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A review of Fiji's energy situation: Challenges and strategies as a small island developing state

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ABSTRACT

Fiji is an island country with just over 300 small islands and approximately 853,000 people. It is a small island developing state (SIDS) that is heavily dependent on imported fossil fuel for its energy needs. The paper attempts to determine the past and current energy situation in Fiji, challenges faced and strategizes to overcome these challenges. In 2014, Fiji generated 859 GW h of grid electricity from 259.8 MW of power plants. Here, 45.4% of grid electricity was produced by hydro, 50.9% by diesel generators and the remaining by biomass. However, Fiji's transport sector is completely dependent on fossil fuels with fuel import bill equivalent to an average 58% of export earnings and taking up 21% of total import bill. The smallness of Fiji and dispersed islands within Fiji group leads to many challenges to have accessible, affordable and sustainable energy supply. These challenges are comprehensively discussed in this paper. Strategies such as increasing private-public partnership in renewable energy projects, changing customer behavior, setting up a credible feed-in tariff structure, developing locally owned business in renewable energy and energy efficiency, setting up of risk mitigation facilities and strengthening institutions supporting energy sector are discussed to overcome or minimize challenges.

1. Introduction

Knowledge of the past and present energy situation is imperative for a country as it allows decision/policy makers and researchers to strategize and make judicious decisions leading to sustainable development. Sustainable development does not only focus on economic growth but focuses on development that is economically feasible, environmentally friendly as well as socially acceptable [1]. It is even more important in small island developing states (SIDS) which rely heavily on imported fossil fuel for their energy needs, Table 1. According to (UNFCCC) [2] SIDS' exclusive economic zone (EEZ) is usually larger than their land area and 90% of the SIDS are in the tropics. Even though renewable resources such as solar, hydro, biomass are being exploited for water heating and electricity generation, most SIDS are still heavily dependent on imported fossil fuel with their volatile prices making SIDS's economies extremely vulnerable. Considering Table 1, most island nations are using biomass for cooking and fossil fuel for electricity generation and transport. Most PICs have targeted to having renewable source of electricity generation.

Fiji is one of the SIDS and lies in the middle of the Pacific Ocean at longitudes between 174° East and 178° East and latitudes between 12° and 22° South. It has just over 300 islands of which one third are inhabited with a population of 853000 in 2011 [7]. The land area of Fiji is 18,333 km^2 where Viti Levu (10,500 km^2) and Vanua Levu

Abbreviations: ADO, Automated Diesel Oil; CBO, Central Business Organisation; EE, Energy Efficiency; EEZ, Exclusive Economic Zone; ESCO, Energy Service Companies; EYR, Energy Output Ratio; FBoS, Fiji Bureau of Statistics; FDoE, Fiji Department of Energy; FEA, Fiji Electricity Authority; FiT, Feed-in-tariff; FJD, Fijian Dollar; FSC, Fiji Sugar Cooperation; GCF, Green Climate Fund; GCPV, Grid-connected photovoltaic; GDP, Gross Domestic Product; GoF, Government of Fiji; GW h, Gigawatt hours; HFO, Heavy Fuel Oil; IDO, Industrial Diesel Oil; IPP, Independent Power Producers; kW, kilowatt; LHV, Lower Heating Value; LPG, Liquefied Petroleum Gas; MAPE, Strengths, Weaknesses, Opportunities and Threats; MOU/A, Memorandum of understanding/agreement; MW, Megawatt; PPA, Power Purchase Agreement; PPP, Public-Private Partnership; RE, Renewable Energy; REPS, Renewable Energy Portfolio Standards; RESCO, Renewable Energy Service Company; REU, Rural Electrification Unit; SEFP, Sustainable Energy Financing Project; SEIAPI, Sustainable Energy Industry Association of the Pacific Islands; SHS, Solar Home Systems; SIDS, Small Island Developing States; SPC, Secretariat of the Pacific Community; MAPE, Strengths, Weaknesses, Opportunities and Threats; TWIL, Tropik Wood Industries Limited; UNDP, United Nations Development Program; UNFCCC, United Nations Framework Convention on Climate Change; USD, United States Dollar; VEP, Vat Exclusive Price

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Table 1
Selected PICs' demography and energy data.

Parameter	PNG	Solomon Islands	Vanuatu	Fiji	Samoa	Tuvalu	Tonga
Land area (km^2) [3]	452860	28000	12200	18333	2934	26	748
# of islands [3]	Over 600	Nearly 1000	80	320	2 main islands	8	176
Populations (million) [3]	Over 7 (in 2012)	0.515870 (2009)	0.234023 (2009)	837271 (2007)	0.187820	0.009860	0.103036
Electricity rate (%) [4]	13 (2010)	14	28	89% (2007 census)	98	94	89
Average electricity price (FJ cents/kW h) [5]	60.12	147.83	93.30	36.5	58.75	69.08	89.38
Lighting source	Kerosene lamps (over 50%)	Kerosene	Kerosene	2007 census data:	Electricity (97%)	Electricity	Electricity
	open fires (25%) [3]	Open fire	Open fire	Electricity (78.5%) Benzene (2.4%) Kerosene (18.1%) Open fire (1%)	Kerosene (3%) [3]		Biogas [3]
Cooking source	Fuelwood (~90%) LPG or Electricity (3%) [3]	Biomass (89%) [3]	Fuelwood	2007 census data: Fuelwood (42.2%) Kerosene (25.9%) LPG (27.9%) Electricity (3.5%) Biogas (0.4%)	Fuelwood (65%) Kerosene (4.5%) Electricity (6.5%) Charcoal (4.3%) LPG (19%) [3]	Kerosene LPG Biomass [3]	Biomass Kerosene Electricity LPG Biogas [3]
Electricity generation mix [6]	Hydro Geothermal Oil	Mainly diesel	Diesel Wind Solar PV Biomass & biofuel	Hydro Oil Wind Solar Biomass	Diesel Hydro Solar PV	Diesel Solar PV	Diesel
RE % in electricity generation (2011 data) [6]	58	0.2	8.5	59.4	32	0.6	0.0
National RE target for electricity [6]	Government to decide	20% by 2018	No RE goal	90% by 2020	20% by 2030	100% by 2020	50% Re for main grid by 2012

(5500 km^2) are the two largest islands [8]. Fiji's EEZ covers 1.3 million km^2 of the South Pacific Ocean. Fiji Electricity Authority (FEA) is the only power utility (established in 1966) and is responsible for generation, transmission and retail of grid electricity on Viti Levu, Vanua Levu and Ovalau ever since. The rest of the islands in Fiji are electrified through diesel generator sets, microhydro systems or generators running on biofuel. The electrification of the off-grid population comes under Fiji Department of Energy (FDoE).

The access to electricity in Fijian households in not 100%. From the last 3 consecutive censuses data, in 1986, 1996 and 2007, 48%, 67% and 89% of households have access to electricity [9]. Electricity is provided by FEA (grid-connected) or distributed generators such as solar home systems or diesel generators or biofuel generators or microhydro schemes. In 2007, 75% of the Fiji's population had grid electricity while 14% of the rural population had access to distributed electricity [59. 100% of both rural population and urban population has access to modern forms of lighting while 29% of rural and 85% urban population had modern cooking fuel (all types of fuels except traditional biomass) [10,11]. The consumption of final energy by different sectors (residential, industry and transport) is shown in Fig. 1. Industrial sector is the largest for final energy consumption.

FEA began hydro power production on large scale in 1982 (80 MW

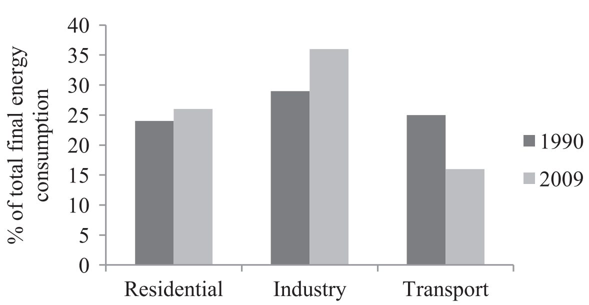

Fig. 1. Energy consumption by sector, 1990–2009 [12].

Monasavu Hydro Power) and escalating fuel prices from 2004 has motivated FEA to turn to renewable energy sources for electricity generation. FDoE started with setting up diesel generators in outer islands for lighting sources but recently from 2010 islanders are more interested in solar home systems. Transport sector is dominated by used of fossil fuels and there has been very minute change in in terms of replacement of fossil fuels with other clean and local fuel. However, government, academic institutions and other stakeholders are rigorously working towards finding some workable solutions. Fiji's commitment for clean source of energy is evidenced by its various actions plans and its communications to UNFCCC.

The objective of this paper is to study the past and present energy situation in Fiji in terms of the energy resources available, electricity generation and consumption and consumption of imported fossil fuel. In addition, challenges and threats prominent to Fiji as a SIDS are to be identified and strategies to overcome these are to be discussed. This will help Fiji form concrete strategies towards achieving its Nationally Determined Contributions (NDC). Fiji's NDC [13] was developed to achieve the objective of the UNFCCC which is consistent with Green Growth Framework 2014 (GGF) [14] and Sustainable Energy for All (SE4ALL) initiative of United Nations [15]. The NDC start in 2020 and end year is 2030. Its targets are reducing the import of diesel and heavy fuel oil to 200 million litres, close 100% renewable electricity and emission reduction of 30% by 2030.

Based on the data and information collected and analysed from Fiji Bureau of Statistics (FBoS), FEA, FDoE, and also from various stakeholders via personal visits, telephone and email correspondence, the objectives of this paper is achieved. The next section presents population and economic growth in Fiji, followed by past and current energy situation. This leads to the discussions on challenges and threats to energy access in Section 4. Section 5 discusses strategies that would help Fiji overcome some of the challenges and threats to its energy security and access. These discussions will be beneficial for potential investors in renewable and energy efficiency in Fiji and also to

Table 2
Population distribution in urban and rural areas in Fiji.
Source: Fiji Bureau of Statistics [8].

