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

Table of Contents

List of Figures 3
List of Tables 3
1. Executive Summary 4
2. Background 6
2.1 About ISA 6
2.2 About SSAAU Programme 7
3. Introduction 10
3.1 About Nauru 10
3.2 Overview of Energy Scenario 11
4. Technical Feasibility Assessment 13
4.1 Assessment Criteria 13
4.1.1 Total Dynamic Head 13
4.1.2 Pump Curves 14
4.1.3 Crop Water Requirement 15
4.1.4 Pump Sizing 15
4.2 Country Assessment 15
4.2.1. Connectivity and Accessibility 15
4.2.2. Climate and Rainfall 16
4.2.3. Geology and soils 17
4.2.4. Groundwater Status 18
4.2.5. Agriculture 18
4.2.6. Solar Irradiance 20
5. Financial Feasibility Analysis 21
5.1 Indicative Inputs 21
5.2 Indicative Crop Water Requirement 21
5.3 Indicative Irrigation schedule 22
5.4 Indicative Outputs 22
6. Recommendations 23
7. Proposed next steps 24

List of Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
CIE	Department of Commerce, Industry and Environment
DC	Direct Current
EBRD	European Bank for Reconstruction and Development
EESL	Energy Efficiency Services Limited
EIB	European Investment Bank
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GDP	Gross Domestic Product
GoN	Government of Nauru
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
MW	Megawatt
NDB	New Development Bank
NFP	National Focal Points
NUC	Nauru Utilities Corporation
PV	Photovoltaic
R&D	Research and Development
REA	Electricity Regulatory Authority
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
UNCTAD	United Nations Conference on Trade and Development
USD	United States Dollar
UL	Underwriters Laboratories

List of Figures

Figure 1: Work Packages and Responsibility Division 9
Figure 2: Map of Nauru 11
Figure 3: Installed capacity and Power Generation of Nauru 11
Figure 4: Energy institutional map of Nauru 12
Figure 5: Factors involved in feasibility analysis of solar pump 13
Figure 6: Schematic diagram of total dynamic head of a Solar pump 14
Figure 7: Pump Performance Curves 14
Figure 8: Road Network of Nauru 16
Figure 9: Daylight hours in Boe, Nauru 17
Figure 10: No. of days of Rainfall over the year in Boe, Nauru 17
Figure 11: Percentage contribution of subsistence income to total subsistence income 19
Figure 12: Percentage distribution of total land area cultivated by active farmers in Nauru 19
Figure 13: Global Horizontal Irradiation for Nauru 20

List of Tables

Table 1: Key Activities under SSAAU Programme 7
Table 2: Demand received from various ISA member countries for solar pumps 8
Table 3: Key features of Internal Competitive Bidding for Price Discovery of Solar Pumps 9
Table 4: Key Economic Parameters of Nauru 10
Table 5: Electricity Tariff of Nauru as on 2018 12
Table 6: Effect of major climatic factors on crop water requirement 15
Table 7: Temperature Variation in Boe, Nauru 16

1. Executive Summary

Nauru is an island country in southwestern Pacific Ocean consists of a raised 21 km^2 coral island located in southeastern Micronesia, 40 km south of the Equator. The island is about 1,300 km northeast of the Solomon Islands; its closest neighbour is the island of Banaba, in Kiribati, approximately 300 km to the east. Nauru has no official capital, but government offices are located in the district of Yaren.

Most of the island's residents are indigenous Nauruans. There are small numbers of I-Kiribati (Gilbertese), Australians, New Zealanders, Chinese, and Tuvaluans; many members of the latter two groups were recruited as workers by the phosphate industry. Though Nauruan is the national language, English is widely spoken. Nauru is considered one of the most Westernized countries in the South Pacific.

Nauru Electricity Sector

Nauru is entirely dependent on imported fuel for generation of electricity. The government relies on grant funding from Australia and Japan for the purchase of imported fuel. Electricity consumption per capita is 2,035.8 kWh/person/year.

The state-owned Nauru Utilities Corporation (NUC) is responsible for electricity and water supply. Though the electrification rate is 100%, the installed capacity (99% diesel-based) is insufficient to meet the demand. The NUC is working to build generation capacity and refurbish existing equipment to provide more reliable power supply. The Government of Nauru has set a renewable energy target of 50% by 2020.

Connectivity and Accessibility

A sealed 19 km road goes all the way around and driving takes about 25 minutes to circumnavigate the island. A paved road system links all villages. Surface transportation to other destinations is difficult because there are no wharves or natural harbours; passengers and cargo are shuttled by barge between oceangoing vessels and a small artificial anchorage. Most regional and international travel is by air. Nauru's sole airport is located in Yaren district. In 1970 the country launched its national airline and is currently owned by a government corporation.

Climate and Rainfall

The climate of Nauru can be described as a typical warm, tropical climate with two different seasons, Dry and Rainy seasons. The country has consistent monthly average temperatures throughout the year which are strongly tied to the surrounding ocean temperature. The wet season usually starts in November and continues to April of the next year, while drier conditions occur from May to October.

Soil

Nauru soils are generally poor and suffer major deficiencies of key elements (particularly nitrogen and potassium). Currently, however, agriculture and home gardening activities are still rather limited. Measures to alleviate these problems include education programs within schools to improve awareness of the necessity to produce local food, mobilization of community groups to train the families on food production activities, and the provision of propagation materials and tools for home garden activities. As the people of Nauru become aware of the need to improve their food security and nutrition status, agriculture is beginning to grow in importance as more people are now starting to plant crops.

Agriculture

An estimation indicates freshwater layer of at least 7 m thickness beneath most of the island. The area of land potentially available for agricultural purposes is small (there is only about 4 km^2 of fertile land, much of which is taken up by residential housing). Availability and sustainability are constrained by plot size, soil type, proximity to housing and other alternate use. Agriculture and Fisheries have been identified as priority sectors for development in view of their direct link to and role in improving nutrition and food security. However, after years of mining, the only fertile areas are in the narrow coastal belt and the land surrounding Buada lagoon. Inadequacy of bore water and frequent droughts mean that availability of water is also a limiting factor for agricultural production. Currently very few food crops are grown; most food items are imported, and only limited varieties of fruit trees and vegetables are cultivated on a very small scale for home consumption. There is currently no formal commercial agriculture in Nauru.

