INTERNATIONAL SOLAR ALLIANCE

Draft Pre-Feasibility Report for Implementation of Solar pumps in Fiji

Table of Contents

List of Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
a.s.l.	Above Sea Level
DC	Direct Current
EBRD	European Bank for Reconstruction and Development
EESL	Energy Efficiency Services Limited
EFL	Energy Fiji Limited
EIB	European Investment Bank
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Green House Gas
HP	Horsepower
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
km	Kilometre
kW	Kilowatt
kWh	Kilowatt Hours
LNG	Liquefied Natural Gas
LoC	Line of Credit
MDEC	Merowe Dam Electricity Company
MW	Megawatt
NFP	National Focal Points
PV	Photovoltaic
R&D	Research and Development
REA	Electricity Regulatory Authority
REREDP	Rural Electrification and Renewable Energy Development Project
RHH	Rural Households
SHS	Solar Home Systems
SSAAU	Scaling Solar Applications for Agricultural Use
SSLS	Solar Street Lighting System
SWPS	Solar Water Pumping Systems
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
UL	Underwriters Laboratories

List of Figures

List of Tables

1. Executive Summary

Fiji, located in the South Pacific Ocean, is an archipelago of 333 volcanic islands and 522 islets. Of its 333 islands, 110 are inhabited. Viti Levu and Vanua Levu are the two largest islands accounting for 87% of the total Fiji population.

Fiji is having geographical advantages to have a reasonable electricity generation mix between the renewables and thermal sources. Apart from mountain ranges, rivers and dense and marshy forest, the country is also having undulating coastal hills and lowland plains.

Fiji claimed independence in 1970 and is a multicultural and harmonious country. The population consists of indigenous Fijians, Indians, Chinese and Pacific Islanders in addition to this there are a lot of tourists that visit to the islands throughout the year.

Fiji Electricity Sector

Fiji's national electricity access rate of 96% and is highly sourced from the imported diesel oil (approx. 50%). Blessed with advantages of the natural energy potential, the renewable power generators in Fiji have generated approx. 55% of electricity (i.e. 569.26 million units), in 2018. The installed renewable energy capacity in 2018 stood at 213 MW comprising of 138 MW of Hydro power, 54 MW of Biomass, 10 MW of Wind power and 10 MW from Solar energy sources.

Connectivity and Accessibility

The modes of transport used in Fiji include rail, road, water, and air. The rail network is mainly used for movement of sugar cane. Suva and Lautoka are the major ports managed by Fiji Ports Corporation Limited.. There are 122 km of navigable inland waterways. There are two international airports, one other paved airport, and over 20 with unpaved runways.

Climate and Rainfall

Fiji has a tropical climate, with a hot, humid, and rainy/wet season from November to April and a dry season from May to October. Up to 80% of the annual total rainfall falls during the wet period. Tropical disturbances, cyclones and high intensity rainfall are frequent causing floods ranging in magnitude from moderate to very severe. The annual average temperature of Fiji lies between 20-27°C. Changes in the temperature from season to season are relatively small and predominantly depend on the surrounding ocean temperature.

Soil

The country is divided into three major classes of landforms - plains, low mountains and hills as well as the high mountains. Majority of the areas in Fiji are very fertile as the archipelago is made up of volcanic soil and contains a high concentration of Iron, aluminum oxides and hydroxides. The soil is usually reddish or yellowish in color. Under the USDA Classification System the soils found in Fiji fall into nine soil orders.

Groundwater status

Groundwater is available on both the large islands and small low-lying islands at superficial and medium-depth strata, in either fractured rock or sedimentary formations. About 5,273 million m^3/year of renewable groundwater is estimated in Fiji. Groundwater is used by the large number of people in Fiji who obtain their water from springs, hand-dug wells and boreholes. Fiji is also known for utilizing its groundwater resources by the mineral water bottling companies.

Agriculture and Cropping Pattern

Around 23.26% of Fiji's land is used for agricultural purposes. Sugar cane is the main agriculture crop. In addition to sugar cane farming coconuts, ginger, cassava, taro, kava, bananas and breadfruit are the other major crops grown in Fiji. The crop planting pattern is largely determined by the variations in the rainfall.

Financial Feasibility Assessment

Fiji has submitted demand for 27 Nos. solar water pumping systems. At an average price of USD 8,443 per 2 HP pumpset[1], Fiji requires financing of USD 0.23 million to roll out deployment of 27 Nos. solar water pumping systems across the country.

Recommendation

The pumps should be adequately sized so as to meet the crop water requirements of the area. The meteorology of Fiji is characterized as tropical climate with consistent rainfall throughout the year. Also, the Ground water table depth across Fiji is less than 50 meters. Hence, a smaller sized pump may be able to give enough discharge for the crop as a major portion of water requirement can be meet through rainwater. Considering these parameters, the water requirement can be sufficed by 2 HP pumps with an incremental payback of 10 years. However, we noticed if the capacity of the pumps is reduced to 1 HP the payback gets improved to 7 years.

[1] Average L1 price of 2 HP AC Surface, AC Submersible, DC Surface and DC Submersible SWPS discovered through International Competitive Bid (ICB) by ISA

2. Background

2.1 About ISA

International Solar Alliance was launched on November 30, 2015 by India and France to implement the Paris Agreement and the ISA Framework Agreement came into force on December 7, 2017. The headquarter agreement with India was signed on June 6, 2018 when the ISA Secretariat acquired a judicial personality under the Framework Agreement. ISA held its first Assembly on October 3, 2018 and the second one is being held on October 31, 2019. To date, 79 countries have signed the Framework Agreement. ISA aims to provide a dedicated platform for cooperation among solar resource-rich countries where the global community, including bilateral and multilateral organizations, corporates, industry and other stakeholders can collaborate and help achieve the aim of increasing the use of solar energy in a safe, convenient, affordable, equitable and sustainable manner.

The International Solar Alliance (ISA) has been conceived as an action-oriented, member-driven, collaborative platform for increased deployment of solar energy technologies to enhance energy security and sustainable development, and to improve access to energy in developing member countries. In this respect, ISA has been continuously working towards coordinating joint and collaborative efforts for mobilizing more than USD 1000 billion investments in the solar sector thereby facilitating scaling up of solar deployment in various member countries.

As guided by the Framework Agreement of the ISA, the interests and objectives of the ISA are as follows:

1. To collectively address key common challenges to scale up solar energy applications in line with their needs;
2. To mobilize investments of more than USD 1000 billion by 2030;
3. To take coordinated action through programmes and activities launched on a voluntary basis, aimed at better harmonization, aggregation of demand, risk and resources, for promoting solar finance, solar technologies, innovation, R&D, capacity building etc.;
4. Reduce the cost of finance to increase investments in solar energy in member countries by promoting innovative financial mechanisms and mobilizing finance from Institutions;
5. Scale up applications of solar technologies in member countries, and
6. Facilitate collaborative research and development (R&D) activities in solar energy technologies among member countries.

To expand its reach, the ISA has entered into strategic and financial partnerships with the UNDP, the World Bank, the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD), the African Development Bank (AFDB), the Asian Development Bank (ADB), the Asian Infrastructure Investment Bank (AIIB), New Development Bank (NDB), and the Green Climate Fund (GCF), IEA, IRENA, Climate Parliament and UNIDO on enhancing cooperation on solar energy deployment to further the mandate of the ISA. The United Nations including its organs are strategic partners of the ISA.

On the request of the ISA, the Government of India has earmarked around US $ 2 billion Line of Credit (LoC) to the African countries for implementation of solar and solar related projects out of its total US $ 10 billion LoC under the Indian Development and Economic Assistance Scheme (IDEAS) to various African and other developing countries. India has set up a project preparation facility which will provide consultancy support to partner countries to design bankable projects.

Following these commitments, India has provided $ 1.4 billion concessional financing to 27 solar projects in 15 developing countries so far. As a co-founding member of the ISA, Government of France through the Agence Française de Développement, has also offered €1000 million for solar projects across ISA member countries. 17 projects have been funded by AFD for approximately Euro 300 million. ISA will similarly persuade other countries to contribute to the cause of solar deployment globally.

ISA is currently working towards coordinating a joint and collaborative effort amongst member countries so that strategies suited to the requirements of individual countries can be formed, and feasible solar technologies can be deployed. ISA is acting as a facilitator to contribute to the solar deployment efforts of individual member country. For this, ISA has formed a framework of programs and initiatives to develop a dedicated approach towards scaling up of various solar technologies. All the Programmes of ISA are member driven. The current programmes of ISA are:

1. Affordable finance at scale
2. Scaling Solar Applications for Agricultural Use (SSAAU)
3. Scaling Solar Mini-Grids
4. Scaling Solar Rooftop
5. Scaling solar supported e-mobility and storage
6. Programme for Solar Park

2.2 About SSAAU Programme

ISA's first programme, Scaling Solar Applications for Agricultural Use (SSAAU), was launched in New York, USA on 22nd April 2016. The SSAAU Programme mainly focusses on decentralized solar applications in rural settings. Major focus areas of the programme include Solar Water Pumping Systems (SWPS), solar drying, solar chilling, solar milling, etc. Other activities under the programme include R&D, capacity building, and developing common standards, facilitate transfer of technology, etc.

