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AN EVALUATION OF THE BIOFUEL PROJECTS IN TAVEUNI AND VANUA BALAVU, FIJI ISLANDS

SOPAC Technical Report 392

October 2006

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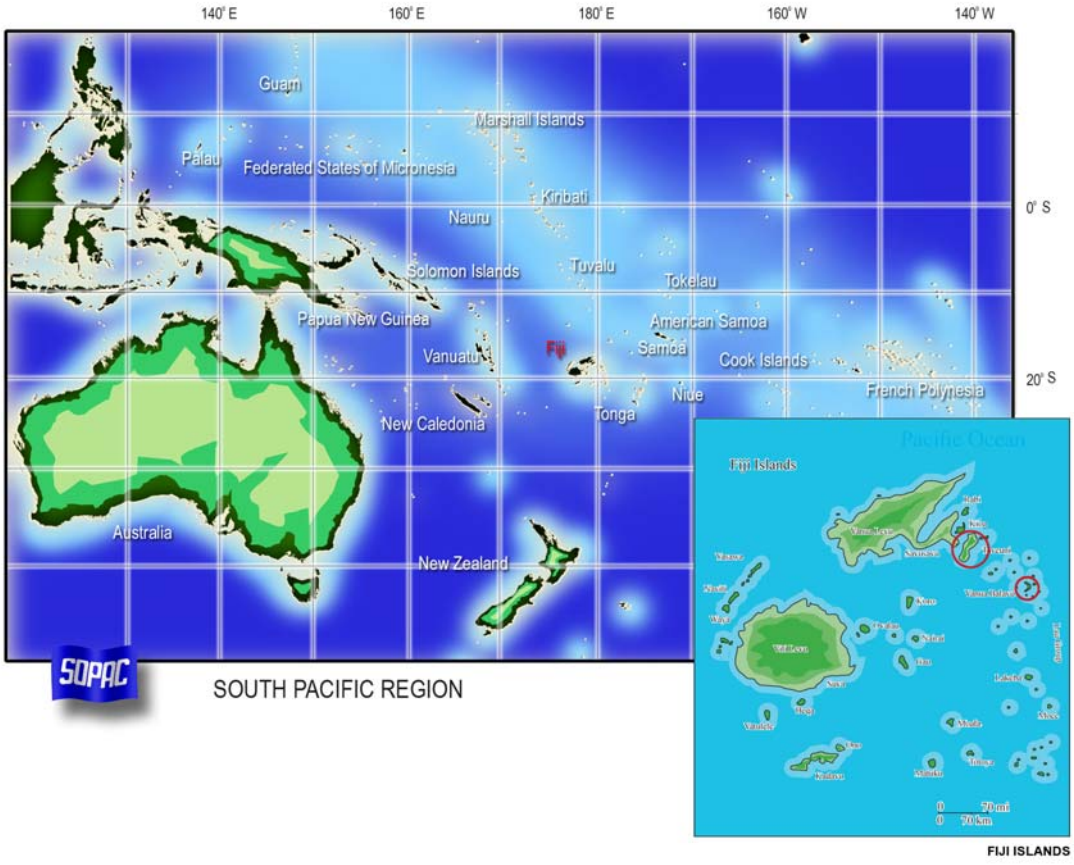

EXECUTIVE SUMMARY

The Fiji Department of Energy through its rural electrification programme developed two community-based biofuel projects in Vanua Balavu (villages of Lomaloma, Naqara and Sawana) and Welagi in Taveuni with funding assistance provided by the French Government through the Secretariat of the Pacific Community. The primary objective of the projects was to use coconut oil to generate electricity for the communities. The Vanua Balavu Biofuel Project was installed in April 2000 and the Welagi Biofuel Project was installed in July 2001.

The projects composed of two specially-modified biofuel engines to use coconut oil and diesel as fuel. The dual fuel tanks enabled the engines to start on diesel fuel and when the engine reaches its operating temperature, it automatically switches to coconut oil. Fuel is switched back to diesel before the engine is turned off.

At the request of the Fiji Department of Energy, SOPAC carried out an evaluation of the projects in February 2006. The evaluation was structured primarily to look into the technical and economic aspects of the projects. Information was gathered through a series of interviews with residents from the respective villages, observations during visits; community meetings; and discussions with operators, committee members and other key stakeholders including DOE and Partners in Community Development Fiji.

The outcomes of the evaluation are presented in this report highlighting lessons learnt that are expected to provide directions and improved approaches to the Fiji Department of Energy and SOPAC in their respective biofuel programmes.

INTRODUCTION AND BACKGROUND

The Department of Energy (DOE) organised two community-based biofuel projects in Vanua Balavu (villages of Lomaloma, Naqara and Sawana)[1], and Welagi[2] in Taveuni with the primary objective of using coconut oil to generate electricity for the communities.

The projects composed of two specially-modified biofuel engines to use coconut oil and diesel as fuel (detailed specifications are appended as Annex 1). The dual fuel tanks enabled the engines to start on diesel fuel and when the engine reaches its operating temperature, it automatically switches to coconut oil. Fuel is switched back to diesel before the engine is turned off.

Funds for the purchase of the gen-sets was provided by the Secretariat of the Pacific Community (SPC) through its Rural Energy Development Programme with the Fiji Government through DOE taking responsibility for the local costs and logistics of the project implementation. Additional funding was provided by the French Embassy with technical assistance by CIRAD-AMIS of France. The respective communities also contributed about F$8,000.00 (each) towards the projects.

Electricity Supply in Welagi, Taveuni

Figure 1. Location of Welagi Village in Taveuni.

Welagi village is located on the North-West coast of Taveuni, 5 km from the chiefly village of Somosomo and about 9 km south of Matei Airport.

The village at present has 48 households[3] connected to the mini-grid. In 1991, the village purchased a piece of land at a cost of F$323,000[4]. The repayments have continued to be the priority for the village. The village committee[5] has leased this land to 30 farmers who pay an annual lease of F$1,000 each. The F$30,000 is administered by the village committee who pays F$11,000 for the annual land repayment and the balance for village development projects including the payment of diesel for the gen-set. The current electricity tariff is F$3.50 per household per week. The tariff is collected

[1] Commissioned in April 2000.
[2] Commissioned in July 2001.
[3] There were 54 households when the project was commissioned in July 2001.
[4] All dollars in this report are expressed in F$ unless stated. The US$ to F$ exchange rate is about 1.719.
[5] The village committee was set up to administer the commercial (income-generating) activities of the village.

on a weekly basis. The gen-set runs from 6 to 10 pm daily with a weekly consumption of about 200 litres of diesel. The current weekly fuel cost is F$295. Copra production has declined given that villagers find more income through cash crops such as dalo (currently sold at F$0.60/ kg to a maximum of F$2.10/ kg during November and December) and remittances from relatives in the urban centres.

