Chapter 1
An Overview of Climate-Smart Technologies in the Pacific Region

Pritika Bijay, Veronika Schulte and Shivneel Prasad

Abstract The Pacific Island Countries (PICs) are especially vulnerable to problems associated with climate change (CC), which is considered as one of the greatest risks to the people of the PICs. This poses a threat to the livelihoods, security and welfare of the people in the Pacific. PICs are considered to be one of the lowest contributors of factors contributing to climate change, yet they are the most vulnerable to the impacts of CC. Therefore, it becomes extremely important that PICs develop ways to adapt to and address the impacts of CC with climate intelligent technologies. Renewable energy (RE) has a large potential to displace emissions of greenhouse gases resulting from the burning of fossil fuels, and thereby to mitigate climate change. This paper gives an overview of climate intelligent technologies in the Pacific, and it goes into detail with some concrete examples. Although it is believed climate intelligent technologies cannot solve all the climate problems of PICs, it can help them to achieve a certain level of economic and social development that will be very beneficial for the Pacific. The present paper is based on the experiences gained by the "Small Developing Island Renewable Energy Knowledge and Technology Transfer Network (DIREKT)", which is a cooperation scheme involving universities from Germany, Fiji, Mauritius, Barbados, and Trinidad and Tobago. The aim of this project is to

P. Bijay (✉)
School of Engineering and Physics, The University of the South Pacific, Faculty of Science, Technology and Environment, Laucala Campus, Suva, Fiji
e-mail: pritika_m@usp.ac.fj

V. Schulte
Research and Transfer Centre "Applications of Life Sciences", Hamburg University of Applied Sciences, Faculty of Life Sciences, Lohbruegger Kirchstraße 65, Sector 4S, Room 0.33 21033 Hamburg, Germany
e-mail: veronika.schulte@haw-hamburg.de

S. Prasad
College of Foundation Studies, The University of the South Pacific, Faculty of Science, Technology and Environment, Laucala Campus, Suva, Fiji
e-mail: prasad_sv@usp.ac.fj

W. Leal Filho et al. (eds.), *Climate-Smart Technologies*,
Climate Change Management, DOI: 10.1007/978-3-642-37753-2_1,

strengthen science and technology capacity in the field of RE of a sample of African, Caribbean and Pacific (ACP) small island developing states, by means of technology transfer, information exchange and networking. The project is funded by the ACP Science and Technology Programme, an EU programme for cooperation between the European Union and the ACP region.

Keywords Pacific island countries · Climate change · Climate intelligent technologies · Renewable energy

Short Introduction

Climate change (CC) has been identified as one of the greatest challenges faced by any nation, including the Pacific Island Countries (PICs). Threats associated with CC have lead to many nations looking for ways to reduce their impact. Although PICs are considered one the lowest contributors of CC, they are currently heavily reliant on fossil fuels to meet their energy demand (IPCC 2007 and Prasad 2009). Together with this, the diverse geographical nature of the PICs makes it difficult and expensive to transport fuel and other basic necessities (SPC 2011).

To increase their energy security, and at the same time lower their greenhouse gas (GHG) emissions, the PICS are increasing the share of Renewable Energy (RE) in their energy mix. Furthermore, for PICs with not many RE resources, energy efficiency (EE) measures are a solution. Both of these become synonymous with a reduction in GHG emissions, and an important tool for CC mitigation.

Climate Change and the Pacific Island Countries

Despite their diverse physical and socioeconomic features, the PICs share many common issues, with one major issue being how to face the challenges of CC. PICs face devastating and urgent consequences from sea level rise, to more frequent and stronger storms, to the changing distribution of disease vectors. The PICs account for less than 0.1 % of global GHG emissions, due primarily to their relatively small population, limited industrial activity, and underdeveloped energy services (ADB 2010), yet the consequences of CC are obviously inconsistent with their contributions to GHG emissions globally.

CC poses a threat to the livelihoods, security and welfare of the people of the Pacific. The Pacific Island Forum Leaders have stated that if the issue of CC is not immediately and successfully addressed, its impacts will result in severe damage, undermine security and undo progress towards the achievement of national priorities and the Millennium Development Goals (MDGs) in the Pacific. Many countries worldwide are developing and implementing initiatives in order to limit and mitigate GHGs' concentration in the Earth's atmosphere. Concerns for sustainable development, with emphasis on mitigating CC, have lead to concentration on RE and EE. RE sources are not only abundantly available resources, but also provide energy without the emission of GHGs. Similarly, the use of more energy efficient appliances also lowers the emissions of GHGs. Therefore, RE and EE play an important role as tool for CC mitigation.

