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

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List of Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
AFD	Agence Française de Développement
CIA	Central Intelligence Agency
CSP	Concentrated Solar Power
DC	Direct Current
EBRD	European Bank for Reconstruction and Development
EdD	Electricité de Djibouti
EESL	Energy Efficiency Services Limited
EIB	European Investment Bank
ETo	Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiance
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
kVA	Kilo Volt Ampere
LAC	Latin America and the Caribbean
LNG	Liquefied Natural Gas
LoC	Line of Credit
MW	Megawatt
MTE	Ministry of Transport and Equipment
MERN	Ministère de l'Energie, chargé des Ressources Naturelles
NDB	New Development Bank
NFP	National Focal Points
PV	Photovoltaic
RO	Reverse Osmosis
R&D	Research and Development
REEEP	Renewable Energy and Energy Efficiency Partnership
REPS	Rural Electrification Policy Statement

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
UNCTAD	United Nations Conference on Trade and Development
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

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1. Executive Summary

Background

Djibouti is one of the smallest countries in Africa, lies at the Southern entrance to the Red Sea. It covers a surface area of 23,200 square kilometres (km^2) with 370 km of maritime coastlines, and shares borders with Eritrea, Ethiopia and Somalia.

Djibouti is bounded by Eritrea to the North, Ethiopia to the West and Southwest, and Somalia to the South. The Gulf of Tadjoura, which opens into the Gulf of Aden, bifurcates the eastern half of the country.

Djibouti's Electricity Sector

Djibouti is a small country with a population of 884,000 people. The electricity sector in Djibouti has not seen much progress for several decades. The country had no proven reserves of Coal, oil, hydropower, natural gas, or refining capacity. The country's is supplied primarily by thermal plants (about 120 MW) and some imported hydro energy from Ethiopia. However, the supplemental supply of power from Ethiopia does not always satisfy Djibouti's demand for power. Based on 2017 data, Djibouti's national electrification rate reached 88%.

It has a dual energy system with coexisting traditional and modern energy and practice, although the traditional system composed of fuel wood has been shrinking over time from 94,000 cu meters in 1996 to 72,000 cu meters in 2016. Most people live in towns, which influences the nature of energy consumption in favour of modern fuels such as electricity, kerosene and Liquid Petroleum Gas.

Connectivity and Accessibility

Road network in Djibouti classified as urban roads, national roads stretching to a total of 1,193 Km and districts roads totalling to 1,700 Km. 430 km are reported by Ministry of Transport and Equipment (MTE) as paved road and 763 Km are non-paved. In addition, from the non-paved roads, among these 763 Km, 311 Km are considered by the ministry as priority roads whereas the rest (452 Km) are non-priority roads.

While some main roads in Djibouti are well maintained, roads are often narrow, poorly lit, or washed-out. Many secondary roads are in poor condition or completely washed-out.

Climate and Rainfall

The torrid climate varies between two major seasons. The cool season lasts from October to April and typifies a Mediterranean style climate in which temperatures ranges between 20°C to 30°C with low humidity. The hot season lasts from May to September. Temperatures increase as the hot khamsin wind blows off the inland desert, and they range from an average low as 30°C to a stifling high to 40°C. This time of year is also noted for days in which humidity is at its highest.

The average annual precipitation is limited and is usually spread over 26 days. Different regions of the country receive varying amounts of precipitation: the coastal regions receive 160 mm of rainfall per annum, while the Northern and mountainous portions of the country receive about 380 mm. The rainy season lasts between January and March, with the majority of precipitation falling in quick, short bursts.

Soil

Little soil data is available for Djibouti and the country's soils are generally little evolved due to a dry climate, thin, very poor in organic matter and very stony. Some of the country's soils are very heterogeneous, generally formed by colluvium deposits of alluvial fans and stratified alluvial soils with a silty clay texture. In some areas, soils on bedrock fall within three categories of brown soils (from basalt), lithosols and calcareous coral sands. The lithosols are rhyolites from soil and are more acidic and low in fine particles than the soils derived from basalt. Saline soils represent 5% of the surface area where soils are subjected to a body of salt water.

Groundwater Status

The source of irrigation water in Djibouti is classified into three types, namely, deep groundwater, sub-surface water (or shallow groundwater) and surface water.

Groundwater is the main source of water in the country, both urban and rural, for domestic, agricultural and industrial use. Most irrigation using groundwater is small scale, because there are few locations with high yielding aquifers. Most farmers use small volumes of groundwater from shallow hand dug wells or boreholes in alluvium in wadis, where the shallow alluvial aquifer is recharged periodically by ephemeral river flows after rainfall events.

Wadi alluvial aquifers are used extensively for rural water domestic, irrigation and livestock supplies. More than 700 rural shallow (hand dug) wells and a few tubular wells abstracting from this aquifer, mainly in agricultural areas, for domestic, irrigation and livestock use, with an estimated cumulative abstraction of around 4.2 million cubic metres per year. About 20 wells were used to supply 1 million cubic metres per year to rural areas and Tadjourah and Obock towns.

Agriculture and Cropping Pattern

The major cropping seasons are summer cropping season (March to August) and winter cropping season (September to February). Because of high temperature, kinds of crops cultivated in summer are limited and melon, watermelon, okra and fodder crops are major crops in the summer cropping season. On the other hand, other crops and the crops of summer cropping are cultivated in winter. The harvest seasons of fruit trees are May and April for guava, June and July for mango and July and August for date palms.

Farmers generally cultivate some annual crops (vegetables and fodders) and tree crops (fruit trees and fodder trees). In addition, they raise livestock, mainly goat and sheep, and use the dung as manure for the cultivation. Therefore, their farm management is multiple farming.

Financial Feasibility

Djibouti has submitted demand for 100 Nos. solar water pumping systems. At an average price of USD 12,849.5 per 5 HP pumpset[1], Djibouti requires financing of USD 1.28 million to roll out deployment of 100 Nos. solar water pumping systems across the country.

