Report

IRENA
International Renewable Energy Agency

Pacific Lighthouses

Renewable energy opportunities and challenges in the Pacific Islands region

Fiji

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.
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Note on currency:
On October 23, 2012, the exchange rate was FJD 1.773 per USD

(Note the devaluation of the Fiji dollar in April 2009, so that the rate was FJD 1.76 per USD 1 on 14 April 2009 and was and 2.14 per USD 1 on 15 April 2009.)

Preface

In the Abu Dhabi Communiqué on accelerating renewable energy uptake for the Pacific Islands (of 13 January 2012), leaders from the Pacific Island Countries and Territories (PICTs) called on the International Renewable Energy Agency (IRENA) to "…map the Renewable Energy Readiness of the Pacific Islands Countries and Territories to ascertain the status of renewable energy opportunities and identify pathways to close gaps" and to integrate all IRENA activities in the region "…into a coherent roadmap for the Pacific Islands". In response, IRENA has carried out a wide range of activities of specific relevance and application to the PICTs as well as other Small Island Developing States (SIDS). This work has now been integrated into the IRENA report: ***Pacific Lighthouses: Renewable Energy Roadmapping for Islands***.

The report consists of an overview roadmap framework and 15 island-specific studies on the respective energy situations, and the challenges and opportunities for renewable energy deployment, around the region. These studies are available for the Cook Islands, the Federated States of Micronesia, the Republic of Fiji, Kiribati, the Republic of the Marshall Islands, the Republic of Nauru, Niue, the Republic of Palau, Papua New Guinea, Samoa, the Solomon Islands, the Kingdom of Tonga, Tokelau, Tuvalu and the Republic of Vanuatu. The IRENA Pacific Lighthouses report draws on those studies, as well as an additional study on a diesel-renewable energy hybrid power system, intended as a transition measure to a renewables-based energy future for the PICTs, which is also part of the series.

IRENA, in collaboration with its members and other key development partners, will continue to support the development national roadmaps and strategies aimed at enhanced deployment of renewables in the Pacific and other island states and territories.

Acronyms

FDOE	Fiji Department of Energy
FEA	Fiji Electricity Authority
FJD	Fiji Dollar (currency)
FSC	Fiji Sugar Corporation
GDP	Gross Domestic Product
GWh	Gigawatt hours (thousands of millions of watt hours)
kT	Kilotonnes (thousands of tonnes)
kVA	Kilovolt amperes (Voltage times amperes – measure of power)
kVarh	Kilovolt amperes reactive hours
kW	Kilowatt (thousands of watts)
kW/m	Kilowatt per metre (measure of wave energy)
kWh/m^2	Kilowatt hours per square meter (Solar measurement)
kWh/day	Kilowatt-hours per day (thousand watt-hours per 24 hour period)
LPG	Liquefied Petroleum Gas
m	Metres
ML	Mega litre (million litres)
MW	Megawatt (millions of Watts)
OTEC	Ocean Thermal Energy Conversion
PV	Photovoltaics
REP	Rural Electrification Programme
RESCO	Renewable Energy Service Company
SHS	Solar Home System
USAID	United States Agency for International Development

1. Country context

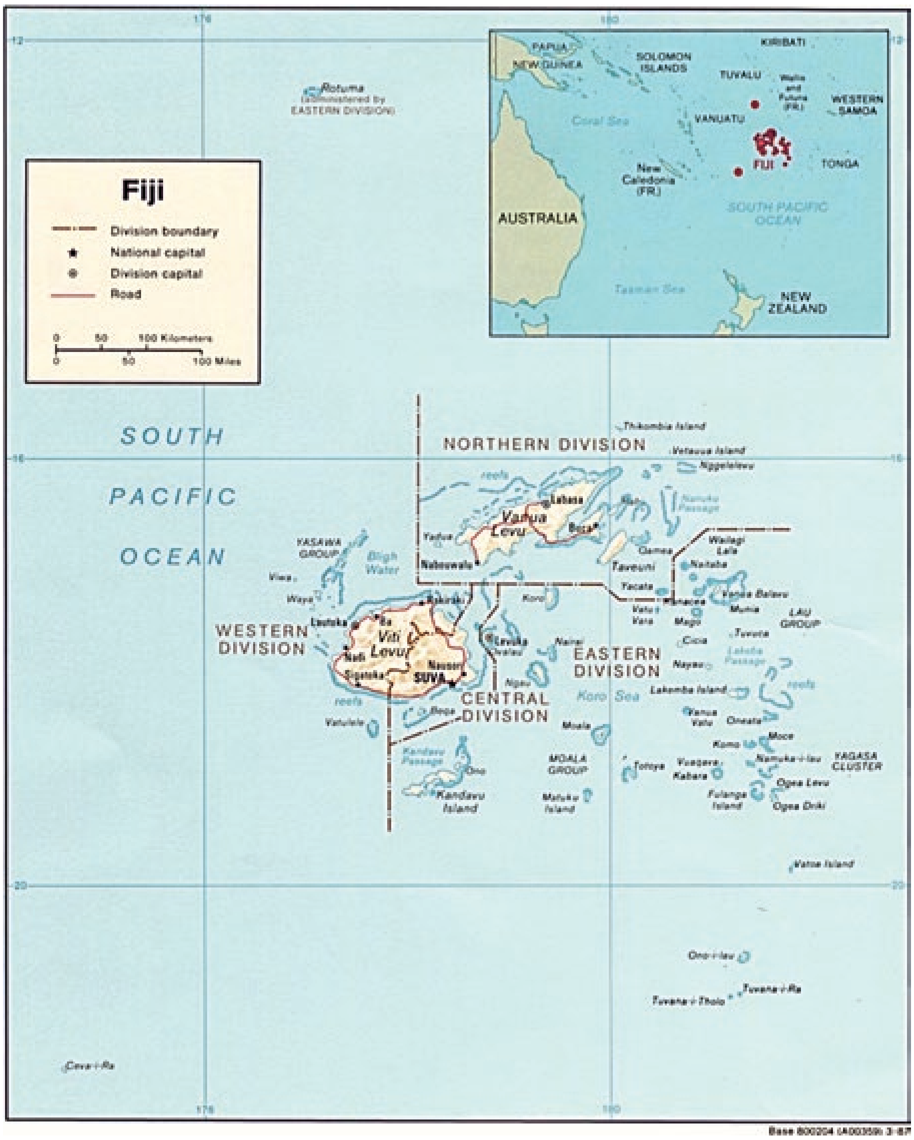


Figure 1. Map of Fiji and its location in the Pacific

Source: www.lib.utexas.edu/maps

The boundaries and names shown on this map do not imply official acceptance or endorsement by the International Renewable Energy Agency.

