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The Potential for Renewable Energy to Promote Sustainable Development in Pacific Island Countries

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This paper examines the potential for renewable energy technologies to promote sustainable development in rural areas in Pacific island countries. The paper examines the link between access to energy supplies and sustainable development. The current heavy dependence on imported fossil fuels for meeting the primary needs of countries is examined, as well as the high costs associated with supplying electricity to rural areas. The potential for renewable energy technologies for providing electricity to meet the basic energy needs of rural households is examined, including the cost-effectiveness of solar energy; micro-hydroelectric energy and biofuel compared with conventional energy options. The paper then concludes that in order to promote rural electrification in the Pacific, policies must place a greater emphasis on the use of renewable energy options.

1. INTRODUCTION:

Access to energy services has been identified as a necessary prerequisite for sustainable development, since it can lead to improvements in household health, education and income levels. Pacific island countries face a particularly difficult challenge in expanding rural electrification. As a result of their unique geographical characteristics, where long distances separate sparsely populated areas, and markets are too small to achieve cost savings through economies of scale in electricity production, the cost of supplying electricity to rural areas is very high. Although most Pacific island countries are almost completely dependent on imported fossil fuels for meeting their energy needs, there is a large potential for renewable energy resources to supply electricity to rural households. In order to assess the cost-effectiveness of using renewable energy technologies to supply electricity to households in rural locations in Pacific island countries, three renewable energy projects from across the region were selected as case studies. The case studies were chosen in order to reflect as wide a range of renewable technologies as possible in a variety of different Pacific island settings. These include O'ua Island, which is part of the Ha'apai Solar Electrification Project in Tonga; the Welagi and Vanua Balavu Coconut Biofuel Projects in Fiji; and the Bulelavata Micro-Hydroelectric Project in the Solomon Islands.

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2. ACCESS TO ENERGY AS A PREREQUISITE FOR SUSTAINABLE DEVELOPMENT

2.1 Energy Services and sustainable development

Energy supply is an important factor for raising living standards, since it is a critical input into education, health, water supply, transport and production. As a result, access to affordable and reliable energy services has been identified a necessary prerequisite for sustainable development and poverty reduction (REN21, 2005).

Currently, more than 1.6 billion people worldwide lack access to electricity (Modi et al., 2006). Because of the important link between energy and sustainable development, developing and donor countries pledged to improve access to affordable energy services as a means of achieving the UN Millennium Development Goals (MDGs), presented in Table 1 below, at the 2002 World Summit for Sustainable Development in Johannesburg (REN21, 2005).

Table 1. *Millennium Development Goals*

Goal 1. Eradicate Extreme Poverty and Hunger
Goal 2. Achieve Universal Primary Education
Goal 3. Promote Gender Equality and Empower Women
Goal 4. Reduce Child Mortality
Goal 5. Improve Maternal Health
Goal 6. Combat HIV/AIDS, Malaria and other diseases
Goal 7. Ensure Environmental Sustainability
Goal 8. Develop a Global Partnership for Development

The benefits associated with household access to modern energy services, which promote the achievement of many of the MDGs, include (ESMAP, 2002):

- Education: improved lighting enables longer hours of study that may lead to improved educational outcomes over time. Also, access to electricity may improve retention/recruitment levels among teachers in rural areas.
- Health: This may come in the form of improved hygiene as a result of being able to store and cook food properly, or a reduction in indoor pollution levels.
- Entertainment and Communication: electricity allows for the use of devices such as radios, mobile phones and video players.
- Improved Productivity Levels: Household members may be able to engage in productive activities for longer hours each day (e.g. weaving handicrafts) as a result of better quality lighting at night; or save time doing domestic work as a result of electrical appliance use, such as washing machines.
- Increased Savings: if spending on electricity is less than spending on alternative energy sources such as kerosene and dry cell batteries.

2.2 Energy and Sustainable Development: the Pacific Island Context

Pacific Island Countries face a particularly difficult challenge in providing basic energy services to rural areas. This is because most countries are characterized by remoteness, small size, long distances between islands and isolated populations, which does not allow for economies of scale in electricity production and distribution, and ensures that the costs of supply remain high (SOPAC, 2004).