More than twenty-one countries namely Bangladesh, Benin, Djibouti, Ethiopia, France, Guinea-Bissau, India, Kiribati, Mali, Mauritius, Niger, Nigeria, Rwanda, Senegal, Seychelles, Somalia, Sudan, Togo, Tonga, Uganda, Vanuatu have been frequently interacting regarding the programme strategy and implementation through the network of NFPs and country representatives via video conferencing. To understand specific requirements of these countries, needs assessment questionnaires have been developed for Solar Water Pumping System (SWPS) and Solar Street Lighting System (SSLS). These questionnaires have been circulated to all participating and signatory countries of the ISA as a first step towards demand aggregation.

The key activities under the SSAAU programme are as under:

S No.	Category	Key Activities
1	Demand Aggregation	▪ Obtaining data for demand aggregation models from various member countries ▪ Bid process management, fixation of price, identification of manufacturer(s)/ supplier(s) for each of the participating member countries
2	Country Strategy	▪ Developing baseline studies and roadmaps for member nations ▪ Constituting global task force for the programme ▪ Facilitating affordable financing for implementation of solar water pumping programme in participating member countries
3	Facilitating Deployment	▪ Facilitating in setting Standards, Performance Benchmarks, Testing and Certification Protocols through identified test centers ▪ Development of base document for global tendering and best practices for procurement, installation and maintenance ▪ Monitoring and Evaluation
4	Outreach Strategy	▪ Development of media outreach strategy for the programme ▪ Organization of workshops and seminars for promotion of SSAAU programme

Table 1: Key Activities under SSAAU Programme

As a part of the demand aggregation exercise, ISA has aggregated a demand of 272,579 Nos. of off-grid solar pumps to be implemented across 22 countries spanning 4 different continents. The key objective of the demand aggregation exercise was to bring down the costs of the system so as to enable implementation of viable and bankable solar pumps projects in various ISA countries.

The demand aggregation exercise comprised of the following sub-steps:

1. Needs Assessment: In collaboration with National Focal Points (NFPs) and Country Representatives, need assessment questionnaires for Solar Water Pumping Systems (SWPS) were circulated to participating member countries
2. Ascertaining Demand: The filled in needs assessment questionnaires were used to ascertain demand of solar water pumping systems including information on type, quantity and technical specifications in each of the participating member countries
3. Demand Validation: Coordinating with National Focal Points and Country Representatives for obtaining country specific data and information and for validation of demand
4. International Competitive Bidding for Price-Discovery: Energy Efficiency Services Limited was hired for management of International Competitive Bidding for price discovery of various types of solar water pumping systems in participating member countries

The demand aggregation of Solar Water Pumps from ISA Member Countries given in the table below:

Sl. No.	Name of the Country	Demand of SWP (Nos)
1	Benin	50,000
2	Cabo Verde	100
3	Democratic Republic of Congo	80,000
4	Djibouti	100
5	**Fiji**	**27**
6	Guyana	111
7	Mali	15,000
8	Mauritius	27
9	Nauru	400
10	Niger	15,000
11	Peru	1,750
12	Senegal	4,000
13	Somalia	500
14	South Sudan	6,800
15	Sri Lanka	2,000
16	Sudan	50,000
17	Togo	5,000
18	Tonga	258
19	Tuvalu	10,000
20	Uganda	30,000
21	Yemen	1,500
22	Zambia	6
	Total	**2,72,579**

Table 2: Demand received from various ISA member countries for solar pumps

Subsequent to the demand aggregation exercise, Internal Competitive Bidding was undertaken by EESL on behalf of ISA for price discovery of various types of solar pumps in the participating member countries. The price discovery tender is one of the largest tenders for solar pumping systems globally and is expected to open up huge market opportunity for implementation of solar pump programme in participating member countries. Through this tender, it is expected that local market ecosystem for solar pumps will be developed which will help in greater penetration of technology amongst the farmers. It is envisaged that in the long-run solar pumps would replace the existing diesel pumpsets in these member countries thereby leading to significant reduction in GHG emissions apart from providing a reliable irrigation solution for the farmers. The key features of the International Competitive Bidding for price discovery is summarized as below:

S. No	Category	Description
1	International Standards for Solar Pumps	▪ Internationally accepted IEC and UL standards for various solar pump components
2	Technical and Financial Qualifying Criteria	▪ Technical Qualifying Criteria: Based on experience of supply and installation of solar pump sets and solar power plants ▪ Financial Qualifying Criteria: Based on average annual turnover and net worth
3	Specifications for minimum bidding quantity	▪ Mandatory to bid for 5 countries with a total bid quantity of at least 27000
4	Two separate bid packages	▪ Only supply ▪ Supply and Five-Year Comprehensive Maintenance Contract
5	Two stage evaluation process	▪ Based on technical and commercial evaluation ▪ Award of contract to various bidders based on L1 prices

Table 3: Key features of Internal Competitive Bidding for Price Discovery of Solar Pumps

The price discovery was conducted for two broad service contracts namely:

- Service 1: Supply, Custom clearance, Local transportation, installation, testing and commissioning of complete system & services at Employer's site of Solar PV based Agricultural Pump Set system
- Service 2: Supply Custom clearance, Local transportation, installation, testing and commissioning of complete system at site of Solar PV based Agricultural Pump Set system

The roles and responsibilities of the bidder and the respective member nation as a part of the price discovery tender is summarized in the figure below:

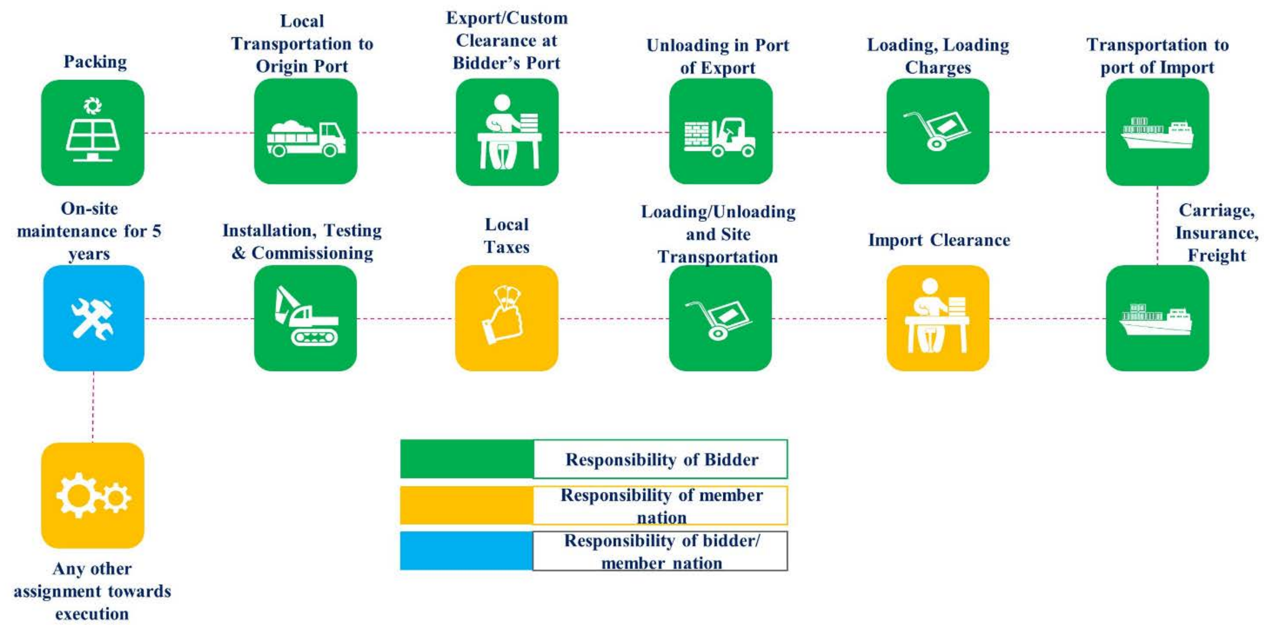


Figure 1: Work Packages and Responsibility Division

Five bidders have participated in the price discovery tender and have submitted the prices for various capacities of solar pumps in the participating member countries. ISA is currently analyzing and evaluating the prices and will subsequently share with the member countries for final decision at their end.

3. Introduction

3.1 About Fiji

Fiji is a country and an archipelago in the southern Pacific Ocean and is part of the continent of Oceania. The country comprises of 333 islands and 522 small islets covering a total area of 75,000 sq miles. Of the 333 islands, only 100 are inhabited by the 884,887 residents of the country, as of 2017. It was a British colony from 1874 to 1970 when it became an independent state. Fiji is a tropical paradise with white sandy beaches that attract tourists from across the globe and pristine clear waters and botanical reefs ideal for fishing and recreation activities like scuba diving[2].