Physical description. Fiji lies between 177°and 178° east longitude, and between 12° and 22° south latitude, with a land area of 18 333 square kilometres (km^2) and includes 320 islands of which about a third are inhabited. The majority of the land mass is on continental-like volcanic islands that rise to well over 1 000 metres in elevation, although many of the outer islands are low-lying raised coral or atoll-type islands. Over 87% of the land is concentrated on the two main islands of Viti Levu and Vanua Levu. Fiji's climate is tropical, averaging 26°C with annual rainfall ranging from 1 800 millimetres (mm) to 2 600 mm. Fiji is considerably richer in natural resources than its Polynesian and Micronesian neighbours, with extensive timber, rich soils, mineral deposits and fish.

Yet the country is subject to earthquakes, landslides, tsunamis, cyclones, flooding and storm surges, making it second only to Papua New Guinea as the Pacific island country most affected by natural disasters since 1990.

Population. The most recent census was held in 2007, when Fiji's population was 837 271 with an annual average growth rate of only 0.7% since 1996. About 50.7% of the population is urban with over 250 000 people living in the Suva-Nausori-Lami corridor. Nearly 80% of the population live on Viti Levu which occupies 57% of the country's land area, while 95% of the population live on the three largest islands having 90% of land area. Between 1986 and 1996, a significant percentage of Fiji's labour force emigrated, resulting in a huge loss of skilled, experienced people. Continuing emigration remains a serious issue for the country.

Economic overview. According to the Fiji Bureau of Statistics, price-adjusted GDP fell for four years in a row between 2007 and 2012 (an overall GDP growth of -1.1% in 2007, -0.4% in 2008, -1.9% in 2009 and -0.4% in 2010), partly due to a further decline in the sugar industry, investor risk perceptions, and the general world recession that began in 2008.

The sugar industry, one of Fiji's economic backbones, has been declining since 1994 and requires considerable restructuring to survive.

2. The energy landscape

Institutional and regulatory arrangements for energy

Acts of Parliament. A number of Acts of Parliament provide legal oversight of the energy sector. These include the Electricity Act, which established the Fiji Electricity Authority (FEA); the Petroleum Act establishing standards for fuel storage and transport; the Fuel and Power Emergency Act, which regulates supply, distribution and use of fuel and electric power during emergencies; the Public Enterprise Act for restructuring and regulating government commercial companies in the public interest; and the Commerce Act, which promotes competition and reviews electricity tariffs. A Renewable Energy Based Rural Electrification Bill was proposed in 2002 to provide a private sector mechanism for managing renewable energy services, particularly in remote areas and is still being considered as part of the legislation that is used to promote renewable energy expansion.

Department of Energy. The Fiji Department of Energy (FDOE) is the largest government energy agency in the Pacific islands region with approximately 70 employees. From 1993 to date, the FDOE notes that Fiji has spent well over FJD 100 million (approximately USD 56 million) for rural electrification. According to FDOE, electricity coverage in 2012 stood at around 92–95%. In addition the Department aims to have 100% electricity access by 2016. The FDOE states that it is confident that this goal will be reached as a result of the work that is being done to develop the energy resources of the country.

Fiji Electricity Authority (FEA). The FEA is a government-owned power utility with over 600 staff. It is responsible for electricity supply nationally "where financially and economically viable" and operates on the islands of Viti Levu, Vanua Levu and Ovalau. The utility is essentially self-regulating although there have been discussions that could lead to the regulatory functions shifting to an independent external body.

There are also small grids at outer island government centres that were established to electrify government facilities but have grown to include a number of surrounding private residences and buildings. They are all diesel powered and include government centres of Rotuma, Kadavu, Nabouwalu, Koro, Gau, Lakeba, Vanuabalavu, Taveuni, Moala and Cicia.

Commerce Commission. The Commerce Commission establishes and enforces maximum petroleum prices for motor spirit, kerosene, liquefied petroleum gas (LPG) and automotive diesel oil. Three companies (Mobil, Pacific Energy and Total) import petroleum products into Fiji. LPG is imported by Fiji Gas and Bluegas and is also price-controlled.

National Energy Policy 2006. The overall goal of the national energy policy is for an energy sector in Fiji that is efficient, cost-effective and environmentally sustainable. The policy has four strategic areas covering energy planning, energy security, power sector reform and renewable energy. The power sector reform includes establishment of Renewable Energy Service Companies (RESCOs) and increased funding for the rural electrification programme (REP). The heavily-subsidised REP, which operates under the FDOE, provides diesel gensets with a mini-grid system operated at the village level, small hydro where practical, and solar photovoltaics (PV) for lighting and basic appliances. Rural grid extensions that FEA does not consider economically attractive are also provided under the REP.

Energy supply and demand

Petroleum. Fiji is a major distribution centre for the South Pacific and so there are large volumes of fuel that are imported and then exported to other island countries and territories in the region. Table 1 shows domestic use (imports minus exports) by fuel category for 2005 to 2009, the latest dates available at the time of compiling the data.

