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

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List of Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
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
GoS	Government of Sudan
GHG	Green House Gas
HP	Horsepower
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
km	Kilometre
kW	Kilowatt
kWh	Kilowatt Hours
LNG	Liquefied Natural Gas
LoC	Line of Credit
MDEC	Merowe Dam Electricity Company
MoWIE	Ministry of Water Resources and Electricity
MW	Megawatt
NDB	New Development Bank
NFP	National Focal Points
PV	Photovoltaic
R&D	Research and Development
REA	Electricity Regulatory Authority
REPS	Rural Electrification Policy Statement
REREDP	Rural Electrification and Renewable Energy Development Project
RHH	Rural Households
SDG	Sudanese pound
SETCO	Sudanese Electricity Transmission Company
SEDC	Sudanese Electricity Distribution Company
SHS	Solar Home Systems
SHGC	Sudanese Hydro Generation Company
SSAAU	Scaling Solar Applications for Agricultural Use
SSLS	Solar Street Lighting System

SWPS	Solar Water Pumping Systems
STPC	Sudanese Thermal Power Generation Company
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

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1. Executive Summary

- Sudan is located at the crossroads of Sub-Saharan Africa and the Middle East, bordered by seven countries: Egypt, Eritrea, Ethiopia, South Sudan, the Central African Republic, Chad, Libya and Red Sea to the northeast.

- Sudan relies heavily on hydro resources both for producing electricity and for supply of water to the agriculture sector. Total electricity generation in Sudan was 15,679 GWh in 2017, of which 60% was generated by hydropower. The country is making efforts to integrate other renewable energy resources and aims to have 11% of electricity generation come from renewable energy by 2031, excluding hydro.

- Oil contributes to a major proportion in meeting the country's energy needs with 35% of the energy supply being met by primary and secondary oil sources. There is an urgent need to explore sustainable and alternate energy sources to **replace the 35% supply currently being met by oil resources**.

- Although power generation has continued to grow in the post-independence era, only 56% of the population had access to electricity in 2017 with a significant disparity between urban (70%) and rural (22%) areas. Access to clean cooking solutions is limited to 41% of population.

- The country is blessed with a wealth of 300-400 million acres of fertile land. Nearly 1/3rd of the GDP comes from Agriculture. More than 1/3rd of the national workforce is engaged in agriculture and agro-processing industries. The irrigation is primarily rain fed and carried out by mechanized and semi mechanized techniques. Majority of **farmers rely on government led large irrigation schemes surrounding Red Sea** to meet their crop water requirements.

- Groundwater is more readily available than other water resources during the long dry season of winter. At least 80% of the population depends almost entirely on groundwater for agriculture. Away from the Nile basin and other non-Nilotic river wells, groundwater is the only source of water. Available groundwater is 900 billion cubic metres (BCM), with an annual recharge of 1,563 BCM.

- **Gezira scheme**, being implemented in coordination with **The World Bank and OFID is one of the largest irrigation projects in the world**. Major international development and funding agencies have increasingly started implementing projects to ensure sustainable irrigation for farmers using solar pumps. **UNDP, OCHA, JICA, IFAD are currently running projects on replacement on diesel powered pumps with solar pumps around Northern Sudan. The Ministry of Water Resources, Irrigation and Electricity (MoWIE)** is acting as the nodal ministry for locally managing and coordinating international projects.

- Sudan has abundance of solar resources with average solar insolation ranging between **5.5 kWh/m^2/day in January to 7 kWh/m^2/day in April.** The water table depth typically ranges **around 40-140 m** and varies based on nature and type of aquifer.

- Sudan has submitted demand for 50,000 Nos. solar water pumping systems. At an average price of USD 5134.75 per 5 HP pumpset[1], Sudan requires financing of USD 256.74 million to roll out deployment of 50,000 Nos. solar water pumping systems across the country.

