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BIO-ENERGY SYSTEMS AT THE COMMUNITY LEVEL IN THE SOUTH PACIFIC: IMPACTS & MONITORING

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Abstract. Read, Sims and Adams (2001) detailed a case study for bio-energy implementation in a notional small Pacific Island and elaborated a theoretical model for assessing and simulating the socio-economic impacts of a particular bio-energy system designed to produce an exportable liquid fuel along with rural electricity supplies. An important conclusion was that there is no silver-bullet 'one size fits all' bio-energy system suited to all situations. Moreover, a system appropriate at one place and time may become obsolete with exogenous technological advance and/or as a community advances down its own development pathway. In order to understand how these issues interact in practice, a selected set of implementation projects is reviewed highlighting scale, capacity, community, technology, governmental policy and the concept of critical mass, as factors that are central to the successful development of the bioenergy sector. Through this evaluation, it is shown that: 1. A significant biomass supply resource base often exists locally in the form of agricultural and forestry residues on which modern bioenergy programmes could be initiated. The use of biomass energy flow charts are an important tool for evaluating the potential of local and national resources. 2. Without an integrated multi-disciplinary, multi-sector and whole-systems approach to the implementation of bioenergy schemes, long term success is likely to remain elusive. 3. There is a requirement at the national level for a coordinated approach with strong policy signals that overcome perverse and practical obstacles.

Keywords: bio-energy, biofuel, biogas, biomass resources, coconut oil, electricity generation, Fiji, flow chart, gasification, Tuvalu, Vanuatu

Introduction

A wide range of demonstration and investment bio-energy projects, using many technologies, have been attempted in various Pacific Island Countries (PICs). Such projects ranged from large to small hydro, biomass-based steam generation, alcohol fuels, coconut oil as a diesel substitute, digesters (biogas), wood and bio-char ("charcoal") stoves, PV, etc. Technology-led projects in the region have yielded disappointing results (see case studies below). Given the real opportunities for cost effective and sustainable energy provision from biomass in the islands of the South Pacific and the complexity of biomass project implementation, it is clear that careful planning is required. The site, temporal and physical heterogeneity and the sheer range of potential biomass energy conversion technologies available today can lead to the appearance of overwhelming complexity. This complexity, in particular due to the great number of "horizontal" interactions, has been recognised as an additional constraint in assessing the feasibility of bioenergy applications. Additionally, modelling of biomass energy systems may have limited value because of the decentralised and diverse nature of biomass. Models tend to be site-specific or examine the biomass sector from either the supply or demand side and therefore provide little insight into critical replicability factors.

In order to understand how these issues interact in practice, a selected set of South-Pacific projects is reviewed highlighting scale, capacity, community, technology, government policy and support and the concept of critical mass, as factors that are central to the successful development of the bioenergy sector. Through this evaluation, it is shown that without an integrated multi-disciplinary, multi-sector and whole-systems approach to the implementation of bioenergy schemes, long term success is likely to remain elusive. The requirement for a coordinated approach with strong and persistent policy signals that overcome perverse and practical obstacles is confirmed at the national level. These issues are highlighted through three case studies reviewed in this paper:

Case Study 1. Fiji.
Case Study 2. Vanuatu.
Case Study 3. Tuvalu.

The non-energy use of the biomass is not evaluated since there is no competition between energy and non-energy uses in the case studies under consideration, but there are often synergies, which are outside the scope of this article, that can further improve the case for bio-energy.

Background

Geographical and physical characteristics (e.g. small catchments, intensity of tropical storms, frequency of cyclones, exposure of low lying land to ocean incursions, etc.), of the PICs, makes these islands highly vulnerable to a range of environmental impacts at rates and intensities above those found elsewhere in the world. Key social factors also need to be evaluated, including geographic isolation, ecological fragility, rapid human population growth, limited land resources, high dependency on marine resources, exposure to extremely damaging natural disasters, low economic diversification, exposure to changes in climate, trade and markets; all of which contribute to increasing vulnerability. Table I summarises the consequence of these social factors in relation to the major environmental challenges and therefore highlights the context within which bioenergy systems must be applied.

For the adoption of bio-energy in the region there are many pressing issues which mitigate against successful and sustainable implementation (see below). However, as will be demonstrated in the Case Studies, there are many opportunities available

TABLE I
Major environmental challenges facing PICS

Category	Main challenges/difficulties
Land	– Rapid population growth and resultant expanding urban areas and decreasing vegetation cover
	– Land and soil degradation
	– Land title/tenure problems
	– Shortages of land
	– Land contamination (e.g. from mining, chemical, waste, sea water)
Forests	– Increased deforestation (e.g. for agriculture and firewood, commercial logging)
	– Lack of clear forestry policy and monitoring, or lack of enforcement
	– Poor human and financial resources
	– Fire hazards
	– Natural disasters (e.g. cyclones, droughts)
Biodiversity	– Extensive coral reefs and high marine diversity
	– Fragile ecosystems
	– Endemic species
	– Loss of diversity caused by human and natural conditions
Fresh water	– Water shortages
	– Increasing salinity of ground water
	– Limited surface water and high evapo-transpirational losses
	– Pollution (e.g. poor sanitation)
Coastal	– Many low-lying land areas
	– Pollution (e.g. waste disposal, sewage, sediments from mining, silting due to deforestation, etc.)
	– Lost of habitats
	– Natural disasters (e.g. coastal erosion, cyclones, etc)
Climatic	– Large potential effect from climate warming (e.g. low-level land areas which could be flooded)
	– High exposure climatic variations (e.g. storms, floods, winds, landslides, droughts)
Cross-cutting issues	– Global warming
	– Sea-level rise
	– Rapid population growth, particularly urban
	– Loss of traditional systems, high expectations amongst the young
	– Class system (e.g. land tenure systems)
	– Poverty (energy poverty & low household income)
	– Gender issues

Source. Rosillo-Calle et al. (2003) and SOPAC (2002).

for successful adoption of sustainable bio-energy systems which could be developed and which, if carefully implemented, would in turn help solve a range of the issues highlighted in Table I.

In assessing the potential of bioenergy at the community level, the tightly coupled issues surrounding energy poverty and the wider adoption of renewable energy technologies in PICs need to be evaluated. Energy poverty issues were comprehensively addressed in the region in a number of reports and the central points are highlighted below (Raratonga Declaration 2002; Rosillo-Calle et al. 2003; Woods et al. 2003):

- Problems posed by isolated and dispersed population centres.
- Problems posed by, often, very small markets without significant economies of scale.
- Lack of access to modern energy services:
  - 70% of the regional population is without access to electricity (SOPAC 2002).
- The existence of a wide range of ecosystems, predominantly influenced by marine systems that make infrastructure development difficult and environmental impacts significant:
  - These ecosystems are generally considered to be highly fragile and vulnerable to climate change and inappropriate exploitation.
- Lack of indigenous petroleum resources and of hydropower potential in most cases. Thus PICs are highly vulnerable to energy supply disruptions and liable to pay considerably over world market rates for their energy supplies. Imported oil is a major drain on foreign exchange resources in all PICs – see Table II.
- Effects on ecosystems posed by environmental damage, habitat loss, increasing pollution rates.
- Lack of modern bioenergy applications due to use of inappropriate technology, poor institutional mechanisms, and problems posed by small and dispersed markets.

TABLE II

Oil markets in six country islands in 2002 (FOB; US$28 per barrel)

Island	Litres (thousand)	US$ (thousand)
Fiji	454,257	79,995
Kiribati	12,583	2,216
Samoa	53,764	9,468
Tonga	40,128	7,066
Tuvalu	2,790	491
Vanuatu	29,369	5,172

Source. Pacific Islands Forum Secretariat (Petroleum Advisory Service).

- Limited scope for market reforms caused by the variation, size and low density of markets.
- Limited human resource capability to respond to these challenges.
- Lack of technical expertise and weak institutional structure to plan, manage and maintain renewable energy programmes.
- The absence of clear policies and plans to guide renewable energy development.
- Lack of successful demonstration projects.
- Lack of understanding of the biomass and other renewable energy resource potentials.
- Lack of confidence in various technologies on the part of policy makers and the general public.
- Lack of local financial commitment and support for renewable energy due largely to economic constraints, including low household and per capita income (Table III).
- Continued reliance on aid-funded projects.
- Low policy priority for energy efficiency: as a result the many opportunities for energy savings in most economic activities and in the domestic sector are often ignored.
- General neglect of the role of women in energy use. Women are key users of energy services and should be central to energy policy development & implementation.