S.No.	Particulars	Unit	Value
1	Amount of subsidy	USD	-
2	Amount of loan to be availed	USD	11,565
3	Yearly installment towards loan repayment	USD	2,271
4	Monthly installment towards loan repayment	USD	189
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	331
6	Number of hours of solar pump operation required	Hours	1,402
7	Number of days of solar pump operation required	Days	200
8	Incremental payback of solar pump w.r.t. diesel pump	years	6

[1] Average L1 price of AC Surface, AC Submersible, DC Surface and DC Submersible

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

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:

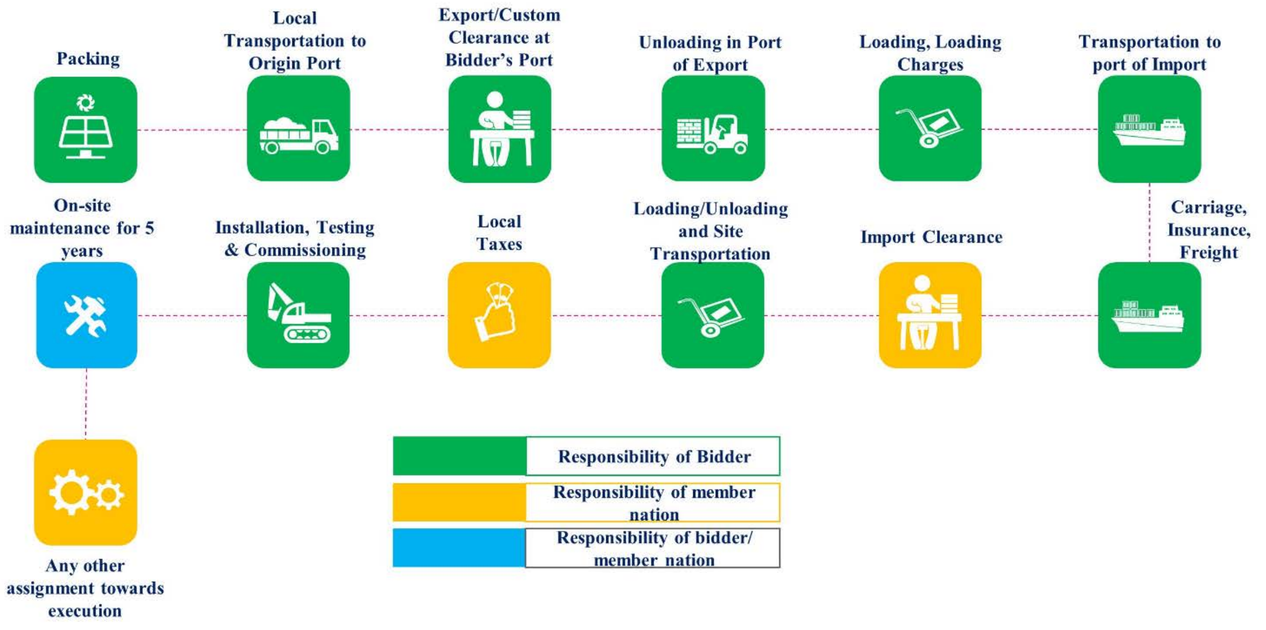


Figure 1: Work Packages and Responsibility Division

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 Djibouti

Djibouti is one of the smallest countries in Africa which lies at the Southern entrance to the Red Sea. It covers a surface area of 23,200 square kilometres (km^2) with 370 km of maritime coastlines, and shares borders with Eritrea, Ethiopia and Somalia.

Formerly known as French Somaliland (1896–1967) and the French Territory of the Afars and Issas (1967–77), the country took Djibouti as its name when it gained independence from France on June 27, 1977. Djibouti's capital, Djibouti city, is built on coral reefs that jut into the Southern entrance of the gulf; other major towns are Obock, Tadjoura, Ali Sabieh, Arta, and Dikhil.

Djibouti is bounded by Eritrea to the North, Ethiopia to the West and Southwest, and Somalia to the South. The Gulf of Tadjoura, which opens into the Gulf of Aden, bifurcates the eastern half of the country[2].

Figure 2: Map of Djibouti

The landscape of Djibouti is varied and extreme, ranging from rugged mountains in the North to a series of low desert plains separated by parallel plateaus in the West and South. Its highest peak is Mount Moussa at 6,654

[2] Britannica

feet (2,028 metres). The lowest point, which is also the lowest in Africa, is the saline Lake Assal, 509 feet (155 metres) below sea level.[3]

The country is internationally renowned as a geologic treasure trove. Located at a triple juncture of the Red Sea, Gulf of Aden, and East African rift systems, the country hosts significant seismic and geothermal activity. Slight tremors are frequent, and much of the terrain is littered with basalt from past volcanic activity. In November 1978 the eruption of the Ardoukoba volcano, complete with spectacular lava flows, attracted the attention of volcanologists worldwide.

The republic recognizes two official languages: French and Arabic. However, Somali is the most widely spoken language, although it is rarely written and is not taught in the schools. The use of Afar is mostly restricted to Afar areas. Many Djiboutians are multilingual.

3.2 Overview of Energy Scenario

Djibouti is a small country with a population of 884,000 people. The electricity sector in Djibouti has not seen much progress for several decades. The country had no proven reserves of Coal, oil, hydropower, natural gas, or refining capacity. The country is supplied primarily by thermal plants (about 126 MW) and some imported hydro energy from Ethiopia. However, the supplemental supply of power from Ethiopia does not always satisfy Djibouti's demand for power. Based on 2017 data, Djibouti's national electrification rate reached 88%[4].

Djibouti is endowed with abundant solar, wind, and geothermal natural resources, along with extensive coastline and dedicated port areas. The country has the potential to generate more than 300 megawatts (MW) of electric power from renewable energy sources, and much more from other resources, given its coastline and proximity to fuel-producing nations of the Gulf. Djibouti currently has just over 126 MW of installed generation capacity, of which only 57 MW is reliably available to serve its population and its key industries. Djibouti's geothermal resources have been recognized for years, and exploration activities are currently underway to identify economic vapor resources[5].

Despite high resource potential and opportunities for cross-border export, Djibouti's power sector faces significant challenges, including overall coherence of planning and goals, infrastructure development, deal flow and market entry for independent power producers (IPPs). Most of these issues may be easily resolved with regulatory clarity, institutional capacity building, and interconnection protocols.

There is high potential for solar energy exploitation as daily insolation levels range between 5.6 and 6.5 kWh/m^2/day in all areas of the country[6]; the government intends to use this to ensure economic development. Plans are in place to use solar energy to power a desalination plant to supply the city of Djibouti. It is estimated that about 40,000 m^3/day of salt water will be treated using a hybrid Concentrated Solar Power (CSP) and Reverse Osmosis (RO) plant.

3.3 Electricity Generation Transmission and Distribution

It has a dual energy system with coexisting traditional and modern energy and practice, although the traditional system composed of fuel wood has been shrinking over time from 94,000 cu meters in 1996 to 72,000 cu meters in 2016[7]. Most people live in towns, which influences the nature of energy consumption in favour of modern fuels such as electricity, kerosene and Liquid Petroleum Gas.