Electricity Supply in Lomaloma, Sawana & Naqara Villages, Vanua Balavu

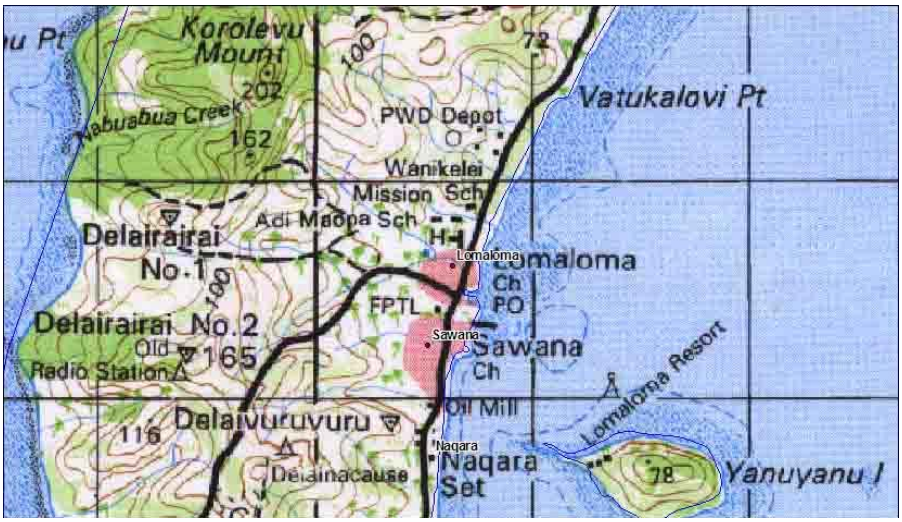

Figure 2. Map showing the location of the three villages.

The evaluation exercise revealed that fuel continues to be expensive[6] on the island of Vanua Balavu. The inter-island shipping service seemed to have a regular schedule, at least once every fortnight thus the consistency in the supply is not considered to be an issue.

Unlike Welagi Village in Taveuni, the three villages of Lomaloma, Sawana and Naqara do not have a consistent income as a community (with the exception of civil servants, Post Fiji and Telecom Fiji employees). Income-generating activities have been basically from the sale of farm produce, pigs, cows, etc, for ceremonial activities. In addition, there are small income generating activities (run by women) such as mat weaving, making cosmetic oil and selling sweets and snacks.

Currently, the three villages have not had access to electricity since March 2005 due to mechanical problems with the community biofuel gen-set except for those who have their own small gen-sets[7].

[6] Diesel cost ranges from F$1.80 to over F$2.00 per litre.
[7] These families reported currently spend between F$30 – F$50 per week on fuel.

Given the delay in repairing the engine the village of Lomaloma (and Sawana) is (are) exploring options of obtaining their own gen-sets. A load survey was carried out by DOE in October 2005. DOE on the other hand has not totally ruled-out the biofuel gen-set thus the need for the evaluation exercise to lay out the options.

On the social aspects, information gathered seems to indicate a very weak cooperation and institutional structure between the villages. This rules out the opportunity for any communally organised task to be carried out successfully, including the effective operation of the community's electricity supply.

Evaluation Methodology

The evaluation was structured primarily to look into the technical and economic aspects of the projects as set out in the terms of reference (TOR) see Annex 2. The evaluation exercise was carried out by SOPAC as part of their Regional Biofuel Initiative funded by the Government of Japan at the request of DOE.

Information was gathered through a series of interviews with residents from the respective villages, observations during visits; community meetings; and discussions with operators, committee members and other key stakeholders including DOE and Partners in Community Development Fiji (PCDF)[8]. It is also noteworthy that the outcomes of the PCDF Social Survey are published separately and can be obtained from DOE.

The village visits for these surveys were carried out by Mr. Rupeni Mario, Energy Adviser, Ms. Emiline Veikoso, Energy Officer and Ms. Allison Woodruff, Resource Economist. Welagi Village was visited for 2 days and Vanua Balavu for 3 days.

The outcomes of the evaluation are expected to provide directions to DOE and SOPAC in their respective biofuel programmes.

[8] PCDF carried out a social survey at the two project sites in December 2005.

FINDINGS

Currently, residents in Welagi are provided with four hours of electricity daily at an expense of $3.50 per week. The largest economic impact in Welagi has been in terms of fuel savings, since residents would otherwise spend a larger portion of their income on energy, in absence of the project. However, there have also been important non-economic benefits from the biofuel project including the reduction of women's work burden due to the widespread use of electrical household appliances; and fluorescent tube lights, which allow children to study at night, both of which can have important indirect economic impacts.

Supply of fuel and organisational issues pose an enormous constraint for the future viability of the biofuel project in Vanua Balavu. First, the coconut oil mill has ceased operation and thus no local supply of oil is currently available. Second, freight costs make importing coconut oil prohibitively expensive. In addition, current diesel fuel costs are significant at $1.80[9] per litre. The benefits of providing electricity to the villages in Vanua Balavu are likely to be very large. This is because the willingness to pay, based on current energy expenditure by many of the villagers, is very large. Thus, if electricity could be provided at a cost of less than $20 - $50 per week for 4 – 6 hours per day, which is the current cost of operating a small household gen-set, the consumer surplus (used to measure project benefits) would be large.

The following sub-sections provide a summary of information relating to specific areas as stated.

Technical Aspects

Resource Risk and Supply

One of the biggest challenges when considering a renewable energy resource for electricity generation is its ability to provide sufficient and consistent supply. Resource risk can be significantly reduced through adequate data recording and perhaps smart modeling. In the case for coconut oil, a good understanding of the copra industry and variation in coconut oil quality and prices is required. It is noteworthy to mention that coconut oil is also used to produce a range of other commodities such as soap and cosmetics that comparatively provide a better return per litre than burning it as fuel.

[9] Note that there is no duty concession on diesel fuel for rural electrification.

In the design phase the projects did not seem to consider the resource risk and coconut oil supply aspects. For instance, in Vanua Balavu installation and commissioning of the biofuel gen-set proceeded despite the closure of the Oil Mill that supposedly used to provide coconut oil for fuel – this was attributed to political reasons and the assumption that the operation of the Oil Mill could be revived[10].

Figure 3. Coconut Plantation in Taveuni.
Picture: Rupeni Mario, February 2006

Use of Local Resources for Electricity Generation

The projects successfully demonstrated the use of locally-produced coconut oil as a diesel substitute to generate electricity. The non-operation of the coconut oil component of the gen-sets has been attributed to minor technical faults – in Welagi – it was the case of a faulty auto-switch, which can be repaired. The project set up in Welagi also successfully demonstrated the possibility of having a copra dryer and mini oil mill established within the proximity of the powerhouse. The deteriorated situation of the copra dryer and oil mill has been attributed to the gen-set not being able to use coconut oil due to the faulty switch. And since there is a better return from selling cash-crops such as dalo instead of copra production there is no incentive for the villagers to continue cutting copra.