Most, if not all of the issues listed above will impact on the planning, implementation and long term success of bioenergy projects, particularly on resource availability. As the basis of any successful bioenergy scheme is ensuring the reliable, consistent and affordable supply of biomass feedstock, national and/or local monitoring and analysis of the availability and use of the biomass resource is crucial. Planning and implementation tools necessary to understand the resource dynamics for bioenergy are of limited availability and few have been tested through practical use in project development and monitoring.

TABLE III
National economic overviews for 6 PICs

Country/ Territory	Year	GDP (M$)	GDP ($/capita)	Agriculture (%)	Industry (%)	Services (%)
Fiji	2000	1,605	1,972	16	30	54
Kiribati	2000	42	466	14	7	79
Samoa	2000	237	1,400	15	24	61
Tonga	2000	143	1,425	32	10	58
Tuvalu	1998	138	1,385	n/a	n/a	n/a
Vanuatu	1999	266	1,212	20	9	71

Note. Dollars are all US; *Source*. SOPAC (2002).

The biomass flow charts constructed for these case studies aim to put into perspective the present role of biomass systems in meeting biomass requirements, paying particular attention to the energy sector. The flow-chart methodology can also be used to monitor and optimise biomass supply and use once bioenergy systems are developed. Given careful planning at regional, national and local levels, sustainable bioenergy, as both modernised and traditional fuels, could become increasingly important in PICs' energy future. Biomass energy flow-charts have been developed for each of the case study countries in order to highlight supply-side issues as discussed below.

Case Studies

Three national case studies have been carried out which are summarised in order to highlight the critical issues defining the potential for bioenergy in the South Pacific at national and local 'community' levels. For each case study a specific community bioenergy project is evaluated using biomass energy flow charts to highlight the relevance of the selected case study to overall energy sector at the national level.

The biomass energy flow-charts presented for each case study evaluate the three main areas of biomass production viz; agriculture, forestry and livestock as potential suppliers of biomass for energy. The flow-charts provide estimates of the total biomass energy theoretically available, its production, present utilisation levels, and by deduction the potential availability of biomass residues from agriculture and forestry. The flow of biomass in all its forms is followed from its production at source and harvest through to its end-use where it is categorised into a product or 'end-use' group e.g. food, fuel, residues, etc. Existing work on vegetation classes and productivity could be used to establish and monitor the sustainability of bioenergy use at present and identify where opportunities exist for future bio-energy use as population, and demand for energy services, continue to rise.

Fiji case study

Fiji comprises over 300 island archipelagos (about 150 islands are inhabited), spread over a land mass of 18,272 km^2, with an Exclusive Economic Zone (EEZ) covering 1.6 million km^2. The largest island is Viti Levu, which covers 10,390 km^2, followed by Vanua Levu with 5538 km^2. Together they account for 87 percent of the land area and 90 percent of the population. The larger islands, especially Viti Levu, Vanua Levu, Taveuni, Kadavu and the Lomaiviti group, are quite mountainous and of volcanic origin. The southeast or windward sides of the islands are covered in dense forests. The wet eastern sides support tropical rainforest while the drier west supports a higher proportion of grass and savanna ecosystems.

Of the 1,827,000 ha total land area, 815,000 ha (45%) are forests, approximately 10% is arable [of which 4% is under permanent crops??], 10% is under permanent pastures, and 11% under other land-use categories. While over 60% of the total land area is suited to some form of agricultural activity, only about 16% is suitable for sustained arable farming. A major constraint to sustainable land use in Fiji is the uncertain-tenure which engenders a very short-term farming perspective and hinders sustainable land-use practices. Furthermore, the existing legislation which might allow some protection of tenure is not properly enforced so tenants [have no incentive?] to practice good husbandry and soil degradation continues (Rosillo-Calle et al. 2003; Woods et al. 2003).

National Level

Terrestrial above ground biomass production and utilisation in Fiji was analysed for the years 2000–2003 using FAOSTAT-derived data and the resulting biomass flow chart is provided in Figure 1. For the years 2000–2003, the total annual average biomass energy production was estimated at 91 PJ (75% from agricultural crop production, 17% from forestry, and 8% from livestock). Of the 78 PJ produced from agricultural and forestry operations, 14 PJ of biomass was harvested and burnt (717,816 t carbon equivalent), 22PJ was harvested for food, 42 PJ was unutilised for crop and forestry residues, 6 PJ was harvested crop residues for use directly as fuel. Livestock produced a further 7 PJ, of which only 0.1 PJ was harvested and used for fuel.

Only 37 PJ (43%) of the 91 PJ of biomass energy produced was actually utilised. 43PJ remained as unused residues and dung (from agricultural production and livestock), and a further 6 PJ was unused forestry residues. The total amount of biomass (fuelwood, residues and dung) used directly to provide energy was estimated at 14 PJ (16.6 GJ per capita per year or 1.2 t fuelwood equivalent). Therefore, in theory, over

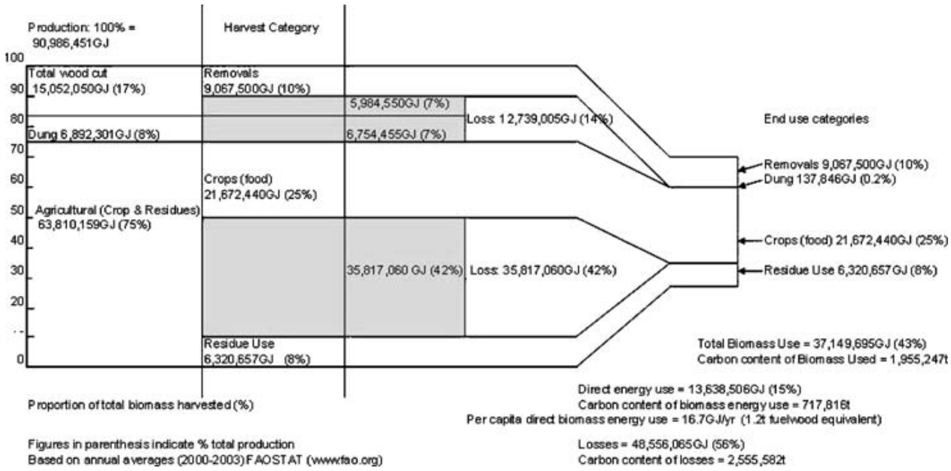

Figure 1. Biomass energy flow chart for Fiji.

TABLE IV
Use and availability of biomass resources in Fiji (PJ)

Sector	Gross resource	Available resource for bioenergy	Existing biomass resource use	Net available for bioenergy systems
Forestry	15.0	5.98	Very little	5
Agriculture	63.81	42.14	6.32	35
Livestock (Dung)	6.89	6.75	Very little	6
Total	85.7	54.9	6.5	48.4

Note. Derived from Figure 1.

7 times more biomass energy is available in residues than is currently being used for energy (Table IV) or roughly five times 2002 oil imports.

On a national level, within Fiji's agricultural sector, the most promising crop residues for biomass energy supply are sugarcane bagasse (plus tops and leaves) and coconuts, although there are other crops that could hold some promise in the future. Sugarcane residues remain in the short term the most promising option for use in cogeneration, which is currently being promoted in the country. The use of sugar cane for energy (including transport fuels, electricity & heat) are not considered further within this paper as it lies outside the direct remit of the community-level. The potential for the exploitation of the human and animal waste resource for biogas production in Fiji and in the rest of the South Pacific is high primarily because of the linkage between safe and environmentally responsible disposal of these wastes and the benefits to the local community that can be provided by coupling safe disposal with the provision of modern energy services into homes and schools.

Local level: coconut oil for electricity generation in Fiji[1]

Two small scale community-based projects were funded by the French government and designed and set up by the CIRAD Energy Unit, France and SPC (The Secretariat for the Pacific Community) Rural Energy Development Programme working with the Fiji Department of Energy. The two demonstration projects were established on the rural outer islands of Taveuni and Vanubalavu in Fiji in 2000/01 to demonstrate the viability and benefits of small scale coconut oil production and use as a diesel substitute for electricity generation in remote areas.

