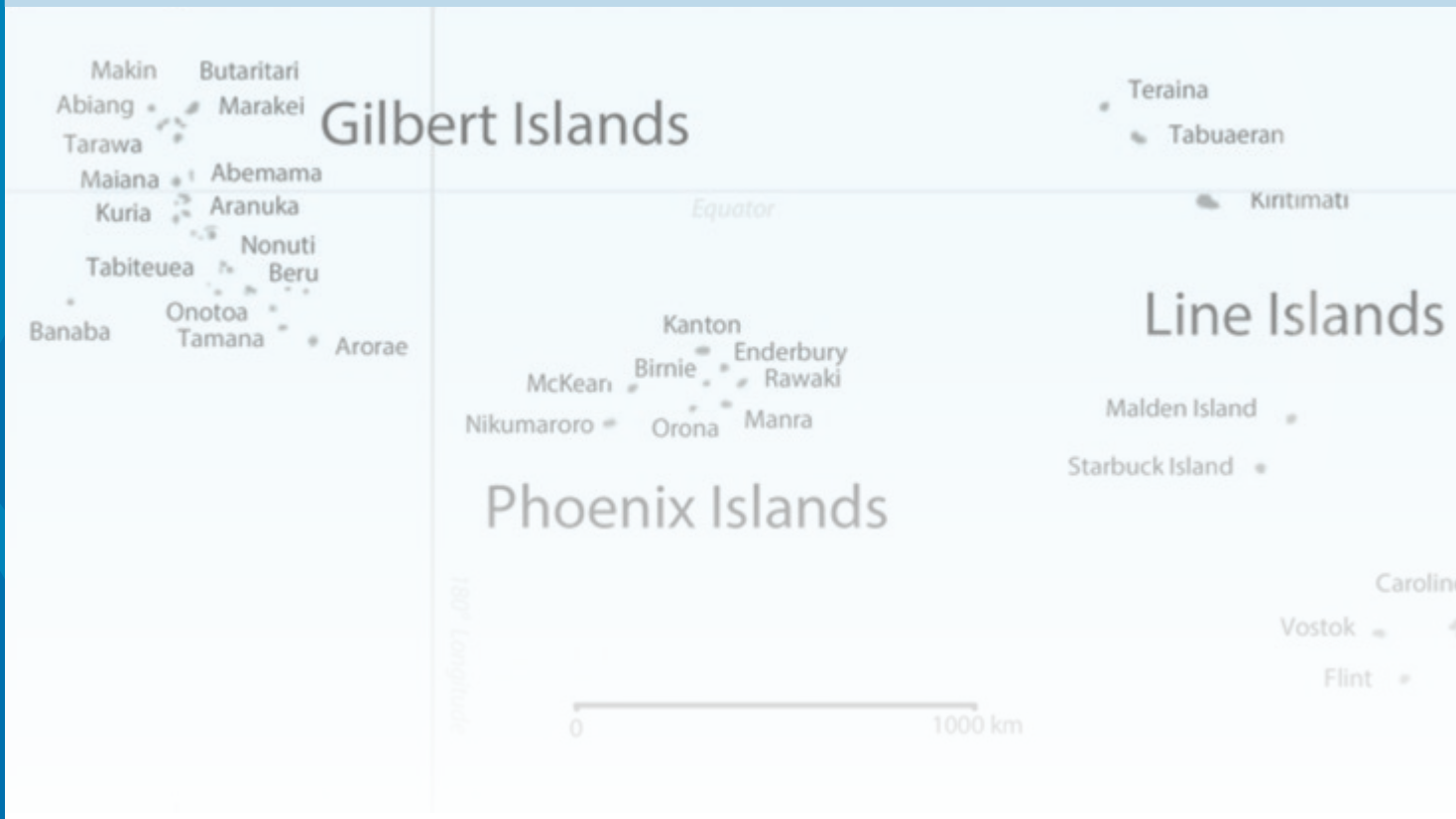
Report

IRENA
International Renewable Energy Agency

Pacific Lighthouses

Renewable energy opportunities and challenges in the Pacific Islands region

Kiribati



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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Acknowledgements

The work and data for the preparation of this paper was carried out by Herb Wade (Consultant). The kind assistance and support provided by Terubentau Akura (DS Power), Tiaon Aukitino (Ministry of Public Works and Utilities), Koin Etuati (Secretariat of the Pacific Community), Rutete Ioteba (Kiribati Solar Energy Company), Kireua B. Kaiea (Ministry of Public Works and Utilities), Apisake Soakai (Consultant) and Tiante Tarakia (Kiribati Solar Energy Company) are gratefully acknowledged. This country report could not have been completed without their generous assistance.

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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August 2013

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Note on currency:
On October 24, 2012, the exchange rate was Australian Dollars (AUD) 0.972 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

Ah	Ampere-hour
AUD	Australian Dollar (currency)
CNO	Coconut Oil
EDF	European Development Fund
EPU	Energy Planning Unit
EU	European Union
FSED	Forum Secretariat Energy Division
FSPK	Foundation for the Peoples of the South Pacific, Kiribati
GDP	Gross Domestic Product
GWh	Gigawatt hours (millions of kilowatt hours)
JICA	Japan International Cooperation Agency
KCMCL	Kiribati Copra Mill, Ltd.
KOIL	Kiribati Oil Company
KSEC	Kiribati Solar Energy Company, Ltd.
kWp	Kilowatts peak (for solar photovoltaics)
kVA	Kilovolt-ampere
LPG	Liquefied Petroleum Gas
MPWU	Ministry of Public Works and Utilities
MLPID	Ministry of Line and Phoenix Development
MW	Megawatts (thousands of kilowatts)
PEC	Pacific Environment Community
PUB	Public Utilities Board
SHS	Solar Home System
UNDP	United Nations Development Programme
USD	United States dollars
WB	World Bank

1. Country context

Figure 1. Map of Kiribati

Source: Wade, H. (2012) adapted from CIA World Fact Book

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

Physical description. Kiribati includes one raised coral island (Banaba) and 32 atolls in three island groups (Gilbert, Line and Phoenix) spread over an ocean area of 4 200 km east to west and 2 000 km north to south with a total land area of 811 km^2. Both the Equator and the 180th meridian pass through Kiribati, and so it lies in both the northern and southern hemispheres. The capital and all the governmental offices are on Tarawa in the Gilbert island group; although there has been little development on the other islands within this group. Kiribati exemplifies the development challenges facing a small, remote and resource-poor island state during a period of rapid global change.