Approximately seventy percent of the population in Pacific Island Countries, (fifty percent excluding Papua New Guinea), lacks access to electricity (SOPAC, 2004). However, the proportion of the population with access to electricity in the region varies considerably from country to country, with universal access to electricity in Niue, compared to less than ten percent in Papua New Guinea, as Table 2 demonstrates.

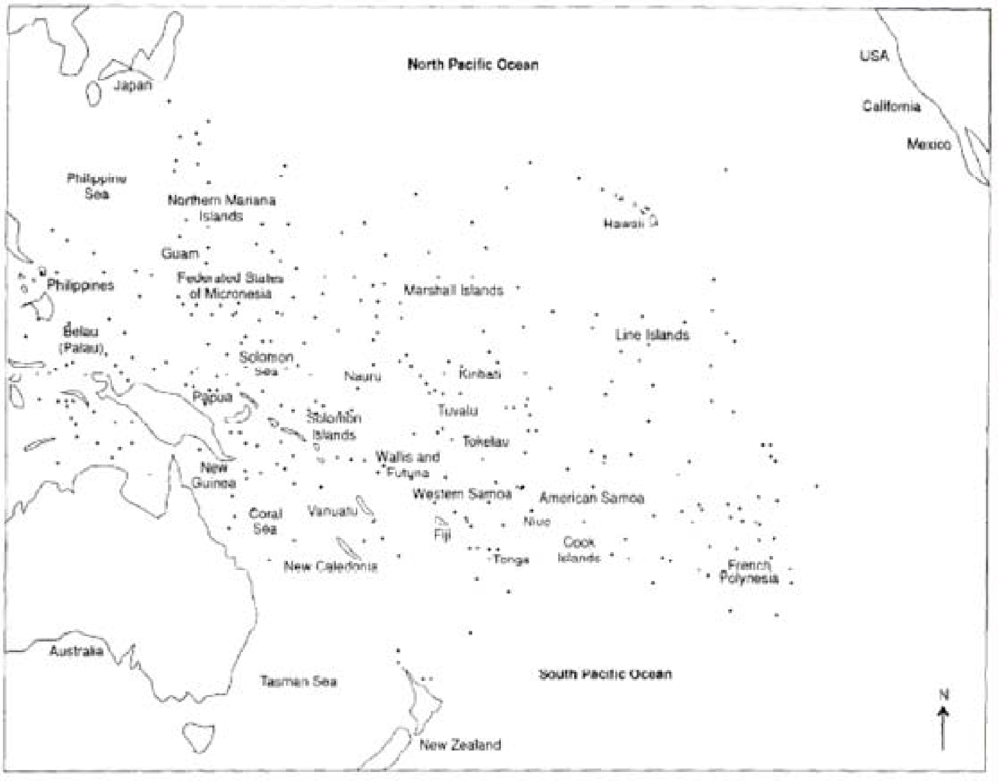

Figure 1. Map of the North and South Pacific.[•]

[•] Source: Yu and Tapling (1997)

Table 2. Percent of households with access to electricity in Pacific Island Countries

Country	Year	Population	Percent of Households with access to Electricity
Cook Islands	2004	18,000	99%
Federated States of Micronesia	2000	107,000	54%
Fiji	1996	844,000	67%
Kiribati	1993	85,000	29%
Marshall Islands	1999	54,600	63%
Nauru	2002	10,100	100%
Niue	2003	1,700	100%
Palau	2004	19,100	97%
Papua New Guinea	2003	5,200,000	< 10%
Samoa	2001	176,100	93%
Solomon Islands	1999	457,000	16%
Tokelau	2003	1,500	100%
Tonga	1999	100,000	80%
Tuvalu	2003	9,300	> 95%
Vanuatu	1999	212,000	19%
Total		7,285,300.00	78%
Total (excluding Papua New Guinea)		2,095,400.00	48%

Source: Wade et al. (2005)

Also, Pacific Island Countries, with the exception of PNG, have few indigenous petroleum resources, and are highly dependant on imported fossil fuels for meeting their energy needs. Isolation and large distances from major petroleum markets are key factors in raising the costs of fuel in Pacific Islands. Diseconomies of scale in transport, storage facilities, and the structure of the fuel distribution system also increase the costs of petroleum products in the region (Yu and Tapling, 1997). Transport costs add 5-10% to the cost of fossil fuels in the main distribution centres in Fiji, Guam and Papua New Guinea; and 20-40% for smaller secondary ports (Rizer and Tavanavanua, 1988).

