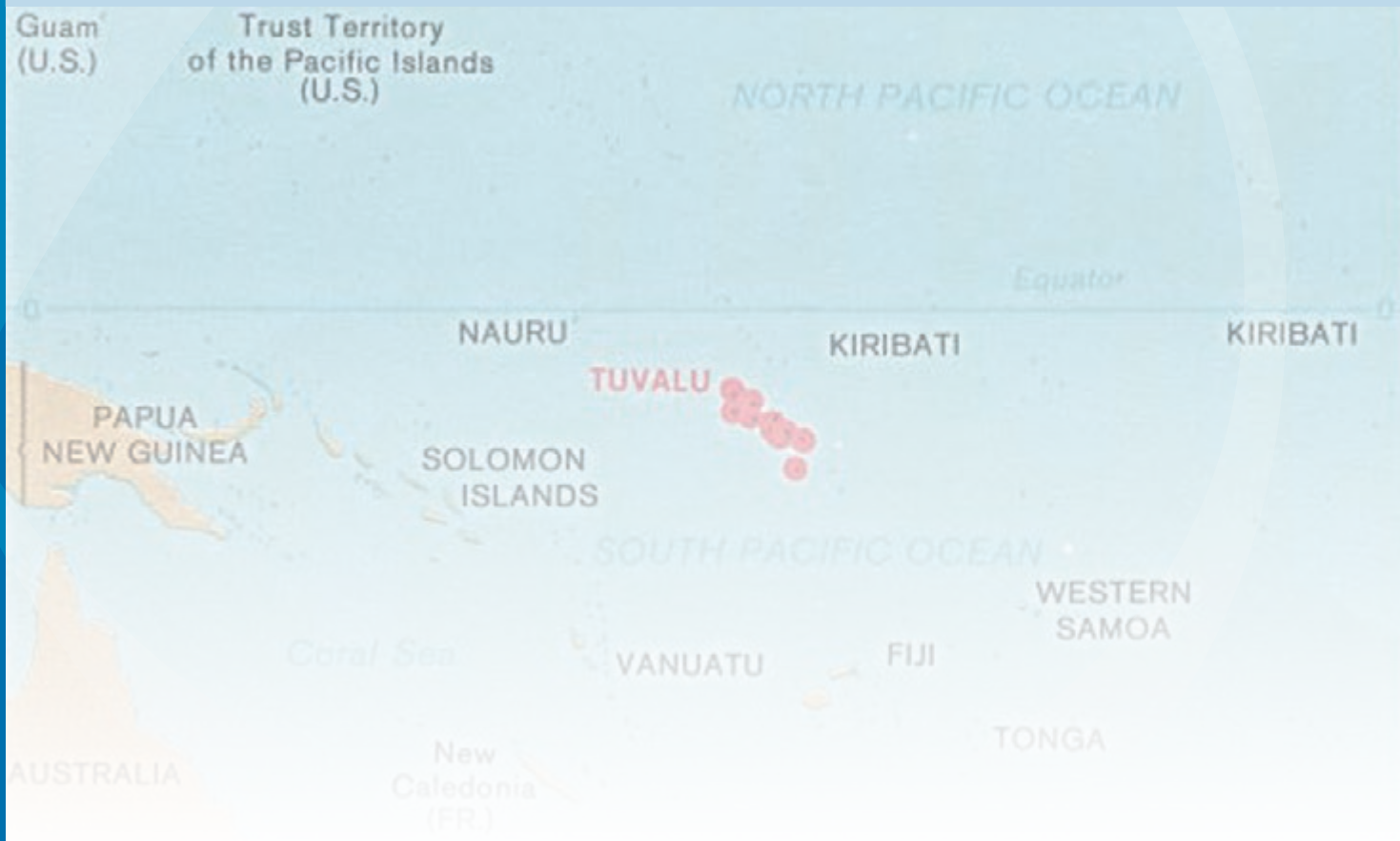
Report

IRENA
International Renewable Energy Agency

Pacific Lighthouses

Renewable energy opportunities and challenges in the Pacific Islands region

Tuvalu



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The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.
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Note on currency:
On 23 October 2012, one Australian dollar (AUD) exchanged for United States dollars (USD) 1.032.