	Population											
	1986 (census data) Amount	%	1996 (census data) Amount	%	2007 (census data) Amount	%	2010 (Projected) Amount	%	2020 (Projected) Amount	%	2030 (Projected) Amount	%
Urban	277025	39	359495	46	424846	51	446000	52	527000	56	629000	61
Rural	438350	61	415582	54	412425	49	411000	48	409000	44	405000	39
Total	**715375**		**775077**		**837271**		**857000**		**936000**		**1034000**	

government and non-government organizations.

2. Fiji's population and economic growth

The energy demand is greater in urban areas than in the rural areas mainly due to the high population and relatively high income compared with rural areas. High income earners tend to increase their end use energy demand such as for electricity, fuel usage for transport and activities which are highly energy intensive. For Fiji, the population in the urban and rural areas is shown in Table 2. From 1986 to 1996, urban population increased by 30% while the rural population decreased by 5%. In the next decade (1996–2007) urban population increased by 18% while rural population decreased by 0.8%. The percentage of urban population increases mainly due to more job opportunities in urban areas than in rural areas or remote islands. For rural areas, jobs are mainly available in agriculture /farming and fishing sectors. In 2008 average rural household size was 4.8 persons compared to 5 in 2002 while the average household size for urban areas was 4.5 persons in 2008 compared to 4.7 in 2002 [16]. It is projected, that by 2030, Fiji's population will reach the 1 million.

The historical data for gross domestic product (GDP) at current factor cost and GDP per capita and annual population data were obtained from FBoS [7]. These data are presented in Fig. 2. The average annual population growth rate from 1968 to 2011 is determined to be 1.3% with a maximum annual growth rate of 3% and minimum of −0.3%. The decrease in population growth occurred in 1988 due to the first political upheaval (overthrowing of democratically elected government by military) in 1987 which lead to migration of a fair percentage of population [17]. If the annual growth rate in population is taken as 1% on average, then by 2030 the population of Fiji would just cross the 1 million mark.

GDP is a measure of a country's economic performance and gauges a country's standard of living [18]. GDP is the sum of private and public

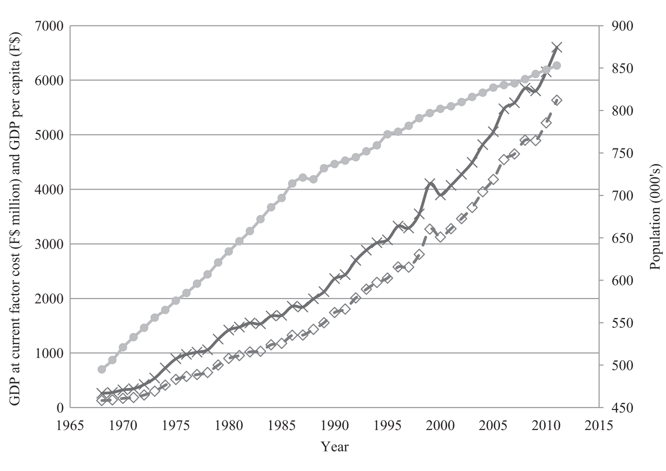

Fig. 2. Historical data for GDP at current factor cost, GDP per capita and population. Data Source: Fiji Bureau of Statistics [7].

consumption, government outlays, investments and exports less imports that occurs in a nation over a specific time. Fiji's economy has grown substantially over last 4 decades. Considering Fig. 2, the average annual growth rate for GDP from 1968 to 1980 was 17.4%, from 1981 to 2000 it was 6.5% and then from 2001 to 2010 it was 5.3%. However, there are a number of negative growths in GDP due to internal and external factors. The major internal factor is the political upheaval in 1987, 2000 and then again in 2006 which saw a decline in country's economic performance [19]. In addition, external factors such as spike in food and fuel prices in 2008 and global economic crisis in 2009 [19] also reflect in the negative growth.

Manufacturing industry contributed the most to the GDP in 2013, followed by transport, storage and communication and then by real estate and business, (Fig. 3). However, it should be noted that tourism industry (hotels, restaurants and transport) which has grown over the past years, is one of the main drivers of the economy and is the largest source of foreign exchange [20]. Tourism earnings contribution to GDP from 2011 to 2013 is 24–22% [21]. Each sector, in Fig. 3, one way or another relies on energy either in the form of electricity, fuel for heat or cooking or fuel for transport for its progress.

3. Current energy situation in Fiji

Fiji's economy has been growing steadily over the past decades resulting in increasing demand for energy in industrial, transportation, agriculture, tourism and commercial sectors. The energy situation in Fiji is described below in terms of available energy resources, electricity generation and energy consumption.

3.1. Energy resources

Fiji neither has any fossil fuel energy resources nor any nuclear power stations. It imports all its fuel requirements for transportation and electricity. Renewable energy resources are mainly used for electric power generation. Due to geographical location of Fiji, it has good renewable energy resources such as solar, wind, biomass and hydro. The following sub-sections describe the situation vis-à-vis these resources.

3.1.1. Solar energy

Annual solar insolation on horizontal surface in Fiji ranges from 4800 MJ/m^2 to 8900 MJ/m^2. The western side of Fiji is the dryer side of the country with higher solar insolation compared to the central or eastern side. Solar home systems (SHS) are commonly used in remote area and outer islands in Fiji and by the end of 2014 installed capacity for SHS will be 1170 kW, comprising approximately 5,800 units [22]. Grid-connected photovoltaic (GCPV) system is gaining momentum in Fiji and there are about 1.7 MW of GCPV and mini off-grid solar PV systems installed.

3.1.2. Wind energy

FDoE has set up wind monitoring stations at various locations in Fiji where there was a potential of good wind regime. The wind map

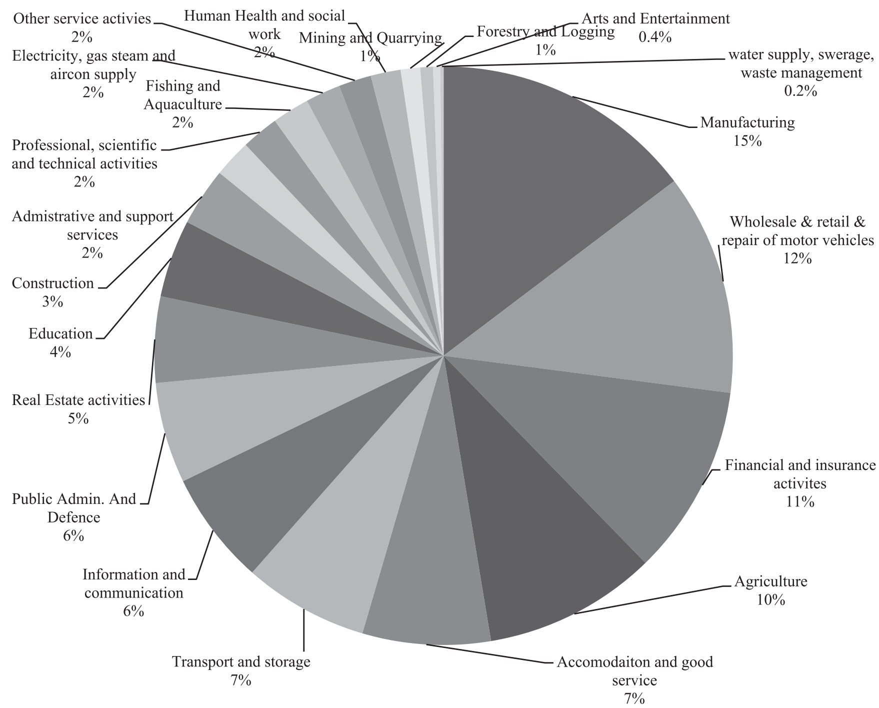

Fig. 3. Share of different sectors towards GDP at current basic prices for year 2013. Data Source: Fiji Bureau of Statistics [8].

created by AWS Truewind reveals that at 45 m height, Northern and Western part of Viti Levu, wind speeds are more than 6 ms^{-1} while the interior or highlands in Viti Levu and Vanua Levu wind speeds are more than 4.5 ms^{-1} [23]. This corresponds to class 2 and class 3 of wind power density ranging from 200 to 400 W m^{-2}. Presently, Fiji has a 10 MW wind farm which was installed and commissioned by FEA in 2007 and so far it has generated 33.4 GW h i.e. 120 TJ. This operation has saved FEA FJD12 million in diesel fuel cost and about 22 ktonnes of CO_2 emission by 2012 [24].

3.1.3. Hydro power

Hydro power makes the largest contribution from renewable energy resources for electricity production in Fiji. Currently, there is 130 MW of installed capacity of hydro power out of which 0.18 MW is installed by FDoE for off-grid power while the rest is installed by FEA (grid-connected). FDoE has started works on a 700 kW mini hydro in Taveuni with the help of Chinese government. In addition, FDoE has done hydro preliminary study for various sites around Fiji and found out 22 sites mainly in Vanua Levu and other smaller islands feasible for further long-term monitoring (2–3 years) [25]. Small hydro power (less than 1500 kW) potential in Fiji is around 14.7 MW [26]. Belena of FDoE [27] reports that Vanua Levu has 3 MW while Viti Levu has 83.3 MW of hydro potential.

3.1.4. Biomass energy

Fiji has huge biomass resource; 58% of its land area is covered by forests and agriculture is the 6th largest contributor to the GDP. 89% of the forest cover comprises indigenous trees while remaining 11% are exotic plantations (pine and mahogany) [28]. From 2001 to 2011, annual log production was 413,887 m^3 where 74.7% log production was from pine plantations, 19.7% from indigenous forest and 11.6% from mahogany plantations [29]. During timber production in saw-mills, approximately 40–70% of waste are generated in the form of slabs and sawdust [30] which can be used for energy production.

