Report

IRENA
International Renewable Energy Agency

Pacific Lighthouses

Renewable energy opportunities and challenges in the Pacific Islands region

Papua New Guinea

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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Authors: Mirei Isaka (IRENA), Linus Mofor (IRENA) and Herb Wade (Consultant)

For further information or to provide feedback, please contact: Linus Mofor, IRENA Innovation and Technology Centre. E-mail: LMofor@irena.org or secretariat@irena.org.

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Note on currency:
On October 24, 2012, the exchange rate was Papua New Guinea Kina (PGK) 1.97 per United States dollar (USD).

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

APEC	Asia-Pacific Economic Cooperation
CSO	Community Service Obligation
DPE	Department of Petroleum and Energy
DSP	Development Strategic Plan 2010–30
GWh	Gigawatt hour (thousands of millions of Watt hours)
MTDP	Medium Term Development Plan 2011–15
ML	Megalitres (thousands of kilolitres)
MW	Megawatt (millions of Watts)
OTEC	Ocean Thermal Energy Conversion
PGK	Papua New Guinea Kina (currency)
PIREP	Pacific Islands Renewable Energy Project
PNG	Papua New Guinea
PNGSEL	PNG Sustainable Energy Ltd.
PPL	PNG Power Ltd.
PV	Photovoltaics
SPREP	Secretariat of the Pacific Regional Environment Programme

1. Country context

Figure 1. Map of Papua New Guinea

Source: Adapted from the Perry-Castañeda Library Map Collection, University of Texas.

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

Physical description. Figure 1 shows the map of Papua New Guinea (PNG) which is located in the south-western Pacific Ocean at 6° south latitude and 47° east longitude. It has a total area of approximately 462 840 square kilometres (km^2) and a land area of 452 860 km^2. The country is by far the largest of the Pacific island countries and territories. PNG, located to the east of Indonesia and some 160 km to the north of Australia, has four regions with 22 provinces consisting of over 600 islands. The landscape consists of an extraordinary physical variety of mountainous and costal lowlands.

Population. The World Bank's estimate of the population of PNG stands at just over 7 million people in 2012, with more than 800 indigenous languages. Approximately 87% of the population, which grows at just under 2% per year, live in the rural areas.

Environmental issues. The climate of PNG is tropical. PNG has a large stock of rain forest and biodiversity that are under threat from over-logging, over-hunting, clearing for agriculture and plantations, and trading in threatened or endangered wildlife species. The marine environment is threatened by coral reef destruction. Al-

though about 97% of land is under traditional clan ownership, providing an opportunity for people to manage land for their long-term benefit, there continues to be concerns about instances of inappropriate land acquisition by some developers. Of all the Pacific Islands, PNG is the most affected by natural disasters.

Economic overview. PNG has two distinct economies: a modern cash economy dominated by mining, timber, oil and gas and agricultural exports (coffee, cocoa, tea, oil palm and copra); and a traditional subsistence economy and semi-subsistence farming, with most villages producing little or no surplus for trading. The gross domestic product (GDP) is dominated by exports, mostly relating to large-scale extraction of minerals and plantation-based agriculture. In 2008, exports generated 71% of GDP, and according to the Asian Development Bank (ADB), minerals constitute approximately 77% of all exports, agricultural products 17% and forestry products 5%. Economic growth has varied considerably but averaged at less than 3% annually in real terms since independence in 1975, with per capita income less in 2002 than at independence. Current development plans are aimed at public debt reduction, reduced budget deficits, and more stringent cost controls. GDP growth in 2010 was estimated at 7.1%, largely due to the exploitation of PNG's large natural gas resource currently underway. Natural gas development is expected to provide a major input to GDP growth in the future.

2. Energy landscape

Institutional and regulatory arrangements for energy.

The Energy Division. The Energy Division is part of the Department of Petroleum and Energy (DPE). The Division is responsible for energy policies and plans, data collection and analysis, and advice to the Government on energy sector issues. According to the DPE, extremely limited resources have seriously hampered energy related data collection and analysis. Data collection for renewable energy has been particularly difficult to gather. In practice, the DPE concentrates on electric power, although PNG Power Ltd, the national electricity utility, undertakes most power sector planning.

PNG Power Ltd. PNG Power operates three interconnected distribution systems as well as many provincial power systems. About 100 small rural electricity systems called "C-centres" are operated at government administration centres by local authorities. These systems use diesel generators, small hydro and occasionally solar photovoltaics (PV) for electricity generation. Responsibility for financing, managing and planning of these small grids rests with provincial authorities with many systems not operating well.

The Independent Consumer and Competition Commission. The Independent Consumer and Competition Commission licenses generation of electric power, establishes electricity tariffs and controls the maximum prices of some petroleum fuels. There is a national power tariff for those served by PNG Power though actual power delivery costs are not the same from place to place. Fuel prices are set the same at the four main ports but are considerably higher, though still controlled, in remote areas. The Petroleum Division of DPE is responsible for oil and natural gas exploration and development. Shell, Exxon-Mobil and British Petroleum market most of PNG's petroleum fuel. A 36 000 barrel-per-day refinery began producing fuel for the local market in 2004.