The largest island Viti Levu covers about 57% of the nation's land area and has the two largest metropolitan areas (the capital Suva, and Lautoka). It also hosts and most of the other major towns, i.e, Ba, Nasinu, and Nadi (the site of the international airport) and contains some 69% of the population. The second largest island, Vanua Levu, is 64 km to the north of Viti Levu, covers just over 30% of the land area and is home to some 15% of the population. The two main towns are Labasa and Savusavu[3].

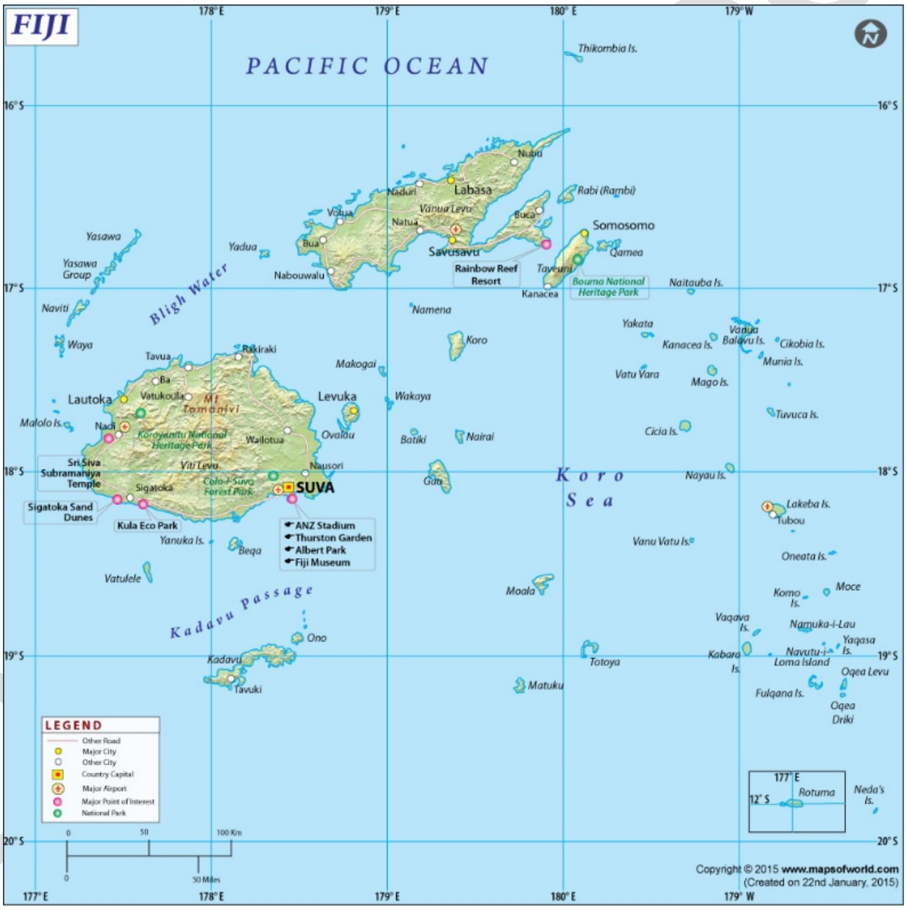


Figure 2: Map of Fiji[4]

Fiji's major cities, industries, and tourism facilities are located in Viti Levu and it consists of four basic kinds of terrain: plateau, mountain, upland, and coastal. In the center of the island the Nadrau Plateau raises up to an elevation of 1,000 meters a.s.l. and covers about 130 square kilometers of dense and marshy forest. There are two mountain ranges running north and south of the plateau form the major divide. Mount Victoria (at 1,424

[2] World Atlas – Country Brief
[3] Fiji High Commission
[4] Maps of World – Fiji

meters) is the highest point in Fiji located in northern range. Other mountain ranges above 600 meters separate the island into four upland areas that are separated by rivers. The undulating coastal hills and lowland plains contain most of the population. Fiji's vast rivers and mountainous regions offer excellent hydroelectric potential. Reef systems intersecting with those of nearby islands form barriers around most of the island, sheltering large expanses of coastal waters and making good anchorages, especially at Suva.

With forest, mineral, and fish resources, Fiji is one of the most developed of the Pacific island economies. Fiji has a market economy based primarily on tourism and agriculture. The commercial sector is heavily based on garment manufacturing and on sugarcane. The economy is also having a strong service and light-industrial component and is also serving small neighboring countries, with key activities such as boatbuilding, brewing and paint manufacture[5].

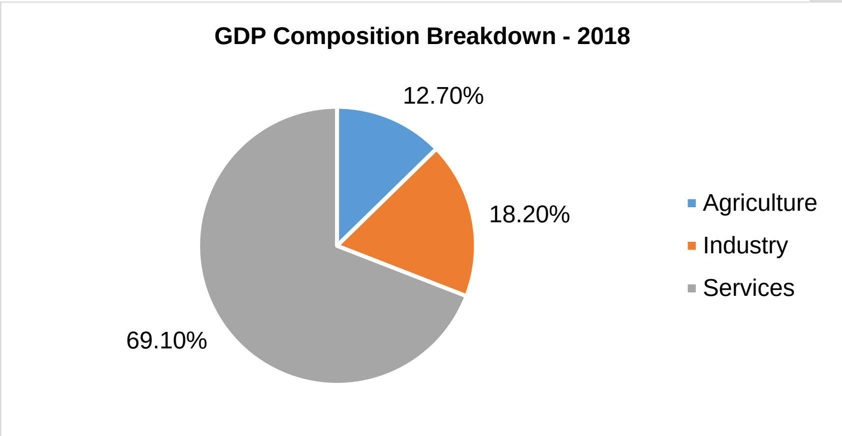


Figure 3: GDP Composition Breakdown[6]

Manufacturing is included in the industry figures which is reported at 10.42 % in 2018, according to the World Bank collection of development indicators. The Fijian agriculture sector is a mix of commercial and subsistence farming, although commercial farming predominates. Fiji's sugar has special access to European Union markets and sugar processing makes up one-third of industrial activity and employs 70% of the workforce. Subsistence farming of coconuts, ginger, and copra are also significant.

Fiji has become an export-driven economy spurred by high technology, knowledge-based and capital-intensive industries. These include the manufacture of textiles, garments, footwear, sugar, tobacco, food processing, beverages (including mineral water) and wood-based industries. The sector employs approximately 26,000 workers and is one of the nation's growing sectors. Fiji made products has made substantial progress in the international trading arena such as the likes of Pure Fiji, Fiji Water, Pacific Green Furniture and FMF Foods Ltd[7].

3.2 Overview of Energy Scenario

Fiji's electricity generation is primarily sourced from diesel (approx. 50%), which is needed to be imported. In last 4 years, Fiji's electricity demand is increase by 18%. The state-owned Energy Fiji Limited (EFL) is the main generator and distributor of the on-grid power and covers around 90% of the population on the main islands of Viti Levu, Vanua Levu, and Ovalau[8].

Fiji is having a national electricity access of 96%, with 99.9% urban and 91.9% rural access[9]. The 20-year National Development plan of Fiji is having targets to have access to electricity by 2021 for all Fijians and by

[5] Britannica – Fiji
[6] World Bank – World Development Indicators
[7] Embassy of the Republic of Fiji – Sector overview
[8] Energy Fiji Limited
[9] World Bank Data

2036 to be 100% powered by renewable sources. In addition to this, EFL is also having an ongoing Power Development Plan (PDP) to invest in new generation transmission and distribution infrastructure[10]. The plan outlines a load forecasting and power-generation plan for the Viti Levu, Vanua Levu, Taveuni and Ovalau power systems, together with the development of associated network assets and the investment strategy for the augmentation of the 132kV and 33kV transmission networks. The total investment for the generation, transmission and distribution sectors is projected to be around $2.5 billion.

3.2.1 Electricity Generation

Fiji is blessed with the advantages of the remarkable natural energy potential. EFL is using these geographic advantages to produce a responsible mix of renewable energy projects across the country.

The EFL's renewable power stations generated 569.26 million units of electricity (55.11%), thermal power stations generated 423.74 million units (41.02%) and Independent Power Producers (IPPs) generated 39.94 million units (3.87%)[11].

