palms per hectare” in a statistically sound way following steps have to be carried out:

1. Grid overlay
2. Random selection of line
3. Counting palms within the grid cells
4. Calculating average and standard deviation

Grid Overlay

The aerial photographs are available as MapInfo GIS backdrops, which enables the display within MapInfo environment. This again allows utilising the MapInfo GridMaker. The operator has to drag the cursor over the area of interest and determine the cell size of the grid, which is proposed with 40 x 40m. The grid orientates itself on the grid of the projection used, which orients all grid cells to north.

When creating a grid MapInfo creates a new layer, where every grid cell can be addressed. It is recommended to utilise this feature and add a new integer field “Palms” in which the interpreter notes the number of palms he counts in the grid cell. This enables a fast work progress and stores the result in a way that it can be checked later.

Random Selection of Lines

Calculations of statistical accuracy are based on random selection of plots, not on systematic selection. For an absolute random selection all grid cells of an area of interest would get an identification number (ID) and randomly IDs would be selected and interpreted. The disadvantage of such a procedure is the difficulty to identify the cells in the field at a later stage. As a compromise it is proposed to count the number of palms for every second grid cell in one or two lines. To stay in a statistically sound way the lines get an ID number and are selected randomly.

Figure 6: A MapInfo inbuilt grid function allows a grid overlay and to store counted coconuts in the corresponding record linked to each grid cell of attached tabular database
Counting of Palms
After the interpreter has counted the number of palms for a grid cell he clicks with the curser on it, which displays the corresponding record of the table and allows to write the number into the field "Palms", see figure 6.

Calculating Average and Standard Deviation
After completing the palm counting the grid layer has to be exported to dBASE. To avoid exporting cells for which palms were not counted, the operator has to copy the grid layer to a new file, run a SQL selection and deleting unnecessary grid cells. Then he opens the file with Excel and saves it as Excel spreadsheet to be able to utilise all Excel functions. For the counted figures Excel provides the function Average and Standard Deviation.

7.5.3 Field Measurements
The field data collection has to identify:
- Number of stems per hectare,
- Average height of palms,
- Distribution of palm varieties,
- Average age of palms.

Identification of Sample Plots
From each line of sample plots, for which the number of stems was counted using the aerial photographs, a number of plots have to be selected to visit in the field. The exact number of plots, which have to be visited, depends on the variance between tree counting in the field and tree counting using the aerial photographs.

For a number of plots the corresponding GIS display including the grid has to be printed and taken to the field. In the field, properly visible rope has to be used as “fence” for the plot boundaries, as it is important to make a clear decision for trees standing on the boundary.

Counting Palms per Hectare
After the boundaries are marked one worker goes around together with a specialist from CROPS capable to recognise palm species. One team member stands in the middle of the plot and guides the crew and notes the counting per palm variety. In some areas the variety will be homogeneous and the CROPS specialist might be not absolutely necessary.

Measuring the Basal Area
It is not much additional effort to count also the basal area, which is the theoretical surface area if somebody would cut all trees at 1.3m height. The information can be collected fast and provides an estimation of the average diameter of all palms, when dividing the basal area per hectare by the number of stems per hectare.

To count the basal area in m² per hectare the person in the centre uses a stick of 1m length with a 2cm mark.

Figure 7: Determining the basal area, from the centre of the plot the team leader counts all trees which appear larger than the opening of 2cm in front of the 1m length stick.
at the end, see figure 7. He turns around 360 degrees and looks along the stick and counts all trees, which appear bigger than the opening. The number is equal to the basal area per hectare in square meter. If the specialist for palm varieties is present the basal area per species can be determined.

**Measuring Average Tree Height**
The height of palm trees can be measured using the angle and distance to the tree. The height measurement is fast and this additional parameter can be used to determine the age, as there is a strong correlation between height, variety, soil and age. Currently, the correlation is not available, however, as more plots are measured as more accurate this correlation can be established. This then allow to estimation of yield as yield is correlated to age. See appendix VII “Coconut Height and Age”.

**Getting Age Information**
The average age of a coconut plantation has to be extracted from information provided by plantation managers or landowners. The database entry is the year of plantation establishment, not the age in years.

**Accuracy of Information**
The accuracy of yield estimation can be calculated when inventory data has collected. It is essential to a random selection of sample plots, as all calculations of statistical accuracy are based on random selection and not on systematic plot selection.

### 7.6 The Tabular Database

The tabular database has been established at the Samoan Forestry Department and will be maintained from SOPAC through e-mail. Once needed software and human capacity is available at EPC and other relevant entities the database can be copied hereto. The database was built using Microsoft Access, which is a relational database allowing to link the tables within the database. The tabular data also can be linked to the spatial database MapInfo to a) get the annotation information across to MapInfo for any thematic map display and b) to get information across to Access in case a new coconut area is mapped or an area changed in size.

#### 7.6.1 Operating the Tabular Database

The tabular database is currently only installed in the Samoa Forestry Department, as the staff is trained to operate and update such a database. As informed above the database can be copied to any other location such as EPC and CROPS or other sections of the Agriculture Department.

The main form should appear, when clicking on the corresponding icon on the screen. The main form is shown in figure 9. The main form has three different sections:

1. Library tables,
2. Calculate,
3. Display.

The library tables provide information for the calculation of coconut yield per year. The calculation utilises the updated content of the library tables and changes the default values of the main table with newly calculated values. Finally the display section provides a display for individual polygons (coconut areas) or summary information for all coconut strata.
**Library Tables**
Currently there are two library tables, which are actually used for further calculation of coconut yield: a) the table “**CoconutStrata**” which is displayed by a form and allows to change the parameter “stems per hectare” for the different strata. Table 03 in chapter “Coconut Densities” is based on this table and form.

The other important library table is the table “**NutsTreeAge**” which is based on graphs explained in appendix 1 showing for each coconut variety the coconut production per palm and age class. This table is employed when reducing or increasing the default value of coconut production in case the variety or age of the coconuts for a particular area is known.

**The Section ”Calculate”**
The operator has to click all command buttons from top to base.

The first command button is named update "**Stems per Hectare**". The program behind will replace the parameter “stems per hectare” with the content stored in the library table “CoconutStrata”. If there is any update, because field measurements or aerial photo interpretation have shown that the first and rough estimation of the Forestry Department regarding the stems per hectare per stratum seems to be incorrect, the program will change the parameter “stems per hectare” in the main table.

If the operator clicks on the command button "**Age Reduction**" the default value 32 coconuts per palm per year is replaced by a more precise figure. This can be the case if either the age (default value 30 years) is known or the variety (default value Samoan Tall) or both are known for a particular area.

The command button "**Yield per Hectare**" activates a program, which goes through the main table and multiplies the “yield per tree” with the “number of stems per hectare” and updates the field “Yield per hectare”.

The command button "**update Yield Total**" activates a program, which goes through the main table and multiplies the “yield per hectare” with the “number of hectares of each polygon or coconut area. It updates the field “Yield Total”.

**The Section ”Display”**
The section has two command buttons, which both display a form showing the tabular database content and link to MapInfo allowing the display in spatial environment.
The command button "Size Yield Area" activates the form “AreaStratum”. This form sits on the main table and displays all relevant information related to each coconut area such as:

- Area Code,
- Name of stratum,
- Area [hectares],
- Stems per hectare,
- Yield in form of coconut per palm,
- Yield in form of coconut per hectare
- Total yield in form of coconuts per area

An additional field allows clicking on and off, which can be used to select areas to be displayed in MapInfo. By clicking on the MapInfo button these areas will be displayed in red, whereas all other areas will appear in green.

The command button "Area and Yield/Stratum" activates a program, which summarises the information stored in the main table for every area to information combined for each stratum and displays the result with the form “StrataSum”. The form also enables the user to activate MapInfo displaying the stratified coconut area, see figure 11.

### 7.6.2 Main Tables and Link to MapInfo

Main tables are Access tables, which store results of area or yield calculations, ready to be presented for the database user.

*CoconutAreas*

The most important table is called “CoconutAreas”. This table contains the field “Object_ID”, which is the unique ID for every coconut area. This field is the link to the corresponding map element in MapInfo.

Whenever a graphical overview is required the tabular database produces a temporary output table containing the Object_IDs for the corresponding coconut areas. This table is then imported to MapInfo providing the annotation information necessary to create a thematic map.

*StrataSum*

The table “StrataSum” contains the summaries for area [hectare] and yield [total of coconuts] for each coconut stratum. The program “UpdateStratumSum” updates this table using the information stored in the main table “CoconutAreas”.

### 7.6.3 The Library Tables

The library table are necessary to perform any yield calculations. As soon as the correlation between height and age is known for different species differentiated into different soil types an additional table will be created. Currently there are only three library tables.

- CoconutStrata
- NutsTreeAge
- CoconutPlots

*CoconutStrata*

The table CoconutStrata contains the full name of the coconut stratum and the estimated average number of stems per hectare for each stratum. Currently the figure “stems per hectare" is estimated based on experience of the Forestry Department. It will be replaced by figures collected through interpretation of aerial photographs verified by field plots.
The table is used to update the field “StemsHectare” of the main table.

*NutsTreeAge*

The table “*NutsTreeAge*” contains the number of coconut per tree per year for different varieties. This table is a copy of the corresponding Excel table explained in Appendix 1. The Access Basic program “*CalculateReductAge*”, which is part of Access Form “*MainForm*”.

### 7.7 The Spatial Database (GIS)

The spatial database is based on MapInfo software and contains two major types of information a) the map layer which is connected to a table within MapInfo and b) MapBasic programs which can be activated from the tabular database in Access.

#### 7.7.1 The MapInfo Layer

The MapInfo layer “ForestAreas_050422.TAB” currently contains 2359 polygons from which 594 represent areas, where coconut is recognisable part of the vegetation cover. The polygons as map elements are connected to a MapInfo table, which originally contained many different types of information, which is now exported to Access. The table is reduced to two fields a) “Area” containing the area size in hectares and b) a unique identifier “Object_ID” containing an integer value for each area. This unique identifier is utilised for the link to the Access table, a very critical field. This is the reason that all areas not containing coconut as part of the vegetation cover are left in the layer and table. They are filtered out by a query in Access environment.

#### 7.7.2 MapBasic Code

There are two programs written in MapBasic, which import a temporary file from the tabular database in Access, link it to the MapInfo table “*ForestAreas_050422.TAB*” and create a thematic map.

**Program ShowAreas.MBX**

The programme “*ShowsAreas*” runs in an Access environment and depicts some areas in red and the other areas in green colour. Figure 03 shows a display created by this program. The program can be activated from the Access form “*AreaStratum*”

**Program StratifyAreas.MBX**

The program “*StratifyAreas*” shows all coconut areas stratified into the 16 strata shown in table 03. Figure 3 shows the display created by this MapBasic program. The program can be activated from Access form “*StrataSum*”.

### 7.8 Conclusion

A custom-designed Coconut Resource forestry GIS-Database has been installed at the Ministry of Natural Resources and Environment, Forestry Division. Based hereon a preliminary coconut recourse assessment has indicated that Samoa at present can produce some 126 million coconuts per year.

The resource assessment description in this chapter contains guidelines for further refinement of the database content by including variables such as soil type, age and a distribution of coconut variety. Inclusion of these variables, which are now taken as averages based on forestry best practices, will result in a more accurate estimation.