In Vanua Balavu, the closure of the oil mill[11] in Sawana had a huge impact on the project. It is however, noteworthy that at the time of the feasibility study, the Oil Mill was producing up to 40 – 80 tonnes (around 21,000 – 42,000 litres) of coconut oil per month. The gen-set, providing electricity to the villages would have required between 1,500 and 3,500 litres per month.

Figure 4. 95kVA biofuel gen-set at Sawana, Vanua Balavu.
Picture: Rupeni Mario, February 2006

[10] Note that the operation of the oil mill was never revived.
[11] The closure was attributed to poor financial management. The workers at a stage could not get their wages as there was no money. It is also important to note that the oil mill was owned and operated by a private investor and not a community project. Thus the closure of the oil mill does not in anyway reflect the communities' inability to operate and manage such an entity.

Suitability of the Technology

In the situation where a new technology[12] is introduced to a remote community, a strong track record, good manufacturer guarantees and user-education have to be considered. The successful performance of the new technology is often associated with its impact on the development of the community, particularly living standards. Therefore, it is imperative that in measuring success a clear understanding of the project's objectives is necessary. Like any other new technology, there are bound to be adaptation issues.

The current status of the projects has raised questions on whether the technology failed due to its inability to adapt to local conditions and/or due to the communities' lack of capacity to manage its operation. There are certainly additional factors such as the quality of fuel (coconut oil) used and the design (e.g. properly sized for the loads – load calculations are appended in Annex 3).

The use of biofuel gen-sets in Taveuni and Vanua Balavu has enabled the respective communities' access to services that are usually available in urban areas. A significant distinction in such services was clearly apparent in Welagi where women are now able to use washing machines instead of going to the river/creek. Results indicated that 50% of the households interviewed had washing machines.

The other aspect of the technology was the introduction of a mini oil mill in Welagi. The screw press with an input capacity of 30 kg/hour of crushed copra was considered suitable. Technical analysis at the time of project design showed an energy consumption of 180 kWh/day. This would need about 60 kg (34 litres[13]) of coconut oil per day which requires the village to produce 2 tonnes of dried copra per month. Note that at present the energy consumption is below 180 kWh/day – and more likely to be 85 kWh/day based on the current fuel consumption. Load calculations are appended in Annex 3.

Figure 5. Current state of the Crusher in Welagi, Taveuni.
Picture: Rupeni Mario, February 2006

[12] Technology in this case can be considered to include the gen-set, the mini oil mill and all the electrical appliances bought by the respective households.
[13] The mini oil mill in Taveuni produces 52% oil from dried copra.

With the gen-sets currently not in operation as planned (i.e. to run on coconut oil) there still remains the issue of whether the biofuel component was the main cause of problems. In Welagi, the response during the site visit indicated that the community would have preferred that the gen-set continue to run on diesel only. The community has the perception that coconut oil will lead to mechanical problems thus, disruption in the electricity supply.

Introducing Complexity

The introduction of new technology to a community demands new skills and knowledge. From discussions it was noted that the education level of villagers may not be sufficient to absorb the new skills and knowledge required to manage the operations of the project. This stresses the importance of having a well-structured and simple training component whereby the trainees are taken through the entire process of basic maintenance and monitoring the gen-set performance.

As part of DOE's role, training of the operators was scheduled as follows:

- During commissioning of the projects;
- For Welagi, a 3-day training in 2001 including a detailed step-by-step approach to maintenance and operation;
- During the first inspection by the French experts in 2002 – hands-on training was provided to the operators in Welagi; and
- As part of the DOE Rural Electrification Operators Training in 2003, the operators were provided training on Finance and Management procedures.

There is however, no information or monitoring to measure the success of the training activities. Based on the present situation record keeping and monitoring does not seem to be important to the operators.

Additionally, information sharing between DOE and the community appears to have been limited with except during the formulation and commissioning of the projects. An issue highlighted by some of the residents where they indicated that they too would like to know how the gen-set is operating.

Power Quality

The quality of power is an important feature in any electrification project. To monitor these, good metering and record keeping is required.

Findings reveal that in general, the supply is unreliable. Welagi for instance, had disruptions (and was not in operation for a couple of months) when the gen-set was using coconut oil. This was due to mechanical problems resulting into the situation as shown in Figure 6. As for Vanua Balavu, the gen-set has not been operating since March 2005.

Environmental Impacts

Substitution of fossil fuel by biofuel (coconut oil) reduces the production of pollutants and greenhouse gases. To analyse how the projects have contributed to environmental benefits, data on the quantity of coconut oil used is needed.

Figure 6. Carbon deposits at the Manifold outlet.
Picture: Courtesy of Fiji DOE

In Welagi at the time when the mini oil mill was in operation, the village had to produce at least 34 litres[14] of coconut oil per day (thus, 238 litres per week[15]). In the situation where there is insufficient dried copra available to produce coconut oil, the village then had to make up the required volume by buying commercially produced coconut oil.

If we consider the scenario where the Welagi gen-set uses coconut oil continuously at a load of 180 kWh per day as an estimate, the result would be a savings of about 900 litres of diesel per month (equivalent to $1332 @ $1.48 / litre). Also based on 180 kWh per day, greenhouse gas reduction would amount up to 65.7 tonnes of CO_2 per annum[16].

Given that the gen-set only ran on coconut oil for about 6 months, the actual savings were therefore much less; with current estimated usage of 86 kWh/day, in this period approximately 17 tonnes of CO_2 was avoided. After that the engine ran on diesel, hence no additional environmental benefits were achieved.

Figure 7. Inside one of the houses in Welagi, Taveuni.
Picture: Rupeni Mario, February 2006

[14] Based on the load being 180 kWh
[15] This depends on whether the village has sufficient dried copra.
[16] Based on an efficiency of 3 kWh per litre of diesel, assume 1 kg CO_2 per kWh.

Economics

Access to Electricity

For residents of Welagi, having access to electricity is a major achievement towards efforts to develop socially and economically, as the village did not have electricity prior to the project. As mentioned earlier, they are provided with 4 hours of electricity daily at a cost of $3.50 per week. The willingness and ability to pay for electricity, using energy expenditures on kerosene, benzene, petrol or diesel for personal gen-sets and lanterns prior to the implementation of the project as proxy, is approximately $10 – $20 per week.

Consumer Surplus in economic terms is defined as the willingness to pay for something less current market prices. In this case, the Consumer Surplus is between $6.50 and $16.50 per week, indicating that the benefits from the project are quite high. Even when the true cost of $8.50 (see Section on Tariff Structure and its Sustainability) is considered, rather than the subsidised price of $3.50 that is paid.

Having access to electricity is not new for the villages of Lomaloma, Sawana and Naqara in Vanua Balavu. The three villages have previously enjoyed such services through a 100 kVA Caterpillar gen-set that was used to provide electricity to the Copra Oil Mill in Sawana. With the biofuel gen-set currently not in operation, households have experienced a weekly fuel bill of up to $50 to run their private gen-sets.