Policies and laws regarding energy. The Division of Energy is responsible for renewable energy and electricity policy. There have been several major policy and energy related studies in recent years, including an Australian Aid-funded energy policy review project, a World Bank assistance to build the capacity of DPE's Petroleum Division, a World Bank-sponsored rural electrification policy and strategy project and a review of petroleum product pricing. Although there have been several drafts of energy policies – with the most recent draft authored in 2011 by the Energy Division – none have yet been adopted and they have no formal status. The key draft policies with regards to renewable energy, that are currently under review or being considered include: the National Energy Policy; the Rural Electrification Policy and Strategy; the Geothermal Energy Policy; the Renewable Energy Policy and the Electricity Industry Policy. There is already existing a Development Strategic Plan 2010–30 (DSP) and a Medium Term Development Plan 2011–15 (MTDP) that include some energy components. Rural electrification policy guidelines were developed in 1993 to address the low rate of rural electrification, high costs and subsidies to C-centres, high costs of grid connections, and the relative effectiveness of mission station electrification compared to government initiatives. The guidelines advocated decentralised diesel generators, very small hydro and PV. Despite these and more recent policy initiatives, rural electrification remains *ad hoc* and C-centres perform very poorly. A draft Energy Division strategic plan for 2004–2008 called for the creation of a Rural Electrification Authority with enabling legislation, but that has not yet been implemented.

Acts of Parliament that deal with energy issues include:

- The Electricity Supply Act, regarding powers of the Minister for Energy for generation, supply and extension of electricity from power facilities built with government funds.
- The Electricity Industry Act, regarding the functions and powers of PNG Power.
- The Independent Consumer and Competition Act, regulating electricity, petroleum and their pricing.
- The Independent Public Business Corporation Act, under which the government holds all shares of PNG Power.
- The Organic Law on Provincial Government and Local Level Government, which grants authority to 19 provincial and 299 local (district/sub-district) governments to regulate electricity.
- The Community Services Trust Act, which essentially requires PNG Power to supply services at subsidised rates to rural or low-income populations.

- The Environmental Act, which can require environmental impact assessments for prescribed energy investments.

Energy supply and demand

Petroleum. Since 1992, PNG has recovered over 400 million barrels of light crude oil, from recoverable reserves of roughly 550 million barrels. Production will steadily decline as the resource is becoming depleted (Figure 2). The oil refinery is located across the bay from Port Moresby and supplies both the domestic and export markets.

In terms of primary energy supply, in 2011 oil products accounted for approximately 57%, biomass 37%, and hydro, gas and geothermal power the remaining 6%.

The natural gas resource is huge and is equivalent to at least 2 700 million barrels of oil (perhaps far more), over ten times PNG's remaining recoverable oil reserves. PNG is investing about PGK 8.865 billion (USD 4.5 billion) in a "Gas to Queensland Project", which may earn over PGK 21.67 billion (USD 11 billion) in exports over 28 years. The same company that operates the refinery is developing a gas liquefaction plant for export of the country's huge gas resource.

Imports of refined petroleum products vary considerably each year but averaged nearly 7 000 million litres (ML) from 1997–2000. In the years since 2004, which marked the construction of PNG's own refinery, most petroleum usage has been from local sources. The Asia-Pacific Economic Cooperation (APEC) prepared an energy balance for PNG in 2000. Net primary energy supply was 573 kilotonnes of oil equivalent (ktoe). Light crude oil and petroleum accounted for 61%, natural gas 25% and hydro 14%. 79% of indigenous commercial energy production (i.e. oil) was exported. There are no recent studies of non-commercial energy use but the PIREP mission in 2004 estimated that about 1 000 ktoe of wood are used annually for cooking and this does not appear likely to have decreased since most of this was used in areas where there is little access to other cooking fuels.

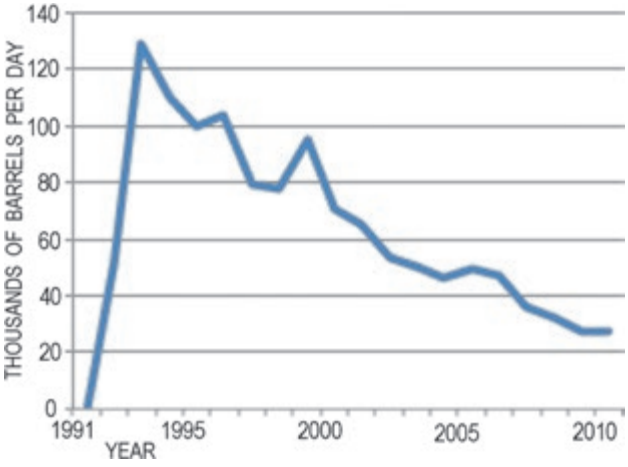

Figure 2. PNG Oil production 1991-2011

Source: www.indexmundi.com

Electricity generation and demand. In 2010 only about 13% of the population had access to electricity. This shows little change from a 1996 household survey when 2% of all households were surveyed. At that time 12% had electricity and fewer than 9% had either a refrigerator or television. Over half of the households used inefficient kerosene lamps as their main source of light and a quarter relied on open fires. Nearly 90% cooked mainly with fuelwood and 3% used liquefied petroleum gas (LPG) or electricity.