Further data gathering and input into the database can be co-ordinated from SOPAC in the future; however will not be implemented as part of the CocoGen project.
8. Overall Conclusion and the Way Forward

The fieldwork in Samoa by the CocoGen experts has indicated a favourable environment for coconut oil as a fuel. The great willingness by EPC to make it happen, combined with a large coconut resource available, in a time that the traditional coconut industries seem to be struggling for survival in dwindling export markets, a highly variable diesel price and low coconut oil world market prices all indicate a green light for this renewable energy source. Last but not least, the successful trial in EPC’s Saleloga Power Station, with a 10% coconut oil blend is very encouraging in this respect.

Even though the first indication of the price of coconut oil per litre seems very favourable both in terms of the world market and secondly in the preliminary calculations in this Debriefing Report, more refining during the Cocogen Feasibility Study is required.

There seem also a number of issues that need to be resolved before coconut oil as a fuel can take off on a larger scale in Samoa. First, more clarity and perhaps Government support will be required in assisting to get the coconut oil sector back on its feet. Secondly, clarity by the Samoan Government would be very useful on framework of taxation for these fuels, as this will have serious implications on the feasibility of this alternative fuel. Thirdly, for coconut oil to play a major role in the fuel sector in Samoa, significant investment is required to set up an efficient milling process, a cost-effective transport system and the useful application of coconut by-products. The feasibility study will in more detail describe these requirements and offer potential solutions to these challenges. Finally, more support will be required from the engine manufacturers with respect to behaviour using alternative fuels.

Immediately after the fieldwork, lube-oil samples before and after the pilot were sent through to the laboratory of the University of the South Pacific in Fiji and to a specialised laboratory in France. The lube-oil analyses pointed that no harmful level of contamination of (unburnt) coconut oil could be detected in the lubricant. Therefore, the test can be described as successful and the recommendations of the Saleloga Power Station manager (Appendix VIII) can be followed to continue the pilot. The Cocogen team proposes continuation of lube oil analysis at regular operation intervals.

After EPC and UNDP Samoa have provided comments on a first draft CocoGen Feasibility Study report a final draft Feasibility Study report will form the basis of a stakeholder consultation workshop in Samoa which has the aim of providing comments on the final draft report and importantly increasing the awareness on the opportunities of coconut oil as a fuel and creating a framework in which the implementation of this energy source can be started.

After the workshop, a project proposal will be formulated with the aim of accessing financial support for the application of biofuels by EPC.
Annex I - List of meetings

The meetings below have been with Dr. Gilles Vaitilingom and Mr. Jan Cloin, and the following people:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name</th>
<th>Subject of Meeting</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNDP-Samoa</td>
<td>Mr. Thomas Jensen</td>
<td>Discuss progress of project, logistical support for meetings, telephone and email. Prepare meeting with EPC.</td>
</tr>
<tr>
<td>FAO</td>
<td>Mr. Aru Mathias</td>
<td>Discuss the links between the Cocogen project and the on-going efforts of FAO to increase sustainable forestry practices and resource assessment. Has indicated to send a letter to the CEO of Ministry of MNRE and copy to FAO-rep, Vili Vaovao for release of data from the existing Forestry database.</td>
</tr>
<tr>
<td>ADB</td>
<td>Mr. Luigi Bodda</td>
<td>Meet at EPC. ADB is currently finalising a feasibility study to build a hydro power station close to the originally planned site. There might still be some land issues but appear to be resolvable.</td>
</tr>
<tr>
<td>COPS</td>
<td>Mr. Andrew Feero</td>
<td>COPS is in serious financial problems, but has managed to mill 1,396 tonnes of oil with local and imported oil from Kiribati that is awaiting shipment. Last price paid for copra was US$515/tonne on the wharf. There is 22 tonnes of copra in stock, but no money to buy diesel to start operation. Inspection tour through the mill.</td>
</tr>
<tr>
<td>EPC</td>
<td>Mr. Muaausa Joseph Walter</td>
<td>Discuss the progress of the project, the inception report and the planned tariff increases. There is a great interest to take on the oil production as part of the EPC operation. Even though biodiesel might not be feasible now, there is still interest. Obtained logistical support for the technical consultant.</td>
</tr>
<tr>
<td>EPC Power Station Apia</td>
<td>Mr. Tile Tuimalealifano, Mr. Aialo, Mr. Menu</td>
<td>Discussions on the opportunities to carry out a pilot coconut oil fuel in Apia. Prepared the trip to Savai’i with EPC staff. Discussed options for fuel use and likely associated risks. Discussed current issues that the power station faces, including expansion in the near future.</td>
</tr>
<tr>
<td>Ministry of Finance</td>
<td>Ms. Silia Kilepoa Ualesi</td>
<td>Discuss the tax structure on fuel, along with the pricing template. Requested support for a letter (Drafted) to release data from the MNRE on the resource assessment. Kindly provided logistical support with telephone.</td>
</tr>
<tr>
<td>NZ High-commission</td>
<td>Mr. Philip Hewitt</td>
<td>Courtesy visit to discuss briefly the Cocogen project, ongoing NZ activities in the field of energy. Discussed briefly the biogas project that is expected to be de-commissioned.</td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>Mr. Frank Fong</td>
<td>Discuss the state of the coconut sector and the potential role CocoGen plays in it. There seems to be very strong competition in the export of coconut products, including oil, cream and desiccated coconut.</td>
</tr>
<tr>
<td>EPC Power Station Savai’i</td>
<td>Mr. Tiafau Magele Tafu</td>
<td>Discuss the state, history and current operation of the power station, demand for electricity. Carry out site visit. Discuss the options to carry out a pilot with coconut oil fuel. Discuss briefly the state of the coconut sector on Savai’i. During a second visit the next morning, two proposed pilot options were presented and discussed. Mr. Tiafau Magele Tafu indicated he is reluctant to the pilot with respect to the medium term effects however with the backing of Management from Apia, he will support the pilot.</td>
</tr>
<tr>
<td>EPC</td>
<td>Mr. Muaausa Joseph Walter</td>
<td>Presentation of the pilot options. Decided was to go ahead with the pilot on engine #2A in Savai’i.</td>
</tr>
<tr>
<td>COPS</td>
<td>Mr. Tupola</td>
<td>Discussion on the delivery of coconut oil for testing in Savai’i. It is unclear as yet whether there will be coconut oil available in the week of the planned pilot.</td>
</tr>
</tbody>
</table>

The meetings below were carried out between Wolf Forstreuter and the following people:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name</th>
<th>Subject of Meeting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forestry Department</td>
<td>Afamasaga Sami Lemalu</td>
<td>Coconut database will be first established in Samoan Forestry Department later it can be transferred to other organisations. Forestry is interested to carry out coconut resource inventory if Agriculture Department and/or CROPS assists.</td>
</tr>
<tr>
<td>CROPS</td>
<td>Laisene Samuelu Ass.</td>
<td>CROPS is very interested to participate in a coconut resource inventory. CROPS do not have the knowledge to carry out such activity.</td>
</tr>
<tr>
<td></td>
<td>CEO</td>
<td>Inventories, but CROPS will provide labourer and specialists to recognise different coconut palm varieties.</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>EPC</td>
<td>Mr. Muaausa Joseph Walter General Manager</td>
<td>EPC is very interested to have a clear picture of available coconut resource and is assuming that the resource can be expanded once farmers see that they can sell copra. It would be also possible that EPC produces oil from coconuts if there is sufficient sustainable resource. The coconut resource assessment should be a part of an EPC GIS.</td>
</tr>
<tr>
<td>FAO</td>
<td>Paul Tomane Assistant FAO Representative (before CROP management)</td>
<td>Figures about yield [coconuts per tree] differentiated to age and coconut variety must be available at CROPS research section.</td>
</tr>
<tr>
<td>FAO</td>
<td>Aru Mathias FAO Forestry Advisor</td>
<td>The Samoa Forestry Department is the organisation capable to a) carry out an inventory and b) handle GIS and relational database.</td>
</tr>
<tr>
<td>Atherton Consultancy</td>
<td>James Atherton Consultant</td>
<td>If the relational database is based at the Forestry Department he is willing to assist in database handling.</td>
</tr>
<tr>
<td>Department of Agriculture</td>
<td>Lafaele Enoka Principal Policy Officer Agriculture Department</td>
<td>Discussion of information requirements and need for coconut resource inventory, Mr. Franck Fong was not in the office.</td>
</tr>
<tr>
<td>EPC</td>
<td>EPC Managers of sections: Power generation, system analysis, finance, network administration, engineering, corporate services, metering services.</td>
<td>Discussion about information requirements for estimation of available coconut resource. EPC advised on the importance of plantation age and the regeneration potential after cyclone damage. Demonstration of GIS potential for EPC for asset management and as planning tool.</td>
</tr>
</tbody>
</table>
Annex II - EPC Tariff Increase public Announcement

(Source: Samoan Observer 31/03/2005)

PUBLIC ANNOUNCEMENT

TARIFF ADJUSTMENT

Since recent years the Electricity Power Corporation has been enthusiastic in its endeavours to improve its service to all its customers. We were able to do this by adopting ways and means to supply electricity to all consumers at prices which enable EPC to effectively provide this essential service at all times.

Because of these efforts the Corporation was able to hold its electricity tariff at the same levels for almost seven years. However, the aggregate escalating fuel costs (see graph 1), as well as the rise in the value of the New Zealand and Australian currencies over the last five years (graph 2), has adversely affected the financial position of the Corporation.

Most of the Corporation's revenue comes from the sale of fuel oil and procurement of income from energy from overseas (graph 3). These commodities form the bulk of the Corporation's operational expenses. Since the last tariff increase in September 2000, the Corporation has been unable to absorb all these costs in income by overstretching its financial resources.

The increasing costs due to these factors beyond our control have made it absolutely necessary for the Corporation to adjust electricity tariffs to ensure that the supply of electricity to our customers is always made economically available.

The public is therefore advised that effective 1 May 2005, the revised electricity tariffs will be as follows:

- **Domestic Consumers:**
  - 1-50 units: 0.36c per unit
  - 51-200 units: 0.39c per unit
  - 201 units and upwards: 0.43c per unit

- **All Other Consumers:**
  - 0.69 c per unit

The Corporation regrets having to share the burden of rising electricity production costs with our customers. We appreciate your understanding and cooperation and remain committed to our mission to provide reliable and affordable electricity to Samoa.