Financial Feasibility Assessment

Nauru has submitted demand for 400 Nos. solar water pumping systems. At an average price of USD 3,849 per 1 HP pumpset[1], Nauru requires financing of USD 1.54 million to roll out deployment of 400 Nos. solar water pumping systems across the country.

Recommendation

The pumps should be adequately sized to meet the crop water requirements of the area. The meteorology of Nauru is characterized as tropical climate with almost consistent rainfall throughout the year. Also, the ground water table depth across Nauru is less than 15 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 1 HP pumps with an incremental payback of 8 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 services contract 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:

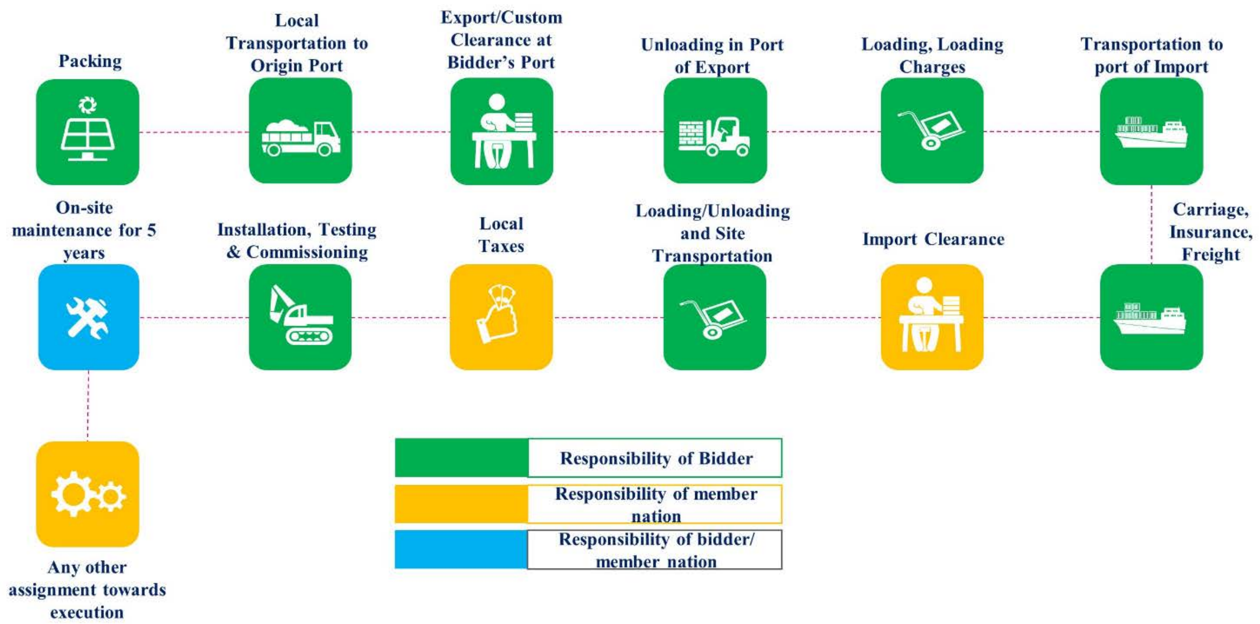


Figure 1: Work Packages and Responsibility Division

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 Nauru

Nauru is an island country in southwestern Pacific Ocean consists of a raised 21 km^2 coral island located in southeastern Micronesia, 40 km south of the Equator. The island is about 1,300 km northeast of the Solomon Islands; its closest neighbour is the island of Banaba, in Kiribati, some 300 km to the east. Nauru has no official capital, but government offices are located in the district of Yaren.

Most of the island's residents are indigenous Nauruans. There are small numbers of I-Kiribati (Gilbertese), Australians, New Zealanders, Chinese, and Tuvaluans; many members of the latter two groups were recruited as workers by the phosphate industry. Though Nauruan is the national language, English is widely spoken. Nauru is considered one of the most Westernized countries in the South Pacific.

Agriculture, fishing, manufacturing, and tourism are of minor value to the overall economy. However, Nauru has an exclusive economic zone extending 320 km offshore. The sale of commercial fishing licenses began to bring in a steady revenue during the 1990s.

Phosphate has been mined on Nauru since 1907. For decades it was Nauru's main resource and sole export, dominating the island's economy, and its quality was the highest in the world. The phosphate industry and government services together provided almost all of the island's salaried employment. For much of the 20th century the phosphate industry was owned and operated by a corporation jointly managed by the British, Australian, and New Zealand governments. The government of independent Nauru gained control of phosphate operations in 1970, and in the 1980s Nauru was for a time one of the wealthiest countries in the world in terms of gross domestic product per capita.[2]

Historically, Nauru has not had recognized political parties within its Parliament. Nauru's political situation has remained very fluid, with frequent votes of no confidence, to the detriment of good governance.

Parameter	Units	Value	Year
Population	Nos.	12,704	2018
Country GDP	USD Million	125.6	2018
GDP growth rate	%	5.7%	2018
Foreign Direct Investment	USD Billion	0	2018
World Bank Political Stability Index	Nos.	0.51	2018
Retail inflation rate	%	2.5%	2019
Per capita GDP	USD	9,889	2018
Corporate Tax rate	%	25%[3]	2018

Table 4: Key Economic Parameters of Nauru[4]

[2] Britannica – Nauru
[3] Republic of Nauru Government Gazette
[4] World Bank – World Development Indicators

Figure 2: Map of Nauru[5]

3.2 Overview of Energy Scenario

Nauru is entirely dependent on imported fuel for generation of electricity. The government relies on grant funding from Australia and Japan for the purchase of imported fuel. Electricity consumption per capita is 2,035.8 kWh/person/year.[6]

The state-owned Nauru Utilities Corporation (NUC) is responsible for electricity and water supply. Though the electrification rate is 100% the installed capacity (99% diesel-based) is insufficient to meet the demand. The NUC is working to build generation capacity and refurbish existing equipment to provide more reliable power supply. The Government of Nauru has set a renewable energy target of 50% by 2020.

