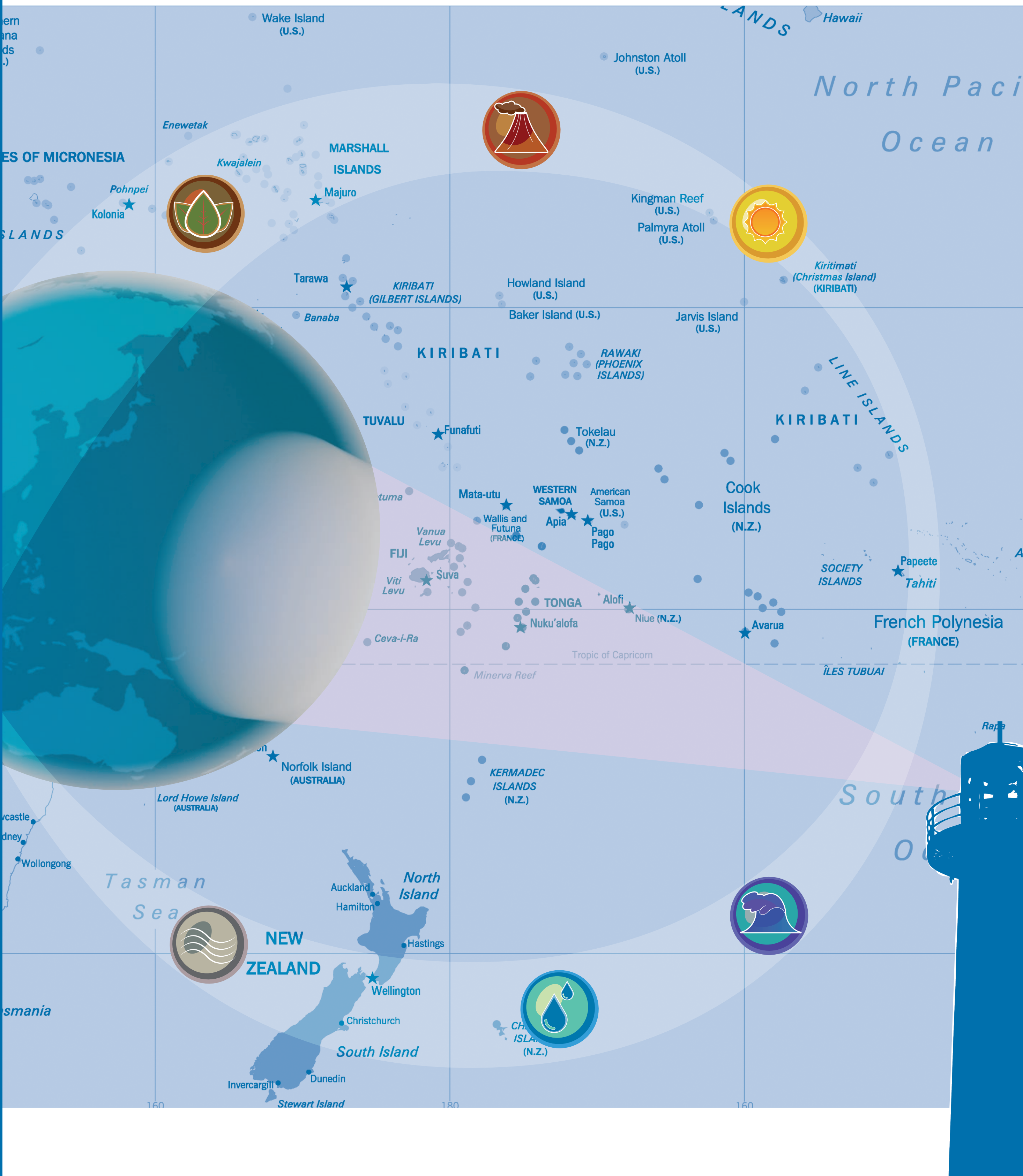
Report

IRENA

International Renewable Energy Agency

Pacific Lighthouses

Renewable Energy Roadmapping for Islands



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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Pacific Lighthouses

Renewable Energy Roadmapping for Islands

August 2013

Foreword

Pacific islands are endowed with a rich variety of renewable energy resources, providing a viable and attractive alternative to fossil fuel imports. Globally, as deployment rises and manufacturing costs fall, the economic equation increasingly favours renewable energy technologies. This is particularly true for the Pacific region, which has already taken significant steps to alleviate its dependence on fossil fuels, which entail a volatile global market as well as high costs for local distribution.

In January 2012, the International Renewable Energy Agency (IRENA) hosted a Pacific Leaders Forum in Abu Dhabi. In the resulting Abu Dhabi Communiqué, leaders from 11 Pacific Island Countries and Territories called on IRENA to work jointly on establishing an enabling environment for renewable energy deployment in the region. They asked for this work to be integrated into a roadmap for accelerated renewable energy uptake in the Pacific.

Since that time, IRENA has worked closely with a wide range of stakeholders in the Pacific, including governments, utilities, the Pacific Power Association, the Secretariat of the Pacific Community, North-REP, the Sustainable Energy Industry Association of the Pacific Islands and others, to identify gaps and produce innovative, practical and island-specific solutions.

IRENA's multi-faceted work in the region is reflected in *Pacific Lighthouses: Renewable Energy Roadmapping for Islands.* The main report, intended to provide a framework for further action, is supported by 15 reports on specific islands and a document detailing hybrid power systems for the Pacific. Together, these reports identify key concepts, challenges and best practices for the accelerated uptake of renewable energy in the region. The aim is to provide island governments and, indeed, all stakeholders, with baseline information to assist in the development of local renewable energy deployment roadmaps, as well as strengthening the implementation of regional initiatives.

I trust this publication will prove useful to countries and territories with action plans in place, to those still formulating national roadmaps, and to the various development partners working to promote clean energy solutions and sustainability in the region. As our world works towards a future based on clean, secure and affordable energy services for all, the Pacific Island Countries and Territories have the opportunity to become beacons of confidence that can help chart the course for other island regions and beyond.

Adnan Z. Amin
Director-General, IRENA

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Acronyms

CROP	Council of Regional Organisations in the Pacific
FAESP	Framework for Action on Energy in the Pacific
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation (Gesellschaft für Internationale Zusammenarbeit)
IPESP	Implementation Plan for Energy Security in the Pacific
IPP	Independent Power Producer
GREIN	Global Renewable Energy Islands Network
PICTs	Pacific Island Countries and Territories
PPA	Pacific Power Association
RE	Renewable Energy
REMAP	Global Renewable Energy Roadmap to 2030
RRA	Renewables Readiness Assessment
SE4ALL	The United Nations Sustainable Energy for All Initiative
SHS	Solar Home System
SIDS	Small Island Developing States
SPC	Secretariat of the Pacific Community
PIGGAREP	Pacific Island Greenhouse Gas Abatement through Renewable Energy Project

Summary

The Abu Dhabi Communiqué, issued by leaders from 11 Pacific Island Countries and Territories (PICTs) in January 2012, called for assistance to the region with assessing renewable energy readiness, ascertaining opportunities, identifying pathways to close gaps and integrating all activities to promote renewable energy in the region into a single, coherent roadmap. The International Renewable Energy Agency (IRENA) responded by carrying out a wide range of activities of specific relevance and application to the region in close collaboration with existing regional organisations and key stakeholders.

This *Pacific Lighthouses* report, along with 15 reports on specific islands and another on hybrid power systems for the Pacific that are attached to it, aims to support various local and regional initiatives on renewable energy (RE) roadmaps by: (i) identifying the key concepts, challenges and best practices needed to increase the uptake of renewables in the region in an integrated and cost effective way; (ii) providing the countries and, indeed, all stakeholders, with baseline information; and (iii) highlighting areas of support from IRENA to national and regional initiatives aimed at promoting enhanced deployment of renewables in the region. The report also highlights best practices and lessons from the transition to RE in some PICTs that could benefit other islands and regions.

The key messages arising from this report are the following:

- (i) Although the Pacific Islands region is varied in terms of its RE resource distribution, solar photovoltaic (PV), bioenergy and, to a lesser extent, wind energy are the RE technologies with the greatest technical and economic potential for near-term deployment in the region.
- (ii) An integrated approach promoting balanced implementation – with a strong emphasis on both RE and energy efficiency, and incorporating, among other measures, detailed resource, land availability, grid, energy storage and capacity development assessments – is required to arrive at the optimal solution in terms of feasibility, cost, social acceptance and phasing.
- (iii) Due to the variability of solar PV and wind power, integrating into diesel generator-based power systems requires the use of a variety of enabling technologies.
- (iv) The spatial constraints of islands requires that for successful large-scale deployment of RE, the energy, water and land-use nexus must be assessed carefully with stakeholder involvement in the planning process.
- (v) The current dominance of development assistance financing for RE projects in the developing economies of the Pacific Islands region limits the opportunities to enhance investor confidence through demonstration of the commercial attractiveness of existing projects.
- (vi) An enabling regulatory environment is needed to attract private sector investments in renewable energy deployment in the region.
- (vii) Islands need to improve their collaboration – for example on common legal tools, training and regulations – to create economies of scale.
- (viii) In the medium and long term, RE-based power solutions would be the most sustainable and cost-effective solutions for Pacific Islands communities. In the transition to that stage, RE and diesel hybrid systems with high levels of RE integration and energy efficiency measures can play a key role in the energy supply for island communities and are, indeed, a viable option for the PICTs.
- (ix) The “many partners, one team” approach needs to be put into practice through increased coordination between development partners, donors, regional institutions and national authorities and institutions.
- (x) RE-based transport options (such as electric cars and sustainable biofuels) can directly benefit island power-generation systems. As such, RE-based transport systems should be an important consideration in the long-term planning of the PICTs.

In line with the regional vision of the Framework for Action on Energy Security in the Pacific (FAESP), along with national targets and policies, the following key actions are recommended to accelerate the transition to a renewables-based energy future for the PICTs:

- Strengthen institutional frameworks in the energy sector: In many cases renewables transition planning takes place outside the group of energy ministries and utilities. Such an approach should be avoided as it reduces the chances of success significantly.

- Strengthen cooperation between the Pacific Power Association (PPA), Secretariat of the Pacific Community (SPC) and University of the South Pacific to develop a critical mass for transition planning for the Pacific Islands.
- Strengthen strategic energy planning, combining RE deployment with energy efficiency promotion and implementation.
- Strengthen policy and regulatory frameworks as the essential enabler for enhanced RE deployment.
- Strengthen the collection and management of energy data. This will assist in the development of robust energy information, notably for the transport sector.
- Assess the cost of RE solutions for island communities and provide information on technology availability and options.
- Assess and monitor RE resource potential. RE potential varies widely across PICTs, thereby necessitating the need for regional and island-specific RE strategies.
- Assess grid stability for high shares of RE integration. It will be important to consider careful design and deployment of hybrid diesel–renewable systems with high shares of renewables in the immediate term. This requires modelling and assessment of grids for different levels of RE penetration, supported by a step-by-step approach to realise the transition to renewables.
- Harmonise technical standards for implementation of RE technologies: This should facilitate effective system operation with reduced failure of components. With most RE projects in the PICTs arising from development assistance, a wide range of RE equipment of different makes is being installed. This complicates operation and maintenance greatly. An energy development initiative for Small Island Developing States (SIDS), such as SIDS-DOCK, could help to overcome such problems, provided funds are managed through the unified programme and not cut into many small projects with different decision makers.
- Undertake capacity development for RE at various levels – from vocational education to training for policy makers.
- Coordinate various RE projects and financing. This and a database of best practice cases for sharing of knowledge should facilitate an efficient and uniform strategy for successful RE deployment in the region.
- Develop bankable renewable projects. The quality of project proposals needs to be improved across the region. The IRENA Project Navigator can help towards bankability of project proposals. The fact that virtually all renewable power projects are funded from grants or soft loans endangers sustainability and is detrimental to the development of the RE sector. For renewables projects, more than for diesel generators, it is critical that projects include a sustainable business model where investment costs are readily recuperated. This is particularly so if productive uses for energy are prioritised in such models.

IRENA's work on islands expanded as of early 2013, with the aim of accelerating the transition to renewable-based energy systems in other island regions. Meanwhile, the organisation continues its work on Pacific Islands Countries and Territories in response to requests from its members. To this effect, IRENA is extending its work on grid stability to cover 15 countries and territories by 2015 and will also focus on other grid-related technologies and enablers, including extension of previous IRENA work on storage options for island power. Ocean energy technologies provide a potential opportunity of high impact in the deployment of renewables in island regions. These technologies are still in the development and early deployment stages. IRENA is working on evaluating the status of these technologies and their market outlook for deployment in the context of remote islands, particularly with regards to ocean thermal energy conversion (OTEC) for power generation, cooling and heating. In the subsequent work programmes, IRENA will continue to work on areas of relevance and interest to countries in the region as they mobilise efforts towards achieving their various RE targets.

IRENA's *Pacific Lighthouses* set of reports aims to provide a better understanding of current energy conditions in the Pacific Islands region and to facilitate the continued assessment of challenges and opportunities for the deployment of RE in island environments. The set also constitutes an IRENA input for the Third International Conference on Small Island Developing States to be held in Samoa, 1-4 September 2014.

1. Introduction and context

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) requested the International Renewable Energy Agency (IRENA) to "…map the *Renewable Energy Readiness* of the Pacific Island 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 in this IRENA support document for renewable energy roadmapping for islands aimed at the accelerated uptake of renewables in the Pacific Islands region.

A renewable energy deployment roadmap in itself is not sufficient to achieve an energy transition; yet it is not just a report. It is a living document and entails a process that requires regular monitoring and evaluation of progress towards a set renewable energy target, while adjusting to new circumstances. It clearly spells out the present energy situation and renewables potential, and identifies gaps and needs, analyses and evaluates deployment strategies, puts in place action plans for achieving the target, and allocates the resources required to implement the plans. Finally, a roadmap should provide valuable benchmarks for monitoring and reviewing progress towards specified goals. Therefore, a renewable energy deployment roadmap needs proactive leadership at the highest level and wide stakeholder engagement, supported by clearly defined roles and responsibilities, time frames for action, a clear sense of priorities for action and allocation of resources. Furthermore, availability of skilled staff is essential in order to develop and implement an RE roadmap that provides the framework for development partners (including multilateral development finance institutions and bilateral donors) and the private sector to provide the funds needed for investment in bankable project proposals with replicable and scalable business models.

Most PICTs have committed in policy statements to a path that will bring them ever closer to breaking the ties with fossil fuels. A number of islands have already started substantial deployment of renewable energy, with some countries having put in place ambitious targets of up to 100% renewables in the energy mix. However, in many cases, roadmaps laying out short, mid- and long-term strategies to meet such targets are not sufficiently developed, or implementation has been inadequate.

The PICTs can become lighthouses in the transition towards renewable energy, which is a core component of sustainable development. Renewable energy roadmaps or strategies and their associated implementation plan can provide an important, ambitious and commitment-driven mechanism for achieving the United Nations Sustainable Energy for All (SE4ALL) initiative. IRENA's REMAP 2030 is the global framework for promoting a doubling of the share of renewables in the global energy mix by 2030 as one of three inter-related objectives of the SE4ALL initiative. The PICTs renewable energy transition roadmaps will therefore contribute to the REMAP objective and vice versa. IRENA is involved in the Tonga Energy Roadmap (TERM) and, together with the German Agency for International Cooperation (GIZ) and the Secretariat of the Pacific Community (SPC), is assisting Nauru in the development of its energy roadmap. As a result of the Renewables Readiness Assessment (RRA) conducted for Kiribati jointly by the Ministry of Public Works, the utilities of Kiribati and IRENA, five concrete actions needed to enable the development and scale-up of renewable energy in Kiribati have been identified; their successful implementation would lead to the need for a long-term roadmap through which the goal of being energy independent could be realised. Other parties, such as the World Bank, also support roadmap development elsewhere in the PICTs, including the recently-completed Vanuatu National Energy Roadmap.

This document, in accordance with IRENA's renewable energy roadmapping framework for islands, focuses on identifying the key concepts, challenges and best practices needed to increase renewable energy uptake in the PICTs. The report, together with the accompanying island-specific study reports, is intended to provide PICT members of IRENA and, indeed, all stakeholders, with baseline information that could assist them in the development of their national renewable energy deployment roadmaps or action plans, as well as contribute to the implementation of regional initiatives such as the *Framework for Action on Energy Security in the Pacific (FAESP)* and its associated *Implementation Plan for Energy Security in the Pacific (IPESP)*. The data provided in the report and accompanying reports compliment and/or supplement those in other national and regional studies, including the SPC's Country Energy Security Indicator Profiles[1], the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) report on Pacific Perspectives on the Challenges to Energy Security and the Sustainable Use of Energy[2], the Pacific Islands Renewable Energy Project (PIREP)[3], and the Pacific Power Association (PPA) benchmarking reports, among others[4].

In the following sections, the report outlines the case for increased renewable energy (RE) deployment in the PICTs in the context of the existing energy landscape in the region and policy targets (Sections 2 and 3). It then highlights RE resource potential for power generation in the region, together with their operation and maintenance requirements (Section 4). Section 5 presents the importance of sustainable energy systems design, modelling and planning as an integrated and comprehensive approach towards the transition to a renewables-based energy future in the Pacific region. Section 6 looks at renewable opportunities for the transport sector in the region. Section 7 highlights key barriers to increasing the share of renewables in the energy mix of the PICTs. Section 8 outlines key IRENA activities in the PICTs, including the country studies and key messages arising from them. The report concludes with Section 9, which summarises identified key actions needed to overcome barriers to enhanced deployment of RE in the PICTs, together with the possible roles for IRENA, working in partnership with the PICTs, member states and development partners, towards a renewables transition in the Pacific islands region.

1 *Available at www.spc.int/edd/en/section-01/energy-overview/179-country-energy-security-indicator-profiles-2009*

2 *See www.unescap.org/apef/preparatory-process/scm/Pacific/documents/energy-security-final.pdf*

3 *www.sprep.org/Pacific-Islands-Greenhouse-Gas-Abatement-through-Renewable-Energy-Project/pirep-documents*

4 *www.ppa.org.fj/publication-report/*

2. The rationale for renewables in the Pacific Islands region

Pacific islands face a unique combination of geographic and economic factors that pose a particular risk to their energy security. More than 3,000 islands collectively known as the PICTs[5] are mostly spread over the west of the Pacific Ocean. The islands are diverse and the distances between them are large.