At the project's outset, benefits offered by decentralised power production in remote rural areas using locally produced coconut oil were stated as being:

> 'To provide an opportunity for local development through strengthening existing activities and developing new ones (processing, development and storage of agricultural and fishing products, wood processing and rural handicrafts), employment and income generation, apprenticeship and training possibilities,

a satisfactory response to local needs and the preservation of the ecosystem through coconut management, may help restrict urban drift and dependence on imported products' (Courty et al. 2000; Courty 2000).

The project was designed in close collaboration between CIRAD, SPC and a Fiji Government Working Group. The feasibility study and project design was carried out by a team of French consultants who were accompanied by Fijian counterparts and included short participatory studies (lasting a few days) in the chosen sites into the resource, 'social-cultural' and economic feasibility of the project and its costs and benefits (Courty et al. 2000).

Expected project outputs

"The establishment of a copra oil-powered generator and small-scale oil extraction unit, at village level, is expected to produce:

- Rural electrification, higher energy independence and lower real energy costs.
- Greater local added value and optimal returns on crops and increased diversification.
- Renewal of interest in coconut products and rehabilitation of coconut groves.
- Lower GHG emissions than diesel electrification.
- Improved local and national balance of trade.
- Direct and induced domestic informal sector job creation and creation of local industry and income generating opportunities.
- An alleviation of the problem of urban drift.
- The establishment of a benchmark for similar projects in the region" (Courty 2000).

Project feasibility analysis

(1) Technical and resource feasibility:
The projects were deemed technically viable and the assessment revealed that there was more than sufficient coconut resource to supply the projects.

(2) Economic feasibility:
To be economically sustainable, it was considered that the project would have to deliver electricity from coconut oil at a real price (a price excluding subsidies) that was lower than from diesel. Moreover, the local price paid for the electricity should be its real cost. It was suggested that the economic viability of coconut oil as a locally produced fuel substitute was dependent on the cost of delivering diesel fuel to the location concerned. The real cost of fuel (without subsidies) varies from US$0.60 to US$2.50/l and 'it is obvious that wherever the cost of diesel is high, the price paid for copra to producers will be correspondingly low' (Courty 1998), as the price of rural labour will be lowest in the most remote locations.

According to the project researchers, the price for copra (excluding any subsidies) at that time (August 2000) was US$155/tonne in Suva (the capital of Fiji) and US$115/tonne in Vanubalavu. The price of diesel in Vanubalavu was US$0.43 per litre. The researchers estimated that they could pay the producers 60% more than the market price (US$183/tonne or, Fj$380/tonne). When the profit from the sale of the copra cake by-product for animal feed, the higher cost of the modified generators and the labour payments for running the mill and the power house were included, the real cost of the electricity from coconut oil was calculated to be US$0.25/kWh. This compared to a cost of US$0.43/kWh for diesel electricity. Furthermore, 68% of the price of coconut oil generated electricity would be re-cycled into the village economy compared to just 5% of the diesel electricity revenue (Courty 2000).

(3) Benefits to the village (Vanubalavu):
   - 3 tonnes a week of copra to be purchased from the villagers, worth some US$15 000 to 20 000 a year, which would go into the local economy.
   - 3 to 4 full time jobs created in oil production, copra cake production and sale and in running the power house.
   - Another 8 to 10 jobs from the revitalisation of the copra mill.
   - Environmental and local ecological benefits.

The project appeared to be cost competitive at a price for copra that would be attractive to the producers, economically sustainable, and socially and environmentally beneficial.

Project implementation

Two sites were chosen for the Fiji demonstration projects. One generator was installed on the Island of Vanubalavu in a village called Lomaloma. The other generator was installed on the island of Taveuni in the village of Welagi. In both projects the Fiji Department of Energy and the Public Works Department funded and built the local grid which the generator was to supply. The villages contributed labour.

(1) Lomaloma copra biofuel project, Vanubalavu:
Lomaloma is the administrative centre of the island of Vanubalavu. The project was to supply power to some 200 consumers in three villages, a hospital and a post office. It was assumed that a local coconut oil mill could supply oil to the project. A 90 kVA generator was installed in April 2000. The project was to be run and overseen by an electrical committee formed from the three villages.

(2) Welagi copra biofuel project, Taveuni:
In Welagi, a 45 kVA generator was installed in July 2001 to serve a village of 58 households. It was also managed by a village committee with the labour for the collection of coconuts being organised by the village. Village youth collected coconuts for the project as part of their labour service to the *matagali* (clan). A different *matagali* was responsible for supplying coconuts each day of the week.

For both projects, the generators were manufactured in France and had modified fuel systems. They had twin fuel tanks (one for coconut oil and one for diesel) so that they could start and stop on diesel. A heating system heated the coconut oil and when it reached the right temperature an automatic switch changed the fuel supply from diesel to coconut oil. In both projects a small coconut oil mill was installed in the power house to produce the oil for the machines. It was also intended that a power house operator and assistant would be trained and paid to maintain and run the generators and coconut oil mills. A meter reader would be employed to read individual meters and bill consumers (FDoE 2003; Matakiviti and Gani 2003).

The situation 3 years after implementation (August 2004)

Initially, the Fiji demonstration projects were officially heralded as a success. It was reported that they had ‘run trouble free since implementation’ (FDoE 2003). However, both generators are now running on diesel-only and not coconut oil and one of the generators has been out of action for some time in need of spares and repairs. The reason they no longer run on coconut oil is not technical – there were no inherent problems with using coconut oil as a fuel and the generators worked well. The problems have been to do with the design and implementation of the project and the social, political and economic problems with running them. These factors are briefly evaluated below.

Lomulomu

A major factor in the choice of Lomulomu as a site for one of the projects was the availability of a local coconut oil mill. The owner of the mill (who was also the local chief) was keen to have the project located in Lomulomu and the consultants assumed the project could use oil from the mill. However, the mill was in a very poor state of repair and they had not consulted with the owner on whether he would be willing to supply oil to the project. There were a number of barrels of coconut oil that were ‘lying around’ the mill and these were used up. However, no further oil was supplied from the mill, at the time the project was implemented it was not made clear that the mill was actually operational. When the old barrels of oil had been used up, the electrical committee bought in coconut oil from the commercial mill at Savusavu (on another island). This turned out to be more expensive than imported diesel but they did it because they had not been told that the generators could be run on diesel alone. When the FDoE told the committee that the generators would work on diesel-only they reverted to importing diesel to run the generator.

Welagi

The small coconut oil mills and filtering machinery that had been supplied by CIRAD for both projects could not produce enough oil for the consumption needs of the generators. The machinery from the Lomulomu project, therefore, was moved to Welagi. In Welagi there were problems supplying enough coconuts. Taveuni had been hit by a cyclone in 2003 which seriously affected the coconut crop. More importantly, though, there were political problems in the village which led to a lack of cooperation between the *matagali* who were supposed to supply coconuts to the project. The Welagi project ended up buying coconut oil from a local plantation. The Welagi generator has been out of action since February 2003 in need of a new starter motor, battery and solenoid. The solenoid needed replacing as it had become corroded from water leaking in through the roof of the power house. It is anticipated that when it is fixed it will be run on diesel-only.

Problems experienced with both projects

For both projects local people were trained to maintain the generators and mills. In the original project design they were supposed to be paid but the local electrical committees decided that they should do the work as part of their village service and in return for living in the house of the chief. The people that were originally trained when the project was set up used the qualification gained to move away and find paid work elsewhere. In both projects there have been communication problems between the committee and the FDoE. The generators are under the supervision of the FDoE who are responsible for supplying engineers and spare parts. It is very expensive for an FDoE engineer to visit the islands and this, coupled with the engine logs not being maintained, has meant that the engines have not been serviced properly. Furthermore, the generators are a different make from any other generators used in Fiji. As a result, the FDoE has had difficulty sourcing spare parts and only has a couple of engineers who are experienced in working on them.

Although the projects were designed to be economically sustainable, this has not been the case. Instead of electricity charges being based on the economics laid out in the project design, the electric committee decided on a set charge of Fj$5/month per household (about US$2). This was not enough to sustain the project. Furthermore, there have been problems with collecting these payments. In both villages meters have now been installed.