Electricity generation and demand. The FEA has an extensive grid system on Viti Levu and three smaller grids on Vanua Levu and Ovalau. Over half of Viti Levu's power comes from hydro, diesel generators, a 10 Megawatt (MW) wind farm, and some power generated privately from burning bagasse and wood mill waste. Except for a small hydro system on Vanua Levu, all other FEA generation is diesel-based. Although more hydropower is being brought on-line, it is barely adequate to keep up with load growth. In 2010 the FEA had 14 power stations with 194 MW of installed capacity, including over 85 MW of hydro. The peak load in 2011 was 139 MW. Viti Levu accounts for 90% of generation, Vanua Levu

Table 1. Domestic Fuel Use 2005 to 2009 (in litres)

Categories	2005	2006	2007	2008	2009
Motor spirits	49 144 081	61 414 323	60 520 397	49 404 282	69 270 459
Jet fuel	93 551 555	152 359 776	141 588 270	112 649 150	137 361 129
Automotive diesel oil	101 524 300	70 727 269	50 011 951	33 922 843	141 560 188
Industrial diesel oil	277 990 307	313 252 830	263 630 457	235 182 797	111 653 817
Total	522 212 248	596 801 204	515 753 082	431 161 088	459 847 602

Source: Unpublished presentation at ESCAP (Oct 2012) High Level Policy Dialogue on Macro Economic Framework and Energy Security Situation in the Pacific.

8% and Ovalau 2%. Growth in generation has been uneven but averaged 6.4% from 1997 through 2003. Average transmission and distribution losses were 9.9%, 8.2% and 11.7% for the Viti Levu, Savusavu and Labasa systems respectively.

The FEA hopes that additional national and private sector investments in hydro, geothermal, wind, biomass and municipal waste to energy projects will add more renewable energy to the national energy matrix. However, demand for energy is growing fast; the Reserve Bank of Fiji estimates a demand growth rate of 4% for overall energy and 5% for electricity. This provides opportunities for increased power generation and integration from renewable sources into the main grid to keep up with demand. In July 2012, a public broadcast by the FEA said that it would need to invest around FJD 1.5 billion (USD 0.83 billion) by 2020 to keep up with the growth in energy demand.

In the FEA's 10-year Power Development Plan for 2010-2020 renewable energy plays an important role. Table 2 summarises the planned renewable capacity additions through to 2017.

In 2010 around 66.8% of FEA's power delivery came from renewable energy with 62.1% hydro, 0.6% wind and 4.1% from biomass generation by Fiji Sugar Company (FSC) and Tropik Wood Industries Ltd. The remaining 33.2% was generated by diesel engines according to the FEA's figures.

The majority of hydro input is from the Monasavu installation with its 81.2 MW of generation located at Wailoa. Other hydro installations include Nagado (3.3 MW), Wainiqeu (0.8 MW), and Nadarivatu (44 MW). The mix of thermal and hydropower for 1990–2008 is shown in Figure 2.

Diesel generation is provided from plants at Kinoya (50.32 MW), Vuda (24 MW), Sigatoka (4 MW), Nadi (2 MW), Rakiraki (2 MW), Korovou (1 MW), Deuba (4.5 MW), Savusavu (3 MW), Labasa (10.8 MW), and Levuka (3 MW), reaching a total of 104.62 MW. There is also 10 MW of rated capacity in a wind farm near Sigatoka on Viti Levu (see Section 4 for details).

A 10 kW grid-connected solar installation at the FEA Lautoka facility was installed as a grid-connection trial by FEA in the late 1990s but is now out of service due to an inverter failure and is not expected to be repaired as it was installed as an experiment that has run its course.

FEA expects to be able to reduce the percentage of thermal generation by 2015 through the expansion of hydro and other renewable energy inputs.

Table 2. Planned renewable energy additions to FEA capacity (2013–2017)

Technology	Total capacity planned (MW)	Location
Biomass thermal	106.5	Viti Levu, Vanua Levu
Biomass gasification	9.4	Vanua Levu, Ovalau
Hydro	57	Viti Levu
Geothermal	8	Vanua Levu

Source: Executive Summary, FEA Power Development Plan for Viti Levu, Vanua Levu and Ovolau (2011).

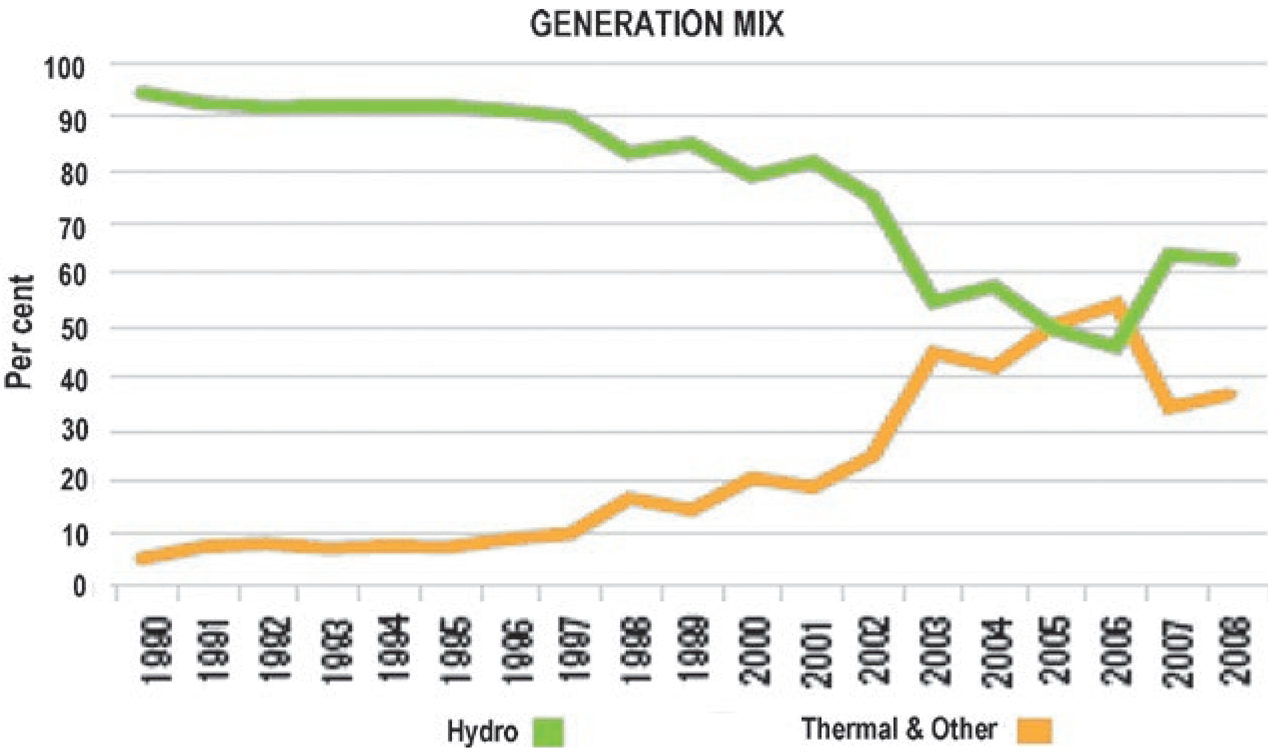


Figure 2. FEA Generation Mix

Source: FEA Annual Report (2011).