[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
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:

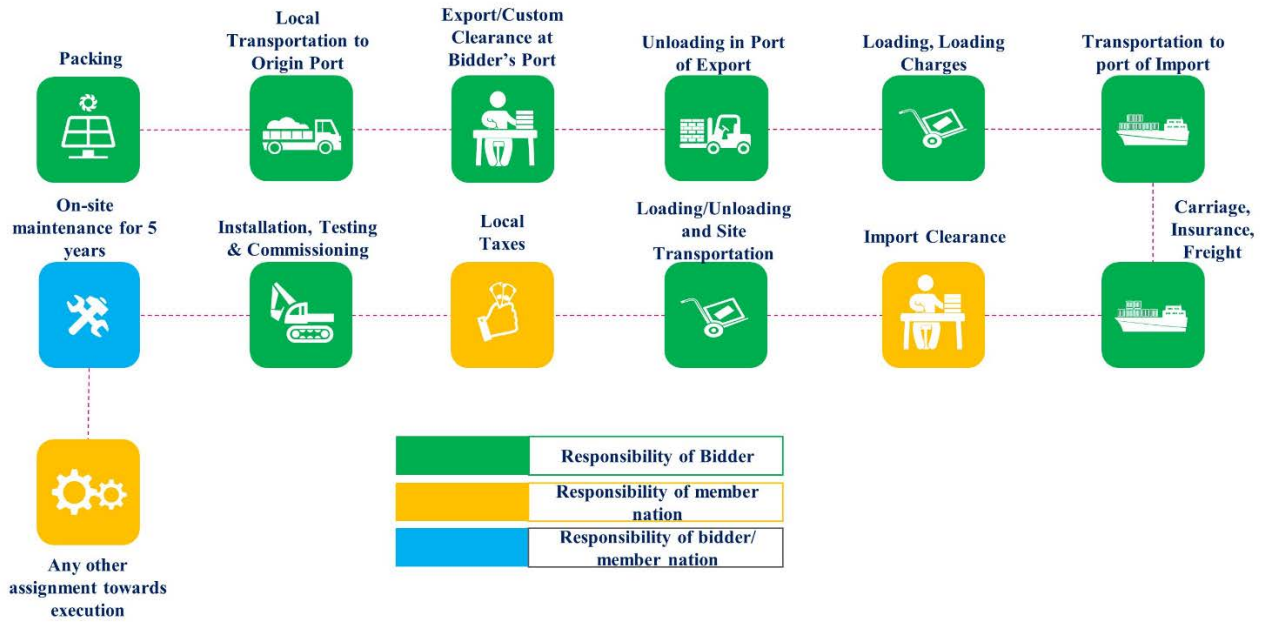


Figure 1: Work Packages and Responsibility Division

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 Sudan

Sudan is located at the crossroads of Sub-Saharan Africa and the Middle East, and is bordered by seven countries: Egypt, Eritrea, Ethiopia, South Sudan, the Central African Republic, Chad, and Libya. Sudan also boarders the Red Sea to the northeast. Its capital, Khartoum, lies at the confluence of the White and Blue Niles, and its main port on the Red Sea. Although mostly desert, Sudan has fertile land, mountains, and livestock.

Since ancient times the Sudan region has been an arena for interaction between the cultural traditions of Africa and those of the Mediterranean world. Islam and the Arabic language achieved ascendancy in many northern parts of the region, while older African languages and cultures predominated in the south.

Sudan is one of least-developed nation in the world with a population of 41,592,539, with about 1/3rd of its inhabitants dependent on farming and animal husbandry for their livelihoods. Though its role in the economy has declined in the decades since independence, agriculture still accounts for about 1/3rd of Sudan's GDP. Oil production began in the late 1990s, and petroleum quickly became the country's most important export[2].

Figure 2: Map of Sudan[3]

[2] Sudan - Britannica
[3] Administrative Map of Sudan - Nations Online Project

3.2 Overview of Energy Scenario

Sudan is in the midst of a major energy transition ever since the secession of South Sudan in 2011. Oil contributes to a major proportion in meeting the country's energy needs with 35%[4] of the energy supply being met by primary and secondary oil sources. However, the secession of South Sudan has led to frequent disruptions in oil production and disputes over oil revenue sharing impacting the economy of both countries. Sudan lost 75%[5] of its oil production to South Sudan and now primary relies on transit and processing fees of South Sudan's oil production for its revenue. Sudanese Electricity Transmission Company (SETCO), transmit electrical energy from the different generation sources inside and outside the country via high-tension transmission lines to the stations of the Sudanese Electricity Distribution Company Ltd (SEDC). The Transmission and Distribution losses in 2017 were 5% and 19% respectively.