Population. The 2010 census recorded 103 058 residents with an overall annual population growth rate of 2.01%. For the same year, the urban area of Tarawa grew at a rate of 3.17%, reaching 50 182 persons (48.69% of the total population). Dense urban areas and growing populations continue to represent a major problem in the delivery of services and protection of the environment. During the last 20 years or more the Government of Kiribati (GoK), to relieve the pressure on Tarawa, has encouraged migration to Kiritimati. The population of Kiritimati between the years 2000 and 2005 reached 5 115, an increase of 6.7%. Emigration to the other islands in the Line group was also encouraged, though incentives have since ended, now that the island populations appear optimum. Relocation to the uninhabited Phoenix Islands is now being encouraged. Fast growth of the urban population on both Tarawa and Kiritimati has also brought about rapid expansion in the energy sector on those two islands. For the rest of Kiribati, the population is expected to remain stable or even decline. Any increase in outer island energy demand is expected to be due to rising income rather than population growth.

Free education is provided from pre-school until the completion of high school. Post-secondary learning is

available at the University of the South Pacific centre on Tarawa while vocational training in several technical fields is provided by the Kiribati Institute of Technology (KIT). The well-respected Marine Training Centre provides high-quality training for those seeking work in the European merchant marine sector. Remittances from seamen are a major source of cash income on the outer islands.

Environment. Kiribati's climate is maritime equatorial with temperatures changing little throughout the year. Daytime averages are above 30˚C, and night-time above 20˚C. Rainfall varies from north to south, with the Phoenix island group in the south particularly dry with only around 800 mm per year, while the northernmost islands receive as much as 3 000 mm per year. All of Kiribati, but especially the Line group of islands, is affected by the El Niño/El Niña Southern Oscillation and suffers cyclic droughts, which have the potential to become extended droughts and are the primary climatic hazard for the islands. Winds are moderate, seasonal and variable, and cyclones are currently not a problem in Kiribati.

Rainwater is the main source of potable water with brackish atoll lens water often used for washing. South Tarawa provides piped water from the atoll freshwater lens (groundwater), although usage now appears to be reaching the limit that can be extracted without serious salt water intrusion into the lens. Rainwater catchment at residences remains an important source of drinking and cooking water on Tarawa as well as on the outer islands.

Land-based biodiversity is low due to poor soil, brackish ground water and periodic droughts.

Kiribati is a signatory to most treaties and conventions relating to environmental protection and has a special interest in climate change mitigation and adaptation since even a modest rise in sea level endangers its low-lying atoll islands.

Economic overview. Phosphate, once Kiribati's leading source of income, was exhausted by 1979, although there is still some income from a phosphate reserve fund established in 1956. Outer islands mostly have a traditional subsistence and barter economy, and only Tarawa and Kiritimati can be considered full participants in the money economy. Although by conventional definitions of poverty Kiribati's rural residents could be considered impoverished, there is strong evidence that the average quality of life, and lifespan, are often better on rural islands than in urban Tarawa. True poverty, entailing problems in meeting basic human needs, is more common in Kiribati's urban, rather than rural, areas. To help sustain the outer islands' economy and help reduce migration to already very overcrowded Tarawa, production of copra derived from coconuts is subsidised and provides what amounts to a ready source of cash when needed. One of the reasons for the success of the outer island solar programme is that almost any household, by cutting copra, can make the necessary cash to pay the AUD 9 (USD 9.24) monthly fee.

Drought is the primary variable factor in the subsistence economy and market prices for coconut oil and the sale of fishing licences to foreign fishing vessels are the main variables in the money economy. As is typical of atolls, the agricultural base is narrow, with coconuts, breadfruit, pandanus and giant taro the only significant land-based food resources. The sea is the main resource and around 80% of households consider fishing, even though it is mostly of a subsistence nature, as their main economic activity.

All inhabited islands of the Gilberts have airports and are served by scheduled flights, typically once or twice a week, by 20–30 seat aircraft. The nearest large markets are Honolulu in Hawaii, and Brisbane in Australia, both around 4 000 km from Tarawa. A major problem for the government is maintaining the linkage between Kiritimati and Tarawa as there is insufficient traffic to support direct flights making travel between the two urban centres of Kiribati complicated.

The World Bank calculated Kiribati's gross domestic product (GDP) in 2010 at AUD 151.18 million (USD 155.22 million). Since the economy is dependent on external markets and weather, its growth rate has been very variable, with a long-term average annual growth of less than 2%, although as high as 12.6% in one year (1998). In recent years there has been little growth and GDP fell slightly from 2007 to 2010. Investment income is currently about a third of GDP. About 20% of the population participate in the formal wage economy that accounts for over 90% of GDP. Nearly 80% of paid employment is provided by the government or by government-owned enterprises. Remittances from Kiribati citizens working as seamen are also significant.

Kiribati's National Development Strategy is meant to foster economic growth; equitable distribution of development benefits; improved efficiency of public enterprises; expansion of practical training and health services; sustainable use of resources; and protection and effective use, at both national and village levels, of the country's financial reserves.

Private sector investment, both local and foreign, is encouraged. The Development Bank of Kiribati specialises in loans for economic development, while the Bank of Kiribati is a full-service commercial bank. The Australia and New Zealand Banking Group Ltd (ANZ) has offices on Kiritimati Island.