In 2011 renewables contributed 489 GWh to the total energy generated. Thermal power plants contributed 340 GWh and IPPs 36 GWh according to the FEA's annual report for that year.

There are three user sectors defined by the FEA for billing purposes – industrial, commercial and domestic. Table 3 shows the use patterns of the three sectors from 2008 through 2010. In 2010 the domestic sector took 30.4% of the total demand, commercial (which includes government) was the largest user at 44.7%, and industrial users accounted for about 24.9% of the total demand.

With regards rural electrification, the FEA continues to extend the main grid to rural areas while the Department of Works manages small grids that serve provincial centres. Additionally, villages develop their own diesel-based grids with the support of the FDOE. Since 1993, more than 900 communities have applied to FDOE for rural electrification and over 600 diesel systems have been commissioned, serving around 7 500

Table 3. Sales between 2008–2010 (kWh)

Sector	2008	2009	2010
Industrial	176 103 520	172 274 337	190 224 808
Commercial	317 811 591	317 207 755	341 456 980
Domestic	224 510 517	225 814 165	232 550 244
TOTAL	718 425 628	715 296 257	764 232 032

Source: Fiji Bureau of Statistics (September 2011).

households, typically for four and a half hours daily. An unknown, but significant, number of these systems no longer function due to poor management, poor operation and maintenance, and high fuel costs. The cost of power from these village diesel generators is around FJD 2.00/kWh (USD 1.13/kWh) and stand-alone solar is a cost-competitive option with around 2000 homes with solar home systems installed and around 1000 more planned for installation in 2013 with funding from Japan.

In 2000, the most recent year for which FDOE has attempted to prepare an energy balance, Fiji imported about 330 ML of petroleum fuels, excluding LPG and re-exports. However, the data are imprecise. Due to rural electrification efforts, the percentage of homes with an electricity supply has steadily increased. In 1996, only 67% of households had some sort of electricity supply, 86% of which were supplied by the FEA; 7% used their own generators; 5% were connected to village grids; and 2% received power from other small industrial or government grids. As a result, 87% of urban and 49% of rural households had access to electricity, the latter often for only a few hours per day. As of 2011, roughly half of households cooked mainly with wood on open fires while around 30% used LPG, 20% kerosene, and 3% electricity. In contrast, some 82% of homes surveyed had electric lighting (including rural solar home systems) and 37% use kerosene or benzene lamps. About 55% of petroleum fuel is used for transport, 26% for electricity generation (public and private), 8% for industry, 8% for households and 3% in businesses.

Electricity tariffs. There is a national tariff, but the real cost varies greatly, with supply to rural Ovalau being several times the cost to urban Viti Levu, implying a cross-subsidy from urban to rural consumers. The FEA does not provide services to uneconomic remote areas along its grid unless there is a subsidy from the government or sufficient capital contribution from the customers. Although a national tariff is politically expedient, in the past it has seriously hindered efforts to develop rural electrification since generation costs in rural areas are substantially higher than the national tariff. It also has hindered efforts to encourage consumer energy efficiency in high-cost areas. Table 4 shows the national tariff that was in force in early 2013.

Table 4. National Tariff in force in early 2013 (On 15 Jan, 2013, the exchange rate was FJD 1.758 = USD 1)

Tariff Categories	Current Tariff Rates (cents/unit)	Approved Tariff Rates (cents/unit) Effective 7 November 2010	Approved Tariff Rates (cents/unit) Effective 1 April 2011
Domestic Lifeline Tariff (prior to 7 November, 2010) Domestic lifeline cents per unit. Less than or equal to (<=) 130 kWh per month	17.20 cents	No longer applicable	No longer applicable
Domestic Tariff (applicable from 7 November 2010, onwards) Cents per unit. Less than or equal to (<=) 75 kWh per month Note: The government will subsidise at the rate of 17.64 cents per unit for all consumption equal to or less than 75 kWh per month	-----	34.84 cents (17.64 cents/unit will be subsidised by the government and hence in effect, the customer will pay only 17.20 cents/unit)	34.84 cents (17.64 cents/unit will be subsidised by the government and hence in effect, the customer will pay only 17.20 cents/unit)
Cents per unit – greater than >75 kWh per month will **not** be entitled to government subsidy. All consumption will be charged at the rate of 34.84 cents per unit.	34.84 cents	34.84 cents	34.84 cents
The current VAT rebate, applicable on the first FJD 30 of the monthly bill for domestic customers, is removed.			
Commercial and Industrial Tariff Cents per unit – for units up to 14 999 kWh per month	37.47 cents	39.34 cents	42.00 cents
Commercial and Industrial Tariff Cents per unit – for units in excess of 14 999 kWh per month	39.47 cents	41.44 cents	44.00 cents
Maximum Demand Tariff (i) Demands over 1000 kW Demand Charge FJD per kW per month Energy Charge in cents per kWh	FJD 27.59/kW 18.81 cents	FJD 33.11/kW 24.92 cents	FJD 40.20/kW 33.50 cents
(ii) Demands between 500 kW to 1000 kW Demand Charge FJD per kW per month Energy Charge in cents per kWh	FJD 27.59/kW 20.88 cents	FJD 31.73/kW 25.06 cents	FJD 38.50/kW 31.00 cents
(iii) Demands between 75 kW to 500 kW Demand Charge FJD per kW per month Energy Charge in cents per kWh Excess Reactive Energy penalty fee in cents per kVArh	FJD 27.59/kW 21.58 cents 19.64 cents	FJD 31.73/kW 24.82 cents 44.00 cents	FJD 36.20/kW 28.50 cents 44.00 cents
Maximum Demand and Commercial & Industrial consumers who elect to take a power supply directly at the high voltage, receive a discount of 4% on their monthly bill.			

