ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

PEER REVIEWED
ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Role of Solar Photovoltaics in Future Electricity Generation in Fiji

Ravita D. Prasad[1,2], and Atul Raturi[1]

[1]*Faculty of Science, Technology and Environment, The University of the South Pacific, Laucala Campus, Suva, Fiji.*
[2]*College of Engineering, Science and Technology, Fiji National University, Nabua Campus, Suva, Fiji*
E-mail: ravita.prasad@fnu.ac.fj and atul.raturi@usp.ac.fj

Abstract

This main objective of this work is to investigate how different penetration levels of solar PV in Viti Levu's grid aids in achieving diversification of supply, reducing Fiji's fossil fuel consumption in generation, achieving Nationally Determined Contributions (NDCs) and also contributing to Fiji's Green Growth Framework (GGF). GGF is a living document developed to strengthen environmental resilience while at the same time growing the economy and driving social improvement. Long Range Energy Alternatives Planning (LEAP) tool developed by Stockholm Energy Institute is used for modelling where the base year is 2015 and the end year is 2040. The input data were mainly sourced from Energy Fiji Limited (EFL) annual reports, Fiji Bureau of Statistics and personal communication with EFL personnel.

With Fiji's GDP increasing at 3% per annum and population growing at 0.6% per annum, this study finds that Fiji's NDC target of 100% RE generation is possible at an investment cost of around 1.3 billion USD. In 2015, emissions from grid-electricity generation was calculated as 359 Gg of CO_2-e from modelling.

1.0 Introduction

Solar photovoltaics for electricity generation is rapidly gaining popularity among commercial businesses in Fiji. This is mainly due to a business model that one of main energy companies is using for grid connected solar PV. In this model, the solar company designs, installs, monitor, maintain the solar PV system and the customers only pay for the energy generated by the system. All the upfront costs of the system is paid by the solar company. Another reason can be declining cost of electricity from solar PV. In Fiji, a roof-top based solar PV system can cost around FJD3,000/kW or around FJD3,500/kW for ground based installation without considering the land cost. At present, a total of 3.6 MW grid connected solar PV is installed at multiple locations around main islands which supply power to commercial sector, Table 1. Most of these installations are roof-top. In comparison the peak load for Viti Levu is around 170 MW. So at the moment, grid connected PV is just 2% of the peak demand.

Table 1. Commercial sector grid connected solar PV in Fiji. Data Source: (PRDR, 2016; Sunergise, 2017; SunnyPortal, 2018)

Company	Type	Installed capacity (kW)
Western Viti Levu		
Terraces Apartment Resort Denarau	Roof top	72.5
Radison Blu Resort Denarau	Roof top	420
Rooster Poultry	Roof top	515
RB Patel Supermarket Jet Point	Roof top	125
RB Patel Supermarket West Point	Roof top	46
Port Denarau marina	Roof top	68
Port Denarau marina Retail complex	Roof top	250
Drasa Sai School	Roof Top	5
Central Viti Levu		
USP Lower campus	Ground based	45
USP Renewable energy training center		6
RB Patel Center Point Supermarket	Roof top	135
MarkOne Apparrel	Roof top	275
Coca-cola factory kinoya	Roof top	1100
Shreedhar motors Ford Dealership	Roof top	69
Shreedhar motors Subaru Showroom	Roof top	55
International secondary school suva	Roof top	88
Performance Floatation Development	Roof top	147
ANZ Pacific Operations Service center	Roof top	140

There are plans underway for the development of 5 MW grid connected photovoltaic (GCPV) power plant (FEA, 2016). Average annual insolation on a horizontal surface in Fiji is 5.4 kWh/m^2/day. Figure 1 shows average monthly insolation for different locations in Fiji where on the south side of Viti Levu (suva, Lakeba island Kadavu island) insolation varies from 3.7-6.4 kWh/m^2/day while on the west to north side of Viti levu insolation varies from 4.2-6.7 kWh/m^2/day (Figure 2 shows the locations). The World Bank (WBG, 2016) estimates that solar PV power potential ranges from 1022-1067 kWh/kW$_p$/year depending on location.

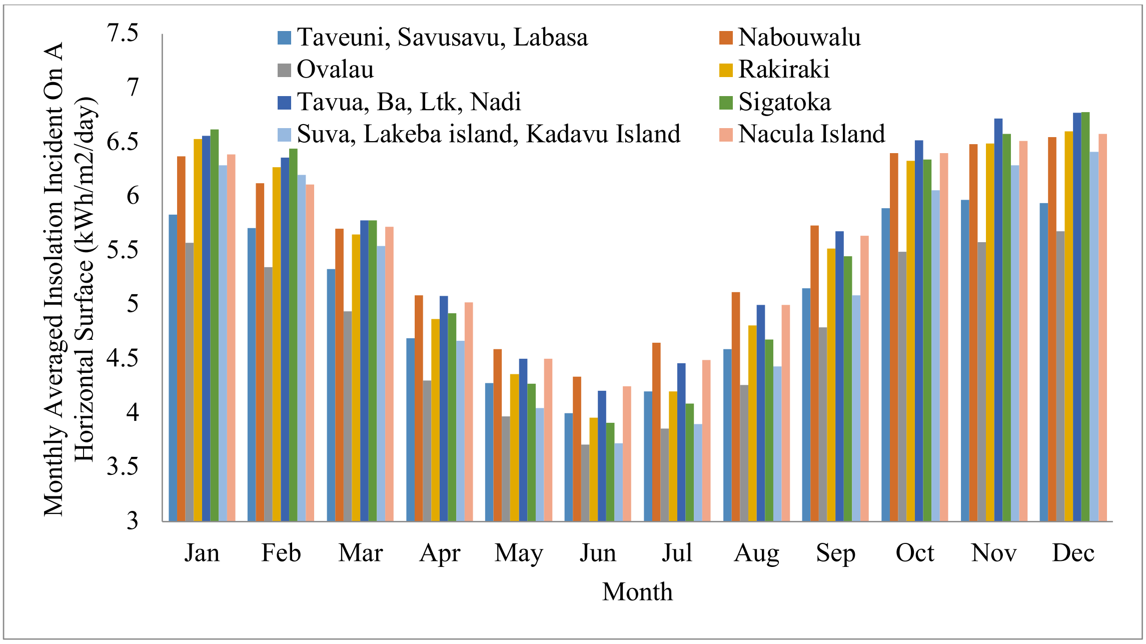


Figure. 1. Horizontal surface average monthly variation in solar insolation at various locations in Fiji. Data Source: (NASA, 2017).