Heavy reliance on fossil fuel imports, which account for between 8-37% of total imports, has led to a situation where most Pacific Island Countries face large balance of payments deficits, since exports are insufficient to finance fuel imports. In some cases, import levels, of which fuel is the single largest commodity import, are many times higher than exports levels as illustrated in Table 3. For example imports account for 233% and 340% of exports in Kiribati and Palau, respectively.

This heavy dependence on imports also makes Pacific Island economies very vulnerable to global shocks such as increases in world oil prices, which can lead to macroeconomic instability. For example, rising fuel prices can exert inflationary pressure on economies of Pacific Island Countries by raising input costs.

Table 3. Pacific Island Petroleum Imports

Country	Year	Percentage of Total Imports	Percentage of Total Exports
Papua New Guinea	2004	27	19
Fiji	2005	29	68
Solomon Islands	2004	27	24
Samoa	2005	20	307
Vanuatu	2005	11	45
Federated States of Micronesia (FSM)	2004	18	167
Tonga	2004	20	134
Kiribati	2003	13	233
Marshall Islands	2000	37	223
Cook Islands	2005	8	130
Palau	2004	22	340

Source: ADB (2006)

2.3 Costs of conventional energy supply

Given their heavy dependence on imported fuel for electricity production, it is not surprising that rural electrification poses an enormous challenge to Pacific Island Governments with limited financial resources. In most Pacific Island Countries, grid-based, publicly distributed electricity is provided only on the main island, and as a result supply to rural areas is limited (Wade et al., 2005). Until recently, rural electrification strategies have focused on providing energy to rural communities using conventional fossil-fuel based options, such as extension of the electrical grid and the installation of centralized, village diesel generators.

Extension of an existing electrical grid, where adequate capacity exists, is generally the preferred option for supplying power to remote areas, because it allows for the provision 24-hour power, minimizes maintenance costs and maximizes reliability and efficiency, compared with smaller stand-alone diesel generators (Cheatham, 1990; NRECA, 2000). Unlike standalone energy options, there is virtually no limit on power consumption, so enough electricity is provided to supply rural industries in addition to household lighting and appliances (NRECA, 2000; ESMAP, 2000). However, in the Pacific Island context grid extension, particularly to rural areas, especially those located on outer islands, with isolated populations is generally not feasible due to the long distances involved and low population densities (Cheatham, 1990).

Diesel-powered generators, on the other hand, are inexpensive to install at a cost of about US$1,000 per kilowatt of production capacity (Cheatham, 1990). Diesel systems also have the advantage that they are subject to economies of scale, so that per kilowatt-hour costs fall as outputs increases. However, due to high fuel costs, electricity in rural areas is rarely available for more than a few hours in the evening. Also, diesel generators have high maintenance requirements, and as a result, they operate unreliability and inefficiently in remote locations, where there is a shortage of spare parts and skilled technicians to carry out routine maintenance work.♠

2.4 The Potential for Renewable Energy Production in Pacific Islands

Despite their heavy dependence of fossil fuels, Pacific Island countries have an abundance of renewable energy resources, including solar, hydropower and biomass resources. Generally, renewable energy technologies (excluding large hydroelectric plants) are not the least-cost option for meeting the energy demands of urban and commercial consumers, since diesel systems are

♠ According to a survey conducted in 1991 by the Fiji Department of Public Works, diesel generators were found to be out of service for an average of 77 days per year in remote locations, due to mechanical failure and unavailability of fuel (Liebenthal et al, 2004) better able to take advantage of economies of scale in electricity production which results in lower per unit costs.

However, renewable energy technologies may provide the least cost means of supplying basic energy services to rural households located in remote and sparely populated locations with low demand for energy. For example, both Liebenthal et al. (1994) and Cheatham (1990) find that solar home photovoltaic (PV) systems in Tuvalu and Kiribati, respectively, are the least-cost option for rural electrification when the total number of households in a given area is less than 500, and household demand for energy is low, and is restricted to energy demand for lighting and the use of basic appliances. This is because although the capital costs associated renewable energy technologies such as photovoltaic or micro-hydro systems are high, subsequent operation and maintenance costs are low, particularly because such systems do not require imported fuel inputs.