RE plays an important role in providing energy in a sustainable manner, such as from resources occurring naturally in the environment, and can be replenished in a short period of time. Some examples of RE include, solar, wind, hydro, geothermal, biomass, ocean and hybrid power. On the other hand, EE refers to using less energy to achieve the same task. An example of EE would include using energy-saver lamps (compact fluorescent lamp) instead of incandescent lamps.

CC results from activities such as the burning of fossil fuels, deforestation, industrial activities and any other activities which results in the release of GHGs into the atmosphere. The World Bank warns (WB 2000) that the impacts of CC in PICs are likely to result in a decline in ground water quantity and quality, reductions in agricultural output, significant health impacts (such as increased diarrhoea, dengue fever and fish poisoning), extensive damage due to storm surges and lowered fish production. According to a report prepared by Wade et al. (2005), the Federated States of Micronesia (FSM), Kiribati, the Marshall Islands, Tokelau and Tuvalu are among the countries predicted to endure the greatest impact of CC—including the disappearance of some islands in the worst-case scenario.

Therefore, if PICs are to lower their GHG emissions, adopting RE and EE measures is one option. In a worldwide context, emissions from the PICs are remarkably low, but, on a per-capita basis, many of the PICs are significant emitters (Wade et al. 2005). Hence, as the World Bank (WB 2000) has stated, the future well-being of the Pacific Island people is dependent on choosing a development path that decreases the islands' vulnerability to climate events and maintains the quality of the social and physical environment.

Current and Future Energy Scenarios in the Pacific

The PICs are heavily reliant on fossil fuels to meet their energy demands, even though great potential exists for them in the form of RE (Jafar 2000; Marconnet 2007). Currently, more than 90 % of the PICs' energy demand sare met by the use of fossil fuels alone, with the lowest energy security of a month to be found in the Cook Islands (Oberender 2010). Diversifying their energy needs is the only way for the PICs to improve their energy security at the same time as lowering their carbon footprint. Approximately 25 % of fossil fuel imports in the PICS are used for power generation, with the other 75 % used for transportation (air, water and land) (Gielen 2012). PICs are starting to realise the true potential of RE to meet their energy demands, with Fiji and Samoa leading the way (Marconnet 2007).

In 2009, 99 % of the Cook Islands' energy demands were met by the use of fossil fuels alone, consisting of 12.7 million litres of diesel (7.2 million litres for electricity generation alone), 4.2 million litres of petrol and 9.7 L of kerosene. A minority of 0.03 % of energy demand was met by renewable, a PV and grid connected wind system (40 kW) on Mangaia plus some Solar Home Systems (SHS) on Pukapuka (SPC 2012a).

Nauru's energy demands in 2009 were mostly met by fossil fuels, accounting for a massive 99.95 %. The imported petroleum mix consisted of 11.7 million litres of diesel and 2.2 million litres of petrol. In addition to that, 9.45 t of liquid petroleum gas (LPG) were imported for household cooking, while there was a minute use of biomass. In 2009, 17 GWh of electricity were generated in Nauru, of which only 0.3 % (accounting for only 0.05 % of total energy demand) was accounted for by renewables; this was supplied by a 40 kW grid connected PV system at Nauru College (SPC 2012b).

Similar to Nauru and the Cooks, Niue's energy demands in 2009 were mostly met by the use of fossil fuels (estimated at 99 %) (SPC 2012d). Of this 99 %, 1.2 million litres was diesel (60 % used for electricity generation), 532,000 L was petrol and 25.8 t was LPG. Prior to 2008, cooking and water heating accounted for the majority of electricity consumption, which was greatly reduced by the introduction of solar hot water systems and LPG stoves, an initiative of the REP-5 Programme. Approximately 0.3 % of Niue's energy consumption is met by renewables. The renewable portion of energy production is mainly met by three grid connected systems (52.5 kW) installed as an initiative of REP-5 Programme.

Approximately 91 % of Fiji's energy demand is being met by a net import of 259 million litres of diesel, 58 million litres of petrol, 191 million litres of kerosene and 16 kt of LPG. The transport sector accounts for the most major use of fossil fuel imports, accounting for approximately 70 % of the energy demand (SPC 2012c). The electricity sector mostly met its energy demands using hydro, which accounted for approximately 55 % of electricity generation in 2011, with a contribution of 1 % by wind and 4 % by independent power generators respectively (FEA 2012). The rest was met by diesel, which accounts for the 30 % of total energy demands. Unfortunately, only 72 % have access to grid connected electricity, while the rest are provided power by the Public Works Department and Fiji Department of Energy's rural electrification units. This is achieved by the installation of diesel and microhydro in-grid systems, and SHS.