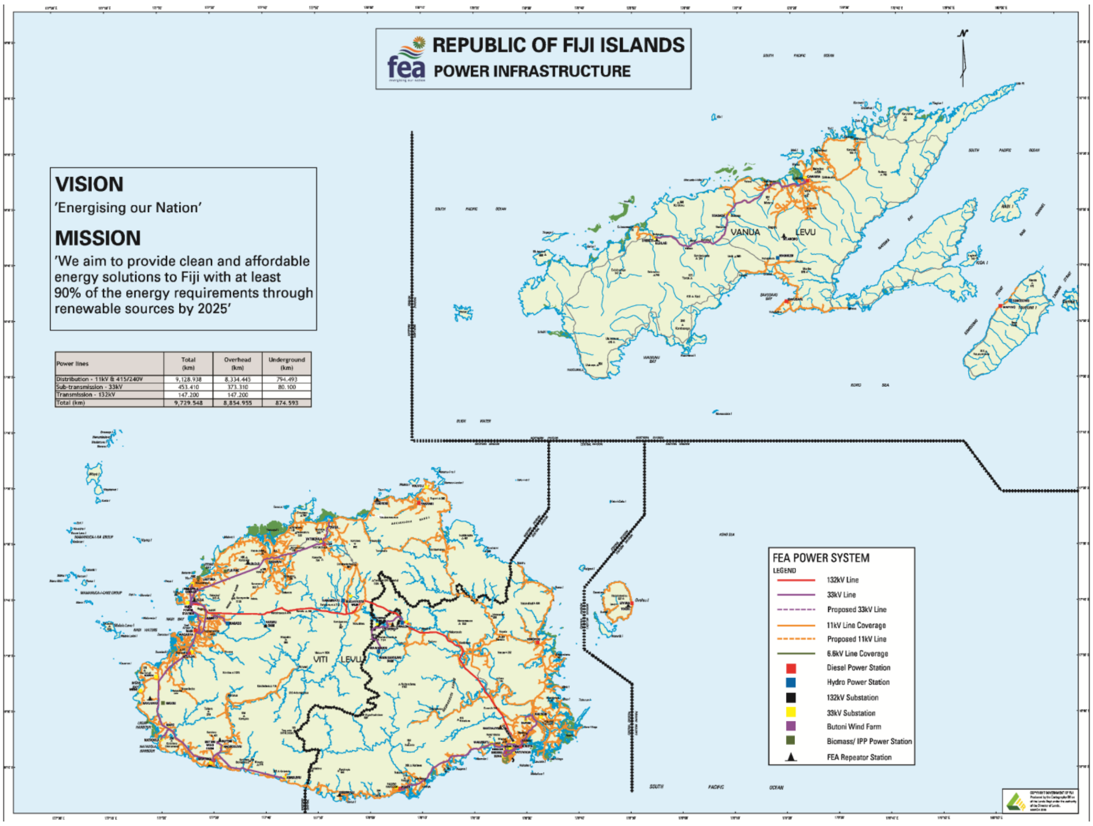


Figure 2. Power Infrastructure of EFL. Source: (Rao, 2016a).

The next section of the paper presents Fiji's grid electricity supply and demand. Section 3 describes the scenarios for increasing Solar PV share in electricity generation mix and section 4 presents results and discussion. Finally, some conclusions are made.

2.0 Fiji's grid electricity supply and demand

Fiji has more than 330 islands out of which third are inhabited with a total population of 884,887 people in 2017 and a GDP of 6.71 billion FJD[1] in 2016 respectively (FBoS, 2018a, c). Viti levu (VL) is the largest island, followed by Vanua Levu (VNL) and Ovalau. According to 2017 census data, 78% of total households are connected to grid electricity, Figure 3. supplied by Energy Fiji Limited (EFL). The off-grid households are supplied electricity by government through the Fiji Department of Energy (FDoE). These off-grid systems comprise solar home systems, diesel generators, pico-hydro and solar hybrid systems.

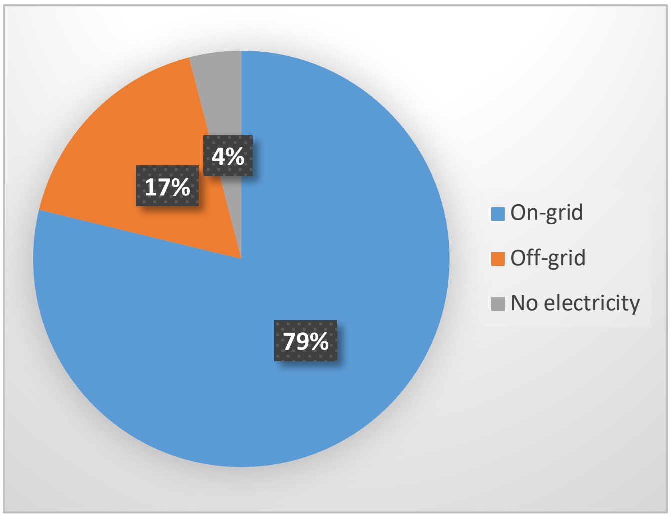


Figure 3. Electrification of total households in Fiji. Data Source: (FBoS, 2018b).

Grid electricity planning, generation, sales, transmission and distribution is soley done by EFL formely known as Fiji Electricity Authority (FEA). EFL has been responsible for generation, transmisison and distribution of electricity to Viti Levu, Vanua Levu and Ovalau, Figure 2. Recently in 2017, Taveuni island has also come under EFL operations. All these islands have thier own grid network with no inter-connections between them. The peak demand with their available generation capacity is given Table 2. It is seen that Viti Levu island has the largest power grid in Fiji. According to EFL's annual report, it had 174,530 customers in 2016, increasing by 1.5% relative to 2015 Viti Levu has the largest share of customer numbers as well as the largest demand for on-grid electricity with 94% of the total demand from Viti Levu, 5% from Vanua Levu and 1% from Ovalau in 2013.

A total of 842 GWh of electricity was used in 2016 which was an increase of 1.9% from 2015 consumption (FEA, 2016). Almost 75% of the total electricity consumption is by the commerical and industrial sectors.

To cater for this demand, EFL has 281.25 MW of available generation capacity, Table 2. Taveuni island has 0.7 MW of hydro power station with a 2 MW of diesel generator set installed in 2017. In 2016, 934 GWh of electricity was generated by FEA and Independent power producers (IPPs), Figure 4. Comparing energy consumption and generation data, there is around 10% difference relative to generation. This could be due to transmisison and distrubiton losses.

---

[1] FJD is Fijian Dollar where 1 FJD = 0.48 USD.

In the late 1990's, renewable energy (RE) share of electricity generation was high (around 85%), almost all hydro which has since decreased with RE share ranging from 46-67% over the last decade, Figure 4.

Table 2

EFL's available capacity for generation as at Dec 2015.

Location		Available Capacity (MW) (Rao, 2016b)	Peak demand (MW) (ParlimentFiji, 2018; Rao, 2016b)	Capital cost (FJD/kW) (Patel, 2015; Taylor et al., 2015)	Calculated reserve margine[2] (%)
Existing					
Viti Levu	Hydro	120.30			
	Wind	9.90			
	Industrial diesel oil (IDO)	72.85			
	Heavy fuel oil (HFO)	58.0			
	Total	*261.05*	170		54
Vanua Levu	Hydro	0.80			
	IDO	14.40			
	Total	*15.2*	7.4		105
Ovalau	IDO	2.30	1.8		28
Taveuni	Hydro	0.7			
	IDO	2.0			
	Total	*2.7*	0.28		614
		281.25			
Future					
	Solar PV			3,100	
	Biomass			8,000	
	Hydro			12,452	
	Pumped hydro			12,000	

Due to decreasing share of RE in electricity generation mix, EFL is burning more diesel and heavy fuel oil, which is financially and environmentally expensive for Fiji. The volume of fossil fuel utilized by EFL gradually increased from 87 to 119 million liters at an average rate of 6.1 % per annum from 2005 to 2015 while for this same period average annual increase in total electricity generation was 3%.