Fiji's electricity tariff for commercial and domestic consumers as on October 2019 is shown in the table below:

Consumer	Tariff/kWh (USD)	Criteria
Domestic[12]	34.01 cents	-
	16.34 cents (Subsidy)	For ≤ 100 kWh/month consumption + total household income ≤ $30,000/year
Commercial[13]	40.99 cents	For units ≤ 14,999 kWh/month
	42.95 cents	For units >14,999 kWh/month
	42.95 cents	For excess reactive energy kVARh/month

Table 4: Electricity Tariff of Fiji

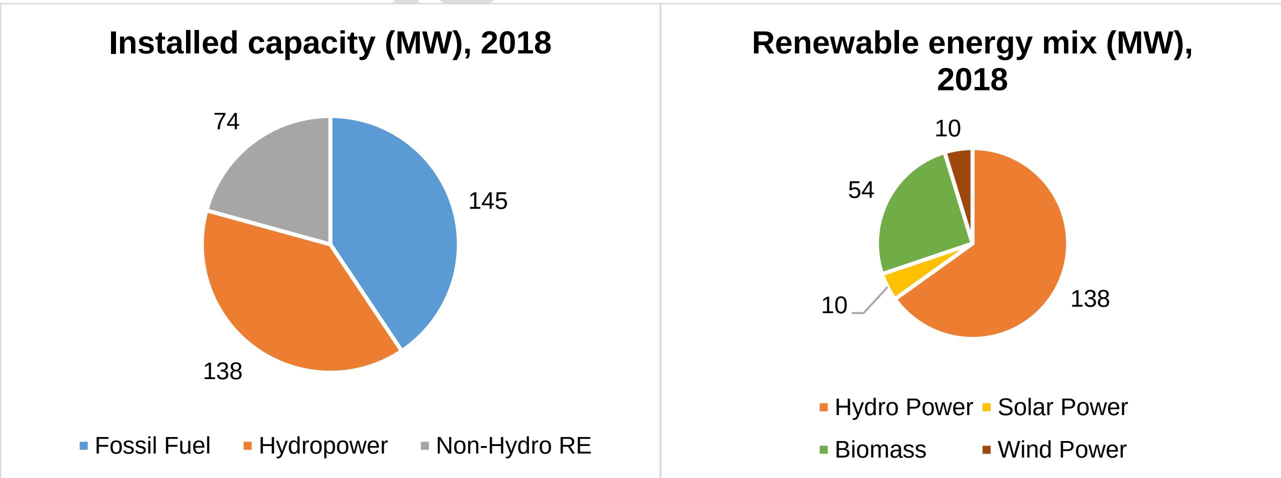


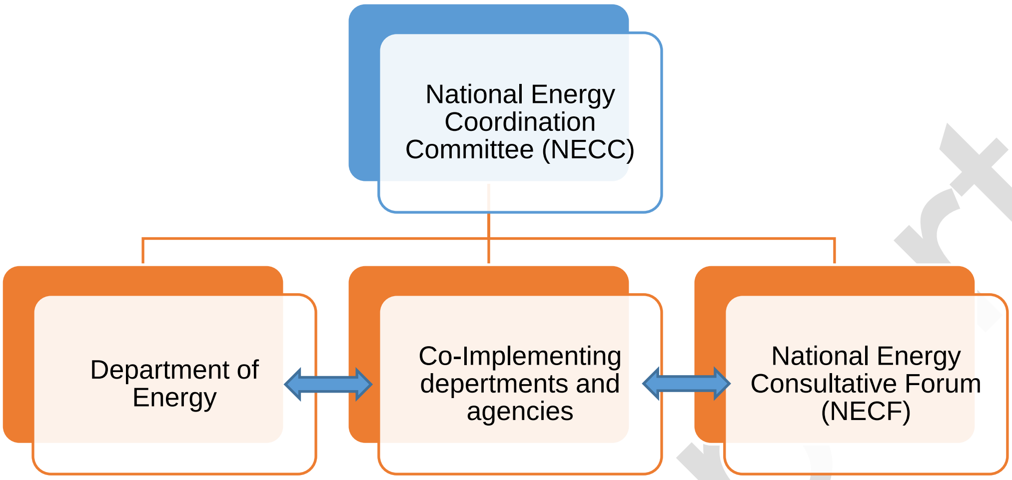
Figure 4: Installed capacity, Renewable Energy mix and Power Generation of Sudan[14]

The installed renewable energy capacity in 2018 stood at 213 MW comprising of 138 MW of Hydro power, 54 MW of Biomass, 10 MW of Wind power and 10 MW from Solar energy sources.

[10] National Development Plan – Ministry of Economy
[11] Annual Report 2018 - Energy Fiji Limited
[12] Energy Fiji Limited – Electricity Tariff and rates
[13] Energy Fiji Limited – Small Business Tariffs
[14] IRENA Stat Tool

3.2.2 Institutional Framework

The energy portfolio in Fiji is currently held by the Ministry of Infrastructure and Transport under the Department of Energy (DoE)[15]. The proposed institutional framework for implementing the National Energy Policy is as follows:



National Energy Coordination Committee (NECC) leads the overall coordination for implementing the National Energy Policy. The NECC is also be responsible for facilitating coordination between the concerned ministries and the departments under them for implementing the National Energy Policy.

The planning and policy development in the energy sector is the primary responsibility of DoE and NECC will review the National master plans and cross-cutting policies developed by DoE.

The Fiji Electricity Authority (FEA) now known as Energy Fiji Limited (EFL) will remain responsible for planning of the national grid, including generation and network planning and planning of grid extensions.

DoE will be responsible for national master plans, including for renewable energy and electrification, and the plans prepared by EFL will be expected to be in accordance with these. Responsibility for policy matters such as the role of the private sector in the electricity industry and development of frameworks for private sector participation in the electricity sector will be transferred from EFL to DoE to avoid potential conflicts of interest.

DoE will also consult at least once yearly with representatives of external stakeholders in the energy sector through a National Energy Consultative Forum (NECF) modelled on the similar body established for the transport sector.

An annual report will be presented to the NECF and comments received from stakeholders through this mechanism will be provided to NECC for its consideration. Based on the findings, Government may decide to amend targets and actions as considered necessary[16].

[15] UNDP - FREPP
[16] Fiji National Energy Policy

4. Technical Feasibility Assessment

4.1 Assessment Criteria

The feasibility of a solar powered irrigation system depends on a wide array of factors ranging from geographic parameters such as temperature, rainfall, water table depth to site specific parameters such as cropping pattern, land size, planting date, irrigation technique etc. Any feasibility analysis of a solar powered irrigation system would involve both the technical feasibility and the financial feasibility. The technical feasibility would analyze the site-specific conditions to determine whether such system can be installed considering the different technical aspects such as solar irradiance, size availability, panel size, tracking systems, water table depth etc. The technical feasibility would also provide recommendations on the ideal pump size and type considering the dynamics of the site. Once technical feasibility for a given system is established, the costs involved, and the expected returns are calculated using financial feasibility analysis. The below figure summarizes the interplay of various parameters involved in technical and financial feasibility analysis.

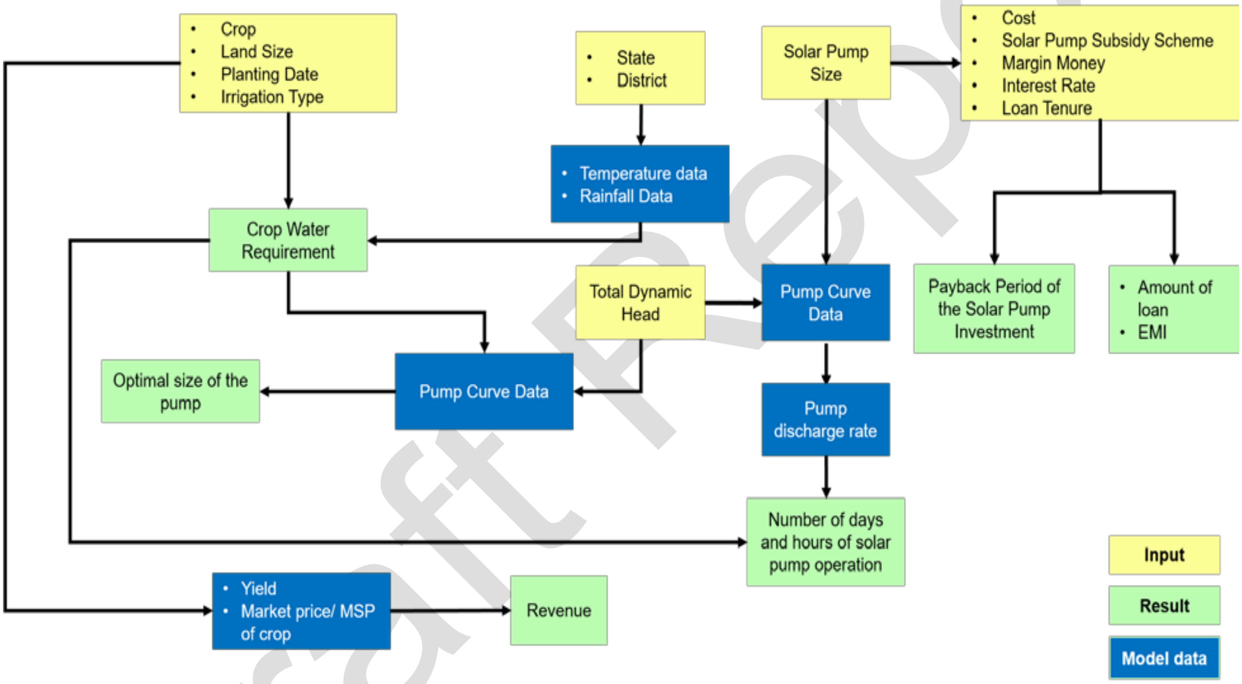


Figure 5: Factors involved in feasibility analysis of solar pump

4.1.1 Total Dynamic Head

The total dynamic head is a very important parameter of a solar pumps which determines the various head losses that the pump must overcome. It is a summation of the suction head, discharge head and the friction losses. The total dynamic head and the desired flow rate of the system are applied to the pump performance curve, which is used for proper pump selection based on required electrical power input and optimum efficiency.