Also, the use of renewable energy technologies for rural electrification yields important environmental benefits in terms of reduced greenhouse gas emissions. Although they are insignificant emitters of greenhouse gases on a global scale, there is an incentive for Pacific Island Countries to takes steps towards addressing global warming, since they are expected to bear many of the negative consequences associated with climate change, including sea level rise and the increased frequency and intensity of storms, floods and droughts.

3. ECONOMIC ANALYSIS OF SELECTED RURAL ELECTRIFICATION RENEWABLE ENERGY PROJECTS IN PACIFIC ISLAND COUNTRIES

Least-cost analysis was used to compare the total life-cycle costs associated with each renewable energy technology utilized at each project site on the case study islands with the estimated costs of installing, operating and maintaining diesel systems in the same location.

The lifecycle costs, valued in present value terms, using a discount rate of 10 percent were calculated as follows[♣]:

- **Initial capital costs (CC):** This includes initial and up-front costs associated with a project including the costs of any project feasibilities studies, system design costs, and equipment purchase, transportation and installation. In other words, all costs incurred up to the point where the project starts running are considered capital costs.
- **Operation and maintenance costs (OM):** This includes any costs associated with maintaining and operating the project such as administrative costs, wages and transport costs associated with operating the project.
- **Replacement costs (R):** These are the costs of purchasing spare parts and the replacement and repair of equipment.
- **Fuel costs (F):** These include the market value the annual costs of any fuel used, such as diesel or biofuel.

The methodology employed in this study to assess the cost-effectiveness of selected renewable energy technologies in Pacific island countries was intended to be simple, straightforward, and easy enough, so that it could be understood and applied, even by non-economists, involved with rural energy planning issues in Pacific island countries.

[♣] A discount rate of 10 percent was used in the economic analysis of selected renewable energy technologies conducted as part of this study. This follows the methodology used in other recent economic studies conducted in Pacific Island countries including Lal et al (2005, 2006).

3.1 The Ha'apai Solar Electrification Project, Tonga

As part of the Ha'apai Solar Electrification Project, households on six islands in the outer island group of Ha'apai in Tonga were provided with solar home systems.• The island of 'O'ua, one of the islands included in the project was chosen as a case study, in order to assess the cost-effectiveness of solar home systems for supplying electricity in a remote Pacific island context compared with a diesel system.

Approximately 38 households live on the remote island, ninety percent of which rely on mat weaving and fishing as sources of income. Over a 10-year period, 'O'ua has experienced a thirty-three percent decline in population due to outward migration (SPC, 2000). Prior to the implementation of the solar project, the majority of households living on the island relied on kerosene and dry cell batteries to meet their energy needs.

The solar home systems provided to households under the project consist of two 75 peakwatt panels, a 12 Volt battery, three 13-watt lights and a ¼ watt nightlight. As part of the program, households were required to pay an installation fee, as well as monthly fees to cover maintenance and repair work, carried out by island technicians. Electricity supplied by the PV systems is sufficient to provide basic energy services to households including lighting and the use of a small appliance such as a radio. In addition, the project was designed so that PV systems were large enough to power outdoor lights on each home at night in order to provide street lighting.

In order to assess the cost-effectiveness of supplying electricity on 'O'ua using solar home systems, the estimated life-cycle costs of 40 systems were compared with those of a 36 kW diesel generator, over a 20 year period. Table 4 below presents the capital investment, operation and maintenance costs associated with each system.

Table 4. *Breakdown of Energy System Costs*

	Solar Home System 1 (40 units)	Solar Home System 2 (40 units)	Diesel Generator
Capacity	150 W_p	75 W_p	36 kW
Capital Cost (US$)	80,051	69,882	51,000 (36,000 generator cost + 15,000 distribution system cost)
Annual O&M cost	1% of capital costs	1% of capital costs	5% of capital costs
Other maintenance costs	Battery replacement every 7 years at a cost of US$240	Battery replacement every 5 years at a cost of US$240	Engine overall every 5 years at a cost of 25% of initial generator cost; Generator and switching system overhaul every 7 years at a cost of 20% of initial generator costs
System Lifetime (years)	20	20	10
Unit cost of delivered fuel (US$/litre)	N/A	N/A	1.20

Given that outdoor lighting would be unavailable with the diesel systems, since they are assumed to operate only five hours per day, using PV systems with smaller panels (i.e. 75 Wp), provides a fairer comparison between the two technology options. The life cycle cost comparisons are presented in Table 5 below.