In Kiribati, petroleum products met approximately 75 % of energy demands, with 25 % being met by biomass and an insignificant amount, of less than 1 %, being met by solar (Mala 2008). Similarly, the Federated States of Micronesia (FSM) meet their energy demands with approximately 85 % petroleum, 14 % solar and less than 1 % solar (Wade et al. 2005). Energy demands in Samoa consisted of 70 % for transport, 20 % for power and the remaining 10 % in the commercial, agriculture, forestry and fishery, and residential sectors. In 2009, this electricity generation consisted of 58 % diesel, 41 % hydro, 1 % biofuel and about 0.01 % solar (Energy Unit 2010). Tonga meets 75 % of energy demands with fossil fuels, with the significant amount of 25 % from biomass and off-grid solar.

Before the opening of the grid connected PV system in Tonga, almost 100 % of Tonga's electricity generation was from fossil fuels alone (TERM 2010). Data for rest of the countries are limited; however, reports compiled as part of the Pacific Islands Renewable Energy Project in 2004 indicate that PICs are heavily reliant on fossil fuels to meet their energy demands (Wade et al. 2005).

PICs mostly utilise RE for electricity generation and, as such, to move towards a more energy secure future. Targets have been set to increase RE contribution to electricity generation in the near future (Table 1.1). Targets range from a low of 20 % to a maximum of 100 % to be met by the PICs by 2020.

Renewable Energy Technologies in the Pacific

RE technologies, such as solar, wind or hydropower, have the potential to reduce emissions. Most of the PICs possess RE resources in abundance as seen in Table 1.2.

The main RE sources of interest to the Pacific are solar water heating, solar PV, hydro, wind, biomass, and biofuel (Syngellakis 2012). Other sources that are also possible are biogas (not proven in PICs), geothermal (remote and very capital intensive) and hybrid. Wave and ocean energy could also be possible in some of the countries, although they are currently at the experimental stages of development.

Table 1.1 Current and projected targets for RE electricity generation by PICs (*Source* Gielen 2012)

Countries, territories and associated sates	RE electricity generation (% of Total)	RE targets % of Total	RE targets years
Cook Islands	<1	50	2015
		100	2020
Fiji	75	90	2015
FSM		Urban 10 and Rural 50	2020
Kiribati	<1	10	ND
Marshall Islands	1	20	2020
Nauru	< 1	50	2015
Niue	3	100	2020
Palau	3	20	2020
PNG	46	No target set	
Samoa	42	+20	2030
Solomon Islands		50	2015
Tokelau	1	100	2012
Tonga	<1	50	2012
Tuvalu	25	100	2020
Vanuatu	19	25	2012

Table 1.2 Resource potential in the PICs (Johnston 1995)

Country	Solar	Wind	Biomass	Hydro	Geothermal	OTEC	Wave
Cook Islands	✓✓✓	✓✓	✓✓			✓✓	✓
Fiji	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓
FSM	✓✓	✓	✓✓	✓✓	✓✓	?	?
Kiribati	✓✓✓	unlikely	✓			✓✓	?
Marshall Islands	✓✓✓	✓	✓			✓✓	?
Nauru	✓✓✓	unlikely	✓			✓✓	?
Niue	✓✓✓	✓✓	✓			?	?
Palau	✓✓✓	✓	✓✓			?	?
PNG	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	?	?
Samoa	✓✓	✓✓	✓✓	✓✓	✓✓	?	?
Solomon Islands	✓✓	✓✓	✓✓✓	✓✓✓	✓	?	?
Tonga	✓✓✓	✓✓	✓			?	✓✓
Tuvalu	✓✓	unlikely	✓✓			?	?
Vanuatu	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	?	?

Hydro

Hydropower is an RE source, where the power is derived from water sources. This technology has the best conversion efficiency of all energy sources, while also being a proven, mature, predictable, as well as typically price-competitive, technology (Kumar et al. 2011). In the PICs, hydropower has also proved to be one of the best sources of energy, especially in the high islands. Hydropower is the main source of electricity generation in Fiji, while in French Polynesia, New Caledonia, Papua New Guinea (PNG), Samoa, the Solomon Islands and Vanuatu, it is the second largest source (Marconnet 2007). Details of some of the hydropower schemes are provided below, and have been adapted from Wade et al. (2005).