2.1 Fossil-fuel dependence

The majority of the PICTs depend almost exclusively on imported refined oil products to meet their power generation and transportation energy needs with most of the islands located far from major oil refining and distribution hubs and depending on complex and lengthy fuel supply chains. Fuel delivery logistics are often further complicated by lack of modern port facilities in some islands, requiring the use of smaller, specialised ships. The fuel demand of individual islands is small. The small geographic size and economic resources of islands constrain fuel storage. Both factors reduce the purchasing power for oil. As a result, the PICTs face some of the world's highest fuel costs and have greater exposure to price volatility and supply disruptions. Furthermore, diesel-based power generation is dominant in the region and is the most expensive form of power for most situations in the region. For example, in 2010 the region's utilities had consumer electricity tariffs that averaged between USD 0.39 and 0.44/kWh for household (200 kWh/month) and commercial (500 kWh/month) users[6]. For some islands the tariff exceeded USD 1.00/kWh. In fact actual electricity production costs are likely to be higher as many PICTs provide subsidies (whether explicit or indirect) to protect consumers from the full price of power generation.[7]

High energy costs, price volatility and risks to fuel supply are of particular concern because most PICTs have small economies. The high cost of fuel dominates the trade deficit for the region, driving up prices of food and other essential items and thus limiting investments in education, infrastructure and other key services.

2.2 The impact of climate conditions

As clearly demonstrated by various studies[8], the PICTs are particularly vulnerable to the impacts of climate change and so face a significant threat from rising ocean levels (with some island having a maximum elevation of less than five metres above sea level), increased severity and frequency of storm activity and frequent weather disruptions. In this region unusual variability in the magnitude and timing (seasonality) of rainfall can affect hydropower output and dam design, as well as the yield of crops for biofuels. Slight temperature changes can affect the suitability of specific crops for biofuels. Modest changes in wind speed can significantly affect wind power output. Sea level rise can affect water tables and salinity gradients, which has consequences for energy needs related to water supply. Increased frequency and severity of cyclones could affect design considerations for wind and solar power systems. High temperatures and salinity require special attention to the durability of technology solutions. Therefore the design of RE systems for the PICTs needs to take into account the specific climate conditions of the region.

2.3 Renewable energy can be a cost competitive alternative

Successful widespread deployment of RE technologies in the Pacific would increase energy and economic security by significantly reducing or even eliminating the

5 *The PICTs referred to in this document are: Cook Islands, Federated States of Micronesia, Republic of Fiji, Kiribati, Republic of the Marshall Islands, Republic of Nauru, Niue, Republic of Palau, Papua New Guinea, Samoa, Solomon Islands, Kingdom of Tonga, Tokelau, Tuvalu and the Republic of Vanuatu.*

6 *See, for example, the Pacific Power Association Benchmarking Report for 2011. Available at: www.ppa.org.fj/wp-content/uploads/2013/03/03-Benchmarking-Report-Dec-2011.pdf*

7 *Pacific Economic Monitor, Asian Development Bank, July 2010*

8 *See, for example, Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports. Available at: www.cawcr.gov.au/projects/PCCSP/publications1.html; and also ADB's report on Climate Risk and Adaptation in the Electric Power Sector by Peter Johnston. Available at www.adb.org/publications/climate-risk-and-adaptation-electric-power-sector.*

dependence on imported oil. Several PICTs possess a variety of abundant RE resources with high technical potential that, given the high price of oil in the region, could be economically feasible and price competitive with fossil fuel-based energy supplies. Integrating high levels of RE technologies into the existing power systems will require a highly skilled workforce and while this is a challenge it also opens the opportunity for creating local, high-wage jobs. High levels of RE would alter island marketplaces with new technologies and services, creating local entrepreneurship opportunities.

Notwithstanding the important and pressing drive to address the sustainable energy needs of island communities with tried and tested renewable energy technologies, it is equally crucial to note that islands present unique challenges and opportunities for the deployment of RE in general. Islands can be lighthouses or beacons for the early commercialisation phases of RE technologies through collaborative research, development and demonstration (RD&D) that leads to enhanced RE technology development and deployment suitable for island conditions. However, this has to be based on carefully chosen and targeted deployment that can lead to scale-up and replication potential in areas such as the PICTs, while also considering the technical capacity available locally for deployment, and the operation and maintenance of such systems. Furthermore, the small sizes of populations as well as power plants and grids make it easier to widely deploy entire new energy systems based on renewables. Along with small scale, the isolation of island power systems allows for meaningful analysis of new technologies at varying levels of penetration and investment, thereby allowing for a much shorter feedback loop for corrective actions than would be likely on large, interconnected mainland power grids. In addition, the small physical scale of islands results in comparatively short driving distances, thus making electric vehicles (EV) an attractive transportation option for PICTs to consider, especially if electricity costs can be substantially lowered and the batteries are not charged from fossil fuel-powered systems but from renewable sources.

2.4 Barriers to renewable energy uptake in the Pacific Islands

While RE has the potential to greatly improve the energy security of the PICTs, there are significant challenges that need to be overcome. In the early stages, new and unfamiliar power generation and transportation systems based on renewable resources could be seen as difficult to design, operate and maintain in the PICTs, in comparison to the established oil-based systems in place today. However, the costs of renewable energy technologies are decreasing globally. This could contribute to the potential for increased deployment of RE in the PICTs. A properly designed system depends on detailed knowledge of site specific RE resource availability; this is lacking or limited on many islands. Furthermore, the durability and successful operation of RE systems in island environments depend very much on the appropriate selection of system components that are suitable for the high temperatures, salinity and climatic variability found in the Pacific Island region. There are also specific stability issues to consider, with the integration of increasing shares of variable renewables into diesel generator-based grids. Specific skill sets are needed for the proper operation and maintenance of systems that address these issues and are often found to be lacking. In some cases of donor-funded projects PICTs have little input on equipment selection and project design, resulting in a high risk of failure in operating and maintaining the installed system. As a result of these issues, as well as various management and business model limitations, many of the past RE systems deployed in the PICTs have not performed according to expectations. However, as RE systems have become increasing more common recently and the support systems have improved, the success rate of RE deployment has improved in more recent years.

In addition to technical and human capacity issues, the social, policy and economic environment on islands can present barriers to RE uptake. Land tenure in the PICTs is complex, with most land being communally owned and having complex systems of access rights. This factor, together with the small size of islands and the existence of numerous cultural sites, can pose challenges to those RE systems that have significant land requirements. Therefore including all key stakeholders in the planning process and building social acceptance is essential to RE project success. Policy and regulatory frameworks on many islands have been set up for centralised utilities that are usually vertically integrated and state owned. These frameworks will likely require some adjustment to allow widespread RE deployment.

Finally, while it is important to find commonalities among the PICTs and develop recommendations that are widely applicable across the region, it is critical to note that the PICTs are extremely diverse in size, geography, population density, gross domestic product (GDP), resource availability, access to funding and many other key characteristics. These island specific characteristics greatly affect RE resource availability and RE project implementation.

2.5 The need for a regional and national framework for renewable energy uptake

The SPC, together with the Council of Regional Organisations in the Pacific (CROP) agencies[9], PICTs, industry representatives and development partners, led the development of "A Framework for Action on Energy Security in the Pacific (FAESP)[10]", which was endorsed by leaders at the 41st Pacific Islands Forum in August 2010. The FAESP provides a regional framework for improved coordination and a whole-of-sector approach to addressing the energy security challenges in the Pacific region. It acknowledges that "...the national energy policies and plans must be the principle means for achieving energy security in the Pacific." and outlines areas for action to support the efforts of the PICTs to improve their energy security. In terms of energy production and supply FAESP identifies RE as an important part of the efforts to reduce dependence on fossil fuels in the PICTs.

In order to achieve the energy security outcomes defined in FAESP, a separate regional "Implementation Plan for Energy Security in the Pacific" (IPESP) was also developed, with the lead taken by the SPC in collaboration with the CROP, PICTs, industry representatives and development partners. The IPESP is a 5-year plan from 2010 to 2015, which aims to support the implementation of FAESP reflecting the priorities of the region. The work of the Energy Programme of the SPC is guided by, and reported under, the IPESP. The SPC's energy security indicators (2009) for various PICTs are published under FAESP/IPESP[11]. The SPC is conducting a mid-term review of IPESP that is planned for completion by December 2013. It is clear that regional solutions provide the scale that would be attractive for private sector investors to provide viable RE generation at a reduced unit cost. The Pacific islands region clearly requires strong support in terms of both engagement and implementation capacity to realise the IPESP projects for a sustainable energy development in the region. More recently, a number of countries have developed national energy roadmaps – such as the Tonga Energy Roadmap (TERM)[12], the Cook Islands Renewable Electricity Chart[13] and Tuvalu's Enetise Tutumau. Vanuatu and Nauru are in the process of completing their roadmaps in 2013. Kiribati has carried out a RRA. Other PICTs are reviewing their energy policies and considering the development of their own roadmaps. Table 1 gives a summary of various regional energy programmes, national energy roadmaps and key documents in the PICTs.

9 *CROP (Council of Regional Organisations in the Pacific) is a regional organisation which is mandated to improve cooperation, coordination, and collaboration among the various intergovernmental regional organisations in the Pacific region to work together for achieving the common goal of sustainable development.*

10 *Available at www.sprep.org/att/irc/ecopies/pacific_region/686.pdf*

11 *www.spc.int/edd/en/document-download/finish/68-pacific-energy-advisory-group-meeting/813-session1-faespipesp*

12 *See, for example, www.tonga-energy.to/*

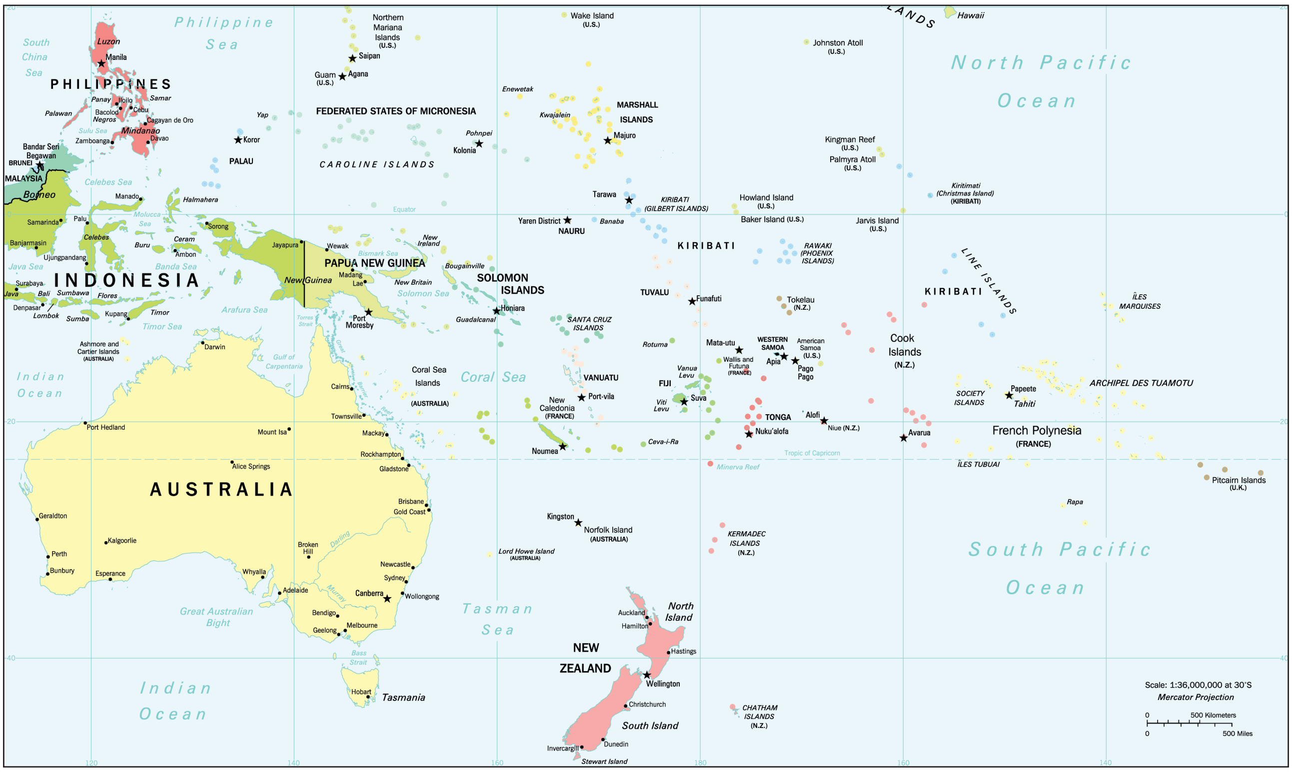
13 *http://cook-islands.gov.ck/docs/renewableenergy/Cook%20Islands%20Renewable%20Energy%20Chart%20Final%20April%202012.pdf*

Table 1: Existing energy roadmaps, documents and programmes in the Pacific Island Countries and Territories

Pacific Island Countries and Territories	Existing National Energy Roadmap/Strategy	Status	Development partners
Cook Islands	National Energy Policy 2003 Renewable Energy Chart 2011 Renewable Energy Chart Implementation Plan 2012		ADB, NZMFAT, EIB, PIFS, SPC, UNDP.
Fiji	National Energy Policy 2006	Review is in progress and expected to complete by 2013.	GIZ, SPC UNDP, ADB, EIB, GIZ, IRENA, IUCN, PIFS, REEEP, WB.
Federal States of Micronesia	Energy Policy 2010		ADB, EC, EIB, FSM, PIFS, SPC, UNDP
Kiribati	Kiribati National Energy Policy 2009	RE target revised following IRENA RRA workshop.	EC, GIZ, IRENA, PIFS, UNDP, WB.
Republic of Marshall Islands	National Energy Policy and Energy Action Plan 2009	Review to commence during second half of 2013.	ADB, AusAID, EC, IUCN, JICA, PIFS, REEEP, UNDP, WB.
Nauru	Nauru Energy Policy Framework, 2009 (NEPF) Nauru Energy Roadmap	Review in progress and expected to complete by 2013. Energy roadmap currently under development.	AusAID, EC, GIZ, ADB, IRENA, IUCN, UNDP.
Niue	Niue Energy Policy and Action Plan 2005		EC, IUCN, PIFS, UNDP.
Palau	Palau National Energy Policy, 2010		IUCN, EC, SPC, EIB, IRENA, JICA, REEEP, SPC, UNDP, WB .
Papua New Guinea	PNG National Energy Policy 2006		ADB, EIB, NZMFAT, UNDP, WB.
Samoa	Samoa Energy Sector Plan 2012-2016		ADB, AusAID, EIB, IUCN, NZMFAT, PIFS, REEEP, UNDP.
Solomon Islands	National Energy Policy Framework 2007	Review in progress.	ADB, AusAID, EIB, IUCN, JICA, NZMFAT, PIFS, SPC, UNDP, WB.
Tokelau	Tokelau National Energy Policy and Strategic Action Plan 2004 (NEPSAP)	Achieved approximately 100% RE in 2013.	NZMFAT, UNDP.
Tonga	Tonga Energy Roadmap 2010-2020 (TERM)	Well advanced. http://energy.gov.to/	ADB, AusAID, EC, EIB, GIZ, IRENA, IUCN, JICA, NZMFAT, PIFS, REEEP, SPC, UAE, UNDP, WB.
Tuvalu	Enetise Tutumau 2012-2020 (Master Plan for Renewable Electricity and Energy Efficiency in Tuvalu)		EC, GIZ, IUCN, NZMFAT, UNDP
Vanuatu	Vanuatu Energy Roadmap 2012 (VERM)	Expected to be adopted in 2013	AusAID, EIB, EU, GIZ, IUCN, JICA, NZMFAT, REEEF, UNDP, WB.

Where: ADB is Asian Development Bank; AusAID is the Australian Government Overseas Aid Program; EC is the European Commission; EIB is the European Investment Bank; EU is the European Union; FSM is the Federated States of Micronesia; GIZ is the German International Cooperation Agency Deutsche Gesellschaft für Internationale Zusammenarbeit; IRENA is the International Renewable Energy Agency; IUCN is the International Union for Conservation of Nature; JICA is the Japan International Cooperation Agency; NZMFAT is the New Zealand Ministry of Foreign Affairs and Trade; PIFS is the Pacific Islands Forum Secretariat; REEEP is the Renewable Energy and Energy Efficiency Partnership; SPC is the Secretariat of the Pacific Community; UAE is the United Arab Emirates; UNDP is the United Nations Development Programme; WB is the World Bank.

3. Energy landscape in the Pacific Islands region



Source: Courtesy of the University of Texas Libraries, University of Texas at Austin, Texas, US.

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

Figure 1: Regional map of the Pacific Islands region

3.1 General characteristics of Pacific islands

Figure 1 illustrates the dispersion of the Pacific Island Countries and Territories across the Pacific region.

IRENA's efforts to increase sustainable uptake of RE for social, environmental and economic development in Pacific are focused on 15 PICTs. The basic characteristics of these PICTs as listed in Table 2, were collected from the CIA World Factbook, the PPA and island utilities.

3.2 Energy use in the Pacific region

Transportation, power generation, and cooking dominate energy use in the Pacific. Industrial use of energy

Table 2: PICTs' land area, population, GDP and electricity access

Country	Land area (km²)	Population '000 (2011 estimate[2])	GDP per capita PPP (USD)	Electricity Access[1]	Comments
Cook Islands	240	17	10,300	100%	14 islands; 90% of people and 88% of land on 8 southern islands (volcanic & raised coral). Northern islands mostly small atolls. Population declining -3.2% per year.
Federated States of Micronesia	702	107	2,200	46%	607 islands varying from mountainous to atolls spread over four states extending 2500 km east-west & 1000 km north-south. Population change of -0.3% per year.
Fiji	18,300	883	4,400	81%	320 islands, ⅓populated. Largest two islands have 87% of land & ~ 95% of population. Population growth 0.8% per year.
Kiribati	811	101	6,200	60%	32 widely scattered atolls in three groups plus one raised coral island stretching 4200 km east-west & 2000 km north-south. Population growth of 1.3% per year, urban increasing 1.9% per year.
Marshall Islands	181	67	2,500	80%	29 atolls (22 inhabited) and 5 raised coral islands (4 inhabited). No land higher than 5 m above sea level. Population growth of 2% per year; 72% of people in urban Majuro/Kwajalein.
Nauru	21	9.3	N/A	100%	Single isolated equatorial island. Two plateaus with 'topside' peak of 71 m, typically 30 m above 'bottom side'. Population growth of about 0.6% per year.
Niue	259	1.3	5,800 ('03)	100%	Reputedly the world's largest raised coral island. Reef is close to land and no lagoon. Land rises nearly vertically to perimeter height of 25-40 m. Population stable with very slow decline.
Palau	458	21	9,300	98%	200+ islands, most very small and in a compact area, only 9 are permanently inhabited; 95% of islands & 90% of population within the main reef containing Babeldaob, Koror & Peleliu islands. Estimated 0.4% growth rate per year.
Papua New Guinea	462,800	6,188	2,500	12%	600+ islands, with 80% of population in the eastern half of the island of New Guinea. Estimated population growth of 2% per year.
Samoa	2,934	193	5,500	98%	Volcanic islands of Savai'i (58% of land & 24% of population) and Upolu (38% & 76% respectively) plus 8 small islands. Population growth of 0.6% per year.
Solomon Islands	28,450	572	2,900	~10%	Nearly 1000 islands of which 350 are inhabited. 6 main islands account for 80% of land area and bulk of population. Population growth of 2.2%, urban growth 4.2% per year.
Tokelau	12	1.4	N/A	100%	Three atolls: Atafu, Fakaofo and Nukunonu. Highest land about 5 m above sea level. Population changing very little. No urban population.
Tonga	748	106	6,100	~90%	176 islands in 4 groups (Tongatapu, Ha'apai, Vava'u & Niua) with 36 inhabited islands. Population growth estimated at 0.25% per year.
Tuvalu	26	10.5	3,400	94%	6 atolls with large lagoons enclosed by a reef plus 3 raised coral islands without large lagoons. Funafuti with 22% of land has about 50% of population. Estimated annual growth rate 0.7%.
Vanuatu	12,200	225	5,100	28%	Over 80 islands, mostly volcanic, 65 populated. 80% of the population is on 7 islands. Population grew by 2.6% per year from 1986-1996 but current rate is 1.3%.