[3] Britannica
[4] Access to electricity - World Bank
[5] Power Africa - USAID
[6] Energy profile of Djibouti - UNEP
[7] UN Data

Djibouti relies entirely on imported electricity and fossil fuel for electricity generation. This is mainly heavy fuel oil for the main power plants and diesel for the provincial power stations. These are operated by public utility company Djibouti Electricity Company (Electricité de Djibouti) (EdD), which manages approximately 38,000 connections for the metropolitan area Djibouti City. The network is based on a 5 km, 63 kilovolt (kV) cable connecting the Boulaos and Marabout stations, and a 225 kVA interconnection line from Ethiopia which covers about 65% of the national domestic needs during the summer months. Electricity is supplied to the customers through around 300 distribution substations at 20kV. The isolated system grids are based on lower voltage distribution networks. Electricity access in Djibouti is about 55%[8].

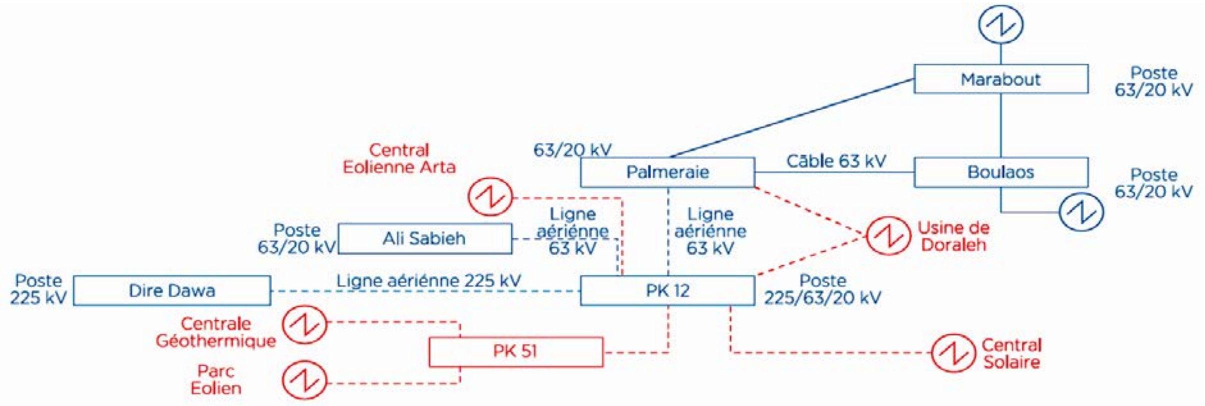


Figure 3: Transmission network in Djibouti[9]

Domestically generated power consists of EdD thermal capacities, which rely primarily on ageing generation capacity running on expensive imported fuel oil to produce baseload electricity. The utility has 18 generating units running on heavy fuel oil in Boulaos and Marabout. One 15 MW generator is 10 years old, having started up in 2007. Meanwhile, 14 generators with a combined capacity of 78 MW are between 10 and 15 years old. The remaining capacity is at least 25 years. Due to the unreliability of older generators, EdD effective generation capacity is limited to 57 MW of the 126 MW installed.

	Power plant location	Total capacity (MW)	Monthly fixed charge (Price/kWh)
Main grid	Boulaos	108.2	15
	Marabout	14.4	6
	Tadjoura	2.2	6
Interconnection	-	-	-
Isolated	Obock	1.2	5
Total		**126**	

Table 4: Installed electricity generation capacity in 2017[10]

Approximately 37% of electricity is consumed by big industries and activities related to the sea port, airport, free zone and military camps. Residential consumers, including a social consumer category, account for 38%. The remaining 25% is consumed by large retailers, public offices and government offices[11]. The service sector and domestic load components dominate peak demand. There are two daily peaks between May and October, largely concentrated during the afternoon office opening hours and in the early hours of the morning when air conditioning systems are in use.

[8] Renewables Readiness Assessment - IRENA
[9] Renewables Readiness Assessment - IRENA
[10] Renewables Readiness Assessment - IRENA
[11] World Bank and Parsons Brinckerhoff

3.3.1 Costs and tariffs

Government sets electricity tariffs and are set by ministerial decree from the Ministry of Economy and Finance in charge of planning. They are subject to review by Ministère de l'Energie, chargé des Ressources Naturelles (MERN).

Tariffs are set according to number of factors, such as electricity production cost (including operation cost), social cost and other political economy criteria. Electricity tariffs in Djibouti are high and average USD 0.32/kWh, mainly as a result of increased oil prices and technical and non-technical inefficiencies. The EdD 2018 tariffs range from a social price of USD 0.153/kWh (lifeline tariff) to USD 0.426/ kWh paid by industry and construction sites. Retailers and government buildings are charged USD 0.397/kWh for their electricity. The cost of electricity in Djibouti is very high compared to USD 0.05/kWh in Ethiopia and USD 0.10/kWh in Kenya, mainly because Djibouti's primary electricity production sources depend on petroleum products. As part of the effort to increase electricity access by low income households, a new law is under preparation to lower connection fees from their present levels of USD 280-350[12].

[12] Renewables Readiness Assessment - IRENA

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.

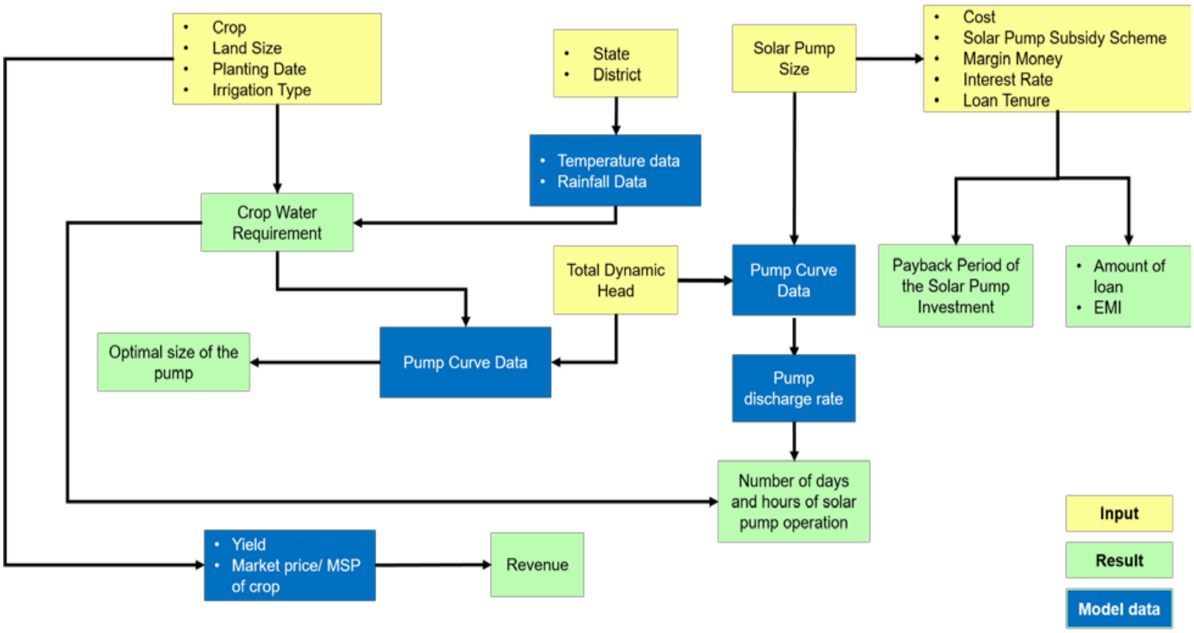


Figure 4: Factors involved in feasibility analysis of solar pump

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[13].