2. Energy landscape

Institutional and regulatory arrangements for energy

The Ministry of Public Works and Utilities (MPWU). The MPWU is responsible for the planning, management and coordination of the energy sector. Other entities with energy sector responsibilities are:

The Energy Planning Unit (EPU). The EPU coordinates the implementation of energy policies, providing advice and assistance on all energy-related matters and activities.

The Public Utilities Board (PUB). The PUB is a government-owned body responsible for provision of power, water supply and sewage services for South Tarawa.

The Kiribati Solar Energy Company (KSEC). The KSEC is a government-owned corporation responsible for the provision of electrical services for rural areas through the operation and maintenance of solar photovoltaic (PV) systems. It currently manages 224 kilowatts peak (kWp) of solar PV for outer island residences, 47.6 kWp of solar systems for community buildings, 7.5 kWp for streetlights and 6.4 kWp for communications. In the past it has also been contracted to maintain solar water pumps for the Public Works Department, solar PV for health centres buildings, school solar systems for the Ministry of Education and solar PV for schools of various church groups.

The Kiribati Oil Company (KOIL). KOIL is a government-owned corporation involved in the distribution of petroleum products throughout Kiribati.

The Ministry of Line and Phoenix Islands Development (MLPID), responsible for all government services on Kiritimati Island and the populated Line and Phoenix Islands.

The Public Utilities Ordinance (CAP 83 of 1977, revised 1998 and 2010) provides the legislative basis for the formation of the PUB.

The Prices Ordinance (CAP 1975 and revised in 1981) includes price controls for petrol and kerosene. Diesel is not under price control.

The Petroleum Act (CAP 69) regulates safety, storage, rationing, and customs inspections.

The Environment Act (Act 9 of 1999 amended in 2007) provides for the protection, improvement and conservation of the Kiribati environment. It is supplemented by Environmental Regulations of 2001.

Energy Policy of 2009. Although the Kiribati Government has had an unwritten policy of allowing only renewable energy for outer island electrification since the 1980s, an overall energy policy was formally only established in 2009. The Energy Policy was established in association with the Kiribati Development Plan 2008–2011 and has as its primary goals: human resource development in the energy sector; development of livelihoods; energy security; and energy access. Its guiding principles are sustainability, gender equity, environmental compatibility, stakeholder participation, good governance, and cultural/traditional compatibility.

With regards to renewable energy, the policies include:

- promoting sustainable renewable energy access;
- ensuring that the limited biomass resources are used in an economic, environmental, and culturally sustainable manner;
- strengthening collaboration with development partners for the advancement of renewable energy programmes;
- promoting and encouraging the use of appropriate renewable energy technologies; and
- expediting the replication of successful solar programmes.

Kiribati has introduced a number of appropriate incentive packages to encourage the use of renewable energy technologies including reduced taxes, duties and tariffs.

The energy policy also requires the MPWU to, among other actions, establish a regulatory framework for the energy sector, coordinate the implementation of climate change mitigation activities by using renewable energy resources, and ensure the coordination of energy requirements for any major infrastructure development.

Energy supply and demand

Since the rural islands depend on solar and biomass for energy, the growth of petroleum imports is almost entirely due to the increased population and growth in services on Tarawa and Kiritimati Islands.

Petroleum is supplied from Fiji by ExxonMobil and BP with the latter ceasing operation in 2007 and supplying only aviation fuels on Tarawa. The Kiribati Oil Company imports petroleum fuels to its depot in Tarawa and Kiritmati Island with an annual import volume of around 23 million litres as depicted in Table 1. Supply to the outer islands is in 200-litre and 50-litre drums and shipping problems sometimes cause shortages. Small deliveries and long distances drive up the landed price, making petroleum in Kiribati more expensive than most other Pacific countries. Although liquefied petroleum gas (LPG) remains relatively expensive, its use is growing on Tarawa as a replacement for kerosene for cooking due to its convenience and efficiency. LPG is provided by KOIL and is shipped in bulk in 11400 kg capacity tanktainers supplied from Lava Gas Company, New Zealand.

Fuel used for aviation and by the PUB is exempted from tax. Kerosene is also duty-free and a component of its base price is subsidised by the government for the outer islands to make it more affordable for household lighting. Kerosene lighting is used in about 34% of Kiribati homes. Petrol and diesel for transport are taxed at AUD 0.07 (USD 0.072) and AUD 0.06 (USD 0.062) per litre respectively. The price of kerosene is currently fixed at AUD 1 (USD 1.03) per litre.

Electricity generation and demand. Electricity from the grid (Table 2) serves about 44% of the total households, with another 17% supplied by solar PV and 3% by electricity from Island Council and church mini-grids. In general, around 64% of Kiribati households have access to some form of electrical power. The grid power system on Tarawa was upgraded under Japan International Cooperation Agency (JICA) funding in 2005–2006. About 5.45 Megawatts (MW) of generation is now installed with 4.2 MW in Bikenibeu and 1.25 MW in Betio.

PUB maintains by far the largest grid with 4108 residential meters, 556 commercial meters and 277 government meters in 2012. There are also 151 street lights on Tarawa.

On Tabiteuea North, all of the 49 staff residences, associated with the new southern island hospital, are connected to the hospital mini-grid. In Kiritimati, village grids in total (as recorded in 2008) had 525 residential meters, 53 commercial meters and 102 business meters excluding the mini-grids serving the two church secondary school campuses and the motel at the far end of Tabwakea village. The National Space Development Agency of Japan's (NASDA) down range satellite tracking station and its business sectors (motels and shops) in Main Camp have their own power systems. On the outer islands, mini-grids are also present in public and church boarding schools, church communities and island council headquarters. Although details are not available, these are known to serve only a small fraction of all households.