---

[2] Reserve margin = (Module Capacity – Peak Demand)/Peak Demand

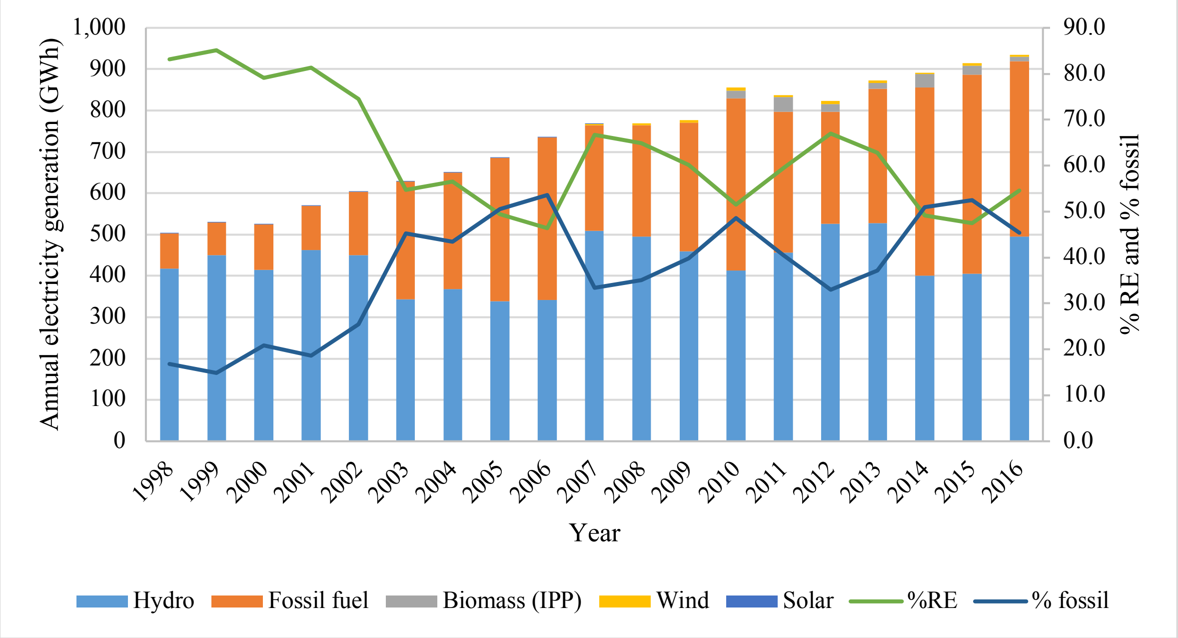


Figure 4. On-Grid electricity generation. Data Source: Various years of annual reports (FEA, 2016).

3.0 Methodology

This work focuses on grid electricity demand and generation for Viti Levu. Viti Levu is chosen for study because as mentioned in section 1, 94% of the total grid electricity demand is from Viti levu. Long Range Energy Alternatives Planning Systems (LEAP) tool is used study scenarios of different solar PV peneration into grid. LEAP tool is a user friendly software that is widely used by different countries around the world for energy-environement analyses. This is a flexible tool, where the user can define their energy systems based on the available data. However, one major drawback of this tool is that it currently does not have any module for grid storage which would allow users to directly model grid based storage. It is well established that for increasing solar PV share in generation mix, it is very important to consider grid storage. Viti Levu has 170 MW of peak demand which is at the moment catered by diesel and HFO generators when hydro is not able to supply. Because there is further hydro potential in Viti Levu, pumped hydro storage can be considered for future.

For modelling, our planning period is long-term (2016-2040). The domestic demand is affected by population where the average annual growth rate (AAGR) is taken as 0.6%. The non-domestic demand is considered to be affected by both population and real GDP. The AAGR for real GDP is taken as 3% while for population it is taken as 0.6%. The transmission and distibution losses are assumed to be 10%. The planning reserve margin (planning for additional generation capacity addition to meet the demand above and beyond a certain margin (Milligan et al., 2012)) is set at 30%.

In the electricity model, the set of existing generators (Table 2) were included along with their capacity factors. For future generation, different technologies such as solar, biomass and hydro were considered. The capital cost for hydro is taken from EFL's presentations (Patel, 2015), solar PV capital cost is based on the cost of installation as supplied by one of Fiji's major renewable energy companies, while all other technologies capital costs are based on IRENA report (Taylor et al., 2015), Table 2.

The dispatch rule used for generators are merit order dispatch except for solar it's dispatch rule is full capacity dispatch. This is to ensure full use of solar PV electricity generated. For the merit order given to different generators are based on them being renewable source or non-renewable. Low merit order means that generator will be dispatched first while higher values mean it would be dispatached later depending on the merit order number given. Existing wind, existing solar and new solar PV are given merit order 1. Existing hydro is given merit order 2, followed by new hydro and new biomass plants given merit order of 3. Pumped hydro storage is given merit order of 4 while the existing IDO and HFO generators and new IDO and HFO generators are given merit order of 5.

One major limitation of LEAP tool is that it is not able to model grid storage. Hence, to model for pumped hydro storage, normal hydro technology is considered but with a different merit order. We called this *pseudo pumed hydro storage*. If the existing and new renewable energy sourced generators are not able to meet the demand, then this pumped hydro storage is dispatched.

IDO and HFO generators are the main GHG emitters in electricity generation sector. (IPCC, 2006) default emission factors are taken in modelling. Main emissions from these sources are carbon dioxide (CO_2), with minor emissions of methane (CH_4) and nitrous oxide (N_2O).

Different scenarios studied are explained below:

3.1 Low solar PV penetration into grid

In this case, a total of 25 MW grid connected solar PV within the period 2015-2040 is installed. In order to cater for increasing demand new IDO and new HFO generators will be introduced if the existing generation processes are not able to meet the demand.

3.2 Medium solar PV penetration into grid with New hydro and new biomass power plants

In this scenario, a total of 80 MW of solar PV is introduced on Viti Levu grid at different times of the planning horizon (2015-2040). New hydro systems (44 MW in Qaliwana in upper wailoa and 40 MW in Namosi) are installed in in 2028 and 2035 respectively. New biomass (40 MW in Nausori and 18 MW in Vuda) will be installed in 2025 at Vuda and in 2030 at Nausori.

3.3 High solar PV penetration into grid with storage

In this case, a total of 200 MW of GCPV is installed on grid at different times in the planning horizon depending on when the existing technologies are not able to meet the demand. New hydro (40 MW in Namosi) is installed in 2028 respectively. New biomass (40 MW in Nausori and 18 MW in Vuda) will be installed in 2025 for Vuda and 2030 for Nausori.

4.0 Results and Discussion

4.1 Energy and peak power demand for Viti Levu in planning period

The demand for Viti Levu increases from 770 GWh in 2015 to 1,800 GWh in 2040 where three quarters of this demand is from commercial and industrial sector, Figure 5 This demand increase is based on 0.6 % population growth and 3% annual growth rate of real GDP.