PNG Power is owned by the Independent Public Business Corporation (IPBC), which in turn is owned by the PNG Government. An Electricity Industry Policy was established in 2011 with the goals of equity and efficiency in the production and delivery of power. The Electricity Act of 2000 and the Independent Consumer and Competition Commission (ICCC) Act of 2002 caused PNG Power Ltd (PPL) to lose its legal monopoly on the sale of electricity, and in 2007, PNG Sustainable Energy Ltd. (PNGSEL) was licensed to generate and sell electricity to retail customers. One of PNG's energy goals is to increase electricity access to at least 41% of the population by 2020, and to 70% by 2030, though there is no clear plan as to how to achieve these goals.

PNG is unusual in the Pacific in that private generation is of the same order of magnitude as that of the public utility. Private generation is mostly undertaken by large mines, plantations and other resource extraction industries, which use hydro, biomass, geothermal energy in addition to diesel-powered generation, resulting in a broader renewable energy mix than that of PPL itself.

PPL operates three separate grids. Two large grids, the Port Moresby system serving mainly the National Capital District and the large Ramu grid that extends into the highlands. Also, PPL operates the small Gazelle Peninsula Grid powered mainly by a 10 MW run-of-river hydro plant. With around 65% of power generated from hydro, PNG is second only to Fiji in the percentage of electricity generated from hydropower. PPL also has recently been made responsible for managing some small provincial centre and rural area grids. PNG Power sales for 2008–2010 are shown in Table 1 and actual generation and fuel usage are shown in Table 2.

Table 1. PNG power sales in MWh

Year	Sector	Sales in MWh
2008	Domestic Supply	123 630.32
	General Supply	419 268.26
	Special Tariff – Ramu Sugar	3 310.64
	Special Tariff – Mining	10 190.17
	Industrial Tariff	129 806.10
	TOTAL	**686 205.49**
2009	Domestic Supply	137 230.60
	General Supply	417 240.16
	Special Tariff – Ramu Sugar	3 855.66
	Special Tariff – Mining	1 573.86
	Industrial Tariff	151 235.75
	TOTAL	**711 136.03**
2010	Domestic Supply	146 993.40
	General Supply	443 542.60
	Special Tariff – Ramu Sugar	4 543.47
	Special Tariff – Mining	757.16
	Industrial Tariff	160 474.60
	TOTAL	**756 311.23**

Source: Provided through communication by PPL (2012).

It is noted that street lighting is a significant unmetered electricity load. In 2011 there were 5 151 streetlights on the grid of which 3 046 were not metered. These are mainly either 80 W mercury vapour lights or 150 W high-pressure mercury vapour lights, although a number of high-pressure sodium vapour lights are also in use. The current monthly street lighting bill for the National Capitol District of Port Moresby is handled by PPL and is around PGK 56 000 (approximately USD 28 425). The streetlights in Lae, Madang and other cities are the responsibility of the relevant provincial or city councils.

Daily load curves (Figure 3 and Figure 4) show a strong weekday peak in mid-day and a weak evening peak on both the Port Moresby and Ramu grids while weekends show the evening to be the higher peak.

PPL purchases power from several Independent Power Producers (IPPs) who have about 24 MW of diesel capacity available. It also purchases hydro power from the Baiune Hydropower Plant in Bulolo, Morobe, owned by PNG Forest Products of Bulolo.

In 2011, PPL had 14 670 standard and 64 153 pre-paid domestic meters in use. There were also 8 355 standard meters and 3 915 pre-paid meters used by general supply customers. There were 77 standard industrial meters including seven Ramu Sugar company meters and two mining company meters in use.

Table 2. PPL generation, fuel use and losses

Year	Actual generation (MWh)	Fuel used (litres)	System Losses (MWh)
2007	817 947	3 155 534.00	146 814
2008	849 678	42 672 915.00	85 124
2009	895 706	4 232 449.00	188 785
2010	953 191	5 000 324.00	200 567

Source: Provided through communication by PPL (2012).