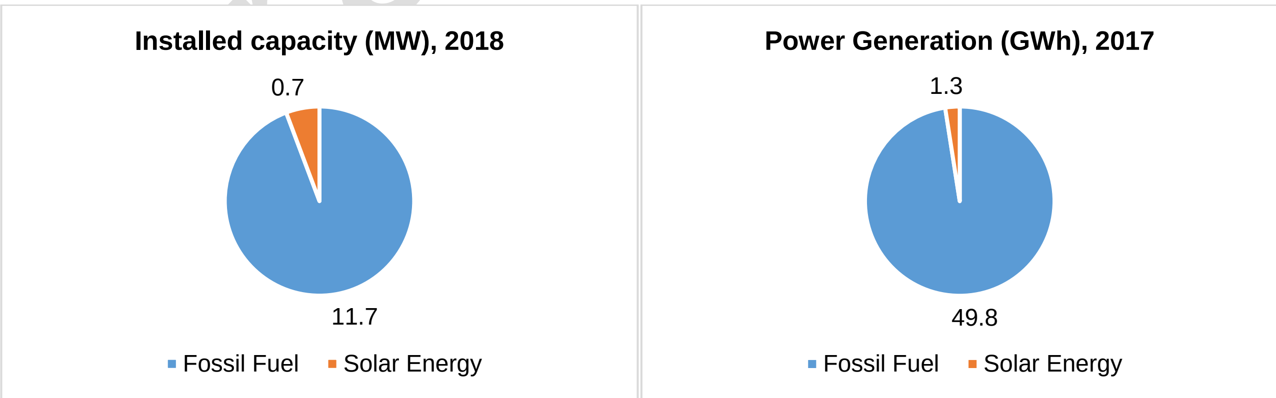


Figure 3: Installed capacity and Power Generation of Nauru[7]

[5] Administrative Map of Nauru - Nations Online Project
[6] Energy Statistics Pocketbook 2019
[7] IRENA Statistics Tool

The Government of Nauru developed the Nauru Energy Road Map (NERM) 2014-2020 in 2013 and updated in 2018 with the following targets:

- 24/7 grid electricity supply with minimal interruptions
- 50% of grid electricity supplied from renewable energy sources
- 30% improvement in energy efficiency in the residential, commercial and government sectors

According to NUC Annual Report 2018, the electricity rates for each category are mentioned below.

Electricity consumer categories	Tariff (US Cents)
Residential	25/kWh – 50/kWh
Commercial	70/kWh
Industrial	70/kWh
Government	70/kWh
Feed in Tariff	20/kWh

Table 5: Electricity Tariff of Nauru as on 2018[8]

With regard to the institutional framework for energy policy making, planning and regulation within government, there have been very limited resources dedicated to the energy sector to date with responsibility for energy policy being allocated to the Environment Division of the Department of Commerce, Industry and Environment (CIE). There is no single staff with responsibility for the energy sector and this has been managed by CIE staff largely on an "as needed" basis under the direction of the Secretary of CIE. An approximate institutional mapping of the energy sector is given in Figure below.

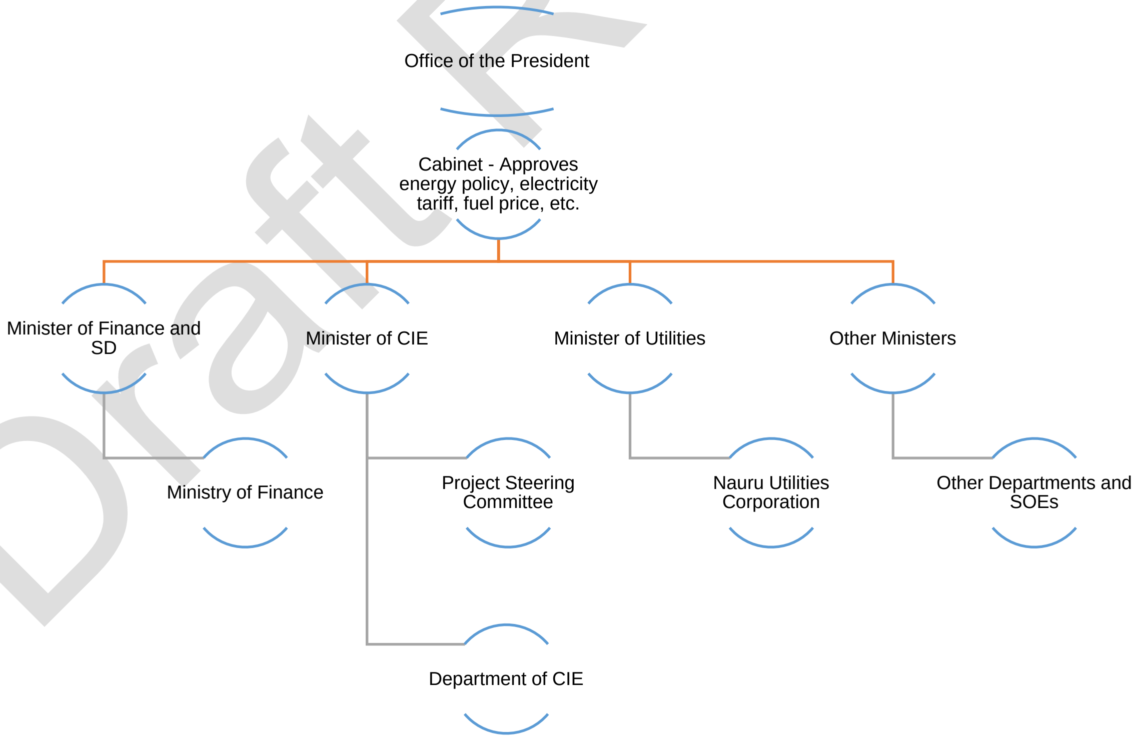


Figure 4: Energy institutional map of Nauru[9]

[8] Electricity Sector Development Strategy Note, World Bank
[9] Asian and Pacific Energy Forum -

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.