EPC
FA'ASILASI AGA TAUA
TOE FA'ATULAGA O LE TAUA
O LE LELETAI
<table>
<thead>
<tr>
<th>Generator Set</th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>5A</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
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<td>Under overhaul</td>
<td>179 hrs</td>
<td>496 hrs</td>
<td>77 hrs</td>
<td>274 hrs</td>
<td>480 hrs</td>
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<tr>
<td><strong>Percent of Production</strong></td>
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<td>4%</td>
<td>29%</td>
<td>5%</td>
<td>22%</td>
<td>39%</td>
</tr>
<tr>
<td><strong>Engine Maker</strong></td>
<td>Cummins</td>
<td>Cummins</td>
<td>Cummins</td>
<td>Caterpillar</td>
<td>Caterpillar</td>
<td>Caterpillar</td>
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<tr>
<td><strong>Engine Model</strong></td>
<td>KTA 38-G3</td>
<td>KTTA 19-G2</td>
<td>KTA 38-G3</td>
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<td>3516</td>
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<td>37115000</td>
<td>33127542</td>
<td>42205310</td>
<td>28202340</td>
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<td>62222</td>
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<td>-</td>
</tr>
<tr>
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<td>1500 rpm</td>
<td>1080 / 1500 rpm</td>
<td>1458/1500 rpm</td>
<td>2324 / 1500 rpm</td>
<td>2324 / 1500 rpm</td>
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<td>8/11/94</td>
<td>2/7/94</td>
<td>8/12/93</td>
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<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
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<td>800 (low)</td>
<td>800 (low)</td>
<td>1515 (high)</td>
<td>1515 (high)</td>
<td>1515 (high)</td>
</tr>
<tr>
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<td>6</td>
<td>12</td>
<td>12</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td><strong>Bore [mm]</strong></td>
<td>159</td>
<td>159.75</td>
<td>159</td>
<td>170</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td><strong>Stroke [mm]</strong></td>
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<td>159.75</td>
<td>159</td>
<td>190</td>
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<td>190</td>
</tr>
<tr>
<td><strong>Type</strong></td>
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<td>4 cycle vertical in line cylinder</td>
<td>4 cycle 50 deg Vee 12 Cylinder</td>
<td>4 cycle 50 deg Vee 12 Cylinder</td>
<td>4 cycle 50 deg Vee 12 Cylinder</td>
<td>4 cycle 50 deg Vee 12 Cylinder</td>
</tr>
<tr>
<td><strong>Cooling System</strong></td>
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<td>Water Radiator</td>
<td>Water Radiator</td>
<td>Water Radiator</td>
<td>Water Radiator</td>
<td>Water Radiator</td>
</tr>
<tr>
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<td>Turbo / cooled</td>
<td>Turbo / cooled</td>
<td>Turbo / cooled</td>
<td>Turbo / cooled</td>
<td>Turbo / cooled</td>
</tr>
<tr>
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<td>37.7</td>
<td>18.7</td>
<td>37.7</td>
<td>51.8</td>
<td>69.1</td>
<td>69.1</td>
</tr>
<tr>
<td><strong>Rotation (flywheel)</strong></td>
<td>CCW</td>
<td>CCW</td>
<td>CCW</td>
<td>CW</td>
<td>CW</td>
<td>CW</td>
</tr>
<tr>
<td><strong>Injection Method</strong></td>
<td>Common Rail HVT</td>
<td>Common Rail HVT</td>
<td>Common Rail HVT</td>
<td>Unit Injector</td>
<td>Unit Injector</td>
<td>Unit Injector</td>
</tr>
<tr>
<td><strong>Type of Nozzle</strong></td>
<td>Direct Injection Hole Type</td>
<td>Direct Injection Hole Type</td>
<td>Direct Injection Hole Type</td>
<td>Direct Injection Multi Hole</td>
<td>Direct Injection Multi Hole</td>
<td>Direct Injection Multi Hole</td>
</tr>
<tr>
<td><strong>Type of Fuel</strong></td>
<td>BS 2869 A1</td>
<td>BS 2869 A1</td>
<td>BS 2869 A1</td>
<td>ASTM 396 No 1.2</td>
<td>ASTM No 1x2</td>
<td>ASTM No 1x2</td>
</tr>
<tr>
<td><strong>Governor</strong></td>
<td>Electric</td>
<td>Electric</td>
<td>Electric</td>
<td>Woodward UG 8L</td>
<td>Woodward UG 8L</td>
<td>Woodward UG 8L</td>
</tr>
<tr>
<td><strong>Starting Method</strong></td>
<td>Electric 24 V</td>
<td>Electric 24 V</td>
<td>Electric 24 V</td>
<td>Electric 24 V</td>
<td>Electric 24 V</td>
<td>Electric 24 V</td>
</tr>
<tr>
<td><strong>Maker</strong></td>
<td>ONAN</td>
<td>ONAN</td>
<td>ONAN</td>
<td>Caterpillar</td>
<td>Caterpillar</td>
<td>Caterpillar</td>
</tr>
<tr>
<td><strong>Generator Model</strong></td>
<td>DFJC</td>
<td>450 DFFB</td>
<td>DFJC</td>
<td>SR</td>
<td>SR</td>
<td>SR</td>
</tr>
<tr>
<td><strong>Serial Number</strong></td>
<td>F940545399</td>
<td>A92A001721</td>
<td>F940545399</td>
<td>3EF01379</td>
<td>6S1G1342</td>
<td>7C168</td>
</tr>
<tr>
<td><strong>Rating</strong></td>
<td>Standby</td>
<td>Standby</td>
<td>Standby</td>
<td>Standby</td>
<td>Standby</td>
<td>Standby</td>
</tr>
<tr>
<td><strong>Spec</strong></td>
<td>675201</td>
<td>5673G</td>
<td>67201</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>KVA</strong></td>
<td>1,000</td>
<td>563</td>
<td>1,000</td>
<td>1,275</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Amps</strong></td>
<td>1521</td>
<td>783</td>
<td>1,521</td>
<td>1,840</td>
<td>2,406</td>
<td>2,406</td>
</tr>
<tr>
<td><strong>KW</strong></td>
<td>800</td>
<td>400</td>
<td>800</td>
<td>1,020</td>
<td>1,400</td>
<td>1,400</td>
</tr>
<tr>
<td><strong>KW (de-rated)</strong></td>
<td>700</td>
<td>250</td>
<td>700</td>
<td>650</td>
<td>950</td>
<td>950</td>
</tr>
<tr>
<td><strong>Volts</strong></td>
<td>220/380</td>
<td>415</td>
<td>220/380</td>
<td>400</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>
Annex IV - Working Instructions Coconut Oil Pilot

WORKING INSTRUCTIONS

TESTING OF A 10,000 litres BLEND
OF 10 % COCONUT OIL – 90 % DIESEL FUEL IN GENSET 2A

SALELOLOGA POWER STATION
EPC – SAVAI'I

A. BACKGROUND

- Through a combination of cost savings and environmental considerations, EPC aims to utilise alternative fuels from diesel will be a part. In addition, the increasing dependence on imported fossil fuels is another main reason to carry out a feasibility study into the use of alternative fuels in the EPC generators. The EPC in cooperation with the Government of Samoa and UNDP/Samoa are undertaking the preparatory phase of the Coconut oil Power Generation (COCOGEN) project.

- None of the gensets currently running at Tanugamanono or Salelologa Power Stations are able to use straight coconut oil as fuel without chemical transformations of the oil or mechanical modifications of engines.

- Nevertheless under precise conditions of operation it is highly probable to use a diesel fuel blend containing up to 10 % of coconut oil.

- In order to cross from highly probable to certain, a test will be carried out in Savai'i Power Station.
  1. This test must respect the following Working Instructions,
     A sample of unused lubricant will be collected
  2. A sample of lube oil will be collected in the sump of engine 2A before starting the test
  3. A sample of lube oil will be collected in the sump of engine 2A after completion of the test and sent to SOPAC/Fiji.

B. WORKING INSTRUCTIONS

B1. Engine:
Lubricant and oil filters must be new or having less than 250 running hours.

B2. Fuel:
A total volume of 10,000 litres will feed engine 2A. It is composed of 1,000 litres of coconut oil and 9,000 litres of diesel fuel. The mixture will then be prepared as 1 volume of coconut oil plus 9 volumes of diesel. This will require the following steps:
  1) Pour 1 volume of coconut oil in the daily tank;
  2) Pour 9 volumes of diesel fuel in the daily tank;
  3) Stir the daily tank for 2 minutes with a stick.
B3. Lubricant:
The same lubricant will be used during the duration of the test. **Added volume of lubricant must be logged exactly.**

B4. Operation of the genset 2A:
Generator Set # 2A must not be used under 50% of its original rating, i.e. 200 kW. Should the occasion arise it must last long less than one hour, **if not shut the genset down.**

B5. Mechanical:
In case of a mechanical intervention on the engine, **collect a sample of lube oil** before starting again. This sample will be joined with the end up one.

B6. Data required – Log book:

Starting the test:
Type of lubricant:
Grade of lubricant:
# of running hours of the lubricant in the sump:

daily:
date:
# of kWh
# of running hours:
Volume of blend used:
Volume of added lubricant:
# of starts during the day:
Observation/trouble shooting

Ending the test:
Collect of the sample of lube oil
Indicate the number of running hours.
Complete the daily logbook
Send the sample and the log data sheet to SOPAC in Fiji.

C: JUSTIFICATION OF TEST

It is highly probable that it is possible to use 10 % of coconut oil in genset 2A if the load is over 50 % of its nominal.

If bad combustion occurs (misfiring or cyclical dispersion) the amount of unburnt fuel - here blend of coconut oil and diesel - could be higher than 1/1000. That means 10 litres over the 10,000 litres of the blend that also means 1 litre of coconut oil. In a sump of around less than 100 litres of lubricant capacity, this will lead to a “pollution” of the lube by triglycerides and fatty acids of 1%. This rate is easy to determine with accuracy.

If the analysis of the lube samples do not reveal such rate and overall reveal very small rate, it will be concluded that the combustion was good and, that under the current operating conditions, 10 % of coconut oil can be added as fuel in this genset 2A.
Annex V - Estimating Coconuts/Tree/Age/Variety

Samoan Tall
For the coconut variety Samoan Tall it is known from available literature and other parameters are assumed, in particular:

a) The coconut production starts with 5 to 6 years.
b) It is assumed and observations of the forestry department show that there is a culmination point about 25 years.
c) Samoan Tall produces 38 coconuts per palm.
d) It is known that varieties type tall can get 60 to 80 years old and an average lifetime of 70 years is assumed.
e) Finally it is assumed that the coconut production is similar to a normal distribution.

These parameters allow drawing the graph below (figure 12), which is the basis of table 04 shown in chapter “Declining Coconut Yield due to Age”.

![Figure 12: estimated production of coconuts per tree (Y axis) for different age classes (X axis).](image)

At a later stage this curve for Samoan Tall has to be revised. For the time being this curve drives the table, which the program uses to correct the production figure per palm as soon as variety or age of the coconut palms of the different areas is known.
**Niu Vai Tall**

For the coconut variety Niu Vai Tall it is known from available literature and other parameters are assumed, in particular:

a) The coconut production starts with 5 to 6 years.

b) It is assumed and observations of the forestry department show that there is a culmination point about 25 years.

c) Samoan Tall produces 32 coconuts per palm.

d) It is known that varieties type tall can get 60 to 80 years old and an average lifetime of 70 years is assumed.

e) Finally it is assumed that the coconut production is similar to a normal distribution.

These parameters allow drawing the graph below (figure 13), which is the basis of table 04 shown in chapter “Declining Coconut Yield due to Age”.

*Figure 13: estimated production of coconuts per tree (Y axis) for different age classes (X axis).*

At a later stage this curve for Niu Vai Tall has to be revised. For the time being this curve drives the table, which the program uses to correct the production figure per palm as soon as variety or age of the coconut palms of the different areas is known.
**RennenTall**

For the coconut variety RennenTall it is known from available literature and other parameters are assumed, in particular:

a) The coconut production starts with 5 to 6 years.
b) It is assumed and observations of the forestry department show that there is a culmination point about 25 years.
c) Samoan Tall produces 72 coconuts per palm.
d) It is known that varieties type tall can get 60 to 80 years old and an average lifetime of 70 years is assumed.
e) Finally it is assumed that the coconut production is similar to a normal distribution.

These parameters allow drawing the graph below (figure 14), which is the basis of table 04 shown in chapter “Declining Coconut Yield due to Age”.