Cost of Electricity

The real cost to generate a kWh in Taveuni is difficult to assess exactly, however it can be approximated by writing off the investment of the gen-set in 5 years, reserving 10% of its cost for maintenance annually and considering fuel (diesel) of 200 litres per week. For Taveuni this works out to be $90,000 plus written off over 5 years, plus an annual $4,500 for maintenance and $15,340 for fuel. 200 litres per week corresponds with 600 kWh per week or 31,200 kWh per annum. The resulting cost per kWh is $1.21. On average, each household consumes 11.54 kWh (600 kWh/yr), paying effectively $0.30 per kWh. Because the villagers do not have a kWh-meter but pay per week with whatever load they can afford, the real cost of kWh cannot be recovered equitably among the households.

The cost of electricity in Vanua Balavu is more difficult to calculate, as it is currently not operational. With the same average use of electricity per household (600 kWh/year) as in

Taveuni, the cost of generation would be $0.99 per kWh (with $155,000 for the gen-set, 10% maintenance and $1.80 per litre of fuel (diesel). This reflects higher cost of diesel, but is more than compensated by generation economies of scale. Again in Vanua Balavu, for an equitable recovery of these costs, kWh-meters are required.

Income-generating Activities

In Welagi, the project had a limited economic impact in terms of promoting economic activities. The household survey results revealed that the project had led to the creation of an ice-making business (which uses power produced by a personal gen-set when the biofuel gen-set is not operating) and a juice-making business. Residents interviewed felt that four hours of electricity alone was not sufficient to stimulate economic activities, such as the creation of small businesses. Also, residents currently engaged in cottage industries such as mat weaving, expressed that they did not wish to extend their working hours, despite having the opportunity to do so with the provision of electricity at night.

Given that the gen-set is currently running on diesel, copra production related to the project has failed to create employment. In addition, in Welagi, copra cutting is an unpaid activity, carried out only on ‘community days’, so it has a limited potential to provide residents with a source of income, with the exception of firewood collection for the copra dryer. In addition, few women expressed interest in producing scented oils from copra cake. Overall, four hours of electricity, although essential for improving the standard of living in Welagi, is probably insufficient to generate a substantial amount of economic activity.

In Vanua Balavu, no new opportunities were created for/by residents to earn an income from copra production, given that the oil mill closed before the installation of the biofuel gen-set. However, whilst the gen-set was operating the operator received free electricity as payment for his time and labour. The then electricity committee decided this because cash collected was not sufficient to pay for the operator’s wages.

Generally, there was no indication by the villagers of any new income-generating activities, which arose as a result of the biofuel project.

Costs of Village Electrification and the Production of Coconut Oil

In Welagi, copra is produced on Monday mornings by the village as a community activity. Twenty members of the village offer their labour services for free. Although these workers are unpaid, there is still an opportunity cost of their labour, since they could spend this time engaging in other economically productive activities such as farming or having leisure time.

Members of the village committee indicated that the village was able to produce approximately 15 x 30 kg bags of copra per week. This meant that the village has the potential to produce approximately 305 litres of coconut oil per week[17]. The copra produced by the village can either be sold commercially for $221[18] or can be made into coconut oil for electricity production. Currently, the biofuel gen-set consumes approximately 200 litres of diesel per week. Thus, replacing diesel with coconut oil would represent a savings of $294 per week at current prices[19]. In addition, since 239 litres of coconut oil would be required per week for the gen-set, based on the current demand for electricity, the surplus copra of 0.09 tonnes could be sold for $45.

If instead of cutting copra on Mondays for coconut oil production, the twenty workers spent this time producing dalo, they could earn $240 – $480 in revenue.

Also, the time spent by the operators producing coconut oil from copra, must be included in the opportunity cost of labour calculations:

The capacity of the crusher	= 30 kg per hour
Volume of copra needed to be crushed	= 65 kg per day
Labour hours required	= 2.17

Therefore, the opportunity cost of labour for two operators is:

1/6 of a working day could produce 40 kg x 1/6	= 7 kg of dalo
For two workers	= 14 kg of dalo
For dalo prices between $0.60 – $1.20, the opportunity cost of producing coconut oil is	= $8.40 – $16.80 per day ($60 – $118 per week)
Thus total opportunity cost of producing copra	= $240 – $480 /week
And total opportunity cost of producing both copra and coconut oil	=$300 – $598 /week

So, in fact, if labour was diverted from copra to dalo production, when the price of dalo is at its highest, the village could afford to buy 200 litres of diesel for the gen-set at a cost of $295 and still have a surplus of $170 per week including the $15 cost of transporting diesel. Thus, economic

[17] This assumes that dry copra can be converted into coconut oil at a rate of 0.52.
[18] The Government controlled price of copra, at the time of this report, was $500 per tonne.
[19] Assuming that the cost of diesel is $1.47 per litre.

welfare would be higher in this case (by growing dalo and buying diesel) compared with producing copra. When dalo is at its lowest price of $0.60/kg, the village could still purchase diesel at a loss of $70.

Alternatively, the village could grow dalo and purchase 239 litres of coconut oil at $1.25 per litre, for a total cost of $298.75. In this case, the village could buy coconut oil for electricity production and have a $131 surplus per week including the $50 coconut oil transportation cost. If the price of dalo was $0.60/kg, the village could buy coconut oil at a loss of $109.

Thus, once opportunity costs of labour are considered, village production of coconut oil is quite costly, even the price of dalo is at its lowest. In addition, restoring village coconut oil production capabilities in Welagi would require substantial investments in repairing the crusher, tractor, copra dryer and fuel switch on the biofuel gen-set.

Least-cost analysis: diesel versus coconut oil for electricity production

Least-cost analysis involves comparing project options, which produce the same output, in this case is – electricity. Since the benefits associated with each option are roughly the same, only costs need be compared, and the project with the lowest present value costs is deemed to be the best project option for providing electricity for Welagi.

OPTION 1

Welagi Village to produce coconut oil for use in the gen-set

Economic cost of labour for coconut collection and copra cutting[20]	=	$360
Economic cost of labour for coconut oil production[21]	=	$ 90
Firewood collectors labour costs	=	$40
Premix for chainsaw	=	$10
Transport (diesel for tractor)	=	$1
Total	=	$510 / week

(Additional costs associated with village coconut oil production that are not included are: cost of new tractor, copra dryer refurbishment and repair of crusher and fuel switch on the biofuel gen-set)

[20] This number is based on the average opportunity cost of labour.
[21] This number is based on the average opportunity cost of labour.