Analysis

The problems experienced by the Fiji demonstration projects are rooted in a number of causes. The first is that there is a significant disjunction between the way the project looked ‘on paper’ and the way it turned out in reality. This was caused partly by shortfalls in the feasibility study process (such as the problems with the operation of Lomulomu mill), perhaps caused by an element of over optimism and a desire to see a demonstration project established. It is also evident that, although there were local people and institutions involved in the process, they were not sufficiently involved in the final process of writing the project proposal.

Insufficient involvement of local stakeholders in the design/sustainable implementation of such projects is a common and fundamental error. Firstly, the need for and capacity to purchase, energy services within the local communities should have been assessed as part of the project planning process. Appropriate technology (i.e. type of generator selected), should then have been based on that need and on the resources available – including local skills and the ability of the local community/FDoE to repair and source parts for the generators as well as the coconut resource available and the ability to process into oil for the generator. “Technology-led” projects should be implemented as demonstration and not implementation projects and this has contributed to the failure of the two coconut generation schemes.

Additionally, consultation and commitment should be carried out at a grass-roots, end-user level – and not just on the basis of consulting community leaders. No women’s groups or women’s representatives appear to have been included in the consultation process which, since women are at the centre of energy use, is a fundamental error in the planning process.

The village political structures in Fiji are very strong and tend to be male dominated. The way projects end up running is more often a result of local decision making than what was intended in the project design. This can be due to a lack of community commitment to the planners decisions (such as charging for services, payment for labour, commitment to supply coconut oil) laid out in the project design when the community is not consulted on these issues. For Lomulomu and Welagi, it would may have been more fruitful if the project designers had included the local communities & political powers from an earlier stage – they would then have realised that there would be problems with elements of the project design at the implementation phase. Additionally, to ensure sustainability of the project, local communities should have been involved from the outset in target setting and monitoring via community monitoring & steering committee.

However, it must be remembered that these were trial projects and the first-of-a-kind in the Pacific. Lessons have been learnt from them and the FDoE is still very keen on the concept of coconut oil for rural electrification. A major short-fall of the projects was the lack of sufficient local consultation and/or acknowledgment of local advice (both with the Fijian authorities and with the communities themselves) by the foreign consultants who played the major role in designing the projects. The lack of community consultation in the planning process meant that the communities had little “sense of ownership” of the projects and were therefore uninterested in the projects success. Community enthusiasm is more likely to be engaged if the communities themselves are involved in planning, setting targets, and monitoring. There is optimism that similar projects could be more successful if designed and implemented in a more ‘Fijian way.’

Lessons learned

The experience of the Fiji projects demonstrates the importance of local social and political complexities to project success or failure. The project designers acknowledged that such complexities were important but in reality did not give them sufficient analysis and consideration in the project design and implementation. It is also evident that the social benefits that it was assumed would arise from the project did not materialise as expected – partly due to lack of community involvement at the planning stage leading to lack of community commitment to labour & service charges laid out by project planners. Project design and feasibility analysis needs to be empathetic to the local cultural and political context and actively involve and incorporate the inputs of local people.

The development process itself, and the way projects are designed and implemented, should be subject to critical analysis. It is evident that in this case, it was the project developers' interests in establishing a demonstration project that was the primary motivation rather than an assessment of community needs and resources – this may have caused some of the evidence that would have questioned the benefit and feasibility of the project to be overlooked.

The case study serves as an example of the way social and political complexities can affect project benefits and feasibility that look practical "on paper" by offering sustainable rural development and a solution to expensive diesel imports. The projects now demonstrate the importance of consideration and proper analysis of various issues surrounding rural bio-energy projects.

Local Level: Digester for biogas production in Fiji

Digesters maintain suitable conditions for bacteria to digest the biologically-active component of the manure, resulting in the production and capture of biogas which is 60–80% methane and therefore highly combustible.

As can be seen from Table IV (above), there is a large theoretical potential for energy production from dung in Fiji totalling approximately 7 PJ, equivalent to 5 million t fuelwood. However, the most promising resources for biogas production come from pigs and fowl, as dung from these animals are more easily collectable than from other livestock as a result of the farming practices in Fiji. Resources theoretically available from pigs alone total approximately 0.5 PJ (equivalent to 31 715 t of fuelwood, approximately 44% of Fiji's current domestic fuelwood use).

This demonstration project centres on Colo-i-Suva Pig Farm which has approximately 300 pigs. The housing for the 75 to 100 pigs was designed so that waste could be flushed through a drainage system into fixed-dome biogas digester of the type commonly found in China. The digester is capable of producing $16m^3$ of biogas per day at standard temperature and pressure (STP).

Expected project outputs

(Source: Matakiviti and Kumar 2003).

- Biogas as a fuel to substitute for, LPG, and diesel for electricity production – providing energy self-sufficiency for the farm,
- provide a residue organic waste which, after anaerobic digestion, has superior nutrient qualities over the usual organic fertilizer – manure,
- waste disposal system – prevent potential sources of environmental contamination and the spread of pathogens,
- support small-scale industries – electric power for rural-based industry,

- income generating opportunities,
- improve quality of life –particularly for women,
- reduce methane, a powerful greenhouse gas, emissions up to 70%.

Project feasibility analysis

(1) Technical and resource feasibility:
The project was deemed technically viable and the assessment revealed that there was a more than sufficient dung resource to supply the digester.

(2) Economic feasibility:
Costs associated with an 8 m^3 digester (the Colo-i-Suva farm digester was 20 m^3):

(a) Appliance

	Cost range US$	
Biogas appliances	32.26	51.19
GI pipe & fittings	42.75	67.83
Construction	60.12	95.39
Guarantee charge	8.02	12.72
Promotion fee	6.68	10.60
Sub total	149.83	237.73

(b) Construction materials & labour costs

	Cost range US$	
Brick or stone	68.14	108.11
Sand	16.03	25.44
Gravel	6.41	10.17
Labour	24.05	38.16
Rod – 8 mm	4.88	7.74
Cement	76.95	122.10
Sub total	196.46	311.71
Total build cost = $346.29 to $549.44		

Biogas electricity generation equipment would be expected to cost a further $600 to $800, and drainage for pig pens $600.

Assumptions:

The life of a biogas plant is assumed to be 25 years.
The cost of fuelwood in Fiji is assumed to be $0.03 kg^{-1}.
Maintenance costs of the digester are between $5.50 and $8.50 per year.

Annual Savings = \$137.34:

Fuel wood (7 kg per day @ 0.03 per kg) = \$76.65
Kerosene/LPG = \$18.00
Fertilizer (slurry) = \$42.69

Annual Costs = \$42.46:

Maintenance = \$8.50
Labour = \$18.96
Other costs = \$15.00

Pay back time = 3.6 to 5.8 years (this figure assumes no subsidies).

(3) Benefits to the farmer
A biogas stove was fuelled by the digester and this provided for all the family's cooking needs. Slurry from the digester was used to fertilise crops.
A significant reduction in odour nuisance from the pig housing was experienced. Keeping the pig-pens clean was less labour intensive.

Project implementation
The 20 m^3 digester could handle about 250 kg of manure per day and was easily capable of dealing with waste from about 100 pigs. The digester produced around 16 m^3 biogas per day. Despite a few teething problems, the digester ran relatively problem free for over 4 years (Matakiviti and Kumar 2003).

The situation 5 years after implementation (May 2003)
The slurry pipes from the pig pens were broken as a result of being used as a walk-way bridging a land drain. Because of the cost involved in their replacement, the farmer decided to decommission the unit after 4 years relatively trouble free running. His plan was to move the pig housing away from the farmhouse, increase the number of pigs at his farm, site another digester close to the new pig-pens and use the biogas to generate electricity and supply a domestic cooking stove. The farmer was very positive about the technology and was willing to fund the new digester & generator.

Problems experienced with the project
Occasionally, after periods of severe rainfall, the digester filled with too much water & had to be drained. The farmer did not service the pipes running from the pig-pens to the digester so they occasionally became blocked.

It was initially envisaged that a diesel electricity generation unit would be purchased by the farmer to provide electricity for the farmhouse and agricultural purposes. However, the farmer never got round to purchasing & installing the generation unit. This meant that the digester produced more biogas than was required for household cooking needs (approx 2 m^3 per day – utilizing the dung of only 10 pigs) and the farmer had to regularly vent biogas from the digester.