![Graph: Estimated production of coconuts per tree (Y axis) for different age classes (X axis).](image)

**Figure 14:** estimated production of coconuts per tree (Y axis) for different age classes (X axis).

At a later stage this curve for RennenTall has to be revised. For the time being this curve drives the table, which the program uses to correct the production figure per palm as soon as variety or age of the coconut palms of the different areas is known.
For the coconut variety Niu Vai Tall x Malayan Red Dwarf it is known from available literature and other parameters are assumed, in particular:

a) The coconut production starts with 3 to 4 years.
b) It is assumed and observations of the forestry department show that there is a culmination point about 20 years.
c) Samoan Tall produces 136 coconuts per palm.
d) It is known that varieties breed between type tall and type dwarf can get 30 to 60 years old and an average lifetime of 50 years is assumed.
e) Finally it is assumed that the coconut production is similar to a normal distribution.

These parameters allow drawing the graph below (figure 15), which is the basis of table 04 shown in chapter “Declining Coconut Yield due to Age”.

**Figure 15:** estimated production of coconuts per tree (Y axis) for different age classes (X axis).

At a later stage this curve for Niu Vai Tall x Malayan Red Dwarf has to be revised. For the time being this curve drives the table, which the program uses to correct the production figure per palm as soon as variety or age of the coconut palms of the different areas is known.
**Rennen Tall x Malayan Red Dwarf**

For the coconut variety Rennen Tall x Malayan Red Dwarf it is known from available literature and other parameters are assumed, in particular:

a) The coconut production starts with 3 to 4 years.

b) It is assumed and observations of the forestry department show that there is a culmination point about 20 years.

c) Samoan Tall produces 129 coconuts per palm.

d) It is known that varieties breed between type tall and type dwarf can get 30 to 60 years old and an average lifetime of 50 years is assumed.

e) Finally it is assumed that the coconut production is similar to a normal distribution.

These parameters allow drawing the graph below (figure 16), which is the basis of table 04 shown in chapter “Declining Coconut Yield due to Age”.

![Figure 16: estimated production of coconuts per tree (Y axis) for different age classes (X axis).](image)

At a later stage this curve for Rennen Tall x Malayan Red Dwarf has to be revised. For the time being this curve drives the table, which the program uses to correct the production figure per palm as soon as variety or age of the coconut palms of the areas is known.
**Samoan Tall x Malayan Red Dwarf**

For the coconut variety Samoan Tall x Malayan Red Dwarf it is known from available literature and other parameters are assumed, in particular:

a) The coconut production starts with 3 to 4 years.
b) It is assumed and observations of the forestry department show that there is a culmination point about 20 years.
c) Samoan Tall produces 114 coconuts per palm.
d) It is known that varieties breed between type tall and type dwarf can get 30 to 60 years old and an average lifetime of 50 years is assumed.
e) Finally it is assumed that the coconut production is similar to a normal distribution.

These parameters allow drawing the graph below (figure 17), which is the basis of table 04 shown in chapter “Declining Coconut Yield due to Age”.

![Figure 17: estimated production of coconuts per tree (Y axis) for different age classes (X axis).](image-url)

At a later stage this curve for Samoan Tall x Malayan Red Dwarf has to be revised. For the time being this curve drives the table, which the program uses to correct the production figure per palm as soon as variety or age of the coconut palms of the areas is known.
From Curve to Table

The Excel spreadsheet "VarietiesAgeNuts.xls" contains for each coconut variety an own graph showing the yield in terms of coconut per year per palm. Each graph is based on values placed in a one record table directly above the graph (see figure x). Changing the values of this table changes the graph. This table is also driving "Table01" and this table again is driving "Table02". The content of Table 5 can be copied to the Access library table "NutsTreeAge" utilised by the Access program to reduce the yield for every plantation as soon as the age is known.

<table>
<thead>
<tr>
<th>Description</th>
<th>0 Y</th>
<th>10 Y</th>
<th>20 Y</th>
<th>30 Y</th>
<th>40 Y</th>
<th>50 Y</th>
<th>60 Y</th>
<th>70 Y</th>
<th>80 Y</th>
<th>90 Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nu Vai Tall</td>
<td>7</td>
<td>16</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Nu Vai Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>Rennell Tall</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Rennell Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>Samoan Tall</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Samoan Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
</tbody>
</table>

Table02

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<th>20 Y</th>
<th>30 Y</th>
<th>40 Y</th>
<th>50 Y</th>
<th>60 Y</th>
<th>70 Y</th>
<th>80 Y</th>
<th>90 Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nu Vai Tall</td>
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<td>16</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Nu Vai Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>Rennell Tall</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Rennell Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>Samoan Tall</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Samoan Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
</tbody>
</table>

Table01

<table>
<thead>
<tr>
<th>Description</th>
<th>0 Y</th>
<th>10 Y</th>
<th>20 Y</th>
<th>30 Y</th>
<th>40 Y</th>
<th>50 Y</th>
<th>60 Y</th>
<th>70 Y</th>
<th>80 Y</th>
<th>90 Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nu Vai Tall</td>
<td>7</td>
<td>16</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Nu Vai Tall x Malaysian Red Dwarf</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>Rennell Tall</td>
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<td>15</td>
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<td>25</td>
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<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Rennell Tall x Malaysian Red Dwarf</td>
<td>7</td>
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<td>30</td>
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<td>40</td>
<td>45</td>
<td>50</td>
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<td>65</td>
</tr>
<tr>
<td>Samoan Tall</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>25</td>
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<td>35</td>
<td>40</td>
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<tr>
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<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
</tbody>
</table>

Figure 18: The picture shows a copy of the spreadsheet, where the curve drives Table 01, which then drives Table 02, which can be copied into the Access database, where it is utilised for the yield calculation.
Appendix VI - MapBasic Code

Below is the MapBasic Code and the Access Basic Code that was used to create the Spatial and GIS Database.

**Program “ShowAreas.MBX”**

```
'****************************************************
'*              ShowAreas               Wolf 22.04.05 *
'*                                                    *
'* This program:                                      *
'*            - displays layer ForestAreas_050422     *
'*            - displays backdrop ?                   *
'*            - labels the polygons                  *
'****************************************************

Declare Sub Main
Include "MapBasic.DEF"
Include "Menu.DEF"

Sub Main
OnError Goto Err_Manage

'+++++++++++++++++++++ Variables ++++++++++++++++++++++
Dim WinID As Integer
Dim PathBackdrop As String
Dim PathMI_Layer As String
Dim PathPlusTAB1 As String
Dim PathPlusTAB2 As String
Dim PathDB As String

'+++++++++++++++++++++++++++++++++++++++++++++++
'++++++++++++++++++ Directories +++++++++++++++
PathMI_Layer = "C:\Users\wolf\CoconutInventoryWS\MapInfo_Layer\"
PathBackdrop = "xxxx"
PathDB = "C:\Users\wolf\CoconutInventoryWS\AccessDB\"

'+++++++++++++++++++++ Set Toolbars ++++++++++++++++++
Alter ButtonPad "Drawing" Hide
Alter ButtonPad "VM" Hide
Alter ButtonPad "Main" Show Fixed

'+++++++++++++++++++++ Open Tables ++++++++++++++++++
Close All
PathPlusTAB1 = PathMI_Layer + "ForestAreas_050422.TAB"
Open Table PathPlusTAB1 As CoconutArea
Map From CoconutArea Max
WinID = FrontWindow()
'PathPlusTAB = PathBackdrop + "xxxx"
'Open Table PathPlusTAB As Backdrop

'Add Map Auto Layer Backdrop
PathPlusTAB1 = PathDB + "CoconutInventory.mdb"
PathPlusTAB2 = PathDB + "TMP_ShowArea.TAB"
Register Table PathPlusTAB1
Type ACCESS Table "TMP_ShowArea"
Into PathPlusTAB2
Open Table PathPlusTAB2 As AOI
```

CocoGen Samoa

'This is a code snippet for processing a database query and creating a thematic map.

Set Map Window WinID Zoom Entire Layer CoconutArea
'This sets the current window to the entire layer of CoconutArea.

'MAPINFO/ACCESS TABLE LINK

SELECT * from CoconutArea, AOI
WHERE CoconutArea.Object_ID = AOI.Object_ID
INTO LinkTable

Set Map Redraw Off
Add Map Layer LinkTable
Set Map Redraw On

'CREATE THEMATIC MAP

Shade window WinID LinkTable with IncludeInMap values
0 Brush (2,32896,16777215) Pen (1,2,0)
1 Brush (2,16711680,16777215) Pen (1,2,0)
default Brush (1,0,16777215) Pen (1,2,0)

'CREATE LEGEND

Set legend window WinID layer prev
display on
shades on
symbols off
lines off
count on
title "Areas of Interest" Font ("Arial",1,10,0)
subtitle auto Font ("Arial",0,8,0)
ascending on
ranges Font ("Arial",0,8,0)
auto display off,
"Other Coconut Areas" display on,
"Areas of Interest" display on

Set Window WIN_LEGEND
Position (0.5,15) Units "cm"
Width 5.5 Units "cm"
Height 2 Units "cm"

Open Window Legend

Run Menu Command M_QUERY_UNSELECT

Res_Main:
Exit Sub

Err_Manage:
  note "Error: " + str$(Err()) + ", " + Error$
Resume Res_Main
End Sub
Program StratifyAreas

*******************************************************************************
*              StratifyAreas           Wolf 22.04.05 *
*                                                    *
* This program:                                      *
*            - displays layer ForestAreas_050422     *
*******************************************************************************

Declare Sub Main
Include "MapBasic.DEF"
Include "Menu.DEF"

Sub Main
OnError Goto Err_Manage

'+++++++++++++++++++++ Variables +++++++++++++++++++++
Dim WinID As Integer
Dim PathBackdrop As String
Dim PathMI_Layer As String
Dim PathPlusTAB1 As String
Dim PathPlusTAB2 As String
Dim PathDB As String

'++++++++++++++++++++++++++++++++++++++++++++++++++++
'++++++++++++++++++ Directories ++++++++++++++
PathMI_Layer = "C:\Users\wolf\CoconutInventoryWS\MapInfo_Layer\"
PathBackdrop = "xxxx"
PathDB = "C:\Users\wolf\CoconutInventoryWS\AccessDB\"

'+++++++++++++ Set Toolbars +++++++++++++++++++
Alter ButtonPad "Drawing" Hide
Alter ButtonPad "VM" Hide
Alter ButtonPad "Main" Show Fixed

'++++++++++++++++++ Open Tables +++++++++++++++
Close All

PathPlusTAB1 = PathMI_Layer + "ForestAreas_050422.TAB"
Open Table PathPlusTAB1 As CoconutArea

Map From CoconutArea Max
WinID = FrontWindow()

'PathPlusTAB = PathBackdrop + "xxxx"
'Open Table PathPlusTAB As Backdrop

'Add Map Auto Layer Backdrop
PathPlusTAB1 = PathDB + "CoconutInventory.mdb"
PathPlusTAB2 = PathDB + "TMP_ShowArea.TAB"

Register Table PathPlusTAB1
Type ACCESS Table "TMP_ShowArea"
Into PathPlusTAB2

Open Table PathPlusTAB2 As AOI

'++++++++++++++++++++++++++++++++++++++++++++++++++++
Set Map Window WinID Zoom Entire Layer CoconutArea