Vanua Balavu – local production of coconut oil to generate electricity

Despite abundant coconut resources and low labour costs, local production of coconut oil is unfeasible in the short term given the closure of the oil mill in Sawana and dissolution of the electricity committee. As mentioned earlier, it is noteworthy that the closure of the oil mill does not imply that the villagers' were not able to manage and operate such an entity. The oil mill was a privately-owned enterprise that failed perhaps due to administration and management issues.

The oil mill closed two years prior to the installation of the biofuel gen-set, thereby eliminating the local supply of coconut oil. Coconut oil produced by the mill was intended to be used as fuel for the gen-set.

Currently, Vanua Balavu produces approximately 10 tonnes of dried copra per month. However, current supply is considered to be below its potential, since all copra is sent to Suva, and producers must cover the costs of freight, and thus lose approximately $100 per tonne in transport and freight costs. Copra production is not currently seen as a profitable activity but more as an income of last resort.

Furthermore, given the weak institutions and low cooperation between Sawana and Lomaloma, village production of coconut oil using an organisational structure such as that being applied in Welagi Village does not seem possible. Also residents of Vanua Balavu seemed interested in producing copra only in exchange for cash payments, which rules out the possibility of using "free" labour, as is done in Welagi Village.

OPTION 2

Welagi Village to purchase diesel for use in the gen-set

Diesel	=	$295
Transport	=	$15
Total	=	$310 / week

Vanua Balavu – repair the biofuel gen-set and run it on diesel

Currently the gen-set is in need of an overhaul[22], which will require an estimated $25,000 in maintenance, repair and parts replacement costs[23]. In addition, the weekly biofuel gen-set fuel costs are approximated as follows:

Diesel (50 litres /day @ $1.80[24] / litre for 5 hours)	= $90
Total	= $630/week

OPTION 3

Welagi Village to purchase coconut oil for use in the gen-set

Commercially purchased coconut oil	= $298.75
Transport	= $50
Total	= $349 / week

(Not included is the cost of repairing the fuel switch on the biofuel gen-set)

Vanua Balavu – repair the biofuel gen-set and run it on coconut oil

An overhaul of the gen-set will require $25,000 as stated above. The current cost of purchasing coconut oil from Savusavu is huge, since the coconut oil has to be shipped via Suva.

Coconut oil (53.6 litres[25] /day @ $1.90[26] /litre for 5 hours)	= $107
Total	= $749/week

An alternative would be to build a mini Oil Mill to produce the coconut oil on site. A mini oil mill would cost from US$2,000, depending on its capacity.

OPTION 4

Vanua Balavu – install new diesel gen-sets in Sawana and Lomaloma

This would require new capital investments in the gen-sets that would cost approximately $80,000 per village, 10% of which would be covered by the villages themselves. Additional costs would also be incurred rewiring houses for the new grid system and the installation of kWh meters for more equitable distribution of costs.

[22] Given that it has not been in operation for the past 12 months.
[23] This is based on standard assumptions that a diesel gen-set requires an overhaul every 5 years at a cost of 25% of the initial cost of the gen-set.
[24] This includes freight costs.
[25] Using the energy content of coconut oil to diesel as 1.08.
[26] An assumption based on the fact that it was more costly than diesel.

In addition, it is likely that operation and maintenance costs would be higher for two diesel gen-sets compared with the current biofuel gen-set, since maintenance work would have to be carried out on two, rather than a single gen-set. There is also the need to form two electricity committees to oversee the operation of the projects.

SUMMARY

TABLE A. Summary of Options.

	Vanua Balavu	Welagi
Benefits	Access to electricity	Access to electricity
Option 1 – Local production of coconut oil.	–	$510/week
Option 2 – Purchase diesel for use in gen-set.	$630 /week	$310/week
Option 3 – Purchase commercially-produced coconut oil for use in gen-set.	$749 /week	$349/week
Engine overhaul costs	$25,000	–
Option 4 – Vanua Balavu only. Replace current biofuel gen-set with 2 diesel gen-sets.	$160,000 (investment cost of buying the gen-sets only; does not include logistical & other costs)	–

For sensitivity analysis, using alternative opportunity costs of labour based on a different range of weekly incomes, see Annex 4.

Tariff Structure and its Sustainability

In Welagi, although most residents were happy with the current tariff structure, it is insufficient to cover the costs of providing electricity (see section on Cost of Electricity). However, the village committee is able to use the income it generates from leasing land to subsidise the costs of operating the biofuel gen-set, including the purchasing of diesel, and covering losses due to non-payment. In theory, this system is sustainable, however subsidies are regressive since income tends to be positively correlated with energy use. With flat tariff rates, those who consume less energy pay proportionately more for their electricity. A fairer system would be created if meters were installed so that tariffs could be based on actual energy consumption levels.

Furthermore, a high willingness to pay for increased service was apparent, as 90% of the village residents surveyed, would be willing to pay $3 – $5 dollars per week extra for 6 hours of electricity daily. In addition, some residents would consider paying up to $15 per week for 24-hour electricity.

Cost life-cycle analysis, based on the current use of diesel in the biofuel gen-set, suggests that over a twenty-year project life, the sustainable tariff rate, which would cover the costs of operation, maintenance and replacement, would be approximately $8.50 per household per week. This amount excludes the initial capital investment costs, but assumes that once the project is handed over to Welagi Village, the village itself must cover any future gen-set replacement costs and on-going maintenance. The results of the cost life-cycle analysis are presented in Tables B & C.

Given that most residents have the ability and willingness to pay higher tariffs, especially if this is in exchange for an improved and extended level of service, tariffs based on full-cost recovery seem possible.

Table B. Cost life-cycle analysis of the biofuel gen-set in Welagi running on diesel.

Component	Frequency	Cost ($F)	Weekly cost per household[27]
Gen-set and engine maintenance	Every year	5,000	0.78
Engine overhaul	Every 5 years	25,000	1.55
Engine replacement	Every 10 years	100,000	1.55
Fuel costs	Weekly	310	4.60
TOTAL			F$8.50

Table C. Cost life-cycle analysis of biofuel gen-set in Welagi running on commercially purchased coconut oil.

Component	Frequency	Cost ($F)	Weekly cost per household[28]
Gen-set and engine maintenance	Every year	5,000	0.78
Engine overhaul	Every 5 years	25,000	1.55
Engine replacement	Every 10 years	100,000	1.55
Fuel costs	Weekly	330	4.92
TOTAL			F$8.80

For Vanua Balavu, using current expenditure on electricity as a proxy, willingness to pay for electricity can be estimated to be quite high. Currently, many households are incurring fuel costs of up to $30 – $50 per week for 4 – 6 hours of daily electricity. In Sawana, 25% of households own gen-sets, whereas in Lomaloma, only 15% of households own their gen-sets. However, average willingness to pay for electricity among poorer households who do not own gen-sets can be expected to be much lower, in the range of $10 – $20 per week.

[27] Costs are discounted by 3% per year except for fuel costs, which are discounted at 2% due to higher diesel inflation costs.
[28] Costs are discounted by 3% per year.