[13] ScienceDirect.com

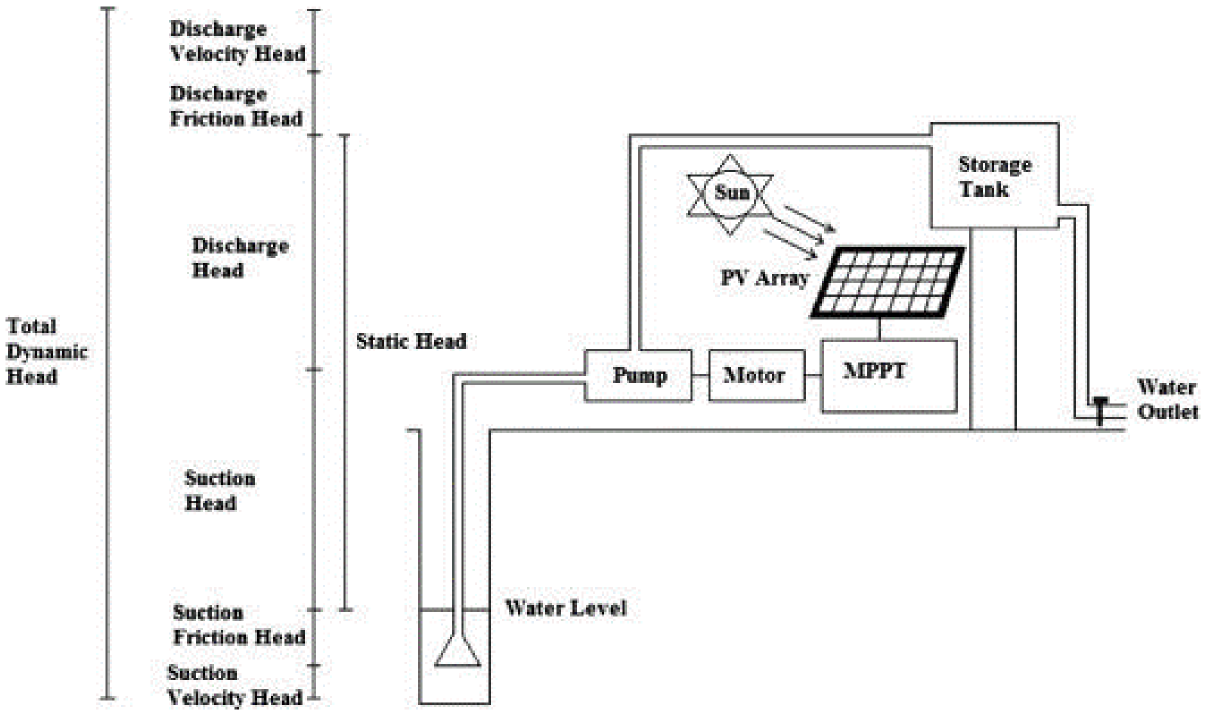


Figure 5: Total Dynamic Head of a solar pump

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[14]. 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[15]:

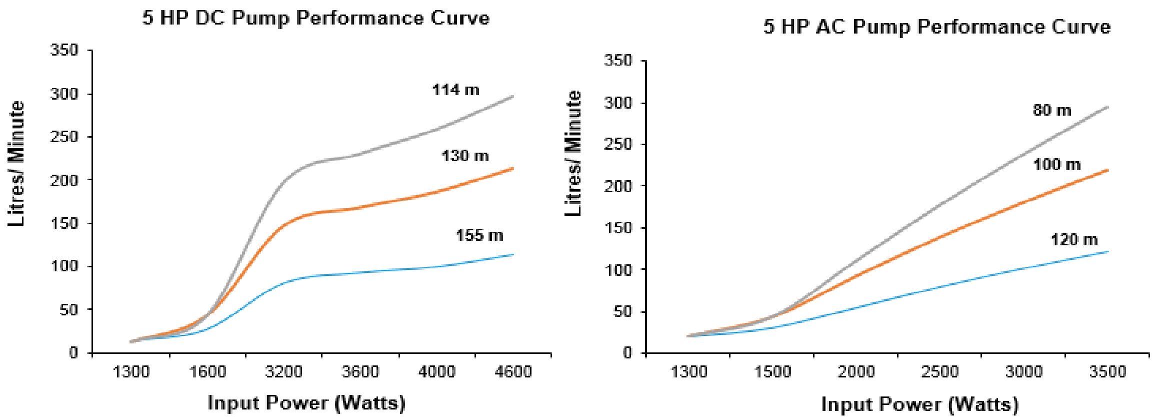


Figure 6: Pump Performance Curves

[14] The Engineering Toolbox
[15] 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)[16]

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[17].

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[18].

4.2 Country Assessment

4.2.1 Connectivity and Accessibility

Road network in Djibouti classified as urban roads, national roads stretching to a total of 1,193 Km and districts roads totalling to 1,700 Km. 430 km are reported by Ministry of Transport and Equipment (MTE) as paved road

[16] Crop Water Needs - Food and Agriculture Organization of the United Nations (FAO)
[17] Crop Water Needs - FAO
[18] Sun Connect News

and 763 Km are non-paved. In addition, from the non-paved roads, among these 763 Km, 311 Km are considered by the ministry as priority roads whereas the rest (452 Km) are non-priority roads[19].

While some main roads in Djibouti are well maintained, roads are often narrow, poorly lit, or washed-out. Many secondary roads are in poor condition or completely washed-out.

	Djibouti	Ali Sabieh	Arta	Dikhil	Obock	Tadjoura
Djibouti		60	30	80	180	120
Ali Sabieh	60		45	35	210	150
Arta	30	45		60	150	90
Dikhil	80	35	60		225	165
Obock	180	210	150	225		60
Tadjoura	120	150	90	165	60	

Table 6: Distances from Capital City to Major Towns (kms)[20]

Djibouti–Ambouli International Airport, which is situated about 6 km from the city of Djibouti, is the country's international air terminal. There are also local airports at Tadjoura and Obock.