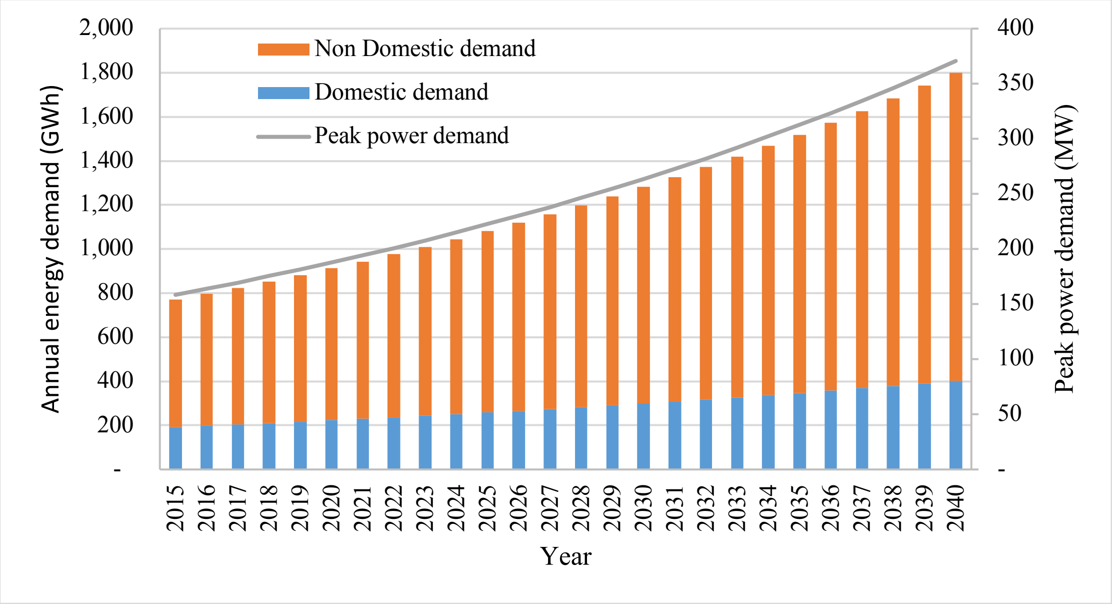


Figure 5. Annual energy and peak power demand for Viti Levu.

4.2 Reserve Margin

It was observed during modelling that when new solar, new hydro and new biomass are added in medium and high solar penetration, the reserve margin drops as low as 7% by 2022. This is because, new generation technologies are added from 2023 and after as time for designing, planning, installation and commissioning are considered to be 5 years from the base year. Hence, in order to keep the reserve margin at 30% (Figure 6), new IDO generators are added endogeously (this means that new IDO will only be added when the reserve margin drops below 30%). 5 MW of IDO was continuously added for medium and high PV penetration scenarios. This enables a more reliable generation capacity. Hence for medium peneration of solar PV, 155 MW of IDO generators are needed while for High penetration of solar PV, 70 MW of IDO generators are needed. Even though these generators are not run all the time, they are there to maintain the reserve margin.

For medium penetration solar PV, reserve margin increases in 2028 due to introduction of new hydro power plant, then in 2030 because of introduction of new biomass power plant and again in 2035 because of the new hydro power plants coming on-grid. Similarly, for high peneration solar PV, reserve margin jumps in 2028 because of introduction of new hydro and 2035 there is high jump in reserve margin because of three new power plants coming on grid in that particular year; new hydro, new biomass and pumped hydro storage.

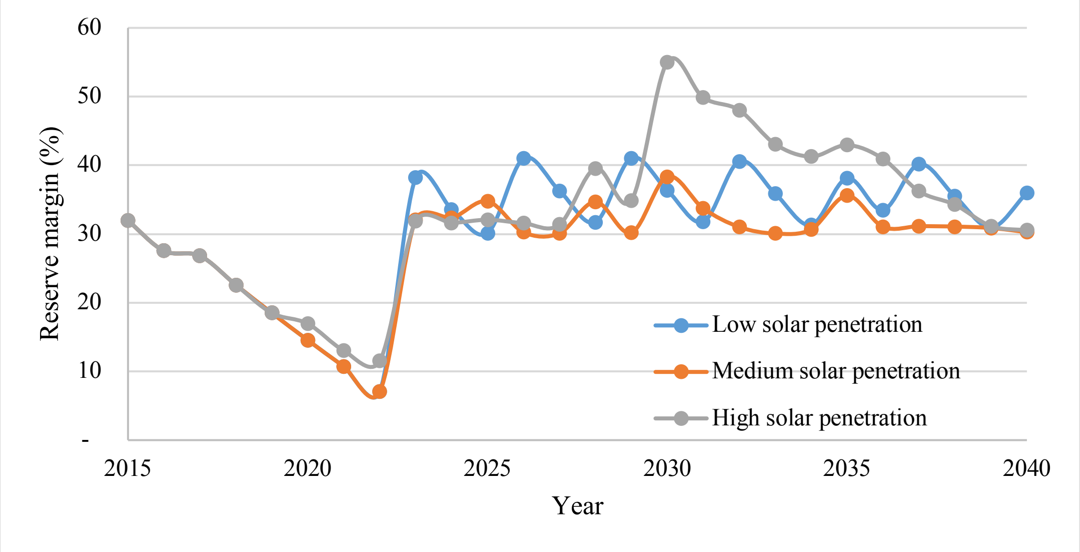
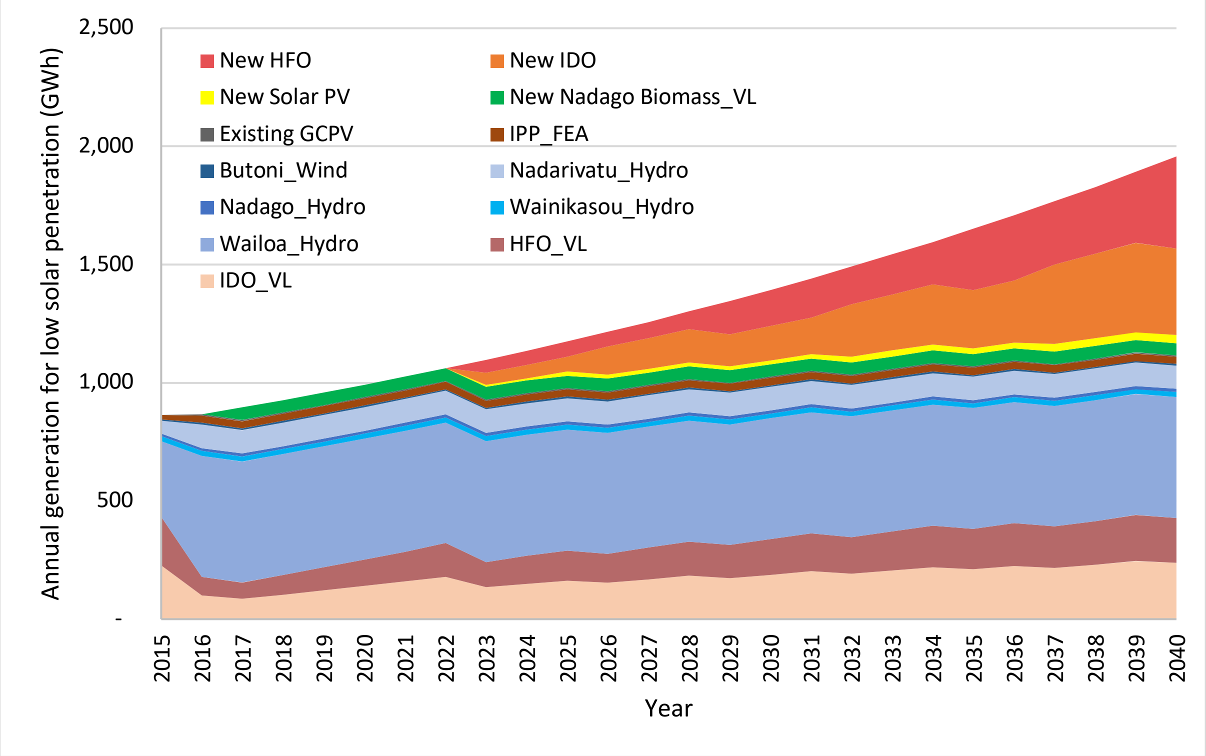