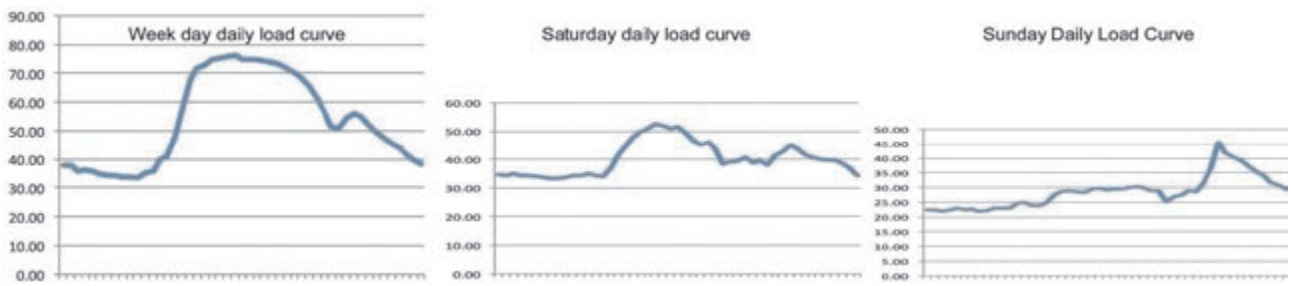

Figure 3. Daily load curve Port Moresby grid

Source: Provided through communication by PPL (2012).

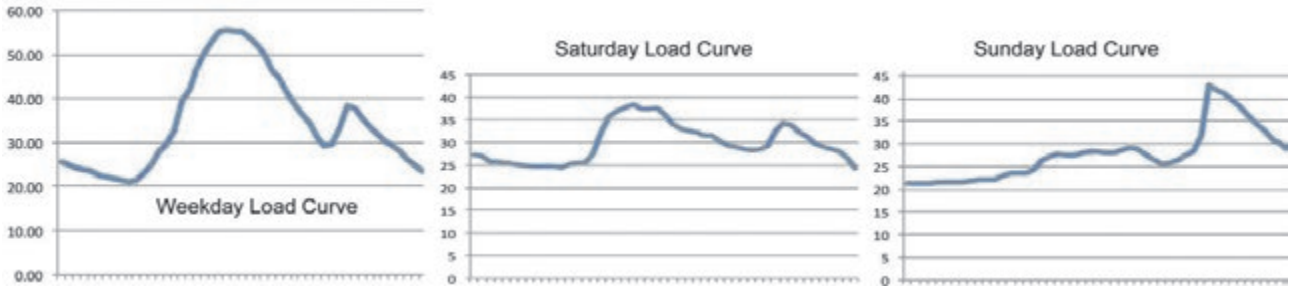

Figure 4. Daily load curve Ramu grid

Source: Provided through communication by PPL (2012).

Table 5. Provincial and isolated grids

Provinces and isolated systems					
Baiune/ Bulolo Hydro, Morobe	Hydro	5.7	5.7	PNGFP	PNGFP and town of Wau (Morobe)
Finsschhafen Diesels, Morobe	Thermal	0.7	0.7	PPL	Finsschhafen
Kerema Diesels, Gulf	Thermal	0.9	0.8	PPL	Kerema
Popondetta Diesels, Oro	Thermal	3.7	2.9	PPL	Popondetta
Wiewak Diesels, East Sepik	Thermal	6.9	6.1	PPL	Wiewak
Maprik Diesels, East Sepik	Thermal	6.2	5.3	PPL	Maprik
Vainimo Diesels, Sandaun	Thermal	2.6	2.0	PPL	Vainamo
Aitape Diesels, Aitape	Thermal	0.7	0.5	PPL	Aitape
Lombrum Diesels, Manus	Thermal	3.6	3.3	PPL	Lorengau
Kavieng Diesels, New Ireland	Thermal	3.6	3.4	PPL	Kavieng
Sohun Hydro, New Ireland	Hydro	0.2	0.2	PG	Namatanai
Alotau Diesels, Milne Bay	Thermal	3.4	2.5	PPL	Alotau
Samarai Diesels Milne Bay	Thermal	3.0	1.6	PPL	Samarai
Sohun/ Namatanai Diesels, N.I.	Thermal	?	?	PG	Namatanai
Lihir Geothermal	Geothermal	52.8	52.8	Lihir Mine	Lihir Mine
Ru Creek Hydro, West New Britain	Hydro	0.8	0.7	PPL	Kimbe
Kimbe Diesels, West New Britain	Thermal	4.3	4.0	PPL	Kimbe
Lake Hargy Hydro, West New Britain	Hydro	1.5	1.3	PPL	Bialla
Bialla Diesels, West New Britain	Thermal	0.5	0.4	PPL	Bialla
Buka Diesels, North Solomon	Thermal	2.2	1.7	PPL	Buka
Tolukuma Hydro, Central	Hydro	1.5	1.5	Tolukuma Mines	Mine supply
Tolukuma Diesels, Central	Thermal	3.2	3.2	Tolukuma Mines	Mine supply
Hides Gas, Enga	Gas	62.0	62.0	Porgera JV Mines	Mine supply
Porgera Mines Diesels, Enga	Diesel	13.0	13.0	Porgera JV Mines	Mine supply
RSL Diesels	Thermal	?	?	Ramu Sugar Ltd	Plant supply
Total Other		183.0	175.6		

Source: ADB, PNG Power Development Plan, Draft Final Report.

Non-PPL grids. PNG has many small- to medium-sized public and private grids serving industrial and residential areas (Table 5). Provincial centre grids were established in the 1980s and are currently mostly managed by PPL. There are also district-level grids although their quality of service is very variable. Mines, plantations and other industrial sites typically provide electricity to the worker residences on their grounds as well as to the facility itself.