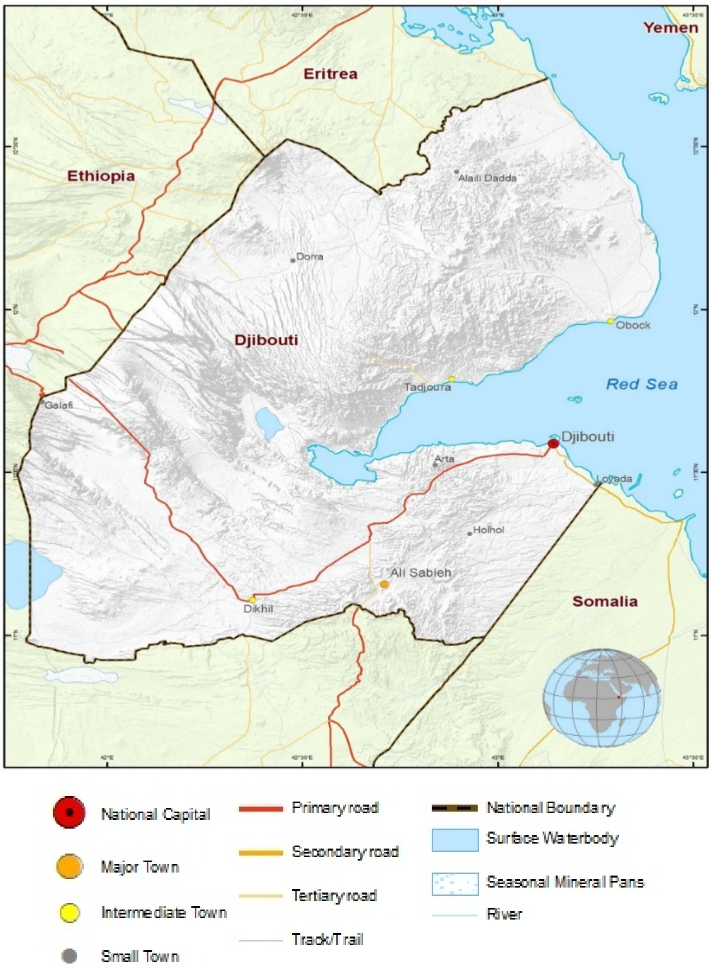


Figure 7: Road Network of Djibouti[21]

[19] Djibouti Road Network - Logistics Cluster
[20] Djibouti Road Network - Logistics Cluster
[21] Djibouti Road Network - Logistics Cluster

4.2.2 Climate and Rainfall

The torrid climate varies between two major seasons. The cool season lasts from October to April and typifies a Mediterranean style climate in which temperatures ranges between 20°C to 30°C with low humidity. The hot season lasts from May to September. Temperatures increase as the hot khamsin wind blows off the inland desert, and they range from an average low as 30°C to a stifling high to 40°C. This time of year is also noted for days in which humidity is at its highest. Among the coolest areas in the country is the Day Forest, which is located at a high elevation; temperatures in the low to -10°C have been recorded.

The average annual precipitation is limited and is usually spread over 26 days. Different regions of the country receive varying amounts of precipitation: the coastal regions receive 160 mm of rainfall per annum, while the Northern and mountainous portions of the country receive about 380 mm. The rainy season lasts between January and March, with the majority of precipitation falling in quick, short bursts. One outcome of this erratic rainfall pattern is periodic flash floods that devastate those areas located at sea level[22].

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	25.8	26.2	27.7	29.1	31.0	33.8	36.0	34.6	32.7	30.0	27.9	26.0
Min. Temperature (°C)	22.7	23.6	24.8	26.0	27.8	30.1	30.7	29.6	29.5	26.6	24.8	22.7
Max. Temperature (°C)	28.9	28.9	30.6	32.3	34.2	37.5	41.3	39.6	35.9	33.4	31.1	29.4
Precipitation / Rainfall (mm)	10	9	15	13	9	0	6	7	4	14	22	12

Table 7: Temperature Variation in Djibouti[23]

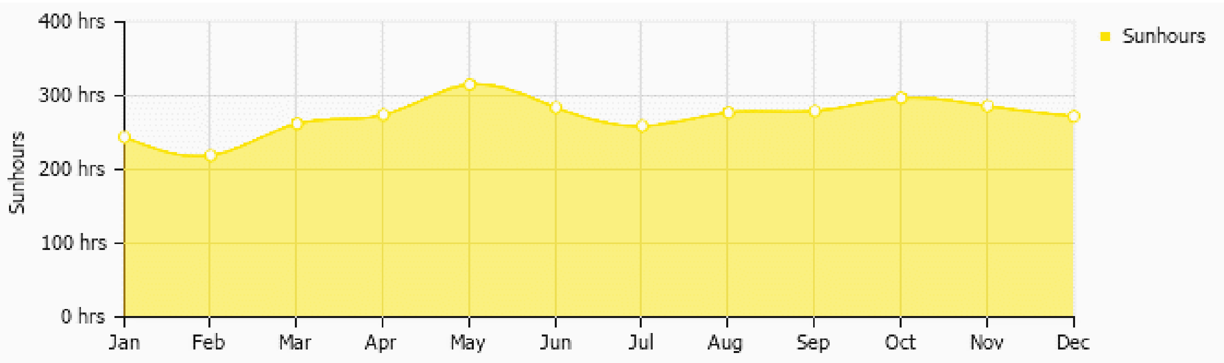


Figure 8: Sun hours in Djibouti region[24]

4.2.3 Soil Pattern

Little soil data is available for Djibouti and the country's soils are generally less evolved due to a dry climate, thin, very poor in organic matter and very stony. Some of the country's soils are very heterogeneous, generally formed by colluvium deposits of alluvial fans and stratified alluvial soils with a silty clay texture. In some areas, soils on bedrock fall within three categories of brown soils (from basalt), lithosols and calcareous coral sands. The lithosols are rhyolites from soil and are more acidic and lower in fine particles than the soils derived from

[22] Britannica
[23] Climate Data
[24] Weather and Climate

basalt. Saline soils represent 5% of the surface area where soils are subjected to a body of salt water. The broad soil types for Djibouti are presented in Figure 11[25]