Energy use is dominated by Tarawa and Kiritimati Islands. On the outer islands, per-capita energy use is low and is dominated by biomass combustion for cooking and copra drying. The biomass used is typically coconut husks, coconut shells, coconut fronds and mangrove wood -all traditional energy sources for Kiribati Island. Electricity in rural areas comes from solar home systems (SHS) except for Island Council offices and some housing immediately around the Island Council compounds where a small generator is usually operated for a few hours each day. These generators serve a total of about 3% of Kiribati Island residences. In the outer islands, petroleum use is mainly restricted to kerosene that is used for lighting or cooking, and petrol (gasoline), which is used to operate a few motorcycles, outboard powerboats and a truck and/or tractor owned by the Island Council for island transport use. Traditional sailing ca-

Table 1. Kiribati Fuel imports 2007–2011 (litres)

Fuel	2007	2008	2009	2010	2011
Petrol (Gasoline)	5 680 633	6 128 853	5 530 708	6 219 381	6 715 560
Diesel Fuel (Automobile Diesel Oil)	14 290 893	15 279 530	13 090 005	14 257 586	12 549 110
Kerosene (Jet fuel)	3 661 142	3 440 160	2 821 765	4 720 171	4 065 635
TOTAL	23 632 668	24 848 543	21 442 478	25 197 138	23 330 305

Source: Provided through communication by KOIL (2012).

Table 2. Existing power generators

Engine #	Location	Manufacturer and Model No.	Capacity (kVA)	Year of installation
DEG 1	Betio	Daihatsu 6 KD 26 0168	1 250	2004
DEG 3	Bikenibeu	Daihatsu 6 KD 26 0168	1 400	2002
DEG 4	Bikenibeu	Daihatsu 6 KD 26 0168	1 400	2002
DEG 5	Bikenibeu	Daihatsu 6 KD 26 0168	1 400	2005

Source: Preliminary Report for "Kiribati Grid Connected Solar PV Power Station Project", Trama Techoambiental, prepared for the World Bank.

noes are used extensively for subsistence fishing, which helps to keep petrol use low on outer islands.

Traditional biomass energy sources continue to contribute around 25% of the overall energy used in Kiribati and biomass very much dominates energy use on the outer islands, although this has been somewhat offset by "modern" fuels such as kerosene and LPG. However, biomass use on the outer islands has changed little over the years compared with its usage on Tarawa, which has fallen significantly as kerosene and LPG have become more widely used in the cash economy.

Copra production usually produces more biomass waste than is used, so there does not seem to be any biomass supply problem caused by scarcity or deforestation, although the premium firewood species, such as mangrove, have become scarce in some areas. Although it is very difficult to get precise information about household biomass usage, estimates suggest it is about 4 000 tonnes of oil equivalent per year, roughly comparable to the amount of fuel used for electricity production.

PUB, like most Pacific utilities, experiences two load peaks during the working week: a daytime peak that corresponds with air-conditioning loads for government offices and a smaller evening peak that corresponds with residential lighting and entertainment use (Figure 2). Weekend load patterns show only an evening peak. This has implications for large-scale solar use since the noontime load on the weekend is around 2.3 MW but

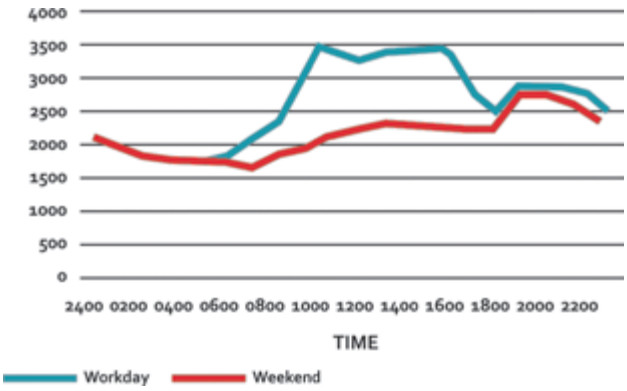

Figure 2. Daily and weekend loads

Source: Provided through communication by PUB (2012)

Table 3. Estimated residential energy usage 2000–2009 (Unit: Terajoules)

Year	Coconut waste	Wood	Kerosene	LPG	Mogas	Electricity	Solar energy	Total
2004	441.6	59.9	16.2	8.11	2.4	20.93	1.8	550.94
2005	441.4	59.9	15.0	7.48	2.7	28.41	1.9	556.79
2006	448.0	60.8	18.0	6.99	2.8	24.71	1.9	563.20
2007	454.8	61.7	14.9	6.89	2.6	27.22	2.0	570.11
2008	461.7	62.7	11.9	5.84	2.4	25.91	2.0	572.45
2009	468.6	63.6	12.2	4.57	2.6	26.62	2.1	580.29

Source: Kiribati Energy Statistics Yearbook 2009 (Gilbert Island Group), unpublished report prepared by the Energy Planning Unit, referenced with permission.

during the working week it is around 3.4 MW. Therefore any problems with integrating solar generation into the grid are most likely to occur on the weekends. These problems can be overcome by selecting inverter that has functionality to switch off a substantial part of the solar generation on the weekends an array on the weekends.

As seen in Table 4, Tarawa electricity demand in 2011 was about 6.6 Gigawatt-hours (GWh) for government customers, 7 GWh for domestic customers and 3 GWh for commercial sectors. It may be noted that there is a slight decrease in the level of electricity consumption from the domestic and government & industry consumers which may be related to the increasing tariff as well as some efforts at improving the efficiency of energy use in government. Electricity generation on Tarawa in 2011 was approximately 17.3 GWh requiring usage of around 5.8 megalitres (ML) of diesel fuel.

Electricity production for Kiritimati is a small fraction of that of Tarawa. Table 5 lists the electrified villages and generation facilities and their approximate maximum and minimum loads.

