# Chapter 2
# Mitigating Through Renewable Energy: An Overview of the Requirements and Challenges

**Anirudh Singh and Pritika Bijay**

**Abstract** Renewable Energy (RE) provides one of the two main means of mitigating climate change. The requirements for the successful implementation of RE projects include RE and human resources, institutional capacity, science and technology infrastructure, policy and legislation, financing and the market-readiness of the renewable energy technology (RET).

This chapter considers each of these requirements in detail in the context of the Pacific Island Countries (PICs) with the help of illustrative examples from both the developed and developing countries, and in particular the Small Island Developing States (SIDS). Developing countries are forced to resort to the device of capacity building in an attempt to make up for their deficiencies.

The chapter then addresses several challenges to the implementation of RE projects in the SIDS. Perhaps chief amongst these is the better ability developed countries have in providing for the requirements for RE implementation than their developing counterparts. This differential ability is amplified in the case of the SIDS, and in particular the PICs. Factors that discriminate against them include their remoteness, lack of manufacturing infrastructure and human resources, finance, institutional frameworks, policy and their difficulty to attract investors. Barriers to RE implementation that are specific to the PICs include the small sizes of their economies, the lack of awareness amongst their decision-makers of the importance of supporting infrastructure development, lack of funding and appropriate institutional support.

RE does not always guarantee a reduction in emissions, and a full Life Cycle Analysis is needed to assess this ability, especially in the case of biofuels.

A. Singh (✉)
School of Science and Technology, The University of Fiji, Lautoka, Fiji
e-mail: anirudhs@unifiji.ac.fj

P. Bijay
Pacific Islands Forum Secretariat, Suva, Fiji



A. Singh (ed.), *Translating the Paris Agreement into Action in the Pacific*,
Advances in Global Change Research 68,
https://doi.org/10.1007/978-3-030-30211-5_2

**Keywords** Renewable energy (RE) · Climate change mitigation · Small Island Developing States (SIDS) · Pacific Island Countries (PICs) · Renewable energy resources · Institutional capacity · Policy · Science and technology infrastructure

## 2.1 Introduction: Why Renewable Energy?

The role of renewable energy (RE) in climate change mitigation can be best understood by first investigating the origins of greenhouse gases emitted to the atmosphere (also referred to simply as emissions) that cause global warming.

Man-made (or anthropogenic) greenhouse gas emissions are caused by several **sources** and **processes**, collectively called **activities**. In addition to sources of emissions, there may be entities that actually absorb or remove greenhouse gases from the atmosphere. These are called **sinks**, and are regarded as part of the activities.

To consider these activities further, they are divided into five groupings or **sectors,** consisting of **energy**, industrial process and product use (**IPPU**), Agriculture, Forestry and other Land Use (**AFOLU**), **Waste** and an **Others** sector (IPCC 2006). Of these sectors, the energy sector is by far the most significant, producing about 90% of the carbon dioxide and 75% of the total greenhouse gas emissions in developed countries (IPCC 2006).

The main reason for this dominant role of energy as an emitter of greenhouse gases is the high proportion of fossil fuels in the total global energy mix. As revealed in Fig. 2.1, fossil fuels make up some 78% of the global primary energy consumption today.

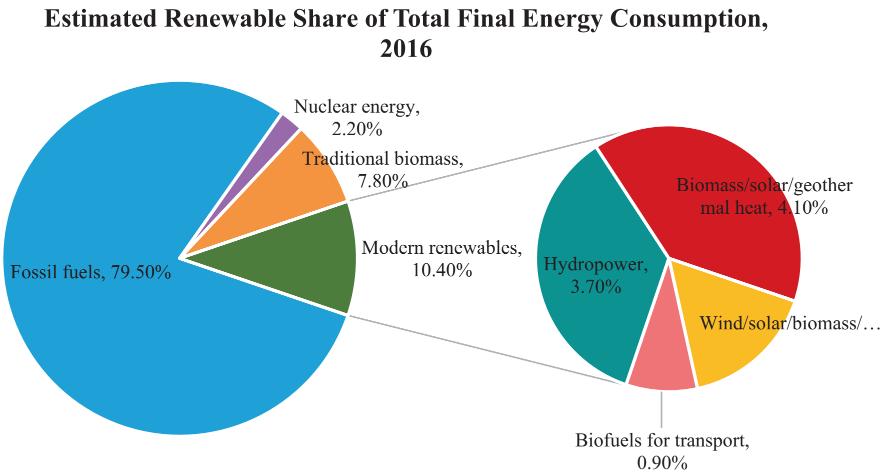


**Fig. 2.1** Estimated renewable share of total final energy consumption, 2016. (Source: after REN21 2018)

Fossil fuels are used mainly in **stationary combustion** in power plants and refineries, and **mobile combustion** in the engines of transport vehicles. In both these processes, one of the final products is carbon dioxide, which contributes directly to greenhouse gas emissions. Reducing the percentage of fossil fuels in the global energy mix thus provides an obvious way of reducing the greenhouse gas emissions that cause global warming and the resulting climate change. One mechanism for achieving this is by replacing fossil fuels by renewable energy (RE), as the various types of RE normally produce little or insignificant amounts of carbon dioxide as compared to fossil fuels.

As Fig. 2.1 shows however, RE currently provides only 19% of the total primary energy requirements of the world. It is clear that to mitigate climate change effectively, there should be a concerted effort to increase this share of renewable energy. This chapter discusses how the Small Island Developing State of Fiji can contribute to this cause through the implementation of RE projects.

The other possible method for mitigating climate change involves the more efficient use of energy (thereby reducing the total energy consumed). Such **energy efficiency** measures can be achieved at both the supply (i.e. production) side and demand (or use) side of energy, and the latter has been suggested as a possible contender for the Fiji NDC Implementation Roadmap (Economy, 2017).

This chapter investigates the requirements (i.e. the pre-requisites) for the successful implementation of renewable energy projects that can bring about new reductions in greenhouse gas emissions, and considers the challenges and barriers encountered by the Least Developed Countries (LDCs) and Small Island Developing States (SIDS), including Fiji in particular, in meeting these requirements.

## 2.2 Requirements for Renewable Energy

### *2.2.1 Discovering the Requirements*

There are certain obvious pre-requisites for the production of RE for human consumption. But the nature and extent of the full set of requirements often becomes clear only after one tries to actually implement the relevant technology. The case study in Box 2.1 is an attempt to illustrate how such a situation arises.

**Box 2.1: Identifying the Requirements for Setting Up a Wind Turbine**
Upon advice from her friend in the US, a cattle farmer in a small Pacific Island Country (PIC) decided to invest $200K in a wind turbine to provide for the 15 kWp power needed for her farm situated in a remote rural location. Her friend had a similar farm in Arizona USA, and he had made a similar investment very productively.