Byproduct of sugar production, bagasse is used in cogeneration of heat and power in the four sugar mills of Fiji Sugar Cooperation (FSC). From 2007 to 2010, 2.2 Mtonnes of sugar cane was crushed annually in Fiji [31]. Pine sawdust is used by Tropik Wood Industries Ltd. (TWIL) to generate electricity mainly for their use. FSC has a total of 16 MW plant capacity while TWIL has an installed capacity of 12.3 MW [32,33]. In 2010–11, the total surplus electricity exported to FEA grid by FSC and TWIL together was 25,150 MW h. Prasad [34] reports that FSC has a potential of 60 MW plant capacity capable of producing year around electricity.

3.1.5. Geothermal

Presently, Fiji does not have geothermal power plants, however, feasibility studies have been carried out at some locations and significant potential has been found. Fiji has 53 thermal areas around the country where surface temperature ranges from 31 to 102 °C which makes some of them contender for geothermal applications [35,36]. Vanua Levu has a potential of more than 23 MW while Viti Levu has 15.2 MW [37]. Overall, a geothermal power potential between 50 and 70 MW has been calculated [38,39].

3.2. Grid electricity generation by source and peak demand

By the year 2014, the total installed generation capacity for FEA was approximately 259.8 MW comprising 135.6 MW hydro, 114.2 MW diesel and 10 MW wind. A total of 14 diesel electricity generation stations are on Viti Levu, Vanua Levu and Ovalau, where 92 MW is installed on Viti Levu [40]. Biomass installed capacity is 28.3 MW by Independent Power Producers (IPP) namely FSC and TWIL [32,33]. Transmission is provided via 145 km of 132 kV lines and 350 km of 33 kV lines. Power distribution is achieved with more than 8000 km of 11 kV and 415/240 V lines [40]. The peak demand for the three main islands is shown in Table 3. From 2011 to 2012 there is a 7% increase

Table 3
Peak demand for grid electricity on main islands [41].

	Peak Demand (MW)			
Year	Viti Levu	Vanua Levu	Ovalau	TOTAL
2011	152.3	12.4	2.8	167.5
2012	162.5	16.1	3	181.6

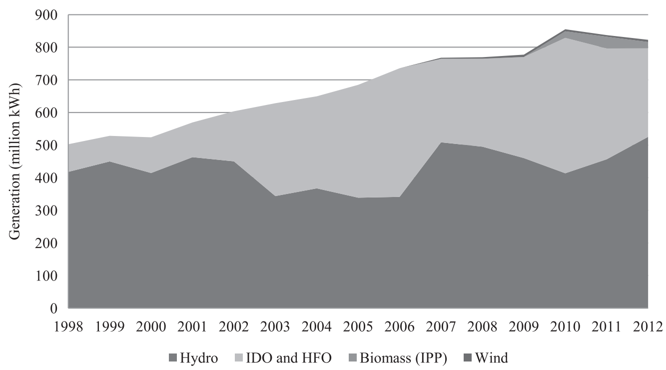

Fig. 4. Grid-electricity generation by source. Data source: Fiji Electricity Authority [24].

in peak demands on Viti Levu and Ovalau and 3% increase on Vanua Levu.

The base-load on Viti Levu is provided by hydroelectricity and during peak hours diesel generators compensate for the excess demand. On the other two main islands (Vanua Levu and Ovalau), grid electricity is provided by diesel generators. Grid electrical energy generated by different sources is shown in Fig. 4. There are three distinct periods for hydroelectricity generation. From 1998 to 2002, there is an average annual generation of 439 GW h; which followed a decrease in generation (annual average 348 GW h) from 2003 to 2006, and an increase again of an annual average generation of 477 GW h from 2007. Low water level at the Monasavu dam was the main factor which contributed to the dip in hydro electricity generation. Diesel generators (running on industrial diesel oil (IDO) and heavy fuel oil (HFO)) have been contributing a higher percentage of electrical energy since 2003. In 2012, 64% of the electricity was generated from hydro, 33% from diesel fuel while remaining 3% was from biomass and wind.

3.3. Energy consumption

3.3.1. Electricity consumption

3.3.1.1. Electricity consumption and generation. Considering 1979–2012 data, the annual average electricity production and consumption is found to be 590 million kW h and 470 million kW h respectively (Fig. 5). This corresponds to an average percentage difference with respect to production of 20%. Production includes electricity generated by FEA and any other independent power producer (IPP). On average there is 4.2% increase in annual electricity production and consumption. The income from sales of electricity has been rising over the years due to increase in tariff rate charged by FEA.

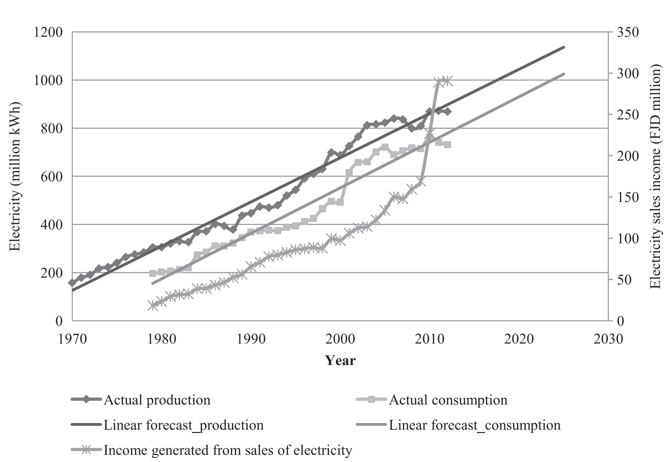

Fig. 5. Electricity generated and consumed in Fiji. Data Source: Fiji Bureau of Statistics [7].

Table 4
Linear projection equation for production and consumption of electricity in million kW h.

	Production	Consumption
Linear projection Equation (Million kW h)	y=18.356x−36035	y=18.91x−37268
R^2 value	0.9734	0.9554
Mean Absolute Error (MAE) (million kW h)	32.3	32.8
Mean Absolute Percentage Error (MAPE)	7.6	7.4

Considering, Fig. 5, there is a linear increase in production and consumption of electricity. Creating a linear trend line from this data gives the equations shown in Table 4 along with their R^2 value. The mean absolute percentage error (MAPE) for production projection is 7.6% while for consumption projection it is 7.4%. Based on this, the production value in 2025 would be 1,136 million kW h while consumption would be 1,025 million kW h.

3.3.1.2. Domestic and non-domestic electricity consumption. From 2007 census data, 75% of households have grid connected electricity while 89% of households had electricity either from grid or distributed generation. Only 4% and 19% of the households in urban and rural areas respectively were without electricity [9]. In central, western and northern provinces there were 15, 21 and 36% rural households without grid electricity which implies that rural electrification is a challenge since population is scattered and extending grid power to these areas is significantly expensive [42].

By 2012, FEA had 89% domestic customers and 11% non-domestic customers. Out of the 11%, 9% are industrial and commercial customers while the remaining 2% is institutions such as primary, secondary schools and place of worship [43]. The domestic customers consume only 28% of the total electricity consumed while the remaining 72% is consumed by the non-domestic sector (Fig. 6). Even though the number of non-domestic customers is significantly low, their consumption is high. The average annual growth rate of electricity consumption of non-domestic customers is 5% while that of domestic customers is 7%. Average annual electricity consumption per capita is determined to be 850 kW h/capita.

3.3.2. Fossil fuel consumption

Fossil fuel is used in all sectors of the nation, especially in the transport sector. Fiji imports all of its fossil fuel which putting a heavy

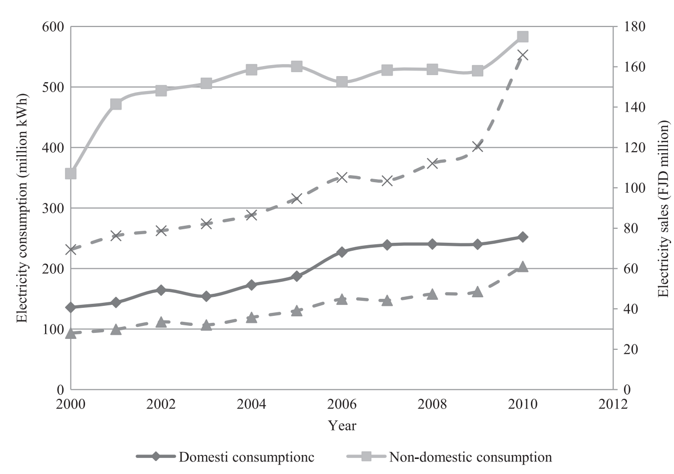

Fig. 6. Domestic and non-domestic grid electricity consumption. Data Source: Fiji Bureau of Statistics [44].

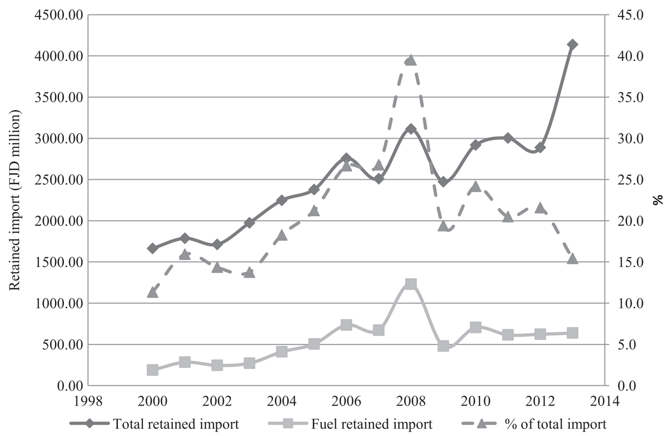

Fig. 7. Retained mineral import in Fiji. Data source: Fiji Bureau of Statistics [47,48].

burden on foreign reserves. Narayan et al. [45] report that over the period from 1996 to 2005 when the crude oil prices increased from USD 23/barrel to over USD 55/barrel foreign reserves in Fiji declined from equivalent to 6 months imports to 2.5 months import. According to Macrotrends [46], in 2000, the global crude oil price was approximately USD 37/barrel which steadily increased to a peak in July 2008 with a price of USD 140/barrel. From 2011 to present, the global price is fluctuating between USD 90–110/barrel.