By 2011, at least 2100 outer island households had installed solar energy for lighting, operating radios and other small appliances. The government-owned KSEC essentially operates and maintains all of them. Typical installations include a 100 Wp panel and 100 Ah battery with three compact fluorescent (CF) light bulbs and a multi-voltage adapter for a radio connection. High-reliability charge controllers are manufactured locally by KSEC for these systems with a few exported for use in SHS. There is currently no mobile phone access on outer islands though a separate charger adapter can be attached to the KSEC systems when the planned extension of the mobile network takes place. SHS charges are AUD 9 (USD 9.26) per month for basic lighting or AUD 10 (USD 10.29) with a radio adapter. Other fees have been negotiated for special cases, such as the use of Citizen Band (CB) radios for fishing boats.

Electricity tariffs. Tariffs are updated regularly to keep up with changes in fuel prices. PUB tariffs for Tarawa are in 2013 AUD 0.40 per kWh for domestic customers, AUD 0.55 for commercial customers and AUD 0.70 for industrial customers. The Kiritimati tariffs in 2012 were AUD 0.30 for residential and AUD 0.33 for others.

Table 4. Electricity statistics 2005–2010 (MWh)

Year	Billed			Not metered Water & Sewer	Not billed PUB[1]	Total (MWh)	Total fuel used at PUB *(Kilolitres)*
	Domestic	Commercial	Gov. & Industry				
2005	7 893.00	5 093.00	3 376.00	568.09	23.48	16 953.57	5 913.73
2006	6 864.00	4 500.00	4 458.00	568.09	3.13	16 393.21	6 235.66
2007	7 562.00	2 854.00	8 331.00	568.09	10.50	19 325.58	6 293.07
2008	7 197.00	3 073.00	7 335.00	568.09	8.52	18 181.61	5 881.87
2009	7 395.58	2 826.61	7 170.05	568.09	44.94	18 005.27	5 812.71
2010	7 137.21	3 032.41	7 007.29	568.09	20.32	17 814.41	5 744.97
2011	7 060.00	3 051.00	6 629.00	568.09	14.03	17 322.11	5 791.26

Source: Provided through communications by Energy Planning Unit.

1: PUB is for all PUB premises' consumption except the power house consumption which is around 4% to 5%.

Note1: Water and sewerage is estimated to be the same every year; however it could vary from year to year.

Note 2: Dom: Domestic; Comm: Commercial; Gov: Government.

Table 5. Kiritimati power systems, load estimates (2012)

Power Station	Total Capacity (kW)	Maximum Demand (kW)	Minimum Demand (kW)
London	750	200	70
Tennessee	125	40	15
Tabwakea	150	70	25
Banana	180	50	20
Poland	60	24	10
NASDA	100	75	25
Captain Cook Hotel	100	65	25
Rawanibakoa Resort	35	25	10
Spivey Secondary College	50	25	10
San Francis Secondary College	50	25	10
Totals	**1 540**	**575**	**210**

Source: Hassan G. "Wind Energy Feasibility Study for Kiritimati Island, Republic of Kiribati, unpublished report (17 August 2012), referenced with permission. Note: Due to the limited data logging by many of the sites, the maximum and minimum demand figures are estimates and need to be confirmed through actual measurements.

3. Renewable energy opportunities

Solar energy. Though the resource varies somewhat from north to south with the southern islands having a larger and more constant resource, the level of solar energy for all of Kiribati is very good with estimates for some islands indicating that more than 6 kwh/m^2/day is available for water heating or electricity generation. Since all of Kiribati lies close to the equator, seasonal variation is small, although there is likely to be some cyclic change due to the El Niño/El Niña climate cycle.

Biomass for combustion. Biomass, mostly in the form of coconut husks, shells and fronds, is sufficient to provide cooking and crop-drying energy without fear of depleting resources on all islands except Tarawa. If coconut is rehabilitated on Tarawa, in order to increase the production of copra to meet an increased demand for coconut oil (CNO) for biofuel, a major replanting programme will be necessary to replace some of the 2.8 million ageing trees, and a significant amount of biomass will then be made available in the short-term as those trees are cut down. However, using CNO for energy on the outer islands would require a major infrastructure investment with a shift from SHS to an island grid system, which may not be the most economic use of the coconut resource, since the logs also have economic potential both as an export product for furniture-making or for converting locally to finished wood products for construction or furniture manufacture.

A Pacific Islands Applied Geoscience Commission (SOPAC) study published in 2006 estimated that annual production of CNO for biofuel could be sustained at 3–4 million litres per year without impacting on traditional uses.

Biofuel. All the atolls of Kiribati have around 70% of their land area under coconut trees. The Gilbert group of islands has about 190 km^2 of land under coconut trees and the Line and Phoenix groups around 330 km^2 (mostly Kiritimati Island) under coconut trees. This represents around 6.1 million coconut trees. Of these, around 2.8 million are considered old and unproductive and are due for replacement if the demand for copra increases. The Department of Agriculture has prepared a project to provide incentives for replanting and the milling of old trees for lumber but the project has yet to be funded.

Unlike many Pacific island countries, copra remains a major cash-generating product for the outer islands largely due to a government price stabilisation policy that has kept the price of copra acceptable to outer island residents. The reasons for the policy include:

- maintaining rural incomes to slow population flows to Tarawa.;
- copra is about the only saleable product that provides outer island incomes;
- helping reduce the income differential between rural and urban Kiribati;
- maintaining future production for either export or biofuels; and
- political reasons as the majority of Kiribati's population is rural.

A coconut oil mill owned by Kiribati Copra Mill Ltd (KCMCL), a government corporation, was established in 2003 and operates on Tarawa. The mill can crush about 35 tonnes of copra each day with a maximum oil extraction yield of about 15–20 tonnes/day, with a by-product of around 10 tonnes of dry copra cake per eight-hour shift. Some of the oil production is used locally for energy at the mill and around 10% is sold in Kiribati. Local sales are mostly for personal use as scented skin oil and or as hand-made soap. Overall, however, the mill is presently economically dependent on its export sales. In 2010 the mill crushed 4 062 tonnes and produced 2 293 tonnes of oil. In 2011 it crushed 7 980 tonnes and produced 4 325 tonnes of oil at a price of AUD 1080 (USD 1158) per tonne, inclusive of cost, insurance and freight.