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

ADB	Asian Development Bank
AECOM	Global provider of professional technical and management support services
AUD	Australian dollar (currency)
EU	European Union
GWh	Gigawatt hours (thousand million watt hours)
km/km²	Kilometres / square kilometres
kW	Kilowatt (thousand Watts)
kWh	Kilowatt hours (thousand Watt hours)
kWp	Kilowatt peak (rated value for solar)
LPG	Liquid Petroleum Gas
MW	Megawatt (million Watts)
OTEC	Ocean Thermal Energy Conversion
PNG	Papua New Guinea
PV	Photovoltaics
TEC	Tuvalu Electricity Corporation
TSECS	Tuvalu Solar Electric Cooperative Society
VAT	Value Added Tax

1. Country context

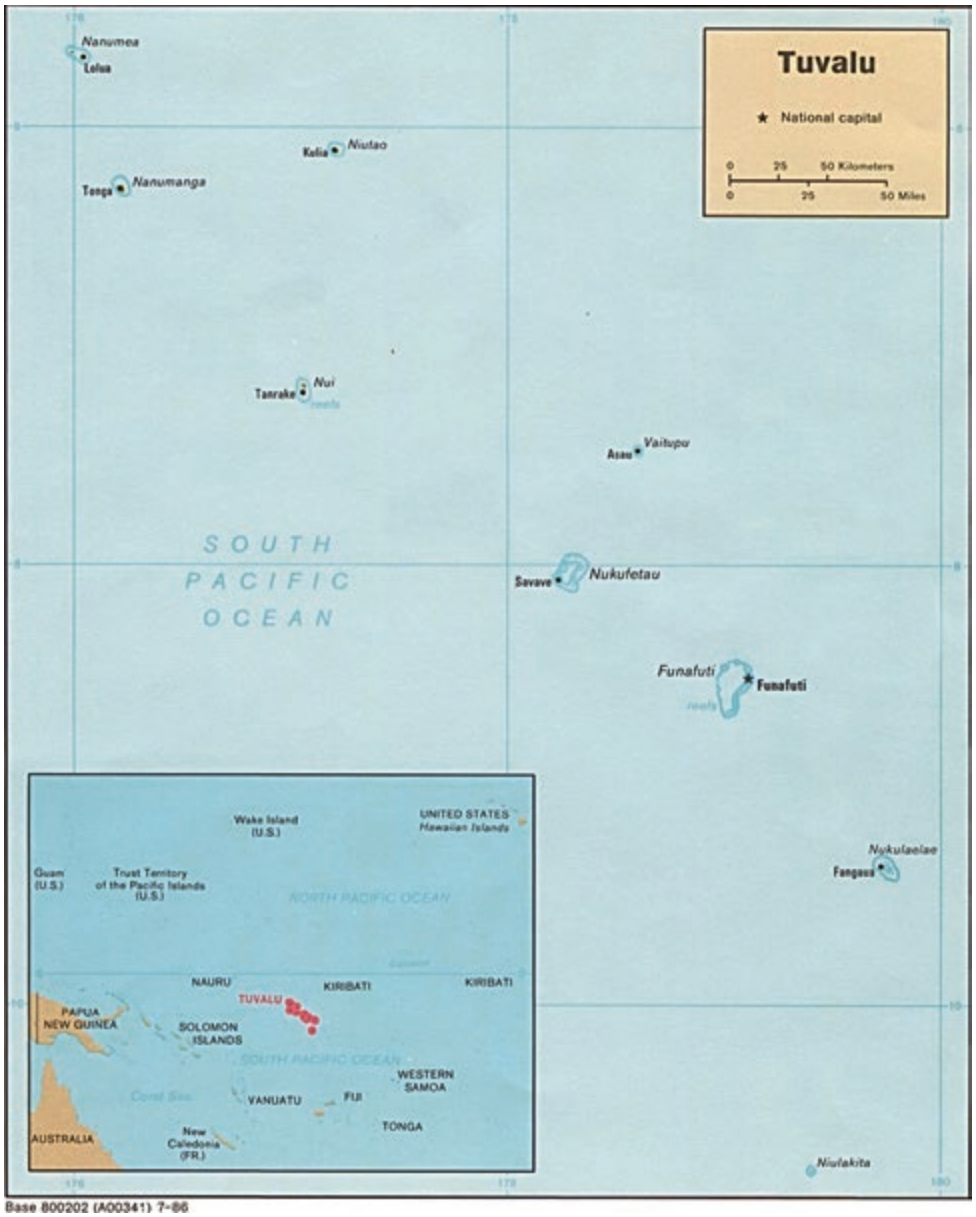

Figure 1. Map of Tuvalu

Source Source: www.lib.utexas.edu/maps

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

Physical Description. Tuvalu lies approximately 1100 kilometre (km) due north of Fiji and centred at about 8° South latitude and 178° East longitude. Tuvalu's Exclusive Economic Zone covers 719 714 square kilometres (km^2). The country's total land area of 26 km^2 is spread over eight islands, the largest of which, Vaitupu, has an

area of about 5.6 km^2 while the smallest, Niulakita, has only 0.42 km^2 of land. The atoll of Funafuti is the centre of government and the hub for air and sea transport.

Population. Population growth has been slow with the 1990 population recorded as 9 043. The population has risen very slowly from 9 300 in 2002 to 9 860 in 2012. Tuvalu's slow population growth is attributed to emigration, particularly to Australia and New Zealand. During the last census there were about 1570 households with an average of six persons each. Funafuti, with 4 492 inhabitants, had more than 48% of the population, followed by Vaitupu, with a population of 1591. The population in the rest of the islands range from 400 to 700, except for Niulakita, where there are only 32 residents.