In early 2011, PPL agreed to a USD 57.3 million power development loan from the ADB. The projects to be implemented under the first tranche of funding include run-of-the-river hydropower plants in Northern Province and the Autonomous Region of Bougainville and a 66-kilovolt transmission line in West New Britain. The transmission line will provide access to about 1 MW of spare generation capacity from the Lake Hargy Hydropower Plant and allow connection of up

to 3 MW of biomass-generated electricity from palm oil plantations.

Electricity tariffs. Electricity tariffs effective from January 2013 as published by PPL on their website are as shown in Table 6. A major problem in attracting private generation in rural areas is the government requirement for a uniform national tariff. The tariff currently in place is an urban tariff and generation in rural areas costs substantially more than the government allows electricity producers to collect through that tariff. To get around this, while at the same time keeping the tariff affordable to rural users, the Government subsidises the difference between the real cost and the recovered cost allowed by the national tariff as a Community Service Obligation (CSO). Unfortunately this approach does not encourage efficient use of CSO money and has not resulted in the rapid development of rural energy projects. Based on its plans for the future the DPE has requested that CSO expenditures be met from an Electricity Trust Fund funded from the national budget.

*Table 6. PPL tariffs for 2012 and 2013**

	TARIFF CATEGORY	UNIT	OLD TARIFFS (2012)	NEW TARIFFS (Applying on the 1st Jan 2013)
A.	**Industrial Customers (Credit Meters)**			
	All energy	toea/kWh	**60.86**	**60.01**
	Demand charge	Kina/kVA/month	**74.14**	**73.10**
	Minimum Demand	kVA/month	**200**	**200**
B.	**General Supply Customers (GS)**			
B.1	**Credit Meters**			
	All energy	toea/kWh	**94.89**	**93.56**
	Minimum charge	Kina/month	**18.00**	**18.00**
B.2	**Easipay**			
	All energy	toea/kWh	**92.55**	**91.25**
	Minimum charge	Kina/receipt	**50.00**	**50.00**
	Easipay Emergency Receipt-GS	Kina/receipt	**50.00**	**50.00**
	Easipay Emergency Service Fee-GS	Kina/receipt	**10.00**	**10.00**
C.	**Domestic Customers (DC)**			
C1.	**Credit Meters**			
	First 30 kWh/month	toea/kWh	**47.94**	**47.27**
	Balance	toea/kWh	**81.47**	**80.33**
	Minimum charge	Kina/month	**12.00**	**15.00**
C2	**Easipay**			
	All energy	toea/kWh	**66.99**	**66.05**
	Minimum charge	Kina/receipt	**10.00**	**15.00**
	Easipay Emergency Receipt-DC	Kina/receipt	**10.00**	**15.00**
	Easipay Emergency Service Fee-DC	Kina/receipt	**10.00**	**10.00**
D.	**Public Lighting Customers**			
	Metered Streetlights-All Energy	toea/kWh	**94.89**	**93.56**
	Type of fitting			
	40W Fluorescent	Kina/annum	**155.00**	**153.00**
	80W Fluorescent	Kina/annum	**243.00**	**240.00**
	50W Mercury vapor HP	Kina/annum	**193.00**	**190.00**
	80W Mercury vapor HP	Kina/annum	**292.00**	**288.00**
	125W Mercury vapor HP	Kina/annum	**445.00**	**439.00**
	250W Mercury vapor HP	Kina/annum	**889.00**	**877.00**
	400W Mercury vapor HP	Kina/annum	**1412.00**	**1392.00**
	70W Sodium vapor HP	Kina/annum	**266.00**	**262.00**
	90W Sodium Vapor HP	Kina/annum	**393.00**	**387.00**
	120W Sodium vapor HP	Kina/annum	**429.00**	**423.00**
	135W Sodium Vapor HP	Kina/annum	**496.00**	**489.00**
	150W Sodium vapor HP	Kina/annum	**558.00**	**550.00**

(Extracted from the published tariffs table on PPL's website at: http://www.pngpower.com.pg/images/ppl_articlesPDFs/tariff.pdf)*

3. Renewable energy opportunities

Technically, the renewable energy potential in PNG is enormous, but most of it is in remote locations where there is limited demand and is not readily exploitable. Rural renewable energy potential was assessed by the University of Papua New Guinea, the University of Technology (Unitech), and the government energy and forestry departments between the early 1980s and 1994, although only limited information has been obtained since then.

Geothermal energy. No systematic geothermal energy assessments have been carried out but reconnaissance studies suggest that the most promising area is the northern coast of New Britain where there are at least seven geothermal sites. The only commercial geothermal development has been at Lihir, north of New Ireland, where there may be up to 70 MW of developable potential.