She tried to find local suppliers for the technology but was unable to do so. She was finally told by an engineering firm that she would have to import the technology as none was available on the market in their island nation. As there was no import precedence for such a commodity, it took a full 9 months for the local supplier and the farmer to have the project approved by the authorities and the import documentation completed. The supplier, a local engineering firm which had no prior experience in wind technology, finally managed to have the technology delivered to her farm where they proceeded to install the turbine and storage system.

They were confronted with some apparent teething problems with the system. The power generated, for instance, was much lower than the rated capacity stated in the documentation. The owner noticed that the blades were idle or hardly turning for long periods of time.

The local engineering firm could not help her. So she consulted the internet for possible leads into the problem and finally managed to locate a company abroad who was willing to advise her. They told her the problem was probably due to the low wind speed profile for the location of the turbine. The cut-in speed (i.e. the minimum wind speed required to turn the blades) of the turbine was 4 m/s. Evidently, this was too high for the average wind speed at the location.

As no detailed wind resource assessment had been carried out for the location, the value of this parameter was unknown. Meteorology Office data gave an average speed of 5.0 m/s for the entire region, but this said nothing about the actual average speed at the location of the turbine. A quick monitoring over a week using a hand-held anemometer (purchased on e-bay) gave an average wind speed of 4.2 m/s for the location.

After more internet research, the problem was finally identified as a poor selection of the exact siting of the turbine. Although the average wind speed for the region was ostensibly sufficient, the speed at the actual location was attenuated due to its low-lying position and shading effects caused by a cluster of rain-trees some 50 m away. The final advice that the owner received from her benevolent internet adviser was to do a thorough wind monitoring study of potential sites nearby and re-locate the turbine to a place with better potential. This was going to be a costly and time-consuming task, and still did not assure a reasonable power output.

The owner had learnt the hard way that there were many more requirements to the generation of wind power than those obvious at first site. She had also become grimly aware that living in a remote PIC had many disadvantages as compared to life in a developed country such as the USA.

This simple case study demonstrates how many essential requirements for the successful implementation of a RE project can remain hidden from view till one actually begins to go through the steps of implementing the project. It also reveals the significant handicap that developing countries have in venturing into RE projects as compared to the developed nations.

In the typical case, the requirements for the successful implementation of RE projects include the availability of the relevant **RE resources**, the required **human resources**, the **institutional capacity** and the **science and technology infrastructure**. They also include the **policy and legislation** as well as the **financing** needed to facilitate the project. It is also assumed that the technology being investigated is **market-ready**, i.e. that it is fully developed and has been in commercial use for some time.

The rest of this section considers each of these requirements in detail.

### *2.2.2 Renewable Energy Resource Requirements*

Renewable energy comprises energy occurring naturally in various forms. Solar energy, for instance, is the energy arriving at the earth's surface from the sun in the form of solar radiation, while wind energy is the kinetic energy contained in the wind. In the utilisation of RE, such natural sources of energy are converted to other forms using the appropriate renewable energy technology (RET). In the case of wind energy for example, the kinetic energy of the wind is turned into electrical energy with the help of a wind turbine.

It is clear therefore that one of the most essential requirements for RE is the appropriate RE resource. Thus, to consider the successful implementation of hydro, biofuel and geothermal energy projects for instance, among the first requirements are the availability of flowing water at a height (called the **head**), edible or inedible vegetable oils and animal fats, and geothermal source of energy below ground respectively.

It must be noted that the availability of RE resources in any country depends on both the geography and geology of that country. One cannot, for instance have ample hydropower potential in a country that is non-mountainous and/or lacks water resources in the form of rivers and streams. Table 2.1 shows the relationship between the geography/geology and RE potentials for some of the Pacific Island Countries (PICs).

Note that the location of these nations within the tropics ensures that solar energy is available in abundance to all. Also, note the irregular distribution of geothermal energy (which depends on the geology) and hydro (which is only available in mountainous countries).

For the successful utilisation of a renewable energy (RE) resource, it is essential to obtain a quantitative assessment of its availability. As the resources usually vary with time, such measurements must be carried out over suitable time periods. RE resource monitoring projects of this nature form integral parts of the feasibility

**Table 2.1** Availability of renewable energy resources in the PICs

| Country | Geography/geology | Solar ($kWh/m^2$/day) | Wind (m/s) | Hydro | Biomass/biofuel | Geothermal |
|---|---|---|---|---|---|---|
| Cook Islands | 15 islands totalling 240 $km^2$ of land. Eight Southern islands are elevated and fertile, have approx. 90% of population. Northern islands are low-lying, coral atolls | 5.5 | 6.1–7.5 | No (implementation costs were too high) | No | Unknown |
| Fiji | Land area of 18,333 $km^2$ and includes 320 islands – one third inhabited, most population on the main islands of Viti Levu and Vanua Levu. Majority of the land mass is on continental-like volcanic islands that rise to well over 1000 m, many of the outer islands are low-lying raised coral or atoll-type islands | 5.1 | ~7 | Yes (Two grid-connected hydro stations (80, 40 MW) on Viti Levu, several micro-hydro on Viti Levu, Vanua Levu and Taveuni, untapped developable hydroelectric potential of 200 MW mostly on on Viti Levu | Yes (Biomass still provides a large fraction of cooking fuel in rural areas. Coconut oil could be used as a feedstock for bio-diesel. Sugar and timber industries produce industrial residues (bagasse and hog fuel) used for power generation | Yes (Assessments show potential at Labasa and Savusavu on Vanua Levu. Potential of 5–15 MW or more of power) |
| FSM | Land area of 702 $km^2$ with an exclusive economic zone exceeding 2.59 million $km^2$ distributed over four states: Chuuk, Kosrae, Pohnpei and Yap. Geology varies from high and mountainous to low coral atolls -majority of islands low-lying and resource poor | 5.5 | Limited assessment | Some potential (Pohnpei has ~ 4–5 MW of developable hydro potential on the Seniphen and Lehnmasi Rivers. Kosrae has a site on the Malem River, potential of ~ 35 kW) | Unlikely | Unknown |

| | | | | | | |
|---|---|---|---|---|---|---|
| Kiribati | One raised coral island (Banaba) and 32 atolls in three island groups (Gilbert, Line and Phoenix) spread over an ocean area of 4200 km east to west and 2000 km north to south with a total land area of 811 km$^2$ | 6 | No | No | Biomass, mostly in the form of coconut husks, shells and fronds. Biofuel in form of Coconut oil | No |
| Marshall Islands | Two groups of atolls and islands – Ralik in the west and Ratak to the east. Majuro is main island. 22 of the 29 atolls, and 4 of the 5 small raised coral islands are inhabited. The islands are typically several kilometres long but rarely over 200 m in width | Adequate solar resources | Potential-requires assessment especially Majuro and Ebeye | No | No, except coconut oil used as a biofuel to replace diesel fuel | No |
| Nauru | A single raised coral equatorial island with land of 21 km$^2$. Surface area is dominated by pinnacles and outcrops of limestone, after a century of mining of the high-grade tricalcic phosphate rock | 6 | 4.2 (close to cut-off speed of 3.5 m/s) | No | No | No |
| Niue | Niue is a single raised coral island of 259 km$^2$ | Yes (good) | Potential | No | No | No |