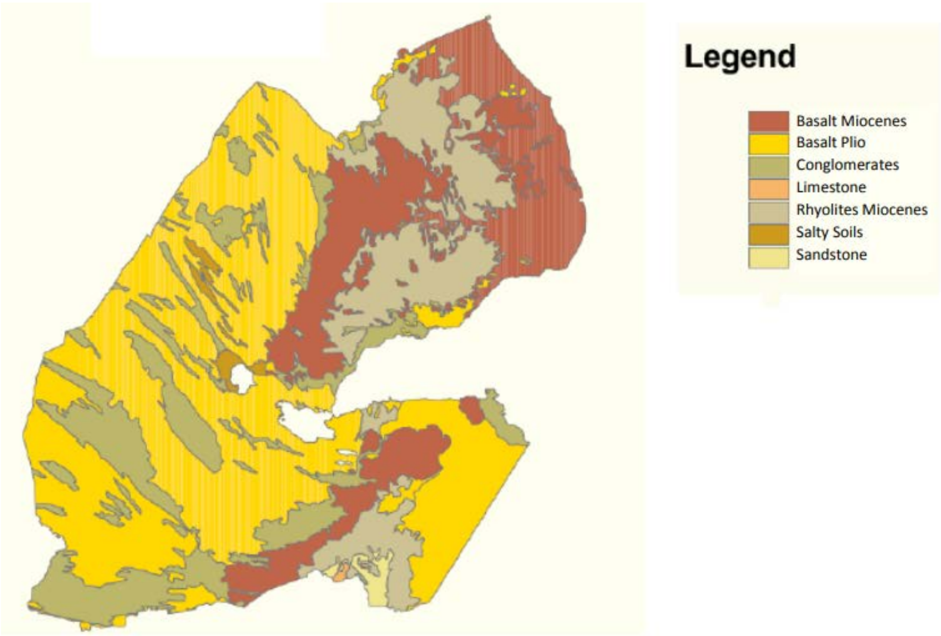


Figure 9: Soil types of Djibouti[26]

Desertification is aggravated by the arid climate due to long droughts which lead to the disappearance of vegetation and exposes soil to wind and water erosion. In the plain of Hanle (in the South of the country) water erosion resulting in flooding wadis has created gullies of 3 meters to over 20km long. Soil salinization occurs under irrigation and inappropriate soil management leads to low soil fertility and overexploitation of soil nutrients.

4.2.4 Groundwater Status

The source of irrigation water in Djibouti is classified into three types, namely, deep groundwater, sub-surface water (or shallow groundwater) and surface water.

Groundwater is the main source of water in the country, both urban and rural, for domestic, agricultural and industrial use. Most irrigation using groundwater is small scale, because there are few locations with high yielding aquifers. Most farmers use small volumes of groundwater from shallow hand dug wells or boreholes in alluvium in wadis, where the shallow alluvial aquifer is recharged periodically by ephemeral river flows after rainfall events.

Wadi alluvial aquifers are used extensively for rural water domestic, irrigation and livestock supplies. More than 700 rural shallow (hand dug) wells and a few tubular wells abstracting from this aquifer, mainly in agricultural areas, for domestic, irrigation and livestock use, with an estimated cumulative abstraction of around 4.2 million cubic metres per year. About 20 wells were used to supply 1 million cubic metres per year to rural areas and Tadjourah and Obock towns[27].

Alluvial plain aquifers are used for larger rural and some urban water supplies, local volcanic aquifers are the most intensively exploited aquifers, with a total estimated abstraction of 15.9 million cubic metres per year.

[25] Report on the African Soil Partnership Workshop – FAO
[26] Weather and Climate
[27] Master Plan Study – JICA

The most intensively exploited supplies Djibouti city with about 35,600 cubic metres per day[28]. A Guelta is a pocket of water that forms in drainage canals or wadis.

District	Borehole	Well	Spring	Guelta	Pond
Djibouti	40	2			
Ali-Sabieh	47	52	1		
Dikhil	34	68	25	16	3
Tadjourah	30	23	43	7	
Obock	17	50	13	1	
Total	**168**	**195**	**82**	**24**	**3**

Table 8: Inventory of water points in Djibouti in 2005[29]

4.2.5 Solar Irradiance

Djibouti shows tremendous solar potential. As illustrated in figure 12, Global Horizontal Irradiance (GHI), is 5.6 – 6.4 kWh per square metre per day (m^2/day) throughout most of the country. By comparison, Germany, which has nearly half the world's installed solar PV capacity, has few locations with a GHI above 3.5 kWh/m^2/day. Phoenix, Arizona — a city in the US Southwest famed for its solar potential — has an average GHI of 5.7 kWh/m^2/ day. Djibouti has two peak periods of insolation (March to April and September to October) with low diurnal variation between maximum and minimum radiation values. The lowest radiation values are observed from June to August, coinciding with the hot and humid season. However, even during these periods, the country receives enough solar radiation (about 5-6 kWh/m^2/day) to make use of solar energy applications. About 82%[30] of the country receives annual mean global radiation of over 2000 kWh/m^2.

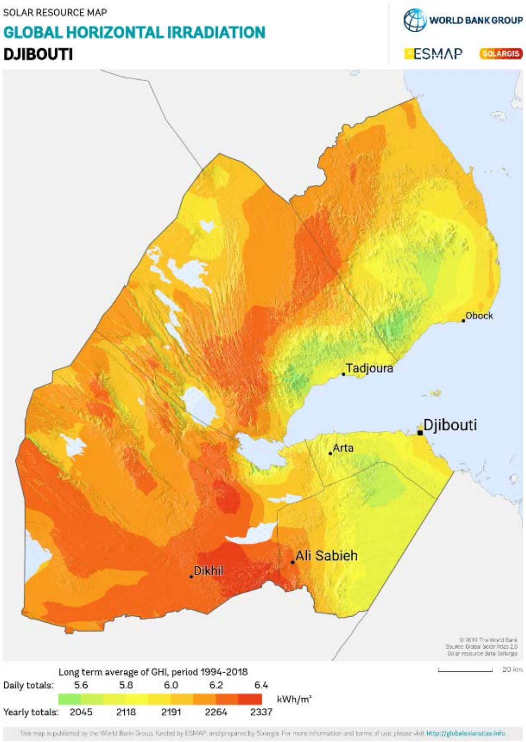


Figure 10: Global Horizontal Irradiation for Djibouti[31]

[28] Jall Udin and Razack report
[29] FAO AQUASTAT
[30] Pillot, et al. (2013); Renewables Readiness Assessment: Djibouti - IRENA
[31] Solar resource maps - Solar GIS

4.2.6 Agriculture and Cropping Pattern

In Djibouti, the agriculture and fisheries sector contributes just 3% of GDP, and only a few people work in farming. Due to the Djibouti climate (arid to semi-arid) and the scarcity of fresh water resources (~160 mm rainfall/year), only irrigated and seasonal agriculture is possible. Djibouti farmers use diesel engine water pumps, which have significant costs to purchase (~$2,000) and operate (~$1,700/hectare). These high costs result in elevated prices for locally produced agriculture products compared to imported fruits and vegetables. Djibouti therefore imports most of its fresh vegetables and fruits from neighbouring countries, including Ethiopia, Yemen, Kenya, and Europe/France[32].