The current tariff level of $1.00/kWh is based on the price of diesel, energy consumption levels and the number of households connected to the grid. In order for the biofuel project to sustain itself over an assumed 20-year lifetime, fuel, maintenance and replacement costs must all be covered by tariff revenue.

Table D. Cost life-cycle analysis of running the 95 kVA biofuel gen-set in Vanua Balavu on diesel.

Component	Frequency	Cost ($F)	Weekly cost per household[29]
Gen-set and engine maintenance	Every year	5,000	0.78
Engine overhaul	Every 5 years	25,000	1.55
Engine replacement	Every 10 years	100,000	1.55
Fuel costs	Weekly	599	0.20
TOTAL			F$4.08

CONCLUSIONS

The biofuel projects in Taveuni and Vanua Balavu have successfully demonstrated the technical possibility to use coconut oil as a fuel for rural electrification. They have however not resulted in the expected socio-economic development as anticipated.

Provision of reliable and affordable electricity services to the remote communities of Taveuni and Vanua Balavu is a highly valued service to improve standard of living.

Diesel has been found the most appropriate and lowest-cost fuel option for the provision of electricity at both sites researched.

Even though thorough feasibility studies on technology and socio-economics have been carried out before the implementation of the projects, the expectations of the villagers and the results of the projects have not been in line with each other.

If the automatic fuel switch on the Taveuni gen-set is repaired, the villagers have the option of whether to use (commercially-produced) coconut oil or diesel as fuel. For Vanua Balavu to utilise coconut oil as a fuel, an oil mill would have to be bought and oil milling organised as it does not appear to be economically attractive to import coconut oil from other islands.

The evaluation findings and social survey conducted by PCDF clearly outlines the social constraints and non-cooperativeness among the 3 villages in Vanua Balavu particularly, that

[29] It is assumed that 190 households are connected to the electricity grid.

between Lomaloma and Sawana. The idea of having an electricity committee comprising of members from the three villages is not practical. Thus, it is unlikely that a common gen-set for the villages is suitable.

The current tariff structure is not sustainable as real costs are neither covered, nor equitable because all households pay the same amount irrespective of their usage.

Generally, new technology can survive and operate as designed provided it is used according to its specifications. The absence of technology in a community will only hinder the community's development plans including (wo)men's, youth and children's efforts to develop socially, economically and sustainably.

RECOMMENDATIONS

Based on the observations and conclusions, below are a number of recommendations to the Fiji Department of Energy. They are not listed in order of priority. They are provided as a set of possible improvements to the current status of the respective projects. They have been classified so as to clearly indicate the project and commonalities that need addressing.

Welagi Village, Taveuni

- Repair the auto-switch[30] and maybe consider having a manual one instead.
- When auto-switch is repaired, it is proposed that the village buy commercially-produced coconut oil – at current prices, the difference margin between diesel and coconut oil is not sufficient to consider producing coconut oil at the village level for electricity generation an economic option.
- Given the current high levels of satisfaction in operating hours and a high willingness to pay for electricity, extending the current levels of service is an option to consider.
- Consider installing kWh meters for all households to avoid the current situation of the less well-off paying proportionately more for their electricity.
- There is the need to have a proper tariff structure so as to enable the community to operate the project in a sustainable manner. The current situation of the village committee subsidising the costs of electricity is a possible sustainable option as long as the village

[30] The auto-switch enables the gen-set to start with diesel and then switches to coconut oil (after a certain period) then switched back to diesel just before shut-down. This is done to maintain a "clean" fuel system that will avoid coconut oil deposits in it.

continues to lease its land. However, the village committee must also consider whether this is the best use of such funds if the majority of residents have a willingness and ability to pay more for electricity.

Lomaloma, Naqara and Sawana, Vanua Balavu

- There is the possibility of reviving the copra industry at the three villages however major investment is required to consider the coconut resource available in Vanua Balavu and nearby islands; rebuilding the oil mill; and the provision of sea and land transportation – to name a few. Therefore, the option of producing coconut oil by the three villages is not yet viable.
- A practical solution to enable villages access to electricity within the short-term is to provide diesel gen-sets, one for Lomaloma and one for Sawana. Given the location of the villages it is most appropriate to have Naqara Village connected to the Sawana gen-set.
- It is proposed that the current biofuel gen-set be decommissioned and relocated to a site where access to coconut oil does not have a major impact on its price. The lessons learnt since its installation in Vanua Balavu would provide a good guideline to as how it should be operated.

Future Biofuel Initiatives

The findings and lessons learnt from the two biofuel pilot projects have provided thoughts on perhaps how future similar projects should be formulated/developed and implemented.

- Any feasibility study to determine the viability of a biofuel project has to consider an integrated approach whereby all aspects are taken into consideration. An energy analysis of a community without taking into consideration the social, economical, environmental and any associated risks to the operation of the project is an incomplete approach. Rural electrification such as diesel/biofuel gen-sets for instance, has to consider the fuel supply risks. This risk has to be allocated to a party participating in the project.
- The participation of all key stakeholders from the development phase to implementation, monitoring and evaluation is an important feature of any project. For rural energy projects DOE has to work and collaborate with other relevant Ministries such as the Ministry of Agriculture and Ministry of Regional Development.

- Tariff has to be structured to include true costs to enable sustainability of the respective projects.
- It is recommended that the Fiji Department of Energy continue its work in the provision of electricity by means of locally-produced biofuel through the application of a RESCO (Rural Energy Service Company) which is run as a commercial enterprise. The evaluation exercise indicates that it might be feasible to set up a biofuel-based RESCO similar to that established for PV systems.

ANNEX 1

Specification of the Gen-Sets

The project specifications are as follows:

Site:	Sawana, Vanua Balavu
Engine:	DEUTZ modified for coconut oil use
Type:	F6L 413 FW
Power Output	74 kW @ 1500 rpm
	air-cooled – four-stroke cycle, 6 cylinders – standard air intake (not turbo)
Injection:	in line pump
Displacement:	9,572 liters
Alternator:	LEROY-SOMER; Type LSA 44.2 US3 C6/4; #90 kVA continuous, 130 Amp
Micro Coconut-Oil Mill:	Taby Press, Type 70
Input Capacity:	40 to 60 kg/H of copra
Oil Yield Delivery	20 to 30 litres per hour
Power Required	1.5 kW (3 phases electric LEROY SOMER motor)
Electrical Grid	220 V, 50 Hz, 3 phases; supplying 200 households, including schools, churches, hospital, Police Post

Site:	Welagi, Taveuni
Engine:	DEUTZ modified for coconut oil use
Type:	F6L 912W
Power Output	40 kW @ 1500 rpm
Injection:	in line pump
Displacement:	9,572 liters
Alternator:	LEROY-SOMER; Type: LSA 43.2 LSA 43.2 S3 J6/4; 45 kVA continuous
Electrical Grid	Supplying 48 households

ANNEX 2

Terms Of Reference For The Evaluation

TECHNICAL AND ECONOMIC EVALUATION OF DEPARTMENT OF ENERGY
"BIOFUEL PROJECTS AT WELAGI AND LOMALOMA"

1.0 BACKGROUND

1.1. Copra Biofuel Project

The Department of Energy (DOE) has organized two community based copra biofuel projects with the primary aim of producing clean electricity for the communities involved. These are the Vanua Balavu Copra Biofuel Project, installed in April 2000, and the Welagi Copra Biofuel Project installed in July 2001.