Source FEA (2013) http://www.fea.com.fj/pages.cfm/customer-care/tarriffs-rates.html

3. Renewable energy opportunities

Incentives. Fiji has enacted incentives for the implementation of renewable energy systems. There are zero fiscal and import duties on a wide range of renewable energy equipment, including wind power resource monitoring instruments; hydro, solar and various equipment for renewable energy generation. For biofuel production, there is duty-free concession for both plant and the chemicals required for biofuel manufacture. Furthermore, a 10-year income tax exemption is offered for companies that are involved in biofuel production. A five-year tax holiday is offered to tax-payers undertaking a new activity in renewable energy projects and power cogeneration.

In late 2012, the Reserve Bank of Fiji extended the eligibility list on its Import Substitution and Export Finance Facility to include renewable energy for import substitution funding. This can assist in accessing concessional rates of interest for activities relating to renewable energy that can provide import substitution effects, such as reducing the import of fossil fuels.

Biomass. Biomass probably still provides about 50% of gross energy use in Fiji. About 700 kilotonnes (kT) of bagasse (crushed cane stalks) are burned at sugar mills, producing process heat and electricity. About 250 kT of biomass is used for household cooking and around 100 kT for copra drying. Forests cover about 47% of Fiji's total land area, with plantation forests accounting for 13% of the total forest area. Although large amounts of biomass are available from forest waste, most of this waste is located where it has little economic value. With Fiji's falling sugar production, less bagasse is available for power generation, thus increasing diesel fuel use.

Bioenergy. Fiji produces coconut oil, which in principle could be used as a diesel oil replacement. Sugar and other crops such as cassava could be used to produce sufficient ethanol to replace a significant percentage of petrol use.

Municipal solid wastes. Nearly 100 kT per year of municipal solid waste are delivered to a landfill serving the greater Suva area. This could reach a volume sufficient to produce about 5 MW of electricity for the FEA grid if existing waste-to-energy conversion systems become economically and technically reasonable for Fiji.

Biogas. Biogas generation from urban sewage could also add more than 1 MW of electricity generation for FEA. Fiji's numerous piggeries, dairy farms and poultry farms suggest the presence of another resource for small-scale biogas production, but the volumes that could be practically used are unknown.

Solar power. Solar radiation has been measured at nine stations in Fiji for some years with some other data available for shorter terms. The measurements at Nadi record the highest long-term annual average of 5.1 kWh/m^2, peaking between November and February; Vanua Balavu (Lau) readings recorded 5 kWh/m^2, and Bua (Vanua Levu) measurements recorded 4.5 kWh/m^2. The lowest long-term readings are near the Monasavu hydro site in VitiLevu's highlands with 3.7 kWh/m^2. However, these measurements are based on horizontally mounted pyranometers. Actual solar energy received by PV or thermal collectors would be both higher and more evenly distributed throughout the year as the collectors are usually tilted toward the sun.

Wind power. Eight sites in Fiji have been collecting long-term wind data with mast heights varying from 10 to 48 metres (m). Ideal wind energy measurements are made at a minimum of 30 m, although 50 m is preferred. Future wind measurement installations are to be all at 50 m. So far, measurements near the grid indicate that Fiji's wind speeds offer marginal benefits for energy generation compared to the FEA's historical generation costs. Some sites should be cost-effective for wind power installations given the FEA's marginal costs for investments in new diesel generators.

As the FDOE has gained experience with wind monitoring, installation of monitoring systems has become more consistent, with most instruments now being installed at the 30 m level and future measurements installations planed to be at 50 m. Some recent 30 m measurement sites away from the grid, notably at Nacamaki on Koro and Wainiaku on Taveuni, show better than 7 metres per second (m/s), which could favour community-scale mini-grid generation from wind turbines, although cyclone passages through the area could be a limiting factor. Promising sites near population centres could be economically feasible for larger wind projects.

Hydropower. The untapped developable hydroelectric potential on Viti Levu is probably in the order of 200 MW with an average annual output of 1000 GWh. Micro-hydro (under 100 kW) and mini-hydro (100–1500 kW) potential has been studied by the FDOE at sites near communities not served by the FEA. Surveys have been conducted at 38 of these smaller sites on six islands showing a total of 3.2 MW of likely capacity that may be technically and economically feasible, while 20 more sites totalling about 0.4 MW still require extra monitoring. Many other sites are yet to be assessed.

Ocean thermal energy conversion (OTEC). The temperature difference between the ocean surface and depth can be harnessed for electric power generation and for heating and cooling. However, no commercially viable OTEC installations in the Pacific islands region have yet been built to date, although there has been a revival of interest in the technology in recent years.

Wave energy. In the early 1990s waverider buoys were used to measure eave energy potential. The results indicated an annual average wave power of 22.9 kilowatt per metre (kW/m) of wavefront near Kadavu. Satellite studies have indicated 6–29 kW/m at a number of near-shore locations in Fiji.

Geothermal energy. Preliminary assessments indicate considerable potential for geothermal-based power generation at Labasa and Savusavu on Vanua Levu. There are numerous other sites in Vanua Levu and Viti Levu where perhaps 5–15 MW or more of power could be generated. However, the drilling necessary to confirm the magnitude of the resource and for its subsequent development could be costly. Access to major loads from the known geothermal fields is also likely to be very expensive.

4. Experiences with renewable energy technologies

Historical background

Fiji's experience with renewable energy dates from about 1980. The resource potential in the country is generally very good and Fiji currently has the highest percentage of renewable energy in its energy mix of all Pacific island countries.

Biomass. Biomass has traditionally been used mainly for cooking and copra drying. In the 1980s, several hundred improved cookstoves were produced to improve women's cooking conditions and to reduce the need for gathering fuelwood. Although the stoves were not widely accepted in residences, this programme led to wider acceptance and the use of biomass-burning stoves in institutions such as schools, where they are still widely used today.