KCMCL is aware of its product's potential as a biofuel and has been refining quantities of CNO for mixing with diesel fuel or kerosene. The refining process includes some reduction in fatty acid content through a 5-micron filtering process. In 2006 the plant boiler successfully used diesel for start-up and biofuel for continuing operation. Tests of various blends of CNO and diesel fuel or kerosene have been carried out and it was found that when more than 20% CNO was mixed with diesel, the boiler was hard to fire up, but with kerosene trials a mixture of up to 40% kerosene and 60% CNO was satisfactory.

Tests also have been carried out on the plant's back-up generator and vehicles, although they were stopped when engine problems occurred.

Biogas. There is a modest potential for biogas generation in Kiribati if community pigs can be kept penned in a small area and their manure collected for biogas generation. However, that would entail a shift from the traditional approach where pigs are family-owned and free-ranging and may therefore be slow to happen. There are no commercial piggeries or cattle farms in Kiribati.

There is interest by several church communities and boarding schools in the outer islands in biogas projects. Their respective community pigs can be the source of a sustainable biogas fuel for cooking with the added benefit of the effluents from the digesters becoming available as fertilisers for their vegetable gardens. In this regard, the replication of small biogas digesters installed in neighbouring PICTs, such as Fiji, could jump-start biogas development in Kiribati.

Wind power. A recently completed wind survey indicates that the windward side of Kiritimati Island has sufficient wind resource to provide cost-effective generation. One of the main issues is connecting together the small grids on the north-west cluster of settlements and also interconnecting the north-east settlement cluster separately. Each can be considered for wind power integration into the two resulting grids. The Ministry of Line and Phoenix Development (MLPID) is now implementing the grid centralisation project for the north-west cluster of settlements – both villages and institutions – by extending the transmission lines and installing a bigger generator to supply the load for that newly interconnected cluster. This centralisation plan is also geared toward future renewable energy integration as planned between MLPID and MPWU. South Tarawa has not yet been surveyed for wind energy but the University of the South Pacific has installed a 34-metre mast near Buota for wind speed measurements. Nearby Abaiang will also receive a similarly instrumented wind survey mast to help provide information for possible outer island wind energy use.

If sufficient wind energy is available at sites useful for the PUB, then some of the potential problems that will need to be overcome to make wind turbines cost-effective on North Tarawa are:

- land access issues;
- environmental issues, such as noise and safety in densely populated South Tarawa;
- the need to cut down large numbers of economically useful tall coconut trees in order to provide a clear path for winds to reach the turbines without turbulence and loss of energy; and
- technical concerns regarding the integration of substantial wind energy capacity with the 900 kW of solar energy that is to be installed on the North Tarawa grid.

Ocean energy. The wave resource around Kiribati is low and wave energy conversion equipment has yet to be tested in the wave regimes of the Pacific tropics so ocean energy is not considered a significant resource for Kiribati in the near term. Although cyclones are not a high-risk problem, storms at sea sometimes cause high waves.

Tidal energy and Ocean Thermal Energy Conversion is not yet commercially available to fit the conditions in Kiribati.

4. Experiences with renewable energy technologies

Traditional use of biomass for cooking and copra drying remains the largest use of renewable energy in Kiribati. Solar water heating and solar electric generation using PV are the other predominant renewable energies used in Kiribati, although biofuels, which have had some use at the coconut oil plant and have been undergoing trials for vehicle use, do offer great potential.

Solar photovoltaics on outer islands

Solar home systems. SHS currently provide electricity to about 17% of Kiribati homes, a number that is set to increase to over 20% within two years. Prior to 1984 there were very few solar panels in the country, mostly brought home by seamen returning from European postings. However, once the benefits of solar for remote areas had been ascertained, the KSEC was established as a private enterprise in 1984 by the Foundation for the Peoples of the South Pacific Kiribati (FSPK), a US-based non-governmental organisation. The FSPK received United States Agency for International Development funding for its start-up costs and KSEC was formed as a private, limited corporation specifically charged with stocking and selling solar systems for the outer islands.

There were technical issues in the systems which were mainly due to the poor connections – wires were often merely wrapped around battery connections – and there was usually almost no maintenance. While the quality of the components was good, the users, despite having received detailed instructions in the local language, did not adequately install or maintain the systems and services were therefore poor.

A consultant from the Tahiti-based South Pacific Institute for Renewable Energy, recommended that KSEC be converted into a "solar utility" modelled after conventional utility structures whereby KSEC would be the owner of the solar equipment up to the house-wiring connection point, and would maintain the equipment while the user would be charged a periodic fee for the services provided.

In 1990 JICA agreed to field a team to test the solar utility concept on North Tarawa, a rural area without electrical power. Installation of 100 Wp SHSs in 57 households and 600 Wp in one community building (maneaba) was completed in 1992. The solar utility concept worked well enough to convince the European Union (EU) to fund an additional 300 installations in 1994, which spread the concept to Nonouti and Marakei, islands in the northern Gilbert group of Kiribati.

Capacity building and capacity maintenance were soon seen by KSEC as important factors for long-term success. With the help of overseas expertise, an in-house training capability was developed at KSEC and has been continually available to train new technicians and to provide continuous professional development courses for existing technicians. For many years, KSEC brought all its field technicians to Tarawa for training, exchange of information and morale-building. During the period 1992 to 2004, this resulted in a high rate of fee collections, generally 85% on time or better and good reliability for the installations.