Hydropower. Due to limited hydrological surveys, only approximate information on hydroelectric potential is available. In 1994, the World Bank estimated the gross potential of large-scale hydro as roughly 20 000 MW and 175 000 GWh/year, with a technically feasible potential of 14 000 MW and 122 600 GWh/year. The economically feasible sites total about 4 200 MW, producing roughly 37 000 GWh/year. These estimates exclude micro- and mini-hydro for rural communities, which have a large exploitable potential. Over 100 potential mini-hydro sites near C-centres have been assessed in 17 provinces, 31 with field investigations. Of 6 MW identified, over half is in the North Solomons Province, but there are other promising locations throughout the country.

Ocean energy. There is little knowledge of PNG's potential for ocean thermal energy conversion (OTEC), tidal energy or wave energy. Near Port Moresby, the tidal range is 2.7 metres compared to 1.1–1.6 metres in most of the country. There is reportedly a 6-metre range in parts of the Torres Strait. There have been very preliminary proposals to tap tidal currents (peaking at 7–11 km/hour) at Buka Passage, Bougainville.

Wind energy. There have apparently been no systematic estimates of wind energy since the 1970s when the best potential was estimated to be in parts of Central, Western, Milne Bay and New Ireland provinces and the Port Moresby area. These estimates (and recent evaluations of the old data) were based on modelling, with very little actual wind gauging.

Solar energy. Solar energy is among the largest potential sources of renewable energy in PNG. Average insolation in much of the country appears to be good with between 4.5 and 8 hours of sunshine daily, though there have been few proper solar radiation measurements to confirm the resource. Due to the mountainous terrain and the associated persistent clouds they cause, the solar energy reaching the ground can vary greatly from place to place and therefore cannot be easily estimated for a particular site from satellite data. Of 23 locations assessed in 1990's studies, Port Moresby is considered PNG's sunniest location with 2 478 sunshine hours per year. The lowest is Tambul, Western Highlands, with 1 292 hours. The best locations for solar PV are the offshore islands and the southern regions due to fewer persistent clouds caused by mountains.

Bioenergy. Although two-thirds of PNG is forested, much of the biomass is inaccessible or unsuited for energy use. An estimated 58% of land is subject to strong or severe erosion and 18% is permanently inundated or regularly flooded. The main practical biomass energy potential is in areas of logging or agricultural production using either the crop output or processing waste. Log exports are about 2 million m^3 per year but very little is processed locally, leaving only relatively small amounts of biomass waste for energy production. There are 18 major wood-processing facilities, but the amount of residue produced and available for energy use is not known.

With additional processing, almost any vegetable oil can be used as a liquid fuel to replace diesel fuel but its practical potential depends on the oil's value as an export commodity compared to the price of diesel fuel. PNG produces about 330 ML of crude palm oil per year and about 33 ML of coconut oil.

Ethanol (alcohol) can be produced from sugar-cane, molasses, sago palm, nipa palm and other crops and blended with petrol to fuel vehicles. Reportedly, between 200 ML and 1100 ML of fuel alcohol per year could be produced from sago palm in the Gulf Province alone and over 250 ML could be produced from nipa palm from the Purari Basin.

4. Experiences with renewable energy technologies

PNG has enormous renewable energy resources and a long-standing interest within its two universities to develop renewable energy technologies. Until the mid-1980s, PNG was the region's leader in biomass energy for agro-processing, biogas use, biomass gasification, wood and charcoal cooking, ethanol production, solar PV implementation, and resource assessments. Today it is well behind most of the region in many of these areas. Recently it has been the private sector that has largely driven renewable energy use. The coffee industry still uses wood-burning driers, the palm oil industry used wastes for electricity production, and Ramu Sugar plans to use wood for combustion in its bagasse boilers to increase their energy production. At least several thousand new solar home lighting systems are expected to be installed in rural PNG each year, overwhelmingly through private initiatives. Yet barriers to the successful long-term and large-scale use of renewables seem to be considerable. About three-quarters of mini/micro hydro systems installed are no longer in use, a high percentage of residential and public facility PV and wind systems have failed, and the majority of C-centre power systems are operating poorly, or not at all.

As a part of the current development plans, total electricity capacity is forecast to increase substantially with most gains in the renewable energy sector (Table 7).

Table 7.
MTDP Targets in PNG total electricity capacity (MW)

Technology	2011	2020
Hydro	207	580
Diesel	198	60
Gas	72	280
Geothermal	53	112
Solar	n/a	8
Wind	n/a	13
Biomass	n/a	24
Biogas	n/a	3
Coal	n/a	30
Total	**530**	**1110**

Source: Medium Term Development Plan 2011–2015.

Geothermal energy. In 2003, a 6 MW geothermal power plant was commissioned on Lihir Island (the first geothermal power facility in the Pacific islands). The facility has been expanded to a capacity of 52.8 MW in 2011. PNG Power may explore the geothermal potential in East and West New Britain.

Hydropower. In the 1980s and 1990s, ELCOM (now PNG Power) carried out numerous feasibility studies to replace small diesel systems with small hydro but no development took place at that time due to the high cost of their development. However, with today's high fuel prices, a number of these sites have become cost-effective and development is planned or underway.