Figure 6. Reserve margin for generation.

4.3 *Energy generation for the 3 cases*

Considering, Figure 7, industrial diesel oil (IDO) and heavy fuel oil (HFO) generation are decreasing with increasing solar PV penetration into grid.



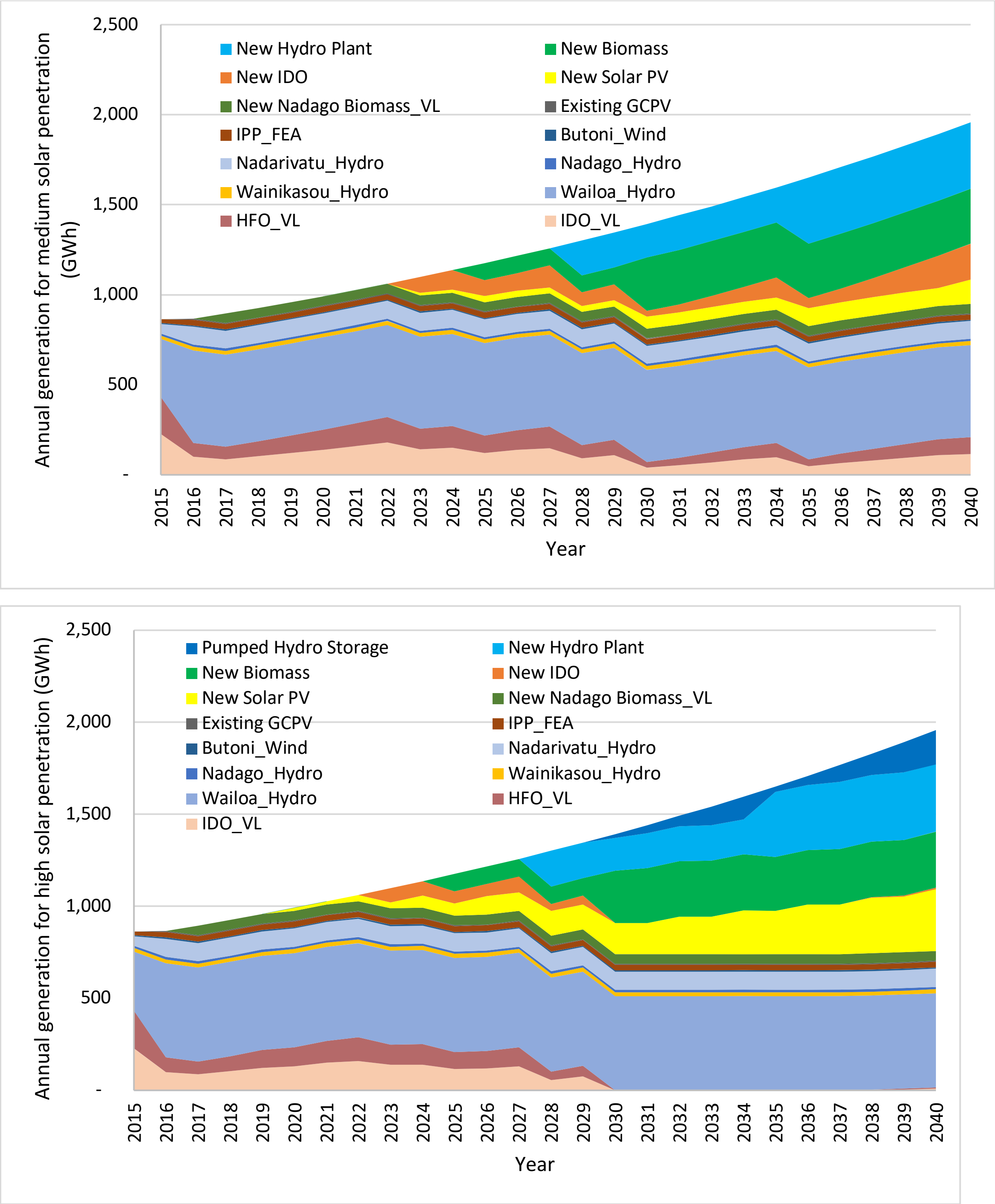


Figure 7. Annual generation from the three studied case for Viti Levu.

4.4 % RE share and emissions

Although Fiji's overall GHG emission is miniscule compared to global emissions, Fiji is very much committed to reducing its emissions as a follow-up to Paris agreement. According to Fiji's Nationally Determined Contributions (NDC) to emissions reduction, Fiji will reduce its BAU emissions by 30% in the energy sector (composed of electricity and transport sector). Out of this 30% reduction, 10% is unconditional while the remaining 20% is conditional on availability of financing for sustainable energy (SE) projects (GoF, 2015). Fiji's NDC reports 1,500 Gg of CO_2 equivalent emissions in 2013 for energy sector. Out of this 340 Gg of CO_2-e emissions was from the electricity sector. This is validated by this study's emission estimation of 397 Gg of CO_2-e in 2015. Fiji's Draft National Energy Policy (2013), targets 100% of electricity generation by 2030 (ECA, 2013) while Fiji's 20-year National Development Plan targets entire population to have electricity by 2021 and 100% of electricity from renewable energy by 2036 (GoF, 2017). On the other hand, EFL targets at least 90% of grid energy requirements to be met by renewable sources by 2025 (FEA, 2016).

In this study, the share of RE with medium PV peneration, reaches 80% by 2040, Figure 8. For High peneration, 100% RE generation is achieved from 2030. This is inline with Fiji's NDC.

Modelling results show that 359 Gg of GHG emissions is from electricity generation in Viti Levu in 2015 which increases to 981 Gg of CO_2-e by 2040 for low peneration solar PV, Figure 9. Medium peneration solar PV reduces emissions to 334 CO_2-e by 2040 while high penetration of solar PV further reduces emissions to 20 CO_2-e by 2040.