'++++++++++++++++++++++++++++++++ Set Label +++++++++++++++
'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++\
IRECT MapInfo and Access Table ++++++++++++++

SELECT * from CoconutArea, AOI
WHERE CoconutArea.Object_ID = AOI.Object_ID
INTO LinkTable

Set Map Redraw Off
Add Map Layer LinkTable
Set Map Redraw On

'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

'++++++++++++++ Create Thematic Map ++++++++++++++++++++++++

Shade window WinID LinkTable with IncludeInMap values
0 Brush (2,32896,16777215) Pen (1,2,0)
1 Brush (2,16711680,16777215) Pen (1,2,0)
default Brush (1,0,16777215) Pen (1,2,0)

'++++++++++++++ Create Legend ++++++++++++++++++++++++++++++

Set legend window WinID layer prev
display on
shades on
symbols off
lines off
count on
title "Areas of Interest" Font ("Arial",1,10,0)
subtitle auto Font ("Arial",0,8,0)
ascending on
ranges Font ("Arial",0,8,0)
auto display off
"Other Coconut Areas" display on
"Areas of Interest" display on

Set Window WIN_LEGEND
Position (0.5,15) Units "cm"
Width 5.5 Units "cm"
Height 2 Units "cm"

Open Window Legend

Run Menu Command M_QUERY_UNSELECT

Res_Main:
Exit Sub

Err_Manage:
note "Error: " + str$(Err()) + ", " + Error$
Resume Res_Main
End Sub
**Access Basic Code**

**Calculating Summary for each Coconut Stratum**

Private Sub UpdateStratumSum_Click()
On Error GoTo Err_UpdateStratumSum_Click

    Dim CocoArea As Recordset
    Dim SumStratum As Recordset
    Dim MsgString As String
    Dim RecNum As Integer
    Dim Area_FO_cn_fs As Double
    Dim Yield_FO_cn_fs As Double
    Dim Area_FS_alb_cn As Double
    Dim Yield_FS_alb_cn As Double
    Dim Area_FS_cn As Double
    Dim Yield_FS_cn As Double
    Dim Area_FS_cn_fs As Double
    Dim Yield_FS_cn_fs As Double
    Dim Area_FS_cn_lo As Double
    Dim Yield_FS_cn_lo As Double
    Dim Area_FS_cn_mm As Double
    Dim Yield_FS_cn_mm As Double
    Dim Area_G_cn_lp As Double
    Dim Yield_G_cn_lp As Double
    Dim Area_MC_cn As Double
    Dim Yield_MC_cn As Double
    Dim Area_MC_cn_fs As Double
    Dim Yield_MC_cn_fs As Double
    Dim Area_MC_cn_lo As Double
    Dim Yield_MC_cn_lo As Double
    Dim Area_P_cn As Double
    Dim Yield_P_cn As Double
    Dim Area_P_cn_co As Double
    Dim Yield_P_cn_co As Double
    Dim Area_P_cn_fs As Double
    Dim Yield_P_cn_fs As Double
    Dim Area_P_cn_g As Double
    Dim Yield_P_cn_g As Double
    Dim Area_P_cn_lp As Double
    Dim Yield_P_cn_lp As Double
    Dim Area_P_cn_mc As Double
    Dim Yield_P_cn_mc As Double
    Dim Area_P_cn_mm As Double
    Dim Yield_P_cn_mm As Double

    Set SumStratum = New ADODB.Recordset
    SumStratum.ActiveConnection = CurrentProject.Connection
    SumStratum.CursorType = adOpenKeyset
    SumStratum.LockType = adLockOptimistic
    SumStratum.Open "SELECT * FROM StrataSum;"
    SumStratum.MoveLast
    SumStratum.MoveFirst
    RecNum = SumStratum.RecordCount

    Set CocoArea = New ADODB.Recordset
    CocoArea.ActiveConnection = CurrentProject.Connection
    CocoArea.CursorType = adOpenKeyset
    CocoArea.LockType = adLockOptimistic
    CocoArea.Open "SELECT * FROM CoconutAreas WHERE Stratum <> ""None_CN"";"
    CocoArea.MoveLast
    CocoArea.MoveFirst
    RecNum = CocoArea.RecordCount

    Set SumStratum = New ADODB.Recordset
    SumStratum.ActiveConnection = CurrentProject.Connection
    SumStratum.CursorType = adOpenKeyset
    SumStratum.LockType = adLockOptimistic
    SumStratum.Open "SELECT * FROM StrataSum;"
    SumStratum.MoveLast
    SumStratum.MoveFirst
    RecNum = SumStratum.RecordCount

    MsgBox MsgString = "Number of Records SumStrata: " + Str(RecNum)
    Set CocoArea = New ADODB.Recordset
    CocoArea.ActiveConnection = CurrentProject.Connection
    CocoArea.CursorType = adOpenKeyset
    CocoArea.LockType = adLockOptimistic
    CocoArea.Open "SELECT * FROM CoconutAreas WHERE Stratum <> ""None_CN"";"
    CocoArea.MoveLast
    CocoArea.MoveFirst
    RecNum = CocoArea.RecordCount

    Dim MsgString As String
    Dim RecNum As Integer
    Dim Area_FO_cn_fs As Double
    Dim Yield_FO_cn_fs As Double
    Dim Area_FS_alb_cn As Double
    Dim Yield_FS_alb_cn As Double
    Dim Area_FS_cn As Double
    Dim Yield_FS_cn As Double
    Dim Area_FS_cn_fs As Double
    Dim Yield_FS_cn_fs As Double
    Dim Area_FS_cn_lo As Double
    Dim Yield_FS_cn_lo As Double
    Dim Area_FS_cn_mm As Double
    Dim Yield_FS_cn_mm As Double
    Dim Area_G_cn_lp As Double
    Dim Yield_G_cn_lp As Double
    Dim Area_MC_cn As Double
    Dim Yield_MC_cn As Double
    Dim Area_MC_cn_fs As Double
    Dim Yield_MC_cn_fs As Double
    Dim Area_MC_cn_lo As Double
    Dim Yield_MC_cn_lo As Double
    Dim Area_P_cn As Double
    Dim Yield_P_cn As Double
    Dim Area_P_cn_co As Double
    Dim Yield_P_cn_co As Double
    Dim Area_P_cn_fs As Double
    Dim Yield_P_cn_fs As Double
    Dim Area_P_cn_g As Double
    Dim Yield_P_cn_g As Double
    Dim Area_P_cn_lp As Double
    Dim Yield_P_cn_lp As Double
    Dim Area_P_cn_mc As Double
    Dim Yield_P_cn_mc As Double
    Dim Area_P_cn_mm As Double
    Dim Yield_P_cn_mm As Double

    Set SumStratum = New ADODB.Recordset
    SumStratum.ActiveConnection = CurrentProject.Connection
    SumStratum.CursorType = adOpenKeyset
    SumStratum.LockType = adLockOptimistic
    SumStratum.Open "SELECT * FROM StrataSum;"
    SumStratum.MoveLast
    SumStratum.MoveFirst
    RecNum = SumStratum.RecordCount

    MsgBox MsgString = "Number of Records SumStrata: " + Str(RecNum)
    Set CocoArea = New ADODB.Recordset
    CocoArea.ActiveConnection = CurrentProject.Connection
    CocoArea.CursorType = adOpenKeyset
    CocoArea.LockType = adLockOptimistic
    CocoArea.Open "SELECT * FROM CoconutAreas WHERE Stratum <> ""None_CN"";"
    CocoArea.MoveLast
    CocoArea.MoveFirst
    RecNum = CocoArea.RecordCount

    Dim MsgString As String
    Dim RecNum As Integer
    Dim Area_FO_cn_fs As Double
    Dim Yield_FO_cn_fs As Double
    Dim Area_FS_alb_cn As Double
    Dim Yield_FS_alb_cn As Double
    Dim Area_FS_cn As Double
    Dim Yield_FS_cn As Double
    Dim Area_FS_cn_fs As Double
    Dim Yield_FS_cn_fs As Double
    Dim Area_FS_cn_lo As Double
    Dim Yield_FS_cn_lo As Double
    Dim Area_FS_cn_mm As Double
    Dim Yield_FS_cn_mm As Double
    Dim Area_G_cn_lp As Double
    Dim Yield_G_cn_lp As Double
    Dim Area_MC_cn As Double
    Dim Yield_MC_cn As Double
    Dim Area_MC_cn_fs As Double
    Dim Yield_MC_cn_fs As Double
    Dim Area_MC_cn_lo As Double
    Dim Yield_MC_cn_lo As Double
    Dim Area_P_cn As Double
    Dim Yield_P_cn As Double
    Dim Area_P_cn_co As Double
    Dim Yield_P_cn_co As Double
    Dim Area_P_cn_fs As Double
    Dim Yield_P_cn_fs As Double
    Dim Area_P_cn_g As Double
    Dim Yield_P_cn_g As Double
    Dim Area_P_cn_lp As Double
    Dim Yield_P_cn_lp As Double
    Dim Area_P_cn_mc As Double
    Dim Yield_P_cn_mc As Double
    Dim Area_P_cn_mm As Double
    Dim Yield_P_cn_mm As Double

    Set SumStratum = New ADODB.Recordset
    SumStratum.ActiveConnection = CurrentProject.Connection
    SumStratum.CursorType = adOpenKeyset
    SumStratum.LockType = adLockOptimistic
    SumStratum.Open "SELECT * FROM StrataSum;"
    SumStratum.MoveLast
    SumStratum.MoveFirst
    RecNum = SumStratum.RecordCount

    MsgBox MsgString = "Number of Records SumStrata: " + Str(RecNum)
    Set CocoArea = New ADODB.Recordset
    CocoArea.ActiveConnection = CurrentProject.Connection
    CocoArea.CursorType = adOpenKeyset
    CocoArea.LockType = adLockOptimistic
    CocoArea.Open "SELECT * FROM CoconutAreas WHERE Stratum <> ""None_CN"";"
    CocoArea.MoveLast
    CocoArea.MoveFirst
    RecNum = CocoArea.RecordCount

    Dim MsgString As String
    Dim RecNum As Integer
    Dim Area_FO_cn_fs As Double
    Dim Yield_FO_cn_fs As Double
    Dim Area_FS_alb_cn As Double
    Dim Yield_FS_alb_cn As Double
    Dim Area_FS_cn As Double
    Dim Yield_FS_cn As Double
    Dim Area_FS_cn_fs As Double
    Dim Yield_FS_cn_fs As Double
    Dim Area_FS_cn_lo As Double
    Dim Yield_FS_cn_lo As Double
    Dim Area_FS_cn_mm As Double
    Dim Yield_FS_cn_mm As Double
    Dim Area_G_cn_lp As Double
    Dim Yield_G_cn_lp As Double
    Dim Area_MC_cn As Double
    Dim Yield_MC_cn As Double
    Dim Area_MC_cn_fs As Double
    Dim Yield_MC_cn_fs As Double
    Dim Area_MC_cn_lo As Double
    Dim Yield_MC_cn_lo As Double
    Dim Area_P_cn As Double
    Dim Yield_P_cn As Double
    Dim Area_P_cn_co As Double
    Dim Yield_P_cn_co As Double
    Dim Area_P_cn_fs As Double
    Dim Yield_P_cn_fs As Double
    Dim Area_P_cn_g As Double
    Dim Yield_P_cn_g As Double
    Dim Area_P_cn_lp As Double
    Dim Yield_P_cn_lp As Double
    Dim Area_P_cn_mc As Double
    Dim Yield_P_cn_mc As Double
    Dim Area_P_cn_mm As Double
    Dim Yield_P_cn_mm As Double