In 1979 a robust 20 kW wood/coconut waste steam power system was installed in Taveuni for copra drying and electricity production. It is still operating, although the technology has been updated several times. In 1987 a similar system, commissioned at a nearby village to supply electricity to 47 homes for 4–8 hours daily, operated intermittently for a decade.

Coconut oil. Coconut oil has been used as an alternative to diesel fuel in power generators at two rural locations – an 80 kilovolts-ampere (kVA) generator which provided electricity for 198 households in Vanuabalavu, Lau, and a 45 kVA generator used to electrify 60 households in Taveuni. The technology appears to be technically viable but there were difficulties with local management of operations and *in situ* production of oil. When the Vanuabalavu coconut oil production system – which was external to the electrification project – closed down, expensive coconut oil had to be imported from other islands and so the engines were switched over to diesel. The Taveuni plant also converted to run on diesel fuel only when its fuel-switching valve failed and was never repaired.

In the 1990s numerous trials were conducted with coconut oil blended with diesel fuel or kerosene. These mixtures were generally technically acceptable but were not sufficiently cheaper than diesel fuel alone to make them commercially attractive.

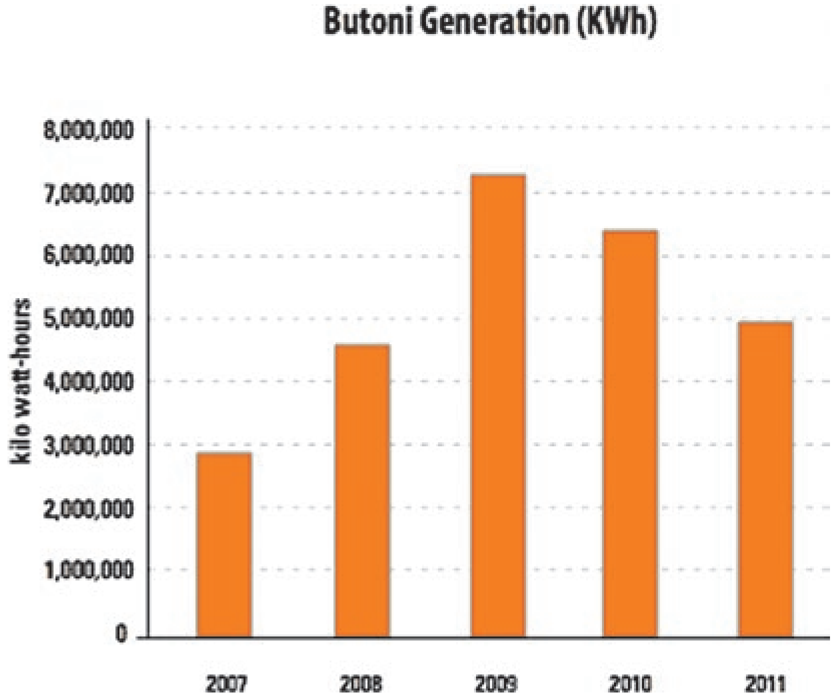
Biogas. Biogas digesters have been tried at small piggeries and dairies for 30 years in Fiji but there have been maintenance problems. Also, farmers found that the time and trouble of keeping the digesters operating was excessive for the energy gained. New designs, better suited to Fiji and emphasising waste control rather than energy, have been tried with more successful results. The biogas produced is mostly used for cooking and the digested material is used as fertiliser.

Bioethanol. Around 1980, during an oil price peak, the Government, the FSC and oil companies considered producing 10–15 ML of ethanol per year from sources such sugar, molasses, or sorghum for blending with petrol. All offered only marginal economic benefits and the plans were abandoned.

Gasifiers. In the 1980s, the FEA experimented with biomass gasification for power production but found the technology unsuitable. Several village energy systems using gasifiers were slated for installation by the EU-funded Lomé II Pacific Regional Energy Programme in the late 1980s but were never constructed due to the poor performance of similar installations in other Pacific island countries.

Microhydro. Small hydro systems have been successfully used at missions and plantations for over a century. In the 1980s and 1990s, five village-scale hydro systems were built in Fiji for small electrical loads – mainly village electrification – but there were technical problems with their electrical systems. Combined with difficult site access, lack of access to financial resources, and limited technical skills in the villages, the result was long power outages, high repair costs, and ultimately the abandonment of the systems.

Solar PV. In 1983, rural electrification through PV with a RESCO management structure was first tried in Fiji at Namara (Kadavu) and Vatulele (Koro) with between 30 and 40 solar PV systems each. Under this arrangement households paid FJD 25 initially, but falling to FJD 3–4 per month. Installations were funded by United States Agency for International Development (USAID) through the Peace Corps. A third installation was scheduled on Totoya but the island's Peace Corps volunteers left early and the installation never took place. The Koro project failed after the Peace Corps volunteer manager left and the village cooperative spent the accumulated funds on other projects, leaving no money for battery replacements. The Namara cooperative also failed as an organisation after the departure of the local Peace Corps



Source: FEA Annual Report 2011.

Figure 2. Electricity generation load curves

volunteer, although its management was taken over by village leaders who successfully maintained the systems through a community structure they established using the technician trained under the original project. Several projects in the late 1980s and mid-1990s increased panel capacity at Namara and provided high-quality battery replacements allowing the project to continue operating to the present day. The Namara solar installation may be the longest continuously running solar electrification project in the Pacific islands region. Although these early pilot projects provided much useful information for later PV projects, they were themselves not considered successful general models for rural electrification projects in the region.

Around 1987, over 100 solar home systems (SHS), similar to the 1983 designs were installed in cane farm settlements in Viti Levu. They were maintained by the FDOE with a monthly fee of FJD 4.50. However, the systems were under-sized causing customer dissatisfaction which, combined with other challenges, led to the project being abandoned.

In the late 1980s PV electrification was tried at ten community centres to provide lighting and video power in rural Viti Levu. Results were mixed, neither very positive nor complete failures.