Environment. As with all atolls, Tuvalu's soil is low in fertility and only a narrow range of food plants can be supported. The sea is the primary source of local food. Tuvalu's climate is tropical to equatorial and although tropical cyclones can cause serious damage, their passage is not common. Storm surges, winds and heavy rain can, however, cause damage to the low-lying islands even if a cyclone does not actually pass through Tuvalu. Rainfall averages 3 500 mm per year, with April through November being the driest months. Droughts can occur and maintaining a fresh water supply on densely populated Funafuti is increasingly becoming an issue. Rainwater is Tuvalu's primary fresh water source but a 65 000 litre per day reverse osmosis desalination unit has also been used in recent years. It is possible to pump some water from wells but it is brackish and the wells can easily be over-pumped, causing an intrusion of salt water.

Climate change presents major challenges for Tuvalu since low-lying areas of land will be rapidly lost as sea levels rise. In terms of per-capita greenhouse gas emissions, Tuvalu registers in the upper half of Pacific island countries, ranked above Tonga, Samoa, Fiji, Tokelau, Kiribati, Vanuatu, Papua New Guinea (PNG) and the Solomon Islands. This is largely as a result of 97% of the population having electricity supplied from diesel-powered generators with the exception of Niulakita, where the few homes on the island are electrified by individual solar home systems. The Pacific island states with lower emissions either utilise significant amounts of renewable energy (hydro in Fiji, PNG and Samoa or solar in Kiribati and Tonga) or still have large rural un-electrified populations (PNG, Vanuatu and the Solomon Islands).