Fiji does not have any "in country" conventional fuel source. It imports all mineral fuel products. Australia, New Zealand and Singapore are the top three countries from where fuel is imported in Fiji. Part of this imported fuel is then re-exported to other Pacific Island Countries. Considering FBoS data from 2000–2013, retained import of mineral products make up an average of 21% of the total annual import bill (Fig. 7). Fuel import bill has been increasing for Fiji (Fig. 7) reaching a peak in 2008 with retained fuel import bill of FJD 1.2 billion due to peak in global crude oil price.

3.3.2.1. FEA fossil fuel usage. The cost and amount of thermal fuel (IDO and HFO) used for FEA grid-connected electricity is shown in Fig. 8. Even though, the % share of electricity generation from thermal fuel has decreased from 2009 (Fig. 4) but from Fig. 8, the cost of fuel has increased in this period. This is attributed to the increase in global price for thermal fuels. For the past 4 years the fuel import bill for FEA varies between FJD100–140 million. The consumption of thermal fuel usage for electricity generation is fluctuating, which supplies electricity once the hydroelectric power plants are not able to meet the demand.

From 2007, FEA began to use HFO in addition to IDO mainly due to the low cost of HFO compared to IDO price per tonne. According to FEA annual report 2013, 35 MW of HFO generators will be installed by mid-2015 to replace energy output from IDO generators at Kinoya Power Station in Viti Levu [24]. However, the environmental cost of burning HFO (residual fuel oil) is greater than burning IDO for electricity generation. For gas/diesel oil the carbon dioxide emission factor is 74.1 tCO_2/TJ while for residual fuel oil it is 77.4 tCO_2/TJ [49].

Hence, the amount of HFO used by FEA should be closely monitored in the coming years. This diesel power station is for supplying peak demand when the hydro schemes are not able to meet the demand. However, if independent power producers (IPP) using renewable energy source for electricity generation who have signed power purchase agreement with FEA to supply grid electricity comes online, then the need for diesel power station will be reduced resulting in less CO_2 emission.

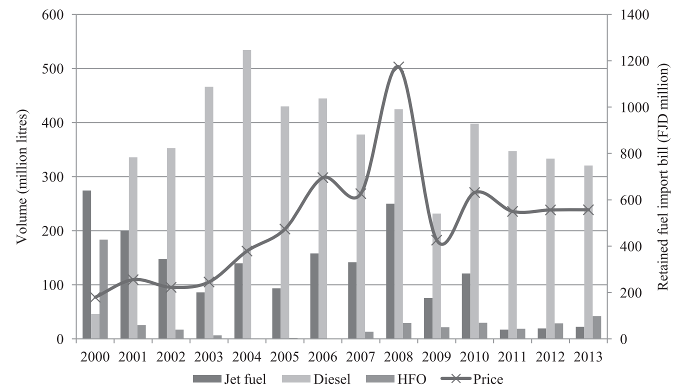

Fig. 9. Transport and industry fuel use. Data Source: [47].

3.3.2.2. Transport and industrial sector fossil fuel usage. The different fuels used in transport and industry sectors in Fiji are shown in Figs. 9 and 10. Overall, diesel consumption is high (annual average of 360 million liters (71%)) in the country compared to jet fuel (125 million liters (23%)) and HFO (30 million liters (6%)) as it is used in transport industry as well in the power generation (Fig. 9). Diesel and petroleum fuel for transport has annual average consumption of 202 million liters. This is on average 56% of the total diesel and petroleum oil consumption. Annual average total transport fuel (jet fuel, diesel and petroleum fuel) is 326 million liters.

From 2007, there has been sharp increase in import of liquefied petroleum gases (LPG) (Fig. 10). Before 2006, annual average consumption of LPG was 12.6 million kg which increased to an annual average of 18.6 million kg from 2007 to 2013. On average, LPG import in Fiji increases by 5% annually. The increase from 2007 is mainly due to the government removing import duty on LPG vehicles.

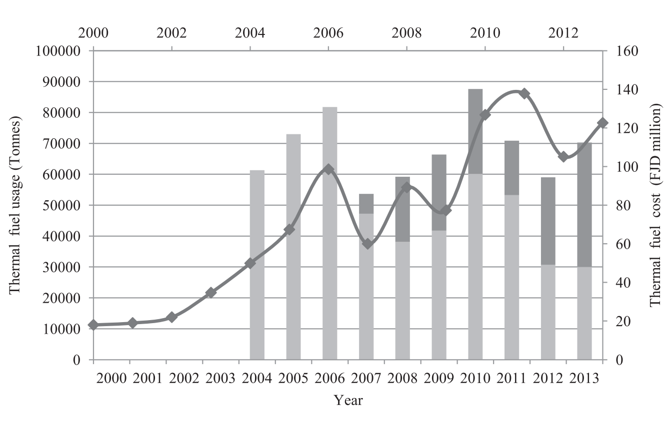

Fig. 8. Thermal fuel usage and cost for FEA from over the past years. Data Source: [24].

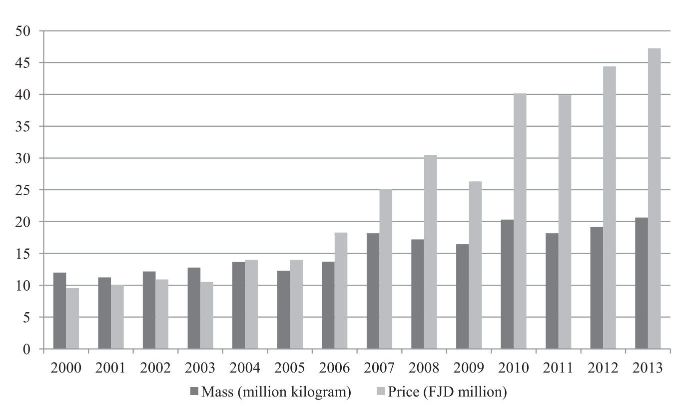

Fig. 10. LPG import in Fiji. Data Source: [47].

3.4. Energy conservation and efficiency

FDoE is the lead institution in Fiji that creates public and private sector awareness on energy conservation and efficiency through talk shows, media advertisements, competitions and helps carrying out preliminary energy audits for buildings. It also regulates and implements standards and labeling for refrigerators and freezers. Importers of freezers and refrigerators have to seek approval from FDoE on importing these products to ensure that only products which are compliant with Fiji/Australia/New Zealand Standards FS/AS/NZS 4474.1 and FS/AS/NZS 4474.2 are imported and affixed with energy star rating [50]. FEA also educates its customers on energy saving habits to help reduce their electricity bills.

Work in underway for FDoE to improve Fiji's building code so that the buildings use energy conservatively and efficiently. The first phase of this project has been completed with a status report and recommendations on what needs to be done to amend the Fiji National Building Code published [51].

4. Challenges and threats

Fiji has energy challenges and threats which are unique to SIDS. The following sub-sections discuss some of these which exist in Fiji.

4.1. High susceptibility to natural disasters

Fiji experiences floods, landslides and cyclones every year. This is due to the location of Fiji in the South Pacific Convergence Zones and mountainous volcanic islands. Tropical cyclones season is from November to April each year with an average of 2 cyclones per year. Over the past decade there has been average of 17 cyclones in total [52].

River flooding occurs every wet season and most landslides occur during heavy rainfall. Severe droughts do not occur every year but in recent times have occurred in 1987, 1992, 1997/98, 2003 and 2010 [53].

These natural disasters may have adverse effect on renewable energy projects if not planned properly.

4.2. High ratio of fossil fuel import to total export in Fiji

Since 2005, more than 50% of the export earnings have gone towards importation of mineral fuel products (Fig. 11). Years 2006–2008 have been the worst years where more than 80% of the export earnings have contributed to fossil fuel import. However, when tourism earnings are also considered then fuel import bill as a % of total earnings (export plus tourism) reduces to an annual average of 40%.

4.3. Dispersed islands within an island country

Dispersion of islands in Fiji makes it difficult to provide grid electricity on every island. Hence, only three major islands have grid electricity while the rest have electricity access through REU of FDoE and resorts on islands have their own diesel generators. For modern electricity access to remote areas and outer islands in Fiji, SHS are implemented which have partial Renewable Energy Service Company (RESCO) approach where SHS remain the property of FDoE, while private companies are contracted to provide service for a fee [54]. Studies carried out on RESCO in Fiji, reveal that problems exists in this approach such as replacement of parts takes a long time, private companies are not making enough profit (due to small number of SHS and low tariff FJD14/month which does not cover the maintenance costs) to invest technical expertise and management capacity [54,55].

Fuel wood is the energy source for cooking in majority of the remote islands as well as in interior of the main islands. According to the 2007 census data, 61% of rural households use wood open fire for cooking while only 2% use electricity. In urban areas, LPG is the dominating source of cooking fuel (45% of urban households), followed by kerosene (35% of urban households). This leads to the challenge of providing modern fuel for cooking in rural areas. Transportation cost of modern fuels (kerosene and LPG) from mainland to smaller outer islands is significant. In addition, there is also the issue of availability of boat or ships to transport fuel to remote islands.

4.4. Slow growth of RE sector in Fiji

Even though fossil fuel is expensive it is still widely used in Fiji. Renewable energy sources are used as alternative energy but its growth rate is very slow. Fiji does not have any RE manufacturing companies. RE and EE technologies in Fiji are brought from developed countries called horizontal technology transfer where a fully commercialized technology is transferred from one geographic location to another [56]. The following sub-sections discuss the growth rate of different RE technologies.