    Set SumStratum = New ADODB.Recordset
    SumStratum.ActiveConnection = CurrentProject.Connection
    SumStratum.CursorType = adOpenKeyset
    SumStratum.LockType = adLockOptimistic
    SumStratum.Open "SELECT * FROM StrataSum;"
    SumStratum.MoveLast
    SumStratum.MoveFirst
    RecNum = SumStratum.RecordCount

    MsgBox MsgString = "Number of Records SumStrata: " + Str(RecNum)
    Set CocoArea = New ADODB.Recordset
    CocoArea.ActiveConnection = CurrentProject.Connection
    CocoArea.CursorType = adOpenKeyset
    CocoArea.LockType = adLockOptimistic
    CocoArea.Open "SELECT * FROM CoconutAreas WHERE Stratum <> ""None_CN"";"
    CocoArea.MoveLast
    CocoArea.MoveFirst
    RecNum = CocoArea.RecordCount
MsgString = "Number of Records CocoArea: " + Str(RecNum)
'MsgBox MsgString

DoCmd.OpenQuery "SetStrataSumZero"

CocoArea.MoveNext

Do While Not CocoArea.EOF
    If CocoArea("Stratum") = "FO_cn/fs" Then
        Area_FO_cn_fs = Area_FO_cn_fs + CocoArea("Area")
        Yield_FO_cn_fs = Yield_FO_cn_fs + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "FS_alb/cn" Then
        Area_FS_alb_cn = Area_FS_alb_cn + CocoArea("Area")
        Yield_FS_alb_cn = Yield_FS_alb_cn + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "FS_cn" Then
        Area_FS_cn = Area_FS_cn + CocoArea("Area")
        Yield_FS_cn = Yield_FS_cn + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "FS_cn/fs" Then
        Area_FS_cn_fs = Area_FS_cn_fs + CocoArea("Area")
        Yield_FS_cn_fs = Yield_FS_cn_fs + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "FS_cn/lo" Then
        Area_FS_cn_lo = Area_FS_cn_lo + CocoArea("Area")
        Yield_FS_cn_lo = Yield_FS_cn_lo + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "FS_cn/mm" Then
        Area_FS_cn_mm = Area_FS_cn_mm + CocoArea("Area")
        Yield_FS_cn_mm = Yield_FS_cn_mm + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "G_cn/lp" Then
        Area_G_cn_lp = Area_G_cn_lp + CocoArea("Area")
        Yield_G_cn_lp = Yield_G_cn_lp + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "MC_cn" Then
        Area_MC_cn = Area_MC_cn + CocoArea("Area")
        Yield_MC_cn = Yield_MC_cn + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "MC_cn/fs" Then
        Area_MC_cn_fs = Area_MC_cn_fs + CocoArea("Area")
        Yield_MC_cn_fs = Yield_MC_cn_fs + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "P_cn" Then
        Area_P_cn = Area_P_cn + CocoArea("Area")
        Yield_P_cn = Yield_P_cn + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "MC_cn/lo" Then
        Area_MC_cn_lo = Area_MC_cn_lo + CocoArea("Area")
        Yield_MC_cn_lo = Yield_MC_cn_lo + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "P_cn/co" Then
        Area_P_cn_co = Area_P_cn_co + CocoArea("Area")
        Yield_P_cn_co = Yield_P_cn_co + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "P_cn/fs" Then
        Area_P_cn_fs = Area_P_cn_fs + CocoArea("Area")
        Yield_P_cn_fs = Yield_P_cn_fs + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "P_cn/g" Then
        Area_P_cn_g = Area_P_cn_g + CocoArea("Area")
        Yield_P_cn_g = Yield_P_cn_g + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "P_cn/lp" Then
        Area_P_cn_lp = Area_P_cn_lp + CocoArea("Area")
        Yield_P_cn_lp = Yield_P_cn_lp + CocoArea("YieldTotal")
    ElseIf CocoArea("Stratum") = "P_cn/mc" Then
        Area_P_cn_mc = Area_P_cn_mc + CocoArea("Area")
        Yield_P_cn_mc = Yield_P_cn_mc + CocoArea("YieldTotal")
    End If
    CocoArea.MoveNext
Loop

SumStratum.MoveNext

Do While Not SumStratum.EOF
    If SumStratum("Stratum") = "FO_cn/fs" Then
        SumStratum.Fields("Area") = Area_FO_cn_fs
        SumStratum.Fields("YieldTotal") = Yield_FO_cn_fs
        SumStratum.Update
    ElseIf SumStratum("Stratum") = "FS_alb/cn" Then
        SumStratum("Area") = Area_FS_alb_cn
        SumStratum("YieldTotal") = Yield_FS_alb_cn
        SumStratum.Update
    ElseIf SumStratum("Stratum") = "FS_cn" Then
        SumStratum("Area") = Area_FS_cn
        SumStratum("YieldTotal") = Yield_FS_cn
        SumStratum.Update
    End If

DoCmd.OpenQuery "SetStrataSumZero"
CocoGen Samoa

SumStratum("Area") = Area_FS_cn
SumStratum("YieldTotal") = Yield_FS_cn
SumStratum.Update
ElseIf SumStratum("Stratum") = "FS_cn/fs" Then
SumStratum("Area") = Area_FS_cn_fs
SumStratum("YieldTotal") = Yield_FS_cn_fs
SumStratum.Update
ElseIf SumStratum("Stratum") = "FS_cn/lo" Then
SumStratum("Area") = Area_FS_cn_lo
SumStratum("YieldTotal") = Yield_FS_cn_lo
SumStratum.Update
ElseIf SumStratum("Stratum") = "FS_cn/mm" Then
SumStratum("Area") = Area_FS_cn_mm
SumStratum("YieldTotal") = Yield_FS_cn_mm
SumStratum.Update
ElseIf SumStratum("Stratum") = "G_cn/lp" Then
SumStratum("Area") = Area_G_cn_lp
SumStratum("YieldTotal") = Yield_G_cn_lp
SumStratum.Update
ElseIf SumStratum("Stratum") = "MC_cn/lo" Then
SumStratum("Area") = Area_Mc_cn_lo
SumStratum("YieldTotal") = Yield_Mc_cn_lo
SumStratum.Update
ElseIf SumStratum("Stratum") = "MC_cn/fs" Then
SumStratum("Area") = Area_Mc_cn_fs
SumStratum("YieldTotal") = Yield_Mc_cn_fs
SumStratum.Update
ElseIf SumStratum("Stratum") = "MC_cn/lp" Then
SumStratum("Area") = Area_Mc_cn_lp
SumStratum("YieldTotal") = Yield_Mc_cn_lp
SumStratum.Update
ElseIf SumStratum("Stratum") = "P_cn/co" Then
SumStratum("Area") = Area_P_cn_co
SumStratum("YieldTotal") = Yield_P_cn_co
SumStratum.Update
ElseIf SumStratum("Stratum") = "P_cn/fs" Then
  SumStratum.EditMode
SumStratum("Area") = Area_P_cn_fs
SumStratum("YieldTotal") = Yield_P_cn_fs
SumStratum.Update
ElseIf SumStratum("Stratum") = "P_cn/g" Then
SumStratum("Area") = Area_P_cn_g
SumStratum("YieldTotal") = Yield_P_cn_g
SumStratum.Update
ElseIf SumStratum("Stratum") = "P_cn/lp" Then
SumStratum("Area") = Area_P_cn_lp
SumStratum("YieldTotal") = Yield_P_cn_lp
SumStratum.Update
ElseIf SumStratum("Stratum") = "P_cn/mc" Then
SumStratum("Area") = Area_P_cn_mc
SumStratum("YieldTotal") = Yield_P_cn_mc
SumStratum.Update
End If
SumStratum.MoveNext
Loop

DoCmd.OpenForm "StrataSum", acViewNormal, acReadOnly

Exit_UpdateStratumSum_Click:
Exit Sub

Err_UpdateStratumSum_Click:
MsgBox Err.Description
Resume Exit_UpdateStratumSum_Click

End Sub
Private Sub CalculateReductAge_Click()
On Error GoTo Err_CalculateReductAge_Click

Dim CocoArea As Recordset
Dim AgeVariety As Recordset
Dim VarCocVari As String
Dim VarAge As Integer
Dim Age As Integer
Dim NutsPalm As Integer
Dim Production As Integer
Dim i_count As Integer
Dim V_YieldTree As Integer

Set AgeVariety = New ADODB.Recordset
AgeVariety.ActiveConnection = CurrentProject.Connection
AgeVariety.CursorType = adOpenKeyset
AgeVariety.LockType = adLockOptimistic
AgeVariety.Open "SELECT * FROM NutsTreeAge;"
AgeVariety.MoveLast
AgeVariety.MoveFirst
RecNum = AgeVariety.RecordCount
'MsgBox MsgString
Set CocoArea = New ADODB.Recordset
CocoArea.ActiveConnection = CurrentProject.Connection
CocoArea.CursorType = adOpenKeyset
CocoArea.LockType = adLockOptimistic
CocoArea.Open "SELECT * FROM CoconutAreas WHERE Stratum <> "None_CN";"
CocoArea.MoveLast
CocoArea.MoveNext
RecNum = CocoArea.RecordCount
'MsgBox MsgString

'++++++++++++++++++++++++++++++++ reducing production by age +++++++++++++++++++++++++++++++++
CocoArea.MoveNext
i_count = 0
Do While Not CocoArea.EOF
Do While Not i_count > 10
VarCocoVari = CocoArea("CoconutVar")
VarAge = CocoArea("Age")
'       Calculating age from Year of Plantation establishment ***********
VarAge = Year(Date) - VarAge
'       get age % from table ProductionAge ***********************
AgeVariety.MoveFirst
Do While Not AgeVariety.EOF
If AgeVariety("VarietyID") = VarCocoVari Then 'PRG searches for record in TAB
If VarAge > 4 And VarAge < 7 Then 'ProductionAge (several varieties)
    NutsPalm = AgeVariety("05Y")
ElseIf VarAge > 6 And VarAge < 12 Then
End If
AgeVariety.MoveNext
End If
End If
End Do
End Do
CocoGen Samoa

NutsPalm = AgeVariety("10Y")
ElseIf VarAge > 11 And VarAge < 17 Then
   NutsPalm = AgeVariety("15Y")
ElseIf VarAge > 16 And VarAge < 24 Then
   NutsPalm = AgeVariety("20Y")
ElseIf VarAge > 23 And VarAge < 34 Then
   NutsPalm = AgeVariety("30Y")
ElseIf VarAge > 33 And VarAge < 44 Then
   NutsPalm = AgeVariety("40Y")
ElseIf VarAge > 43 And VarAge < 54 Then
   NutsPalm = AgeVariety("50Y")
ElseIf VarAge > 53 And VarAge < 64 Then
   NutsPalm = AgeVariety("60Y")
ElseIf VarAge > 63 And VarAge < 74 Then
   NutsPalm = AgeVariety("70Y")
ElseIf VarAge > 73 And VarAge < 84 Then
   NutsPalm = AgeVariety("80Y")
ElseIf VarAge > 83 And VarAge < 94 Then
   NutsPalm = AgeVariety("90Y")
ElseIf VarAge > 93 And VarAge < 104 Then
   NutsPalm = AgeVariety("100Y")
ElseIf VarAge > 103 And VarAge < 114 Then
   NutsPalm = AgeVariety("110Y")
End If
End If