The village of Naroi on the island of Moala was electrified in 1999 using solar home systems provided by France. The systems used 100 Watt-peak (Wp) of panels, a high-quality industrial battery, and a French-designed charge control system that included a type of prepayment meter that would turn on the power for a month if a 16-digit code generated by the FDOE was entered. The codes were sent by radio to the post office near Naroi where, for FJD 14.50 (USD 7.35) villagers could purchase the code and obtain a month's electricity supply. The FDOE received FJD 14 (USD 7.10) and the Post Office the remaining FJD 0.50 (USD 0.253) for their clerical services. Local technicians were trained in maintenance and placed under FDOE contract. Problems included poor performance by the technicians due to inadequate supervision by FDOE, high costs due to failures of the expensive pre-payment meters and loss of confidence in the programme due to failed systems not being repaired. Although the project could not be considered a success, the lessons learned from it were later used in designing the larger-scale Vanua Levu projects that currently form the FDOE's primary solar-based rural electrification efforts.

Solar thermal. Solar water heaters are considered commercially viable and have been locally manufactured since the 1970s. Thousands of locally made and imported systems are installed in homes and tourist facilities.

Solar pumping. The Public Works Department has installed several solar-powered borehole pumps for village water supply, all of which have had technical problems and most are not currently in service.

Wind power. Although Fiji Telecom utilised a number of small wind generators for remote site battery charging in the 1990s, they were soon replaced by solar PV which proved more robust and had lower maintenance cost. After that, wind turbines were little utilised until the Butoni wind farm consisting of 37 Vergnet 275 kW turbines was installed in 2007. The turbines are able to be tilted down to avoid damage from cyclones, a serious problem in Fiji. The site has a measured average wind speed of 5.6 m/s, a moderate level of wind energy for power generation. Although the first year of operation was not profitable, in later years the performance has been much better, although there is clearly a substantial variation from year to year.

Some lessons learned. Experiences from the examples described provided important lessons for later rural renewable energy technology applications in Fiji.

- Rural renewable energy installations require high-quality, reliable components. The more remote the site, the more critical is the long life and high reliability of the service. Reliability for energy equipment requires properly designed components proven to perform well in Fiji's local environment.
- Village technical management, maintenance, money management and repair have generally been poor, even when fees have been charged to households for services. Better training of technicians is essential and is needed on a continuing basis.
- Recipients need to place a high priority on the services provided by renewable energy systems or the systems are very likely to fail. Recipients must be committed to properly operate the systems, pay for costs, and care for the project.
- Under-sizing of systems results in overloading and high failure rates. In the long run, it is more cost-effective to oversize systems.
- An external authority is needed for operation, maintenance and fee collection if village energy systems are to be successful in the long term. Village-based institutional structures do not generally have the technical ability, management competence or discipline to enforce fee collection and proper maintenance. However, any such external authority must provide proper maintenance, repairs and reliable services otherwise fee collection rates will be poor due to a lack of confidence among villagers that the money paid will actually result in the desired services.

Current status and plans

Current Fijian experience with renewable energy and plans for the future (excluding large-scale hydro projects by FEA which are covered in the *The energy landscape* section of this report) include:

Micro/mini hydro. The installed capacity of micro/mini hydro is around 1 000 kW, 80% of which is accounted for by the FEA's Wainikeu system in Vanua Levu. Four sites being monitored and considered for development by the FDOE have a combined potential of at least 220 kW, possibly much more.

Bioenergy. In 2010**,** the FDOE contracted Niu Industries, a producer of small modular coconut oil mills, to install three such mills on the islands of Koro, Rotuma and Cicia. Also in 2012, an additional six plants in the Lau and Lomaiviti islands of Fiji were installed by the FDOE to "reduce the consumption and the dependency of diesel fuel for people living in outer islands but also to provide easy and cheaper fuel for rural electrification". The FDOE also noted: "These mills primarily produce bio-fuel and copra meal with the core objective of assisting these communities in overcoming the hardship encountered with delivery and cost of diesel to the islands. The project ensures that copra farmers get a better return for their produce and lowering fuel costs at the same time."

The traditional method for coconut oil production is to cut the copra in the outer islands and ship it to a central mill for processing. However, since shipping costs have increased with rising fuel costs, there remains less of a margin for profit. Creating the oil where the coconut resource is located improves production and offers an immediate return to the farmer who traditionally had to wait till the copra reached the central mill weeks later to get payment. The main concerns with this local production system have been quality control and continuity of supply. To address quality control problems, the FDOE provides technical and maintenance support to the community-run mills. Supply problems are minimised, since the reduced shipping costs allow a higher price to be paid for the copra. Quality is also better with local production because the copra is always fresh. Previously copra would be kept for weeks waiting for a ship while mould and other problems reduced its quality. Oil keeps far better than copra, especially if produced soon after the copra is dried, and so irregular shipping schedules cease to be a problem. The project has worked well enough to consider its expansion to more islands, and even to other Pacific countries and territories.

In 2011, the Fiji Cabinet approved biofuel standards covering both biodiesel and bioethanol which should help support the expansion and commercialisation of biofuel products. As part of the standards, up to a 5% blend of coconut oil and diesel fuel and up to a 10% blend of ethanol and petrol are allowed for commercial sale. Also, government vehicles are required to start using biofuel where available.

Traditional uses for cooking and drying of copra remain the primary demand for biomass energy. The bulk of sugar mill waste (bagasse) is used for providing process heat and electricity for the mill, with only the surplus electricity sold to FEA. The relatively small Labasa grid is largely supplied by sugar mill bagasse during crushing seasons. Current installed capacity at the FSC is 4 MW at Ba, 3 MW at Rakiraki, 5 MW at Lautoka and 4 MW at Labasa.

Tropik Wood Industries Ltd, the primary mill operator handling the Caribbean Pine plantation production, also generates process steam and electricity for its plant at Drasa near Lautoka. Surplus electricity is sold to the grid from the company's 9.3 MW cogeneration facility.