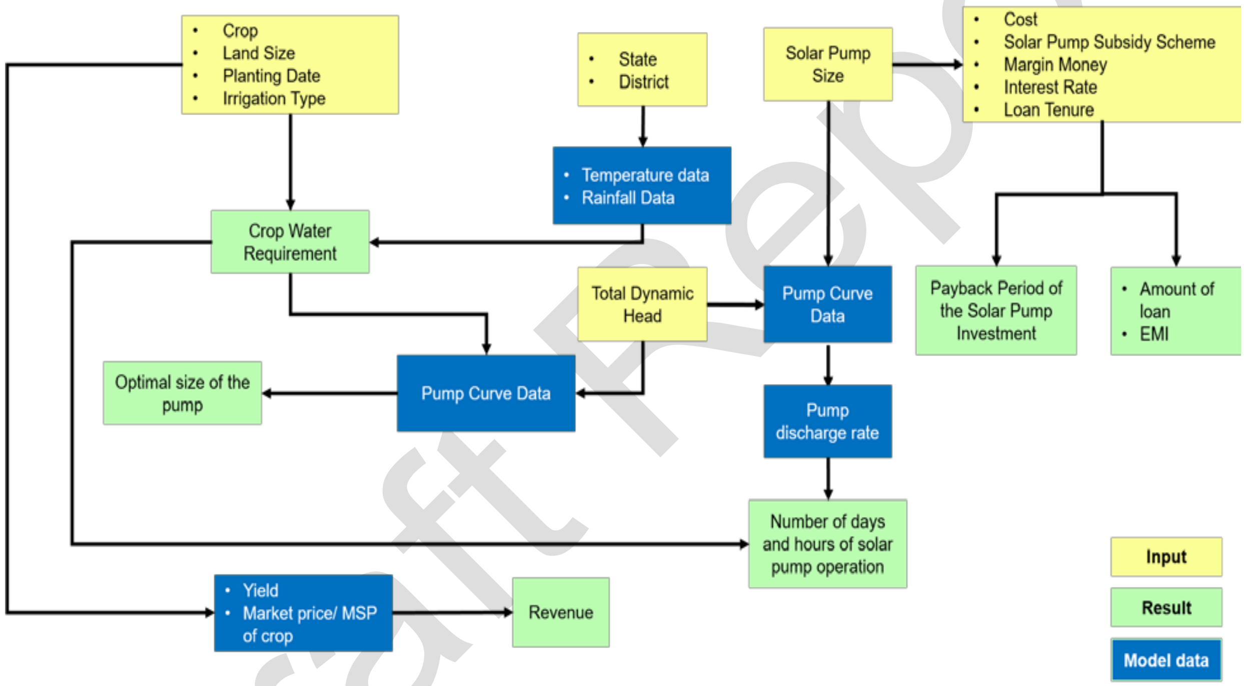


Figure 5: Factors involved in feasibility analysis of solar pump

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[10]:

[10] Review of SWPS - Science Direct

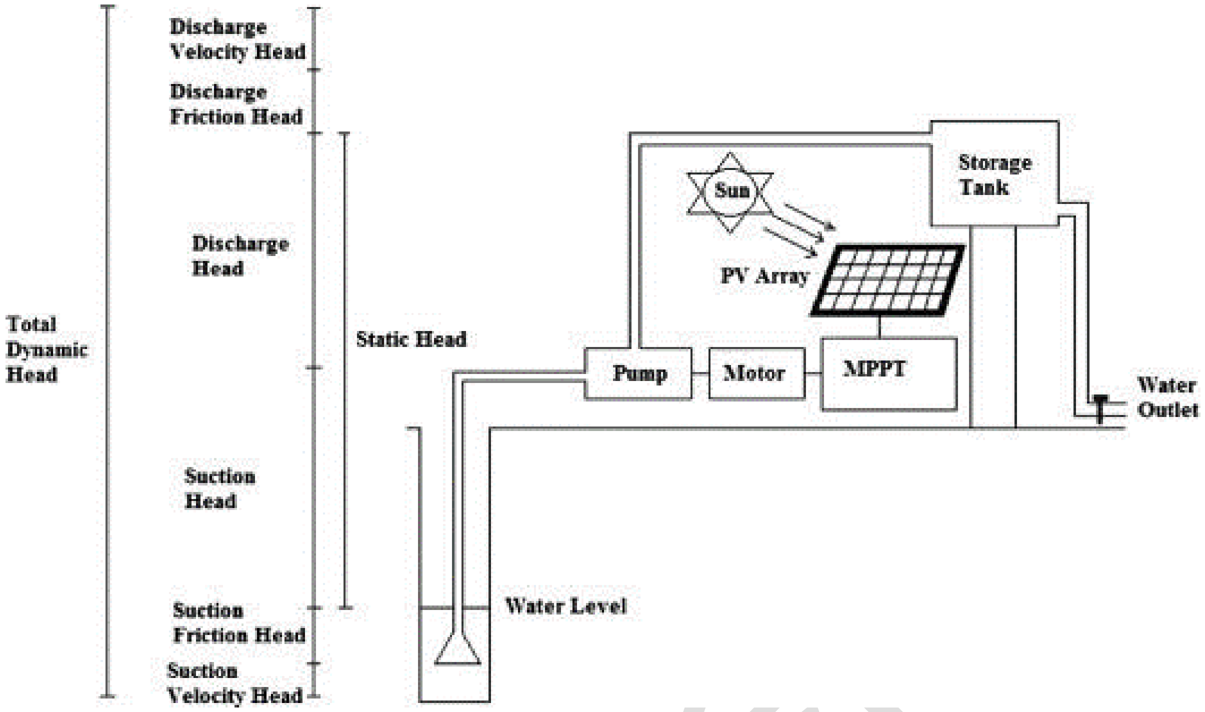


Figure 6: Schematic diagram of total dynamic head of a Solar pump

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[11]. 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[12]:

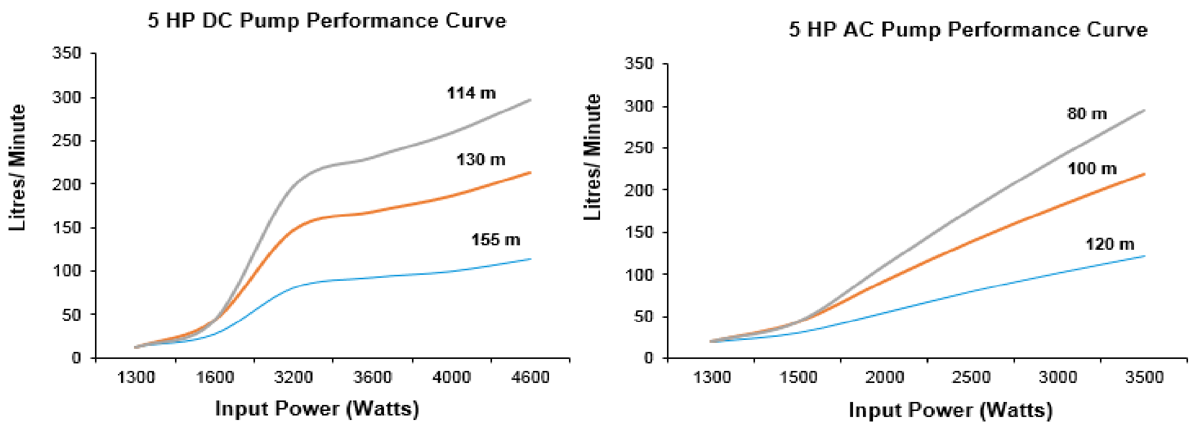


Figure 7: Pump Performance Curves

[11] System Curve and Pump Performance Curve - The Engineering Toolbox
[12] 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)[13]

Table 6: 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[14].

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[15].

4.2 Country Assessment

4.2.1. Connectivity and Accessibility

A sealed road goes all the way around the island and driving takes about 25 minutes to circumnavigate. A paved road system links all villages. Surface transportation to other destinations is difficult because there are no wharves or natural harbours, passengers and cargo are shuttled by barge between oceangoing vessels and a small artificial anchorage. Most regional and international travel is by air. Nauru's sole airport is located

[13] Principles of Irrigation Water Heeds - FAO
[14] Principles of Irrigation Water Heeds - FAO
[15] Basic Guidelines of SWPS – Sun Connect News

in Yaren district. In 1970 the country launched its national airline, control of which was transferred in 1996 to a government-owned corporation.

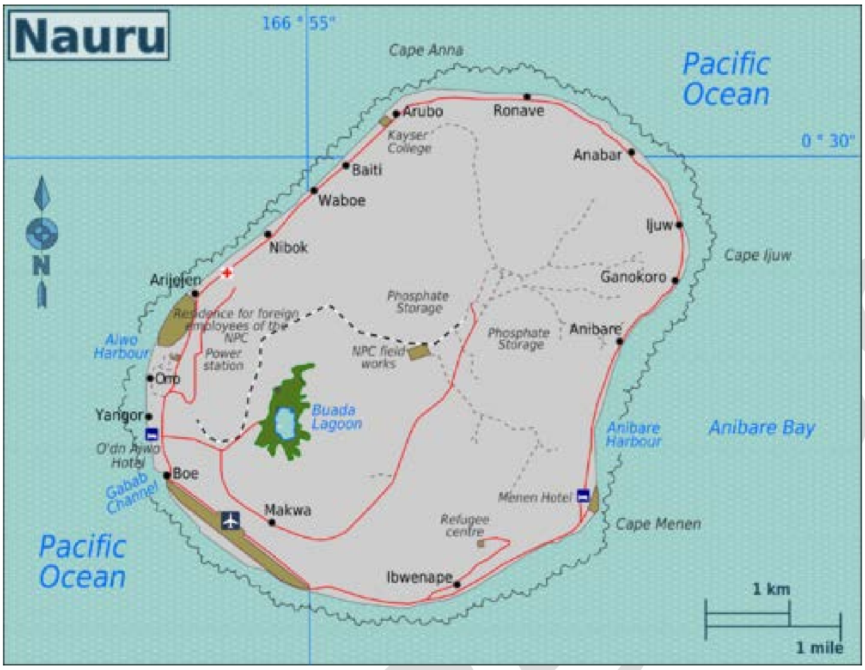


Figure 8: Road Network of Nauru[16]

4.2.2. Climate and Rainfall

The climate of Nauru can be described as a typical warm, tropical climate with two different seasons, Dry and Rainy seasons. The country has consistent monthly average temperatures throughout the year which are strongly tied to the surrounding ocean temperature (Table 7). The wet season usually starts in November and continues to April of the next year, while drier conditions occur from May to October.

Nauru's climate varies considerably from year to year due to the El Niño Southern Oscillation. This is a natural climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the El Niño Southern Oscillation: El Niño and La Niña. There is also a neutral phase. In Nauru, El Niño events tend to bring warmer, wetter conditions than normal, while La Niña events are associated with a delayed onset of the wet season and drier than normal conditions, often resulting in an extended drought[17].

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	27.7	27.7	27.6	27.6	27.9	27.6	27.5	27.6	27.7	28.0	28.0	27.7
Min. Temperature (°C)	24.7	24.9	24.9	24.9	25.2	25.0	24.8	24.8	24.8	25.0	24.9	24.7
Max. Temperature (°C)	30.7	30.6	30.4	30.4	30.6	30.3	30.3	30.4	30.7	31.0	31.2	30.8
Precipitation / Rainfall (mm)	284	251	205	203	128	111	145	140	116	104	115	254

Table 7: Temperature Variation in Boe, Nauru[18]

[16] Wiki Voyage
[17] Pacific Climate Change Science Program – Current and Future climate of Nauru
[18] Nauru: Climate Data