Analysis & lessons learned

Problems such as rain-water flooding of the digester can be easily avoided by correct site design when the digester is built; other technical problems with the project arose because of improper maintenance.

Although need for energy services, appropriate technology and resource availability had been assessed correctly, digester capacity was underutilized. This project successfully demonstrated farm-scale biogas production in Fiji. However, project establishment only covered the cost of the digester and the farmer was unable/unwilling to fund the electricity generating equipment which would have utilized the digester to its full potential. For this type of project there is an important role for innovative financing to enable consumers to spread the high initial cost of energy conversion technology over the life of the equipment (see cost analysis above). This is particularly true for poor farmers running smaller digesters who may have little to offer as collateral and who are unfamiliar with formal credit systems.

- Disadvantages specific to Fiji are that cattle (responsible for 4PJ theoretical potential (8 times that of pigs) are grazed over extensive areas which makes resource collection difficult. Dung is also seen as a low status, low value fuel which is only resorted to when other fuel sources are unavailable. Awareness of compostable materials as a fuel source and the health linkages needs to be increased in Fiji.

VANUATU CASE STUDY

Located at the eastern Melanesian archipelago, Vanuatu is made up of more than 80 islands (of which 70 are uninhabited), some large e.g. Espiritu Santo (3900 km^2), Malakula (2000 km^2), Erromango (1000 km^2), Efate (900 km^2) and Ambrym (665 km^2). Anatom (150 km^2) is the southernmost island in the group; and many small atolls. Around 80 percent of Vanuatu's population still lives in rural villages, where subsistence agriculture, based around shifting cultivation, is the principal means of livelihood for the majority of the population (SOPAC, 2002; Rosillo-Calle et al. 2003). Land distribution is shown in Table V.

The islands of Vanuatu generally consist of a narrow coastal plain rising through broken foothills to a steep mountainous interior.

TABLE V

Land area and distribution in Vanuatu (2000)

Total land area	1,219,440 (ha)
Total forest cover	447,000 (ha)
Percentage of land area covered by forest	36.7 %
Other wooded land	39.3 %
Other land types	24.4 %

Source. FAOSTAT.

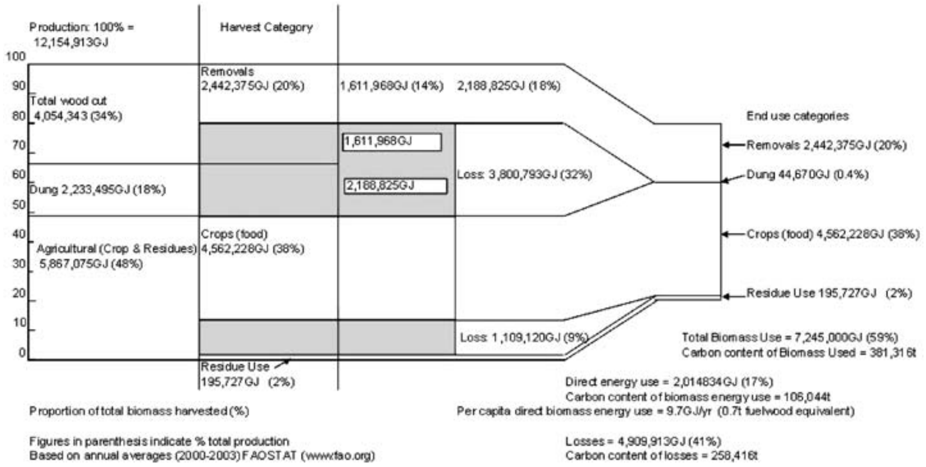

Figure 2. Biomass energy flow-chart for Vanuatu.

The total land mass of Vanuatu is estimated at 1.219 Mha of which 41% is potentially cultivable. The most important crops in Vanuatu are coconut (the backbone of the rural economy), cocoa, cattle, Kava, and to a less extent, garden plots, coffee, etc.

National level

Terrestrial above ground biomass production and utilisation in Vanuatu was analysed for the years 2000–2003 using FAOSTAT derived data (Figure 2; Table VIa–c). For these years, the total annual production of biomass energy was estimated to average 12 PJ (48% from agricultural crop production, 34% from forestry, and 18% from livestock). Of the 10 PJ produced from agricultural and forestry operations, 1.8 PJ of biomass was harvested and burnt (106,044 t carbon equivalent), 4.5 PJ was harvested for food, 3 PJ was unutilised crop and forestry residues, 0.2 PJ was harvested crop residues for use directly as fuel. Livestock produced a further 2 PJ,

TABLE VI

Use and availability of biomass resources in Vanuatu (PJ)

Sector	Gross resource	Available resource for bioenergy	Existing biomass resource use	Net available for bioenergy systems
Forestry	4.05	1.61	Very little	1.6
Agriculture	5.87	1.11	Very little	1.1
Livestock (Dung)	2.23	2.19	Very little	2.1
Total	12.15	4.91	–	4.8

Note. Derived from Figure 2.

of which only 0.04 PJ was harvested and used for fuel. Only 7 PJ (59%) of the 12 PJ of biomass energy produced was actually utilised. 3 PJ remained as unused residues and dung (from agricultural production and livestock), and a further 2 PJ was unused forestry residues. The total amount of biomass (fuelwood, residues and dung) used directly to provide energy was estimated at 2 PJ (9.7 GJ per capita per year or 0.7 t fuelwood equivalent).

For Vanuatu coconuts are the mainstay of economy and have been since the turn of the 19th century. The export of copra is the main foreign exchange earner and provides basic income for the majority of the rural population.

Considerable efforts have gone to improve the coconut industry over the last two decades since this industry has been, and will continue, to be the backbone of the rural economy. For example, about 70% of the rural households own coconut trees (Table VII).

However, the coconut industry in Vanuatu faces serious challenges, including:

- High transportation costs among the islands, due to long distances to markets.
- Small markets due to the small population which is scattered over a large geographic area.
- Coconut is produced by a very large number of smallholders.
- Little investment occurs in coconut production.

Beef cattle farming has been a major success in Vanuatu, achieving self sufficiency and increasing export revenue (Table VIII). This industry might offer a good opportunity for biogas production.

Local level: biomass gasification in Vanuatu

Gasification is the conversion of a solid or liquid feedstock into a gas by partial oxidation under the application of heat. Partial oxidation is achieved by restricting the supply of oxidant – which is normally air. For organic-based feedstocks the resultant gas is typically a mixture of carbon monoxide, carbon dioxide, hydrogen, methane, water, nitrogen and smaller amounts of hydrocarbons. The gas has a

TABLE VII
Coconut and the rural household in Vanuatu, years 1983 and 1993

	1983	1993
Average area smallholding coconut per rural households	3.4 ha	–
Percentage area of trees too young to produce coconuts	11%	24%
Percentage with trees bearing coconuts	78%	76%
Percentage area with trees too old to produce coconuts	11%	n/a
Average annual planting rate (ha)	800 (ha)	2,763(ha)
Average annual planting rate per household	0.04 (ha)	0.58 (ha)
Average consumption per household/day (human consumption)	6 nuts	6 nuts
Average consumption per household/day (animal use)	9 nuts	3 nuts

Source. Anon (1994).

TABLE VIII
The cattle sector in Vanuatu (1983 and 1993)

	1983	1993
No.of smallholders owing cattle	5,700 (27%)	9,420 (43%)
Total no. of cattle in smallholder sector	31,918	82,140
Average no. of cattle per house holding	14 (44% of total)	9 (57% of total)

Source. Anon (1994).

relatively low calorific value (CV), about 4–10 MJ/Nm (the CV of natural gas is about 39 MJ/Nm). This gas, sometimes called producer gas, can be used as a fuel in boilers, internal combustion engines or gas turbines.

Gas turbines can be fuelled by gas produced from biomass converted by thermochemical decomposition in an atmosphere that has a restricted supply of air. Gas turbines have lower unit capital costs than steam turbines, and can be considerably more efficient. In the simplest open-cycle gas turbine the hot exhaust of the turbine is discharged directly to the atmosphere. Alternatively, it can be used to produce steam in a heat recovery steam generator. The steam can then be used for heating in a cogeneration system. In addition to utilisation of biomass fuels in relatively small power plants designed only for these feedstocks, biomass can also be co-utilised with fossil fuels in large scale power plants.