(continued)

**Table 2.1** (continued)

| Country | Geography/geology | Solar ($kWh/m^2$/day) | Wind (m/s) | Hydro | Biomass/biofuel | Geothermal |
|---|---|---|---|---|---|---|
| Palau | 458 $km^2$ of land area spread over more than 200 islands – mostly on single reef structure that includes the heavily populated islands of Babeldaob, Peleliu and Koror. Babeldaob and Koror are mountainous and volcanic, but Palau also includes raised coral islands and atolls | 5.5 | No | No | No | No |
| PNG | Land area of 452,860 $km^2$. Mountainous with costal lowlands | Yes (large potential) | Yes (limited data) | Yes | Biomass available but largely inaccessible or unsuited. Possibility of Ethanol (alcohol) can from sugar-cane, molasses, sago palm, nipa palm and other crops | Yes |
| Samoa | 2934 $km^2$ of land area, mostly on the islands of Savai'i (58% of land) and Upolu (38%). The climate is warm, humid and tropical with distinct wet and dry seasons | 5 | Potential | Yes | Limited practical energy potential of woody biomass waste until 2020. biofuels-coconut oil | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| Solomon Islands | Nearly 1000 islands – 350 populated – with 28,000 km$^2$ of land. The islands are mostly rugged and mountainous and the country is relatively rich in mineral, hydro and forest resources | 5 | Limited data | Yes | Not easy to assess the available biomass energy resource. biofuel-coconut oil | Yes |
| Tokelau | 3 main atolls with a land area of 12 km$^2$ Each atoll consists of a lagoon enclosed by a curving reef with coral islets (motus), typically less than 200 m wide, separated by stretches of reef | 5.5 | No (only likely to be viable on the reef or in the lagoon) | No | Biofuel-coconut oil | No |
| Tonga | 748 km$^2$ land area. Most islands have a limestone base formed from an uplifted coral formation, although some have limestone overlying a volcanic base | 5.8 | No (wind difficult to due to land issues and the prevalence of coconut trees – not enough fetch) | No | Biomass- available cooking and for drying crops, mainly fish and copra. biofuel-coconut oil | Potential presence due to volcanic activity in Tonga – no data |
| Tuvalu | Land area of 26 km$^2$ over 8 islands, the largest (Vaitupu), has an area of about 5.6 km$^2$, smallest (Niulakita), is only 0.42 km$^2$. Soil is low in fertility and only a narrow range of food plants can be supported | 5.5 | 5.79 m/s | No | Biomass in the form of coconut trees | No |

(continued)

**Table 2.1** (continued)

| Country | Geography/geology | Solar (kWh/$m^2$/day) | Wind (m/s) | Hydro | Biomass/biofuel | Geothermal |
|---|---|---|---|---|---|---|
| Vanuatu | Land area of 12,200 $km^2$. 80 islands, 65 of which are populated. The islands are volcanic, mostly mountainous, with narrow coastal plains | 6 | Limited data on wind energy potential | Yes | Biomass-Yes as Vanuatu is heavily forested. biofuel-coconut oil | Yes (12 of Vanuatu's islands have thermal springs) |

Data source: Singh (2012), Isaka et al. (2013), and similar sources
Note: *PNG* Papua New Guinea

studies of RE projects. To take the example of hydropower, the output power of an installation is approximated quite well by the expression

$$\text{Power}\left(\text{kilowatts}\right) = 10 \times \text{Q}\left(\text{cubic metres per second}\right) \times \text{H}\left(\text{metres}\right)$$

where Q is the volume flowrate of the water and H is the head (Twidell and Weir 2015). The Head is fixed for any location and thus needs to be determined once only. The volume flowrate Q of the water flowing through the turbine will, however, depend on the rainfall, and will therefore show a temporal (in particular seasonal) variation. This parameter must therefore be monitored throughout the four seasons for at least 1 year. As the seasons themselves vary in intensity over time either randomly or due to predictable effects such as the El Nino/Southern Oscillation, it becomes necessary to extend the monitoring period to several years.

The flow rate may be either measured directly using a flowrate meter, or inferred from other data such as the rainfall data which has been collected and maintained by the meteorological office over extended periods of time for the region. Measurement techniques for the flowrate include the simple (or bucket) method, the refined method, the sophisticated method or the Weir method (Twidell and Weir 2015). For spot checks of the flowrate, a flowrate meter is quite adequate.

### *2.2.3 Human Resource Requirements*

No human endeavour can proceed without the input of human effort. In any initiative of national scale, human resources will be required at all stages of policy/decision-making, development and implementation. In the case of the implementation of RE projects, the human resources requirements may be conveniently partitioned into human input for the design and production of the technology, and that for its acquisition and use as an economic commodity.

Examples of human input for the technology development include project managers, scientists, engineers and factory floor workers for the design, implementation and evaluation/testing of the product. The trade and marketing of the technology considered as an economic commodity will require, amongst other things

- The services of customs agents, legal firms, specialised commercial bank staff for the import/export of the technology, as well as
- Human resources for the transportation and distribution of the commodity.

The nature of these human resources required by a country will clearly depend on whether the technology is developed/manufactured locally or imported from abroad. As much of the human capacity discussed above is available locally in developed countries, they are more likely to opt for manufacturing rather than importing the technology. The developing countries (in particular the LDCs and the SIDS) are largely reliant on the developed world for the supply of the technology, and require human resources mainly for importing, distribution, installation and maintenance of the renewable energy technology (RET). Their human resource requirements are therefore likely to vary significantly from those of developed nations.

### 2.2.4 Science and Technology Infrastructure

Most of modern technology, including RET is dependent on the results of scientific research and device fabrication, and their manufacture relies heavily on manufacturing technology. A science and technology infrastructure is therefore needed for the design, development and manufacture the RET. It typically consists of

- The physical infrastructure such as research laboratories, materials production and fabrication laboratories and the scientists needed to run these laboratories; and
- Governing institutions (an example being the Australian Research Council (ARC 2015)) that oversee the research and development in science and technology.

This requirement has been assessed to be the weakest link in the development chain for RE in developing countries (Singh 2012).

As an example of the role of science and technology in the RE sector, consider the Solar Photovoltaic (PV) system for energy generation. The components of a typical solar PV system consists of several components including an array of solar panels, an inverter, charge controller, battery storage system and the balance of plant. The solar array is constructed from individual solar panels connected together electrically. Each panel in turn is built from several solar cells that collect light energy for conversion to electricity.

The manufacture of these solar cells requires advanced research and development, including the production of ultra-high purity silicon and the fabrication of the solar cell device. Such research and development is only possible at dedicated research labs that only large established companies are capable of supporting. The same is true for the design and manufacture of the electronics used in the other components of the system. Because of these high technology demands, the manufacture of the basic components of solar PV systems normally remains confined to developed countries and other technologically advanced economies such as China and India.