- PNG's power utility commissioned 162 MW of hydro at eleven locations between 1957 and 1989. A 63 MW system was installed in Port Moresby, 87 MW in Ramu in the highlands and 12 MW in New Britain. Altogether, there is about 220 MW of installed capacity. The government also commissioned three micro-hydro systems between 1988 and 1992 with a capacity of 300, 60, and 100 kW.
- The Fiji Electricity Authority (FEA) commissioned an 80 MW hydro system in the interior of Viti Levu in 1983 and a 0.8 MW scheme at Wainikeu in Vanua Levu in 1992. Between 1930 and 1999, seven small hydropower stations (3–100 kW) were built. A 3 MW hydropower scheme also exists in Nagado in

Viti Levu and a 40 MW at Nadarivatu is expected to be commissioned by end of 2012 (FEA 2012).

- In Samoa, between 1959 and 1992, eight hydro systems have been built at five locations in Upolu, with a total capacity of 12.2 MW. All of these are run-of-river systems, except the largest system (Taelefaga with two 2 MW turbines).
- In the Solomon Islands a 185 kW scheme was built at Buala on Santa Isabel in 1996, which provides electricity to a hospital, a school, a store, fish storage and houses. In 1983 and 1994 two small (10–12 kW) microhydro schemes were constructed in Kolombangara in the Solomon Islands, at Iriri and Vavanga villages respectively, through an Australian development organisation, APACE. A 75 kW microhydro Pelton turbine was installed in 1976 serving a church mission and health centre at Atolifi on Malaita. Currently, there are also operational hydro systems at Manawai (50 kW), Bulelavata (29 kW) and 25 kW system at Raeao (JICA 2009).
- Vanuatu's only experience with hydropower has been the Sarakata system, consisting of two 300 kW turbines which have been used for baseload at Espiritu Santo island and produced on average about 4.5 GWh per year since early 1995.

There is also an existing 2.06 MW hydro facility, though limited to 1.8 MW due to intake restrictions, at Pohnpei in FSM (Wade et al. 2005). There is some potential for hydro in other PICs, although it is limited.

Wind

Wind power is the fastest growing RE technology globally, accounting for 40 % of new RE capacity last year (REN21 2012).Generation from wind is currently negligible due to the low installed capacity in the PICs; however, with proper assessment of wind potential and ability to harness the resource, more potential could be realised in the PICs (Singh 2012a). Electricity generation from wind is the basic conversion of the wind's kinetic energy into electrical energy using wind turbines. Wind resource assessments are currently being undertaken by governments and research organisations in the PICs. Out of all the countries in the PICs only the Cook Islands, Fiji, Vanuatu, New Caledonia, French Polynesia, Hawaii and PNG utilise wind for electricity generation (Marconnet 2007; Andrieu and Pesnel 2006).

Fiji's first wind farm in Butoni, as seen in Fig. 1.1, was commissioned in 2007, with an installed capacity of 10 MW. At the end of 2011 the Butoni wind farm had generated approximately 26.3 GWh of electricity, generating 4.98 GWh in 2011, accounting for fuel savings of approximately FJD 2.13 million (FEA 2012). With a predicted generation capacity of 50 GWh annually, seven wind farms are spread over four locations in Vanuatu, accounting for an installed capacity of more than 25 MW (Andrieu and Pesnel 2006). Approximately 80 kW of wind have been

Fig. 1.1 Butoni wind farm in Fiji

installed in PNG; however, in 2010 they were only used for trial purposes (Tai 2010). The Cook Islands have also had their first experience with wind generation, installing two 20 kW wind turbines; however, they failed due to mechanical failures (Zieroth 2006). A Danish study carried out indicated viability of wind with wind speeds ranging from 6–7.5 m s^{-1} at a hub height of 30 m; however, greater emphasis needs to be placed on operation and maintenance to make it work (SPC 2012a).

Viability of wind power at lower latitudes around the PICs is non-existent, with potential increasing for countries at higher latitudes (Wade et al. 2005), making smaller wind systems better for power generation, however, data need to be compiled properly to obtain the true potential of installed wind power in the PICs.

Solar

Solar energy is the main source of energy from which all other renewables are derived. The PICs' location, in regards to the equator, makes it possible to use solar energy in the form of solar thermal or for electricity generation via use of photovoltaic (PV) panels (Jafar 2000; Woodruff 2007).

Solar thermal is mostly used to heat water in the PICs and most of the technology is imported from abroad, with Fiji, Tonga and PNG having domestic small scale manufacturing (Wade et al. 2005). Due to the easy nature of installation and use, the uses of solar thermal installations are diverse, though they are mostly used in homes and hotels, or wherever hot water is required in large amounts, which would offset the installation costs (Miller et al. 2012).