Source: Updated to 2011 from National PIREP reports (2004)

Note: km² is kilometres square; km is kilometre; and m is metre.
~ is 'approximately'
Per-Capita GDP is from several sources and there are discrepancies between sources so figures should be considered indicative only

[1] Includes rural electricity access through solar home systems

[2] Source: 2012 CIA fact book

is mostly limited to mining on a few islands. More wide spread are agricultural, forestry and fish based industries, almost all of which rely directly on electricity. The traditional use of biomass for cooking remains the largest component of overall energy use in rural areas throughout the PICTs though its use is slowly declining in favour of liquefied petroleum gas (LPG) and kerosene in the more urban areas. With the exception of some notable contributions from hydropower in Fiji, Papua New Guinea and Samoa, energy use in the Pacific is dominated by imported oil. Excluding Papua New Guinea, the lack of known local oil resources and refining capacity in most PICTs means that refined oil products must be imported over large distances.

Transportation sector

In the Pacific, transportation accounts for the highest proportion of energy demand and uses mostly imported refined oil products. A lack of available, accessible, up-to-date and detailed data makes it difficult to determine the exact split of fuel usage between land, sea and air transport. However it can be generally stated that land transport is the largest sector and is dominated by a mix of diesel and gasoline passenger cars and light commercial vehicles. Sea and air transport play important roles for the Pacific states with a wide dispersion of populated islands. Generally sea transport is the larger of the two with varying contributions from inter-island passenger and cargo services and fishing fleets. Local air transportation is generally limit to a small number of light aircraft but can be significant on islands with developed tourist industries (*e.g.* the Cook Islands, Fiji and Vanuatu). It is by and large not practical to include long distance shipping or flights as part of island fuel consumption since international companies that handle their own fuel purchases generally provide these services and most refuelling takes place elsewhere.

At present cost, policy, technical and sociocultural barriers impede a major shift in the transportation sector from fossil fuels to RE. However, given that the transportation sector dominates Pacific island oil consumption, it is essential that RE transportation options be thoroughly examined to determine when and how they can be deployed on a large scale. Given the current barriers to increased use of renewables in the transportation sector, it is evident that increased shares of renewable energy integration in the Pacific Islands region in the near to medium-term would be achieved mainly from the power generation sector where integration of high percentages of RE has been successfully demonstrated and is likely to have the greatest near term impact, together with demand side energy management, on reducing oil dependence and greenhouse gas (GHG) emissions.

Power Sector

In 2010, electricity generation represented approximately 25% of the Pacific Island's oil demand. A review of the PPA 2011 Benchmarking Report revealed that commercial and residential sectors comprise the bulk of Pacific electricity demand. In 2010 these two sectors accounted for 68% of regional electricity sales. This figure is skewed by Papua New Guinea since for most PICTs the commercial and residential sectors account for an even higher percentage of electricity sales. The split between the sectors varies from island to island, but the usage for both is primarily comprised of lighting, cooking, consumer electronics, water production and supply, and refrigeration and air-conditioning. These usages also dominate the 16% of regional electricity sale to governments (mainly for air conditioning, lighting and powering of office equipment). The tropical climate in most of the Pacific limits heating demand. However, tourist resorts and other facilities often consume significant amounts of energy to heat water and for cooling. Industry constitutes only 16% of regional electricity sales and is limited to those islands with forestry, agricultural and fishery industries. Mining consumes large amounts of electricity on a few islands (mostly in Papua New Guinea), but is typically provided by private onsite generation.

The Pacific utilities are dominated by diesel generation with only Tokelau, Papua New Guinea, Fiji, Samoa and Vanuatu currently having more than 10% of electricity production through RE. An overview of the current characteristics of grid power system in the national utilities is seen in Table 3.

In 2011 electricity prices in the PICTs ranged widely from USD 0.15–1.50 /kWh, depending on the islands. The average (a combination of residential, commercial and government tariffs) was around USD 0.35 /kWh. Most of the island countries subsidise residential customers and several subsidise all electricity sales with very few even coming close to a full cost recovery for electricity deliveries. For utilities with a national tariff, there is considerable cross-subsidy from the urban centres to rural consumers (residential and others) on the grid. This could affect the financial viability of RE in smaller rural centres. Generally, most governments are unaware of the actual amount of the subsidy and so a clearer accounting is needed to capture and assess these subsidies. The actual cost of electricity delivery varies widely from place to place. Outer island electricity delivery cost often exceeds USD 1.00 per kWh and even higher for small grids.

Table 3: Pacific Islands Urban Utilities, their tariffs and generation sources (Tariffs as reported to the PPA for 2013)

Country	Utility organisation & reforms	Monthly urban tariff (per kWh in local currency*)	Percentage of Generation from Renewables	Peak Load MW	Diesel Capacity MW	Diesel De-rated Capacity** MW
Cook Islands (Rarotonga)	TAU serves Rarotonga. All diesel but outer islands are planning to change to all renewables by 2020.	**Domestic:** < 60kWh = NZD 0.57 per kWh 61–300kWh = NZD 0.80 per kWh > 300kWh = NZD 0.84 per kWh **Commercial:** NZD 0.81 per kWh plus demand and service adjustments	<1% TAU owned but 7% including net metering and standalone	4.4	10.36	9.5
Cook Islands (Other islands)	12 outer island systems run by island councils. All diesel but outer islands are planning to change to all renewables by 2020.	N/A	<1%	5kW to 400kW	N/A	N/A
Federated States of Micronesia	All four state utilities are government-owned and corporatised: CPUC, KUA, PUC & YSPSC.	Tariffs vary depending on state **Yap** **Residential:** < 50 kWh = USD 0.3712 per kWh 51–250 kWh = USD 0.4242 per kWh > 250 kWh = USD 0.4507 per kWh Outer regions = USD1.0949 per kWh **Commercial:** < 1 000 kWh = USD 0.4507 per kWh > 1 000 kWh = USD 0.5303 per kWh Outer regions = USD1.1948 per kWh **Government:** USD 0.7683 per kWh Outer regions = USD1.6275 per kWh **Kosrae** **Residential:** < 100 kWh = USD 0.428 per kWh 101–1 000 kWh = USD 0.468 per kWh 1 001–10 000 kWh = USD 0.478 per kWh 10 001–100 000 kWh = USD 0.471 per kWh >100 000 kWh. = USD 0.411 per kWh **Commercial:** < 100 kWh = USD 0.468 per kWh 101–1 000 kWh = USD 0.478 per kWh 1 001–10 000 kWh = USD 0.488 per kWh 10 001–100 000 kWh = USD 0.478 per kWh >100 000 kWh. = USD 0.438 per kWh **Government:** < 100 kWh = USD 0.528 per kWh 101–1 000 kWh = USD 0.528 per kWh 1 001–10 000 kWh = USD 0.542 per kWh 10 001–100 000 kWh = USD 0.528 per kWh >100 000 kWh. = USD 0.488 per kWh **Industry:** < 100 kWh = USD 0.528 per kWh 101–1 000 kWh = USD 0.528 per kWh 1 001–10 000 kWh = USD 0.533 per kWh 10 001–100 000 kWh = USD 0.523 per kWh >100 000 kWh. = USD 0.448 per kWh **Chuuk** **Residential:** USD 0.5026 per kWh **Commercial:** USD 0.5326 per kWh **Government:** USD 0.5526 per kWh	<1%	CPUC – 4 KUA – 1.1 PUC – 6.3 YSPSC – 2.3	CPUC – 6.4 KUA – 5 YSPSC – 6.6 PUC – 4.3	N/A

		Pohnpei The following are fixed cost rates on top of which the utility adds a fuel adjustment cost that varies with fuel delivery. In August 2013 the charge was USD 0.47. **Residential:** USD 0.14 per kWh Service charge USD 4.0 per month Large power users: USD 0.12 per kWh Charges USD 19.0 per month **Industrial:** USD 0.12 per kWh (<100 000 kWh per month); USD 0.08 per kWh (>100 000 kWh/ per month); Charges USD 33.10 per month				
Fiji	FEA serves only islands of Viti Levu, Vanua Levu & Ovalau. Includes private generation for supply	**Domestic:** 0–75kWh = FJD 0.3310 per kWh Commercial + **Industrial:** Up to 14,999 kWh = FJD 0.3990 per kWh Over 14,999 kWh = FJD 0.410 per kWh (plus demand charges)	67%	139.6	211.2 (excluding 40 MW Nadarivatu)	106,624
Kiribati	PUB supplies only South Tarawa and a small part of North Tarawa. PWD operates on Kiritimati. KSEC supplies by Solar Home System (SHS) on other outer islands	**Domestic:** AUD 0.40 per kWh **Commercial:** AUD 0.55 per kWh **Industrial:** AUD 0.70 per kWh	<1%	4.77	5.45	4.90
Marshall Islands	MEC operating on Majuro, Jaluit & Wotje, with government meeting revenue shortfalls outside Majuro. KAJUR operates only in Ebeye	**Domestic:** 0–500kWh = USD 0.41 per kWh > 500kWh = USD 0.43 per kWh **Commercial:** USD 0.49 per kWh **Government:** USD 0.50 per kWh	6%	8.0 (Majuro) 1.8 (Ebeye)	KAJUR – 3.8 MEC – 28	KAJUR – 3.0 MEC – 17
Nauru	NUA supplies the entire island	**Domestic:** 0–300 kWh =AUD 0.10 per kWh > 300 kWh = AUD 0.20 per kWh **Commercial:** AUD 0.25 per kWh **Industrial:** AUD 0.50 per kWh	<5% ***	3.3	8	6
Niue	NPC supplies the entire island	All customers: 0–100 kWh = NZD 0.50 per kWh; 101–300 kWh = NZD 0.60 per kWh >500 = NZD 0.70 per kWh All: +NZD 15 per month	3%	0.6	2.1	1.4
Palau	PPUC supplies Koror and Babeldaob on the main grid. Kayangel, Peleliu & Angaur have small grids operated by the utility.	**Residential:** 0–150 kWh = USD 0.282 per kWh 151–500 kWh = USD 0.356 per kWh > 500 kWh = USD 0.405 per kWh Commercial/Government/ Rest of Palau: = USD 0.405 per kWh	3%	15.4	18.9	52
Papua New Guinea	Elcom corporatised into government owned PNG Power Ltd. (PPL), responsible for public power throughout PNG but private power, mostly for industry and mines, has more capacity than PPL	Varies considerably by customer type, usage and payment method. E.g. domestic credit meter customers pay PGK 47.27 per kWh for first 30 units and PGK 80.33 per kWh for balance of units used; minimum charge of PGK 15 per month. Industrial customers pay PGK 60.01 per kWh and a demand charge of PGK 73.10 per kVA; minimum demand of 200 kVA.	46%	92.9	292	NA
Samoa	EPC is government-owned & corporatised. Operates hydro plants and mini grid solar system and diesel plant in both Upolu and Savaii. EPC also owns and operates the mix of 33, 22 kV transmission and distribution networks on all islands in the Samoa group.	**Residential:** 0–50 kWh = WST 0.85 per kWh >50 kWh = WST 1.01 per kWh Prepaid 0–50 kWh = WST 0.84 per kWh Prepaid > 50 kWh = WST 0.99 per kWh **Commercial:** WST 1.01 per kWh Prepaid = WST 0.99 per kWh	32% After Cyclone damaged two plants (Dec 2012)	18.5 Upolu 2.8 Savai'I	43.5 Upolu 6.6 Sava	35 Upolu 5.8 Savai'i

Country	Utility organisation & reforms	Monthly urban tariff (per kWh in local currency*)	Percentage of Generation from Renewables	Peak Load MW	Diesel Capacity MW	Diesel De-rated Capacity** MW
Solomon Islands	SIEA is government owned. No corporatisation plans yet formulated. Main grid is on Guadalcanal but several small grids are operated by SEIA in Provincial Centres	**Residential:** SBD 6.1867 per kWh **Commercial:** SB 6.6465 per kWh **Industrial:** SBD 6.7531 per kWh	<1%	13.8	25.6	NA
Tokelau	Power separate for each of 3 islands. Converted 100% solar 2012	Varies by island. Typically NZD 0.50 per kWh. PV system installed in 2012	Approximately 100%. (prior to PV system installation in 2012: 2% Fakaofo <1% Atafu <1% Nukunono)	prior to PV system installation in 2012: 51.2kW Fak 38.0 Atafu 36.7 Nukun	NA	NA
Tonga	TPL government utility serves Tongatapu & main islands of Ha'apai, Vava'u & 'Eua. Outer islands all on solar except for three with small diesel grids now proposed to be converted to solar. 0.54 MW solar online later in 2013. 1 MW solar PV due for construction in 2014	All customers pay TOP 0.9405 per kWh	4%	9.5	16.8	15.0
Tuvalu	TEC is government-owned & corporatised; serves all islands except for tiny Niulakita which is has SHS only.	**Residential:** 0–50 kWh = AUD 0.30 per kWh 51–100 KWh = AUD 0.39 per kWh > 100 kWh = AUD 0.56 per kWh Commercial & **Government:** AUD 0.56 per kWh	2%	1	5.1	2.8 Funafuti
Vanuatu	UNELCO is private sector monopoly under government concession. It is the utility for the main island operating on major urban islands (Efate, *etc.*) and several rural islands. VUI is the utility for the second urban centre on Espiritu Santo island	**Residential:** < 60 kWh = VUV 18.43 per kWh 61–120 kWh = VUV 65.59 per kWh > 120 kWh = VUV 162.60 per kWh **Businesses:** Low voltage connection VUV 47.15 per kWh; Fixed charge VUV 1084 per kVA High Volt connection = VUV 37.94 per kWh. Fixed charge VUV 1355 per kVA	25%	11.3 Port Vila	23.6 Port Vila	NA

Utilities: Cook Islands: TAU = Te Aponga Uira, Federated States of Micronesia: CPUC = Chuuk Public Utilities Corporation, KUA = Kosrae Utilities Authority, PUC = Pohnpei Utilities Corporation & YSPSC = Yap State Public Service Corporation); Fiji: FEA = Fiji Electricity Authority; Marshalls: MEC = Marshalls Energy Company; KAJUR = Kwajalein Atoll Joint Utility Resource; Kiribati: PUB = Public Utilities Board. Nauru: NUC = Nauru Utilities Corporation. Niue: NPC = Niue Power Corporation, Palau PPUC = Palau Public Utilities Corporation; PPL = Papua New Guinea Power Ltd. Samoa: EPC = Electric Power Corporation, Solomon Islands SIEA = Solomon Islands Electricity Authority, Tonga: TPL = Tonga Power Ltd. Tuvalu: TEC = Tuvalu Electricity Corporation; Vanuatu: UNELCO = Union Electrique de Vanuatu.

Note: MW is Megawatt
Note**: De-rated Capacity varies frequently.
Note*: On the 14th of August 2013, the exchange rate equivalent for 1 USD was as follows:
Cook Islands (NZD) = 1.2447; Fiji (FJD)= 1.8709: Federated States of Micronesia (USD) = 1: Kiribati (AUD) = 1.0927: Nauru (AUD) = 1.0927: Niue (NZD) = 1.2447: Palau (USD) = 1: Papua New Guinea (PGK) = 2.3460: RMI (USD) = 1: Samoa (WST) = 2.3753: Solomon Islands (SBD) = 7.1195: Tokelau (NZD) = 1.2447: Tonga (TOP) = 1.8563: Vanuatu (VUV) = 96.3486.
Note ***: Total RE installations to date at 5% of capacity. Generation figures not yet available.

Table 4: Electricity generation statistics in 2010/2011
(Compiled from the 2012 PPA Power Benchmarking Manual and field survey)

PICT	Installed Capacity (MW)	Peak Demand[1] (MW)	Annual Generation (MWh)
Cook Islands	10.36	4.9	27,763
FSM-Chuuk	2.0	4.0	9,768
FSM-Kosrae	1.5	1.1	6,504
FSM-Pohnpei	7.6	6.9	38,920
FSM-Yap	6.6	2.3	13,000
Fiji	211.2	139.6	835,169
Kiribati	5.5	5.3	21,641
Marshall Islands-Majuro	28	8.9	75,749
Marshall Islands-Ebeye	3.6	2.0	14,183
Nauru	6.04	3.3	17,103
Niue	3.25	0.54	3,168
Palau	18.9	15.4	84,860
Papua New Guinea	292[2]	92.94	796,610 + 1,900,000[3]
Samoa	37.5	18.0	111,353
Solomon Islands	25.6	13.8	83,600
Tokelau[4]	0.927	0.20	34,000*
Tonga	15.3	7.7	52,609
Tuvalu	5.1	1.0	11,800
Vanuatu (UNELCO)	23.9	11.3	60,360
Vanuatu (VUI)[5]	4.1	1.71	3,350
Total	**712**	**349**	**4,201,510**

Where FSM is the Federated States of Micronesia

1: Peak demand main island nation grid only, excludes notable power systems on secondary/remote islands & private generation

2: Excludes substantial generation assets dedicated to private mining activities

3: First value: PNG public utility, second value: private mining operations

*4. Based on Tokelau's new PV-based power system. The old diesel generators are now used as back-up for the PV system (see, for example, Issue 10 of the Pacific Energiser (January 2013), available at www.spc.int/edd/en/section-01/energy-overview/energy/198-pacific-energiser-issue-10, and also www.itpau.com.au/wp-content/uploads/2013/05/TREP-case-study.pdf. *The annual generation is estimated from inverter-level data for May 2013.*

5. From the Vanuatu Utilities Regulatory Authority's 2011 performance of Vanuatu Utilities & Infrastructure Ltd (VUI).

Table 4 presents the results of a review of the electricity generation systems of the 15 PICTs[14]. The total generation capacity for the 15 PICTs in 2012 is approximately 712 Megawatt (MW). In 2011 approximately 78% of the power generation on these islands came from generators fuelled with diesel, heavy fuel oil (HFO) or light fuel oil (LFO). The remaining 22% was primarily provided by hydropower. Fiji, Papua New Guinea and Tokelau are significant outliers in terms of both total capacity

14 These data were compiled using key generation statistics from the CIA World Factbook, the PPA 2011 and 2012 Benchmarking Report and data from local utilities.