4.4.1. Solar

4.4.1.1. Solar home system (SHS). The pilot project of SHS started in 2002 by FDoE and there has been significant increase in the number of SHS installed from 2012 (Fig. 12).

During 2003–2010, SHS units were 100 W each and were mostly installed in Vanua Levu using Government of Fiji (GoF) funds. However, from 2012, Japanese funds were available which ensured SHS installation in maritime areas. Since then, 1000 SHS units have been installed where each unit was 270 W leading to 17% of total SHS installation in outer islands [22].

Before 2010, people were mostly opting for FEA grid extension to their homes or diesel generator system for rural electrification [22]. It can be seen from Fig. 13, that until 2009 diesel generator installation

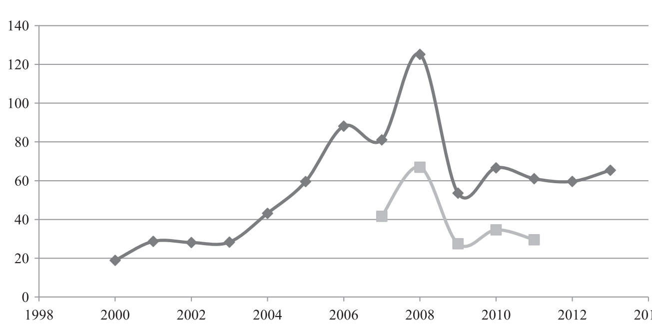

Fig. 11. Retained mineral fuel import as a% of export in Fiji. Data Source: FBoS [47,48].

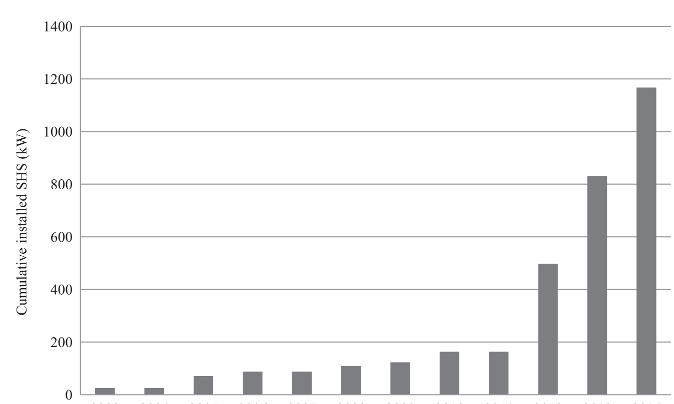

Fig. 12. Growth in installed capacity of SHS in Fiji. Data Source: [22].

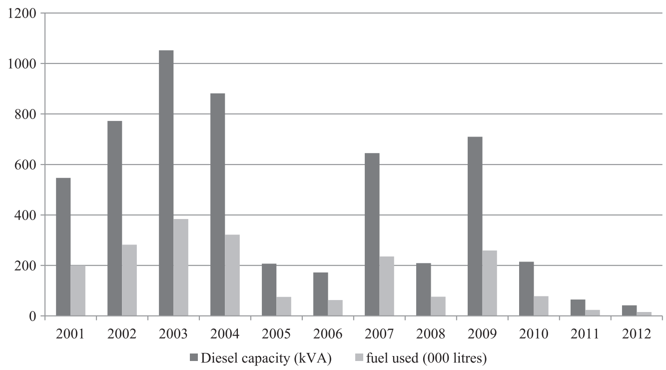

Fig. 13. Annual diesel generator installation and volume of fuel used. Data source: [57].

have been significant in outer islands and remote areas where FEA grid cannot be extended. During this time the cost of diesel was manageable by households and also SHS was not very popular. However, once the price of diesel increased and awareness on SHS were made to people by FDoE, people in outer islands were interested, showed by sharp increase in SHS from 2012 (Fig. 12) and sharp decrease in diesel generator set installation in 2011 and 2012 (Fig. 13). People came to realize that even though initial cost of diesel generators is relatively cheap compared to solar, its running cost over its lifetime is much costly due to its fuel cost which is further increased due to transportation costs to remote and outer island locations.

4.4.1.2. Solar PV mini off-grid and grid connected. Two companies in Fiji are actively involved in installation of GCPV or mini off-grid PV system in Fiji. GCPV systems have been installed however; currently it is not feeding into the grid. These remain off-grid. Mini off-grids are mostly used on island resorts. Two resorts have installed solar PV mini grid for their energy usage. The total mini off-grid and GCPV connected from 2012 to 2014 is 1743.35 kW [58–64].

4.4.1.3. Solar water pumps and solar lights for jetties. FDoE has carried out these installations. From 2007 to 2009, 4 villages have solar water pumps while 3 jetties have been installed with solar lights [22].

4.4.2. Hydro

FEA has installed approximately 130 MW of hydro power schemes mostly in Viti Levu with just 1.6 MW in Vanua Levu. While FDoE has installed 180.3 kW out of which only 30.3 kW is currently working in 2014 [65]. On the remaining 150 kW rehabilitation work is being carried out. In 1982, Fiji's first megawatt grid-connected hydro power scheme (80 MW) was installed. There was no significant increase in hydro capacity till 2002. From 2003 to 2006 10.8 MW was added by FEA while in 2012 40 MW Nadarivatu Hydro Scheme came online [66].

4.4.3. Biomass

4.4.3.1. Traditional biomass. This is referred to the widespread use of firewood for cooking purposes. In 2008, 19% of urban households used fuelwood for cooking while 77% of rural households were using wood [42]. Since the number of electric and gas stoves remain relatively unchanged from 2002 to 2008, increase in wood fuel consumption is due to increased availability of mahogany cut-offs in the market [42].

4.4.3.2. Biogas. Biogas digesters are installed in rural areas to replace LPG fuel for cooking. The FDoE has been installing this technology over the past decade funded by GoF. From 2009 to 2012, there are total of 14 biogas digesters installed in Fiji [67]. Out of this to date 10 are operational of size 111 m^3. The main reason for biogas digesters not operating are less feedstock or digesters were not maintained properly [67]. All the biogas digesters are in the central division.

4.4.3.3. Biofuel for electricity generation. Information gathered from FDOE reveals that till 2012, a total of 5518 kV A diesel generator capacity had been installed in rural areas. Out of this diesel capacity 1551 kV A of generators are now run on biofuel called “renewable diesel” (mixture of 20% coconut oil, 80% diesel with some additives) on 7 outer islands (Koro, Rotuma, Cicia, Vanua Balavu, Gau, Rabi and Lakeba) from 2010. This makes the around 28% of the diesel generators run on renewable diesel. The renewable diesel price at which FDoE sells to villagers in outer islands is 10–20 cents lower than the diesel price at outer islands [68]. It is worthwhile to note at this point that diesel price at different outer islands is different due to the transportation costs of diesel from mainland to the outer islands. The renewable diesel price has to compete with diesel price at outer islands.

4.4.4. Wind

Fiji's experience with wind energy has not been very successful. FEA installed its first and only wind farm of 10 MW capacity in Sigatoka in 2007. It has average annual capacity factor of 7%. This low value can be due to mis-match between the annual wind speed distribution and turbine's power curve. The annual average wind speed for the wind farm site was 5.47 ms^{-1} while the cut-in and rated wind speed for the turbine is 4 and 12.5 ms^{-1} respectively [40,69]. FDoE has not installed any off-grid wind energy conversion systems. However, it has carried out extensive wind monitoring systems over the past years [38]. In 2013, FDoE has been given FJD 0.8 million by GoF to carry out wind monitoring and determine possible wind power locations in Fiji.

4.5. High cost of RE in Fiji

Fiji like the other pacific island countries is far from major RE technologies manufacturing countries. The cost of purchasing a particular RE technology is huge due to additional transportation costs and low currency value. Despite a technology being considered “cheap” for developed countries, the cost of buying, installing and commissioning induces huge upfront capital investment. In addition, training or capacity building on the operation and maintenance is needed.

4.5.1. Installation cost of RE

The cost for different technologies installation cost in Fiji are shown in Table 5. When the size of RE is large, the cost of installation is less. For instance, large hydro installation is the lowest compared to mini hydro. Solar home system, since it is the smallest size it costs more.

4.5.1.1. Solar. According to the data from FDoE, in 2008 the cost per watt of SHS installed on mainland was FJD27 while this decreased to FJD20 in 2012 and 2013 which is a 27% decrease. For maritime areas

Table 5
Cost of installation of RE technologies.

Technology	Cost[a] (FJD/kW)	Source
SHS	20000	[22]
GCPV	13700	[70, 71]
Large Hydro (more than 1.5 MW)	6700	[24]
Microhydro (less than 100 kW)	12600	[72]
Wind	3400	[24]
Biogas	2500/m^3	[67]

[a] An exchange rate of 1FJD to 0.53 USD on 25/09/14 was taken.

the cost is FJD15/W. This cost is low compared to that of mainland installation because for maritime systems each SHS unit size is 270 W while for mainland systems it is 100–135 W.

Cost of 45 kW GCPV at the University of the South Pacific is FJD15600/kW [70] and the mini off-grid PV at an island resort is USD6250/kW=FJD11800/kW [71].

4.5.1.2. Hydro. FEA installed 42 MW Nadarivatu hydro power scheme in September 2012. The cost of this project was USD3.6 million/MW=FJD6.7 million/MW. FDoE installed 30 kW of microhydro scheme in Muana, Cakadrove in 1998. This project was funded by Korean government and the cost of project was USD6667/kW. However, this system is not operational since 2005 due to the pipes being damaged by cyclone and community was unable to fund repair costs [65].

4.5.1.3. Biogas. The average cost of installing biogas digesters is FJD2600/m^3 which takes approximately one month to install in good weather conditions and 2–4 months in bad weather conditions [67]. The cost increases during bad weather due to labor cost. During good weather the average cost of installation is FJD2000/m^3 while for bad weather it is FJD3000/m^3.