The success of the 1994 project encouraged the EU in 1999 to provide funds for 1700 more SHSs and 140 maneabas. The installations were identical to those installed in 1992 and were distributed to the rest of the Gilbert group of islands. Many delays plagued the project, causing many cash flow problems for KSEC, but by 2006 all the SHSs had been finally installed and were operational (Table 6).

The expansion from 350 to 2 000 installations and from three islands to 18 was very difficult for KSEC from a management point of view. The government finally agreed to provide an annual subsidy for much of the cost of battery replacement – a major cost saving for KSEC though the company has yet to fully recover from the cash flow problems. As a result of these problems, around one-third of the SHS installations are not working and fee collections are poor as customers have lost confidence in KSEC's ability to provide its contractual obligations for repairs and maintenance.

A number of lessons were learned through these KSEC projects:

- 100 Wp is the minimum acceptable panel capacity to provide the electrical services desired by most rural Kiribati households, with many desiring and willing to pay for larger systems for additional services, notably video players.
- Good-quality batteries can provide continuous service for 10 years or more if reliable charge con-

Table 6. Outer Island solar 2011

Island	SHS	Number of Maneabas (meeting houses)
Abiaiang	114	9
Abemama	81	3
Aranuka	78	3
Arorae	94	2
Banaba	90	2
Baru	80	3
Butaritari	78	2
N Tarawa	211	10
Kuria	80	2
Maiana	94	5
Makin	92	7
Marakei	320	10
Nikunau	77	1
Nonuti	184	5
Onotoa	93	5
Tabituea	204	3
Tamana	78	3
TOTAL	2 048	75

Source: EPU (2012).

trols and adequate panel capacity are included in the system design.

- Rainwater can be used for battery water if carefully collected and stored.
- A locally manufactured controller using the design established by the South Pacific Institute for Renewable Energy can provide substantially higher reliability and longer battery life than off-the-shelf commercial controllers.
- A majority of rural households in Kiribati can and will pay AUD 9–10 (USD 9.24–10.27) per month for basic lighting and radio services.
- The fee collection rate depends strongly on the reliability of service provided and on the utility's willingness to disconnect for failure to pay fees.
- Field technicians need to be sufficiently mature to have the respect of the community and to be able to fully understand their responsibility for managing funds.
- One field technician can successfully manage the maintenance and fee collection for 100–120 household systems.
- Developing reliable energy service company operations increases opportunities for the sale of PV systems and service of private installations.
- Personnel management is the most difficult part of solar utility company operations.
- Good quality accounting and records management are essential for successful energy service company operations.

Other solar projects

Solar pumps. There have been several solar pumping projects for both villages and schools over the last 20 years. The initial United Nations Development Programme (UNDP) project for village water supply installed positive displacement pumps in the atoll. Most of these pumps failed during the first few years of operation owing to incompatibility with the coral dust in the shallow wells in Kiribati since the pumps need to maintain close tolerances. Later projects have used centrifugal pumps, which have survived much longer. Unfortunately the villages and schools targeted in the earlier projects failed to perform proper maintenance and repairs and almost none of the systems survived for long. Most of the systems have now been rehabilitated with maintenance provided by the Water Engineering Division (WEU) of the Ministry of Public Works and Utilities (MPWU).

In 2009, Italian-funded solar water pump projects for nine rural boarding schools (Church and Government) were implemented by the Energy Planning for the Gilbert Islands group and work at the one remaining school is anticipated to be completed in the first quarter of 2013. So far, the installed solar pumps are still working and minor maintenance of the system is done by trained community members involved in the respective installation phase of the project.

Private schools. Several private (church) schools have installed solar for lighting and refrigerator/freezers at their own expense and, in most cases have managed to provide adequate maintenance to keep them operational over the years.

Health centres. Canadian Aid installed solar systems on outer island health centres to provide power for lights, high frequency radios and a small vaccine refrigerator. The installations worked well and were initially maintained by KSEC. Though there were problems with the mechanical thermostats on the refrigerators due to corrosion, they were neither difficult nor expensive to replace and the systems remained operational for the useful life of the equipment.

However, by 2005 the Ministry of Health and Medical Services (MHMS) decided to cease the maintenance contract with KSEC for economic reasons. Currently, the MHMS electrical section is now maintaining the systems and thus far the savings over KSEC maintenance have allowed the replacement of failed parts by the MHMS.

By late 2008 the EU-funded project known as the "Kiri-EU Outer Island Clinics" had completed the construction of 18 new, permanent health centres on each island and 56 dispensaries in the outer Gilbert Islands. This project, started in 2004, also included solar PV electrification in each of the new clinics which were designed by the project consultant and installed by the project electrical staff. However, the PV systems for all the clinics started to fail a few months after completion due to the demand exceeding the design capacity as well as other short comings with the initial design. The MHMS is now requesting funding to rehabilitate the solar PV systems to meet the needs in all of these clinics. The project is to be assisted by the MPWU.

Telecom centres. Telecom Services Kiribati Ltd (TSKL) has a number of small outer island solar installations that power telephone equipment and have maintenance contracts with the KSEC.

Solar street lights. Though most solar installations are on outer islands, solar street lighting has been used successfully from about 2000 to 2012 on South Tarawa along the 2 km causeway between Betio and Bekinebieu. The lights use an 80 Wp panel and a sealed battery to power a 20 Watt fluorescent-type street light. The batteries and electronics are located underground to protect them from the sun's heat. This approach has worked well with very low maintenance requirements and a battery life exceeding 10 years in some cases. However, by 2012 batteries had largely failed and maintenance has not been carried out. Plans are in place for replacement of the street lights with higher efficiency LED-type units and the existing lights are expected to be moved to other areas where area lighting is needed, but access to power for street lighting is expensive.

Solar projects in the pipeline

The European Development Fund SHS project. A number of separate solar projects are included under the current EU project that is ready for tender. The main component of this project is the provision of about 1750 small home lighting kits (pico-solar) that include one 5 Watt LED light and two 3 Watt LEDs and additional installations for the maneabas. This time the SHSs will not be limited to 100 Wp each. Some 200 Wp SHSs will be installed for teachers and some 300 Wp SHSs for businesses. Small maneabas will receive 300 Wp of solar and larger ones 600 Wp.