Table 5: WEPP Pacific island operational diesel generator statistics (2013)

PICTs	Capacity (MW)	Number of Units	Unit Size (MW)		Operational Year	
			Min	Max	Oldest	Newest
Cook Islands	11.04	24	0.025	2.1	1990	2009
FS of Micronesia	35.09	36	0.027	3.2	1974	2012
Fiji	67.03	39	0.06	10.15	1953	2011
Kiribati	8.90	9	0.6	1.4	1994	2005
Marshall Islands	41.90	33	0.06	6.4	1982	2003
Nauru	4.00	5	0.8		2002	2005
Niue	1.68	4	0.421		no data	
Palau	18.88	17	0.1	3.4	1997	2012
Papua New Guinea	141.34	28	0.14	15	2007	2011
Samoa	16.59	15	0.045	3.5	1979	2001
Solomon Islands	37.78	44	0.04	4.2	1971	2006
Tonga	14.44	19	0.056	1.729	1972	1998
Tokelau	no data					
Tuvalu	3.71	30	0.045	1	1982	2001
Vanuatu	15.46	14	0.1	4.23	1994	2010
Total	**418**	**317**				

Where FS of Micronesia is the Federated States of Micronesia

and generation mix, with Tokelau having transitioned to approximately 100% renewable power generation from solar PV. Omitting Papua New Guinea and Fiji, the total generation capacity in the PICTs is roughly 175 MW and consists mostly of diesel generators. Additionally, because many PICTs are composed of numerous islands, the 175 MW of capacity is divided among many smaller power plants – most of which are on the main island of each PICT. To determine the characteristics of these individual power plants IRENA reviewed the Platts 2013 World Electric Power Plants (WEPP) database. The database shows that the bulk of the region's generation capacity consists of power plants of less than 10 MW utilising several generators with capacities ranging from around 25 kilowatt (kW) to 10 MW (Table 5). Figure 2 shows a breakdown of the year-by-year and cumulative installation of the diesel generator fleet up to 2011. The figure excludes Papua New Guinea and Fiji in order to give a better representation of the typical conditions on the smaller Pacific islands.

In the Pacific it is common for populations to be concentrated in urban areas on main islands with a single power station supplying the community's electricity. Widespread high voltage transmission grids are uncommon except in Nauru and Niue. The individual power stations usually have significant overcapacity to increase security of supply, although the extent of overcapacity estimated from the Platts WEPP data can be misleading for the PICTs, as many of the power generation systems are in poor condition and significantly de-rated.

The small and isolated nature of the majority of Pacific diesel power plants is a particular concern for the integration of high levels of variable RE. Large interconnected mainland grids usually have a wide variety of generation assets they can draw on to balance out variable RE power generation. Pacific grids, however, are typically dependent on one or two diesel power stations, which are often not inter-connected and will have to augment their existing generation systems with new

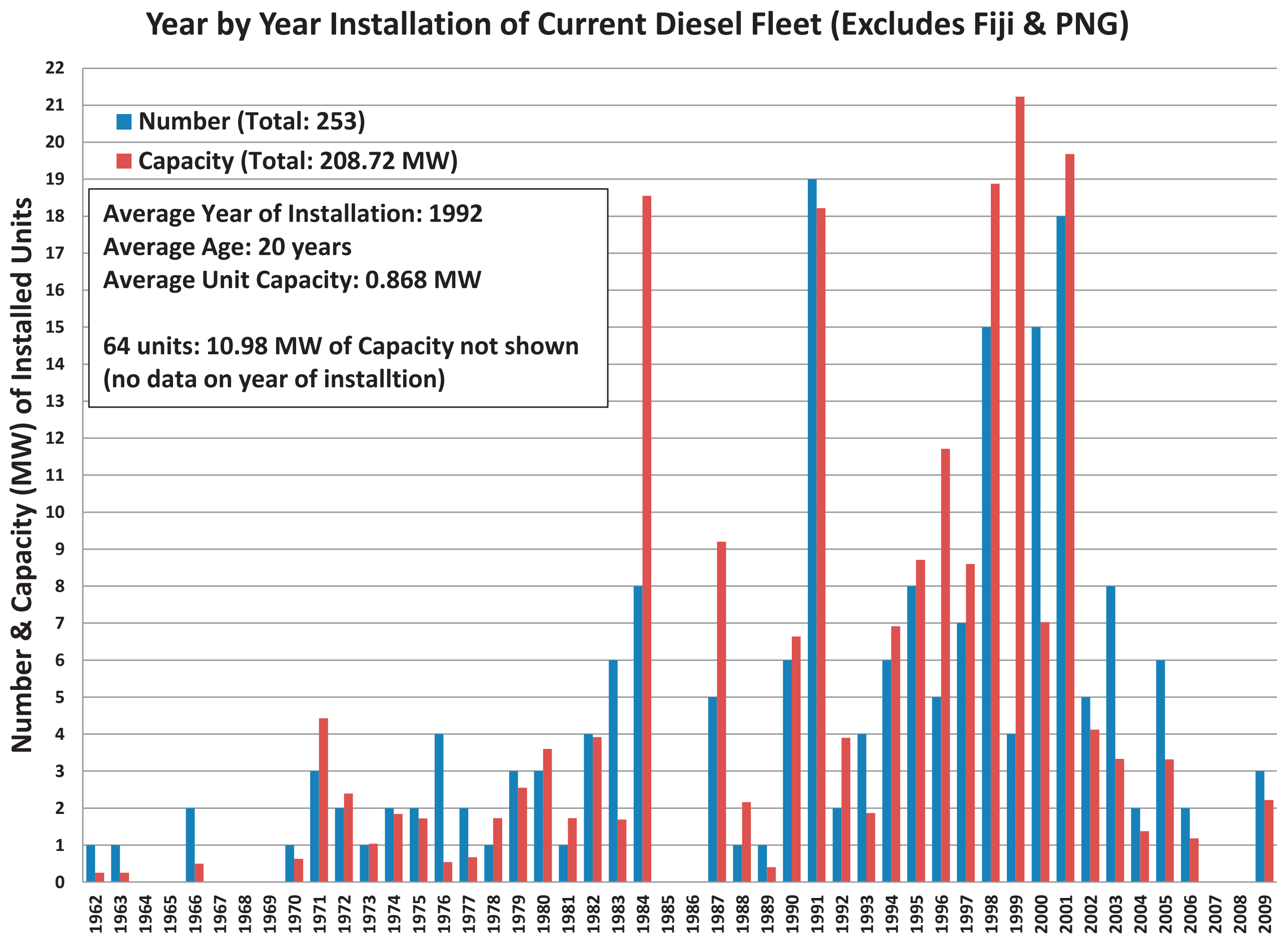


Figure 2: Year-by-year installation of diesel fleet of power generators in the PICTs up to 2011 (excludes Fiji & PNG).

technology to compensate for variable RE from solar and wind power sources without storage.

Another key concern is the advanced age of the diesel generators in the region. The average genset in the PICTs is around 20 years old. Figure 2 shows that the last major deployment of generators occurred over ten years ago. This means that many generators in the area are approaching or have exceeded the manufacturers recommended lifespan. It should be noted that compilation of the WEPP database does not always include direct data verification for remote areas such as the Pacific. Therefore, some of the older generators in Table 4 may no longer be in operation. However, inquiries with the PPA identified generators that have been in continuous use since the early 1980s.

The aged status of the many gensets in PICTs has significant implications when considering high levels of RE penetration. Older units usually lack computer control systems and are likely to have slower ramp rates (*i.e.* the rate at which the system can increase or decrease its power output) and reduced fuel efficiencies when compared to more modern diesels generators. A basic review of diesel generator function and the effects of RE integration are given in one of the supporting studies for this report, title "Pacific Lighthouses: Hybrid power systems". This case study sheds light on the particular challenges posed by the small capacity, isolation and advanced age of the Pacific islands' diesel fleet of electricity generation systems.

Energy for cooking

The traditional use of biomass for cooking remains the largest component of overall energy use throughout the PICTs, particularly in outer islands. However, there are increasing shifts to the use of liquefied petroleum gas (LPG) and kerosene on the main islands. The use

Table 6: Overview of renewable energy installations, studies and resource assessments in the PICTs up to 2012

Country	Grid-Connected Solar	Mini Grid Solar	Solar Home System	Wind	Bioenergy	Hydro	Geothermal
Cook Islands	Aitutake ANZ Bank 18 kWp, net metering on Rarotonga with several private installations total of ~380 kWp in 2012.	PV mini-grid system for Rakahanga being tendered and planning including studies underway for converting several other outer island diesel grids to solar.	Pukapuka installations destroyed by cyclone. Some homes on other islands with private installations. Electrification to replace diesel on outer islands with solar planned.	Wind resources monitoring and assessment undertaken for Rarotonga, Aitutaki and Mangaia. In addition resource monitoring undertaken for a few other outer islands. Mangaia 40 kW trials, but no longer operational. 2 MW proposed for Rarotonga. Some private small wind on net-metering in Rarotonga.	None other than traditional use for cooking and crop drying.	none	none
Federal States of Micronesia	Kosrae: 51.3 kWp Feasibility study positive for 300 kWp on Yap, 270 kWp capacity over five outer islands expected for commissioning late October 2013. Pohnpei: 180 kW pilot system in Palikir, funded Japan International Cooperation Agency	Conversion of outer island diesel to mostly solar, and new mini-grid electrification by solar for outer islands scheduled for 2013-14, using EU funding.	All outer islands of Yap to be electrified by SHS in 2012-13 (if not provided with a mini-grid) with EU funding. Additional systems for Chuuk are planned. Few SHS in Federal States of Micronesia currently operational, though over 400 installed over the years.	Feasibility study underway for 1.5 MW for Yap grid.	None other than traditional use for cooking and crop drying. Formerly some biofuel interest on Pohnpei, but plant put out of commission by fire.	Pohnpei planning to rehabilitate the 1.8 MW Nanpil hydro and considering other run-of-river development.	none
Fiji	University of the South Pacific 45 kW 110 kW at Denarau, 6 kW at Lautoka. FEA: 10 kWp currently out of service.	260 kW at Turtle Island.	More than 3000 SHS have been installed throughout Fiji, with about 1200 installations active on Vanua Levu and over 1000 more to be installed in 2013.	10 MW grid connected 2008. Wind energy surveys underway.	Fiji Sugar Corporation ~11 MW during sugar crushing season. Tropik Wood ~4 MW. Biofuel trials. Biogas on farms. Traditional uses. Two private suppliers of 5% mix coconut based biodiesel.	127 MW installed on grid with additional available for the future, particularly small village scale hydro.	none
Kiribati	Kiritimati ANZ Bank 18 kWp.	Scheduled for Kiritimati Islands, conversion of diesel grid. Solar mini grid to be installed at Chevalier College on Abemama using Italian funding. Schools to be electrified under EDF 10.	~2100 installed, but not all presently operational. ~1,700 LED lighting kits scheduled for EDF 10 installation.	Resource measurements underway with a pre-feasibility study for Kiritimati completed.	Coconut oil for biofuel trials, traditional use for cooking and drying. Feasibility study completed for Kirimati island.	none	none
Marshall Islands	Hospital 209 kW and 57 kW at the College of the Marshall Islands. 12.5 kW at University of the South Pacific centre.	6 Schools to be electrified under EDF 10.	Over 2000 installed and ~1,500 more coming under EDF 10.	Proposed but not committed for installation on the Majuro reef for COM. Wind resource monitoring underway in two outer islands	Coconut oil for biofuel, traditional use for cooking and drying.	none	none
Nauru	40 kW at the Nauru College and 30 kWp on Government buildings.	None	60 installed around the island.	Wind resources monitoring and assessment undertaken.	None but traditional use.	none	none

Niue	Grid connected 52 kW with 180 kW in the pipeline.	None	3 kW at a private home.	Wind resources monitoring and assessments undertaken. Being considered for the future.	None at present other than traditional use for cooking and drying.	none	none
Palau	539 kW connected public and private.	Solar being considered for outer island conversion from diesel.	NDBP financing off-grid for purchase.	Wind resource monitoring underway.	None at present other than traditional use for cooking and drying.	Feasibility study indicates some possibility, but very high cost and many land issues.	none
Papua New Guinea	none	NA	N/A	Some small Chinese installations	Some private biomass generation from sugar and forestry processing co-generation	221.5 MW public and private. Substantial resource remains untapped.	52.8 MW at Lihir Gold Mine. Private generation.
Samoa	Feasibility study completed for 400 kWp through Japanese finance.	Apolima Island 13 kWp (2006).	A few private installations. Plan is to complete the last few percent of electrification using SHS.	Wind resources monitoring underway for Upolu and Savaii and resource assessment undertaken for Upolu.	Formerly wood waste generation but closed. None at present other than traditional use for cooking and drying. Small scale coconut oil utilisation by power utility.	9.71 MW connected	none
Solomon Islands	none	None	~8000 installed with ~2000 coming under PEC (Japan) funding.	Wind monitoring underway in Kirakira, Buala, Rennel and Taro.	Guadalcanal Palm Oil Facility for own plant and associated housing use. Traditional use for cooking and drying. Coconut oil for fuel.	15 MW being developed Tina River. Several village scale installations installed, but many not operating.	Savo being explored by Kentor Energy
Tokelau	All grid power is from Solar (Total capacity 927 kWp).	All three islands converted to 100% solar generation. Approximately 300 kWp per island.	none	none	None at present other than traditional use for cooking and drying. Coconut oil for biofuel planned.	none	none
Tonga	1.3 MW in a single array next to the power plant. Another 1 MW in the pipeline over 500 kw proposed for Vava'uu.	Fa'fa Resort Island 2010. Under consideration to convert outer island diesel systems to solar.	Over 1,000 installed or being installed.	Wind assessment underway with a pre-feasibility study completed	None at present other than traditional use for cooking and drying. Consideration of use of waste from forest products mill on 'Eua using a gasifier.	none	none
Tuvalu	Funafuti 40 kWp and Vaitupu 42 kWp.	Vaitupu boarding school mini-grid provided by Japan in 2008.	200 systems left over from 1990s projects.	Wind monitoring and assessment undertaken for Funafuti	None at present other than traditional use for cooking and drying.	none	none
Vanuatu			~500 installations but many not working.	3 MW grid-connected on Efate. Small battery charging units off grid. Wind monitoring underway in Vanua-Lava, Pentecost, Santo, Malekula, Tongoa and Tanna	Extensive use of coconut oil for fuel. Traditional uses.	1.2 MW at Sarakata. Other sites available but undeveloped.	Possible 4 MW to 8 MW development on Efate soon

Note: kWp is kilowatt-peak

of biogas for cooking has had varied experiences on a number of islands.

3.3 Use of renewable energy

Hydropower provides a major contribution to electricity generation in Fiji, Papua New Guinea and Samoa. Presently there is generally limited use of biomass to offset fossil fuel consumption for power generation on islands with forestry and agricultural processing facilities where there is potential for use of biomass residues as feedstock for energy generation. PV systems, used primarily for rural electrification, are spread across the region. There are also a number of medium to large scale grid-connected PV installations serving urban areas. Utility scale wind farms are operational in Fiji and Vanuatu. However, the vast bulk of power generation capacity is based on internal combustion engine generators utilising imported diesel, HFO and LFO. Table 6 summarises experiences with various renewable energy resources in the PICTs.

3.4 Energy policy frameworks

Since the fuel price shocks of 2008 and the economic difficulties that were exacerbated as a result of it, gov-

Table 7: Renewable power goals of the Pacific Island Countries and Territories

Countries, Territories & Associated States	Renewable Electricity Generation	Renewable Electricity Targets (*Primary Energy)	
	Approximate % of Total	% of Total	Year
Cook Islands	<1%	50%	2015
		100%	2020
Fiji	67%	90%	2015
Federal States of Micronesia	<1%	30%*	2020
Kiribati	<1%	Official targets in the process of being approved by the Cabinet	
Republic of Marshall Islands	6%	20%	2020
Nauru	<5%	50%*	2015
Niue	3%	100%	2020
Palau	3%	20%*	2020
Papua New Guinea	46%	No target set to date	
Samoa	32%	+ 10 %*	2016
Solomon Islands	<1%	50%[1]	2015
Tokelau	95%	100%	2012
Tonga	4%	50%	2020
Tuvalu	2%	100%	2020
Vanuatu	25%	40%[2]	2015
		65%[2]	2020

Source: Mostly from various national renewable energy policy documents

1: Unofficial goal

2: January 2013 draft National Energy Roadmap goals, mostly from geothermal ernments and utilities have placed a higher priority on increasing the use of renewable energy to generate electricity in urban areas. Almost all the PICTs have established policies and goals to increase their use of renewable energy to generate power and to reduce fuel imports. Table 7 summarises RE generation targets promulgated by the various PICTs.

The various renewable goals represent a clear political commitment to RE power generation in the region. To understand how widespread RE deployment can be achieved in the Pacific it is critical to review the potential of Pacific RE resources and determine which resources can play a major role in island power generation.

With regard to a regional energy framework, SPC, together with CROP agencies, PICTs, industry representatives and development partners, led the development of FAESP (that was approved by the region's leaders in 2011) aimed at achieving energy security in the Pacific islands region through a "whole of sector" and "many partners, one team" approach that pools together efforts from the PICTS and international and regional stakeholders into a collaborative effort. The framework identifies seven themes for action to achieve energy security in the region, namely:

- Leadership, governance, coordination and partnerships
- Capacity development, planning, policy and regulatory frameworks
- Energy production and supply (including renewable energy)
- Energy conversion
- End-use energy consumption
- Energy data and information; and
- Financing, monitoring and evaluation.

Following the FAESP, the IPESP was developed and adopted by Pacific Energy Ministers as a 5-year regional implementation plans for the period 2011 – 2015 to realise the goals of FAESP. The implementation plans outline regional activities, impacts indicators, timeframe, indicative costs and lead implementing partners for each of the seven themes defined in the FAESP. Energy Security Indicators under the broad heading of Energy Access, Energy Affordability, Energy Efficiency/Productivity and Environment Quality were adopted by Pacific Energy Ministers to be used monitoring the impacts of the FAESP. SPC has published the 2009 energy security indicators as the baselines for the FAESP and its IPESP. Increased deployment of RE in the region is highlighted and the key priorities for actions include resource assessment, investment in RE, capacity development and higher percentage of RE in the energy mix.

An IRENA study on "Policy challenges for renewable energy deployment in Pacific island countries and territories"[15] assessed the policy design and implementation for the successful deployment of RE in the region. It encourages policy makers in the PICTs to support the adoption of policy and regulatory frameworks to establish enabling environments to attract investments RE deployment.

15 *The report is available on IRENA website: www.irena.org/ Publications*

4. Renewable energy resource potential in the Pacific Islands region

Generally, solar energy is an economic resource everywhere in the Pacific. Fiji, Papua New Guinea, Solomon Islands and Vanuatu are the richest in geothermal, biomass and hydro resources. Wind resources are widely distributed, but tend to increase with distance away from the equator.