Farmers generally cultivate some annual crops (vegetables and fodders) and tree crops (fruit trees and fodder trees). In addition, they raise livestock, mainly goat and sheep, and use the dung as manure for the cultivation. Therefore, their farm management is multiple farming.

The major crops cultivated in the study area are shown below. However, the kinds of crops are not many. The cultivation of tomato, onion and melon is relatively major among the crops below while almost no major grain is cultivated in the study area.

Vegetables	Tomato, Onion, Green pepper, Okra, Eggplant, Table beet, Melon, Watermelon
Fruits	Guava, Mango, Date palm, Citrus, Papaya
Fodders	Sorghum, Guinea grass, Rhodes grass, Moringa, Leucaena

Table 9: Classification of major crops in Djibouti[33]

Generally, farmers divide their farms into small plots. They select some crops from the above mentioned crops and cultivate one crop in the one plot. Simultaneously, they cultivate fruit and fodder trees between the plots. However, there are both farmers who cultivate crops in small scale like a home-garden and who commercially cultivate crops with advanced management.

4.2.7 Cropping Season

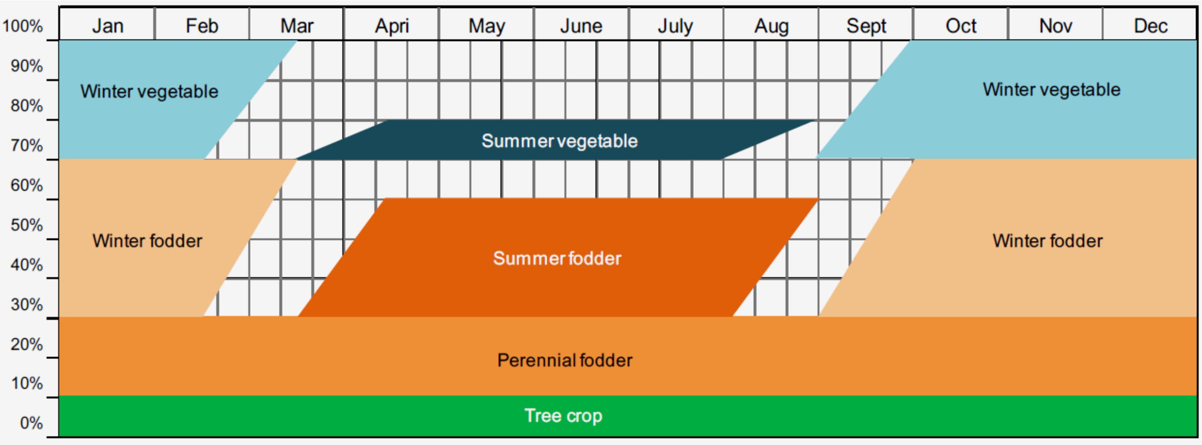
The major cropping seasons are summer cropping season (March to August) and winter cropping season (September to February). Because of high temperature, kinds of crops cultivated in summer are limited and melon, watermelon, okra and fodder crops are major crops in the summer cropping season. On the other hand, other crops and the crops of summer cropping are cultivated in winter. The harvest seasons of fruit trees are May and April for guava, June and July for mango and July and August for date palms.

Water Source / Facility		Farmers' Group			
		Home garden Farmers' Group	Beginners Farmers' Group	Self-sustained Farmers' Group	Advanced Farmers' Group
Groundwater	Shallow Well	Shallow well (Home-garden farmers' group) **SW-H**	Shallow well (Beginners farmers' group) **SW-B**	Shallow well (Self-sustained farmers' group) **SW-S**	Shallow well (Advanced farmers' group) **SW-A**

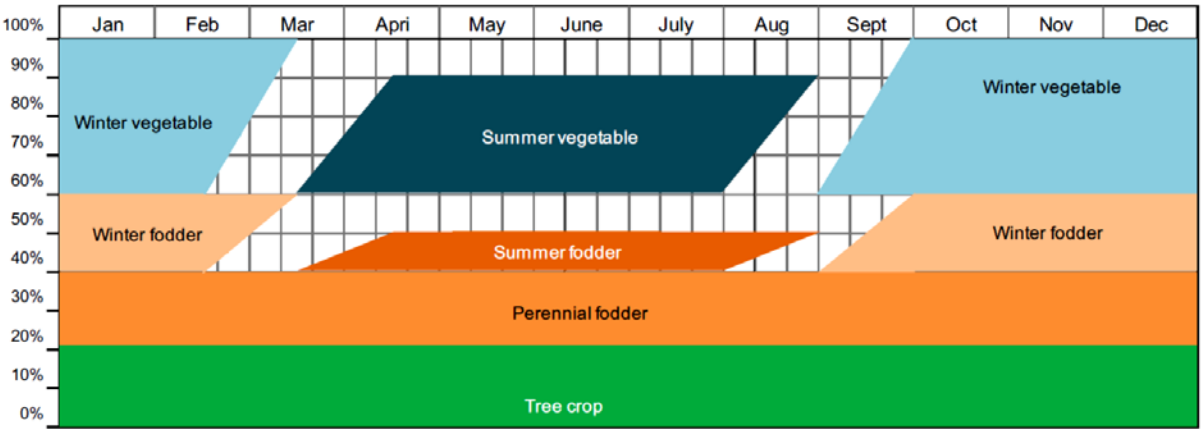
Table 10: Irrigation Farming Model[34]

[32] Master Plan Study – JICA
[33] Master Plan Study – JICA
[34] Master Plan Study – JICA

Cropping Pattern (SW-H) (SW-B)



Cropping Pattern (SW-S)



Cropping Pattern (SW-A)