DME's Energy Division had assessed 45 potential hydro sites near C-centres by 1987, completed 14 feasibility studies and commissioned three small hydro systems (60–300 kW) by 1992. PNG Power has 161.5 MW of hydro capacity (as shown in Table 8) and Ok Tedi Mining nearly 60 MW.

Church missions, NGOs and community organisations have built a number of small hydro systems but details are not available. The 2004 PIREP mission estimated that there may have been as many as 200 pico- (single household size), micro- and mini-hydro systems installed in rural PNG between 1960 and 2004, of which perhaps 20–25% are still functioning, including about 20–25 systems on Bougainville and roughly the same number throughout the rest of PNG. Many more such systems are planned if funding can be found.

Table 8. Principal hydro sites of PPL

Site	MW
Ramu	75
Rouna	61
Pauanda	12
Warangoi	10
Sirinumu	1.6
Ru Creek	1.5
Lake Hargy	0.9

Source: Provided through communication by PPL (2012).

In 2010 Queensland (the Australian province nearest to PNG) and PNG agreed to consider a 1800 MW hydropower plant on the Purari River in PNG to supply 1200 MW of electricity capacity to Queensland through a 250 km undersea cable. Origin Energy of Australia is the promoter. The remaining 600 MW of the plant's capacity would become available for local use.

Wind energy. Several wind turbines were installed in Morobe Province after independence but it is not known if any still function. PNG Power may be considering a wind farm near Port Moresby but no wind monitoring has yet begun. In 2002, the Chinese government donated 50 small combined wind/solar generators to PNG and a number have been installed in various coastal locations.

Although full details were not available the Chinese Government has reportedly also provided around 1 MW in small wind systems to the Duke of York Islands of New Britain to power the local hospital and other facilities.

Three sites near Port Moresby are currently being investigated by PPL for possible wind energy trials although apparently none of them are a high priority for development.

Solar energy. At least 25 small-scale applied research projects involving solar energy took place in PNG between 1989 and 1994, mostly at Unitech. The studies included solar drying, water heating, PV monitoring and solar pumping. In the 1980s, solar drying of copra, cocoa and coffee was widespread, particularly by smallholders. Also in the 1980s, the government supported a solar water heating retrofit programme for commercial users, industry and households, with at least 3 000 household systems installed. In 2004, at least 7 000 homes in Port Moresby used solar water heating.

Solar PV has spread gradually in PNG over the past 30 years, with small independent solar systems marketed by private suppliers and used mainly for lighting, but also for communications. Some 3 000 solar home lighting systems were sold to individuals between 1998 and 2002, with perhaps 1 000 new systems sold per year since then. PNG Telecom has hundreds of solar sites with a total capacity of over 200 kWp. The expansion of the mobile phone system into rural areas is rapidly increasing solar use for telecommunications and increasing demand for solar-powered phone chargers. A major problem however is protecting these facilities against vandalism and theft.

At least a dozen PV pumping systems and a dozen PV-powered refrigerators were installed at health centres in the 1980s. A PGK 15 million (about USD 11.3 million) Japanese-supported project provided solar electrification for 320 schools in all 20 PNG provinces in 1997–1998, but by 2004, only a few of the panels installed were still operating. Several problems contributed to the lack of long-term success, including poor installation quality, inadequate maintenance and support, difficulties in transport of spare parts, and security issues leading to numerous thefts of panels. Since 2000, about 300 solar and LPG-based vaccine refrigerators have been installed in health facilities, many of which have again suffered from poor design, lack of maintenance and theft of solar panels.

As is the case with Fiji, the presence of a large hydro generation capacity has kept PNG's electricity prices much lower than in all-diesel generating countries in the region. Therefore the cost-effectiveness of grid connected solar and wind is not as good. As a result PPL has not been under pressure to institute a net metering policy since private investors see little or no benefit from connecting solar energy systems to the grid.

Bioenergy. Traditional biomass probably accounted for over 50% of PNG's national energy consumption in 2010 though there have been no recent surveys to document its use. Biomass is largely used for cooking, with some industrial use at sugar, palm oil and wood product facilities (Table 9). Although there have been several attempts to introduce efficient wood stoves and charcoal stoves, most cooking continues to be done on open fires. Some electricity and process heat is produced from biomass wastes within the oil palm industry, at sugar mills, and in the wood processing industry.

Although current use is unknown, in 1990 there were about 80 gasifiers installed for using biomass waste in the copra, cocoa, coffee and tea industries as a replacement for imported fuels. Ramu Sugar Mills, which produced about 4 million litres of ethanol per year as a fuel in the 1980s, uses bagasse (sugar-cane waste) as a fuel for its operations. It operates about 8 000 hectares of cane plantations and produces over 80% of PNG's sugar production. The company currently produces around 0.3 million litres of ethanol which mostly is exported to Australia.