While there is abundant technical and economically viable renewable resource potential in the Pacific, renewables still only contribute about 10% of the average base load electricity generated, with the great majority of that share coming from hydropower in Fiji and Papua New Guinea. Traditional biomass use for cooking – although slowly declining in favour of LPG and kerosene – still accounts for the largest share of overall energy use in rural areas throughout the Pacific. Although biofuel opportunities are greatest in Fiji, Papua New Guinea, Solomon Islands and Vanuatu, almost all the PICTs have the technical potential to develop coconut oil for biofuel because much of the land, even on atolls and raised coral islands, is covered with coconut trees. However, this may not be economically viable in all cases.

Biomass, geothermal and hydro energy are suitable for base-load generation and can directly offset existing diesel generators. Solar energy and wind energy are also very important resources for reducing the amount of fuel used for power generation, but these resources are variable, with power output varying according to weather conditions. Therefore, in order to maintain power quality on the grid, integration of high shares of these resources typically requires spinning reserves or advanced controls and energy storage that can instantly pick up the load in case of clouds or calm winds.

4.1 Abundant technical and economic renewable energy resource potentials

Solar power

Thus far, solar energy has been the most commonly used RE resource because it is available and cost-effective virtually everywhere in the region. A solar PV system, if correctly designed, requires minimal maintenance. All the islands have an excellent solar resource, although it can vary significantly from one island to another, and even among different parts of a relatively small island, because of the cloud cover. IRENA is leading the development of a Global Atlas for Solar and Wind Energy, which aims to assist planners by identifying the resource potentials of these resources, especially in areas where existing field data are limited. The tool will support decision-making for RE deployment at global, regional and national levels.

Wind power

The number of islands with reliable data and assessment for an economic wind resource is limited. A few installations are operational *e.g.* in Fiji, Vanuatu, New Caledonia and French Polynesia. However, the use of wind turbines by Pacific Island utilities has been limited as a result of the following constraints:

- Island states need to understand the local wind regime sufficiently to have the confidence in the economic soundness of a wind energy installation. Wind energy is site-specific, and the only way to be sure of the resource is to determine where suitable sites probably are and then put wind-measuring equipment on towers at those sites.
- Manufacturers of utility grade turbines have increasingly focused on larger and larger turbines for the world market. Consequently, there are few production models within the 100 kW to 300 kW range, which is the most appropriate for these islands, currently being manufactured.
- Tropical storms with winds in excess of 200 km/hour occur on most islands in the Pacific, which requires storm-resistant wind turbines.
- At the other extreme, drops in wind level necessitate some type of spinning reserve to pick up the load.
- In many PICTs, wind is highly seasonal.
- The presence of El Niño Southern Oscillation adds complications. El Niño episodes – involving sustained warming of the central and eastern tropical Pacific Ocean decrease the strength of the Pacific trade winds, change the wind direction in some areas and affect the formation, strength and paths of cyclones.

- Atoll islands have very little land, and conflicts over land ownership in most PICTs often make it very time consuming to negotiate access to land for solar and wind farms.

- The isolation of many islands, and their limited port and road infrastructure, constrain the sizes and types of wind turbines that can be imported and transported to site for installation. Available cranes tend to be small and the infrastructure network for logistical delivery of components on site is limited

Hydropower

Economically feasible hydro generation can be developed on mountainous islands that have high rainfall and large enough areas for rainfall collection to generate the required volume and consistency of flow.

Fiji and Papua New Guinea have sufficient land area to support large hydro installations. Papua New Guinea has a huge potential for large hydropower, with a number of studies ongoing for large hydropower development, particularly from the Paruri River. The proposed 1.8 GW project on this river, if developed, would result in a high export of electricity from Papua New Guinea to Australia[16]. The Solomon Islands and Vanuatu may be large in total land area, but their individual islands are mostly not large, so for those islands hydro development is necessarily limited to smaller-scale installations useful mainly for community electrification in rural areas. Samoa, with a hydropower installed capacity of approximately 12 MW, has very good potential for small hydropower.

Fiji, Papua New Guinea, Solomon Islands and Vanuatu have many possibilities for developing small hydropower stations with small impoundments that could serve as pumped storage for solar. In this type of installation, a solar power generator could be connected to pump the water from the outfall of the hydro plant back into the reservoir, making it available for use later. Cook Islands also has potential for such pumped storage hydropower. This is of particular interest for rural mini-grids where the peak load is in the evening, several hours after the solar PV system has ceased to generate. There is obviously a loss of available energy in this approach because of the conversion of electricity to pump the water and then again in the conversion of water flow to electricity in the hydropower generation phase.

16 See, for example, www.originenergy.com.au/files/FactSheet PNGRenewableEnergyProject.pdf

Coconut oil biofuel

Most of the PICTs have some potential for producing coconut oil biofuel. Coconuts grow well in the region and are a traditional source of food, fibre and fuel. Further, the land under the coconut trees is not heavily shaded and can be successfully used for other crops. There are many economic advantages to coconut oil as, at least, a partial replacement for imported diesel fuel. The most obvious benefit is that the money spent on coconut oil supports local industry, creating local employment and reducing foreign exchange expenditures on energy. Other advantages include less environmental damage from fuel spills, lower levels of air pollution, local control over pricing and the existing familiarity with the harvesting and processing of coconuts. Using a plant indigenous to the region ensures resistance to adverse local conditions such as soil salinity and periodic droughts.

Pure coconut oil has been found to work well as a replacement for diesel fuel with some types of engines and not so well with others. Experiments in a number of island countries indicate that adding up to about 15% of properly filtered coconut oil to diesel fuel has no obvious detrimental effect on the larger diesel engines used for ships and power generation. Fiji now allows blending to 5% coconut oil with diesel fuel to be sold without restriction, as long as the customer is informed that it is a blend of coconut and diesel oils. Customers will need time to gain confidence in diesel-coconut oil blends, especially in view of earlier trials that resulted in clogged filters and in some cases possible engine damage.

There are, however, numerous problems that must be overcome before coconut oil production can be assured for local fuel supply. The main issue is to ensure the reliability of obtaining sufficient coconuts for oil production. In many island countries, a high percentage of trees have become aged with lowered productivity. In those cases, rehabilitation may take ten years or more.

Other biofuels

Palm oil and sweet sorghum are possible options for biofuel on a few larger islands, although it needs more processing than coconut oil to make it acceptable for unmodified engines. Other oil-producing crops have been considered, including jatropha, but there have been no trials in the region to date.

In a few islands such as in Fiji, sugar cane is a potential feed stock for ethanol[17] – which is widely blended

17 The Fiji Sugar Corporation is awaiting recommendations from Brazil on its initial feasibility study for ethanol production in the country (www.fiji.gov.fj/Media-Center/Press-Releases/FIJI%E2%80%99S-ETHANOL-PRODUCTION-AWAITS-RECOMMENDATIONS.aspx) around the world with gasoline for vehicle transport. In Fiji and Papua New Guinea, where the facilities for growing, transporting and processing cane are already in place, the investment needed to switch to ethanol production would be much less than starting with a new feedstock. However, as with all forms of bioenergy, the nexus between food, energy, water and land use must always be properly evaluated and addressed before using the resource.

Biogas

Biogas provides opportunities for simple and effective household-level energy solutions for a number of PICTs, with many years of mixed experiences with the use of biogas in the region. Cook Islands, Fiji, Kiribati, Palau, Samoa, Tuvalu and the Federated States of Micronesia have modest potential and opportunities for the production of biogas from animal wastes as a renewable energy resource.

Biomass

All the mountainous islands in the Pacific have dense vegetation in their natural state. For renewable energy, the total amount of biomass on an island is not as critical as the amount that (a) can be removed annually without environmental damage; and (b) is accessible enough for economical energy production.

The biomass resource most suitable for energy is waste from the agricultural and forestry industries, primarily sugar, palm oil and wood products. In Fiji, Papua New Guinea and the Solomon Islands, these industries have facilities for generating electricity from their waste. The energy produced is used to power the industrial facility and any surplus is sold for distribution through the local grid. The forest products processing facility in Tonga also is expected to be capable of producing electricity from its waste and its use for generation through biomass gasification is planned.

Low lying atoll and raised coral islands have less-dense, slower-growing vegetation, mostly limited to a few species of trees resistant to salt content in the ground water (*e.g.* coconut, breadfruit, causarina and pandanus). For these islands, biofuel from coconut oil may be useful to support base load generation, but the capacity for energy production through biomass combustion or gasification is limited. There is enough biomass for traditional uses, including cooking and drying of copra or other produce, but not the large amounts needed for electricity production. However, if coconut oil production for biofuel is engaged on a large scale, sufficient biomass waste in the form of coconut shells and husks may become cost effective for generating electricity and heat.

Geothermal

A useable geothermal resource is generally available for islands located in the area of the ocean where the tectonic plates overlap. For the PICTs in this report, this is an area lying generally between Vanuatu and Tonga in the south and running north, and somewhat to the west. So far, only Papua New Guinea has actually tapped this resource with a privately owned 50 MW plant at the Lihir gold mine. The Vanuatu Government recently granted an exploration license to a private company for geothermal energy on the country's main island, Efate, with plans for new grid construction to increase rural electricity access. There are several companies currently studying geothermal potential in Fiji but the high cost of drilling is impeding progress.

Ocean energy

Ocean energy can be derived from tidal action, waves, algae, salinity gradients and temperature differentials between surface and deep water bodies of the ocean. Technologies for this type of energy are still in the early research, development and demonstration stages but there are ongoing developments in these technologies in various parts of the world, notably in Australia, Canada, China, the EU (Denmark, France, Ireland, Norway, Portugal, Spain, Sweden and the UK), Japan, Korea and the USA. Islands are surrounded by an endless supply of ocean energy in different forms, but it has yet to be proven that this energy can be tapped in a cost-effective manner to produce electricity for island grids. The state of Kosrae in the Federated States of Micronesia is in the early stages of developing a 1.5 MW wave power system. If the installation proves successful, it could represent the start of a major expansion in renewable energy generation for many small island countries.

Tidal flows into and out of atoll lagoons are sometimes through narrow reef openings and may also offer modest power generation potential. However, good sites for tidal energy in the PICTs are rare, and for a site to be cost effective it needs to be near a load centre, which further limits the opportunities for the deployment of this technology in the region. Tidal energy may be cost effective in a few locations where there are large tidal flows passing through a narrow channel. A site in Vava'u in Tonga has considerable potential and, if developed, possibly could generate much of the electricity for the island. A proposal for a feasibility study that will include collection of necessary data and an economic analysis for the Tonga site has been prepared.

The surface water layers of oceans absorb and store a huge amount of energy in the form of heat, thus creating a temperature difference between the surface and deep layers. Ocean thermal energy conversion (OTEC) makes use of this thermal differential to provide energy

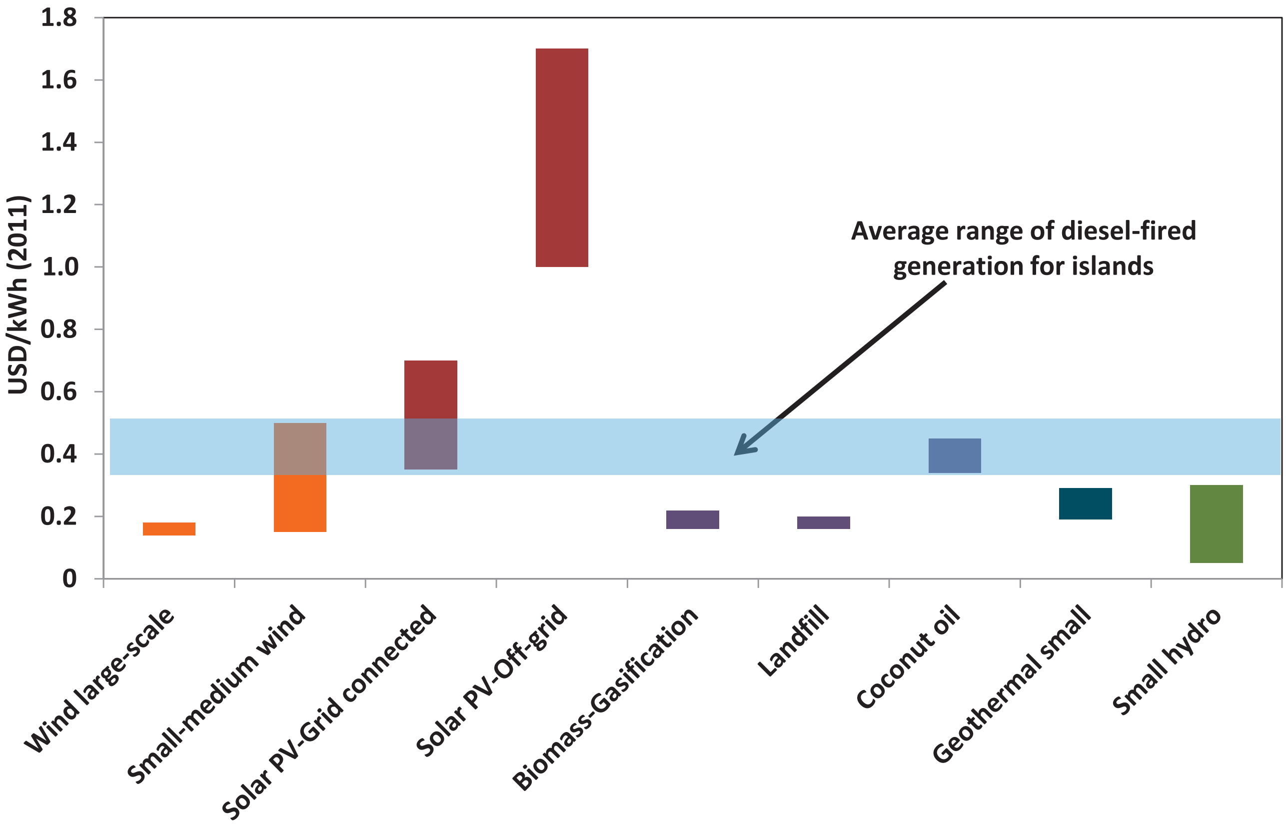


Figure 3 – Levelised cost of electricity from renewable power generation for Pacific islands (Source IRENA 2013)

for power generation, cooling and/or heating. For power generation the warm surface water is used to vaporise a low boiling point fluid to provide the vapour needed to drive a turbine. The cold water from the deeper layers is used to condense the vapour back into a fluid. OTEC technology is unlikely to be part of mainstream generation in the PICTs for many years because of the lack of technology maturity and the high lifecycle cost expected of OTEC installations. However, the favourable factors for OTEC in the Marshal Islands (such as strong thermal stratification and the short distance from the shore to the deep ocean) have resulted in a proposal by the Organisation for the Promotion of Ocean Thermal Energy Conversion and GEC Co Ltd of Japan to launch a commercial OTEC plant at Kwajalein Atoll[18]. Other developments of interest in OTEC include the proposed 10 MW power plant off the southern coast of China and a number of projects in French Polynesia.

The environmental impacts of ocean energy technology are not yet well understood, particularly for island environments such as the PICTs, with very little monitoring and research to date. Such research is needed, considering the sensitivity and value of Pacific marine biodiversity.

18 See, for example, www.marshallislandsjournal.com/Archive%203-9-12-page.html; www.rnzi.com/pages/news.php?op=read&id=66710

4.2 Renewable energy costs and maintenance requirements

Throughout the Pacific the main rationale for using RE is to reduce dependence on fossil fuels and thereby protect the island economies from the volatility of fossil fuel prices and from the spectre of continually increasing fuel costs. The ultimate goal is to eliminate the use of imported fuels altogether, and a few countries, such as Tokelau, Cook Islands, Niue and Tuvalu, have set the goal to provide all their energy needs from renewable sources. However, there are many challenges, including costs and maintenance issues that lie between setting goals and achieving them.

The costs of RE options vary depending on, among others, resource availability, output capacity and technological maturity. Figure 3 shows the typical range of the levelised cost of electricity from renewable sources

Table 8: Summary of estimated costs (2012) and technical staff training requirements for solar PV and wind power in the Pacific

Technology	Cost estimate	Relative complexity	Training needs
Off-grid solar (DC only)	USD 7 – 10 per Wp (includes battery)	Low	Periodically repeated short-term training of village technicians has been found to be adequate.
Off-grid AC delivery for schools, health centres, government offices	USD 8 – 15 per Wp (includes battery)	Medium	Medium-term training that is repeated periodically. Must understand AC and DC components and more safety problems. Utility-based is best.
PV mini-grid systems for village electrification (with or without diesel back up)	USD 7 – 15 per Wp (includes battery). For recent Tokelau 930 kWp PV system the cost estimate, including batteries, is approximated USD 7 per Wp.	Medium if properly designed, but can be complex.	Medium-term training that is repeated periodically if there are proper island designs. Long-term training will be needed for overly complex designs. Utility-based is best.
Grid-connected solar <100 kWp	USD 3 – 10 per Wp depending on mounting	Low	Periodically repeated short-term training adequate.
Grid-connected solar >100 kWp	USD 3 – 6 per Wp	Medium	Periodically repeated medium-term training. Utility-based maintenance.
<1 kWp wind systems for battery charging	USD 4,000 – 10,000 per kW rating depending on design (includes battery).	Low	Periodically repeated short-term training adequate.
Grid-connected wind	USD 2,000 – 3000 per kWp of capacity	High	Longer-term, regularly repeated training required. Utility-based maintenance or external contractor.

(in USD/kWh) in the Pacific Islands region, with costs in some cases falling below typical island electricity prices.

The costs of hydro and geothermal installations vary widely with local conditions and ease of access to the grid. Hydropower costs also vary depending on the size and type of installation and size of impoundment, if any. In general, hydropower installations in the PICTs, although tending to cost more than similar projects in developed and larger developing countries, have proven economically attractive compared to diesel-based generation.

Information on biomass combustion and gasification costs is limited for the Pacific because they are only found in private, industrial settings with no up-to-date cost information available. Table 8 summarises the estimated investment costs and technical staff training requirements for solar and wind technologies.

Solar power

For most Pacific Island utilities over the next decade, an increase in solar input to the grid is likely to have the highest priority since it can be installed easily almost anywhere where there is sunshine, has low maintenance requirements, is cost effective for a wide range of sizes and is socially acceptable in rural and remote communities. In addition, the output from solar PV matches the load curve for most urban grids. Once about 15% of the total energy comes from solar, however, it will be increasingly difficult to proceed further with solar without major storage investments, and so the development of wind and biofuel will look increasingly attractive.

Cost

Solar panel prices have dramatically fallen within the last three years due to the massive scale-up of solar manufacturing, productivity gains through more efficient manufacturing processes and over capacity requiring a reduction in manufacturer profit margins. Thus, it should be possible to have grid-connected solar installations that cost under USD 3 per installed peak watt (Wp) in 2013- down from about USD 6 per Wp in 2009- even after including the relatively high costs of shipping and installation.