AgeVariety.MoveNext
\* ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

CocoArea("YieldTree") = NutsPalm
V_YieldTree = CocoArea("YieldTree")
CocoArea.Update

\* 'MsgString = Str(i_count) + ", Age = " + Str(VarAge) + ", Nuts/Tree = " + Str(V_YieldTree)
\* 'MsgBox MsgString

CocoArea.MoveNext
i_count = i_count + 1

Loop

Exit_CalculateReductAge_Click:
   Exit Sub

Err_CalculateReductAge_Click:
   MsgBox Err.Description
   Resume Exit_CalculateReductAge_Click

End Sub
Appendix VII - Coconut Height and Age

**Figure 18:** Estimated coconut height and age relation

**Figure 19:** Estimated coconut yield and age relation

When comparing figure 18 and 19 it becomes clear that it is essential to establish a statistically clear relation between age and height for the different varieties. This relation also has been linked to the soil type, however, the soil types are already available as GIS layer.
Appendix VIII - Test report Saleloga Power Station

The following is an excerpt from the Test report written by EPC Plant Manager Saleloga, Mr. Tiafau Magele Tafu

Testing OF A 10,000 litres BLEND OF 10 % COCONUT OIL – 90 % DIESEL FUEL IN GENSET 2A

Background

Through a combination of cost savings and environmental considerations, EPC aims to utilise alternative fuels from diesel. In addition, the increasing dependence on imported fossil fuels is another main reason to carry out a feasibility study into the use of alternative fuels in the EPC generators. The EPC in cooperation with the Government of Samoa and UNDP-Samoa are undertaking the preparatory phase of the Coconut oil Power Generation (CocoGen) project. This first phase was approved and conducted to one of the engines in the Savaii
**Test:**
The test started on Saturday 2\textsuperscript{nd} of April 2005 with the present of Dr Vaitilingom from France. Mr Vaitilingom is the Bio-Fuel Specialist and UNDP representative working on this project called CocoGen Samoa. There were 6X44gal of coconut oil delivered from Apia used in this first phase of the project. Dr Vaitilingom conducted a small introduction and procedures of mixing before the actual test proceeded. It was recommended strongly that the load of the engine should not be below 80\% of normal load. For this engine, the normal load is 200kW and therefore the load should be above 150kW at any time. If the load is below 150kW, then the engine must be shut down to avoid any sign of unforeseen failure. The test took about 3 weeks to complete 6x44gal of coconut oil that is on April 23, 2005.

**Statistics:**
- Duration of test (days): 22
- Amount of coconut fuel used: approx 1,000 Litres
- Amount of hours during test: 245
- Average hour per day: 11
- Top up Oil during test: 26 litres
- Total kWh: 46,278kWh

With the cost savings aspect of the test, it is quite obvious that if coconut oil is less expensive than diesel, EPC could save some money during this trial.

**Comments:**
The successful completion of the test reveals positive direction of coconut oil as an alternative fuel, provided that it is less expensive that diesel fuel. Mechanically speaking, there was no sign of any defective during the test. At the moment, there is no confirmation or green light given to continue with this process until we have received lube oil analysis and report from Dr Vaitilingom. It has been confirmed that the maximum share of coconut oil in the blend should not exceed 30\%. At this stage it is well safe not to recommend 30\% coconut oil.

**Required Data:**
The oil sample together with required data is to be sent over to Fiji to Jan Cloin of SOPAC for analysis and reporting. These data includes; log sheets, lube oil type used, running hours of lube oil before test, kWh produced etc.

**Recommendations:**
1. The test is not long enough to find out the impact of the test to engine components. It is suggested of at least 1,000 hrs of running is appropriate and consumed approximately 4,500 litres of coconut oil.
2. After 1000 hrs of test, the engine should be conducted with thorough checks on its cylinder heads, injectors, liners, pistons, piston rings, and fuel pump etc for any abnormal signs or defects.
3. The exhaust gas during this test was not satisfactory and therefore suggested strongly that the recommended sulphur content of the fuel should be between 0.25 and 0.50 percentage by weight.

Tiafau Magele Tafu, **Acting Manager Savaii**
Appendix IX - Cost of Coconut Fuel Production in Samoa

Please find below some rough calculations on the costs of coconut oil fuel production on Savai'i. These calculations will be further refined during the feasibility study.

### Rough Calculation of the Cost of Producing Coconut Fuel for Diesel Generation in Samoa

(Based on the CocoGen Second Mission Report)

S$1 = 0.36 USD

<table>
<thead>
<tr>
<th>I. Capital Costs of Proposed Mill (adjacent to new power plant on Savai'i)</th>
<th>Estimated Cost (S$)</th>
<th>Estimated Cost (US$)</th>
<th>Useful Life (years)</th>
<th>Annual Depreciation Cost (S$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant components capable of processing</td>
<td>5,000,000</td>
<td>nuts annually</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buildings and Design Equipment</td>
<td>556,000</td>
<td>192,500</td>
<td>30</td>
<td>18,333.33</td>
</tr>
<tr>
<td>Dryer</td>
<td>230,000</td>
<td>87,500</td>
<td>10</td>
<td>25,000.00</td>
</tr>
<tr>
<td>Expellers</td>
<td>400,000</td>
<td>140,000</td>
<td>5</td>
<td>80,000.00</td>
</tr>
<tr>
<td>Fuel Tanks</td>
<td>100,000</td>
<td>35,000</td>
<td>20</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Ripping, Bolts, Infrastructure</td>
<td>250,000</td>
<td>87,500</td>
<td>15</td>
<td>16,666.67</td>
</tr>
<tr>
<td>Total</td>
<td>1,556,000</td>
<td>542,500</td>
<td></td>
<td>145,000</td>
</tr>
</tbody>
</table>

### II. Annual Operating Costs

<table>
<thead>
<tr>
<th>Assumed:</th>
<th>3,000,000</th>
<th>nuts annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial operations use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuts required to produce 1 litre of fuel</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Price paid per coconut collected (S$)</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

**Transport Costs**

| Truckloads per month | 60 |
| Distance per truck per load | 60 km |
| Cost per truck (S$) | 2.00 per km |

**Labour**

| Person (S$) | 2,000.00 |
| Management | 375.00 |
| Labourers employed full-time at the Mill | 15 |

<table>
<thead>
<tr>
<th>Estimated Annual Cost (S$)</th>
<th>Estimated Annual Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of Coconuts (roadside)</td>
<td>450,000</td>
</tr>
<tr>
<td>Delivery of Coconuts to Mill</td>
<td>72,000</td>
</tr>
<tr>
<td>Labour</td>
<td>91,500</td>
</tr>
<tr>
<td>&quot;Consumables&quot;</td>
<td>60,000</td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>etc</td>
<td></td>
</tr>
<tr>
<td>Consumption of Capital</td>
<td>145,000</td>
</tr>
<tr>
<td>Total Costs</td>
<td>818,500</td>
</tr>
<tr>
<td>Total output (litres of fuel)</td>
<td>600,000</td>
</tr>
<tr>
<td>Input costs per litre</td>
<td>1.36</td>
</tr>
</tbody>
</table>
ANNEX IV

CocoGen Stakeholder Meeting Minutes
CocoGen Stakeholder Meeting Minutes

Prepared for: EPC, UNDP Samoa
Prepared by: SOPAC Cocogen Team

September 2005
**Introduction**

After publishing the first draft of the Cocogen feasibility study, all stakeholders involved with the coconut sector or otherwise potentially connected with the proposed use of coconut oil in power generation were invited to voice their views on the study. This is a report on the stakeholder consultation.

The meeting was very well organised by EPC management and support staff, with name badges, name plates for the major stakeholders.

**Present:** 45 Attendees (See list)

**Agenda:**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Presenter/Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:15 pm</td>
<td>Welcome Opening Prayer</td>
<td>EPC (Sam XXX)</td>
</tr>
<tr>
<td>1:25 pm</td>
<td>Opening Remarks Goals &amp; Objectives of the Meeting</td>
<td>EPC General Manager (Muaausa Joseph Walter)</td>
</tr>
<tr>
<td>1:45 pm</td>
<td>Overall Presentation of CocoGen Study by SOPAC</td>
<td>CocoGen Project Manager (Jan Cloin)</td>
</tr>
<tr>
<td>2:00 pm</td>
<td>Presentation: Use of Coconut Oil in Reciprocating Engines For Power Generation</td>
<td>Hawthorne Caterpillar Inc. (Don Anderson)</td>
</tr>
<tr>
<td>2:30 pm</td>
<td>Detailed Presentation of CocoGen Draft Feasibility Study by SOPAC</td>
<td>CocoGen Project Manager (Jan Cloin)</td>
</tr>
<tr>
<td>3:00 pm</td>
<td>AFTERNOON TEA BREAK</td>
<td></td>
</tr>
<tr>
<td>3:30 pm</td>
<td>Questions &amp; Discussion in Plenum</td>
<td>EPC General Manager (Muaausa Joseph Walter)</td>
</tr>
<tr>
<td>5:30 pm</td>
<td>Adjourn</td>
<td></td>
</tr>
</tbody>
</table>

During the detailed presentation of the Cocogen Draft Feasibility study, a 5-minute video was presented, showing the coconut oil blending test in Savai’i. Mr. Tiafua Magele Tafu, manager of Saleloga Power Station provided the video with comments. Key points:

- With no investments, 1,000 litre of coconut oil was mixed in the day-tank with diesel, stirred with a stick;
- The oil was filtered with a cloth only and there were no deposits in the oil;
- Before and after the test, lube oil samples were taken and sent to labs in Fiji and France for testing. Results have pointed out that there were no signs of dilution of the lube oil by (unburnt) coconut oil. On this basis, EPC has decided to continue the experiments at 15%. EPC have recently acquired 5,000 litres of coconut oil from COPS at an effective price of 1.48ST$ per litre.
According to the records, 1 litre of coconut oil replaced 1 litre of diesel (i.e. there was no sign of coconut oil having a lower energy value per litre.

During the week of the stakeholder meeting, EPC have had issues with blocking filters at the test machine (blocking after 57 hours of operation), through particulate matter in the coconut oil (second batch). The Japanese senior volunteer has investigated the filter and concluded that pre-filtering of the coconut oil will be required. This will be further investigated during a site visit on 17/7/2005.

Discussion during and after the presentation of the feasibility study

Mr. Fonoiava Sealiitu Sesega representing the STEC plantation remarked that any solution that yielded less than 15 sene per coconut was out of the question, it would at least have to be 20 sene. He also has a bakery and gets nuts at 25 sene delivered at his bakery.

The Coconut Growers Association representative remarked that for 60,000 ST$, a mill could be acquired for producing 1,000 litres per day (1.67 tonnes of copra per day or 70 kg per hour). There has been a proposal in circulation in Samoa to enable small co-operatives of farmers to buy such mills, to produce their own oil. This could then produce pharmaceutical grade oil with high yields, higher than coconut oil fuel.

Mr. XXX (Agricultural department) reiterated that less than 20 sene per nut was ridiculously low.