This case study centres on the 'failed' Onesua School Gasifier project (50 kW_e; Vanuatu). This project was initially set up to demonstrate biomass gasification as a viable technology along with 2 other identical systems in Vanuatu.

Project outputs
Technology demonstration.
Reliable electricity supply of 25 kW_e to Onesua School.
Job creation.
Utilise "free" GHG neutral biomass (tree) resource.

Project feasibility analysis:
1/Technical and resource feasibility:

The project was deemed technically & financially viable and assessment revealed that there was more than sufficient fuel available to supply the gasifier in the form of woody biomass. Installation of the unit was paid for by a grant.

Project implementation
This 50 kW_e downdraft BTG [is this a firm or a technology – if the latter please spell out] gasifier was commissioned in 1986 and ran until 1994. In this time it gained 8500 operating hours and averaged 10 to 11 kW_e output. The engine was a 6l Ford block converted by 'PowerTorque', a British company who mainly convert engines to work on CNG for emergency use. The main modification of the engine

was the complete removal of the diesel supply system and its replacement with a gas supply system. The injectors were replaced with spark plugs and the compression ratio had to be lowered by machining the head and a distributor was attached. Gas clean-up was via 2 cyclones and baffle filter (spark arrester) and then fibreglass bag filters to remove all particles down to 1 micron. The bag filters were followed by a forced draft tube cooler to cool the gas to ambient air temperature. The ash bin needed emptying every day.

The energy content of the gas produced was 6 MJ/Nm^3 and contained approximately 1% methane, 20% CO, 15% H_2, 14% CO_2 and 50% N_2. The gasifier had an effective 4:1 turndown ratio although it was only rated at 3:1.

At the time of its installation, the BTG gasification technology was at the research stage and there were many failed examples of similar projects. However, Rob Wilkinson, the physics teacher at the school had the practical skills and enthusiasm to make the technology work. A dedicated feed system was designed and built and experiments with fuel type and supply were undertaken. Wood billets of *Leucaena leucocephala,* a fast growing nitrogen fixing tree species found in abundance on the school grounds, were found to be the most suitable available resource for the job. Fuelwood for the gasifier was cut by school pupils during their lunch break.

The system then ran well for several years and a school pupil was trained as a technician. The gasifier was designed by BTG (Hub Stassen) and had a maximum operating capacity of 50 kWe (i.e. twice the max potential required by the school).

The situation 17 years after implementation (May 2003)

In 2001, RENERELTECH had a new agreement with the school that it would run the gasifier and sell the school electricity at 2 VT/kWh cheaper than the direct diesel electricity production costs and not more than VT35/kWh. From 2000–2002 US$120,000 was spent on renovation the gasifier and engine (which had to be sent to NZ for an overhaul). However, during this time the Australian High Commission required a “reliable” electricity source for the AusAid office adjacent to the school and donated a Perkins 4 cyl 60 KVA diesel electricity generator to the school but at the same time the High Commission stipulated that the gasifier could no longer be used to generate electricity. Therefore, the gasifier was decommissioned, even though it had been reliable & economic in the past! The new generator was oversized for the job & broke down within 2 months of installation – the school has now returned to producing its electricity supply with an old Lister diesel generator.

However, recently, VAST (Vanuatu Sea Transport), a private enterprise that produces 4000 litres of coconut oil per week as a diesel substitute now supplies the fuel for the 2 diesel generators which consume 1000 litres of coconut oil per month. The generators run only on coconut oil (from a heated tank) and the only problem encountered is that oil filters have to be changed twice as regularly as they do when running on diesel (Parmenter 2003).

Problems experienced with the project

A wood moisture content of less than 25% was recommended for use in the gasification system, however, due to location and climate it was difficult to maintain low moisture contents and the average moisture content of the wood used was around 30% and up to 36%. Above this moisture content bridging starts to occur in the gasifier throat.

Due to the experimental and pioneering nature of this project there were several glitches with the technology:

- There were problems about 2 years into the project as the throat of the gasifier corroded as it wasn't made from the correct materials for coping with the higher moisture content of the feed-biomass. A New Zealand company cast some new throats using vanadium steel and corrosion was no longer a problem with new throats lasting about 3000 operating hours before needing replacement.
- Another weakness was the Heinzman Electronic governor which 'struggled' under lower loads i.e. less than 8 kWe, but the frequency drift was only 1 Hz which was within the British standards of 2 Hz. When run at less than 5 kWe load the gasifier did suffer from tar production problems but only produced 1–2 mg tar/Nm^3 under normal operating conditions.
- The trained technician obtained a scholarship and left without training a replacement technician properly. When problems occurred the new technician dismantled the gasifier and damaged it in the process. This meant that an old Lister diesel electricity generator had to be re-commissioned.

Analysis & Lessons learned

The project successfully demonstrated that biomass gasification technology could provided a reliable and cheap source of electricity to the school. Although the project was technology rather than demand led, it was a site specific design, economic to run, and GHG neutral. The project succeeded initially due to the skill and enthusiasm of a few committed individuals. The project was prevented from succeeding over a longer term due to a lack of technical support and barriers imposed by external agencies.

TUVALU CASE STUDY

Tuvalu's total land mass consists of just 26 km^2, spread over 750,000 km^2 of ocean across its exclusive economic zone. It consists of nine island groups with Funafuti containing the capital and Vaitupu the main educational and agricultural centres. The nation is populated with just over 10,000 people but it has been rising rapidly.

Tuvalu consists of a large number of relatively small islands with the largest island covering only 520 ha and the smallest 42 ha. The nation is regarded as exceptionally vulnerable to rising sea levels and increased storm activity as the maximum height above sea level is a mere 5 m (SOPAC 2002; Rosillo-Calle et al. 2003; Woods et al. 2003).

The climate is sub-tropical, with temperatures ranging 28 to 36 °C, uniformly throughout the year. There is no clear marked dry or wet season. The mean rainfall ranges between 2,700 to 3,500 mm per year in Tuvalu, but there are significant variations from island to island. Rainwater run-off is collected for drinking water.

In total, approximately 18 km^2 (1,800 ha) are classified as potential agricultural land, however, this potential area is highly fragmented between the islands. In addition, agricultural land is unequally divided among the 9 islands. The small size of these islands poses serious difficulties to the development of a modern agricultural system based on conventional cropping. Innovative solutions are clearly needed if agriculture and bio-energy are to play a role in future development. Maintaining soil organic matter levels and continuing salinisation (from encroaching sea water) are also barriers. One of the most important influences on land use and agriculture development is the system of land ownership which will impact on any bio-energy project. Land use is governed by the 'Native Lands Act' with all land being owned under customary laws. The Government leases back land under 'Native Orders' for development purposes. The traditional land-tenure systems, which are based on the principle of subdivision and inheritance, have resulted in the fragmentation of land plots, disputes over land boundaries and problems with multiple ownership. These problems have arisen as a result of a strictly limited land resource and continued population growth (SOPAC 2002; Rosillo-Calle et al. 2003; Woods et al. 2003).

Adding to the problems of sustainable bio-energy use in Tuvalu, the soil is generally of poor quality, and only supports limited flora and vegetation which is dispersed unequally through the islands. However, coconut woodland is the main form of forest cover, occupying about 54% of the land area, followed by mangroves which cover about 17% (SOPAC 2002). From a biomass resource point of view, coconut is by far the most attractive raw material for bio-energy projects. There is also a big problem with MSW disposal, so biogas digesters are also an option worth investigation.

National level

Terrestrial above ground biomass production and utilisation in Tuvalu was analysed for the years 2000–2003 using FAOSTAT derived data (Table IXa–c). For these years, the total production of biomass energy was estimated at an annual average of 122,549 GJ (51% from agricultural crop production, 0% from forestry, and 49% from livestock). Of the 10PJ produced from agricultural operations, 42,647 GJ was harvested for food, 71,203 GJ was unutilised crop residues, 3,036 GJ (160 t carbon equivalent) was harvested crop residues for use as directly as fuel. Livestock produced a further 59,663 GJ, of which only 1,198 GJ was harvested and used for fuel. Only 51% of the biomass energy produced was actually utilised. 75,673 GJ remained as unused residues and dung (from agricultural production and livestock). Data for fuelwood collection and use was not considered as it had not been included in FAO statistics (FAOSTAT 2004).