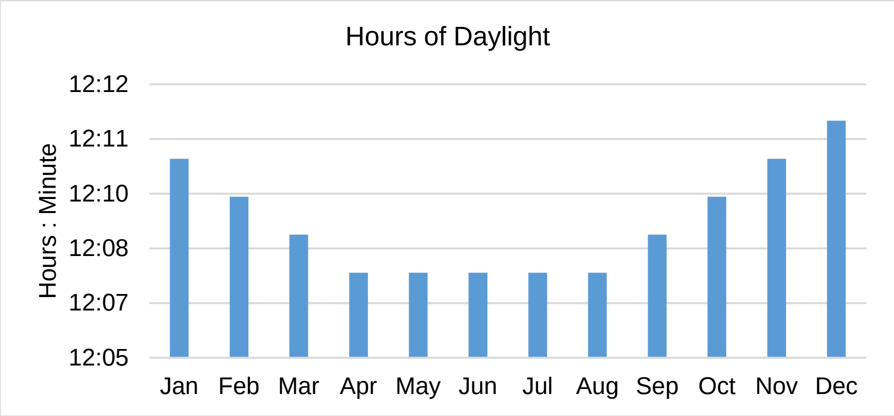


Figure 9: Daylight hours in Boe, Nauru[19]

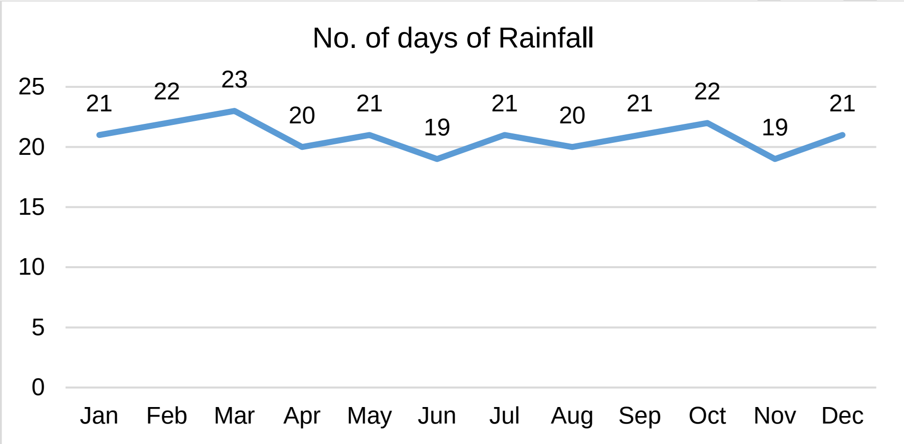


Figure 10: No. of days of Rainfall over the year in Boe, Nauru[20]

4.2.3. Geology and soils

The coastal perimeter inshore of the reef comprises a zone of sandy or rocky beach on the seaward edge, a beach ridge or foredune, behind which is flat ground or, in some places, low-lying depressions or small lagoons filled by brackish water where the surface level is below the water table. The most extensive system of these landlocked lagoons is found near the border of Ijuw and Anabar Districts. Scattered limestone outcrops or pinnacles also can be found on the coastal plain and on the intertidal flats of the fringing reef, particularly in the Anibare Bay area.

Nauru soils are generally poor and suffer major deficiencies of key elements (particularly nitrogen and potassium). Use of fertilizer and composting is not common due to costs and lack of farmer skills. But given resources, these problems can be rectified. Currently, however, agriculture and home gardening activities are still rather limited. Measures to alleviate these problems include education programs within schools to improve awareness of the necessity to produce local food, mobilization of community groups to train the families on food production activities, and the provision of propagation materials and tools for home garden activities. As the people of Nauru become aware of the need to improve their food security and nutrition status, agriculture is beginning to grow in importance as more people are now starting to plant crops. Donors are giving support to the effort; however, activities are currently piecemeal and unorganized in nature. Small-scale production of vegetables and tree crops has been encouraged and effort to improve productivity made, targeted at the coastal strip.

[19] World Data - Nauru
[20] Boe, Nauru - Weather Atlas

4.2.4. Groundwater Status

Two hydrologists viz. Hill, P.J. and Jacobson, G. conducted a groundwater investigation on behalf on the Commission of Inquiry on Phosphate Mining. They drilled 12 exploratory boreholes, from 30 m to 70 m deep, and used geoelectrical soundings to estimate the thickness of the fresh layer of the groundwater. The estimation of the thickness of the fresh layer was not accurate (estimates ranged from 0.5 m to 7 m for the northern bores and 3.5 m to 7 m for the southern bores), but overall the results indicated a freshwater layer at least 3 m thickness beneath most of the island. The salinity of the groundwater rapidly increases with depth – being too salty for potable water uses only 2 m below the assumed base of the freshwater.

They stated that "The thinness of the freshwater layer (4 – 5 m) precludes the use of pumping bores because of the likelihood of upconing saltwater disrupting the freshwater layer". Because of the risk of upconing, they suggested that groundwater should be skimmed from the surface of a multiplicity of bores at very low extraction rates (< 0.1 L/s) or by a long horizontal gallery.

They measured TDS (total dissolved solids) at 25 coastal wells. The median TDS was 1,480 mg/L, just within the acceptable range. However, 30 % of the wells had a TDS over 1,500 mg/L, above the normally accepted upper limit for drinking water. Replenishment or recharge of the freshwater lens is dependent on rainfall. A first approximation of the average groundwater recharge for Nauru is 800 mm per year: [21]

$$\text{rainfall (2,100 mm)} - \text{evapotranspiration (1,300 mm)} = \text{groundwater recharge (800 mm)}$$

4.2.5. Agriculture

Agriculture and Fisheries have been identified as priority sectors for development in view of their direct link to and role in improving nutrition and food security. However, after years of mining, the only fertile areas are in the narrow coastal belt and the land surrounding Buada lagoon. Also, the will to till the soil, plant crops and raise livestock has largely disappeared from the general population, as have most of the fertile soils, through phosphate mining. Inadequacy of bore water and frequent droughts mean that availability of water is also a limiting factor for agricultural production. Currently very few food crops are grown; most food items are imported, and only limited varieties of fruit trees and vegetables are cultivated on a very small scale for home consumption. There is currently no formal commercial agriculture in Nauru.