The uniqueness of these projects is that, the specially modified biofuel gen-sets are able to use coconut oil to generate electrical power for the homes in the villages. The dual fuel tanks contain diesel oil and coconut oil. The diesel oil is used to start the engine and when the engine is heated, the coconut oil takes over as the primary fuel source to run the engine for the duration of its intended purpose. The switch over from diesel to coconut oil is automatic. Just before switch off, the engine has to be turned off on diesel.

In early 2000, a joint agreement for implementation of Renewable Energy Project was signed by the DOE and the Secretariat of the Pacific Community (SPC). The objective of this agreement was to promote activities of scientific and technical co-operation in favour of Rural Energy Development.

Under the agreement, DOE took all responsibilities to incur local costs of project implementation while SPC provided for the transfer of the new technology (bio-diesel gen-set) for electricity gen-set. This was through CIRAD-AMIS – France that provided the technology. Additional funding was provided by the French Embassy.

1.1.1. Lomaloma Copra Biofuel Project

Location: Sawana, Vanua Balavu; Lau Group.

Brief: This is the first biofuel project site in Fiji. Its was a joint initiative between DOE, SPC – CIRAD and the French Government. PWD (Electrical) carried out electrical works for the project. After socio-cultural and economical feasibility, one 90 kVA generating set was installed in Vanua Balavu to electrify three villages; 198 households and an oil-mill, with a 150/200kg/h copra milled capacity. This electricity generating plant is able to use crude coconut oil as fuel. It is the first in the world to be connected to a grid for domestic use.

The project has been through tough times, especially due to mechanical and electrical problems. As it is, spare parts have been identified and an inventory set-up. Electrical grid lines will be updated in future.

Equipment:

Engine: DEUTZ modified for coconut oil use; Type: F6L 413 FW. Power Output: 74 kW @ 1500 rpm. - air-cooled - four-stroke cycle, 6 cylinders - standard air intake (not turbo). - Injection : in line pump - Displacement : 9,572 liters; # Alternator: LEROY-SOMER; Type LSA 44.2 US3 C6/4; #90 kVA continuous 130 Amp.

Micro Coconut-Oil Mill; Taby Press, Type 70 Input capacity : 40 to 60 kg/H of copra, Oil yield delivery : 20 to 30 litters per hour. Power required : 1.5 kW (3 phases electric LEROY SOMER motor)

Electrical grid, 220V, 50Hz, 3 phases; supplying 200 households, including schools, churches, hospital, Police Post

Date of Service: April 2000 power house was commissioned. MOU signed in February 2002.

Expense: DOE local cost amounted to $120,000, including new grid electrification and workmanship and SPC through the French Government provided for the $150,000 gen-set.

Services Provided: Sawana, Lomaloma, Naqara. Thus a total of 198 households are electrified, including a Hospital, Adi Moape Junior/primary School and other government quarters. Oil is imported from Savusavu while diesel from Suva.

Operation and Management

An agreement was signed in Feb 2002. As part of the MOU, the village is to provide a gen-set operator and manage an Electricity Committee. This committee will handle day to day affairs of the gen-set business. The DOE as its responsibility maintains the gen-set and servicing of the system and spares.

1.1.2. Welagi Copra Biofuel Project

Location: Welagi Village. Welagi is a coastal village located north-west of Taveuni. About 10mins from the Matei Airport to the north and 15mins from the main administrative centre of Somosomo in the south.

Brief: In 1998, after a survey by French scientists with DOE and other country counterparts of the feasibility of Welagi as a possible site for a copra biofuel, it was concluded that the socio-economic pre-conditions favoured the implementation of the biofuel project here. Project implementation began in April 2001 with the Public Works Department (PWD Electrical) contracted to carry out electrical works of the 57 houses that were to be electrified to the underground mini-grid system linked to the newly constructed power house. Each house was fitted with two tube lights and a power point. The powerhouse consists of a work shed, a processing room and the gen-set room. On 20th July 2001 electricity was generated for the first time in the village.

Equipment:

#ENGINE: DEUTZ modified for coconut oil use Type: F6L 912W
Serial number: 8600353 Power Output: 40 kW @ 1500 rpm. #ALTERNATOR: LEROY-SOMER Type: LSA 43.2 LSA 43.2 S3 J6/4 Serial number: 112821/1. 45 KVA continuous

Date of Service: On 7th December 2001, the Welagi Copra Biofuel power plant was officially opened. On 19th July 2001, power was first generated at the power plant.

Cost: DOE local costs of project implementation ($80,000) and SPC through French Government $100,000 for biofuel gen-set.

Service provided: Project implementation began in April 2001 with PWD (Electrical) contracted to carry out electrical works of the 57 houses that were to be electrified to the underground mini-grid system and linked to the newly constructed power house. The house wiring along with grid set up took 8 weeks to complete. Each house was fitted with two tube lights and a power point. The powerhouse consists of a work shed, a processing room and the gen-set room.

Operation and Management

Agreement signed on April 2001 with the village chief Rt Jone. Basically requires the village to provide workmanship for the power house and services to DOE staff upon their inspections to the project. In return, the DOE would provide training and technical support for maintenance of the gen-sets. Monthly fee of $5.00 is collected by the Electricity Committee which pays for people involved in the power house. In future, plans are to extend the lines to new homes and install kWh meters at the homes.

2.0 RESEARCH OBJECTIVE

To carry out an independent evaluation of the existing copra biofuel projects and provide recommendations for future improvements on the sustainability of such rural electrification projects in Fiji.

3.0 SCOPE AND FOCUS

This service involves the preparation of 5 reports to establish the existing condition of the biofuel projects and improvements required to assist in the establishment of a sustained biofuel based program.

4.0 ACTIVITIES

- Perform desktop study on the background documents on the two projects;
- Interview main stakeholders that were involved in the project inception and implementation;
- Carry out field survey into the technical, economical and organisational performance of the projects;
- Interview members of the communities on the socio-economic impacts, labour inputs, income opportunities and local organisational issues;
- Assess the conversion chain from coconut to kWh;
- Assess the monthly fees levied and its suitability for project sustainability;
- Identify opportunities for future DOE interventions and opportunities for ESCO – type electrification using biofuels.