TABLE IX
Use and availability of biomass resources in Tuvalu (PJ)

Sector	Gross resource	Available resource for bioenergy	Existing biomass resource Use	Net available for vioenergy systems
Forestry	–	–	Very little	–
Agriculture	0.069	0.017	0.003	0.01
Livestock (Dung)	0.06	0.05	0.01	0.04
Total	0.13	0.06	0.01	0.05

Notes. Derived from unpublished analysis.

National level policy implications for community bio-energy in Tuvalu

Electricity from diesel generators plays a major role in Tuvalu. For example, in Funafuti (Fogafale Electricity Generation Station) electricity is supplied to a local grid and used in most households for lighting and increasingly for air conditioning. Total sales in all islands (2002) amounted to MAU$1,218 (million Australian dollars) (Rosillo-Calle et al. 2003). Tuvalu's total diesel consumption for electricity generation in 2003 was 1.66 Ml (Burnyeat 2004).

Throughout Tuvalu, there are 25 diesel generator sets with a total capacity of just under 4.3 MW and only one power house and one grid. The outer islands (except Niulakita) were electrified with diesel generators in 2000. The MAUS$1.7 capital costs of diesel electrification were paid for by the government in a year of a large budget surplus, but running costs are high (see below). Diesel electricity generation largely replaced a solar electrification scheme that had been running for ten years but was in decline.

This case study concerns the potential for the development of locally produced coconut oil as a substitute for imported diesel for electricity generation. In 2002 a macro economic and resource feasibility study was undertaken (details below) which concluded that coconut oil for diesel substitution was viable on the grounds of economics, resource availability & technical capability (Woods et al. 2003; ICCEPT/SOPAC 2003). Since then, however, the situation has changed with the adoption of new policies for subsidies by the Tuvaluan Government meaning that, for Tuvalu, coconut as a diesel substitute is no longer viable in simple macro economic terms (Burnyeat 2004). However, there are potential external benefits that could justify coconut oil programmes at the community level where household incomes are low and affordable energy services are required.

Theoretical coconut oil resource potential

Resource potential for production of coconut oil depends on:

- Number of palms per unit land area (hectare)
- Productivity of palms (nuts per palm)

- ○ Quality of nuts, their processing to copra and access to markets
- ○ Efficiency of oil extraction from Copra
  - Typically 400 g oil per kg Copra
  - Approximately 60% of total oil

	Low	Medium	High
Coconut trees per ha	151	254	351
Nuts per tree	50	80	120
Flesh per nut (kg; 50% moisture)	0.276	0.34	0.416
Shell per nut (kg)	–	0.2	–
Flesh per ha (kg; 50% moisture)	2084	7004	17522
Copra per [ha?] (5% moisture)	1146	3852	9637
Recoverable oil per kg Copra (kg)	0.3	0.4	0.55
Recoverable oil per ha (kg)	344	1541	5300
Recoverable litres oil/ha:	378	1693	5825
Recoverable energy GJ/ha:	14.8	66.3	227.9

Source. Woods et al. (2003) and ICEPT/SOPAC (2003).

- A 700 KVA diesel generator running at 30% efficiency would require 180 l diesel/h or 204 l coconut oil/h running at peak load.
  - ○ The greater requirement for coconut oil is a reflection of its reduced energy content.
- At 1,690 l/ha, one hectare would provide 8.3 hours peak running time. The 2,000 ha of palms in Tuvalu could therefore provide 16,570 hours of generation at peak load. C.f. 8,670 hours in a year currently used.
- Theoretically, existing palms on Funafuti alone could provide 2 108 hours of peak generation!

Economic evaluation (2002)
(Source: Woods et al. 2003; ICCEPT/SOPAC 2003)

- In 2002 copra was purchased by the Tuvalu Coconut Cooperative at AU$1/kg:
  - ○ equivalent to US$1.20 per litre coconut oil
  - ○ imported diesel costs US$0.55 per litre (2001/2)
- The world market price for copra was about AU$300 to 400 /t copra (AU$0.3 to 0.4/kg).
- On top of the payment for copra it was costing the Tuvalu Government AU$200 per tonne (AU$0.2/kg) to ship the copra to Fiji.
- Total cost of copra to Tuvalu delivered to Fiji was estimated to be AU$1.3 /kg c.f. a world market price of about AU$0.35/kg.
- Tuvalu was subsidising copra production by about AU$1 per kg or AU$2 (US$1.20) per litre coconut oil.

Under these subsidy conditions, converting to coconut powered electricity production Tuvalu would save itself US$0.55 per litre diesel, and US$0.12 per litre in copra shipping costs giving a total saving of US$0.67 per litre of coconut oil used for electricity production! In effect it was costing a minimum of US$0.78 per litre to deliver coconut oil to Fiji whilst importing diesel at US$0.55/l.

By using coconut oil for electricity generation Tuvalu would save:

- The cost of imported diesel
- The cost of subsidising copra production and shipping.

However, additional costs would be incurred through the need to modify the fuel supply systems used for diesel generation and in extracting the oil from the copra. The residual copra pulp would have value as pig feed.

The situation post 2002

(Adapted from Burnyeat, 2004).

The copra yield was in decline for various reasons before the copra production subsidy ended. Even with an all time high domestic price, with the removal of subsidies the copra industry finally collapsed in 2002 – the annual yield was only 133 tonnes. This would only have produced about 66,500 litres of oil. This suggests a decreasing number of people are interested in coconut farming and copra cutting and the potential productivity may be even lower than the 2002 quantity. While these figures may seem small compared to Tuvalu's annual diesel consumption for electricity production of c.1.7 million litres, it must be realised that Funafuti consumes a huge amount more diesel than the outer islands. All the outer islands together consumed only 330,000 litres of diesel for electricity production in 2003. Therefore, the quantities above would make a significant impact if used in a mix with diesel in the outer islands.

The current state of the coconut resource also needs to be taken into account. Most of the land that was being harvested for copra has become overgrown. Only enough coconut plantation is still managed to meet human and animal domestic consumption needs. This is mostly land around the villages and patches of land around people's pig and chicken pens if kept outside the village. To revive coconut farming for coconut oil production on any significant scale would require clearing the undergrowth from the plantations, thinning the trees and re-establishing some kind of re-planting program. Plantation management would further increase the cost of producing coconut oil.

In 2001, Tuvalu had a trade deficit of MAU$9.6 (ADB 2002), with the total value of imports being MAU$13 in 2000, this would seem to be a cause for concern. However, Tuvalu's main income is not from trade but from licensing revenues, remittances and donor funding. These revenues more than cover the trade deficit and Tuvalu has not yet been forced to borrow. Tuvalu has not experienced the cycle of debt that has been the economic ruin of some developing countries and per capita GDP (Table III) compares favourably with other PICS with lower trade deficits. In 2002, Tuvalu had a MAU$10.2 budget surplus because of windfalls from dotTV and fisheries revenues. However, maintaining the surplus is dependent on circumstances beyond Tuvalu's control. The effect of reliance on external income sources is that government budgetary spending ability fluctuates greatly from year to year.

Diesel imports for electricity generation are a major expenditure and loss of currency for Tuvalu. However, the amount of coconut oil Tuvalu would be likely to produce would only offset around AU$50,000 worth of diesel imports – some 3% of Tuvalu's total fuel import bill of around AU$1.5 million per year (around 8–10% of Tuvalu's total national budget). Between 2000 and 2002, the government's revenues, expenditures and budget surplus all had fluctuations of greater than AUS$10 million which is partly a result and illustration of Tuvalu's reliance on external income sources. Offsetting of AU$50,000 worth of 'exposure' by using coconut oil would not have a significant effect on the trade deficit which is probably now greater than the 2001 figure of AU$9.6 million. There is also a large scope for fuel and cost savings in terms of improving the efficiency of consumption. Distribution losses are very high and generation efficiencies are low in the outer islands as the generators are running at well below rated capacity. Distribution losses (as a percentage of gross generation) range between 17% (Funafuti), equivalent to approximately AUS$176,000 worth of diesel. On the outer islands, the financial costs of distribution losses total around AUS$180,000. Improvements here could probably save more in fuel imports terms and total cost than a coconut oil substitution programme.