School electrification on AC power. So far, all solar installations have only provided DC power, although portable inverters could be connected to the DC supply by users if they needed to operate AC appliances. It is expected that, starting with the EU project currently being prepared, full grid-quality AC electrification will be provided for six outer island schools (Table 7) with systems ranging from 16 kWp of solar charging a 4 200 ampere-hour (Ah) 48 V battery to 42 kWp with a 10 200 Ah battery. The electricity will typically be used to operate lights, a computer lab, office equipment and a kitchen with freezers and refrigerators. Also scheduled is a 36 kWp installation, funded by Italy, at Chevalier College, a large boarding school on Abemama, which will reduce diesel fuel use for electricity generation.

Table 7. School electrification projects in the pipeline

EU-funded School Solar System	PV array (kWp)	Battery (Ah @ C_{10} rating)	Inverter (kVA, 3 phase)
Morikao (Abaiang)	16	4 200	9
Tabwiroa (Abaiang)	16	4 200	9
Hiram Beingham (Beru)	25	6 300	9
Taborio (North Tarawa)	25	6 300	9
Teabike (Tabiteuea North)	29	6 800	9
Kauma (Abemama)	42	10 200	15

Source: EPU (2012)

Solar mini-grid. As part of the EU EDF10 project, a small diesel grid for Poland village on Kiritimati Island will include 16 kWp of solar with sufficient battery storage to provide much of the village's energy requirements, leaving the existing diesel to act as a backup.

Grid-connected solar photovoltaics on Tarawa and Kiritimati Islands. To date there has been only one grid-connected solar installation in Kiribati, which is a private installation on Kiritimati Island owned by the ANZ Bank, with 18 kWp of solar used to offset air-conditioning costs. There are however plans for substantial grid-connected solar installations on South Tarawa. In 2010 a pre-feasibility study by a World Bank (WB) team recommended large-scale introduction of grid-connected solar. The WB funded a feasibility study in 2011 which proposed that 800 kWp of solar be dispersed among the population centres of South Tarawa. The final amount to be installed through funding sourced by the WB will be determined by negotiations with the Kiribati government, since also around 400 kWp of grid-connected solar has also been approved for Kiribati by the Pacific Environment Community (PEC) Fund of Japan. Since the WB feasibility study indicated that 900 kW is about the upper limit for grid-connected solar without special regard for grid stability, it appears likely that around 500 kW will be funded through the WB and 400 kW through the PEC Fund. The solar installations are likely to be integrated into the grid and spread over the length of South Tarawa to reduce problems with large solar variations caused by passing clouds.

Another part of the EU project involves installing 10 kWp of grid-connected solar for the KSEC offices on South Tarawa.

Solar thermal. Some solar water heating has been installed in the hotels and guesthouses of Tarawa and Kiritimati Islands, but there has been little use in households or for other purposes. The market is limited by the cost of the units, their poor record (due largely to using high mineral content ground water that results in rapid build-up of scale in the water heaters) and the small demand by households for piped hot water.

Wind power. No wind energy generation has been developed in Kiribati but a wind resource assessment is underway on Tarawa and Kiritimati to determine if it is economical to develop the resource further. Based on the wind feasibility study on Kiritimati Island carried out by White (2012), there are indications that the wind resource on the island has a good potential for utilisation.

Biomass, biogas and biofuels. Except for traditional biomass use for cooking and copra drying, there has been no development of biomass or biogas for energy production.

Under Italian Fund financing, a biofuel refining project at KCMCL tried using a 70% CNO and 30% diesel fuel blend in its own vehicles but stopped the trials following mechanical problems. KCMCL is now looking at using 100% CNO for its own energy needs. There has also been a recent feasibility study into the use of CNO on Kiritimati Island. By using both CNO and other renewable energy sources such as wind and solar, Kiritimati Island could be powered by 100% renewable energy. PUB has also indicated a strong interest in CNO for electricity generation, but only after extensive testing has shown that there is little risk to generator engines.

5. Challenges and opportunities for renewable energy deployment

- The population is widely dispersed on numerous atoll islands and often further fragmented as islets in an atoll, making centralised management of outer island energy systems difficult.
- The life-cycle cost of renewable energy generation through solar and wind is competitive – in some cases substantially cheaper than diesel generation – but the high initial investment cost remains a barrier to investment.
- There is almost total dependence on external funding for energy projects, which results in long lead times and adds complexity to implementation.
- Duties and taxes for renewable energy systems are applied inconsistently.
- Grid-connected solar projects in the pipeline will approach the level where there are stability issues for the grid. Adding more grid-connected solar on Tarawa may require including storage or special control systems to avoid grid stability problems.
- The EPU and KSEC may require further assistance for energy planning, project development and donor coordination.
- The PUB, KSEC and KOIL have limited capacity for financial planning and analysis.
- Availability of energy data is limited, with both record-keeping and data management needing some improvement in the energy companies.
- There is a lack of local training capacity in business management and renewable technologies.
- There is a lack of trained or experienced personnel for management or technical positions in energy companies, especially on outer islands.
- There are difficult environmental conditions for energy equipment.
- International transportation by air and by sea is neither reliable nor of good quality. It is also often expensive, making delivery of replacement parts both slow and costly.
- There is a small and fragmented energy market making development of private energy-related businesses difficult.
- There is a lack of public awareness regarding renewable energy and energy efficiency.

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 for Kiribati.

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In the preparation of this report, primary sources were used as much as possible. Personnel from the Energy Planning Unit, the Solar Energy Company and KOIL spent considerable time in locating and providing much of the requested information as well as in helping to find additional sources. Where primary sources were not available, the following secondary and tertiary sources were used.

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