Some battery types, such as lead-acid, are a mature technology and so the opportunity for any significant cost reductions in their contribution to the balance of system cost is very limited for off-grid solar PV installations. They have shorter life-spans when compared with the more expensive newer long life types of storage, which are expected to fall in price significantly over the next few years. It is therefore logical to consider the newer types of batteries in the specification and design of new systems as they could offer better opportunities for cost reductions in balance-of-system costs over the longer term. However, this choice has to be balanced against other constraints (such as limited experience and special charging requirements) for the newer technologies.

On very remote islands, the cost of power that comes from batteries charged by solar PV modules is comparable to the cost of power from small diesel generators; therefore, replacing those diesel generators with solar PV systems often makes economic sense. Land availability is another issue for multi-megawatt solar arrays on islands. Early grid-connected solar PV in the PICTs relied mostly on government-owned land, the roofs of government buildings and/or parking lots.

The larger island utilities currently have no plans for completely replacing their multi-megawatt diesel engines with either solar PV and/or wind power. They can, however, strive to increase the amount and share of solar and wind energy that can be accepted by the grid through smaller storage banks that do not carry the load, but instead manage the power flows from the solar or wind systems so that they vary more slowly.

Maintenance

The Pacific islands environment presents special maintenance issues:

- Except for the interior of the larger islands, there is the problem of corrosion by airborne salt, and during high winds, salt spray is an issue. The moisture, salt and fine coral dust that is present in the atoll islands contribute to corrosion and can result in short circuits on electronic boards in devices not designed for the climate.
- Equipment exposed to the elements must be capable of withstanding the high winds and turbulent gusts associated with tropical cyclones/typhoons. Especially at risk are wind turbines and ground-mounted solar panels.
- Sealed batteries need special attention because high operating temperatures (*i.e.* 35°C and above) can substantially shorten their life. Open-cell batteries are generally less sensitive to high ambient temperatures than sealed batteries.

Thus far, utilities and a few private contractors have generally done a good job of operating and maintaining the grid-connected installations. When energy storage starts to be required to add more solar capacity, the systems will become more complex and technicians will likely need additional training.

In order for stand-alone solar installations to be sustained on the outer islands, a competent institution must operate and maintain the solar electrical systems. Where the power utility has operated and maintained these installations, the results have generally been good. Where the community or facility owners (*e.g.* the local Department of Education or Department of Health) have been responsible, the quality of maintenance has not been very good.

In addition, because of the cost of access, local, on-site technicians must operate and maintain off-grid solar. A train-the-trainer approach – where bi-lingual trainers, taught typically in English, train local technicians in the local language – has worked well. The most successful approach has been for the expert trainers to conduct training programmes in the country's capital, using the same type of equipment that is to be installed on the outer islands and which must be maintained by the village technicians.

The Pacific projects that have survived well were all designed around the "solar utility" concept where ownership of the solar installations remains with the operating institution, which employs and trains all the technicians responsible for maintenance, charging users monthly fee that is sufficient to pay the cost of battery replacement and preventive maintenance. Though there are problems with this model – notably with fee collections and with supervision of the outer island technicians – the projects under that type of structure have worked much better than any other approach thus far tried in the islands.

Regarding maintenance of outer island systems, observation on the ground shows that:

- Maintenance by users is unreliable and so should be carried out by specially trained personnel and systems should be designed not to need more than a monthly visit by local technicians.
- Community-managed systems have not been very successful at collecting tariffs and scheduling appropriate battery maintenance and replacement. Therefore designs should include excess panel capacity to extend battery life.
- Components used in remote islands need to be able to survive the difficult island environment and be of the highest possible quality in order to attain an acceptably low life-cycle cost.
- Technicians must be well trained for the specific installations to be maintained.

Design and installation

Challenges in the design and installation of solar PV power in the Pacific include the following:

- *Difficulty landing the large batteries needed for mini-grid installations on remote islands.* Although landing materials on remote islands without a wharf is always difficult, it is particularly difficult to land the relatively fragile lead-acid batteries (which can be nearly 200 kilogramme (kg) for each 2 Volt cell) for village-scale mini-grids. It is therefore important to choose lighter cells that could be transported dry. This makes the case for using lighter weight and longer lasting battery types for projects in such environments.
- *Land issues.* Large solar arrays require assured access to large areas of land for at least 30 years. Preferably, the land should be near major loads or the power house. Such land is hard to find on many PICTs. Roof-mounted solar or solar sources built to provide shade over public parking lots has become a common way to get around that problem. The main reason for avoiding private land where possible is that in most PICTs there are often disputes over ownership, as well as access rights, to large pieces of land, and negotiating terms with many claimants for the same land is typically difficult and very time consuming.
- *Lack of trained manpower, especially on outer islands.* Although the installation processes for outer island solar installations are not difficult, they are not familiar to local residents. Since it is very costly to import installation crews for outer island solar installations, it is necessary to train local people to assist in the installation of the systems. The trained local people will still need to work under knowledgeable supervisors, but experience indicates that most of the work can be carried out by newly trained local workers.
- *Need to design outer island installation processes that do not require power tools.* Although it is possible to land a portable generator and the fuel to run it, the experience has been that the use of power tools should be minimised. On a rural island, it may take a week or longer to replenish fuel or fix a generator breakdown. Careful consideration needs to be given to including only installation processes that can be accomplished without power.

Some important characteristics of successful off-grid solar designs include the following:

- *A conservative design.* The design should use only components that have already been proven to have a low failure rate and good performance in the Pacific, and should include excess capacity in solar panels and batteries. That added capacity lowers the stress on all components and lengthens their operational life.
- *Pacific-proven electronic components.* Electronic equipment is particularly susceptible to problems due to corrosion and high ambient temperatures. A piece of electronic equipment in use for five years or more with few problems can be considered "proven for the Pacific" and should be specified over unproven products, particularly for projects in remote areas or where high reliability is needed, such as for health centre electrification. As donor-funded projects do not allow a specific brand and/or product to be specified, products provided have sometimes been of a poor choice for the island environment where components with high protection ratings are required.
- *A simple design.* Since the technical support capacity in the islands – even on most main islands – is limited, complex installations will cause problems for troubleshooting and repair. While automated installations are excellent when they work properly, repairs are difficult and often take a long time to accomplish. For example, computerised controls that automatically start backup diesel generators when battery charge levels fall too low have been the source of many problems. A design more suitable for the technical capacity in the smaller Pacific islands would use simple manual controls for all system management, including starting the engine and switching between diesel and solar. While this requires constant operator attention and training for operators, problems can be more easily solved and repairs more easily made.

- *Use of only factory-installed connectors or high-quality bare wire connections.* Hand-crimped connectors have caused many problems in the islands and should be avoided. Only factory-installed connectors and screw-type connections that work with bare wires should be used. All junction boxes should only use compression-type screw connections that can work with bare wires. The use of tinned copper wires, with connection tightened at the right torque and regularly inspected, is also good practice for minimising corrosion.
- *Use of generation modules that can be replicated and connected in parallel.* Having many different designs for solar installations on one island makes it difficult and costly to provide proper maintenance. Personnel must then be trained in each design and spare parts must be stocked for each design as well. If instead, independent and identical generation clusters are used and installed in parallel in the numbers needed to meet different generation needs, it is possible to reach a wide range of capacities without changing either spare part inventories or the training of maintenance personnel.

Wind power

Wind is a significant resource that can be tapped in the Pacific Islands region, but it requires a different approach for its deployment than solar. First, the power output from a wind turbine generally increases with the cube of the wind speed. A passing storm front can create huge and rapid variations in power. As with solar, short-term storage can be used to reduce the rate of change of power and the extent of the power changes. However, the much larger and faster power swings from wind turbines require more complex controls and a type of storage that can accept rapid changes in absorbing and delivering energy. Unlike solar, where there is little difference in the mode of power delivery from the installations, each wind turbine has its own power delivery characteristics, so wind system control and power management devices need to be designed specifically to fit each type of turbine.

Another characteristic of wind power in the islands is that wind speed varies seasonally in most of the lower latitude countries. Months with a 6 metre/second (m/s) average wind speed can have as much as eight times the energy generation of months with 3 m/s winds making year-round management of wind power generation more complex.

Land issues also pose a problem for wind power generation in the PICTs. Wind is very site-sensitive, and if access to good sites is not possible, economically reasonable wind generation will also not be possible.

Considering these issues, the probability of being able to add cost-effective wind generation to a grid will likely be lowest for an atoll island country near the equator, and greatest for larger islands that are above 15°latitude though a lower latitude island that has a wind concentration zone near an existing transmission line may allow cost-effective wind generation.

Successful deployment of wind power on islands in the PICTs will require focus on the small scale cyclone-proof designs, such as the Vergnet sub-MW systems that are widely deployed in the Pacific region (Australia, Fiji, New Caledonia and Vanuatu) and the Caribbean. These types of systems are relatively easy to mobilise and deploy and therefore very suitable for the island environments. Unfortunately, more and more established equipment manufacturers are phasing out these small scale units. General Electric and Vestas have developed large-scale cyclone-proof wind turbine designs that have been successfully deployed in the Caribbean and elsewhere, but these are generally too big for deployment on islands in the PICTs region. There is therefore a niche market opportunity for development of small-scale cyclone-resistant turbines for island regions.

Cost and maintenance

There are insufficient data and information currently available to determine the installation and maintenance costs of wind power in the PICTs. Globally, the cost of wind turbines has fallen to the order of USD 1,000 per kW or even lower (IRENA, 2013). Although the turbine system generally dominates the cost of wind installations, it is clear that in island regions logistic and maintenance cost components would be high as well.

5. Comprehensive power systems planning approach

5.1 Renewable energy resource data collection

The first step in a comprehensive power systems approach is a detailed review of locally available RE resources. The underlying RE resources are the key driver for the configuration and power output of the system and need to be understood in detail. As has been noted previously, comprehensive, accessible RE resource data is lacking for most of the Pacific islands region even though a number of studies on RE have been compiled by various development partners/organisations. Unfortunately, a great deal of the data from those studies have not been collated in a systematic and centralised manner. IRENA could support the PICTs in this effort through its Global Renewable Energy Islands Network (GREIN), REMAP, statistics, Global Atlas, and costs analyses activities. Furthermore, many RE resource assessment need a minimum of a few years of data to account for seasonal variations. As such island RE planning should start as soon as possible with an effort to identify key RE production sites and begin data collection to verify resource availability.

5.2 Renewable energy integration

In the medium- and long-term RE-based power solutions would be the most sustainable and cost-effective solutions for Pacific islands communities. In the transition to this state, RE and diesel hybrid systems with high levels of RE integration will play a key role in the energy supply for island communities and are indeed a viable option for the PICTs to greatly offset diesel generator fuel consumption. The relatively simple design process, and operation and maintenance of low penetration solar/diesel hybrid systems means that many Pacific islands can successfully deploy limited RE projects in the near future while moving up their learning curve for higher utility scale RE integration. However raising levels of solar/wind RE integration rapidly increases the complexity and the cost of the systems needed to control variable RE output and ensure grid stability. Medium and high penetration hybrid systems using solar and/or wind power may also require islands to invest in new diesel generators and will likely require upgraded grid infrastructure to access large scale RE generation sites

Table 9: NREL guidelines for low, medium and high penetration hybrid systems*

Penetration Class	Operating Characteristics	Penetration	
		Peak Instantaneous	**Anual Average**
Low	• Diesel(s) run full-time • Wind power reduces net load on diesel • All wind energy goes to primary load • No supervisory control system	<50%	<20%
Medium	• Diesel(s) run full-time • At high wind power levels, secondary loads dispatched to ensure sufficient diesel loading or wind generation is curtailed • Requires relatively simple control system	50–100%	20–50%
High	• Diesel(s) may be shut down during high wind availability • Auxiliary components required to regulate voltage and frequency • Requires sophisticated control system	100–400%	50–150%

*: See, for example, www.akenergyauthority.org/wind/02_Wind-diesel_power_systems_basics_01-01-2008.pdf

and be able to handle multidirectional power flows. Investment in smart meters and load control systems are needed if islands want to boost RE penetration through demand side management, where it is technically necessary, feasible and economical to do so. These additional costs must be weighed against the money saved through reduced fuel consumption. Determining both the system cost and fuel savings requires a detailed knowledge of the final system configuration and power output. This requires islands to adopt a comprehensive power systems approach that takes into account relevant information, including the possible impacts of climate change, and a long-term RE integration plan with clear and measurable goals.

The National Renewable Energy Laboratory (NREL) of the US has developed definitions for low, medium and high penetration hybrid systems based on its experience with wind/diesel hybrid systems. These classifications are detailed in Table 9.

To facilitate high penetration of PV or wind power in existing diesel powered grids in the region policy makers need to ensure that (i) a comprehensive system modelling is undertaken to help select the most cost effective system and identify key technical challenges, and (ii) local PV and wind expertise is developed to ascertain sustainable operation and maintenance of the resulting complex grids and proper coordination among all stakeholders.

5.3 Grid modelling and verification

The need to integrate RE systems into existing grids and the notable impact this can have on diesel generators and grid stability requires that islands have a thorough understanding of current grid function. This entails a detailed examination of local demand characteristics and generation assets along with an assessment of the physical and electrical grid structure.

Once this information has been collected, comprehensive static and dynamic modelling should be performed. Static modelling examines power system performance under a constant load and is used to locate grid losses and inefficiencies which need to be corrected so that the full value of RE production can be delivered to customers.

Dynamic modelling allows system designers to examine how possible fluctuations of RE power generation affect grid stability. In addition to detailed knowledge of the grid and attached loads, effective dynamic modelling requires knowledge of the RE resource. This allows identification of the key effects of potential RE technologies on grid stability and drives the selection of the additional technology best suited to allow RE integration.

A number of software packages exist that can perform static and dynamic modelling and IRENA is in the processing of assisting Pacific islands in identifying which of these packages is best suited for the particular conditions on small islands. However, more important than which package is chosen is the selection of a modeller who has expert skills in the operation of small diesel based grids.

All model results need to be directly verified with onsite measurement. Due to the highly dynamic nature of small island grids a very high sampling rate for data collection is required and represents a substantial expense.

5.4 Energy efficiency

Static modelling will help to identify grid related energy efficiency opportunities but all island RE planning efforts need to go beyond this and include a comprehensive examination of opportunities for increasing energy efficiency across the island. Energy efficiency efforts such as replacing inefficient electric water heaters with solar thermal ones, or eliminating the use of incandescent light bulbs through replacement with high efficiency bulbs, can lead to a notable reduction in demand, thereby allowing a smaller and less expensive RE system to cover a higher percentage of island energy demand. Many energy efficiency efforts can be readily deployed leading to immediate reductions in diesel consumption, resulting in savings that could be further invested into additional renewable power capacity.

5.5 Selecting partners with relevant experience

Detailed knowledge of RE resource availability and the results from grid modelling and verification will help to define the baseline options for an island's hybrid power system. However even with these details established the wide variety of RE technologies and diversity of associated power electronics, storage technologies and other equipment required to control RE power production results in a large number of possible system configurations.

Sorting out which system is most efficient, economical and best fits an island's power needs requires the expertise of a power system designer with established experience in field of hybrid systems. In addition, island specific challenges such as limited infrastructure, high local knowledge, temperature, humidity, salinity, strong storms and other key factors need to be taken into consideration in the design and selection of components. This makes the selection of designers and system installers with island experience and knowledge of local conditions an important factor in successful system deployment. The lack of a good pool of RE systems designers and installers that meet these requirements is currently one of the significant barriers to enhanced and accelerated deployment of RE in the PICTs.

Island RE project planners should place a high priority on identifying experienced project partners. Given the limited Pacific RE system deployment, island RE project planners need to make sure off-island experts are accounting for island specific challenges. IRENA is in the process of identifying key players with experience in island/isolated hybrid system to share with island RE project planners.

5.6 Robust implementation guidelines and measurable goals

The technical complexity and numerous processes required to deploy RE systems that can reduce island oil dependence can be overwhelming. RE planning efforts should take a long-term view and develop a detailed understanding of the specific steps required to achieve high levels of RE penetration. This step-by-step process needs to include clearly defined and measurable goals so that RE project planners can ascertain their progress, identify particular challenges and prepare for the upcoming phases of project implementation. This comprehensive approach can identify which project options have a positive return on investment and guards against costly mistakes. This is particularly relevant given the limited experience with risks assessment and allocation for the development of commercial RE projects in the PICTs.

A comprehensive power systems approach is essential for widespread RE deployment in the Pacific. However, IRENA's review of RE projects to date and consultations with local utilities and policy makers have identified a number of critical policy and financial challenges that will have to be addressed before RE power systems can be widely deployed in the Pacific. It is essential that the project planning process be expanded beyond technical design and include local experts with knowledge of the Pacific's unique policy and financial environment. To assist in this process some of the key non-technical challenges identified by IRENA are detailed in Section 8.

6. Renewable energy for the transportation sector in the Pacific Islands

6.1 Overview

Due to the physical and economic diversity of the Pacific Islands, there is a wide range of patterns of energy use for transportation. One of the barriers to the development of RE programmes for transport is the difficulty of getting accurate data for the transport sector.

Nauru and Niue have no coastal shipping as each consists of a single, raised coral island that limits sea transport to small personal boats using gasoline powered outboard engines or small inboard diesel engines. Land transport is also limited due to the small size of the islands and their small population. For these two islands, the greatest use of fossil fuels is for power generation.