4.5.1.4. Wind. 10 MW wind farm in Sigatoka, Viti Levu was commissioned in 2007 and its cost was FJD3.4 million/MW.

4.5.2. Cost of electricity generation

Hydro has the lowest cost of electricity generation while wind energy is the highest (Table 6). Dornan and Jotzo [73] have calculated these costs and also determined the future cost of electricity generation from RE technologies by considering the cost reduction shown by the World Energy Outlook (IEA [74]). The future costs of generation are based on future RE installation. Bagasse and wind power plant the two technologies whose cost of electricity generation decrease in future with bagasse leading. The cost of electricity generation from new hydro power scheme almost doubles in future.

4.6. Lack of or minimum power sector reform

Reform in the power sector would lead to increase in competition and private sector participation, resulting in lower generation costs and increase in efficiency where customers would get electricity at a lower price and get better services [75]. Dornan reports that 13 out of 19 power utilities in Pacific SIDS are government monopolies which are performing poorly [75].

Political situation of a country is one of the factors which determine the success of the power sector reform process. Despite the political upheavals, Fiji has some degree of success in its reform in electricity sector. However, this success has not been to what it was initially planned [75]. There is still low private sector participation in the electricity sector. Currently only two IPPs; FSC and TWIL are generating electricity to sell to grid. However, calling FSC an IPP would be inappropriate as it is also state owned. FEA annual reports from 2005 to 2009 [24] report a number of private investors who have signed power purchase agreement (PPA) with FEA to supply grid electricity (Table 7). However, these developments have not been realized as yet.

Table 6
Present and future cost of electricity generation [73].

Technology	Cost (FJc/kW h)		% change
	Present (2009)	Future (2025)	
Hydro-power	19.59	32.41	+65
Oil-power	38.54	41.72	+8.3
Bagasse	28	17.21	−39
Sawdust	23	23.44	+1.9
Wind-power	92.62	73.34	−21
Solar-power		51.59	
Geothermal		22.68	

Table 7
PPA signed by IPPs with FEA [24].

Year Reported	Details
2005	250 kW wind power in Malevu. Pacific Free Energy Ltd has signed PPA with FEA.
	5 MW biomass power plant in Deuba fuelled by woodchips supplied by Fiji Hardwood Corporation and other sawmills.
2007	20 MW biomass power station in Nadi. Tropik Woods Industries Ltd (TWIL) signed PPA with FEA.
2008	Elpicon Ltd of Australia signed PPA with FEA to build Hybrid/biomass power station in Coral Coast.
2009	18 MW wood fired biomass power plant near Vuda Point. Pacific Renewable Energy Ltd signed PPA with FEA.
	10 MW waste to energy plant near Sigatoka. IViti Renewable Development signed PPA with FEA.

The customer tariff did not change much over past several decades (Fig. 14). Year 2010 saw the largest increase in tariff rate which was 34% for domestic (residential) customers, 31% for non-domestic (commercial and industrial) customers that consume up to 14999 kW h and 43% increase for non-domestic that consumes in excess of 14999 kW h. In January 2013, GoF decided to reduce tariff by 5% for all customers. A gradual increase in tariff over the past decades would have (i) made customers reduce their consumption as well as look into energy conservation and energy efficiency and (ii) decreased the impact of huge cost felt by customers due to the recent increase from 2010.

4.7. Higher energy output ratio or energy intensity

Rao and Rao [77] have determined energy output ratio (EYR) for various energy sources in Fiji using 1970–2005 data. EYR is mega joules (MJ) of a particular fuel to produce one million worth of output, i.e., energy output divided by constant GDP. This is sometimes also called higher energy intensity. They [77] found out that out of unleaded petrol and automotive diesel oil (ADO), unleaded petrol is more efficiently used (mean of 1.395 MJ/million constant factor GDP while ADO has ERY of 2.430). The total energy consumed in Fiji including electricity has an EYR of 7.419 while excluding electricity EYR is 6.809. This high value of EYR indicates Fiji government to consider energy efficiency and conservation.

From 2008 to 2012, FBoS data was analyzed to determine the

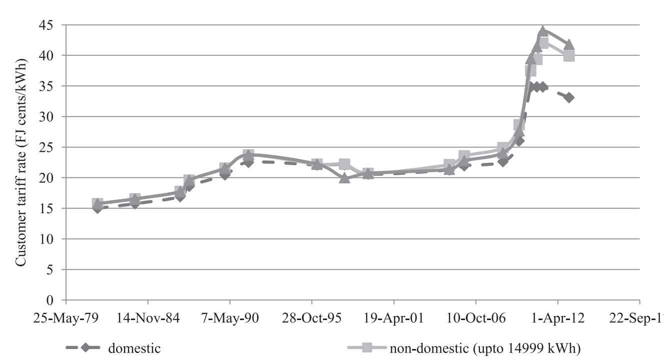

Fig. 14. Historical change in customer tariff rate in Fiji. Data Source: [76].

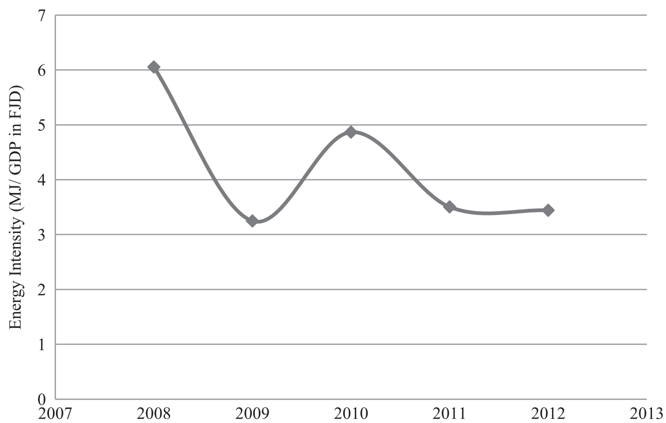

Fig. 15. Energy intensity in electricity and transport fuel consumption in Fiji over past 5 years.

energy intensity for Fiji. On average, annually 4.22 MJ of energy is consumed (electricity and transport) for every Fijian dollar of GDP. Fig. 15 shows the variation of energy intensity (energy consumption per GDP at current basic price of 2008) over the past 5 years. FBoS provided data on mineral fuel import and re-export. The retained import on mineral fuel was determined and then for different transport fuels the volume and mass of fuels were converted to energy value using lower heating values (LHV) for different fuels. The LHV was obtained from the energy statistics manual [78].

Considering Fig. 15, the energy intensity over the past 5 years is decreasing. One reason for this decrease can be due to the increasing electricity price to consumers. Another factor can be the introduction of standards and labeling for refrigerators and freezers from June 2011. From 2010 to 2011 there was a 3.05% decrease in electricity consumption while from 2011 to 2012 there was a 1.24% decrease.

Despite this measure, there is still room for improvement. More standards and labels must be available for electrical equipment so that it operates efficiently. In addition, consumer behavior has to change in order to reduce their energy consumption.

4.8. External aid in energy sector

Due to the small economy and limited financial and technical resources for capital investment in off-grid renewable energy and energy efficiency projects are restricted. This creates a need for external aid. Niles and Lloyd [79] emphasize that growth in energy technologies in SIDS for producing energy is possible with external aid as indigenous government do not have budget to invest in renewable energy or energy efficiency capital intensive projects.

From 2012 to 2014 in Fiji, projects concerning solar PV have received external funds totaling of USD2.334 million [80]. Funds have also been received in the past to carry out low carbon tourism in Fiji and for review of the national energy policy. In energy efficiency, fund was provided to promote cycles to reduce carbon emissions and congestion on roads and also for standards and labeling. There were support provided for capacity building of staff from utilities as well as “train the trainers” for off-grid solar PV. Assistance is also provided in organization, providing reports or assessments on how options available for increasing RE in power and transport sector, how to improve bulk procurement of fuel, quarterly report on fuel price market and what other energy option are there for Fiji and Pacific. In addition, there are some funds which have to be shared with other PICs.

5. Strategies

Measures taken on the challenges presented in the previous section would ensure sustainable development of energy in Fiji as SIDS. Considering the escalating fossil fuel cost and transportation cost of fuel to remote outer islands, Fiji's best option is to invest in RE and EE technology. In addition, to increase FEA's percentage of RE electricity generation, IPP contribution to grid must increase. However, for RE to be successful, energy needs to be used efficiently and conservatively. The following sub-sections discuss how this can be achieved with SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis done for every strategy, Table 8. SWOT analysis can assist in decision making on which strategy to prioritize. SWOT assists in building the strengths of the strategy, addressing the weaknesses, considering the opportunities available for a particular strategy and guarding against the threats. Strengths and weaknesses are internal factors which can be controlled while opportunities and threats are external factors.

Table 8
Energy institutions in Fiji.
Source: [91].

Institution	Energy Activity
Government	
Fiji Department of Energy, FDoE	Responsible for energy policies and plans, energy efficiency and conservation, renewable energy (RE) and rural electrification. Overall coordination of all energy related activities.
Fiji Electricity Authority, FEA	Responsible for generation, transmission and distribution of grid electricity. It plans the national grid.
Ministry of Public Enterprises & Public Sector Reform	Overseas business performance of FEA as a state owned enterprise. It also scrutinizes FEA's corporate plan and statement of corporate intent.
Fiji Commerce Commission	Economic regulation of the energy sector, including competition regulation and setting of fuel and electricity prices.
Prices and Income Board	Regulates wholesale and retail prices of motor spirit (also called gasoline or petrol), kerosene and automotive diesel oil (ADO) and influences to some extent the technical specification of fuels.
Ministry of Finance and National Planning, MoF	Responsible for planning and monitoring of energy budget for policy implementation and establishing and enforcing maximum petroleum fuel prices.
Non-Government	
Multilateral Agencies such as SPC, IRENA, Forum Secretariat, ADB, GEF.	Responsible for providing funding for energy related projects. Also provides their technical expertise.
Bilateral agencies such as AusAid, NZAid, JICA, KOICA, etc.	Provides funding for energy related projects. Also provides their technical expertise.
Educational Institutions such as USP, FNU and UoF	Responsible for carrying out research in energy.