92% of Sudan's primary energy consumption is from fossil fuels, with 8% accounting from hydropower. The country is making efforts to further integrate other renewable energy resources and aims to have 11% of electricity generation come from renewable energy by 2031, excluding hydro. Sudan also adopted a National Energy Efficiency Action Plan (NEEAP) in 2012 and has set cumulative energy efficiency targets of 11.8%, aiming at 32% by 2020.

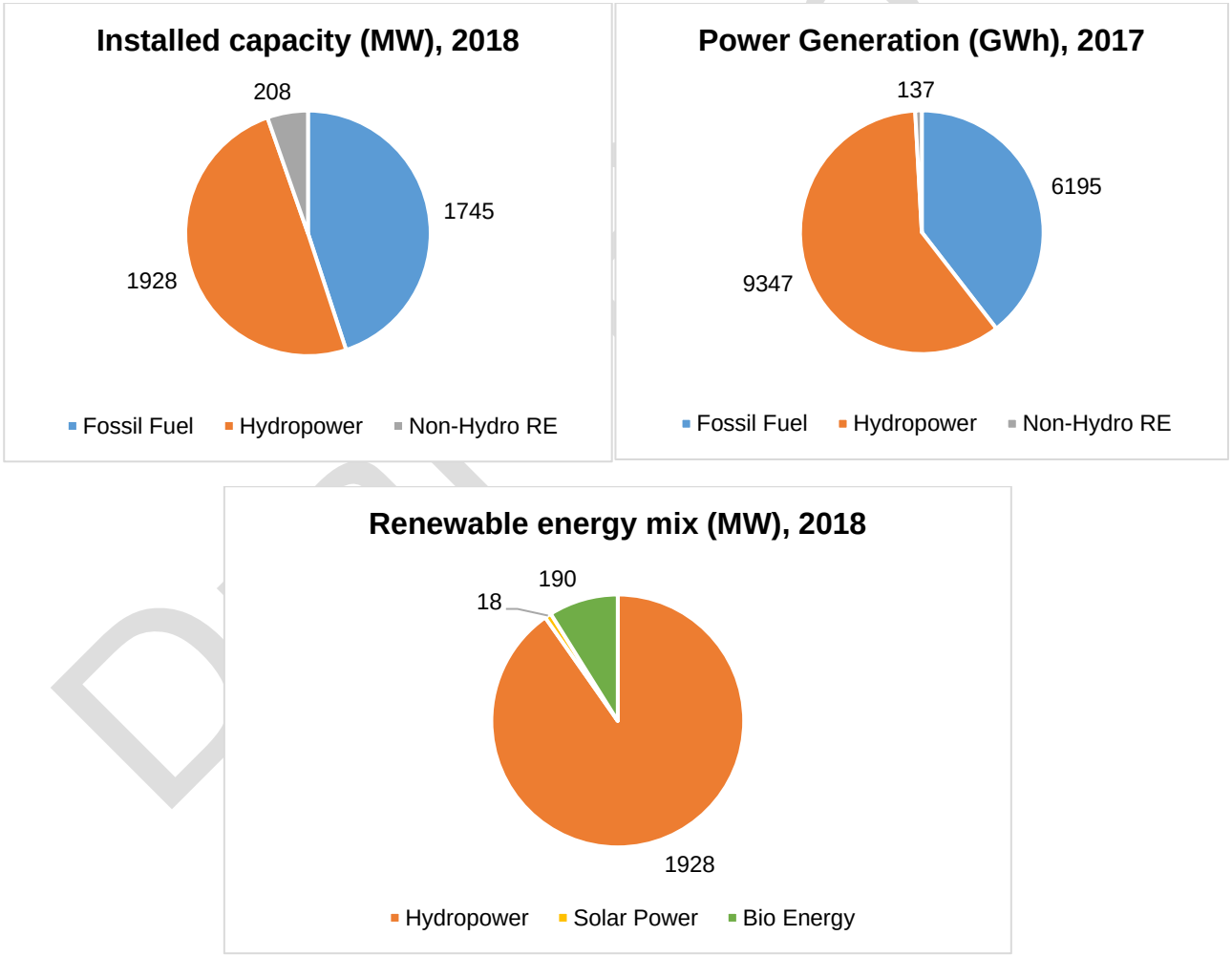


Figure 3: Installed capacity, Renewable Energy mix and Power Generation of Sudan[6]