Mr. Rodney Parker (COPS) reminded the participants that with the current world market prices it was virtually impossible to pay a fair price to the farmers. He remarked that one tonne of copra required 5,200 nuts (i.e. 7.93 nuts per litre); therefore the output price comes down to 15.3 sene per nut (based on US$640 and cost-to-market US$130, July 2005). This is very close to the reward the farmers receive when they make copra, i.e. 12.7 sene per nut (ST$ 0.6614/kg, July 2005).

Mr. Steven Rogers (EU) remarked that he supported the concept, however the price of nuts proposed (13 sene per nut) is too low to set up a sustainable business. He suggested to introduce a levy on transport fuel of 2 sene to enable a premium to be paid to the coconut farmers.

Mr. XX (Meti, an NGO) remarked that most producers that have coconut as inputs would like to get more coconuts but are struggling. He further proposed the re-introduction of donkeys in the collection process, a farmer walks next to the
donkey (can carry 100 nuts in two baskets) and picks up the nuts with his bushknife.

Mr. XXX remarked that there was some more strategic thinking to be carried out on the production and supported EPC go ahead with the project.

Mr. Randy Etheridge (Caterpillar / Hawthorne) suggested the price of coconut oil could follow the price of oil, hence providing more return as the oil price rises further. Others questioned what would happen if the oil price would fall.

Ms. Adi Tafunai explained she represents an NGO that produces DME coconut oil. She proposed to build several small mills instead of one large mill to build capacity and to decrease the rate of urbanisation by providing rural income opportunities.

Mr. Fonoiafa Sealiitu Sesega (STEC) remarked that they were hoping this project was not one of the many white elephants that came by in Samoa, and questioned whether the EU would be interested in supporting in financing a mini-mill (tinytech).

Mr. Steven Rogers (EU) remarked that the price developments on the world market can make or break rural development. He used the example of the egg-market where imported eggs from the US (with significant subsidies) are dumped on the Samoan markets, pushing the local eggs out of the market. He foresaw the situation that it would be cheaper to produce coconut oil somewhere else in the world cheaper than in Samoa, would lead EPC to import coconut oil and lead to ‘rural destruction’.

Mr. XXX (MNRE) questioned whether the increase in NOx emissions were not a matter of concern. Mr. Randy Etheridge (Hawthorne) remarked that overall emissions are much lower and that NOx emissions with biofuels are only 10 – 20% higher.

Mr. XXX (Agriculture) proposed to set a national price level for coconuts and Samoan rates for coconut oil, to be used as a fuel. Setting up own storage facilities, not trying to compete with world market prices.

Mr. Fonoiafa Sealiitu Sesega (STEC) remarked that times were much better when there was still the Copra Board and called for a more active role of Government, to increase production in the copra industry.

Mr. Frank Fong (Agriculture) remarked that 13 sene appeared clearly to be insufficient to obtain enough coconuts. He asked the farmers to indicate to the Ministry to come with suggestions. In addition he reported on the large role of biofuels on the World Agricultural Forum held in St. Louis (US) this year. Biodiesel was reportedly still in its infancy stage but held great promises.

Mr. Steven Rogers (EU) suggested to look for the solution of the price for coconuts in the macro-economic sphere, by making CocoGen a Green Project by taxing regular diesel higher and thereby generating a sustainable income stream to subsidise the coconut sector.

Mr. Cloin remarked that the opportunities for subsidy are probably limited through the accession of Samoa to the World Trade Organisation (WTO).

Mr. Fonoiafa Sealiitu Sesega (STEC) suggested an alternative use for the 600kUS$ investment, by installing smaller mills with co-operatives of farmers.
Mr. XXX (USP) indicated that he supports the project and suggested the alternative uses of the by-products are manyfold; he encouraged the study to look at the whole picture and not focus on oil as a fuel only. He also remarked that the CocoGen team did not incorporate an agricultural technology expert, which appeared to be a missing competence.

Mr. XXX (Agriculture) indicated the Ministry supported the project, however the coconut price was too low.

Mr. XXX (MP) support the project and suggested that WTO rules should not be an obstacle. “Rules are meant to be broken” with the greatest proponent, the US, as the best example.

Final remarks & Closing
# List of Attendees

<table>
<thead>
<tr>
<th>Company/Institute</th>
<th>Name</th>
<th>Stakeholder Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC</td>
<td>Mr. Muaausa Joseph Walter</td>
<td>EPC General Manager</td>
</tr>
<tr>
<td></td>
<td>Mr. Tile Tuimalealifiano</td>
<td>EPC Manager Generation</td>
</tr>
<tr>
<td></td>
<td>Mr. Tiafua Magele Tafu</td>
<td>EPC Saleloga Power Station Manager</td>
</tr>
<tr>
<td></td>
<td>Mr. Iwano Noburo</td>
<td>EPC Saleloga Power Station Technical Support (JICA Senior Volunteer)</td>
</tr>
<tr>
<td>Ministry of Finance</td>
<td>Mr. Iulai Lavea</td>
<td>Ministry of Finance</td>
</tr>
<tr>
<td></td>
<td>Ms. Sil’ia Kilepoa</td>
<td>Ministry of Finance, Energy Unit</td>
</tr>
<tr>
<td>UNDP Samoa</td>
<td>Ms. Easter Galuvao</td>
<td>Financier of CocoGen</td>
</tr>
<tr>
<td></td>
<td>Mr. Thomas Jensen</td>
<td></td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>Mr. Asuao Seumanutafa M. Iakopo</td>
<td>Coconut Industry Support</td>
</tr>
<tr>
<td>CROPS (Nuu)</td>
<td>Mr. Frank Fong</td>
<td></td>
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<tr>
<td></td>
<td>Mr. Laisene Sauelu</td>
<td></td>
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<tr>
<td></td>
<td>Mr. Emele Meleisea</td>
<td></td>
</tr>
<tr>
<td>MNRE</td>
<td>Mr Mulipola Ausetalia Titimea</td>
<td>Forestry Division</td>
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<tr>
<td></td>
<td>Mr. Afamasaga Sami Lemalu</td>
<td></td>
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<tr>
<td></td>
<td>Mr. Sunny Seuseu</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>Ministry of Women, Community and Social Development</td>
<td>Ms Sala La’ulu Alosio</td>
<td>Community developments</td>
</tr>
<tr>
<td>Samoa REEP Steering Committee</td>
<td>Mr. Papalii Tommy Scanlan</td>
<td>Central Bank of Samoa</td>
</tr>
<tr>
<td>FAO</td>
<td>Mr. Aru Matthias</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Head of South Pacific)</td>
<td></td>
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<tr>
<td>COPS</td>
<td>Mr. Rodney Parker</td>
<td>Coconut Industry</td>
</tr>
<tr>
<td>STEC</td>
<td>Mr. Fonoiava Sealitu Sesega</td>
<td>Coconut Industry (Government Estate)</td>
</tr>
<tr>
<td></td>
<td>(CEO)</td>
<td></td>
</tr>
<tr>
<td>DESICO</td>
<td>Mr. Papalii P T Moala</td>
<td>Coconut Industry</td>
</tr>
<tr>
<td>Caterpillar / Hawthorne</td>
<td>Mr. Randy Etheridge</td>
<td>Diesel Engine Manufacturer</td>
</tr>
<tr>
<td></td>
<td>Mr. Don Anderson</td>
<td></td>
</tr>
<tr>
<td>Women in Business</td>
<td>Ms. Adimaimalaga Tafunai</td>
<td>Agricultural business NGO</td>
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<tr>
<td></td>
<td>(Executive Director)</td>
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<tr>
<td>Australian High commission</td>
<td>Ms. Asenati Tuiletufaga</td>
<td>Potential Donor</td>
</tr>
<tr>
<td>German Consulate</td>
<td>Mr. Werner Schreckenberg</td>
<td>Potential Donor</td>
</tr>
<tr>
<td></td>
<td>(German Honorary Consul)</td>
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<tr>
<td>NZ High commission</td>
<td>Ms. Kilali Alailima</td>
<td>Potential Donor</td>
</tr>
<tr>
<td></td>
<td>(Sr. Activities Manager)</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>Contact Person(s)</td>
<td>Role</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>--------------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>JICA</td>
<td>Mr. Hisaharu Okuda (Programme Manager)</td>
<td>Potential Donor</td>
</tr>
<tr>
<td>European Union</td>
<td>Mr. Steven Rogers (Head of Delegation)</td>
<td>Potential Donor</td>
</tr>
<tr>
<td>Matuaileo’o Environment Trust Incorporated (METI)</td>
<td>Dr Walter Vermeulen &amp; Mrs. Maimoana Vermeulen</td>
<td>Advocate for funding</td>
</tr>
<tr>
<td>Samoa Union of Non-Governmental Organisations (SUNGO)</td>
<td>Mr. Raymond Voigt (Acting National President)</td>
<td>Community Development</td>
</tr>
<tr>
<td>Samoa Tropical Products</td>
<td>Mr. Maiava Visesio Lino (Director)</td>
<td>Coconut Industry</td>
</tr>
<tr>
<td>Samoa Ports Authority</td>
<td>Mr. Papali John Ryan (General Manager)</td>
<td>Advocate</td>
</tr>
<tr>
<td>SOPAC</td>
<td>Anare Matakiviti (PIEPSAP Energy Adviser)</td>
<td>General Support</td>
</tr>
<tr>
<td>Fiji Electricity Authority</td>
<td>Mr. Babu Singh</td>
<td>Interested party</td>
</tr>
<tr>
<td></td>
<td>Mr. Isikuki Pumivalu</td>
<td>Interested Party</td>
</tr>
<tr>
<td>Public Works Department</td>
<td>Uani Loneli (Energy Consultant)</td>
<td>Interested party</td>
</tr>
<tr>
<td>Ministry of Foreign Affairs</td>
<td>Mr. Aiono Mose Sua (CEO)</td>
<td>National Sopac Representative</td>
</tr>
<tr>
<td>The University Of the South Pacific, Alafua (USP)</td>
<td>Dr. Mareko Tofiga (Sr Lecturer In Crop Science)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Unasa Mesalii, Papali Natu Tugaga, Asiata Saleimoa Vaai, Siaosi Matalavea, Tuulima Laiti, Alofa Leulua’iali’i, Sala Vaimili II Ulil Luatua, Aukuso Leavaga, Victor Adamsaga</td>
<td>Coconut Industry</td>
</tr>
</tbody>
</table>
Assumptions
- Diesel price to BPC still 1US$/litre
- Coconut price is 13 sena per nut
- No Excise on Coconut Oil Fuel
- Separate Tanks for Coconut Oil Fuel
- Dual Fuel Systems at low Blends
- Use of waste heat from generators
- Use of Shell/Husk to dry coconuts

Sensitivity Analysis (1)
- Sensitivity Diagram of CO2 emissions components

Sensitivity Analysis (2)
- Sensitivity Diagram of CO2 emissions components

Sensitivity Analysis (3)
- Sensitivity Diagram of CO2 emissions components

Environmental Impact Assessment
- Make "Development Consent"
- Appropriate uses for waste streams
- Noise / Air Pollution / Nutrient Balances
- Preliminary: No Significant Unsuitable Environmental Problems

Recommendations (1)
- Negotiate with COOP on Quality and Quantity to start COF use
- Develop project proposal (partly) funded by donor (0.6 - 1.4 MSEK)
- Develop detailed design of COF plant and engine adaptations
- Start with Phase 1, then Phase II

Recommendations (2)
- Government bodies to support initiative by creating enabling environment
- Develop further biomass opportunities when COF plant is in operation
- Full Environmental Impact Assessment

Questions?
- Please feel free!