• This project was part of the Pacific Rural Renewable Energy France Australia Common Endeavor

Table 5. Total Life-cycle costs

Energy System Type	Total Discounted Life-Cycle Costs (US$)
75 Wp Solar Home Systems (40 units)	87,090.48
150 Wp Solar Home Systems (40 units)	93,804.51
36 kW diesel generator	97,792.40

All values in 2005 US$ and converted into present value terms using 10% discount rate

The results from the analysis indicate that solar home systems are the least-cost option for rural electrification, compared with diesel systems on 'O'ua island. Sensitiivty analysis revealed that even when the price of diesel falls by 50%, to US$0.60 per litre, the 75 Wp solar home systems remain the least-cost choice for electricity production. The results are consistent with previous studies conducted in Pacific islands, which demonstrate that where household demand for energy on both an aggregate and per capita basis is low, and not expected to increase significantly, and where distances from urban centres are large, PV systems present the most cost-effective option compared with fossil-fuel based systems, for rural electrification in Pacific island countries.

3.2 The Bulelavata Community Micro-hydro System, Solomon Islands

Bulelavata is a remote community, accessible only by sea, which consists of approximately 300 people, and is located in the Western Province of the Solomon Islands (Bryce and Soo, 2004). The Bulelavata micro-hydro scheme, which was constructed in 1999, is one of a number of community micro-hydro schemes, implemented in the Solomon Islands over the past 20 years, with assistance from the Australian-based non-government organization, Appropriate Technology for Community and Environment (APACE).

Prior to the implementation of the micro-hydro scheme, the community depended on biomass, kerosene and dry cell batteries for meeting their energy needs (Delaka, 2003). Under the project, many households have benefited from improved lighting, and greater appliance use such as water heaters and radios. Also, a small number of households have purchased video machines, refrigerators and electric drills. The project also supplies electricity to the Provincial Secondary School.

In order to determine the least-cost option for providing electricity to the rural community of Bulelavata and the local secondary school, the total life-cycle costs associated with the micro-hydro system were compared with the estimated life-cycle costs of operating a 29 kW diesel generator in the same setting. A breakdown of the capital, operation and maintenance, and fuel costs is presented in Table 6 below.

Table 6. Breakdown of Energy System Costs

	Micro-Hydroelectric System	Diesel Generator
Capacity	29 kW	29 kW
Capital Cost (US$)	268,857	60,000 (29,000 generator cost + 15,000 village distribution grid +16,000 transmission line to school)
O&M costs	US$103 per year	5% of capital costs per year Engine overall every 5 years at a cost of 25% of initial generator cost; Generator and switching system overhaul every 7 years at a cost of 20% of initial generator costs
System Lifetime (yr)	20	10
Unit cost of delivered fuel ($US/litre)	N/A	1.30

The results from the analysis, presented in Table 7 below, indicate that the micro-hydro system is the least-cost option for supplying electricity to the community and school. However, sensitivity analysis revealed that when the price of diesel fell by 25%, to US$0.98 per litre, the diesel generator became the least-cost choice for electricity production.

Table 7.Total Life-cycle costs: micro-hydro versus diesel systems

Energy System Type	Total Discounted Life-Cycle Costs US$)
29 kW Micro-hydroelectric System	229,794
29 kW diesel generator	269,542

All values in 2005 US$ and converted into present value terms using 10% discount rate

In addition, reliability is likely to be higher and hours of service longer for micro-hydro systems compared with diesel systems, since power is available from the micro-hydro system 24 hours per day, and only basic regular maintenance is required to keep the system operating.[∞]

3.3 The Coconut Biofuel Program, Fiji Islands

The coconut tree is a vital component of island ecosystems and economies, and traditionally copra has been an important source of rural income on many of Pacific islands. Although the technology has been around for many years, it has only been in the last ten years, that there has been renewed interest in using coconut oil as a biofuel in the Pacific (Cloin, 2005). The development of coconut oil as a renewable energy in the region not only provides the opportunity to reduce reliance on imported fossil fuels but also to provide rural communities with a cost-effective source of energy.