Cost of electricity 2003

Real cost of electricity (Funafuti): AU$0.4 to 0.5/kWh
Of which fuel = AU$0.3/kWh
Real cost of electricity (outer islands): AU$1.10 to 1.30 (Viatupu c. 0.90)
Of which fuel (excluding transport costs39) = AU$0.34 to 0.66/kWh

Cost of transporting fuel on the government supply ships is not included. Imports of fuel accounts for 60% of Tuvalu Electricity Corporation's (TEC) total operating costs (ADB 2002).

To be competitive with diesel at AU0.78/lt, the copra/coconuts would have to be supplied at a price (minus coconut oil processing and transport costs) of:

Copra (assuming 2 kg = 1 lt of oil): AU$0.39/kg
Coconut (low estimate of 10 nuts = 1 lt of oil): AU$0.08/nut
(High estimate of 15 nuts = 1 lt of oil): AU$0.05/nut

An annual government subsidy for electricity production of around Aus$300,000 means that the price of electricity is becoming increasingly disconnected from actual cost – electricity service provision is now increasingly exposed to the same risk that eventually brought the copra industry to collapse.

The Asia Development Bank review of TEC (ADB 2002) recommended that TEC reduce its subsidy to provide an incentive for reducing currently excessive operating costs and increase cost recovery. Some general points made on energy sector subsidies are that they:

- Skew energy supply choices.
- Encourage wasteful consumption.
- Increases burden of energy service provision on the government.
- Result in substantial economic losses and impose burdens on the environment.
- Increase energy poverty if not targeted correctly.

Tuvalu is too small for a liberal market economy to develop in the electricity sector and it appears that subsidies are necessary to cover the high cost of essential service provision. While it is conceivable that the tariff on Funafuti could cover at least the costs of production, the cost of electricity on the outer islands is so high that it is unlikely that costs could be recovered from sales. Many outer island consumers struggle to pay the current tariff. The shortage of cash income-earning opportunities in the outer islands is becoming a problem with the increase in demand for consumer goods and an increase in living costs such as electricity and fuel bills. On a community level, if coconut oil substitution for diesel could reduce the cost of electricity provision to the outer islands, it would be a significant benefit.

Analysis

The risk attached to any subsidy dependence (copra or electricity) is that the economy generated by that subsidy is dependent on national government policy and national government budget which, in turn, is dependent on external international economic and policy factors. For the communities in the outer islands in particular, subsidy (and remittances) dependence means that they do not have control over their own economy. The resulting development problem should be defined as how to reduce this dependency and increase economic control. For the outer islands, the offsetting of diesel imports would not be felt as a benefit as they are cushioned from the expense of these imports by the electricity subsidy.

However, under certain subsidy conditions (copra = AU$400 per tonne, diesel price AU$0.8 per litre), substitution of imported diesel with locally produced coconut oil has the potential macro economic benefits of reducing the trade deficit, the export of capital, and economic exposure; which are all problems related to Tuvalu's increasing diesel import dependency.

Although there may be a decreasing number of people dependent on copra production as their main means of income, there were people left with no means of income when the copra industry collapsed in 2002. On a community level, if the development of a coconut oil programme would provide a means of income for these people it would be an important benefit. People on the outer islands are willing to put considerable time and effort into communal labour. However, it is only likely to be an attractive employment prospect to the people who do not have a better means of earning income (such as fishing or remittances) so it is unlikely to transform the employment base of the outer islands. In countries such as Kiribati, where the per capita GDP is less than US$500 per year, copra production is a worthwhile economic activity for the rural population and coconut oil bio-energy projects would be more likely to succeed on economic grounds.

The most likely technical option for Tuvalu would be the use of pure coconut oil, or coconut oil in a diesel mix, in a standard engine with a modified fuel system. The benefit of using coconut oil in a mix is that varying the mix can absorb price and supply fluctuations in both fuel supplies. The quantities of fuel substituted can adapt to the changing economic situation. If diesel prices go up then more coconut oil can be used and vice-versa. To provide the opportunity for such a mechanism to work, the capacity for coconut production and use has to be developed and the capacity for diesel import and use has to be maintained. Using coconut oil in a mix also reduces the potential impact of project failure and allows the project to evolve without affecting the service delivered.

Additionally, there are potential external socio-economic benefits of providing a more viable market for Tuvalu's collapsed coconut industry and, therefore, much needed income earning opportunities on the rural outer islands.

Due to the vulnerability of Tuvalu to climate change, the use of renewable energy on the islands may increase Tuvalu's influence internationally.

Conclusions, Lessons Learned & Recommendations

Following on from the experience of past projects, and the SOPAC Biomass Resource Assessment Exercise (2003) there are exciting and significant opportunities for the development of practical biomass energy projects and programmes in the South Pacific. Biomass is a fuel that people are familiar with since traditional use of biomass fuel currently provides the majority of energy to the domestic sector. However, although continued use of traditional biomass will provide for basic needs, it will not solve the problem of providing the modern energy services required for economic growth and improved living standards.

In addition to political and techno-economic changes, it is likely that the modernisation of biomass energy use will involve some social and cultural changes, as people move away from traditional uses of biomass – this is why community involvement in project planning is so crucial – and a major, but achievable, challenge. The flow charts indicate (Figures 1 and 2) that, even where land is limited, residues, wastes and existing agricultural and forestry activities could be used as the basis for the provision of sustainable biomass energy resources for modern applications. In addition, by doing so, national climate change adaptation programmes would be greatly assisted. Because of its inherent energy storage properties, biomass can also play a pivotal role in the wider implementation of renewable energy in general. Although the biomass resource base in the South Pacific region has not been fully quantified, it is evident that biomass resources should not be considered a limiting factor for biomass-based energy projects in most cases (Woods et al. 2003).

It is evident that a programme for developing regional and national bioenergy programmes is required to assist the process of successful bio-energy project development and implementation which will also require significant community, local political and regional support. It is now necessary to make modern biomass energy a reality for the island nations of the South Pacific and in doing so send a clear message that this region is determined to create a sustainable future for itself. The case studies presented indicate that understanding and reconciling the community needs for energy services and the resources available must be the initial starting point for any community based bio-energy project. They also show that communities must be involved in the decision making and project planning process from the outset.

Methods for promoting information exchange and capacity building are likely to be important to the successful development of regional and national biomass energy resources. The case studies have identified a number of critical biomass supply chains for the provision of modern biomass energy services in the region:

- The use of anaerobic digestion to treat waste streams, primarily human and animal sewage.
- The use of coconut resources to provide liquid biofuels, particularly biodiesel.
- The development of small scale gasification programmes to exploit woody residues and dedicated biomass supplies.

The successful implementation of these technology supply chains may only be possible when the following support is developed at the regional level because the small size of many of the island nations of the South Pacific may not allow sufficient capacity to be developed by them individually:

- Primarily information exchange:
    - Technical
    - Best practice
    - Examples of failure
    - Examples of success
- Supply chain networks and cooperatives.
- Develop framework planning guidance.
- Exchange of information between project developers, local public, government and interested NGOs.
- Identify ‘productive uses of biomass energy’.
- Raise awareness of the fact that local energy needs can be met locally thereby promoting “ownership” of biomass energy strategies on a local to regional basis.
- Coordination of support for, and communication between, stakeholders at all levels.

The development of regional and international support will also be necessary in establishing technical support capacity to underpin the successful development of biomass energy projects and programmes in the South Pacific. This is necessary in order to:

1. Promote the development of clusters of projects based around similar production, supply and conversion pathways – aim is to develop entrepreneurial capacity to carry out maintenance, repair and development of systems.
2. Establish academic R&D programmes in Universities and linkages with international groups and the private sector already involved in bioenergy R&D – avoid re-inventing the wheel.
3. Develop capacity in local and regional government to support biomass energy projects and schemes.
4. Enlist the support of NGOs and publicly active groups, particularly women's groups.
5. Establish the technical capacity and presence to attend important international forums such as WTO, Kyoto (UNFCCC), FAO, etc and ensure that the development of future programmes supports the development of sustainable bioenergy schemes and recognises externalities.

Note

1. Source for this case study: Burnyeat (2004).

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