Economic overview. Tuvalu ranks third in the Human Poverty Index among the Pacific developing member countries of the Asian Development Bank (ADB). The main barriers to Tuvalu's economic development are its small size and isolation. The Tuvalu Trust Fund provides over 10% of the government budget. Marketing of the "dot TV" internet domain has brought in several million dollars. Additional sources for income include sale of foreign fishing licences and remittances from overseas residents and Tuvaluans working as seamen. Copra is no longer traded and exports of other products are negligible. Donor inputs in 2001 amounted to over one-third of the country's gross domestic product (GDP) with Japan as the main contributor.

The Government is the main employer, providing around 70% of salaried employment. The private sector consists mainly of small shops and service providers on Funafuti and traders of agricultural products from the outer islands.

Two ships, the *M.V. Nivaga II* and the *M.V. Manu Folau,* provide inter-island shipping. Only Funafuti and Vaitupu have wharf facilities. Unfortunately the Vaitupu wharf cannot accommodate the inter-island ships and off-loading must be done at anchor. Shipments to outer islands must be transferred to small boats for landing, often through narrow channels blasted through the reef, at some risk to both cargo and passengers.

Of the 28 km of roads in Tuvalu, 19 km are on Funafuti. Most vehicles are owned by the government or government-owned corporations, although private ownership of vehicles is rapidly increasing.

The main financial institutions are the Development Bank of Tuvalu, which focuses on development loans, and the National Bank of Tuvalu, which is a full-service commercial bank.

2. Energy landscape

Institutional and regulatory arrangements for energy

Energy activity, regulation and administration are not centralised.

Energy Office. The Government's Energy Office within the Ministry of Public Utilities develops energy policy and administers renewable energy projects.

The Tuvalu Electricity Corporation (TEC). The TEC is a 100% government-owned commercial utility charged with providing a cost-effective and reliable electricity supply to all of the islands of Tuvalu.

The Tuvalu National Energy Policy. The National Energy Policy was endorsed in 2009 with the goal of promoting the use of renewable energy resources and cost-effective, equitable, reliable, accessible, affordable, secure and environmentally sustainable energy systems to improve the well-being of the people of Tuvalu.

Enetise Tutumau 2012-2020. In 2012 the Government launched the "Enetise Tutumau" – the Master Plan for Renewable Electricity and Energy Efficiency in Tuvalu. The plan has the goals to generate electricity with 100% renewable energy by 2020 and to increase energy efficiency on Funafuti by 30%.

Energy supply and demand

Petroleum. Fuel is now imported by Pacific Energy (formerly BP Southwest Pacific, Ltd.), which owns all storage and distribution facilities. All fuel imports, other than diesel fuel for TEC, are subject to import duty and value-added tax (VAT).

Ever since the 1990s petroleum (gasoline) has replaced biomass as Tuvalu's largest energy source. Between 2006 and 2010 the marine transport and power sectors were the largest users of fuel (Table 1). In the outer islands there are very few vehicles and so most of the fuel consumption for transportation is outboard motorboats. There is no domestic aviation, although Tuvalu purchased part ownership in Fiji Air, which provides an international flight service to and from Tuvalu twice a week, with additional flights when demand is high.

In the 1990s, kerosene was promoted as a replacement for wood for cooking, but in the 2000s liquid petroleum gas (LPG) began replacing kerosene, particularly on Funafuti, where over half the households now use LPG for some of their cooking. LPG is imported in individual small tanks, which are refilled in Fiji.

Electricity generation and demand. Tuvalu's electricity supply includes 2.345 megawatts (MW) of firm capac-

Table 1. Petroleum imports by year and end use sector (litres)

Year	Cooking	Fishing	Transport	Electricity	Total
2006	221 050	131 975	570 724	1 816 234	2 739 983
2007	405 875	195 390	2 096 574	2 164 627	4 862 466
2008	122 200	58 976	1 241 104	1 662 775	3 085 055
2009	121 500	61 240	2 071 131	1 784 382	4 038 253
2010	63 114	36 935	1 752 274	1 662 480	3 514 803
2011	34 001	83 063	1 059 787	1 482 089	2 658 940

Source: Provided through communication by Tuvalu Energy Office (2012).

ity on Funafuti, 260 kilowatts (kW) on Vaitupu and between 128 kW and 208 kW of diesel generation on the other islands (excluding Niulakita where only solar power is used). TEC was corporatised in December 1991 and in late 2012 had a staff of 57 distributed around the country. Peak demand on the outer islands varies between 25 kW and 55 kW, making the large engines installed there oversized and inefficiently used.