In order to promote rural electrification and sustainable livelihoods, and demonstrate the use of biofuel as a substitute for diesel, the Fiji Department of Energy, with support from the Secretariat of the Pacific Community and the French Government, installed specially adapted generators, designed to operate on pure coconut oil, in Welagi Village located on Taveuni Island in 2001, and in Sawana Village, located on the island of Vanua Balavu, in the Northern Lau group, in 2000 (Courty, 2000).[◊] Village committees are responsible for overseeing the operation and

[∞] Since the micro-hydro system was installed in 1999, it has operated for all but four days.

[◊] The biofuel generator installed in Vanua Balavu, although located in Sawana, is intended to supply electricity to the villages of Lomaloma, Sawana, and the settlement of Naqara. Diesel generators were adapted by adding a duel fuel tank system and a fuel heater, which allows the generator to stop and start with diesel fuel, since coconut oil must be heated to a temperature of 70-80 degree Celcius in order to avoid system clogging.

maintenance of the generators, as well as setting and collecting user fees in order to ensure that the projects are financially sustainable (Fiji Department of Energy, 2001).

It is assumed that the cost of purchasing, operating and maintaining diesel generators are equivalent, regardless of whether diesel or coconut oil is used.[∇] As a result the two technology options can be compared on price of fuel alone. Data on coconut oil prices was obtained from the UNCTAD commodity price database, and data on diesel fuel prices was obtained from the Pacific Island Forum Secretariat Fuel Price Monitor. The price of diesel is based on the wholesale cost of diesel in the main port of Suva, and both diesel and coconut oil prices have been adjusted for transport costs and taxes. Figures 2 and 3 present a price comparison of coconut biofuel and diesel fuel at each project site.