On the power generation side, PV was a bit slow to develop in the PICs due to the initial high costs of installations. However, with costs going down and the rise in the prices of fossil fuels, some of the PICs have turned to PV for power generation, either using large grid-connected systems or small home systems (SHS).

SHS was the first to be initiated in the PICs, since grid power was unavailable to most of the islands. Several thousand homes have been provided with access to electricity for their basic needs using SHS since 1995 (Wade et al. 2005).

Kirbati had the most successful SHS scheme, with a total of more than 2000 SHSs installed (Akura 2004). There are various PV initiatives, as well as installed systems, around the PICs (www.sprep.org). These include the 500 plus SHSs in Tonga, with a total of 42 already installed, with a capacity of 160 W. In Tuvalu, two grid connected systems were in operation, 46 kW in Motufoua and 40 kW in Fongafale, which were able to save around 6,143 L of fuel. Also highlighted, was that schools and homes in the Solomons and Kiribati were using PV (SHS systems plus grid standalone) systems to meet their basic energy needs, such as lighting and water pumping, with more being installed in the second quarter of the year (www.sprep.org).

In Vanuatu, SHS systems have been funded by the Japan International Cooperation Agency (JICA), ranging from small systems of 40–100 W with battery storage of 70–100 Ah, enough to provide electricity need for 8 or 15 W lights respectively (Chow 2010). Chow (2010) also stated that there were many rural community institutions in Vanuatu that had standalone solar power systems ranging from 80 to 400 W, with the majority of the systems below 300 W.

The Electric Power Corporation in Samoa successfully installed a self-sufficient 13 kW PV power system on Aplomia Island, demonstrating the environmentally friendly standalone PV system (www.epc.ws). In Fiji, two grid connected systems have come online, the first in 2011, a 12 kW pilot project in Lautoka (Nanjangud 2012). The second is a 45 kW system, as seen in Fig. 1.2, commissioned in February 2012, constructed at the University of the South Pacific's lower campus. The systems have a dual purpose: to generate clean energy, and at the same time to serve as training ground for aspiring graduates.

Tonga has the PICs' largest grid connected PV system at a rated peak power of 1.3 MW, commissioned in July 2012. The system is predicted to meet at least 4 % of Tonga's energy demands at the same time avoiding CO_2 emissions of up to 2,000 t per year.

As part of the REP-5 programme, the FSM, Nauru, Niue, Palau and the Marshall Islands, have directly benefited by having grid connected and standalone PV systems installed at various sites to provide electricity to schools, hospitals and

Fig. 1.2 45 kW grid connected PV system in Fiji

airports, whilst at the same time providing smaller systems to homes to cater for their basic energy needs (REP-5 2010).

Tokelau is about to implement grid connected PV in September 2012 on three of its atolls Fakaofo, Nukunonu and Atafu. The system will boost Tokelau's RE capacity from almost nil to around 90 %, reducing their dependency on fossil fuels, as well as saving 12,000 t of CO_2 emissions over its lifetime (Pacnews 2012).

Geothermal

Geothermal resources consist of the thermal energy from the Earth's interior, stored in both rocks and trapped steam or liquid water (Arvizu et al. 2011). This energy can be used to generate electrical energy in a thermal power plant or in other domestic and agro-industrial applications requiring heat, as well as in CHP applications. PNG, Fiji, Samoa and Vanuatu have known geothermal resources, while the Solomon Islands probably also have geothermal resources. The only known operating geothermal plant in the Pacific is in PNG. Lihir Gold Mine in the West New Britain Province is powered with a 53 MW geothermal plant (JICA 2009).

Biomass

Traditional biomass has been in use in the PICs since ancient times and is still being used as fuel wood for cooking, heating and electricity generation, accounting for nearly half of energy consumption in the PICs (Jafar 2000). There are a few plants around the Pacific that use biomass for purposes of electricity generation and transportation. Biomass for power generation has been utilised in Fiji, PNG, the Solomon Islands and Samoa (Wade et al. 2005, and www.sprep.org). Fiji has around 16 MW of electricity generation capacity from bagasse by the Fiji Sugar Corporation during the sugar harvesting season. Tropik Woods Fiji also provides electricity by using wood chips as fuel to run steam generators. Biomass accounted for the largest RE contribution towards Samoa's energy production in 2010. Biomass accounted for 41.11 kt of oil out of the 44.74 kt of oil of RE consumption (Government of Samoa 2012). RE contribution in Vanuatu is mainly by biomass; however, potential for power generation by wood chips in saw mills does not appear to be promising, with most of the waste product from them being used as firewood or compost (Johnston and Vos 2004). Kiribati's main RE contributor is also biomass which accounted for 25 % of energy demands in 2005 (Mala 2008).