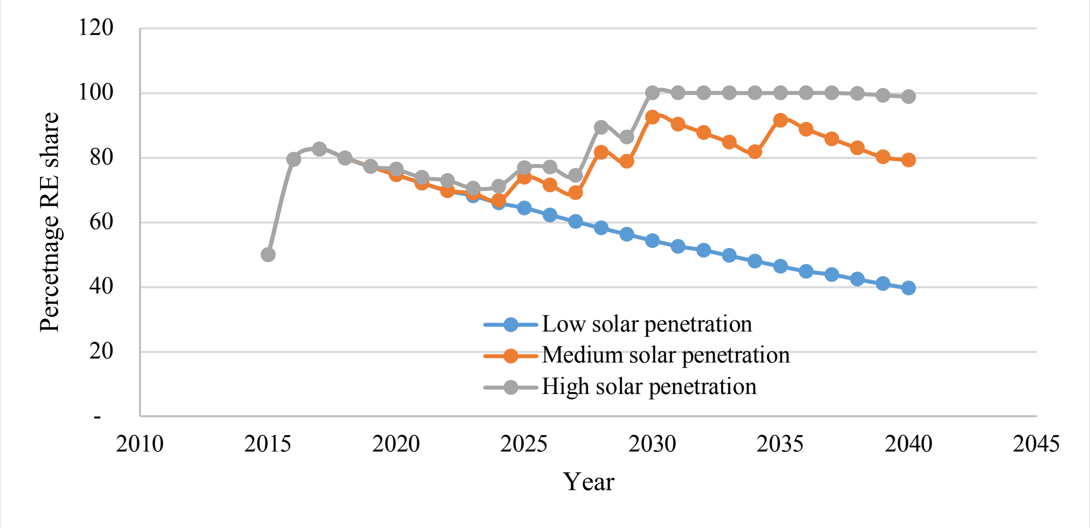


Figure 8. Share of RE generation for Viti Levu.

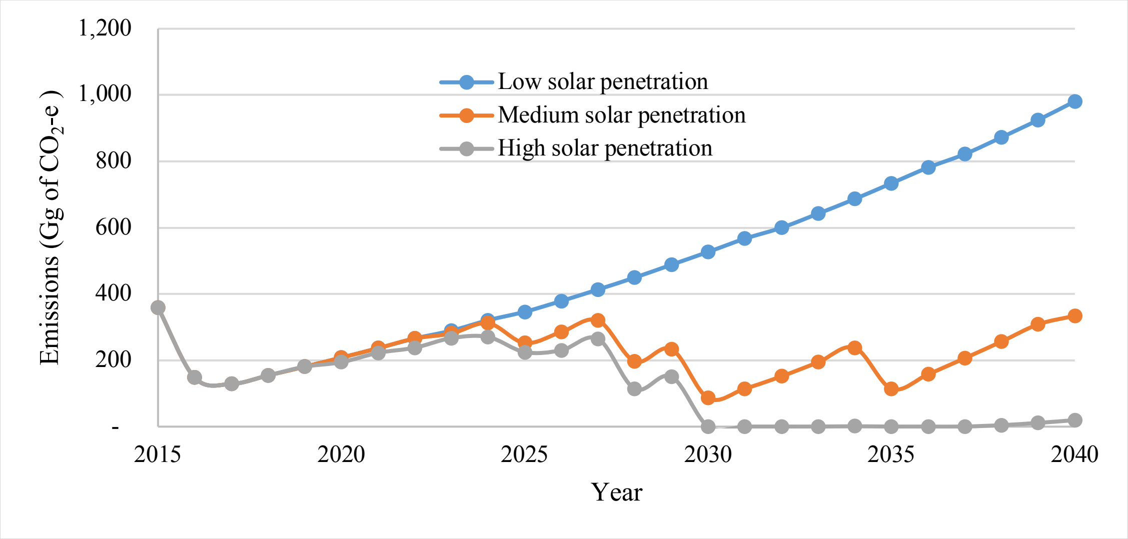


Figure 9. Emissions from the 3 cases.

4.5 Investment costs

To reduce emissions and achieve 100 % RE electricity generation while maintaining 30% reserve margin costs money. Taking indicative values for costs of investment of new hydro, new biomass and new solar PV projects in Fiji (Table 2), it is seen that for 100% RE share in electricity generation will have a total costs of USD1.6 billion by 2040. It should be noted that all this investment will not be needed at the same time but is gradually dispersed over the planning period, Figure 10.

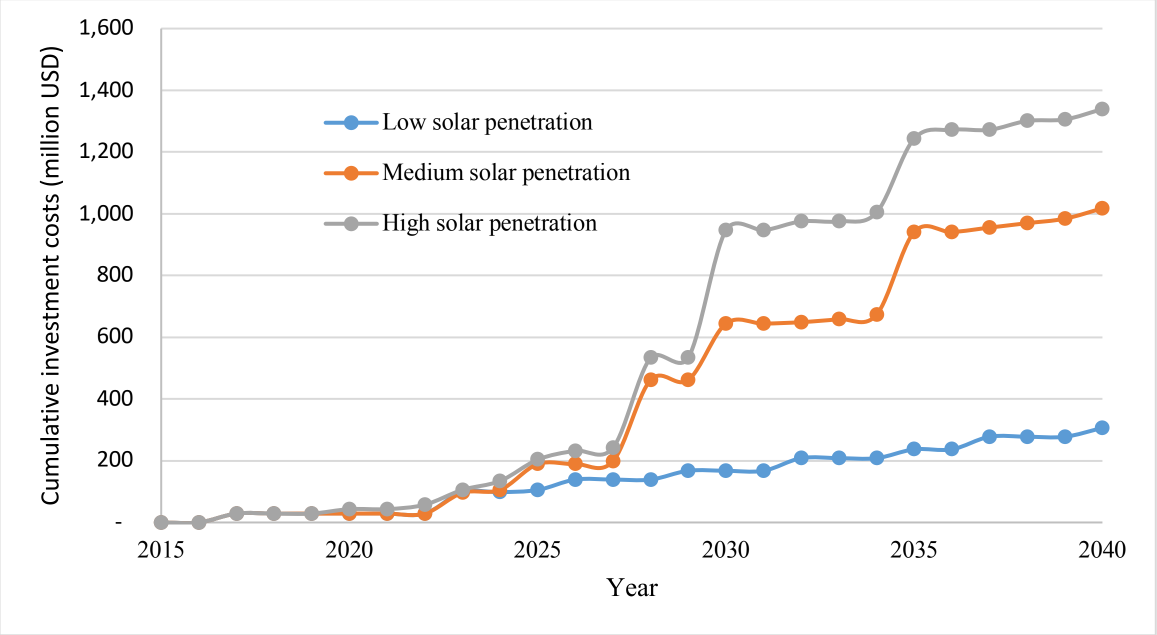


Figure 10. Cumulative investment costs for new generation technologies added to Viti Levu grid.