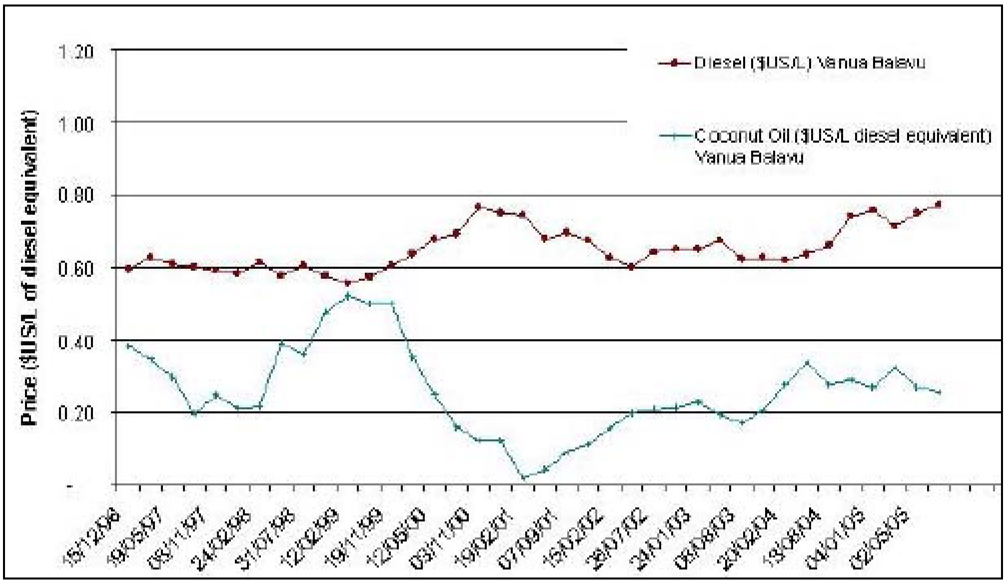

Figure 2. *Coconut oil and diesel fuel price comparison for Vanua Balavu, Fiji*

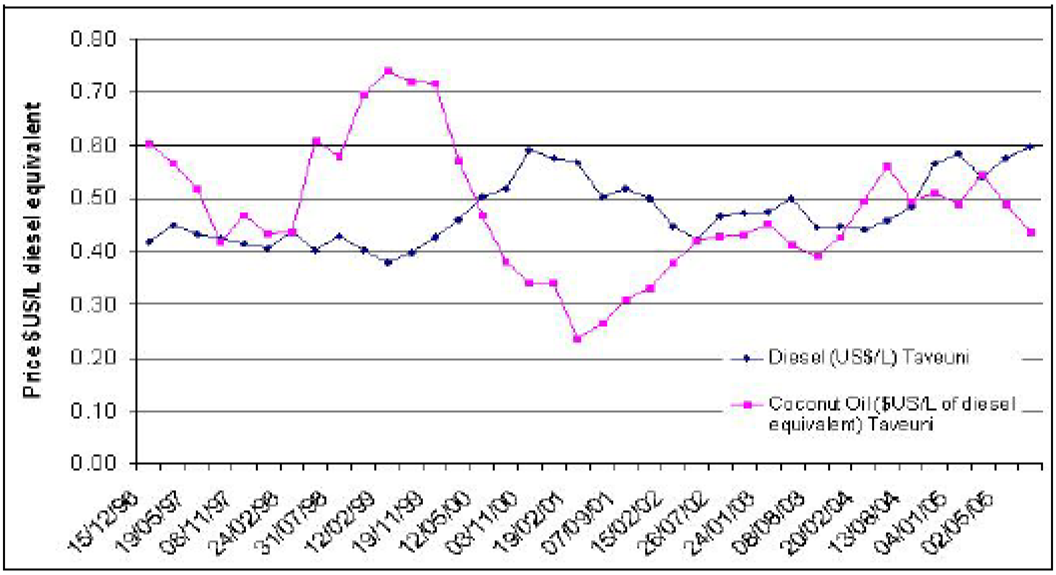

Figure 3. *Coconut oil and diesel fuel price comparison in Taveuni (Welagi), Fiji*

[∇] This assumption does not seem unreasonable, however experience with using coconut biofuel in adapted generators for electricity production is limited.

Figure 3 demonstrates that in Vanua Balavu, given high transport costs, locally produced coconut oil enjoys a clear price advantage compared with imported diesel fuel. However, the coconut oil mill on the island, which was intended to supply the project with biofuel has ceased operations, and a local source of coconut oil is no longer available. For a brief period, coconut oil was shipped to the project site from another mill, however, added transport costs meant that using coconut oil in the generator was more costly than diesel fuel (Khan, 2005). In Welagi, the price advantage of biofuel compared with diesel fuel is less clear-cut, as Figure 3 demonstrates, since diesel fuel transport costs from the main port of Suva are lower. Also, the Welagi generator currently operates on diesel fuel since there is a limited local supply of coconut oil (SOPAC, 2006). Ideally, the community could switch between fuels, depending on which fuel is least cost. Therefore the results from the analysis indicate that for coconut biofuel to provide the least-cost option for rural electrification, compared with diesel fuel, there must be sufficient low-cost coconut oil resources available locally, and households must be located in a remote enough location so that added diesel fuel shipping costs are sufficiently high to make locally produced coconut oil cost competitive.

4. CONCLUSIONS:

The energy situation in many Pacific island countries poses a challenge to the sustainable development of the region. Low levels of electrification and high costs of electricity supply have resulted in a situation where many households lack access to the basic essential services required for raising living standards in many Pacific island countries.

It is clear that renewable energy technologies including solar PV home systems, micro-hydro systems and biofuel generators have the potential to supply electricity to rural areas in a cost-effective manner, where distances are long, demand for energy is low and technical expertise is low. However, it is important to note that there is no one least-cost option for supplying energy, as it is very much dependent on local conditions and resource availability.

In addition to the direct energy cost savings associated with renewable energy technologies, other benefits, which are not measured in this study, may include increased reliability of energy services, longer hours of daily service, reduced noise and pollution, and increased energy independence. Also, the more widespread use of renewable energy technologies in Pacific island countries can at least symbolically assist in addressing global climate change by limiting the region’s green house gas emissions.

In order to promote the use of renewable energy technologies, countries should develop policies, which ensure that renewable energy technologies are adequately considered as options in rural energy planning. For example, the only Pacific island country that requires the utility to consider renewable energy options in the development of energy plans, is Palau (Wade and others, 2005).

Also, since the start-up costs associated with renewable energy technologies tend to be high, it is recommended that policies be introduced, which assist in lowering the initial costs, which is another major barrier to their use. This can be achieved in a number of ways such as through the use of cost-sharing schemes, import tax exemptions, the provision of soft loans, or increasing users’ ability to pay for energy, through the introduction of income-generating schemes in conjunction with rural electrification projects.

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