Biofuels are derived from biomass and can be used for electricity generation or transportation. Singh (2012b) and Woodruff (2007) highlighted that coconut oil and ethanol could be used to replace fossil fuel imports in Fiji. Experience with biofuels has been limited in the PICS. However, in the past decade, interest in using biofuels has been increasing with rural electrification projects showing the viability of using coconut oil as a fuel substitute for diesel (Woodruff 2007). Biofuels show potential in replacing fossil fuels in the transport sector, as well as in electricity generation.

Energy Efficiency

EE measures improve the use of natural resources and fossil fuels, thus reducing emissions and easing pressure on land resources. EE projects are being implemented by a wide variety of project proponents in the public, industrial and commercial sectors. Certain activities in the Pacific have been carried out to demonstrate EE.

The REP-5 (2010) programme, implemented by the Pacific Islands Forum Secretariat (PIFS) and funded from the 9th European Development Fund (EDF9) focuses on RE and demand-side EE activities. Through this project Nauru, Niue, the Republic of the Marshall Islands, the Federated States of Micronesia and Palau through were involved in conducting some EE activities. Amongst these activities included, conducting energy audits, distribution of compact fluorescent lamps, installation of lockboxes on thermostats and purchasing energy efficient materials for a building. Apart from this, EE awareness campaigns have been conducted, and, in some PICs, EE has been included in the National Energy Policy document. Some PICs, such as Fiji, are also ensuring that energy efficient white goods are being imported by following Minimum Energy Performance Standards and Labelling. Currently, refrigerators with star ratings are being brought into the country, and the Fiji Government is also developing this scheme for other appliances. PICs that do not have the necessary RE resources are still able to reduce their GHG emissions through EE measures.

Climate Change Mitigation Initiatives

CC mitigation efforts in the Pacific are being directed at reducing fossil fuel use, developing RE, improving EE and reducing GHG emissions. According to the International Energy Agency's (IEA) "BLUE" scenario, end-use efficiency accounts for 36–44 % of all reductions, and renewables account for 21 % (46 % of the electricity mix in 2,050) (United Nations 2010). This scenario is applicable globally, including in the Pacific, although it is one of the lowest contributors of climate change. Nevertheless, PICs are the most vulnerable to the impacts of climate change.

RE and EE have potential to reduce GHG emissions, and thus help PICs meet their commitments under the Kyoto Protocol and mitigate the effects of climate change. Reduction in the use of carbon based energy sources and reduced energy consumption in transport, construction, at home and at work will help prevent GHG concentrations in the atmosphere from reaching a dangerous level. Table 1.3 shows the potential GHG savings (ktons CO_2) for each RE resource in each PIC.

Currently, the Cook Islands, Fiji, Kiribati, Nauru, Niue, Papua New Guinea, Samoa, the Solomon Islands, Tonga, Tuvalu and Vanuatu are able to implement appropriate mitigation measures through RE activities under the Pacific Islands Greenhouse Gas Abatement through RE Project (PIGGAREP), extended to include Clean Development Mechanism (CDM) initiatives and EE as funds become available. The national assessments that were carried out under Wade et al. (2005) have identified Nauru, Niue, Palau, Samoa and Tuvalu as suitable for grid applications. Fiji, FSM, Kiribati, the Marshall Islands, PNG, the Solomon Islands and Vanuatu have shown large opportunities for both grid and off-grid applications. Tonga has potential for both on-grid and off-grid RE technology applications for rural electrification.

In order to mitigate GHG significantly, use of RE and efficient use of energy are absolutely necessary. For the Pacific, mitigating CC by using RE resources is possible, given the plentiful supply of some of these inexhaustible resources, like sunlight, wind, waves and the ocean etc. Similarly, incorporating EE measures can also help to mitigate climate change.