5.0 OUTPUT

Five hard copies and an electronic version of the report that includes amongst other things:

- Existing technical and economic justification for the projects
- Recommendations on further improvements of the existing project setup from a technological and economical perspective.
- Recommendations to DOE to improve the existing services.
- Recommendations for future biofuel rural electrification projects.
- Recommendations on future investments in the existing systems, such as an oil mill or separate organisational setup.

NOTE: a separate assessment will also be undertaken to assess the social impact of the project.

6.0 DURATION

Total 4 weeks of independent work by the team starting in July, 2005, including report drafting/finalisation, presentation and handover.

7.0 BUDGET

Budget for Technical and Social evaluation of Department of Energy Biofuel Projects at Welagi and Lomaloma

	Input [Person-Hour]	Cost [$]
Organisational Evaluation	2 * 16 Desk Research	In kind
Technical Evaluation	2 * 32 Fieldwork	In kind
Economic Evaluation	2 * 20 Desk Research	In kind
Opportunities for ESCO-operation	2 * 16 Fieldwork	In kind
Reporting	60	In kind
Total Hours	228	In kind
Travel		1000
Per diem		1000
Consumables		500
Total		2500
SOPAC Contribution		$1,250
DoE Contribution		$1,250

Note: Hourly budget assumes an even contribution from DoE and SOPAC in time allocation to this evaluation and is seen as an in-kind contribution.

ANNEX 3

Load Calculations

Vanua Balavu

The numbers below are the result of a load survey conducted by DOE in October 2005.

		Lomaloma			Naqara			Sawana	TOTALS		
	Qty	Ratings (W)	Total Ratings (W)	Qty	Total Ratings (W)		Qty	Total Ratings (W)	Qty	Ratings (W)	
Households/customers	42			16			70		128	-	
Fridges	23	1000	23000	3	3000		20	20000	46	46000	
Irons (electrical)	20	1000	20000	6	6000		22	22000	48	48000	
TVs / videos	15	400	6000	5	2000		26	10400	46	18400	
Washing Machines	5	1500	7500	2	3000		21	31500	28	42000	
Water heaters (instantaneous)	5	1000	5000	-			9	9000	14	14000	
Microwaves	1	800	800	-			1	800	2	1600	
Rice cookers	2	1000	2000	-			2	2000	4	4000	
Radio	5	700	3500	-			3	2100	8	5600	
Fan	7	75	525	-			9	675	16	1200	
Computer	1	100	100	-			2	200	3	300	
Mixer	2	100	200	-			1	100	3	300	
Fax	2	100	200	-			1	100	3	300	
Musical Instruments	-	100		3	300				3	300	
Amplifier	-	1000		1	1000				1	1000	
DVD		1000					1	1000	1	1000	
			68825		**15300**			**99875**		**184000**	
Total Rating			68.83		15.30			99.88		184	kW
At 50% Load	0.50		34.41		7.65			49.94		92	kW
At 25% Load	0.25		8.60		1.91			12.48		23	kW
Energy at 50% Load 4 hours /day			137.65		30.6			199.75		368	kWh
Energy at 25% Load 4 hours /day			34.41		7.65			49.94		92	kWh
		kVA @ 50%	43.02		9.56			62.42		115	
		kVA @ 25%	10.75		2.39			15.61		29	

Taveuni

The following calculations are based on the assumption that the number of households (38% of total households connected to the mini-grid) surveyed is representative of the entire village.

		Welagi		
		Qty	Ratings (W)	Total Ratings (W)
Households/customers survey		18		
Fridges		6	1000	6000
Irons (electrical)		10	1000	10000
TVs / videos		12	400	4800
Washing Machines		9	1500	13500
Radio		10	700	7000
DVD		6	1000	6000
				47300
Total Ratings			47.30	kW
Load factor	0.50		23.65	kW
Load factor	0.25		11.83	kW
At 50% Load for 4 hours /day			94.6	kWh
At 25% Load for 4 hours /day			47.30	kWh
kVA @ 50% Load			29.56	kVA
kVA @ 25% Load			14.78	kVA

ANNEX 4

Sensitivity Analysis

Based on income estimates provided by the most recent social survey carried out by Partners in Community Development in January 2006, it was estimated that incomes range from $40 to $200 per week. As a result, the opportunity cost of labour may differ from the calculations in the Report.

Using the social survey income estimates, the opportunity cost of labour can be calculated as:

Scenario 1: The majority of households in Welagi have a weekly income of $120

Based on results from the social survey, it is assumed that average household income from activities such as dalo and kava planting is $120 per week.[31] Thus, the average income from one working day would be approximately $24.

If instead of cutting copra on Mondays for coconut oil production, the twenty workers spent this time on their regular income-generating activities, they could earn $240 as shown below.

Opportunity cost of harvesting copra (half a working day's work) = $12
For twenty workers = $12 x 20 = $240

Also, the time spent by the gen-set technicians producing coconut oil from copra, must be included in opportunity cost of labour calculations:

The capacity of the gen-set = 30 kg per hour
Volume of copra needed to be crushed = 65 kg per day
Labour hours required = 2.17

Therefore, the opportunity cost of labour for two technicians is:

Opportunity cost of technicians producing coconut oil (1/6 of working day) = $24 x 1/6
= $4
For 2 technicians for 7 days $4 x 2 x 7 = $ 56

Thus total opportunity cost of producing copra = $240/week
And total opportunity cost of producing coconut oil = $56/week

Total opportunity cost of labour for copra and coconut oil production = $296 per week

So, in fact, the opportunity cost of producing coconut oil in the village is slightly lower when compared with purchasing diesel (at a cost of $310) or commercially produced coconut oil (at a cost of $331). However, restoring village coconut oil production capabilities in Welagi would require substantial investments in repairing the crusher, tractor, copra dryer and fuel switch on the biofuel gen-set.

Scenario 2: The majority of households in Welagi have a weekly income of $40

Only when it is assumed that the majority of households in Welagi Village live close to the minimum weekly income threshold of $40, does village production of coconut for the biofuel gen-set increase economic welfare[32].

Opportunity cost of harvesting copra (half a working day's work) = $4
For twenty workers = $4 x 20 = $80

[31] The survey found that in Welagi, incomes ranged from $40-$120 per week.
[32] That the majority of households have an income of $40 per week is quite an unlikely situation given current expenditure on energy in terms of fuel for personal gen-sets, and widespread electrical appliance ownership including: TVs, DVD players, washing machines and refrigerators; which are found in many households.

The opportunity cost of labour for two technicians is:

Opportunity cost of technicians producing coconut oil (1/6 of working day)		= $8 x 1/6
		= $1.33
For 2 technicians for 7 days	$1.33 x 2 x 7	= $ 18.62

Total opportunity cost of labour for copra and coconut oil production = *$98.62*

Therefore, in this case, the opportunity cost of labour is quite low, and village production of coconut oil would improve household economic welfare, since it is less expensive than purchasing diesel or commercially-produced coconut oil.

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