At the Tarte coconut plantation on Taveuni, a small (approximately 20 kW) alternator is turned by a piston-type steam engine using steam from a boiler fired by coconut waste. The plant, which has been operating since 1979, provides energy for the plantation and an associated village. Based on its success, a similar but smaller 5 kW facility was installed at the Taveuni village of Nakakawau in 1987 using USAID funding. The system provided steam and electricity off and on for almost a decade before finally being abandoned.

Besides the small-scale biogas digesters that have been installed on pig farms and dairies through the FDOE, the PWD in 2003 began building a locally financed biogas system at Suva's sewage treatment plant in Kinoya, adjacent to one of the FEA diesel power plants. The system was only partially built, although if completed, it could probably fuel a 250 kW engine providing electricity for internal use at the sewage plant. Landfill gas also could be a useful resource but so far has not been utilised.

Solar PV. The continued expansion of Vanua Levu SHS since the initial pilot project in the year 2000 has resulted in around 2000 households being electrified through solar PV systems supplied by the FDOE RESCO. Another 1000 rural homes are expected to be electrified by solar home systems in 2013. In this approach, a variant of the Kiribati "Solar Utility" structure, the FDOE owns the installations, collects a monthly fee and provides all maintenance and repairs through a private contractor. This is not the true RESCO approach, given that the maintenance company is paid by the FDOE and not by the customers themselves. This means that there is less incentive to provide the high-quality support services and rapid repairs that inspire customers to quickly resume fee payments after a system failure. The approach is highly subsidised by the FDOE, but has been operating with reasonable levels of service reliability for over a decade.

In 2010 RESCO customers were interviewed by an Australian National University team, which found that installations were poorly maintained with some households having to wait more than a year for repairs. A majority of the households surveyed considered that the service they received was poor but remained with it because they did not want to go back to using kerosene for lighting.

Many outer island telephone exchanges and remote installations on the main islands use solar power, but no details are available.

Grid-connected photovoltaics. The relatively low cost of power in Fiji has been a deterrent to the addition of solar PV to the grid. A few small installations have been connected but FEA has no general policy regarding the connection of solar to the grid by private parties. The largest installation is the 54 kilowatt-peak (kWp) installation at the University of the South Pacific in Suva that is part of a renewable energy project funded by the Korea International Cooperation Agency (KOICA) which also includes capacity building, and a resource monitoring and data centre.

Wind systems. A small 20 kW Vergnet wind system was installed at the headquarters of the South Pacific Applied Geoscience Commission (SOPAC) in Suva in 2004 but the turbine came apart in high winds and was never repaired.

In 2002 the FEA commenced a joint wind farm venture with Pacific Hydro Ltd of Australia but Pacific Hydro did not consider the selected site as financially attractive and pulled out in 2003. FEA continued with the project after engaging PB Consultants of Australia to provide technical advice. Installation of 37 turbines of 275 kW each was completed at Butoni near Sigatoka, Viti Levu in 2006. The turbines are made by Vergnet in France and can be tilted down for protection in the event of a cyclone. This approach was well-proven in New Caledonia in 2003 where several conventional fixed turbines were severely damaged by Cyclone Erika while the tilt-down units in the same wind farm area survived with little damage. As is the case with most renewable energy deployment, the first year of operation was economically disappointing for the project. The FJD 34 million (USD 19.4 million) investments yielded a loss. However, subsequent years have been more economically favourable.

Diesel/wind/PV hybrid. In 1997, PV and wind energy were integrated with an existing diesel generator at Nabouwalu government station in Vanua Levu. The system, operated by the PWD, comprised eight 6.7 kW wind turbines, 37.4 kW of PV and 200 kVA of a diesel-powered generator. The design demand was 720 kWh/day, with 60% intended to come from the renewable sources. Wind and solar initially did provide over 60% but this fell steadily to less than 15% due to the loss of foreign technical support, lack of local capacity to train operators and technicians, and component failures, particularly in the complex automatic interface between the solar, wind and diesel generators. Because fees only covered around 30% of actual operating costs, the PWD had no incentive to maintain the wind and solar components resulting in "diesel creep" – the increase in the diesel component of hybrid energy systems – as diesel operation is easier and better understood than the maintenance and combination operation of the wind and solar components. The wind turbines have now all failed due to corrosion and lack of maintenance. The solar panels are unused.

Small wind installations for battery charging were used for a few years by Fiji Telecom at remote sites but high maintenance requirements resulted in their being replaced by solar battery chargers.

5. Challenges for renewable energy deployment

There are numerous barriers to the successful deployment of the various renewable energy technologies in Fiji. These barriers include fiscal, financial, legislative, regulatory, institutional, technical, business, information, and knowledge and public awareness factors. The specific barriers identified include:

- Electricity legislation is not in place to extend the FEA's mandate to include cost-effective energy conservation (demand side management), internal efficiency improvement (supply side management) and preference for renewable energy wherever it is cost-effective, whether installed by the FEA or private investors. The FEA should have the legal basis and incentives to provide efficient energy services, not just sell electricity.
- There is no sustainable institutional framework, including fee collections, to develop, operate and reliably service rural electrification on a commercial basis. FEA grid extensions are a partial exception, but the capital costs of some remote extensions are highly subsidised.
- Along with other Pacific island countries and territories, Fiji has no national standards or certifications to assure that imported renewable energy technologies are suitable for local conditions. (A similar barrier exists for effective energy efficiency services.)
- Past project failures suggest that renewable energy development is risky for potential investors, making private sector involvement difficult to obtain without the inclusion of risk abatement incentives.
- There is limited expertise in business management and marketing strategies in rural areas.
- Travel to outer islands is expensive, often time-consuming and irregular. Outer islands also have small populations, which makes it difficult to economically develop both public and private renewable energy systems.
- Fiji is susceptible to natural disasters, particularly cyclones, that can damage equipment, such as hydro power systems, wind farms and ground-mounted solar farms, and resources needed to produce energy, such as coconut trees.

IRENA can suggest pathways to overcome these challenges through its Global Renewable Energy Islands Network (GREIN) and believes that regional and national roadmaps should reflect these pathways. IRENA will continue to work with existing regional and national stakeholders to achieve the transition to renewable energy for a secure and sustainable energy supply.

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