Solar PV is an economically viable option as the behind the meter grid connected solar PV have costs below the tariff charged to EFL customers in Fiji. According to (Berno, 2017), the rate the customers pay for solar PV generated electricity is less than rate that grid electricity customers pay to EFL. However, PV penetrations of more than 20-30% of total grid demand will cause grid stability challenges (Kumar et al., 2016). According to (Steen et al., 2014), 30% of the annual load demand can be met by solar PV without causing any voltage rise or overloading issues. Wind and solar outputs are highly variable due to their dependence on weather conditions. Changes in the wind speed or cloud cover can alter output almost instantaneously leading to grid voltage issues. (Katz et al., 2015) recommends dispersing solar panels or wind turbines geographically to reduce the impact of variability on the whole system.

Another option for achieving grid stability is grid storage that is discussed below.

For all the three scenarios, IDO and HFO generators are used to meet the peak demand. In order to minimize usage of IDO and HFO during peak load, it would be advisable to have some kind of grid storage in place. In our modelling, for high solar PV peneration scenario, pumped hydro storage is considered. This storage system was able to meet the peak demand and led to reduced power generation from diesel generators. In addition, storage allowed greater penetration of solar PV into the grid, thereby, increasing the RE share in electricity generation. From Figure 11 it is seen that solar PV installed capacity is equal to 5% of the peak demand for low penetration while for medium and high it is 21% and 54% respectively.

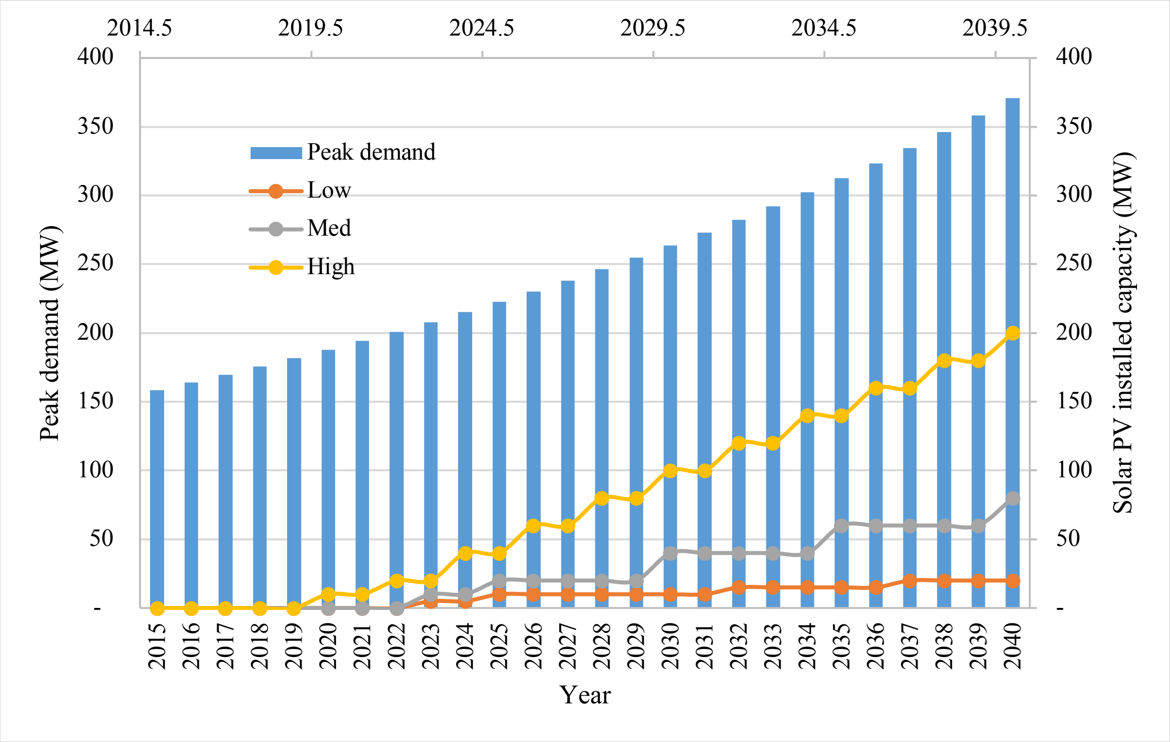


Figure 11. Ratio of solar PV installed capcity to peak demand

This study has shown that high level of PV penetration is more manageable when there is pumped hydro storage. Presence of grid storage provides additional capacity to meet peak demand, reduces the need for new generation capacity and consequently reduces the investment cost of generation. In addition, grid storage will be able to absorb excess elecctricity generated from solar PV when the demand is less and grid storage will generate power when existing generators are not able to meet the demand. This would ensure a stable grid network. However, there will be added costs of establishing grid-storage systems.

There are a number of grid storage options available such as pumped hydro storage, batteries, super-capacitors, flywheels, compressed air energy storage and others (IEC, 2011). However, according to (IEA-ETSAP and IRENA, 2012), pumped hydro storage is currently the only commercial storage option. (Blakers et al., 2017) have discussed about pumped hydro storage in Australia for achieving 100 % RE electricity system and that would provide greater grid stability. Fiji has the geography and water resources for establishing pumped hydro systems. Feasibility study needs to be carried out for this option. In 2017, EFL has opened a tender for feasibility study carried out for pumped hydro storage at Wailoa power station in Monasavu (FEA, 2017). Considering its geography, there could be many potential sites for establishing pumped hydro in Fiji.

In addition, recently, there has been an increase in battery-grid storage systems in some countries. Lithium-ion batteries are the main storage technology used for battery grid storage due to its decreased costs and greater capacities are being manufactured (IEA, 2018). There were close to 400 MW capacity of Lithium ion battery storage in different countries (Huff, 2014). South Australia has built the world's largest 129 MWh Lithium ion battery storage for grid which became operational in December 2017 (Gray, 2017) while New Zealand is considering battery storage for grid system but they plan to use it from 2022 onwards when the cost has much further reduced (TRANSPOWER, 2017). In the Pacific, Samoa has recently integrated Tesla batteries into its grid network (Peters, 2018). Fiji must consider these storage technologies if the target of 100% electricity generation is to be achieved.

5.0 Conclusions

This study explores the implications of introducing of grid-connected PV systems into Viti Levu's grid network in Fiji. Three penetration levels viz. low, medium and high are investigated. It is found that for high penetration of solar PV with an investment of around USD 1.3 billion, it is possible to reduce emission to almost zero and to have 100 % electricity generation from renewable energy sources. This study also found that with 200 MW solar PV (low penetration) , 84 MW hydro and 68 MW of biomass capacity for generation, the planning reserve margin is reduced. Hence, to improve reserve margin to 30%, 70 MW of new IDO generation capacity will need to be added, eventhough it does not run much resulting in minimised emissions. Due to LEAP software limitation of not able to model grid storage, a pseudo pumped hydro was added to study its effect on generation. This was in the high solar PV peneration case. It is seen that almost 100 % RE generation is possible for this case.

Acknowledgement

The authors sincerely thank Fiji Electricity Authority for providing necessary data and information for this research work.

References

Berno, T., 2017. Sunergise Fiji - Investment Case Study, https://cpb-ap-se2.wpmucdn.com/blogs.auckland.ac.nz/dist/0/269/files/2017/10/Sunergise-case-study-Final-281grp8.pdf [Accessed: 23/11/18].