The static head, discharge head and the total dynamic head is explained through the image below[17]:

[17] Review of SWPS - Science Direct

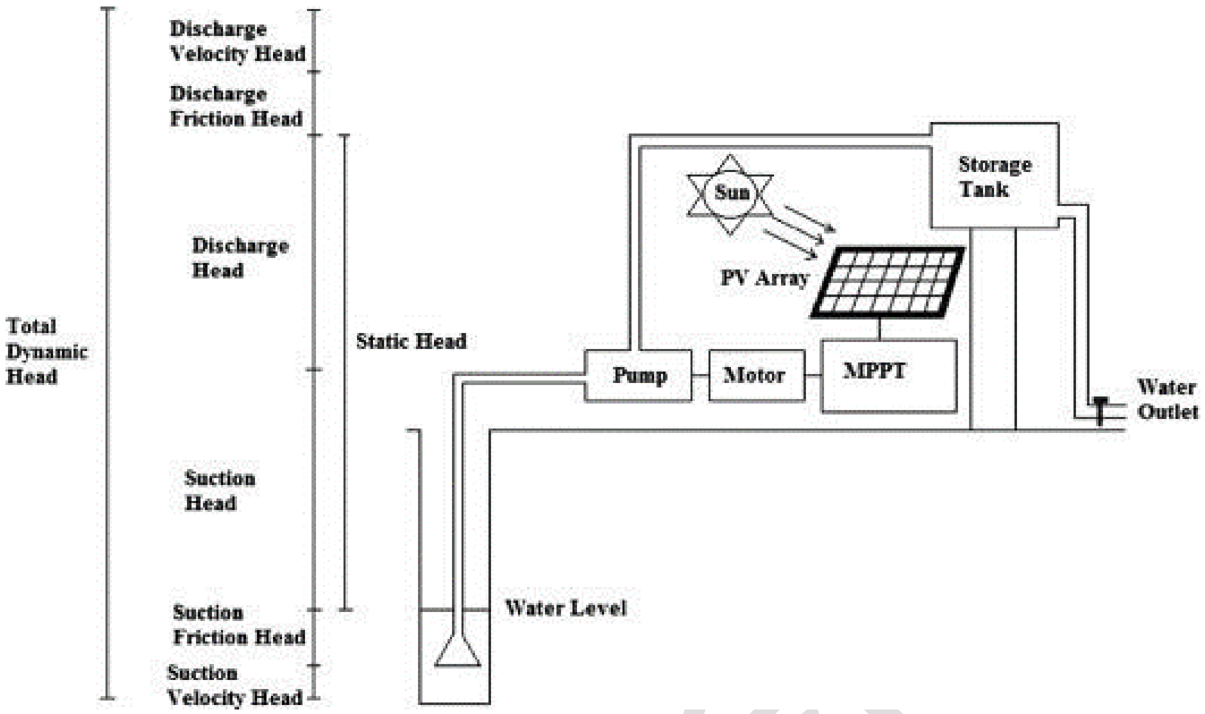


Figure 6: Schematic diagram of total dynamic head of a Solar pump

4.1.2 Pump Curves

The pump characteristic is normally described graphically by the manufacturer as the pump performance curve. Other important information for a proper pump selection is also included - like efficiency curves, NPSHr curve, pump curves for several impeller diameters and different speeds, and power consumption[18]. The performance curve indicates the variation in the discharge rate of a pump with a change in required head and input power. The pump curves are analyzed to determine the optimal size of a solar pump for a given manufacturer and also to assess whether the system will be able to the peak demand requirements of the farmer. The performance curves for a 5 HP AC and 5 HP DC pump is shown as below[19]:

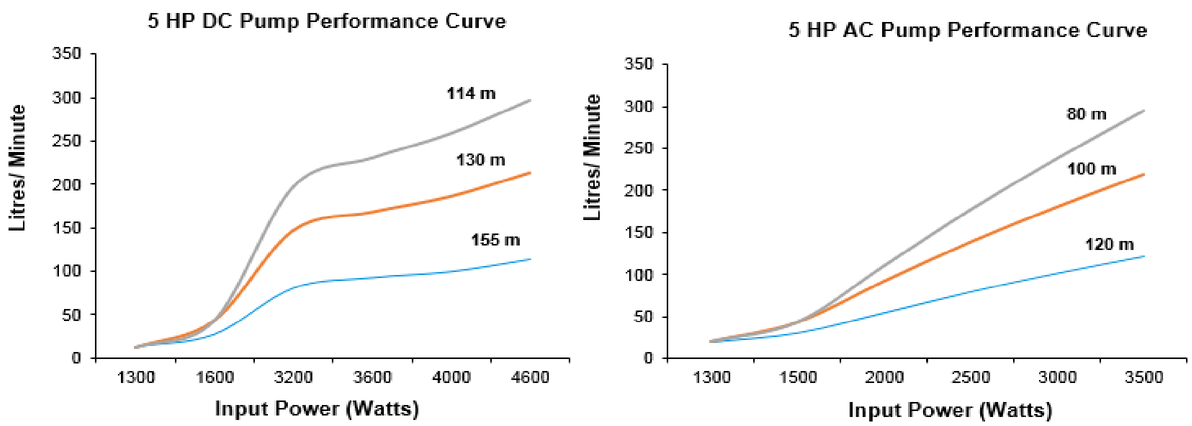


Figure 7: Pump Performance Curves

[18] System Curve and Pump Performance Curve - The Engineering Toolbox
[19] Shakti Pumps (DC pump: 5 DCSSP 2700/3600/4600; AC pump: SSP 5000-100-11)

4.1.3 Crop Water Requirement

The crop water need is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally. The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need mainly depends on:

- **the climate**: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate
- **the crop type**: crops like maize or sugarcane need more water than crops like millet or sorghum
- **the growth stage of the crop**: fully grown crops need more water than crops that have just been planted.

The below table showcases the effect of various climatic factors on the crop water requirement:

Climatic Factor	Crop Water Requirement	
	High	Low
Temperature	Hot	Cool
Humidity	Low (Dry)	High (Humid)
Windspeed	Windy	Little Wind
Sunshine	Sunny (no clouds)	Cloudy (no sun)[20]

Table 5: Effect of major climatic factors on crop water requirement

The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind. The influence of the climate on crop water needs is given by the reference crop evapotranspiration (ETo). The ETo is usually expressed in millimetres per unit of time, e.g. mm/day, mm/month, or mm/season. ETo is the rate of evapotranspiration from a large area, covered by green grass, 8 to 15 cm tall, which grows actively, completely shades the ground and which is not short of water[21].

4.1.4 Pump Sizing

Oversizing would incur unnecessary costs, and under sizing would lead to insufficient performance. This is why each component needs to be properly designed and sized to meet the specific requirements of the project. It is the only way to guarantee reliability and system durability to achieve the desired performance. Similarly, when sizing a solar system, it is recommended to use the 'worst month method'. By sizing the systems for the month with most adverse conditions in the year, it will be ensured that water supply will be enough for all the other months. The worst month in the year will be that in where the gap between the energy required to supply water and the energy available from the Sun is higher. In case the daily water requirement is the same all the year round (meaning too that the energy required is the same all the year round since pump will run for the same number of hours any day), the worst month will be that with least solar radiation[22].

4.2 Country Assessment

4.2.1. Connectivity and Accessibility

Transport is contributing around 10 – 12% of GDP in Fiji's economy and the modes of transport include rail, road, water, and air. The rail network is mainly used for movement of sugar cane. Suva and Lautoka are the

[20] Principles of Irrigation Water Heeds - FAO
[21] Principles of Irrigation Water Heeds - FAO
[22] Basic Guidelines of SWPS – Sun Connect News

major ports managed by Fiji Ports Corporation Limited.[23]. There are 122 km of navigable inland waterways. There are two international airports, one other paved airport, and over 20 with unpaved runways.