### 2.2.5 Institutional Capacity

The production and use of RET requires support from several different types of institutions from within the public and private sectors. These institutions include

- Government institutions involved in facilitating and regulating the local production and use of the RET as well as its import;

- Policy institutions (usually affiliated with the government) needed to oversee and formulate policy;
- Financing institutions, including banks and other lending agencies, to provide for the financing of RE projects; and
- Training institutions (universities, technical and vocational institutes) needed for the training and development of the appropriate human resources.

Table 2.2 below lists some training institutions in Fiji that offer various levels of RE training.

### *2.2.6 Policy and Legislation*

Policy and legislation are needed to guide and facilitate the development of the RE sector of a country or region. Quite often however, they also arise from the nation's commitments to regional or global goals.

The motivating factors for the development of renewable energy policy include

- Implementation of global agreements (e.g. UN's Climate Change agreements commencing from the Earth Summit and ending recently with the Paris Agreement; the Sustainable Development Goals (SDGs)
- Regional development goals (e.g. the Framework for Action on Energy Security in the Pacific (FAESP) (SPC 2011)
- National development goals (e.g. the Fiji National Energy Policy) (FDoE 2013)

**Table 2.2** Some RE training institutions in Fiji and what they offer

| Institution | Name of programme | Training/qualification offered |
|---|---|---|
| The University of the South Pacific (USP), Suva, Fiji | BSc (major in Physics); MSc in Physics PhD in Renewable Energy | Undergrad course PH301; Postgrad courses PH407, PH414, PH416; MSc thesis in renewable energy |
| University of Fiji, Lautoka, Fiji | PostGraduate Diploma in Energy and Environment(PGDEE), and Masters in Renewable Energy Management (MREM) | Postgrad courses REE400, REE401, REM400, REM401, REM402, REM403, REM404, REM406; minor thesis REM407 |
| Pacific TAFE, The University of the South Pacific | Certificate IV in Resilience (Climate Change Adaptation & Disaster Risk Reduction). (*Certificate IV developed by European Union (EU) Pacific Technical and Vocational Education and Training in Sustainable Energy and Climate Change (EU PacTVET), which is being implemented by USP and Pacific Community (SPC)*) | CER41, CER42, CER43, and CER44 |

Usually the most immediate reason for developing RE policies is the need to provide adequately for the energy needs of a nation. Developing countries, especially the PICs, are heavily dependent on imported fossil fuels for their energy requirements, as a result of which a large component of their import bill are due to fuel imports (SPC 2012). The need to reduce this dependency provides a natural motivation for the introduction of the relevant energy policy.

RE policies are usually integrated into the country's National Energy Policy (NEP) framework. This is true for the policies of both developing and developed countries such as Fiji and Germany.

A National energy policy is usually stated in terms of a vision, mission and goals, and is enacted through an Act of Parliament. The basic structure and terminology of National Energy Policies include the following key concepts:

- Vision, mission, aims and goals;
- Energy sectors;
- Key priority areas;
- Energy targets;
- Energy strategies;
- Energy implementation plans;
- Monitoring and evaluation; and
- Energy Indicators.

Table 2.3 below highlights some of the salient features of Fiji's National Energy Policy.

Policy and legislation are powerful drivers in bringing about change in a country's RE sector. This is brought out well in Germany's Renewable Energy Sources Act 1991 (Singh 2012). Like many of the PICs, Germany has, in the past, been

**Table 2.3** Fiji's National Energy Policy – overview of the Targets for Fiji's energy sector (FDoE 2013)

| Indicator | Baseline | 2015 | 2020 | 2030 |
|---|---|---|---|---|
| **Access to modern energy services** | | | | |
| Percentage of population with electricity access | 89% (2007) | 90% | 100% | 100% |
| Percentage of population with primary reliance on wood fuels for cooking | 20% (2004) | 18% | 12% | <1% |
| **Improving energy efficiency** | | | | |
| Energy intensity (consumption of imported fuel per unit of GDP in MJ/FJD) | 2.89 (2011) | 2.89 (−0%) | 2.86 (−1%) | 2.73 (−5.5%) |
| Energy intensity (power consumption per unit of GDP in kWh/FJD) | 0.23 (2011) | 0.219 (−4.7%) | 0.215 (−6.5%) | 0.209 (−9.1%) |
| **Share of renewable energy** | | | | |
| Renewable energy share in electricity generation | 56% (2011) | 67% | 81% | 99% |
| Renewable energy share in total energy consumption | 13% (2011) | 15% | 18% | 25% |

almost totally dependent on imported fossil fuels from its neighbours for its energy needs. Prior to 1991, the country was largely reliant on coal and nuclear energy for its power generation.

In 1991, motivated by concerns for nuclear safety after the1986 Chernobyl disaster and the country's commitment to climate change initiatives, the country passed the Electricity Feed-in Act to encourage the renewable energy to be fed into the grid (Leiren and Reimer 2018). Under this Act, grid operators were to give priority to renewable energy power providers, and a feed-in tariff was introduced for the first time to incentivise RE providers.

The 1991 Act had to face some legal challenges, resulting eventually in its replacement by the Renewable Energy Sources Act of 2000. Since its inception at the turn of the century, this Act has been highly successful in supporting the entry of renewables into the German grid system. As a result of this Act, the renewable energy share in total energy consumption tripled between 1998 and 2008 (Singh 2012). The Act has been revised several times, with the latest review occurring in 2017 (LSE 2019).

### *2.2.7 Finance*

The availability of funding is a determining parameter in the success of a renewable energy project. Obtaining funding is rarely a straight-forward task of filling in a form with the necessary details. It is a complex process, and success usually depends on several key variables. They include the availability of opportunities, and knowledge and understanding of the mechanisms and instruments for obtaining financial assistance from the available sources.

Sources of funding consist of both global/regional financing agencies, such as the World Bank (WB), the Asian Development Bank (ADB), and more recently the Green Climate Fund, as well as national financial institutions including local development banks, commercial banks and other lending institutions. These institutions use specific financial mechanisms and instruments to evaluate and administer applications for funding. They also often provide mechanisms that are designed to facilitate loan approvals by other institutions. Making successful bids for funding depends on your understanding of how these institutions operate together, the nature and requirements of the financial mechanisms and instruments, as well as your skill in writing a successful funding proposal.

A financial mechanism for RE loans that was introduced by the Fiji Department of Energy in association with the Global Environment Fund (GEF) was the *Sustainable Energy Financing Project*. Box 2.2 below provides an account of how this scheme operated.

**Box 2.2: The Sustainable Energy Financing Project (SEFP): An Example of an Enabling Financial Mechanism for RE Projects**

Part of the requirement for obtaining funding for RE projects is a loan guarantee (or collateral) given to the loan provider. Any financial institution providing loans for RE projects will require assurance that someone (the guarantor) will pay back your loan in case you are unable to. A common difficulty with most Medium and Small to Medium Enterprises (MSMEs) is finding such guarantors, with the result that the application process ceases in mid-stream.