Technical losses are estimated at around 4%, which is considered very good, and non-technical losses are also low at 4-5%. Reliability has historically been good. However, station losses approaching 9% are considered high. Fuel efficiency on Funafuti is lower (3.7–3.90 kWh per litre) and even much lower on outer islands.

The maximum power demand in Funafuti is about 900 kW. Electricity sales in 2010 totalled about 3.7 GWh on Funafuti and around 9.3 MWh for the outer islands (Table 3). Appliance ownership is high, even on the outer islands where a high percentage of households have washing machines, irons, refrigerators and freezers. Assuming annual population growth of 2% and a 1% rise in electricity usage per capita, the required demand per person in 2020 is expected to be almost double the level in 2010. Under such a scenario, a programme for accelerated deployment of renewables will be needed to prevent power shortages.

The largest commercial user of electricity is the Tuvalu Cooperative Society, the importer and distributor of most food products in Tuvalu. The government has a demand of about 133 MWh/month.

The load curves on Funafuti (Figure 1) show a mid-day primary peak and a lower peak in the evening. The mid-day peak is attributable to air-conditioning in government buildings. Weekend loads show a dominant evening peak. Since solar potential peaks at noon, the amount of acceptable penetration of solar into the grid has to be based on the minimum noontime load during the week, in this case about 550 kW. The amount of acceptable penetration into the grid for wind must be based on the minimum load, which is about 420 kW.

Fuel efficiency for generation on the outer islands, which switched from solar power to diesel grids in 2000, is poor although performance varies widely from island to island. Power on the outer islands is generally provided 18 hours a day, but on occasions it may run for longer.

There are 210 streetlights on Funafuti, each rated at 100 Watts. They are paid for by a surcharge of AUD 0.01 (USD 0.01032) added to each kWh charged to all customers.