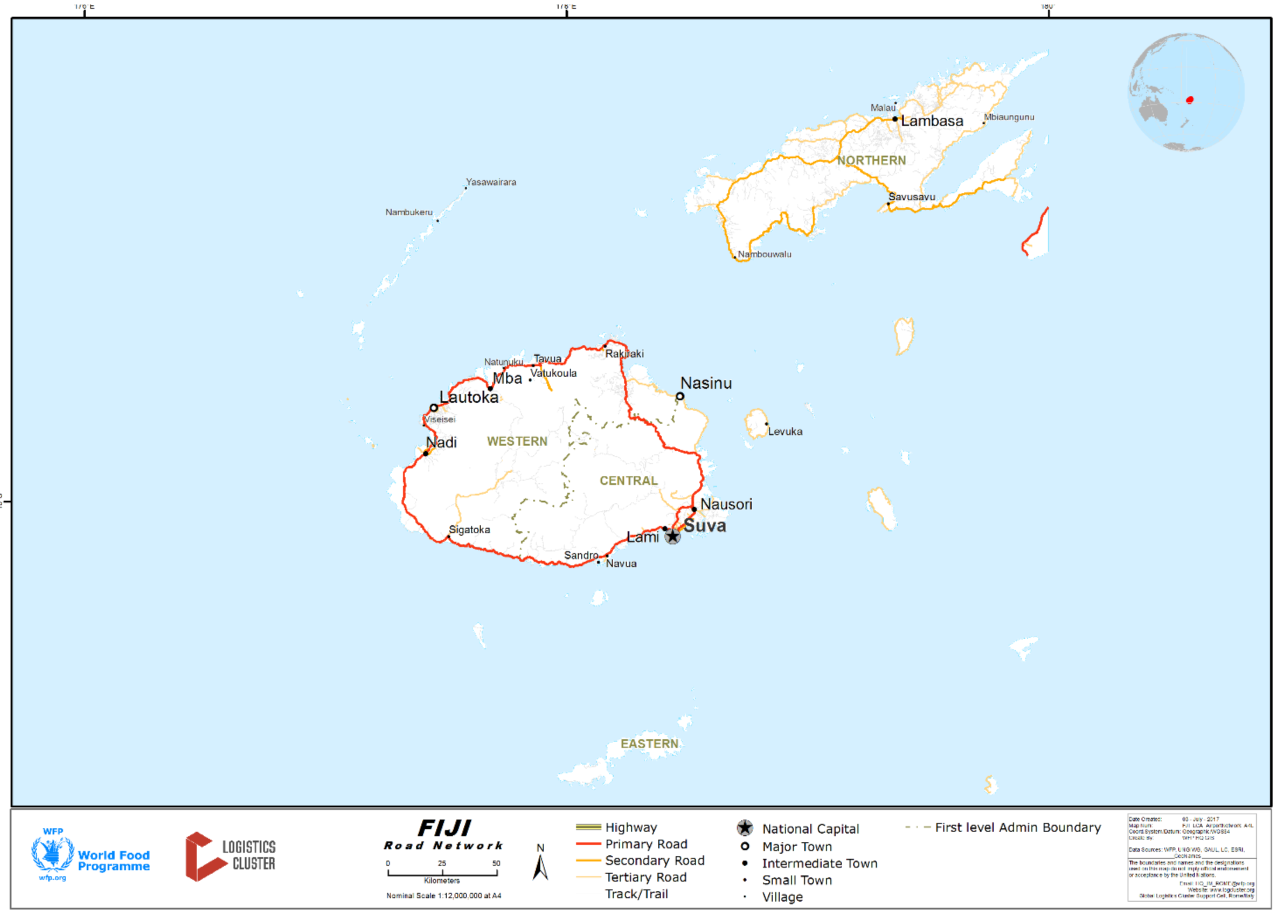


Figure 8: Road Network of Fiji[24]

Fijis road infrastructure is naturally most prevalent on the larger islands and Fiji has 7000 km of roads over 1200 bridges and Jetty's which also fall under its responsibility. There are mainly 2 roads in Fiji which connect the most important hubs in Fiji, Suva & Nadi. These are the Queens road in the South and the Kings road in the North. The distance matrix between the capital city and major towns of the city (via Kings Road and Queens Road) are given in below tables:

Distance Between Capital City to Major Towns via Kings road (in km)							
	Lautoka	**Ba**	**Taua**	**Raki Raki**	**Korovou**	**Nausori**	**Suva**
Nadi Airport	24	62	91	132	239	270	289
Lautoka	-	38	67	108	215	246	265
Ba	-	-	29	70	177	208	227
Tavua	-	-	-	41	148	179	198
Raki Raki	-	-	-	-	107	138	157
Korovou	-	-	-	-	-	31	50
Nausori	-	-	-	-	-	-	19

Table 6: Kings Road connectivity from capital city to major towns

23 Fiji Ports Corporation Limited
24 Fiji – Logistics Cluster

Distance Between Capital City to Major Towns via Queens road (in km)							
	Pacific Harbor	**Korolevu**	**Korotogo**	**Sigatoka**	**Nadi Town**	**Nadi Airport**	**Lautoka**
Suva	49	96	120	127	183	197	221
Pacific Harbor	-	47	71	78	139	148	172
Korolevu	-	-	24	31	92	101	125
Korotogo	-	-	-	7	68	77	101
Sigatoka	-	-	-	-	61	70	94
Nadi Town	-	-	-	-	-	9	33
Nadi Airport	-	-	-	-	-	-	24

Table 7: Queens Road connectivity from capital city to major towns[25]

4.2.2. Climate and Rainfall

Fiji has a tropical climate, with a hot, humid, and rainy/wet season from November to April and a cooler/dry season from May to October[26].

Up to 80% of the annual total rainfall falls during the wet period. Tropical disturbances, cyclones and high intensity rainfall are frequent causing floods ranging in magnitude from moderate to very severe. As little as 20% of the annual rainfall falls during the dry season (May to October) and is non-homogeneously distributed over time and space[27].

In the local language the dry side is known as Babasiga or the hillside exposed to the sun. This also referred to as the leeward and windward sides. The leeward side is usually protected by mountains from the prevailing winds and this side is usually the drier side of the islands. The windward side is upwind and is subjected to the prevailing wind and thus the wetter side of the island[28]. The Figures below gives the variations in temperature and rainfall at the leeward and windward sides of Viti Levu island of Fiji.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	26.3	26.5	26.2	25.5	24.3	23.7	22.8	22.7	23.1	24.1	25.0	25.8
Min. Temperature (°C)	22.9	23.1	23	22.4	21.3	20.9	20	19.8	20.1	20.8	21.6	22.4
Max. Temperature (°C)	29.7	30	29.4	28.6	27.4	26.5	25.6	25.7	26.2	27.4	28.4	29.2
Precipitation / Rainfall (mm)	79.3	79.7	79.2	77.9	75.7	74.7	73.0	72.9	73.6	75.4	77.0	78.4

Table 8: Temperature Variation in Suva[29]

[25] Fiji – Logistics Cluster
[26] Country Profile – Fiji; FAO
[27] Secretariat of the Pacific Regional Environment Programme (SPREP) – Country Briefings Papers
[28] Makeup of Land in Fiji – Property.com
[29] Suva Fiji: Climate Data

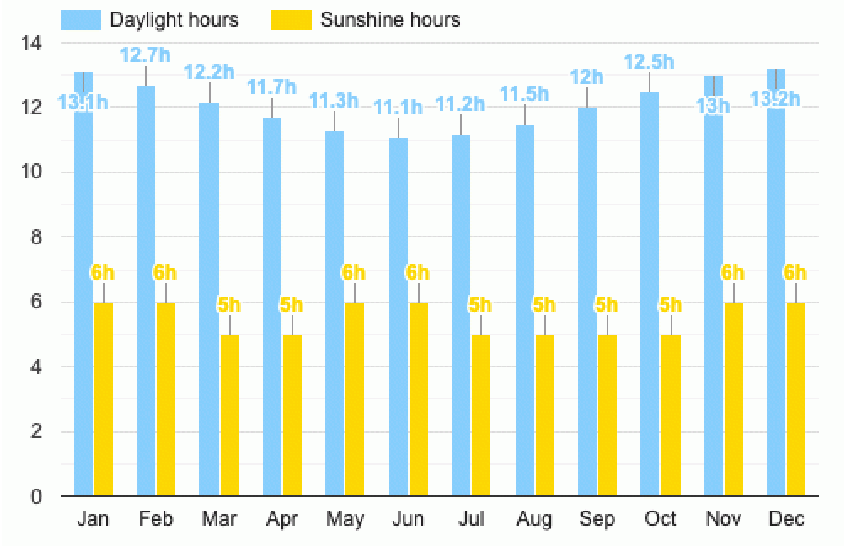


Figure 9: Sun hours in Suva region[30]

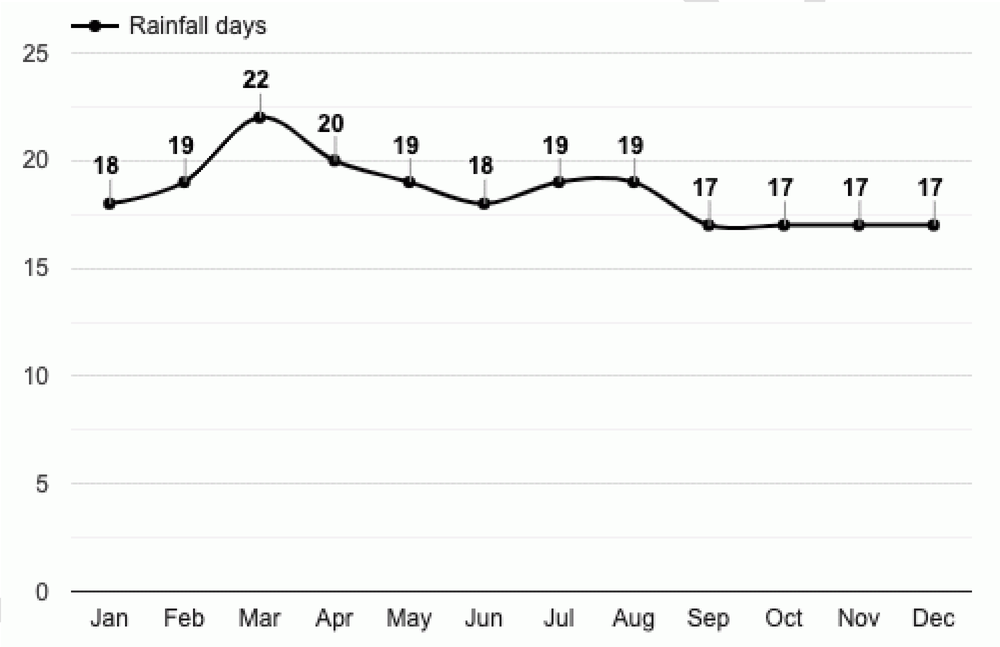


Figure 10: Precipitation Days over the year in Suva region[31]

The annual average temperature of Fiji lies between 22-27°C. Changes in the temperature from season to season are relatively small and predominantly depend on the surrounding ocean temperature.