To alleviate this problem, the Global Environment Facility (GEF) in conjunction with the World Bank (WB) set up the SEFP (World Bank, 2019). This is a "Risk Sharing Facility (RSF) which is channelled through approved Participatory Financial Institutions (PFIs)" for making available 50% of guarantees to encourage financial institutions to provide loans for RE and EE investments.

The stated aim of the SEFP was

> "to increase the adoption and use of RE technologies and more efficient use of energy through a package of incentives to encourage local financial institutions to participate in sustainable energy finance" (Sur 2017).

The project, which was initiated in June 2007 for Fiji, had the Fiji Development Bank (FDB) and the Australia and New Zealand (ANZ) bank as the starting PFIs. The technologies that were supported were

1. Solar Photovoltaic (Solar PV)
2. Pico-hydro
3. Coconut oil as replacement of diesel fuel in diesel gensets and transportation vehicles.

The Fiji Department of Energy (FDoE) was given the Executive Authority to implement and monitor the project (FDoE n.d.). ANZ was assigned the part of Fund Manager.

The FDB's role was to execute the primary function of the scheme, which was to issue loans for the prospective investors in Renewable Energy and Energy Efficiency (RE and EE) projects (FDoE n.d.).

Outcomes:

In 2011, the FDB began making loans of up to $FJ1.0m at an interest rate of 5% to MSME's. Successful projects funding applications included

- Eco-tourism retreats for Fiji's tourism industry, and PV power systems in the 100–300 kW range for
  - A Mariner
  - Poultry farm

(continued)

**Box 2.2** (continued)

- – Garment factory
- – Supermarket
- – Tourism resort

By 2015, the FDB had made 26 loans totalling $FJ5.6 m. The overall outputs of the project included

- US$21.5 M in loans for RE and EE equipment
- 4.3 MW supply of RE power for over 100,000 people
- More than 13,500 units of solar PV
- 11 biofuel generators and 1 biofuel mill

In 2018, the SEFP was extended to include the Pacific Island Nation of Vanuatu, and the life-span of the project was increased to 31st December 2022.

The above example is a demonstration of the enabling effect that a carefully-designed financial mechanism can have in facilitating the implementation of renewable energy projects in the PICs.

## 2.3 Capacity Building

We saw above that developing countries lack several of the important requirements for facilitating the utilisation of their RE resources. These capacities therefore need to be developed for the specific needs through a process of capacity building.

This is conveniently performed in the PICs via capacity building projects, usually funded by Development Partners (i.e. countries and international organisations actively involved in the energy development of the PICs). Table 2.4 below provides a list of EU-funded energy capacity-building projects that were implemented in the Pacific over the past two decades.

### *2.3.1 Market-Readiness of Technology*

Perhaps one of the most important requirements for the utilisation of RE is the renewable energy technology (RET) itself. This must meet certain minimum quality standards. In particular, the technology must be

- Mature (i.e. tested through use and shown to be working and reliable); and
- Market-tested (i.e. been in the market as a commercially-available technology for some time).

**Table 2.4** EU-funded renewable energy capacity building projects in the Pacific (EDD 2014)

| Project Name | Organisation | Dates | Description |
|---|---|---|---|
| European Union Pacific Technical Vocational Education and Training in Sustainable Energy and Climate Change Adaptation Project (EU PacTVET) | SPC and USP | August 2014 (53 months) | The EU PacTVET project is component three within the broader Adapting to Climate Change and Sustainable Energy (ACSE) programme. The project builds on the recognition that energy security and climate change are major issues that are currently hindering the social, environmental and economic development of Pacific African Caribbean and Pacific (P-ACP) countries |
| LifeLong Learning for Energy security, access and efficiency in African and Pacific SIDS ($L^3EAP$) | Hamburg University of Applied Sciences, USP, University of Mauritius and Papua New Guinea University of Technology | 11 October 2013–10 October 2016 | The aim of the project was to strengthen the capacity of the partner HEIs in order to provide high level skills and training required for the energy labour market. In addition, the project also increased the academic and management capacity of university staff to modernise their educational and research programmes and activities, so as to develop labour market oriented lifelong learning concepts for the education of public and private sector staff in meeting the challenges of regional and national energy security and efficiency of supply |
| Small Developing Island Renewable Energy Knowledge and Technology Transfer Network (DIREKT) | Hamburg University of Applied Sciences, USP, University of Mauritius and University of West Indies | 2009–2012 | DIREKT was an international cooperation scheme involving universities from Germany, Fiji, Mauritius, Barbados and Trinidad & Tobago with the aim of strengthening the science and technology capacity in the field of renewable energy of a sample of ACP (Africa, Caribbean, Pacific) small island developing states, by means of technology transfer, information exchange and networking. Developing countries are especially vulnerable to problems associated with climate change and much can be gained by raising their capacity in the field of renewable energy, which is a key area of interest in climate change mitigation |

(continued)

**Table 2.4** (continued)

| Project Name | Organisation | Dates | Description |
|---|---|---|---|
| Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) - A SE4ALL Centre of Excellence to Promote Sustainable Energy Markets, Industries and Innovation | SPC | September 2016 (48 months) | In line with the decisions of the Ministers of Energy of the Pacific Islands States and Territories (PICTs), the aim of the project was to establish and implement the first operational phase of the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE). The centre represents an innovative fusion of regional and international efforts and capabilities. Its design leverages a network of intra and extra-regional partnerships, serving as a "hub" for knowledge and technical expertise on matters related to sustainable energy projects' implementation. It will also serve as a facilitator for innovative partnerships with the private sector |
| SPC/GIZ Coping with Climate Change in the Pacific Islands Region (CCCPIR) Project | SPC and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) | 2009–2018 | The regional SPC/GIZ programme 'Coping with climate change in the Pacific Island Region' (CCCPIR) aims at strengthening the capacities of Pacific Island Countries (PICs) and regional organisations to cope with the anticipated effects of climate change that will affect communities across the region |
| | | | The CCCPIR is focusing on key economic sectors such as agriculture and livestock, forestry, fisheries, and tourism. Further focal areas are energy and education. Improving the sustainable supply of energy with a focus on enhancing renewable energy and energy efficiency is critical for PICs to increase the resilience of their economies. Integrating climate change considerations into primary and secondary education and technical and vocational training (TVET) is also vital to equipping young Pacific Islanders with the knowledge and skills required to cope with the effects of climate change |

(continued)