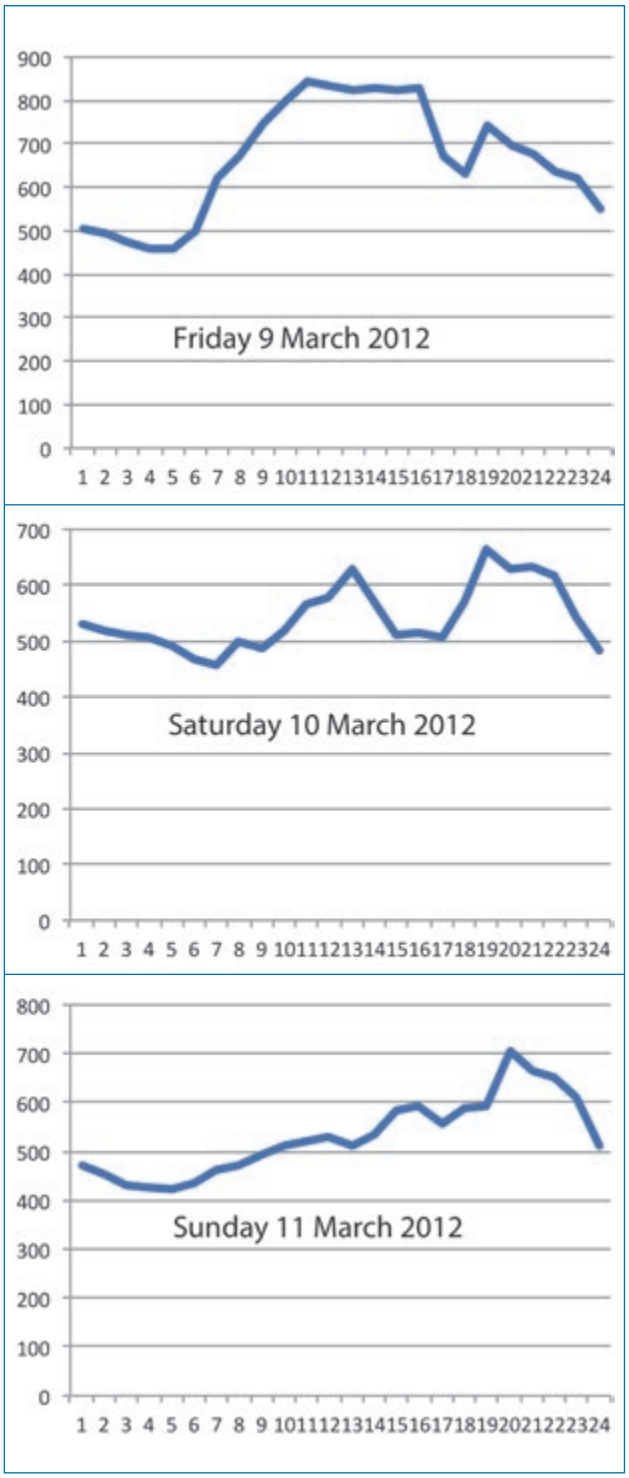

Figure 1. Funafuti load curves (kW)

Source: Provided through communication by Tuvalu Electricity Corporation (2012).

Electricity tariffs. As of June 2012 the tariffs for residential, commercial and government customers of TEC are as given in Table 2. All commercial and government customers paid AUD 0.56 (USD 0.578) per kWh. On the

Table 2. TEC electricity generation and fuel usage

Sector	2009	2010	2011
Residential (GWh)	2.05	2.1	2.05
Commercial (GWh)	1.65	1.65	1.43
Government (GWh)	0.89	1.64	1.6
TOTAL (GWh generated)	**4.59**	**5.39**	**5.08**
Total Funafuti (GWh)	*3.67*	*4.37*	*4.07*
Funafuti fuel use (ML)	1.20	1.42	1.46
Outstation fuel use (ML)	0.378	0.339	0.354

Source: Provided through communication by Tuvalu Electricity Corporation (2012).
Note: GWh is Gigawatt-hours; ML is Megalitres

outer islands, where there is no street lighting, the November 2010 electricity tariff had the same structure as on Funafuti but was reduced by AUD 0.01 (USD 0.0132) in each tier. These charges are greatly below the generation costs of more than AUD 1.50 (USD 1.55) per kWh on the outer islands. Tariffs are set by Tuvalu's Cabinet after being proposed by the TEC Board of Directors.

Table 3. TEC electricity tariffs (as of June 2012)

Consumer type		Tariff (AUD/kWh)	Tariff (USD/kWh)
Residential	0–50 kWh/ month	0.30	0.31
	51–100 kWh/ month	0.39	0.40
	over 100 kWh/ month	0.56	0.58
Commercial and government		0.56	0.58

Source: Provided through communication by TEC.

3. Renewable energy opportunities

Tuvalu has established a goal of reaching 100% electricity generation from renewable energy sources by 2020. Tuvalu's proposed approach is through development of solar and wind energy combined with energy efficiency measures, although it appears likely that in order to reach the desired 100%, the use of coconut oil-based biofuels will also be required. Since the percentage of electrical energy that currently comes from renewables (only solar at present) is about 2%. This factor, together with the recent launch in 2013 of the Enetise Tutumau 2012-2013 (master plan for 100% of electricity generation from renewable sources by 2020 and an energy efficiency increase of 30%), means that there is plenty of scope for deployment of renewables in Tuvalu over the next ten years.