The area of land potentially available for agricultural purposes is small (there is only about 4 km^2 of fertile land, much of which is taken up by residential housing). Availability and sustainability are constrained by plot size, soil type, proximity to housing and other alternate use. This is further constrained as a result of land tenure conflicts and water rights. Land tenure is complicated and can restrict individual developments. Land is fragmented and often polluted. It is relatively infertile, has poor water holding capacity and narrow available water range. Irrigation, if available is rudimentary and will rely on a potentially brackish underground water resource or a fragile rainwater collection system. Rainwater catchments are used to supplement bore water although frequent droughts make dependence on this source risky for commercial operations. FAO recently completed a study into the feasibility of setting up a hydroponics system for the production of vegetables. Insufficient availability of water was identified as one of the most limiting factors. Improving water use efficiency through an appropriate water-use strategy, including conservation, rainwater catchments and appropriate irrigation practices is a priority if agricultural production is to increase.

There are only about 60 recorded vascular plant species native to the island, none of which are endemic. Coconut farming, mining, and introduced species have caused serious disturbance to the native vegetation. There are no native land mammals, but there are native insects, land crabs, and birds, including the endemic Nauru Reed Warbler. The Polynesian rat, cats, dogs, pigs, and chickens have been introduced to Nauru. There

[21] Bouchet L, Sinclair P (2010) Assessing the vulnerability of shallow groundwater domestic wells in Nauru. SOPAC Technical Report. Pacific Islands Applied Geoscience Commission (SOPAC), Suva.

are no honeybees in Nauru, and pollination of fruit trees and vegetables is a key limiting factor to high yields of crops.

There are limited natural freshwater resources on Nauru. Rooftop storage tanks collect rainwater but the islanders are mostly dependent on three desalination plants housed at Nauru's Utilities Agency.

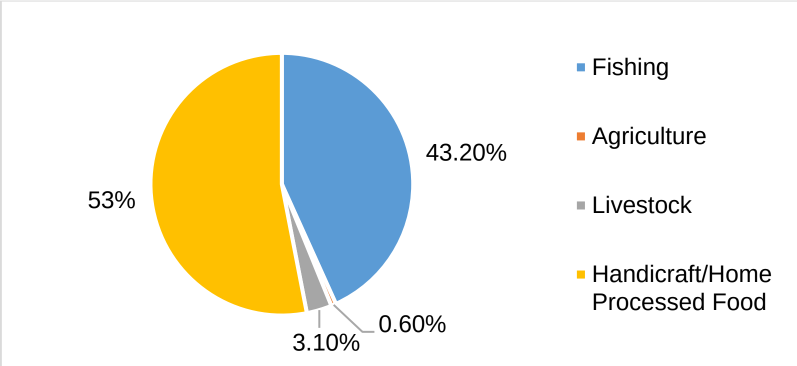


Figure 11: Percentage contribution of subsistence income to total subsistence income [22]

Primary production is confined to fruit and vegetable for domestic consumption, although Nauru is nowhere near self-sufficient in this regard. Coconuts, breadfruits, pandanus, bananas, pawpaw, mangoes, various fruit trees and few root crops are also grown on the coastal fringe.

The number of active farmers in Nauru is mainly those that have been able to participate in development projects where they have been able to access planting materials and water supplies to maintain crops. Moreover, the locals are able to farm if fertile land was available to them to utilize for farming purposes. The difficulties surrounding land ownership often restricts the yield a single farmer can produce due to the limited size of allotments available for agriculture. Most farmers in Nauru come from the Buada and Anabar regions. Many of the active farmers in Nauru are engaged in vegetable farming.

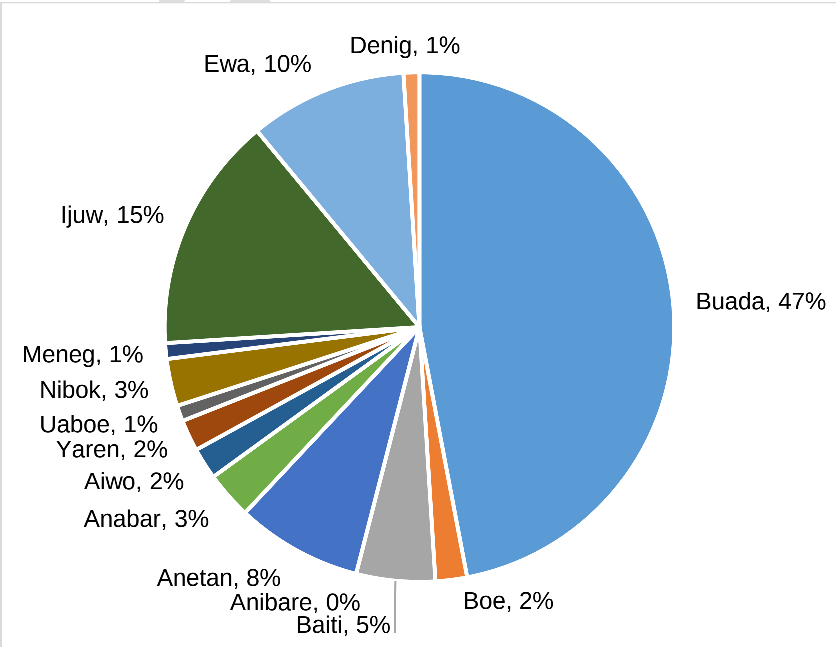


Figure 12: Percentage distribution of total land area cultivated by active farmers in Nauru[23]

[22] Household Income and Expenditure Survey
[23] Household Income and Expenditure Survey

4.2.6. Solar Irradiance

Nauru has abundant solar resource potential and it is the most commonly used technology implemented to date. Average insolation of 5.8/kWh/m2/day but the deployment of storage plays a crucial role to increase the penetration.

The solar radiation map for Nauru is shown in the image below.