5.1. Increase public-private partnership (PPP)

Increase public-private sector partnership to ensure growth in EE and RE market in Fiji. This partnership would ensure that the government provide legislations and policy to promote the RE and EE and private sector to provide technical expertise, finance sector for providing financing even though these projects are high risk, the educational sector to provide training and skills development for operation and maintenance of RE and EE projects. These partnerships would guarantee a whole-sector approach where all stakeholders are involved. Everyone involved would have some portion of their time/money/human resources/land invested in EE and RE projects to ensure that it succeeds and there can be accelerated feedbacks and project accepted readily. The risks in RE or EE projects would be shared by all stakeholders.

Due to dispersed islands in Fiji, distributed generation is often used, hence, pro-poor public-private partnership (5P) model can be adopted for guaranteeing the success of RE and EE in remote areas. In 5P model poor communities or remote/rural islands and villages are not only customers that receive the benefits but are also partners in business ventures [81]. In 5P model private sector involves local development banks, equipment manufacturers, energy service company (ESCO), philanthropic organizations, Central Business Organization (CBO), cooperatives and households themselves to increase the access to modern energy forms [81].

Eight different kinds of successful 5P case studies over the world have been discussed by Sovacool [81] to expand the energy access to poor communities. To achieve self-sustaining market of RE in rural communities there should be stringent technical standards for equipment, fines for business providing low standards equipment, phased grants provided to ESCO, and training for communities and women. Klitenberg et al. [56] stresses that involving the end users of RE or EE project from the beginning would ensure project meeting the requirement of consumers and in return consumers are aware and understand the operation of the system and its limitation.

5.2. Set-up risk mitigation facilities

RE and EE projects are perceived as high risk with regards to technology and cash flows by finance institutions. Parthan et al. [82] reports that absence of risk mitigation facilities in developing countries is constraining the flow of private finance to low-carbon energy investments. Agrawal [83] discusses a broad range (from standard insurance cover to judicious selection of project attributes) of mitigation strategies for RE project financing. This strategy can be adopted in Fiji where insurance is provided for RE projects which covers natural disasters. Past resource data (wind or solar) can be studied to ensure reduction in resource supply risk for energy conversion. In addition, for biomass resource, long-term contracts with resource suppliers should reduce resource risk. A good reputed and bankable contractor for construction minimizes the risks that project might not meet its specifications. Policies and an incentive framework reduce the risk RE and EE market development.

Wulfinghoff [84] presents 10 questions which need to be answered to decide whether a particular RE or EE project would succeed. The first and most important is determining the energy return ratio (ERR) (energy output to energy input) of the project; this ratio does not only consider the finance involved but also the energy required for manufacturing and installing the equipment and the energy needed to support the workers who produced the materials and during construction phase. He [84] informs that for a RE or EE project to be attractive ERR has to be minimum of 3:1 or 5:1. Out of 10 questions, another three questions are very relevant to SIDS:

1. *How close to reality is it?* Technologies introduced in SIDS must be well proven. Anything less would prove to be a risky project where investors are not willing to participate.
2. *Can it work well in our location?* Introduction of a technology which has been successful in other developed countries may not be favorable in SIDS. Factors such the availability of finance, technical expertise and geography for the implementation of RE or EE project need to be considered.
3. *Is the technology needed by the community?* Before introduction of any RE or EE technology in a community, needs analysis must be carried out.

Furthermore, another factor to minimize the risk of RE or EE failure is to educate consumers or community involved, that is, capacity building of stakeholders involved. Capacity building for all stakeholders can be carried out by the donor agency which sets up the RE or EE project or by GoF. Trainers in Fiji, need to trained for skills and knowledge in operation and maintenance of RE or EE systems, to provide more frequent training of communities. Trainers can also provide "refresher" training for communities on a regular basis. Once, communities involved are educated on the operation, maintenance and the cost of maintenance, they would be better prepared when RE or EE system shuts down due to some kind of damage. Capacity building on setting up and managing a finance scheme for maintenance of RE or EE can minimize the risk of failure of RE or EE system. With this knowledge communities can set-up some kind of business in the village to produce and maintain funds for maintenance.

The above paragraph leads to the concept of monitoring of RE and EE projects. For off-grid RE distribution, the FDoE monitors and provides support for the first 3 years. After this period, the recipient villages are the "owners" of the system and are responsible for the operation and maintenance of the system. However, there have been glitches in maintenance of RE system. Having a facility or section in FDoE that does proper and timely monitoring of every RE and EE system and provide necessary advise would remove or minimize the risk of failure.

Land is a sensitive issue in Fiji and before initiation of RE or EE project it must be ensured that some kind of memorandum of understanding or agreement is reached between the land owners and investors. Land owners must be compensated to avoid misunderstanding between stakeholders when the project has been commissioned.

In addition, due to geographic isolation of Fiji from the developed countries, cost of bringing RE or EE technologies in country can be quite significant in term of both finance and time. It is imperative that there should be duties or taxes removed or minimized from importing RE or EE products or equipment. See Section 5.7 for details on what government of Fiji (GoF) is currently doing.

5.3. Change customer behavior

It takes a great deal to change the behavior of customers in regards to their energy use and consumption. However, two important factors are fuel price or electricity price and standards on electrical appliances, fuel and vehicles to promote EE and conservation have significant impact on consumption.

Households: It is noticed that as the income level and social status of households increase, their energy consumption increase. One way to change the behavior is through electricity price which customers pay. Secondly, more standards on electrical appliances would ensure that only energy efficient products are imported. Another way is for FDOE to make contacts with households and informing them on how to monitor their consumption and how to reduce. Study by Vassileva et al. [85] supports this and indicates that there should be frequent communication between customers and energy providers, policy makers, etc. on household's consumption as well as options available to them for reducing it.

Industries: Even though the number of industries is less, their consumption of electricity far outweighs the household consumption. It should be made mandatory for industries to carry out complete energy audits at their premises which would point out areas that needs improvement to reduce their energy consumption as well as costs related to the improvement that need to be carried out. Government should assist industries for improving their energy efficiency by providing them with incentives such as reduced tax on energy efficient products and machines. GoF is currently offering no fiscal duty on imported machinery which is used to manufacture approved goods [86].

Transport: Transportation industry is the major consumer of imported fossil fuel (jet fuel, automated diesel oil (ADO), petroleum oil, LPG and other mineral products for road construction). The behavior of car dealers has to be changed. The choices they make on importing cars depend on the location from where they get the cheapest deal. GoF should provide car dealers with standards to importing vehicles on Fiji which should relate to the age of vehicles, type of fuel used, and engine quality. Currently there are criteria available for import of second hand vehicles [87] and also the excise and fiscal duty on import of LPG, CNG and solar vehicles have been removed [88]. This action will see an increase in importation and use of LPG vehicles which are much cleaner compared to diesel fuel. In addition, pilot program should be introduced for use of electric buses for public transport.

5.4. Credible Feed-in-tariff (FiT) structure for IPP

Introduction of feed-in-tariff (FiT) in earlier years and then renewable energy portfolio standards (REPS) in following years would boost investment in RE and EE sector for electricity generation and make an attractive niche for RE and EE market development. Currently, in Fiji there is no structure for feed-in-tariff (FiT) for electricity generated from different sources of electricity and in the different locations. Fiji Commerce Commission [89] reports that the new minimum IPP tariff rate is 25.65 Fijian cents/kWh. This was then re-evaluated in May 2014 to 33.08 Fijian cents VEP/kW h [90]. This new rate is expected to boost IPP investment.

5.5. Develop locally owned business in RE and EE technology

Usually the cost and time to obtain RE and EE equipment for local use is huge due to procurement done from "overseas". When there is business operating locally which sells equipment and services for renewable energy and energy efficiency, customers do not have difficulty in obtaining replacement parts or do not have to look faraway to purchase EE products. Local business making and selling affordable, durable and efficient wood stoves to rural area customers would boost energy efficiency in cooking stoves and improve lifestyles.

Providing funding to energy service companies (ESCO) would ensure their development and success of distributed renewable energy generation [82]. Conversing with FDoE personnel, it became clear that there is local expertise to install and maintain SHS, however, for hydro power; there are very few businesses who are experts. Usually, there are civil works businesses that are given the job to repair an off-grid damaged hydropower system. Hence, existence of ESCO which specialize in different RE and EE technology would minimize the chance of failure.

5.6. Strengthen the institutions supporting energy sector

The energy institutions in Fiji (Table 9), are responsible for energy planning, energy policy making, energy project financing, determination of energy prices (electricity tariff and fuel prices) and energy research. These institutions need to be well financed and adequately staffed to carry out its responsibilities effectively. In 2013, for renewable energy infrastructure development FJD19.4 million work of external aid was given. This aid either has been in kind or cash.

Using external aid (German Technical Cooperation (GIZ) – Deutsche Gesellschaft fur Internationale Zusammenarbeit and United Nations Development Programme (UNDP)), Fiji has been able to successfully review National Energy Policy for Fiji which acts as a guideline for the goals and objects to achieve by 2030. The access to modern energy to rural or remote islands and villages in Fiji is made possible by external aid; namely Chinese, Japanese, US, Korean, Turkish governments, to name a few. The technologies and expertise is provided by external aid. This assists GoF to install and commission renewable energy projects.

In addition, GoF should allocate more accountable budget for RE and EE development in Fiji to cater for initiation, implementation, construction, capacity building, and monitoring of these projects. This enables a high rate of success.