**Table 2.4** (continued)

| Project Name | Organisation | Dates | Description |
|---|---|---|---|
| North Pacific ACP Renewable Energy and Energy Efficiency Project (North-REP) | SPC | 2011–2016 | North-REP was a multi-country programme where 3 of SPC island member countries (FSM, RMI & Palau) pooled their combined EURO 15.49 m of EDF 10 resources, which have been identified for the development of their energy sectors. SPC is entrusted with the responsibility of managing it. SPC's regional office for the North Pacific in Pohnpei, FSM houses the North-REP management office with Energy Specialists based in FSM, Palau and RMI |
| EU Adapting to Climate Change and Sustainable Energy (ACSE) | GIZ and SPC | 2014 (ongoing) | The ACSE programme will help the 15 Pacific ACP countries (Cook Islands, East-Timor, Fiji, Kiribati, Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Republic of the Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu) to address three main challenges common to all of them: |
| | | | 1. Adapting to climate change; |
| | | | 2. Reducing their reliance on fossil fuels; and |
| | | | 3. Capacity building. |
| Support to the Energy Sector in 5 Pacific Island States (REP-5) | Pacific Islands Forum Secretariat (PIFS), IT Power (ITP), Transénergie, Ademe - French Environment and Energy Management Agency | 2006–2010 | The REP-5 Programme "Support to the Energy Sector in 5 Pacific Island States" was a regional initiative implemented by PIFS supported with funds from the ninth European Development Fund (EDF9). REP5 focused on renewable energy and demand-side energy efficiency activities. There are five countries participating in the REP-5 programme. These are the FSM, Nauru, Niue, Palau and RMI |

Arguably one of the most mature RETs is hydro. This has been generating electricity successfully in various forms for more than 100 years (iha n.d.). During its early history (before electricity was discovered) hydropower was harnessed by waterwheels to perform mechanical tasks such as operating flour mills.

Photo-voltaic (PV) power generation has an encouraging history. The technology was developed several decades ago when solid state semiconductor devices first began appearing on the market. Up till a few years ago however, this RET was too expensive because of the price of the solar panels (also called modules) which provide the basic building block of these power systems. But the (relatively) recent entry into the energy market of China has helped to drive prices down, and as a result this technology is now widely used in all sizes, from roof-top solar systems to large solar farms, all over the world.

Among the least mature RETs are **wave energy** and Ocean Thermal Energy Conversion **(OTEC)**. While several devices have been tested and show promise, many are still at the Pilot Project stage of their development. In the case of wave energy, the **Oscillating Water Column (OWC)** device has been tested at the 296 kW grid-connected Mutriku Power Plant in Spain since 2011 (Torre-Enciso et al. 2009), while the **Pelamis Wave Energy Converter** developed in Scotland (EMEC n.d.) has attracted considerable attention as a potentially viable wave energy device.

In the case of OTEC, an experimental power plant has been running on the Kona Coast in Hawaii for some time (Clancy 2016). Interest in the technology has been re-kindled in Korea more recently, and the Korea Research Institute of Ships and Engineering (KRISO) is in the process of developing a 200 kW plant to become operational in Kiribati from mid-2019 (Trauthwein 2016). While these developments are taking place however, both wave energy and OTEC fall short of the full status of market-readiness required of commercial technologies.

## 2.4 The Challenges

### *2.4.1 Differential Ability to Meet the Requirements*

In the previous section, we have seen several examples where developing countries are unable to provide the requirements for the implementation of RE projects while their developed counterparts are much better equipped to do so. This differential ability between the rich and poor nations to meet the requirements is a key issue in the implementation of RE projects. And the situation is exacerbated by the fact that this disparity tends to depend on the nature of the developing country.

Human resources, infra-structure and finance, for instance, are generally lacking in all developing countries. These countries are not able to develop the science and technology infrastructure and are confronted with unique barriers in their efforts.

The Small Island Developing States (SIDS) however have additional issues due to their remote and/or isolated nature. This is especially important in the case of the PICs such as Fiji.

Remoteness leads to supply chain issues, seriously affecting the availability of resources and technology with consequent mounting costs. The lack of manufacturing infrastructure means that developing countries face enormous problems in producing the RETs themselves. This forces them to import the technology as the only option. This in turn requires them to establish a whole new import industry with its own infrastructure requirements.

A challenge that is non-discriminating between the rich nations and poor relates to the observation that not all RE resources will yield net emissions reductions in all situations. Some RE technologies, such as biofuels for transportation, may produce emissions during their production and use that are close to or may even exceed the emissions (from fossil fuels) they are trying to avoid. It thus becomes essential to obtain a careful assessment of these additional emissions.

To summarise, some of the major challenges and barriers encountered by the SIDS in implementing RE as clean energy to facilitate carbon emissions reductions include

- The lack of infra-structure, human resources, finance and institutional and policy frameworks;
- The difficulty in attracting investors; and
- Assessing the suitability of a particular renewable energy to produce net reductions in carbon emissions.

These issues are considered in more detail below.

### 2.4.2 Lack of Capacity

The lack of capacity in meeting the RE requirements noted above has a debilitating effect on developing nations in their pursuit for the adoption of the renewable energy option. What is of concern is their (sometimes) extreme difficulty in overcoming such deficiencies.

In the case of science and technology infrastructure, for instance, their attempts to redress the issue is often thwarted by the lack of a starting base, the relevant human resources as well as their physical remoteness from the developed countries. This is especially true of the PICs, which do not benefit from economies of scale due to their small populations.

The wind turbine example of Box 2.1 illustrates how the absence of a science and technology base can have a lasting effect on the implementation of a simple RE project. An issue that would plague that project through its entire lifetime would be service and maintenance of the turbine system. The only ostensible solution would be for the local engineering firm to acquire the relevant knowledge. This however would mean going through a steep learning curve for very marginal returns, a situation which provides little incentive to the prospective supplier to develop the service.

Among the specific barriers and constraints encountered by SIDS in their efforts to develop their RE sector are

- The small sizes of their economies which cannot grow or sustain the required research and technology structures and human capacity;
- The lack of appreciation by national decision-makers of the importance of such supporting infrastructure to development (Singh 2012);
- Lack of funding; and
- The lack of institutional and policy support that can facilitate such development of a science and technology base.

Table 2.5 shows how the SIDS, and in particular the PICs, compare with the developed nations in their ability to satisfy the requirements for the successful implementation of RE projects.

In the wake of the launching of the UN Secretary-General's Sustainable Energy for All (SE4ALL) initiative in 2011, the Fiji government carried out an analysis of its own energy access needs. Table 2.6 summarises some of the key gaps and barriers to ensuring energy access to all citizens of Fiji that were identified by the government in this study that concluded in 2014 (Government of Fiji 2014). It provides specific examples of the difficulties faced by the PICs as noted above, and also reveals the importance of relevant and complete data and information on energy needs as an additional requirement.