Table 1.3 GHG savings (kilo t of CO_2) for each RE resource in each PICs (*Source* Wade et al. 2005)

Country	Years	Geothermal	Hydro	Bio-diesel	Ethanol	Other biomass	Solar PV	Wind
Cook Islands	2013	0	0	2.6	0	0	2.1	6.3
Fiji	2010	43	818	4	27	17	1	19
FSM	2012	0	14.2	2.3	0	0	0.3	0
Kiribati	2013	0	0	20.8	0	0	3.7	
Marshall Islands	2013	0	0	7.6	0	0	0.4	0
Nauru	2013	0	0	0	0	0	2.8	0
Niue	2012	0	0	0	0	0	0.64	
Palau	2013	0	0	0	0	0	12	0
PNG	2011	333	691	113	430	Very small	9	10
Samoa	2013	12.8	40.2	27	0	0.3	2.5	1.1
Solomon Islands	2012	Low	31	75	0	2	3	1
Tokelau	2013	0	0	0.15				0
Tonga	2010	0	0	27	0	0	1.4	2.8
Tuvalu	2013	0	0	0.8				0
Vanuatu	2013	17	14	75.6	0	1	2	1

Conclusions

Despite being the lowest contributors of GHG, the PICs are the most vulnerable to CC. Thus, with the need to reduce emissions, the PICs need to play their part in either going green by implementing RE into their energy mix or becoming more energy efficient. The current energy scenario in the PICs indicates that they are heavily dependent on fossil fuels to meet their energy demand.

Thus, the PICs are making an effort, with the help of donor countries and other organisations, to incorporate RE into their energy mix. Some of the PICs are already showing great potential in incorporating RE into the generation of electricity. Hydro has shown great potential, with some of the PICs having it as the largest or second largest contributor to their electricity generation. Solar and wind have also shown great potential in terms of new RE in PICs, and solar is already growing steadily, with most countries having grid connected systems as well as SHSs installed to meet their electricity demands. Biomass has been widely utilised to meet energy demands, but mostly in the area of cooking or heating. Very little biomass has been used for power generation. Biofuels are also emerging to replace fossil fuels in the transport sector, as well as in power generation. A single geothermal power plant in PNG and well surveyed resources indicate good potential from geothermal, however, this needs to be further researched.

Apart from RE, EE has also helped in reducing GHG and the use of fossil fuels in the PICs. This has been achieved by trading less efficient appliances for efficient ones.

All of the above indicate that the use of RE and EE is essential, and has been practiced to mitigate GHG emissions. Previous and upcoming experience in the PICs show great potential for the PICs to mitigate CC by using RE or EE, or both at the same time, to reduce or meet their energy demands.

Combined with their experience and the lowering prices of RE technology, the PICs have set the target of being 100 % fossil free in electricity generation. The dramatic rise in fossil fuel prices, which has highlighted the low energy security of the PICs due to their geographical nature, resulted in looking at alternative energy sources to increase their security, this being energy derived from RE sources.

References

ADB (2010) Responding to climate change in the pacific: moving from strategy to action. Mandaluyong City

Akura T (2004) Review of RESCO-based Kiribati stand-alone PV program. Presentation at APEC Village Power Workshop, Canterbury

Andrieu E, Pesnel P (2006) Integration of a wind farm into the utility grid. http://www.caricom.org/jsp/projects/credp/Vergnet%20Presentation.ppt. Available (August 2012)

Arvizu D, Bruckner T, Chum H, Edenhofer O, Estefen S Faaij A, Fischedick M, Hansen G, Hiriart G, Hohmeyer O, Hollands KGT, Huckerby J, Kadner S, Killingtveit A, Kumar A, Lewis A, Lucon O, Matschoss P, Maurice L, Mirza M, Mitchell C, Moomaw W, Moreira J, Nilsson L, Nyboer J, Pichs-Madruga R, Sathaye J, Sawin J, Schaeffer R, Schei T, Schlomer S, Seyboth K, Sims R, Sinden G, Sokona Y, von Stechow C, Steckel J, Verbruggen A, WiserR, Yamba F, Zwickel T (2011) Technical Summary. In: Edenhofer O, Pichs-Madruga R, SokonaY, Seyboth K, Matschoss P, Kadner S, Zwickel T, Eickemeier P, Hansen G, Schlomer S, von Stechow C (eds.) IPCC special report on renewable energy sources and climate change mitigation, Cambridge University Press, Cambridge, pp 27–160

Chow JT (2010) Assessment of solar home systems (SHS) for isolated rural communities in Vanuatu using project lifecycle/sustainability, MSc Thesis. Michigan Technological University, Michigan

Energy Unit (2010), Energy Review—January to December 2009, No 3, Economic Policy and Planning Division of the Ministry of Finance, Apia

FEA (2012) Fiji electricity authority-annual report 2011. http://www.fea.com.fj/userfiles/files/Annual%20Report%202011.pdf. Available (August 2012)