Blakers, A., Lu, B., Stocks, M., 2017. 100% renewable electricity in Australia. Energy.

ECA, 2013. Draft Energy Policy July 2013. Economic Consulting Associates and Fiji Department of Energy

Eltawil, M.A., Zhao, Z., 2010. Grid-connected photovoltaic power systems: Technical and potential problems—A review. Renewable and Sustainable Energy Reviews 14, 112-129.

FBoS, 2018a. Bula and welcome, http://www.statsfiji.gov.fj/ [Accessed: 12/06/17].

FBoS, 2018b. Household survey data from 2017 census. Fiji Bureau of Statistics, Personal Communication in June 2018 via email.

FBoS, 2018c. Key Statistics. Fiji Bureau of Statistics

http://www.statsfiji.gov.fj/latest-releases/key-stats [Accessed: 02/02/18].

FEA, 2016. Annual Reports 2005-2016. Fiji Electricity Authority, Fiji

FEA, 2017. MR 323/2017 – Feasibility Study of Pumped Storage: Hydropower at Monasavu -Request for Prices. Fiji Electricity Authority, http://efl.com.fj/wp-content/uploads/2017/11/Tender-Specification-MR-323-2017.pdf [Accessed: 16/10/17].

GoF, 2015. Fiji's Intended Nationally Determined Contributions. . Government of Fiji Fiji.

GoF, 2017. 5-Year and 20-Year National Development Plan - Transforming Fiji. Ministry of Economy, Republic of Fiji, http://www.fiji.gov.fj/getattachment/15b0ba03-825e-47f7-bf69-094ad33004dd/5-Year---20-Year-NATIONAL-DEVELOPMENT-PLAN.aspx [Accessed: 15/10/18].

Gray, D.B., 2017. Tesla switches on giant battery to shore up Australia's grid, https://www.reuters.com/article/us-australia-power-tesla/tesla-switches-on-giant-battery-to-shore-up-australias-grid-idUSKBN1DV3VR [Accessed: 19/02/18].

Huff, G., 2014. DOE Global Energy Storage Database: The Role of Storage in Energy System Flexibility. International Energy Agency Workship https://www.iea.org/media/workshops/2014/egrdenergystorage/huff.pdf [Accessed: 19/02/18].

IEA-ETSAP, IRENA, 2012. Electricity storage - Technology brief. International Energy Agency- Energy Technology Systems Analysis Programme and International Renewable Energy Agency, https://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E18%20Electricity-Storage.pdf [Accessed: 22/09/17].

IEA, 2018. Tracking progress: Energy Storage. International Energy Agency, https://www.iea.org/etp/tracking2017/energystorage/ [Accessed: 19/02/18].

IEC, 2011. Electrical energy storage. International Electrotechnical Commission, http://www.iec.ch/whitepaper/pdf/iecWP-energystorage-LR-en.pdf [Accessed: 19/02/18].

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 2 - Stationary Combustion Intergovernmental Panel on Climate Change, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf [Accessed: 12/09/18].

Katz, J., Denholm, P., Pless, J., 2015. Wind and Solar on the Power Grid: Myths and Misperceptions, Greening the Grid. NREL (National Renewable Energy Laboratory (NREL), Golden, CO (United States)).

Kumar, V., Pandey, A., Sinha, S., 2016. Grid integration and power quality issues of wind and solar energy system: A review, Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES), International Conference on. IEEE, pp. 71-80.

Milligan, M., Ela, E., Hein, J., Schneider, T., Brinkman, G., Denholm, P., 2012. Volume 4: Bulk Electric Power Systems: Operations and Transmission Planning in Renewable Electricity Futures Study National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy12osti/52409-4.pdf [Accessed: 13/02/18].

Naivalu, S., 2014. Electricity consumption data by location. Fiji Electricity Authority, Personal Communication via email on 10/6/14.

NASA, 2017. Surface meteorology and Solar Energy. Atmospheric Science Data Center, https://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?skip@larc.nasa.gov [Accessed:07/11/17].

ParlimentFiji, 2018. Standing Committee on Economic Affairs: Report on Fiji Electricity Authority Annual Report 2016 - Parlimentry Paper No. 103 of 2017. Department of Legislature, Parliment House, Suva, http://www.parliament.gov.fj/wp-content/uploads/2018/03/FEA-2016.pdf [Accessed: 04/09/18].

Patel, H., 2015. FEA's strategies & plans and opportunities in Fiji's renewable energy sector, Renewable Energy Investment Forum for Fiji, Fiji.

Peters, A., 2018. The island of Samoa is going 100% renewable - with Tesla's help. Fast Company, https://www.fastcompany.com/90209339/the-island-of-samoa-is-going-100-renewable-with-teslas-help [Accessed: 17/09/18].

PRDR, 2016. Sunergise Solar Grid Connected Systems in Fiji. Pacific Regional Data Repository for SE4ALL, http://prdrse4all.spc.int/node/4/content/sunergise-solar-grid-connected-systems-fiji [Accessed: 06/07/17].

Rao, K., 2016a. Figure for power infrastructure for Fiji. Fiji Electricity Authority, Personal Communication on 24/10/16.

Rao, K., 2016b. Overview of Our Current Work and Progress for Renewable Energy Power Generation in Fiji, Capacity Building Workshop for Local Stakeholders on the Development of Renewable Energy Based Power Generation Systems, Radisson Hotel, Nadi. 12/10/16.

Rao, K., 2016c. Station capacities for FEA grid and Hourly Electricity demand 2016. Personal Communication on 13/12/16 and 11/04/17, Fiji Electircity Authority.

Shah, R., Mithulananthan, N., Bansal, R., Ramachandaramurthy, V., 2015. A review of key power system stability challenges for large-scale PV integration. Renewable and Sustainable Energy Reviews 41, 1423-1436.

Steen, D., Goop, J., Göransson, L., Nursbo, S., Brolin, M., 2014. Challenges of Integrating Solar and Wind into The Electricity Grid. Systems Perspectives on Renewable Power.

Sunergise, 2017. Coca-Cola AMATIL launches energy efficient solar initiative, https://www.sunergisegroup.com/news/2017/7/4/coca-cola-amatil-launches-energy-efficient-solar-initiative [Accessed: 15/10/18].

SunnyPortal, 2018. USP/KOICA 45kW PV System Profile, https://www.sunnyportal.com/Templates/PublicPageOverview.aspx?plant=f46fa170-f258-4618-bde4-63d53a65b45d&splang=en-US [Accessed: 15/10/18].

Taylor, M., Daniel, K., Ilas, A., So, E.Y., 2015. Renewable power generation costs in 2014. International Renewable Energy Agency (IRENA)

Germany.

TRANSPOWER, 2017. Battery storage in New Zealand: Discussion Document, https://www.transpower.co.nz/sites/default/files/publications/resources/Battery%20Storage%20in%20New%20Zealand.pdf [Accessed: 19/02/18].

WBG, 2016. Global Solar Atlas: Fiji. The World Bank Group, http://globalsolaratlas.info/downloads/fiji [Accessed: 08/09/17].