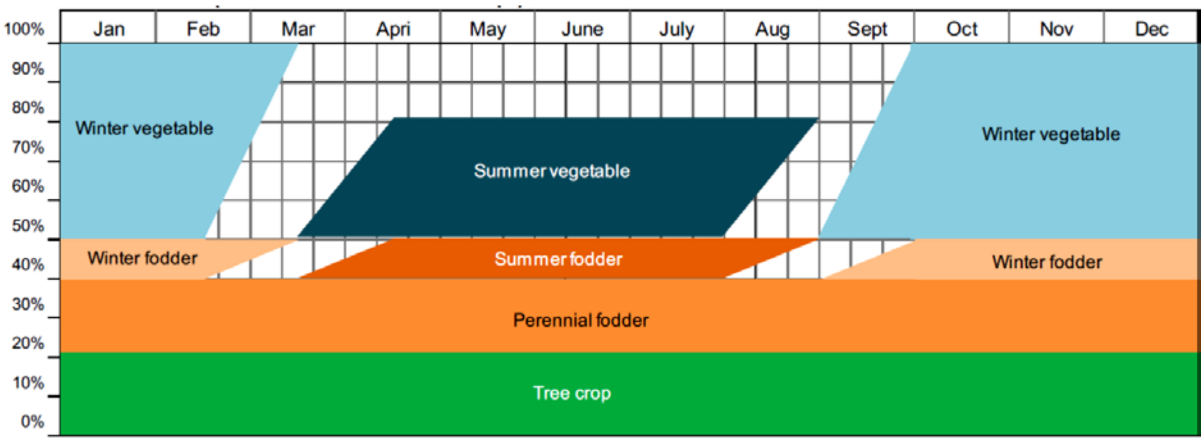


Figure 11: Cropping Patterns and Percentage of water requirement by Irrigation Farming Model[35]

[35] Master Plan Study – JICA

5. Financial Feasibility Analysis

5.1 Indicative Inputs

S.No.	Particulars	Unit	Value	Source
1	Crop to be Irrigated		Tomato, Onion	
2	Land Size	Hectares	0.5 (for each crop)	
3	Planting date		As per cropping calendar of Djibouti	
4	Irrigation type		Flood: Lined canal supplied	
5	Annual average yield of crop	Kg/hectare	Tomato 20,000 Onion 20,000	Master Plan Study – JICA
6	Market Price	USD/quintal	Tomato 4055 Onion 6083	
7	Selected Size of Solar Pump	HP	5	
8	Total dynamic head inclusive of friction losses	Meters	120	
9	Cost of Solar Pump	USD	12,849.5 [36]	Average of L1 prices discovered in ISA tender for Various categories of pumpsets
10	Subsidy	%	0 %	
11	Margin Money	%	10 %	
12	Loan Amount	%	90 %	
13	Interest Rate	%	11.3 %	World Bank Data
14	Loan Tenure	Years	8	
15	Cost of diesel pump per HP	USD	28.93	
16	Cost of diesel	USD/litre	0.98	Published reports and articles
17	Hike in diesel prices (y-o-y)	%	3%	Based on global averages
18	Inflation rate	%	3.8 %	World Data Info
19	Living expense of the farmer (as a % of crop revenue)	%	60 %	Based on global estimates, KPMG Analysis
20	Maintenance costs for diesel pump (as a % of capital costs)	%	10 %	Based on global estimates, KPMG Analysis[37]

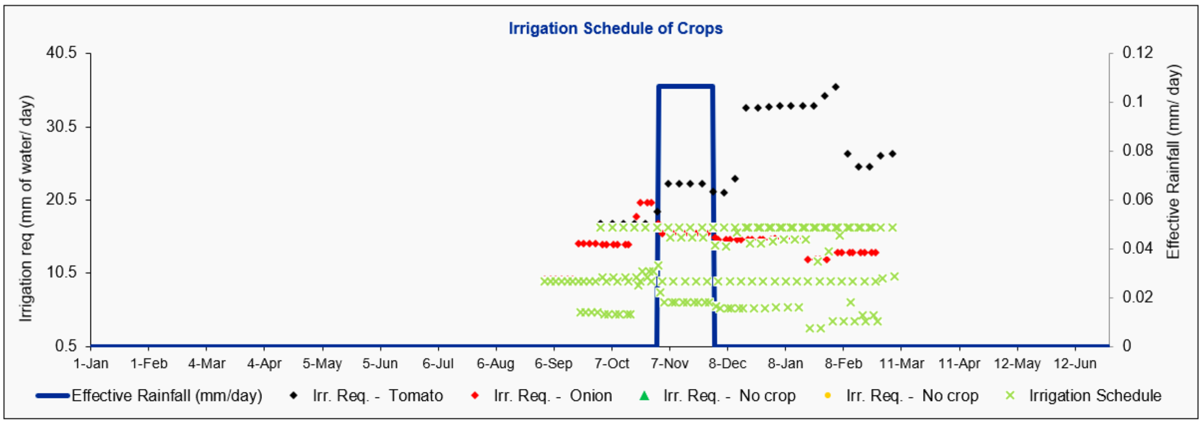
[36] Cost of Solar pumpset includes on-site Comprehensive Maintenance Contract (CMC) for 5 years but exclusive of custom import clearance, duties and local taxes as per ISA International Competitive Bid

[37] The toolkit developed by KPMG for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was used to undertake the analysis.

5.2 Indicative Crop Water Requirement[38]

Total crop water requirement (m³)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2,070	1,684	413	-	-	-	-	-	755	1,694	1,724	1,925
Annual crop water requirement (m^3)				10,266							

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	11565
3	Yearly installment towards loan repayment	USD	2271
4	Monthly installment towards loan repayment	USD	189
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	331
6	Number of hours of solar pump operation required	Hours	1402
7	Number of days of solar pump operation required	Days	200
8	Incremental payback of solar pump w.r.t. diesel pump	years	6

Djibouti has submitted demand for 100 Nos. solar water pumping systems. At an average price of USD 12,849.5 per 5 HP pumpset[39], Djibouti requires financing of USD 1.28 million to roll out deployment of 100 Nos. solar water pumping systems across the country.

[38] 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.
[39] Average L1 price of AC Surface, AC Submersible, DC Surface and DC Submersible

6. Recommendations

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

1. **Number and type of pumps**: Djibouti has submitted demand for procurement of 100 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.
2. **Capacity of Pumps**: The meteorology of Djibouti is characterized as arid climate with low rainfall and continuous high temperature in summer. Ground water table depth is also below 100 meters. Hence the pumps should be adequately sized so as to meet the crop water requirements of the area, since a smaller sized pump may not be able to give sufficient discharge for the crops.
3. **Financing:** There are limited sources available for the government of Djibouti 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. **Financing structures:** Considering external financing would be required as mentioned in point 3. above, mobilization of financing should be done by the authorities and suitable financing structures should be developed to enable the deployment of pumps.
5. **Knowledge development:** Number of motorized agricultural pumps deployed in Djibouti are very limited and farmers have relied on wells, 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 Djibouti under the ISA's programme.
6. **Ecosystem availability:** Though Ministry of Water and Environment 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 Djibouti. 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 Djibouti 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 solar pumps have not been deployed at a major scale in Djibouti, implementation may be planned in phased manner for better visibility and strong impact of the programme which may further be scaled to the country level. The roadmap for the same may be prepared by Government of Djibouti 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 Djibouti basis field reports and feedback from farmers, suppliers / installers and government agencies.