4.2.3. Soil Pattern

The country is divided into three major classes of landforms - plains, low mountains and hills as well as the high mountains. Majority of the areas in Fiji are very fertile as the archipelago is made up of volcanic soil and contains a high concentration of Iron, aluminium oxides and hydroxides. The soil is usually reddish or yellowish in color[32]. Under the USDA Classification System, the soils found in Fiji fall into nine soil orders[33], namely:

[30] Suva, Fiji - Weather Atlas
[31] Suva, Fiji - Weather Atlas
[32] Makeup of Land in Fiji – Property.com
[33] Pacific Island Country – Paper Number 13

1. Entisol – Entisol are soils of recent origin. The central concept is that these soils developed in unconsolidated parent material with usually no genetic horizons except an A horizon.
2. Inceptisol – Inceptisol are soils that exhibit minimal horizon development. They are more developed than Entisols but still lack the features that are characteristic of other soil orders.
3. Mollisls – Mollisls are the soils of grassland ecosystems. They are characterized by a thick, dark surface horizon. This fertile surface horizon, known as a mollic epipedon, results from the long-term addition of organic materials derived from plant roots.
4. Alfisols – Alfisols are moderately leached soils that have relatively high native fertility. These soils have formed primarily under forest and have a subsurface horizon in which clays have accumulated. Alfisols are found mostly in temperate humid and sub-humid regions of the world.
5. Andisols – Andisol are soils that have formed in volcanic ash or other volcanic ejecta. They differ from those of other soil orders in that they typically are dominated by glass and short-range-order colloidal weathering products such as allophane, imogolite, and ferrihydrite (minerals).
6. Ultisols – Ultisols are strongly leached and acidic forest soils with relatively low fertility. They are found primarily in humid temperate and tropical areas of the world, typically on older, stable landscapes.
7. Oxisols – Oxisols are very highly weathered soils that are found primarily in the intertropical regions of the world. These soils contain few weatherable minerals and are often rich in iron (Fe) and aluminum (Al) oxide minerals.
8. Vertisols – Vertisols are clay-rich soils that shrink and swell with changes in moisture content. During dry periods, the soil volume shrinks and deep wide cracks form. The soil volume then expands as it wets up.
9. Histosols - Histosols are soils that are composed mainly of organic materials. They contain at least 20 to 30% organic matter by weight and are more than 40 cm thick.

4.2.4. Groundwater Status

Hydrogeological studies have been carried out in Fiji by the Mineral Resources Department (MRD) and also monitors and projects the abuse of ground water. Fiji's islands have considerable differences in their water resources. The surface water is used as the main source of supply for all major towns on the larger, high islands of Fiji. Some small, low lying islands rely entirely on ground and rain water.

Groundwater is available on both the large islands and small low-lying islands at superficial and medium-depth strata, in either fractured rock or sedimentary formations[34]. About 5,273 million m^3/year (overlapped with the surface water) of renewable groundwater is estimated in Fiji[35].

Groundwater is used by the large number of people in Fiji who obtain their water from springs, hand-dug wells and boreholes. People have dug wells by hand in the low lying areas and lined with concrete blocks or rings or oil-drums. Also the locations with groundwater level at greater depths, or larger quantities of water are required boreholes are drilled, either by the Mineral Resources Department or private drilling companies. Boreholes are usually between 20 and 50 m deep, 100 to 200 mm in diameter and are lined with plastic or steel casing and screen. In Fiji, boreholes usually yield between 0.5 litres per second but yields up to 50 litres per second have been pumped[36].

In addition to this, no permits for groundwater exploration are required in Fiji and there is no record of private drilling and the law is not clear regarding the ownership of ground water[37].

[34] Pacific Water – Fiji Country Profile
[35] Country Profile – Fiji; FAO
[36] Mineral Resources department
[37] Groundwater monitoring in small island developing states in the pacific – IGRAC

4.2.5. Solar Irradiance

Fiji's expected Solar potential is about 52,957,982 MWh/yr[38] with Global Horizontal Irradiation of 4.98kWh/m^2/day[39]. Thus, Fiji has real potential for development and scaling up of photovoltaic projects (both grid-tied and off-grid).

The Figure below shows the average daily solar radiation for different locations in Fiji where on the south side of Viti Levu (Suva, Lakeba island Kadavu island) solar radiation varies from 3.6-4.0 kWh/m^2/day while on the west to north side of Viti levu the solar radiation varies from 4.8-5.2 kWh/m^2/day.

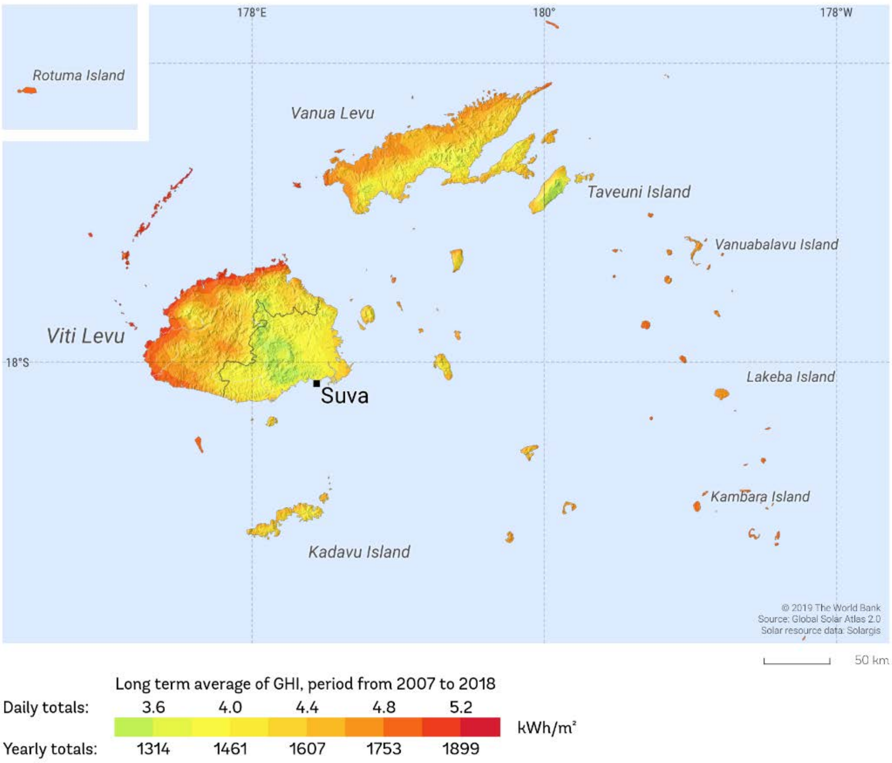


Figure 11: Global Horizontal Irradiation for Fiji[40]

4.2.6. Agriculture and Cropping Pattern

Agriculture is the mainstay of Fiji's economy and directly contributes around 28% to total employment and indirectly employing many more. Fiji has an advantage in producing a wide variety of tropical fruits[41].

Around 23.26% of Fiji's land is used for agricultural purposes, includes 9.03% (of land area) of Arable land and 4.65% of permanent cropland[42]. The land used for arable farming, is the flat fertile land found in valleys, river deltas and on the coastal plains. Patterns of crop planting are largely determined by variations in rainfall.

Sugar cane is the main agricultural crop in Fiji; however there is consistent decline in its production in the 21st century. In 2015, 1,670,564 tonnes of sugar cane is produced in comparison to the 221,390 tonnes of production of other top 10 agriculture crops in Fiji[43]. The other major crops grown in Fiji are coconuts, ginger, cassava, taro, kava, bananas and breadfruit [44].

[38] Fiji: Energy Resources: Open EI
[39] Global Solar Atlas – World Bank
[40] Solar resource maps - Solar GIS
[41] Investment Fiji – Agriculture Profile
[42] Trading Economics – Fiji Arable land
[43] Fiji: Sugar cane production quantity – Fact Fish
[44] New Agriculturist – Country Profile Fiji

To help farmers to estimate most appropriate cropping period, the Fiji Meteorological Service (FMS) issues estimates of rainfall for three-month periods for the Fiji sugar cane belt. The data is presented in the form of normal to above normal rainfall probabilities[45].