Fiji and Papua New Guinea have large land areas and, by Pacific standards, large populations resulting in significant land transport fuel use. Fiji also has over 120 inhabited islands spread over a large area so sea transport is also substantial. Since Fiji and Papua New Guinea both have most of their electricity generated by hydropower, the amount of fuel for transport is far greater than that for power generation. However most of the efforts in the Pacific directed at fuel reductions have been focused on power generation because of the centralised nature of generation that makes it much easier to implement and evaluate fuel saving programmes. The highly fragmented and diverse nature of energy use for transport has made it very difficult to create programmes that can clearly demonstrate substantial import energy savings and carbon emission reductions in the islands. However, the transportation sector is better regulated in terms of

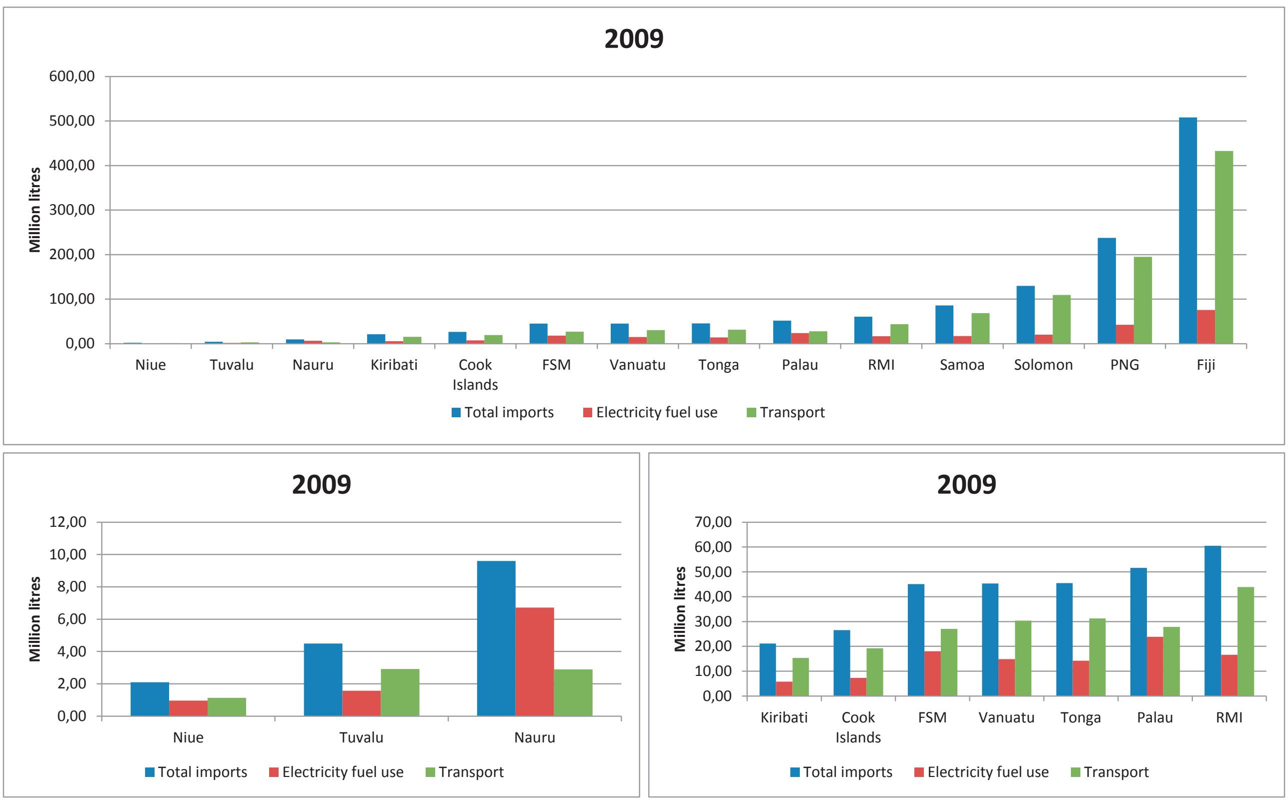


Figure 4: Estimates of fossil fuel imports and its use for transport and power generation (from SPC)

standards to be met, for annual road, air or sea worthiness certificates are issued.

The data collected in the Pacific for fuel use in transportation is mostly very general and not very useful for targeting programmes. Point of sale fuel data are not readily accessible in most of the island countries. In a few cases, such as Kiribati, a government oil company does both importation and distribution of petroleum products and in those cases, good data is possible to obtain. Often fuel use for transportation in the islands is assumed to be the total of petrol imports (which is almost exclusively used for transport by automobiles and boats with outboard motors) and the difference between total diesel fuel imports and diesel fuel used for power generation. While this assumption is reasonable for island countries that have little industrial use for diesel fuel, it does not differentiate between land and sea transport. In some countries, kerosene is used domestically for cooking and outer island lighting comes from jet fuel imports making estimates of domestic jet fuel use less accurate. Figure 4, obtained from SPC, graphically depicts the relationship between retained fuel import quantities and fuel used for power generation and transport.

6.2 Enhancing opportunities for renewables for transportation in the Pacific Islands

In the near term, replacing the use of fossil fuels with RE sources in the transportation sector in the Pacific region will require the development of an alcohol production capacity to replace a part of petrol imports and increasing biodiesel and fuel quality coconut oil production capacity to replace imported diesel fuel for powering ships and vehicles. No immediate replacement of imported fuel used for air transport by RE appears to be practical though for the longer term, it is possible that turbine powered aircraft may be fuelled by aviation certified biofuels imported mainly for international air carriers.

Incentives to promote replacement of existing ships, land transport vehicles and aircraft with more fuel efficient types can make a very significant difference to GHG emissions and fuel import costs. Reducing the quantity of fuel required through more efficient vehicles also will allow the limited local biofuel production that is practical in most of the island nations to increase its percentage of the total transport fuel supply for the islands.

Other ways to explore and promote sustainable use of renewables for transportation in the region include:

Modular coconut oil production facilities

The traditional model for coconut oil production in the Pacific is for outer island residents to produce copra that is shipped to the main island for conversion to coconut oil. That business model has problems due to high fuel costs resulting in increased shipping costs. Furthermore, shipping companies tend to reduce the frequency of visits to outer islands and often vary departures to fit times when the ship can sail with a full load. Without a reliable and consistent shipping schedule it is difficult for copra producers to maintain the quality of product necessary for biofuel production. By having local coconut oil production facilities within the coconut harvesting area, copra can be almost immediately converted to high quality oil which can be stored for long periods without serious loss of quality. Furthermore, the cost of shipping the oil is much less than for shipping the copra needed to make that oil at the main island mill. For these reasons, most recent project designs that include producing biofuel grade coconut oil have proposed using small modular mills located on the coconut producing islands with shipment of the resulting oil, rather than copra, to the main island. Fiji is currently experimenting with this model and it has also been proposed for trial in the Solomon Islands.

Once the coconut oil is produced on the outer islands and shipped to the main island it can be further refined to meet fuel standards and then either used directly in engines designed for coconut oil use, blended with diesel fuel or kerosene for use in unmodified engines or sent for further processing to make biodiesel.

The number of mills that would be put in place on each outer island would need to be related to the coconut production of the island. By making the mills modular and identical, spare parts stocks and the requirement for maintenance training would be minimised. As the modular mills would be trailer mounted or containerised, they could be moved to locations within the coconut producing areas that are currently active. Should one of the modular mills break down, the others could operate additional hours until the failed unit returns to service.

Containerised plants for biodiesel production from coconut oil

In order to provide the widest market for locally produced biofuel, the sustainable conversion of locally grown vegetable oil, such as coconut oil, to biodiesel is needed. Large engines used for power generation and ships may be able to use a dual tank system, whereby the engine burns pure coconut oil when at high loading and switches to diesel fuel at low loading. However, such operation is not practical for land transport. Although biodiesel can be used as a direct replacement for diesel fuel, coconut oil generally is only practical if blended or if the engines are known to be able to use straight coconut oil without problems. Fiji is currently allowing a 5% coconut oil and 95% diesel fuel blend to be sold as a direct replacement for pure diesel oil. Higher percentages may result in rapid fuel filter clogging and possibly carbon build up within engine combustion chambers so cannot be used without caution and monitoring.

The production of biodiesel from coconut oil is not a complex process. There are small containerised chemical plants that directly convert any suitable feedstock (including coconut oil) into biodiesel. The inputs to the process are vegetable oil, such as coconut oil, sodium hydroxide (lye) and methanol. The outputs include a quantity of biodiesel approximately equal to the quantity of oil input to the process, glycerine and mulch that is suitable for animal feed or fertiliser.

Combined grid-connected solar and electric vehicles

Another opportunity concept is to consider the viability of electric vehicles and charging station and how they could be integrated to the grid. In this case consideration needs to be given to how to control the vehicle charging rate in step with solar power output, the ratio of vehicles to solar capacity needed for optimal performance, the costs and benefits of such an approach and a determination of the key variables that most strongly affect the economics of the concept.

Electric motorcycles with solar charging

The use of electric motorcycles supported by solar charging centres is another concept for promoting the use of renewables for transportation, particularly in urban areas with short travel distances. Such motorcycle charging and renting centres could provide income generation activities and employment for young people, particularly in those PICTs with high tourist volumes.

Dual tank freighter trial

The conversion of a small to medium sized inter-island cargo ship to dual fuel use with tanks for both diesel fuel and coconut oil could be a viable concept for reducing the current high fossil fuel consumption rates in inter-island transport. In this configuration, conventional diesel engines that are continuously operated at near rated power have been shown to be able to use straight coconut oil without damage, provided the coconut oil is preheated to keep it is viscosity acceptable. The ship would thus be able to use straight coconut oil during its standard cruise conditions – the time when the bulk of fuel is used in a voyage – and shift to diesel fuel for low power conditions for both manoeuvring and when at anchor.

Kite-assist inter-island sea transport

Another example of improving shipping costs would be to consider the use of kites to tap wind energy for assisted sailing of ships for long inter-island travel.

Renewable energy-powered boats for intra-lagoon transport

Boats for intra-lagoon transport powered by combination of solar PV and micro wind turbines could reduce fossil fuel consumption for transportation while increasing the share of renewables in the sector.

7. Challenges in implementing renewable energy systems in the Pacific Islands

The Pacific Islands region presents unique opportunities, supported by strong policy drives and targets for enhanced deployment of renewable energy technologies and transition to a sustainable renewables-based energy future. However, there are a number of key challenges that must be overcome if the growing momentum for renewables in the region must be sustained to achieve the transition. This section outlines these challenges for specific areas as aspects of renewables deployment.

7.1 Solar, wind and wave energy

Lack of uniform standards and guidelines

Clear, uniform standards and guidelines are needed to safely connect private solar and wind generation to the small utilities of the Pacific. Although the southern island countries mostly use the Australian/New Zealand electricity system standards, their standards for grid connection are not geared to small grids, nor do they consider the environmental and technical capacity problems of the Pacific. The Sustainable Energy Industries Association of the Pacific Islands (SEIAPI) in collaboration with the PPA is attempting to develop the first Pacific island RE standards and guidelines, but they suffer from limited technical capacity and resources.

Lack of net-metering policies

Including small private grid-connected solar and wind installations in the generation mix offers a number of benefits. Dispersing solar and wind generation over a large geographic area tends to reduce the speed and amount of total power variation from those sources, which in turn allows more energy input from solar and wind without the need for storage and complex controls. Also, if the private sector invests in solar or wind, the public sector is relieved of that financing burden.

However, most of the island utilities do not have a net-metering policy, and several are not pursuing the concept, largely because of a lack of understanding of the effects of net metering on utility income and on their quality of power. Assistance to those utilities, perhaps through grid-modelling technology, would help them understand the likely effects and financial ramifications of net metering.

Thus far, net-metering policies have been implemented in some of the PICTs, notably the Cook Islands and Palau. In the Cook Islands, there are concerns that the net-metering policy may allow growth of private grid-connected solar too rapidly, resulting in grid stability problems, but net-metering has been quite successful in increasing the interest of private investors to support grid-connected solar. In Palau, a net-metering law was passed in 2012 laying out the approach for net metering to be used by the Palau Public Utilities Corporation (PPUC), although grid-connected solar has been allowed to be connected to the PPUC grid on a system-by-system basis for at least four years.

Lack of templates for necessary agreements

Although there is some experience in the Pacific with power purchase agreements and Independent Power Producers (IPPs) for diesel, biomass and hydropower, thus far there has not been much for solar, wind or wave power that applies to the small utilities of the Pacific. In developing agreements for solar, wind and wave power, there needs to be legal and technical assistance to develop approaches that minimise the risk for both the utility receiving power and the private party providing power.

Bioenergy development: coconut oil production

Most studies relating to coconut oil for biofuel production have assumed that coconuts would be gathered by individual farmers and transported to a central mill. However, it is increasingly clear that for coconut oil to become an economically viable biofuel resource for widespread use in the Pacific, there are a number of cost advantages for using multiple, relatively small-scale oil production facilities instead of a single, large one as discussed in Section 6.2.1 above. In particular, coconut transport costs can be dramatically reduced and the overall reliability of oil supply increased. If a modular processing facility that includes all aspects of coconut processing and oil production were designed, developed, tested and standardised for the Pacific Islands region use, the cost of coconut oil production could be reduced and many small businesses and farmers could participate.

A second barrier to using coconut oil for biofuel is the lack of oil-testing facilities in the islands. For end users, it is vital that the islands have a standard testing process that shows the level of acceptability of an oil sample quickly and at a reasonable price. The University of the South Pacific recently installed an oil-testing facility in Suva in collaboration with the Government of Fiji[19]. For coconut oil to constitute a major portion of fuel needed for power generation there needs to be a sustainable supply at a stable price.

A third barrier is the result of the wide swings in the international coconut oil and copra markets. Mills are eager for the oil to be used locally for biofuel when international prices are low, but they restrict the supply of oil locally when international markets are higher than the diesel fuel landed price, which is generally the maximum price that utilities are willing to pay for biofuel. Since the utilities are the major user of diesel fuel on the islands, maintaining a large amount of diesel fuel in storage or not being able to optimise fuel shipment quantity and timing can substantially increase the utility's cost of fuel and therefore the cost of generation during periods when mills prefer to produce for export rather than use as biofuel.

7.2 All renewable energy technologies

Incentives

Price incentives have dramatically accelerated private investment in RE in Europe and Asia. The primary incentive used has been for governments to implement a "feed-in-tariff" for RE that provides sellers with additional income per kWh generated above the price in power purchase and IPP agreements. This added value for RE production may be paid for through increased tariffs on fossil fuel-generated electricity (as is done in Germany) or through the development of a special fund for RE and energy efficiency paid for by a small tax on all fossil fuel sales (as is done in Thailand).

Risk abatement approaches may include loan guarantees, subsidies for investments, concessionary loans and other means to reduce the total investment required. This has already been done on a small scale in Palau, where the National Development Bank of Palau provides a loan subsidy for residential grid-connected solar that allows the cost of energy generated by the solar system to be equated with the residential tariff. In Palau, the subsidy funds were provided through a donor.

19 See, for example, www.usp.ac.fj/news/story.php?id=932

Capacity development

A major barrier to the successful implementation of RE has been the capacity available on the islands for the technical support needed to operate and maintain RE systems. This is particularly a problem for off-grid installations on rural islands. Although training is usually carried out at the time of installation, there has been little done to maintain that capacity over time. Refresher training of long-term staff and the initial training of new staff has not been carried out for most outer island projects. The primary reason for not maintaining technical capacity has been the lack of trainers in the countries to provide the training. External trainers – provided by regional agencies and donor institutions – have not been very effective because most outer island residents do not have sufficient English language capability. A solution appears to be to develop the necessary training skills in teachers at national trade schools and technical colleges, as well as providing the schools with the training equipment needed for instruction. Through such technical institutions, train-the-trainers courses can be run, in the local language, wherever needed.

Need for action plans and resources

Although most of the PICTs have declared a goal for RE development (or for fuel import reduction), few have any clear plans for achieving the goals. The only countries that have made any significant progress towards their goals have been those with a clear action plan and predetermined projects that fit that plan.

Energy efficiency

Energy efficiency measures are as critical as RE deployment for reducing the use of fossil fuel in the Pacific region. Recently, the PPA completed a study of technical and non-technical station, transmission & distribution losses, from 20 Pacific utilities and found that just supply-side efficiency improvements could provide import reductions equivalent to more than 5% of the energy delivered at base load levels. Residential energy efficiency benefits of 10%, commercial energy efficiency benefits of 15% and government energy efficiency benefits of 20% are achievable in most of the island countries for a total investment that is much less than the investment needed for the equivalent energy production from diesel systems.

8. IRENA's activities in the Pacific Islands

From its inception, IRENA has acknowledged the exceptional status of islands and placed a special focus on assisting these communities. The opening declaration of the Agency's Statute specifically notes the "...the huge potential of renewable energy in providing... access to energy for isolated and remote regions and islands"[20]. Statute Article IV, which defines the activities that IRENA will engage in to support the uptake of renewables, mandates that the Agency bears "...in mind the special needs of the developing countries, and remote and isolated regions and islands"[21].

One of the first activities of IRENA following its official launch in April of 2011 was a workshop on "Accelerated Renewable Energy Development with Emphasis on Pacific Islands". This workshop took place in Sydney, Australia from the 26th to 28th of October 2011 and brought together key policy makers from numerous PICTs. Discussions focused on identifying key technical, policy, economic and social barriers to the deployment of renewable energy and developing an understanding of how IRENA can assist the PICTs in overcoming these challenges. IRENA organised a Pacific Leaders Meeting in January 2012 in Abu Dhabi[22], UAE, which brought together 11 PICTs, which agreed to support and cooperate in the implementation of the proposed IRENA activities for the Pacific region including an RRA for Kiribati; capacity-building initiatives; strategic planning for regional RE deployment; and increased collaboration with existing regional organisations and key stakeholders such as the SPC and the PPA.

8.1 Country studies

IRENA has carried out 15 specific studies on identifying the key concepts, challenges and best practices needed to increase RE uptake in the following PICTs: Cook Islands, Federated States of Micronesia, Republic of Fiji, Kiribati, Republic of the Marshall Islands, Republic of Nauru, Niue, Republic of Palau, Papua New Guinea, Samoa, Solomon Islands, Kingdom of Tonga, Tokelau, Tuvalu and the Republic of Vanuatu. The studies could support various national and regional initiatives by providing baseline information and understanding for a framework to assist the PICTs in developing their national RE roadmaps or strategies, and to identify integrated and cost-effective pathways for accelerating the transition to a secure and sustainable RE supply. The reports highlight best practices and lessons from the transition to RE in some PICTs that could benefit other islands and regions. The key messages arising from the studies are:

(i) Although the Pacific islands region is varied in terms of its RE resources distribution, solar photovoltaic (PV), bioenergy and, to a lesser extent, wind energy are the RE technologies with the greatest technical and economic potential for near-term deployment in the region.

(ii) An integrated approach that promotes a balanced implementation with strong emphasis on both RE and energy efficiency, and incorporates, among other measures, a detailed resource assessment, land availability, grid assessment, energy storage and capacity development, is required to arrive at the most optimal solution in terms of feasibility, cost, social acceptance and phasing.

(iii) Due to the variability of solar PV and wind power, their integration into diesel generator based power requires the use of a variety of enabling technologies.

(iv) The spatial constraints of islands requires that for successful large-scale deployment of RE, the energy, water and land-use nexus must be assessed carefully with stakeholder involvement in the planning process.

(v) The current dominance of public and development assistance financing for RE projects in the developing economies of the Pacific islands region limits the opportunities to enhance investor confidence through demonstration of the commercial attractiveness of existing projects.

(vi) For the larger PICTs where there is potential for return on investment, private sector investments supported by an enabling regulatory environment, as well as incentives, are needed to facilitate an increased share of RE in the energy mix of island communities.

(vii) Islands need to improve their working together – for example on common legal tools, training and regulations – in order to create economies

20 IRENA Statute, Opening Declaration, Page 2

21 IRENA Statute, Article IV Activities, Page 7

22 The summary and proceedings of the Abu Dhabi Pacific Leaders Meeting are available at: www.irena.org/News/Description.aspx?NType=NWS&PriMenuID=16&catid=84&mnu=cat&News_ID=168

of scale, in achieving a high share of RE whilst reducing high dependence on volatile and expensive fossil fuels for power generation.

(viii) In the medium-and long-term RE-based power solutions would be the most sustainable and cost-effective solutions for Pacific Islands communities. In the transition to this state RE and diesel hybrid systems with high levels of RE integration and energy efficiency measures will play a key role in the energy supply for island communities and are, indeed, a viable option for the PICTs.