**Table 2.5** Major differences between the rich and poor countries in their abilities to implement RE projects

| | Requirement | Developed country competence | SIDS competence |
|---|---|---|---|
| 1 | Human resources (HR) | Full range of expertise available, training institutions available to train the HR | Generally lacking. Limited training institutional capacity means expertise has to be largely imported |
| 2 | Science and Technology infrastructure | Basic infrastructure available – depends on state of development of the country | Poor physical infrastructure such as laboratories, scarce scientific human resources; scientific governing institutions often totally lacking |
| 3 | Institutional capacity | Adequate governing, training and financing institutions | Poor or non-existent governing, training and financing institutions |
| 4 | Policy and legislation | Policies and legislations in place or can be speedily developed | Policies and legislations often lacking or at a developmental stage |
| 5 | Finance | Available via various types of lending agencies, schemes and mechanisms | Largely unavailable, lending agencies reluctant to lend due to collateral issues, financing largely foreign aid-dependent |

**Table 2.6** Typical gaps and barriers to ensuring energy access for all in Fiji (Government of Fiji 2014)

| Requirement | Main gaps and barriers |
|---|---|
| Institutional and policy framework | 1. Legislation for the relevant RE sector is not complete |
| | 2. Data on energy does not exist or is unavailable to the public and potential investors |
| Programmes and financing | 1. No rural electrification master plan exists |
| | 2. Data on household cooking fuels is incomplete |
| | 3. Detailed resource assessments are not available for all RE sectors |
| | 4. Inadequate funding for rural electrification programmes by the government |
| Private sector investment | 1. There is minimal private sector investment in power production, purportedly due to tariff and regulatory barriers |
| | 2. Lack of net-metering legislation prevents individual households in participating in distributed electricity generation |

### *2.4.3 Attracting New Players*

Rising power demand and the need for rural electrification in the PICs has created an urgent demand for more power generation in the region. Such development however cannot proceed without additional funding. In the case of Fiji, almost all electrical power is produced by Energy Fiji Limited (EFL – previously FEA), the country's only national utility, which has limited capacity to cope with this extra burden. The only perceivable solution would seem to be sharing the additional generation burden with Independent Power Producers (IPPs) who are capable of sourcing their own funding.

While this solution might sound simple in principle, it has proven difficult to implement in Fiji's case, where the national utility has, over the years, only been able to acquire the services of two providers (the Fiji Sugar Corporation (FSC) and Tropic Wood) to share the grid load (FEA 2017). Part of the reason was the existence of several barriers to such an IPP strategy. In an effort to remove these barriers, the Fiji Department of Energy introduced the Fiji Renewable Energy Power Project (FREPP) (see Box 2.3 below) in 2011.

**Box 2.3: The Fiji Renewable Energy Power Project**

The Fiji Renewable Energy Power Project (FREPP) was a GEF-funded project implemented by the Fiji Department of Energy (FDoE) in partnership with the UNDP which aimed to remove barriers (including policy, regulatory, market, financial and technical barriers) to grid-connected power generation in Fiji. The project was initiated in 2011 and lasted till the end of 2014.

It consisted of four main components, addressing specific categories of barriers (EDD 2014):

(continued)

**Box 2.3** (continued)

1. Energy Policy & Regulatory Frameworks (including a power development plan for Fiji);
2. RE Resource Assessments and RE-based Project Assessments (including feasibility studies of new power generation from various RE sources)
3. RE-based Power Generation Demonstrations, and
4. RE Institutional Strengthening (including a framework for IPP procurement for large-scale power generation, connecting small-scale RE technologies to the grid and transfer of regulatory functions for the power generation sector to government).

FREPP was expected to facilitate investments in RE-based power generation in Fiji, which would support the socio-economic development of the country, make use of its RE resources and reduce GHG emissions. By the end of the project in 2014 however, while some investors had signed MOUs with the grid-owner, no new power was being provided by IPPs apart from that produced by the two existing IPPs.

The situation had changed only slightly by 2018, with the addition of the 12MW rated capacity Nabou Biomass Power Plant operated by the Nabou Green Energy Ltd. in 2017 (Nabou Green Energy Ltd 2018). EFL has since noted the prospects of a 3–5 MW Solar farm in Western Viti Levu (FEA 2017), while discussions continue with other potential IPPs on new hydro generation in the interiors of Viti Levu and Vanua Levu. The totality of the power produced by all these new sources however, will fall very short of the country's power needs and the expectations of the country's NDC Implementation Roadmap (Fiji Ministry of Economy 2017).

As revealed in Box 2.3, the outcomes of FREPP have been far from satisfactory. Among the probable reasons for the lack of interest shown by investors, the most obvious is the lack of monetary incentive. The feed-in tariff rate of FJ$0.33 per kWh appears to be still too small. Overall, it is clear that there is a continuing need to improve the enabling framework that is needed to facilitate the development of the RE industry in Fiji.

### *2.4.4 Assessment of RE as a Mitigating Agent*

Under what conditions does the utilisation of RE contribute to mitigation? To answer this question, one must first note that the production and use of RE itself produces emissions of greenhouse gases. RE only qualifies as a mitigating agent if it emits less greenhouse gases per unit energy produced than fossil fuel.

To assess the actual emission reduction potentials of various forms of renewable energy, one must note that RE projects invariably require fossil fuel use at some stage of their project development life cycle. The RE resources can be divided into two categories:

- Resources which do not lead to emissions except for certain phases of their life cycles, including those that have embedded emissions (i.e. emissions during their manufacture) only. The analysis of these resources and technologies can be easily dealt with using the concepts of carbon debts and their "payback periods".
- Others that produce emissions in a variable manner, depending on the exact production/use pathway chosen. The net emissions here can become quite significant, and may even become positive (Flugge et al. 2017; Hofstrand 2019). These need a comprehensive quantitative evaluation of the emissions (e.g. the carbon emission).

A Life Cycle Assessment (LCA) (Muralikrishna and Manickam 2017)is needed to carry out the assessment of the actual emission reduction potential of the RE resources. To facilitate this, it is convenient to picture the RE utilisation as a process in which a renewable energy fuel is converted using a renewable energy technology (RET) to produce the final useful form of energy. Note that the RET may involve either a single (one shot) energy conversion (e.g. solar PV cells) or several stages (e.g. biomass power generation, involving the burning of biomass in a furnace to produce heat, which is then converted sequentially to mechanical and electrical energy).

Emissions are possible from the following stages of this energy cycle:

(i) Fuel cultivation/preparation/transportation (e.g. biofuels);
(ii) Technology fabrication (e.g. embedded emission during the manufacture of solar PV cells); and
(iii) Technology installation (e.g. hydropower civil works, technology transportation and installation).

An LCA enables a quantitative evaluation of the emissions from RE relative to fossil fuels. A quick qualitative evaluation can, however, be obtained even without the use of the LCA technique. Table 2.7 shows how such an analysis can provide a useful assessment of the emissions from a RE source.

The table reveals that whereas the total emissions per unit output energy remains small in comparison with fossil fuel emissions for solar, wind and hydro, it can become significant, and indeed exceed that for fossil fuel in the cases of biomass power generation and biofuels for transportation. Extreme care must thus be exercised in the manner in which these latter RE fuels are produced and used.