Solar energy. Tuvalu's solar resource potential has been proven sufficient to reliably power solar home systems. The resource in central areas is estimated to provide about 5.5 kWh/m^2/day, with the values being higher to the north and lower to the south of the country.

Wind power. Wind resource measurements have been carried out on Funafuti but only at the 30-metre level. An average wind speed of 5.79 m/s was recorded, and the consultant making the assessments recommended installation of small turbines in the 20–50 kW range as there is no crane on Tuvalu capable of installing larger turbines. However, since the larger, more cost-effective 275 kW turbines with tilt-up towers (such as used in Fiji, New Caledonia and Vanuatu) do not require cranes for installation, these could also be a practical option for Funafuti where the load is large enough to accommodate the higher power outputs from these turbines.

Many years of meteorological measurements at Funafuti airport indicate a seasonal, highly irregular pattern of wind speeds, often below the speed necessary to economically produce electrical energy. However, there are better locations for wind power, and it therefore makes sense to continue a proper assessment along Funafuti's windward reef and in the lagoon, where there is no interference from the tall coconut trees that cover the land areas. Due to the very small land areas of Tuvalu's atoll islands, wind farm construction would require machines that can withstand rough terrain and the harsh marine environment in addition to being appropriately sized for the small loads typical on all the islands apart from Funafuti.

Biomass. A high percentage of the available biomass on Tuvalu is in the form of coconut trees which cover around 1600 hectares (approximately over 60% of the total land area). Although heavy use of this resource for fuel production is not possible due to the slow growth rate of replacement trees, if the coconut industry is revived by biofuel production, a significant amount of biomass may become available through replacing senile trees. Before large-scale replanting takes place it should be determined whether the best economic use of the senile trees would be for fuel or for wood products.

Biofuel. Tuvalu's copra production has fallen to low levels in recent years. If each island were to have a small oil mill, the remaining coconut resource has sufficient capacity to replace a high percentage of the diesel fuel used for power generation on the outer islands with only small modifications to existing generation equipment. However, the high cost of outer island labour and shipping have priced Tuvalu out of the international coconut oil market. In addition to potential profitability, local fuel production would vulnerability to volatile fossil fuel prices in the global market. Biofuels offer the largest potential for petroleum import reduction of any renewable energy resource available in Tuvalu.

Biogas. Biogas could be produced from pig manure in Tuvalu if islands penned all their pigs in one area and collected the manure for gas production. However, the traditional approach is to have a few family-owned, free-ranging pigs. Small-scale biogas digesters have been tried in other Pacific island countries although all but a few have been abandoned apparently because the users perceive the modest gas output not worth the time and effort necessary to keep the digesters running properly. The only successful biogas generators have been those associated with large-scale commercial animal or dairy production.

Wave energy. Wave energy measurements indicate that there is a moderate resource in Tuvalu but at present there are no commercially viable wave energy conversion machines for deployment in the country.

Ocean Thermal Energy Conversion (OTEC). Although there is a large OTEC resource, it is not presently viable to commercially deploy OTEC generators in Tuvalu. When they do become available, economy of scale would remain a significant challenge, as the cost per kW would be high at the scale Tuvalu requires.

4. Experiences with renewable energy technologies

Solar Photovoltaics (PV). Tuvalu was one of the first countries in the world to attempt rural electrification using solar PV. Over the period 1984–1994, more than 400 solar home systems were installed on the outer islands, reaching nearly 40% of all rural households. The systems provided lighting and basic entertainment services until the mid-1990s. However, the Tuvalu Solar Electric Cooperative Society (TSECS), which operated the systems, collapsed and was de-registered as a cooperative and so no longer provides electricity services. Although solar PV and solar water heaters are the only forms of renewable energy generation that have proven successful in Tuvalu, the solar installations on the outer islands were mostly taken out of service when diesel grids were installed in 2000. The solar equipment remaining was turned over to the individual islands, and more than 200 systems (about 50% of total installations) are still being intermittently used for back-up electricity or electricity during the six hours each day when the diesel power utility does not operate. However, the systems are not professionally maintained, and many households have reverted to basic car batteries and direct connections from the panels to the batteries. If the systems were rehabilitated, they could still provide cost-effective lighting and remove part of the load from the diesel grid. All homes on Niulakita still use solar for electricity, with maintenance by TEC.