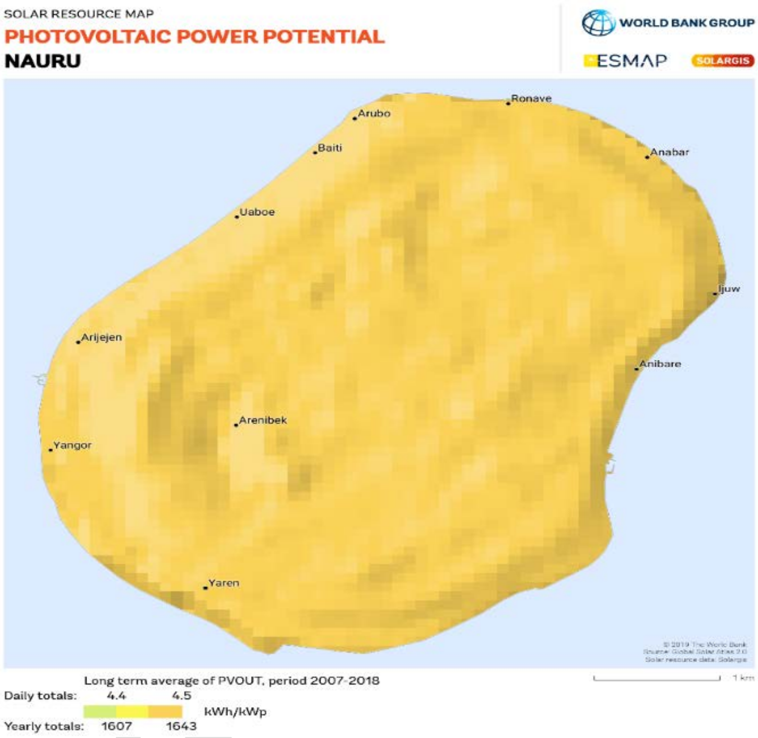


Figure 13: Global Horizontal Irradiation for Nauru[24]

[24] Solar resource maps - Solar GIS

5. Financial Feasibility Analysis

5.1 Indicative Inputs

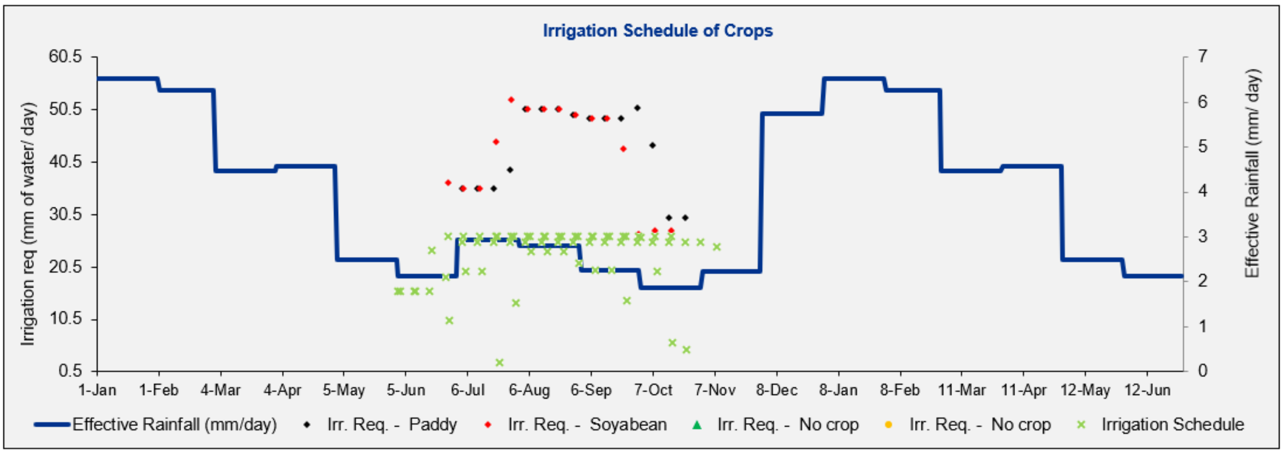
S.No.	Particulars	Unit	Value	Source
1	Crop to be Irrigated		Paddy, Soybean	
2	Land Size	hectares	0.5 (for each crop)	
3	Planting date		As per cropping calendar of Nauru	
4	Irrigation type		Flood: Lined canal supplied	
5	Annual average yield of crop	Kg/hectare	Paddy 4,935 Soybean 6,498	FAOSTAT
6	Market Price	USD/quintal	Paddy 38,928 Soybean 66,775	FAO: Food Price Monitoring and Analysis
5	Selected Size of Solar Pump	HP	1	
6	Total dynamic head inclusive of friction losses	meters	20	
7	Cost of Solar Pump	USD	3848.7 [25]	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	%	8.6 %	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	117	
14	Cost of diesel	USD/litre	1.57	Published reports and articles
15	Hike in diesel prices (y-o-y)	%	3%	Based on global averages
16	Inflation rate	%	2.5 %	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[26]

5.2 Indicative Crop Water Requirement [27]

Total crop water requirement (m^3)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					202	869	1,543	1,534	838		
Annual crop water requirement (m^3)					4,986						

[25] 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
[26] The toolkit developed by KPMG for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was used to undertake the analysis.
[27] 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	3,464
3	Yearly installment towards loan repayment	USD	617
4	Monthly installment towards loan repayment	USD	51
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	64
6	Number of hours of solar pump operation required	Hours	857
7	Number of days of solar pump operation required	Days	122
8	Incremental payback of solar pump w.r.t. diesel pump	years	8

Nauru has submitted demand for 400 Nos. solar water pumping systems. At an average price of USD 3,849 per 1 HP pumpset[28], Nauru requires financing of USD 1.54 million to roll out deployment of 400 Nos. solar water pumping systems across the country.

[28] 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 Nauru based on the above analysis and discussions undertaken during the visit of delegation from ISA Secretariat to Nauru:

1. **Number and type of pumps**: Nauru has submitted demand for procurement of 400 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. **Size of pumps:** The pumps should be adequately sized so as to meet the crop water requirements of the area. The meteorology of Nauru is characterized as tropical climate with almost consistent rainfall throughout the year. Also, the ground water table depth across Nauru is less than 15 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 1 HP pumps with an incremental payback of 8 years**.**
3. **Financing:** There are limited sources available for the government of Nauru 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 Nauru 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 Nauru under the ISA's programme.

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 etc. for financing solar water pumping systems in Nauru. 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 Nauru 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 Nauru so far, installation of these 400 pumpsets may be planned so as to conduct detailed study for various types of crops along with their water requirement. This may help in creating awareness about SWPS in the country.
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 Nauru basis field reports and feedback from farmers, suppliers / installers and government agencies.