Coconut Products Ltd. in Rabaul produced 55 751 631 litres of coconut oil in 2011. The company has 12 presses of which 10 are working with a capacity of 250 tonnes per day. Coconut Oil Production Madang Ltd. produced 10 094 000 litres in 2011 and has seven presses, each working at 25 tonnes per day. Six of the seven presses were working in 2010, but only four in 2011. Coconut oil has been used as a fuel in some districts (including Alotau, Buka and Bogia) but the full extent of use and results are unknown. Esterified coconut oil was tried as a fuel on a small scale in PNG for about a year in the mid-1980s, with no further reported use except in Bougainville during the civil strife of the 1990s.

In the 1970s and 1980s, several biogas systems operated for a short time at the Lae City Council and at a coffee plantation in Mt. Hagen. In early 2004, a small biogas system using the waste from 20 pigs was constructed in Central Bougainville but the results of the project are not available. There have been proposals to incinerate municipal waste in Port Moresby for energy but a SPREP study concluded that waste incineration was unsuitable for Port Moresby, as it would require complex technology, sophisticated operations and management, and would likely produce unacceptable emissions.

New Britain Palm Oil Ltd. is constructing two large biogas digester facilities, one in Mosa and one in Kubango. Both will use palm oil mill effluent to produce electricity and provide gas for cooking at company residences and for mill processing.

Hybrid energy. 50 hybrid energy systems (500 Watts wind, 100 Watts PV) were provided by China in 2002 for use at coastal provincial centres. Apparently only a few had been installed by early 2004 and a number of those soon suffered electronic component failures.

Table 9. Electricity from palm oil production

Site	Name of plant owner	Electricity generation capacity in MW
Mosa – WNBP	New Britain Palm Oil Ltd	1–1.5
Kubango – WNBP		1–1.5
Numondo – WNBP		1–1.5
Kapiura – WNBP		1–1.5
Higaturu – Oro		1–1.5
Sumberipa – Oro		1–1.5
Mamba – Oro		1–1.5
Hagita – MBP		1–1.5
Poliamba – NIP		1–1.5
Kimbe (new const.)		2
Hargy – WNBP	Hargy Oil Palms Ltd	1–1.5
Navo – WNBP		1–1.5

Notes: All palm oil mills in PNG generate part of their electricity from palm kernel shell and fibre wastes with energy used mainly for palm oil processing. Higaturu also supplies some nearby residences with electricity.

5. Challenges for renewable energy deployment

Barriers to the development and commercialisation of renewable energy in PNG are:

- **Fiscal.** Barriers include fiscal policies (import duties, taxes, charges) biased in favour of conventional energy or against renewable energy. Specific barriers include: i) identical fuel prices for Port Moresby, Lae, Madang and Rabaul which in effect provides a fuel price cross-subsidy for the three outer urban areas; ii) a national electricity tariff which is well below the cost of power generation in rural areas; and iii) no incentives, such as low-cost loans, reduced import duties or reduced taxes, for assembling, manufacturing or importing renewable energy technologies.
- **Funding**. The Energy Division funds are reportedly inadequate for effective surveys and data collection. Other financial barriers include: i) lack of cash in most rural communities to pay for renewable energy services, ii) the very high cost of doing business in rural PNG, iii) the perceived high initial costs of renewable energy technologies, and iv) the perception that renewable energy technology for rural energy is high risk.
- **Legislative, regulatory and policy.** To date PNG has no specific renewable energy targets and thus no policy support for attracting private sector investments in renewables, especially for rural areas. There is not yet a formal national energy policy either, with only drafts of the Energy Policy, the Electricity Industry Policy and the Rural Electrification Policy currently available.
- **Institutional**. Institutional strengthening across government departments relating to energy is required for renewable energy promotion. PNG has not effectively tapped existing or potential sources of donor finance for renewable energy deployment in the country. Specific issues include: i) limited capacity within the Energy Division for research, energy planning and analysis; ii) lack of support from national government to provincial and local governments for planning, training, finance, operating guidelines and financial guidelines for rural energy development; iii) limited capacity for the development of bankable renewable energy project proposals or project proposals acceptable to donor agencies.
- **Technical.** Technical barriers include: i) limited knowledge of available renewable energy resource potential in the country; ii) limited resources for increasing technical capacity in rural areas; and iii) little technical evaluation of failed renewable energy projects resulting in the same implementation mistakes being repeated in subsequent projects.
- **Market and private sector**. Among the barriers are: i) a highly dispersed population with poor accessibility; ii) lack of demand for energy for productive uses in remote areas; iii) limited renewable energy knowledge within the private sector; iv) prevalence of theft and vandalism of installed renewable energy components; and v) lack of cash in rural subsistence economies.
- **Knowledge.** Key barriers relating to renewable energy technologies are: i) low level of public awareness; ii) low level of technical capacity for renewable energies; and iii) inadequate technical training available for renewable energy technologies deployment.
- **Environmental and social**. Environmental and social barriers include: i) PNG's vulnerability to natural disasters; ii) land access issues; and iii) lack of appropriate operational framework for renewable energy systems provided to rural communities.

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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IRENA
International Renewable Energy Agency

IRENA
C67 Office Building, Khalidiyah (32nd) Street
P.O. Box 236, Abu Dhabi,
United Arab Emirates
www.irena.org