**Table 2.7** Comparison of life cycle emissions from various RE sources with fossil fuel emissions

| | RE source | Emissions from fuel cultivation/transportation/manufacture | Embedded emissions in technology | Emissions during technology installation | Total emissions/MJ output | Comparison with diesel emission/MJ |
|---|---|---|---|---|---|---|
| 1 | Solar | NA | Yes | Yes | small | Much smaller/insignificant |
| 2 | Wind | NA | Yes | Yes | small | Smaller/insignificant |
| 3 | Hydro | NA | Yes | Yes | Can be significant during early lifespan | Small, and reduces quickly over the years to smaller |
| 4 | Biomass (power generation) | Can be large | Yes | Yes | Can be large | Can be larger |
| 5 | Biofuels (transportation) | Can be large | Yes | Yes | Can be large | Can be larger |

## 2.5 Summary and Conclusions

- The energy sector is by far the most significant contributor to greenhouse gas emissions. Most of the emission is produced from the fossil fuel component of the global energy mix, of which renewable energy (RE) makes up a mere 19%;
- Climate change can be mitigated by increasing the share of RE in the global energy mix. The implementation of new RE projects thus plays a vital role in climate change mitigation;
- The key requirements for the implementation of RE are the RE resources, human resources, the science and technology infrastructure, institutional capacity, policy and legislation, finance, and the availability of market-ready technology;
- Developed countries have better capacity for the production, distribution and installation of renewable energy technologies (RETs) than developing countries. They face less challenges in meeting the requirements for the implementation of RETs than their developing counterparts, and are better-placed to cope with any challenge;
- Developing countries are faced with several challenges in meeting the requirements for the implementation of RE; and
- Developing countries are unlikely to have the resources for the production/manufacture of the technology, and usually have no alternative but to import from developed countries.

## References

ARC. (2015). *About the Australian Research Council*. Retrieved January 8, 2018, from Australian Research Council: https://www.arc.gov.au/about-arc

Clancy, H. (2016, June 15). *Ocean energy: Will Hawaii take the plunge?* Retrieved January 15, 2019, from GreenBiz: https://www.greenbiz.com/article/ocean-energy-will-hawaii-take-plunge

EDD. (2014). Retrieved November 26, 2018, from Pacific Regional Data Repository (PRDP) for Sustainable Energy for All (SE4ALL): http://prdrse4all.spc.int

EMEC. (n.d.). *European marine energy centre*. Retrieved February 5, 2019, from PELAMIS WAVE POWER: http://www.emec.org.uk/about-us/wave-clients/pelamis-wave-power/

FDoE. (2013). *Fiji National Energy Policy 2013–2020*. Suva: Government of Fiji.

FDoE. (n.d.). *Sustainable Energy Financing Project (SEFP)*. Retrieved February 10, 2019, from Fiji Department of Energy: http://www.fdoe.gov.fj/index.php/power-sector/sustainable-energy-financing-project-sefp

FEA. (2017). *Fiji Electricity Authority Annual Report 2016*. Suva.

Fiji Ministry of Economy. (2017). *Fiji NDC Implementation Roadmap 2017–2030*. Suva: Fiji Ministry of Economy.

Flugge, M., Lewandrowski, J., Rosenfeld, J., Boland, C., Hendrickson, T., Jaglo, K., … Pape, D. (2017). *A life-cycle analysis of the greenhouse gas emissions of cornBased ethanol*. Report prepared by ICF under USDA Contract No. AG-3142-D-16-0243. January 30, 2017.

Government of Fiji. (2014). *Sustainable energy for all (SE4All): Rapid assessment and gap analysis*. Suva: Government of Fiji.

Hofstrand, D. (2019, February 10). *Greenhouse gas emissions of corn ethanol production*. Retrieved from Ag Marketing Resource Center Renewable Energy Newsletter: https://www.agmrc.org/renewable-energy/climate-change/greenhouse-gas-emissions-of-corn-ethanol-production

iha. (n.d.). *A brief history of hydropower*. Retrieved January 31, 2019, from International Hydropower Association: https://www.hydropower.org/a-brief-history-of-hydropower

IPCC. (2006). *2006 IPCC guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme* (H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, & K. Tanabe, Eds.). Hayama: Institute for Global Environmental Strategies

Isaka, M., Mofor, L., & Wade, H. (2013, November 13). *Pacific lighthouses: Renewable energy opportunities and challenges in the Pacific Islands region.* Retrieved November 13, 2018, from http://www.irena.org/publications/2013/Sep/Pacific-Lighthouses-Renewable-Energy-Roadmapping-for-Islands

Leiren, M. D., & Reimer, I. (2018). Historical institutionalist perspective on the shift from feed-in tariffs towards auctioning in German renewable energy policy. *Energy Research & Social Science, 43*, 33–40.

LSE (2019). *Renewable Energy Sources Act (EEG, latest version EEG 2017)*. Retrieved February 1, 2019, from London School of Economics and Political Science: http://www.lse.ac.uk/GranthamInstitute/law/renewable-energy-sources-act-eeg-latest-version-eeg-2017/

Muralikrishna, I. V., & Manickam, V. (2017). Chapter five – Life cycle assessment. In I. V. Muralikrishna & V. Manickam (Eds.), *Environmental management: Science and engineering for industry* (pp. 57–75). Oxford: Elsevier Inc.

Nabou Green Energy Ltd. (2018). *About us: Nobou green energy Ltd*. Retrieved February 8, 2019, from Nobou Green Energy: http://ngel.com.fj/

REN21. (2018). *Renewables 2018 global status report*. Paris: REN21 Secretariat.

Singh, A. (2012). Renewable energy in the Pacific Island countries: Resources, policies and issues. *Management of Environmental Quality: An International Journal, 23*(3), 254–256.

SPC. (2011). *Towards an energy secure Pacific: A framework for action on energy security in the Pacific*. Suva: SPC Suva Regional Office.

SPC. (2012). *Country energy security indicator profiles 2009*. Suva: Secretariat of the Pacific Community. Retrieved February 15, 2019 http://www.spc.int/edd/section-01/ energy-overview⟩. http://edd.spc.int/section-01/energy-overview/179-country-energy-security-indicator-profiles-2009

Sur, M. (2017). *Pacific Islands – sustainable energy finance project: Restructuring (English)* Retrieved February 10, 2019, from The World Bank Group: http://documents.worldbank.org/curated/en/631501507081771057/Pacific-Islands-Sustainable-Energy-Finance-Project-restructuring

Torre-Enciso, Y., Ortubia, I., López de Aguileta, L. I., & Marqués, J. (2009). Mutriku wave power plant: From the thinking out to the reality. *Proceedings of the 8th European Wave and Tidal Energy Conference* (pp. 319–329). Uppsala: Uppsala universitet.

Trauthwein, G. (2016, January 29). *Energy from the ocean: The ocean thermal energy converter*. Retrieved February 10, 2019, from Marine Technology News: https://www.marinetechnology-news.com/news/energy-ocean-ocean-thermal-527332

Twidell, J., & Weir, T. (2015). *Renewable energy resources*. Taylor & Francis.