Gielen D (2012) IRENA islands initiative, presentation at workshop on “assessment of grid stability for increased renewable energy integration in the Pacific”. Port Villa

Government of Samoa (2012) Samoa’s Energy Sector, Presentation at “SE4ALL Knowledge Fair”. Bridgetown

IPCC (2007) “Summary for policymakers” in climate change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 7–22

Jafar M (2000) Renewable energy in the South Pacific—options and constraints. Renewable Energy 19:305–309

JICA (2009) Preparatory survey on the program for climate change in the Pacific Islands. Renewable Energy, Final Report June 2009, Report No. A1P JR 09-009, Tokyo

Johnston P (1995), Sustainable development and energy use in the pacific islands: a preliminary examination of opportunities and constraints, east–west center working paper; energy and minerals series no. 19, Honolulu

Johnston P, Vos J (2004) Pacific regional energy assessment 2004: Vanuatu national report. SPREP, Apia

Kumar A, Schei T, Ahenkorah A, Caceres Rodriguez R, Devernay J-M, Freitas M, Hall D, Killingtveit A, Liu Z (2011) Hydropower. In: Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P, Kadner S, Zwickel T, Eickemeier P, Hansen G, Schlomer S, von Stechow C (eds) IPCC special report on renewable energy sources and climate change mitigation. Cambridge University Press, Cambridge, pp 437–496

Mala K, Schläpfer A, Pryor T (2008) Solar photovoltaic (PV) on atolls: Sustainable development of rural and remote communities in Kiribati. Renew Sustain Energy Rev 12(5):1345–1363

Marconnet M (2007) Integrating renewable energy in pacific island countries, Thesis. Victoria University of Wellington, Wellington

Miller M, Voss P, Warren A, Baring-Gould I, Conrad M (2012) Strategies for international cooperation in support of energy development in pacific island nation, Technical Report, NREL/TP-6A20-53188

Nanjangud A (2012) FEA-utility's point of view on grid connected pv systems, presentation at project DIREKT workshop on "renewable energy-economics, application and legislation" on 16th March 2012, Suva

Oberender E (2010) Energy security in the pacific islands renewable energy and energy efficiency partnership, presentation at "Clean Energy Expo Asia 2010", Singapore

Pacnews (2012) Island nation of Tokelau gets ready to go solar. http://www.pina.com.fj/. Available (August 2012)

Prasad, S. (2009), Solar-wind hybrid system: Optimal design for a small load requirement, MSc thesis, The University of the South Pacific, Suva

Ren21 (2012) Renewables 2011 global status report, REN21 Secretariat, Paris

REP-5 (2010) Support to the energy sector in five ACP Pacific Islands (REP-5)-final report

Singh A (2012a) Renewable energy in the Pacific Island countries: resources, policies and issues. Manage Environ Quality: Int J 23(3):254–263

Singh A (2012b) Biofuels and Fiji's roadmap to energy self-sufficiency. Biofuels 3(3):269–284

SPC (2011) Towards an energy secure Pacific- a framework for action on energy security in the pacific. Secretariat of the Pacific Community, Suva

SPC (2012a) Cook Islands country energy security indicator profile 2009. Secretariat of the Pacific Community, Suva

SPC (2012b) Nauru country energy security indicator profile 2009. Secretariat of the Pacific Community, Suva

SPC (2012c) Fiji country energy security indicator profile 2009. Secretariat of the Pacific Community, Suva

SPC (2012d) Niue country energy security indicator profile 2009. Secretariat of the Pacific Community, Suva

Syngellakis K (2012) Costs of renewables in Pacific Island countries presentation at project DIREKT workshop on "renewable energy-economics, application and legislation" on 16th March, 2012, Suva

Tai NK (2010) Energy policy situation in Papua New Guinea. Presentation at "JICA Training and Dialogue Program 2010", Japan

TERM (2010), Tonga energy road map 2010–2020-Final Draft. His Majesty's Government of the Kingdom of Tonga

United Nations (2010), Financing global climate change mitigation. ECE Energy Series No. 37, United Nations, New York and Geneva

Wade H, Johnston P, Vos J (2005) Pacific regional energy assessment 2004: regional overview report. SPREP, Apia

WB (2000) Cities, seas and storms: managing change in Pacific Island economies. USA, Washington DC

Woodruff, A. (2007), An economic assessment of renewable energy options for rural electrification in Pacific Island Countries, SOPAC Technical Report 397, Suva
Zieroth G (2006) Feasibility of grid connected wind power for Rarotonga. Cook islands, PIEPSAP Project Report 69