Grid-connected solar was first introduced by the e8 (an alliance of leading power utilities around the world) in 2008 with a 40 kilowatt peak (kWp) installation in Funafuti from Japan. The plant was intended to reduce fuel use by 17 500 litres a year. A 46 kWp solar mini-grid installation funded by Italy has been functioning on Vaitupu since 2009. It uses batteries to store the solar-generated electricity and smoothly delivers the power to the grid, which directly offsets diesel generation with a projected fuel saving of 43 800 litres per year. Unfortunately its sustainability is limited by inadequate maintenance capacity.

European Union (EU) funding has been approved for 300 kWp of grid-connected solar PV on the three outer islands of Nukulaelae, Nukufetau and Nui aimed at improving reliable access to modern energy services through solar PV systems[1]. The tender for this project was launched in July 2013.

Tuvalu's long-term goal is to convert all outer island diesel generation to solar mini-grids although funding has yet to be found. The Tuvalu Master Plan for Renewable Electricity and Energy Efficiency 2013-2020 lists a number of potential renewable projects for financing.

Solar Thermal. Solar water heaters have been successfully installed in commercial buildings and homes although high costs and the limited market for piped hot water have slowed their widespread use.

Bioenergy. Biomass has been traditionally used for cooking and copra drying and still remains a major energy source for these purposes on the outer islands. The majority of biomass used for cooking is coconut husks and shells, with some mangrove and other types of wood used where available. Although there is no shortage of biomass for cooking and copra drying, mangrove wood, the premium fuel for cooking, is becoming scarce in some high population density areas.

Cultivation of biomass crops is hampered by poor soil and limited land area. Coconut trees, which are hardy and cover most of Tuvalu, are highly valued as a food source, which has discouraged efforts to develop them for biofuel. However, many trees appear underutilised, suggesting that a well-managed biofuel programme could succeed.

Using solar PV as the principal energy generation system for outer island grids, with coconut oil providing fuel for diesel back-up generators, appears to be the most feasible way to achieve 100% renewable power generation on the outer islands.

Wind power. Only small multi-blade windmill water pumps have been installed in Tuvalu. However a 30-metre mast to measure the wind regime at Funafuti has collected data over a sufficient time span. Analysis of the data suggests that the regime is sufficient for an economically useful wind farm along the east coast, north of the port.

The wind resource measurements mast has been shifted to Niulakita for measurements there.

1 http://www.pacificenergysummit2013.com/about/introducing-the-pacific-island-countries/

5. Challenges for renewable energy deployment

- Lack of capacity to prepare complex project proposals for funding by financing institutions.
- Highly subsidised TEC tariffs, especially on outer islands.
- Limited capacity at the energy office for renewable energy development.
- High cost of marine and land transport.
- Land tenure issues.
- Difficult environment for electrical and mechanical equipment.
- Lack of experience in the operation and maintenance of renewable energy systems in the Pacific.
- Small island areas and dispersed populations.
- Limited awareness and knowledge of renewable energy and energy efficiency.
- Lack of a realistic and well-defined action plan to achieve fuel import reduction targets prior to the launch of the Tuvalu.Master Plan for Renewable Electricity and Energy Efficiency in 2013.
- Limited public awareness of energy efficiency and renewable energy options.

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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In the preparation of this report, primary sources were used as much as possible. Some information was obtained through written questionnaires, interviews or through email correspondence. Where primary sources were not available, the following secondary and tertiary sources were used.

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