Currently for electricity tariff the regulators are FEA and Fiji Commerce Commission. However, FEA is in conflict to decide the tariff which IPP should be paid. GoF is working towards making Fiji DoE the regulator, to increase the share of IPP is grid electricity supply [41].

Table 9
SWOT analysis of energy strategies.

SWOT analysis of Pro-poor public-private partnerships (5P) in Fiji	
Strengths	Weaknesses
• PPPs exist for SHS; ESCOs provide maintenance work. • Fiji Development Bank and ANZ bank are offering loans for sustainable energy projects with WB providing 50% guarantee. This is under the Sustainable Energy Financing Project (SEFP). • FDoE provides training to villagers on operation and maintenance of distributed generators.	• Does not have PPP for small hydro, biogas, and other distributed generation systems apart from solar. • Uptake of loans under SEFP is low as remote island customers do not have good credit rating to give the remaining 50% guarantee [94]. • Technical standards for RE and EE equipment do not exist. • There are no penalties for supplying low grade/standard equipment. • Villagers not trained in managing maintenance funds.
Opportunities	Threats
• Outer island populations are now interested in renewable distributed generation. • Funds are available from non-government organization as well as from AusAid, EU and other governments for installation of RE and EE projects. • Competency standards are being developed for RE installers and designers • A number of initiatives are targeting human capacity development • The support from the Green Climate Fund (GCF) facility will help develop more RE/EE projects.	• Low number of customers for RE and EE in outer islands. At times, it may not be appealing to potential business. • Extra shipping costs involved in transportation to outer islands • Frequent cyclones might damage RE installations • Climate change impacts such as reduced rain fall and more intense cyclones affect the RE projects negatively • Consumers in remote locations do not have enough income to pay for energy services.
SWOT analysis of changing customer behavior	
Strengths	Weaknesses
• FDoE has standards on importation of refrigerators. They also have energy usage labels (or energy star rating) on TV, PCs, fridge, washing machine for customers to make the right choice. • FDoE do public awareness on energy conservation and energy efficiency via media as well as running competitions for industries and schools so that young generation is also aware. • Upcoming building codes. • Penalties exist for retailers who do not follow the standards and labeling program from FDoE.	• Not enough public awareness • Customers are still more into comfort rather than saving energy (be it electricity or transport fuel). • Carpooling is a new concept.
Opportunities	Threats
• National policy document supports EE and changing customer behavior.	• Standards for other electrical appliances are still to come out.
SWOT analysis of FiT	
Strengths	Weaknesses
• Electricity exported to the grid will be paid FJD 0.3308. • FDoE willing to formulate IPP investment framework to increase RE based electricity generation [94].	• Fiji does not have technology specific tariff. • Non-existence of effective IPP framework to boost investment in RE based power generation [94]. • FEA needs IPP to export electricity to grid 24/7/365.
Opportunities	Threats
• Standardized power purchase agreement has been drafted [95].	• Power utility not willing to agree to revised PPA.
SWOT analysis of developing locally owned business in RE and EE	
Strengths	Weaknesses
• Have companies which can be ESCO for solar PV systems.	• Non-existence of ESCO specializing in hydro, biofuel, and wind.
Opportunities	Threats
• Growth in RE projects • Duty concession on purchase of RE and EE technology	• High cost • Low rate of uptake of RE in outer islands
SWOT analysis of strengthening institutions supporting energy sector	
Strengths	Weaknesses

(continued on next page)

Table 9 *(continued)*

• Existence of several institutions supporting energy sector	• Coordination between different institutions is weak.
Opportunities	Threats
• Availability of external funds to support activities undertaken by institutions	• Competition between islands countries to obtain external funding.
SWOT analysis of Risk Mitigation Facilities	
Insurance cover for RE and EE projects	
Strengths	Weaknesses
• Have a number of insurance companies in Fiji. • RE and EE projects are increasing in outer islands. This would encourage companies to offer insurance cover for RE and EE projects.	• Currently, insurance cover does not exist for RE and EE.
Opportunities	Threats
• FDoE to provide workshop or information session for potential insurance companies on basics of RE and EE projects.	• RE and EE is not largely known to people at general. Hence, insurance companies have to learn about the technology before they come up with insurance products.
Capacity Building	
Strengths	Weaknesses
• Organizations such as SPC, UNDP, SEIAPI, etc. are constantly providing capacity building on RE and EE. FDoE and tertiary institutions also hold capacity building workshops/training. • Stakeholders are interested to participate in these capacity building workshops.	• Only given during the commencement of a project. Capacity building should be provided constantly to relevant stakeholders as a refresher course. • Human resource not available to take training.
Opportunities	Threats
• External funds are available for capacity building.	• Most RE and EE proposals do not include capacity building throughout the lifetime of the project.
MOU/A with landowners	
Strengths	Weaknesses
• Binding MOU or MOA before starting a RE or EE project. • Skilled human resource to put forward a good MOU/MOA.	• Landowners have to be sensitized on potential benefits of RE or EE project.
Opportunities	Threats
• Income generation for landowners	• No control over mindset of landowners. They change their minds over the years.

5.7. Fijian government initiative to reduce fossil fuel import

GoF has allocated FJD 1 million towards the Somosomo Hydro Project [92]. To promote greener environment and to reduce dependence on imported fossil fuel "Green Tax" has been introduced from 2013. In this tax users to pay an extra Fijian 2 cents for every litre of imported fossil fuel consumed except kerosene, pre-mix and white benzene [92]. However, this tax will not be applicable to public transportation such as bus industry, inter-island vessels and fishing so that these consumers are not burdened with this additional cost.

GoF has also allocated FJD 2.5 million for bio-diesel plants set up in smaller islands. In addition, FJD0.858 million has been allocated to purchase biofuel testing equipment. GoF is also providing 10 year tax holiday for bio-fuel production in Fiji from agricultural commodities into biofuel, duty free importation of plants, machinery and equipment for initial set-up and duty free importation on chemicals required for biofuel production [86]. FJD0.2 million has been set aside for biogas projects [87]. FJD0.4 million has been given to carry out feasibility study of wind, solar, hydro, biomass and geothermal and FJD 8.5 million allocated to grid extension to remote areas in two main islands. This corresponds to a total of FJD12.5 million for use in 2014. For 2013, in 2012 budget FJD 6.5 million was budgeted for renewable energy development projects and FJD8.5 million was budgeted for rural electrification [93].

Duty concessions are in place for purchase of renewable energy technologies. The Reserve Bank of Fiji's (RBF) Import Substitution and Export Finance Facility (ISEFF) was set up to improve Fiji's balance of payment position by assisting exporters, large scale commercial agricultural farming and renewable energy businesses to obtain credit at concessional interest rates [93]. In 2012, FJD2.7 million was used for renewable and sustainable energy funding.

6. Conclusions

This comprehensive study presents the state of affairs of Fiji's energy situation and the SWOT analysis will help develop pathways for Fiji's sustainable development. Fiji is characterized by its smallness, remoteness, lack of technical expertise on maintenance of RE systems and high dependence on imported fossil fuels. Due to a tropical island country, Fiji has vast renewable energy resources but no fossil fuel reserves. In 2012, hydro power dominated (64%) the grid electricity generation. 89% of household in Fiji have access to electricity. The electricity generation and consumption growth rate on average is 4% annually. The non-domestic customers are consuming 70% of the grid-electricity.

All fossil fuel is imported in Fiji and then some of it is re-exported to Pacific Island countries. Out of the total retained import, mineral products import takes up 21%. The year 2008 saw the highest mineral fuel import bill of FJD1.2 billion when there was global oil price hike while from 2010 to present, the retained fuel import bill fluctuates between FJD0.6–0.7 million. Over the past 14 years, the annual average volume of jet fuel and diesel imported in Fiji is 125 and 360 million litres with 16×10^6 kg of LPG where on average petroleum and diesel oil and jet fuel makes up 90% of fuel import bill.

One of salient features on fossil fuel import bill is that over the past 4 years is that it takes up on annual average of 40% of the total export and tourism industry earnings which is threatening to Fiji's economy. Dispersed islands lead to the challenge of accessibility and affordability of modern fuels to remote areas or outer islands. Wood open fire is most popular source of cooking in rural areas whereas LPG dominates in urban areas. Slow growth in RE sector is also a challenge. Reason for this is the huge upfront capital cost. By 2025, electricity generation cost from bagasse is the lowest with a value of FJ17.21 cents/kW h. Hence, it may be in FSC's interest to increase their generation capacity. Minimum power sector reform has led to low or negligible IPP. Potential IPP's have signed PPA with FEA; however, these projects have not been realized. Minimum power sector reform has also led to stagnant customer tariff rates from 1990 to 2005, resulting in increased electricity consumption and customers having no regard to energy efficiency or conservation. Currently, energy intensity is 4.22 MJ/GDP dollar which can be lowered by using energy more efficiently in production. In addition, Fiji has to complete with other PICs to get external aid since in some cases external aid is shared with other PICs.

Since, Fiji is completely dependent on imported fossil fuels for its transportation needs and 33% dependent on electricity generation, it has to import despite increasing costs. In addition, it cannot control the global prices. To overcome challenges in energy sector, Fiji needs to come up with strategies. To reduce dependence on fossil fuel, RE needs to be promoted and for this public-private partnership needs to be strengthened, risk mitigation facilities need to be established and institutions supporting energy sector must be strengthened. IPP tariff rate needs to be revised by considering the cost of generation from different sources. This rate needs to profitable for IPP to foster increase in IPP share in grid electricity supply. In addition, GOF has introduced tax incentives such as duty free on importation of RE and EE equipment, import of LPG vehicles is duty free and biofuel production tax incentives. For RE to be successful and to raise energy efficiency and conservation, customer behavior needs to be changed and locally owned business in RE and EE have to be developed.

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