[45] Pacific Roadmap for Strengthened Climate Services: 2017 - 2016

5. Financial Feasibility Analysis

5.1 Indicative Inputs

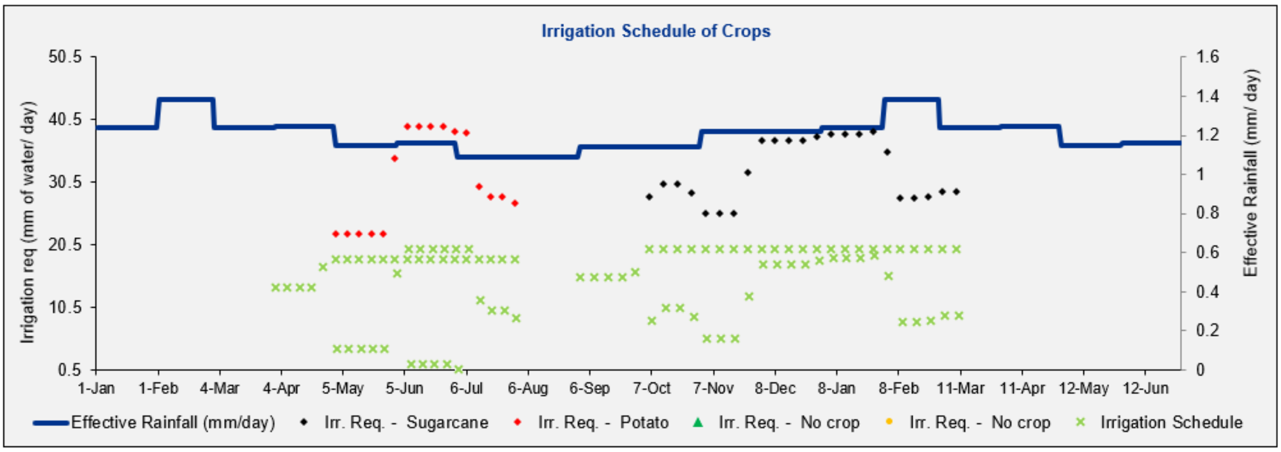
S.No.	Particulars	Unit	Value	Source
1	Crop to be Irrigated		Sugarcane, Cassava	
2	Land Size	hectares	0.5 (for each crop)	
3	Planting date		As per cropping calendar of Fiji	
4	Irrigation type		Flood: Lined canal supplied	
5	Annual average yield of crop	Kg/hectare	Sugarcane 40,686 Cassava 24,270	FAOSTAT
6	Market Price	USD/quintal	Sugarcane 8.5 Cassava 186	FAO: Food Price Monitoring and Analysis
5	Selected Size of Solar Pump	HP	2	
6	Total dynamic head inclusive of friction losses	meters	50	
7	Cost of Solar Pump	USD	8,443 [46]	Average of L1 prices discovered in ISA tender for Various categories of pumpsets
8	Subsidy	%	0 %	
9	Margin Money	%	10 %	
10	Loan Amount	%	90 %	
11	Interest Rate	%	5.7 %	Last data available from World Bank is till 1988; hence 1988 data is considered
12	Loan Tenure	years	8	
13	Cost of diesel pump per HP	USD	86.3	
14	Cost of diesel	USD/litre	0.87	Published reports and articles
15	Hike in diesel prices (y-o-y)	%	3 %	Based on global averages
16	Inflation rate	%	4.1 %	World Bank Data
17	Living expense of the farmer (as a % of crop revenue)	%	60 %	Based on global estimates, KPMG Analysis
18	Maintenance costs for diesel pump (as a % of capital costs)	%	10 %	Based on global estimates, KPMG Analysis, 2020[47]

5.2 Indicative Crop Water Requirement [48]

Total crop water requirement (m^3)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
885	572	257	264	554	1,080	897	-	236	595	548	860
Annual crop water requirement (m^3)				6,749							

[46] Cost of Solar pumpset includes on-site Comprehensive Maintenance Contract (CMC) for 5 years but exclusive of custom import clearance, duties and local taxes as per ISA International Competitive Bid
[47] The toolkit developed by KPMG for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was used to undertake the analysis.
[48] Note: This is just an indicative analysis to be used only for reference purposes. We have taken reasonable assumptions wherever reliable data was not available. A more accurate analysis can be conducted after more data has been obtained from the respective nations.

5.3 Indicative Irrigation schedule



Irri. Req. indicates the net irrigation requirement (considering rainfall) for individual crops
Irrigation Schedule indicates the consolidated schedule over the time period for all the crops

5.4 Indicative Outputs

S.No.	Particulars	Unit	Value
1	Amount of subsidy	USD	0
2	Amount of loan to be availed	USD	7,598
3	Yearly installment towards loan repayment	USD	1,211
4	Monthly installment towards loan repayment	USD	100.9
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	108.9
6	Number of hours of solar pump operation required	Hours	1184
7	Number of days of solar pump operation required	Days	169
8	Incremental payback of solar pump w.r.t. diesel pump	years	10

Fiji has submitted demand for 27 Nos. solar water pumping systems. At an average price of USD 8442.5 per 2 HP pumpset[49], Fiji requires financing of USD 0.23 million to roll out deployment of 27 Nos. solar water pumping systems across the country.

[49] Average L1 price of 2 HP AC Surface, AC Submersible, DC Surface and DC Submersible SWPS discovered through International Competitive Bid (ICB) by ISA

6. Recommendations

Following are the recommendations for the implementation of solar pumps in Fiji based on the above analysis and discussions undertaken during the visit of delegation from ISA Secretariat to Fiji:

1. **Number and type of pumps**: Fiji has submitted demand for procurement of 27 solar water pumps. Considering the low levels of electricity access and frequent brownouts/ blackouts especially in rural areas, off-grid pumps are required to be installed. Further large pumpsets presently being used for water lifting from Juba and Shabelle Rivers may be solarized.
2. **Capacity of Pumps**: The pumps should be adequately sized so as to meet the crop water requirements of the area. The meteorology of Fiji is characterized as tropical climate with consistent rainfall throughout the year. Also, the ground water table depth across Fiji is less than 50 meters. Hence, a smaller sized pump may be able to give enough discharge for the crop as a major portion of water requirement can be meet through rainwater. Considering these parameters, the water requirement can be sufficed by 2 HP pumps with an incremental payback of 10 years. However, we noticed if the capacity of the pumps is reduced to 1 HP the payback gets improved to 7 years.
3. **Financing:** There are limited sources available for the government of Fiji to fund the solar pumps and therefore subsidy shall not necessarily be available for solar pumps. Hence, the financing models envisaged should majorly consider either subsidy from external donor agencies or financing by MFIs/DFIs for the cost of the pump. The subsidy may be required for initial implementation of the solar pumps considering the technology is still new in the country. With the progress of deployment and improvement in costs, the subsidy may be reduced in a phased manner. Further, some amount maybe paid by the farmers upfront while the remaining may be done on periodic basis in the form of loan repayments.
4. **Knowledge development:** Number of motorized agricultural pumps deployed in Fiji are very limited and farmers have relied on river water, surface water or hand pumps for irrigation. Therefore, awareness creation and knowledge development of the farmer with regard to deployment of solar pumps is necessary to enable effective adoption and utilization of the solar enabled pumps. Initially these activities may be undertaken by i-STARCs to be developed in Fiji under the ISA's programme.
5. **Ecosystem availability:** Though Ministry of Energy and Water Resources has already implemented solar water pumping systems for drinking water, the solar ecosystem is not well developed in the country. Therefore availability of local manpower for solar and pumps may be a challenge during the initial phase of implementation. However initial training on the operations and maintenance aspects of the solar pumps will mitigate the challenge to an extent.

7. Proposed next steps

1. **Pre-feasibility report**: The pre-feasibility report may be shared with Multilateral Development Banks (MDBs) such as World Bank, EXIM Bank for financing solar water pumping systems in Fiji. This report assesses the feasibility of implementation of solar pumps with reasonable assumptions as detailed in the report. However, to arrive at a detailed feasibility assessment, site specific and other relevant details (such as, applicable taxes, duties, government incentives etc.) are required from the relevant Ministry.

2. **Capacity building**: Post bid process and financing arrangement, Identification of foundations/ institutions in Fiji to assist in the capacity building of farmers and knowledge development of local technicians may be initiated by pump suppliers and through i-STARCs.

3. **Implementation scale**: Considering that SWPS are not deployed at a major scale in Fiji so far, installation of these 27 pumpsets may be planned as pilot project to conduct detailed study for various types of crops along with their water requirement. This may help in creating awareness for scaling of the programme at country level. The roadmap for the same may be prepared by Government of Fiji in consultation with ISA.

4. **Field preparation**: Boring activities may also be suitably initiated by farmers in the area where the solar pumps are planned to be initially implemented.

5. **Supply and project monitoring**: Regular project monitoring for supply and installation of pumps may be undertaken by ISA and NFP Fiji basis field reports and feedback from farmers, suppliers / installers and government agencies.