(ix) The “many partners, one team” approach needs to be put into practice through increased coordination between development partners, donors, regional institutions and national authorities and institution.

(x) RE based transport options (such as electric cars and sustainable biofuels) can directly and positively impact island power generation systems. As such an RE based transport system should be an important consideration in the long-term planning of the PICTs.

IRENA has strengthened its engagement with the Pacific region since 2011, in close collaboration with existing regional organisations and key stakeholders, achieving further progress in the following key areas:

8.2 Assessment of grid stability

In the transition to renewable energy to achieve a more sustainable and secure energy future in the Pacific, the issue of grid stability becomes critically important as a higher share of variable renewable energy sources are integrated to the existing grid systems. When the inputs to grids vary, the resulting variation in frequency and voltage may affect the power quality, even resulting in blackouts. To better understand how much the island grids can absorb renewable energy without affecting power quality, it is critical to simulate the behaviour of frequency and voltage variability and to identify the threshold point where the variability starts to affect the efficiency of diesel engines, thus requiring additional power control systems and mechanism. The power sector and policy makers therefore need to understand well the threshold to which a grid can sustain the penetration of such variable renewable energy without affecting the power quality. The issue of grid stability is particularly critical in islands where the grids are small and vulnerable to variable power inputs. Integrating high shares of renewable energy into island grids is one of the critical challenges in the Pacific region. The operation of grids with high shares of variable renewables and the transition to such island power systems operation require careful analysis, planning and design.

IRENA, in collaboration with the PPA, convened its first workshop on the subject in July 2012 at the margin of the PPA 21st Annual Conference in Port Vila, Vanuatu. Over 35 experts and Pacific utilities gathered to discuss ways to introduce higher shares of variable renewables, such as solar and wind, into island grids while retaining grid stability. The workshop involved presentations of case studies and discussions on RE integration challenges in the Pacific islands, storage systems for integration, and grid assessments and modelling. Participants recommended that IRENA and other stakeholders in the region continue to support the utilities in the PICTs in their efforts to acquire the capability and technical confidence in energy planning and grid operation to integrate an increasing share of renewable energy. Further information and details of this event are available at: *www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=200.*

Following the above request for support, IRENA carried out a modelling study for the Palau Utilities Corporation, followed by a workshop and training on grid stability for the northern Pacific utilities in April 2013. The second step of the study is to develop a standard methodology for assessing the dynamic effects of variable renewables on frequency and voltage of the grid system, and development of technical and operating solutions to deal with such effects. Data have been collected for various technical options such as inverters, fly wheels and batteries that can be deployed to enhance system performance. The next step will be to work with PICTs members and other development partners to develop capacity for dynamic modelling of specific islands’ grids to assess future system performance with new grid components and rising shares of variable renewables. This work is being done in cooperation with PPA. In this context IRENA has a currently has support programme for 10 grid stability studies in the PICTs to 2015. The strategies and solutions provided will have to be tailor-made for each PICT as the renewable energy resources, energy generation equipment and infrastructure vary from country to country in the region. Further information and details of the Palau training and workshop are available at: *www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=325.*

8.3 Hybrid power systems

The use of diesel generators to power small and isolated electricity grids is especially prevalent in the PICTs region. As such, hybrid RE-diesel systems will be needed in the transition period to a renewable energy-based power system. Such systems use a wide variety of enabling technologies to overcome the difficulties associated with RE resource variability and allow RE generation to be smoothly integrated into diesel power systems. The IRENA study on hybrid power systems for the Pacific, focussed on identifying the key concepts, challenges and best practices strategies to prevent low generator loading (as low as 30% of rated capacity), thus allowing higher levels of variable RE onto the grid in the Pacific islands context, demonstrated with a case study of the Tongatapu diesel and solar PV hybrid power system in Tonga. The study also compiled a database that covers the make, model, age and specifications of all diesel generators in the region. The hybrid power systems for the Pacific report is available in the USB disk accompanying this report as well as on the IRENA publications website at *www.irena.org/Publications.*

8.4 Electricity storage and renewables for island power

In 2012 IRENA completed a comprehensive study on electricity storage options for islands. The report for this work was launched at the High-Level Ministerial Conference in Barbados on SE4ALLin SIDS. The report analysed the role that electricity storage can offer in meeting the challenges of variable electricity demand and supply, associated with renewable energy, and assessed smaller systems suitable for use with islands and remote electricity systems. IRENA's work on grids and Storage will be further refined and expanded to two separate roadmaps, one focusing on transmission and distribution and the other on various types of electricity storage technologies. The 2012 report on electricity storage options for island power is available at the IRENA publications website at *www.irena.org/Publications.*

8.5 Ocean energy

Ocean energy technology is one of the emerging technologies with the potential to become substantive in the renewable energy sector, particularly in niche locations such as islands and coastal areas. The various types of ocean energy include wave, tidal, marine current, salinity gradient, and ocean thermal gradient energy. Unlike some other renewable energy sources, such as wind and solar power, ocean energy is less variable. However, it is still in the early development and demonstration phases with very few at the deployment stage. Patents play a key role in the development and deployment of ocean energy technologies and so patent information is useful for policy makers seeking to promote innovation in ocean energy technology deployment as well as technology developers and private sector investors. IRENA is carrying out studies that include technology briefs on ocean energy technologies, starting with Ocean Thermal Energy Conversion (OTEC), wave, tidal and salinity gradient. These technology briefs are being supplemented with a study to support policy makers and investors in assessing the potential investment and strategic development of ocean energy technologies. The study will provide accurate and up-to-date information on current development trends and market status of ocean energy technologies and will assess the opportunities and barriers against the promotion and deployment of ocean energy technologies and possible solutions to overcome those barriers.

8.6 REMAP 2030: Assisting energy planning in island roadmaps

IRENA's REMAP 2030 is the global framework for promoting a doubling of the share of renewables in the global energy mix by 2030 as one of three inter-related objectives the UN SE4ALLinitiative. IRENA can assist its PICTs members with energy planning for their nation RE roadmaps as part of the REMAP project. IRENA is involved in the Tonga Energy Roadmap (TERM) and, together with GIZ and the SPC, is assisting Nauru in the development of its energy roadmap. The IRENA REMAP report can be downloaded free from *www.irena.org/Publications.*

8.7 Renewables Readiness Assessment

In order to assess how a country can increase readiness and overcome the main barriers to the deployment of RE technologies, the RRA was conducted in Kiribati jointly by the Ministry of Public Works and Utilities of Kiribati and IRENA as a case study in the Pacific. A workshop on the RRA was held in October 2012. More information on the RRA is available on IRENA publications website. As a result of the RRA Kiribati five concrete actions needed to enable the development and scale-up of renewable energy in Kiribati have been identified; their successful implementation would lead to the need for a long-term roadmap through which the goal of being energy independent could be realised in Kiribati. IRENA's RRAs can be downloaded free from *www.irena.org/Publications.*

8.8 Establishment of the IRENA Global Renewable Energy Islands Network (GREIN)

With the aim of pooling knowledge and exchanging ideas and experiences between islands, IRENA's GREIN was established in January 2013, in line with the Malta Communiqué on Accelerating RE Uptake for Islands; issued following the meeting of Ministers and other participants from 48 countries that gathered in St. Julian's, Malta on 6-7 September 2012. The communiqué called on IRENA to establish a 'Global Renewable Energy Islands Network' (GREIN) as a platform for pooling knowledge, sharing best practices, and seeking innovative solutions for accelerated uptake of clean and cost-effective RE technologies on islands. Under the GREIN, island nations and countries with islands are invited to join various interest clusters that would support their transition to renewables, one of which aims at the development of national roadmaps.

The most popular GREIN clusters so far – grid integration and technology roadmaps – were launched at the margin of the Auckland summit in March 2013. A number of pacific island countries have registered in these clusters and they participated in the Auckland event. The cluster leaders were elected and immediate actions for the clusters were agreed. Further information on the launch of GREIN at the Auckland Summit is available at: *http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=326.*

8.9 Capacity-building initiative

IRENA is embarking on a capacity-building initiative to improve the enabling environment conducive for IPPs participation in the renewable power sector. The initiative targets policy makers, utilities and regulators, and aims to enhance their capacities to develop the necessary legal and regulatory frameworks, and financial, technical, and market conditions. The initiative also includes a component that targets higher education institutions.

A survey is currently being conducted to investigate the needed renewable energy skills particularly in relation to private sector engagement and suggest how the higher education sector could meet this demand. Discussions are underway with University of the South Pacific, PPA, SEIAPI and the VOCTEC program for strengthening and extending the existing programs to certification that meets industry standards. IRENA is also developing capacity in the region for harmonised installation of grid-connected solar PV systems through training workshops and dissemination of guidelines

8.10 IRENA Global Atlas

IRENA is leading the development of a Global Atlas for Solar and Wind Energy project which aims to assist planners by identifying the resource potentials of solar and wind resources, especially in areas where existing data is insufficient. This tool will be extended to other resources and will support decision-making for renewable energy deployment at global, regional and national levels.

8.11 IRENA renewable energy country profiles for the Pacific

In 2012 IRENA completed its renewable energy country profiles for the Pacific. These profiles evaluate the latest developments in the field of renewables at country and global levels. Each profile combines IRENA's analyses with the latest available country data and additional information from a variety of sources, including member states. The resulting reports provide a brief but comprehensive picture of the situation with regards to renewable energy, including energy supply, electrical generation and grid capacity, and energy access. Energy policies, targets and projects are also considered, along with each country's investment climate and endowment with renewable energy resources. Through this roadmap support framework, IRENA aims to continue to support its member states in the PICTs with timely and value-added data for policy support for enhanced deployment of renewables in the region. The Pacific country renewable energy profiles are available for download at *www.irena.org/Publications.*

8.12 Policy challenges for renewable energy deployment in the Pacific Islands

Many countries have introduced targets and plans to promote RE deployment. However, policy design and implementation often lags behind. This is particularly the case in the PICTs. IRENA has carried out a study on RE policy making in the Pacific SIDS aimed at promoting measures that can support the successful deployment of RE policies through systematic identification of the existing challenges and opportunities, and recommendations to policy makers on designing and implementing RE policies.

8.13 Harmonisation of RE standards

IRENA work on standardisation of RE includes the pacific region and the aim of this work is to ensure appropriate and effective integration of RE into national grids through harmonised standards. In collaboration with PPA, SPC North REP and SEIAPI, IRENA supports the roll out of RE standards for on/off grid solar installations in the region. In April 2013, the first workshop and training on standards was convened at Palau for policy makers and engineers of the Northern pacific utilities. The workshop for the Southern Pacific Utilities is scheduled for the second half of 2013. Further information and a summary report on the workshop are available at: *http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=325.*

8.14 Assessment of RE technologies suitable for the Pacific

In order to deploy RE technologies that are suited to the conditions of the Pacific, information on possible technology solutions has been collected and analysed. They include electricity storage options for islands, desalination powered by renewable energy, small wind power, and wave power.

An integrated resource management approach for energy, land use, and water resources nexus is crucial to improve energy, water and food security in the PICTs which are vulnerable to resource scarcity. A case study has been developed for the Kiribati main island of Tarawa. The modelling suggests that water supply from desalination may need to be expanded significantly, which can result in a substantial increase in electricity demand for the island. The potential for coconut oil use in diesel generators has been assessed. The analysis suggests that a partial substitution of diesel would be feasible, but land and low coconut tree yields limit the expansion of this option. Based on these findings the study suggests alternative renewable energy pathways to deal with resource scarcity. Similar assessments of resource potentials and technologies are given in the individual IRENA reports for each of 15 PICTs studied as part of this roadmap support document and are available in the USB disk accompanying this report as well as on the IRENA publications website at *www.irena.org/Publications.*

8.15 Assessment of the use of more renewable energy in the transportation sector

The major share of fossil fuels in the Pacific is used in the transportation sector. Assessment of the possible RE technology applications for shipping and land transport in the region has started by reviewing recent technology developments in other parts of the world. The lack of detailed accurate oil product statistics in the region acts as a major barrier to the development of an informed strategy for the increased use of renewables for transportation in the region. Discussions are ongoing with a number of development partners on how the statistical data can be improved.

8.16 IRENA Abu Dhabi Fund for Development project facility

Mobilising finance is one of the greatest challenges for scaling up the use of renewable energy in developing countries. The United Arab Emirates has offered a commitment from the Abu Dhabi Fund for Development (ADFD) of up to USD 350 million to support financing of renewable energy projects in developing countries endorsed by IRENA. The IRENA/ADFD project facility is currently evaluating projects from various countries, including countries in the Pacific Islands region, for the first round of funding from the fund. For further information, please see: *http://irena.org/adfd/*

9. Conclusion: Key priority actions for enhanced renewable energy deployment in the Pacific Islands and possible IRENA roles

Drawn from the above assessments, the 16 separate supporting studies (published as 15 PICTs country reports and a report on RE-diesel hybrid power systems for the PICTs), there are some key priority actions which the Pacific islands region as a whole and individually are encouraged to consider for achieving energy security through the accelerated deployment of RE. The regional approach is critical for pooling resources and engaging with stakeholders together in a coordinated manner; the national approach is important for ownership, leadership and resources allocation and monitoring of the implementation of a RE roadmap action plan. The RE resource potential varies across the PICTs. Therefore national and even island specific roadmaps or strategies are needed, noting that a roadmap or strategy developed without involvement of all key stakeholders and not accompanied by a realistic and resourced action plan for implementation risks failure.

The PICTs have the FAESP priorities to take into account when planning their own national energy strategies or energy roadmaps and action plans. Aligning with the current regional energy vision, FAESP, and the various national targets and policies, the following key recommendations for action are encouraged:

- Strengthen institutional frameworks in the energy sector: In many cases renewables transition planning takes place outside the group of energy ministries and utilities. Such an approach should be avoided as it reduces the chances of success significantly.
- The cooperation between the PPA, SPC and University of the South Pacific should be strengthened to develop a critical mass for the Pacific islands transition planning.
- Strengthen strategic energy planning, combining renewable energy deployment with energy efficiency promotion and implementation.
- Strengthen policy and regulatory frameworks as the essential enabler for enhanced RE deployment.
- Strengthen the collection and management of energy data. This will assist in the development of robust energy information, notably for the transport sector.
- Assess the cost of RE solutions for island communities and provide information on technology availability and options.
- Assess and monitor RE resource potentials. The RE potential varies widely across PICTs, thereby necessitating the need for regional and island-specific RE strategies.
- Assess grid stability for high shares of RE integration. It will be important to consider careful design and deployment of hybrid diesel–renewable systems with high shares of renewable in the immediate term. This requires modelling and assessment of grids for different levels of RE penetration, supported by a step by step approach to realise the transition to renewables.
- Harmonise technical standards for implementation of RE technologies: This should facilitate effective system operation with reduced failure of components. With most RE projects in the PICTs arising from development assistance there a wide range of RE equipment of different makes being installed. This complicates operation and maintenance greatly. SIDS-DOCK[23] could help to overcome such problems provided funds are truly managed as a programme and not cut into many small projects with different decision makers.
- Undertake capacity development for RE at various levels from education to policy makers.
- Coordinate various RE projects and financing. This and a database of best practice cases for sharing of knowledge should facilitate an efficient and uniform strategy for successful RE deployment in the region.

*23 A mechanism to connect the energy sector in **SIDS** with the global market for finance, sustainable energy technologies and with the European Union (EU) and the United States (US) carbon markets, and able to trade the avoided carbon emissions in those markets.*

- Develop bankable renewable projects. The quality of project proposals needs to be improved across the region. The IRENA project navigator can help towards bankability of project proposals. The fact that virtually all renewable power projects are funded from grants or soft loans endangers sustainability and is detrimental for the development of the RE sector. For renewables projects, more so than for diesel generators, it is critical that projects include a sustainable business model where investment cost are readily recuperated. This is particularly so if productive uses energy are prioritized in such models.

The above priority actions are summarised in Table 10 with indicative key players and possible roles for IRENA in supporting PICTs members in their efforts to develop roadmaps or strategies and the accompanying action plans for increasing the share of renewables in their energy mix in the transition to a renewables-based energy future for sustainable economic prosperity.

IRENA's work on islands has expanded as of early 2013 to other island regions, with the aim of accelerating the

Table 10: Indicative roles for IRENA in the development of national RE roadmaps and action plans for the PICTs

Key Action Plans	Indicative Key Players	Role of IRENA	Timeline
Strengthen institutional frameworks in the energy sector	• SPC • Country policy makers	Capacity Building	Medium term
Strengthen strategic energy planning	• SPC • Country policy makers	Scenario modelling	Immediate to medium term
Strengthen policy and regulatory frameworks	• SPC • Country policy makers	Policy advise	Immediate to medium term
Strengthen the collection and management of energy data	• SPC • Country policy makers • PPA	Costing Alliance; REDAF	Immediate to medium term
Assess and monitor renewable energy resource potentials	• SPC • Country policy makers	Global Atlas	Immediate to long term
Assess grid stability for high shares of RE integration	• Island utilities • PPA	Development of capacity for dynamic modelling of grid stability	Immediate to long term
Harmonise technical standards for implementation of RE technologies	• Island utilities • Country policy makers • PPA • SPC • SEIAPI	Harmonisation of RE standards and certification systems for national and regional deployment of RE	Immediate to long term
Undertake capacity development for renewable energy at various levels	• Country policy makers • University of South Pacific • SPC	Country support and capacity building	Long-term
Coordinate various RE projects and financing	• Country policy makers • SPC • Development partners	IRENA/ADFD Project Facility	Immediate to long term
Develop bankable renewable projects	• Country policy makers • Private sector investors	Project Navigator	Immediate to medium term

effectiveness of the transition to renewable-based energy systems for such communities. However, the agency continues its work on Pacific Islands Countries and Territories in response to requests from its members. To this effect, in 2013 IRENA is extending its work on grid stability to cover 15 countries to 2015. The agency will also be focussing on other grid related technologies and enablers for increased shares of renewables in the Pacific Islands region, including extension of our previous work on storage options for island power. Ocean energy technologies provide a potential opportunity of high impact in the deployment of renewables in island regions. The technologies are still in the development and early deployment stages. IRENA is working on evaluating the status of these technologies and their market outlook for deployment in the context of remote islands, particularly with regards to ocean thermal energy conversion (OTEC) for power generation, cooling and heating. In the subsequent work programmes, IRENA will continue to work on areas of relevance and interest to countries in the region as they mobilise efforts towards achieving their various renewable energy targets.

It is hoped that the IRENA *Pacific Lighthouses* series of reports will serve as a basis for better understanding of current energy conditions in the Pacific Islands region and to facilitate the continued assessment of the challenges and opportunities for the deployment of renewable energy in island environments. Therefore, the reports constitute an IRENA input for the Third International Conference on Small Island Developing States to be held in Samoa, 1–4 September 2014.

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In the preparation of this report, primary sources were used where possible. Some were obtained through written questionnaires, some through interviews and some through email correspondence. For data which primary sources were not available, the following secondary and tertiary sources were checked with each source typically providing useful part of the overall picture.

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