[4] Electricity Sector Development Strategy Note, World Bank
[5] Background Reference: Sudan - EIA
[6] IRENA Stat Tool

Electricity consumer categories	Percentage
Government	10 %
Agriculture	6 %
Commercial	13 %
Industrial	14 %
Residential	57 %

Table 4: Electricity consumer segmentation of Sudan[7]

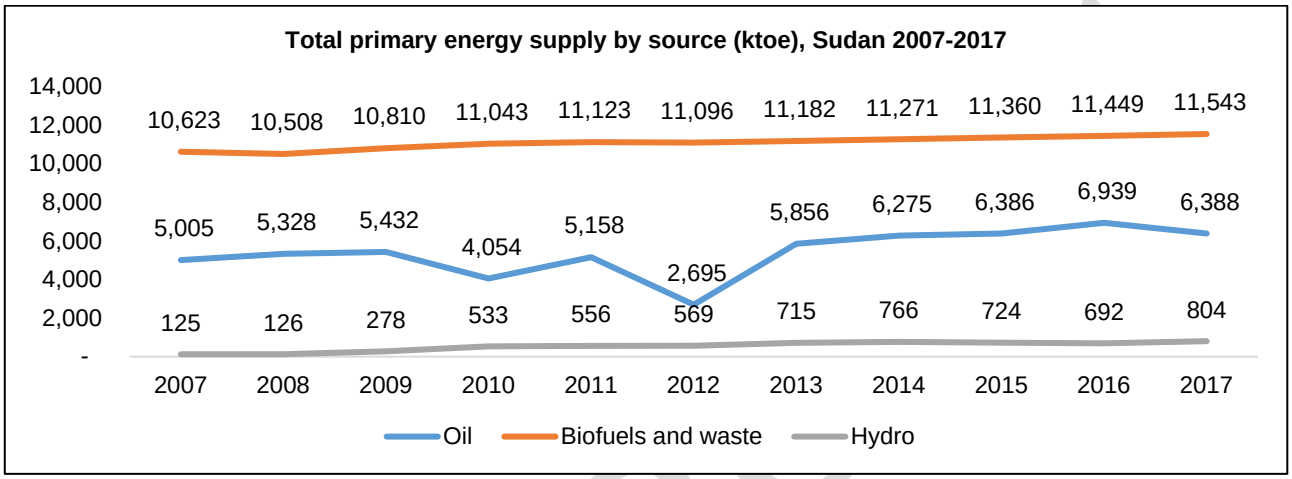


Figure 4: Total primary energy supply by source (ktoe), Sudan 2007-2017[8]

Apart from its dwindling oil reserves, Sudan relies heavily on hydro resources both for producing electricity and for supply of water to the agriculture sector. Total electricity generation in Sudan was 15,679 GWh in 2017, of which 60%[9] was generated by hydropower. Although power generation has continued to grow in the post-independence era, only 56% of the population had access to electricity in 2017 with a significant disparity between urban (70%) and rural (22%) areas, according to latest estimates from the World Bank. Access to clean cooking solutions is limited to 41% of population (at national level),. Sudan has two interconnected grids, the Blue Nile and Western grids, which cover a small portion of the country. An additional 14 centers receive service from thermal generators and local distribution networks. The country targets to achieve integration of 20% renewable energy (excluding Hydro Power) in the power system by 2030 with a target of 1000 MW each for solar and wind energy, 100 MW of solar CSP, 80 MW of Waste to Energy, 80 MW of biomass, 300 MW of geothermal and 50 MW of small hydro plants[10].

The electricity sector of Sudan is governed by the MoWIE (Ministry of Water Resources, Irrigation and Electricity) and is operated by the following entities; Sudanese Thermal Power Generation Company (STPC), Merowe Dam Electricity Company (MDEC), Sudanese Hydro Generation Company (SHGC), Sudanese Electricity Transmission Company (SETCO), and Sudanese Electricity Distribution Company (SEDC). Electricity Regulatory Authority (REA) monitors the performance of the above utilities.

[7] Electricity Sector Development Strategy Note, World Bank
[8] World energy balances and statistics, IEA
[9] World energy balances and statistics, IEA
[10] Sudan First NDC - UNFCCC

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.

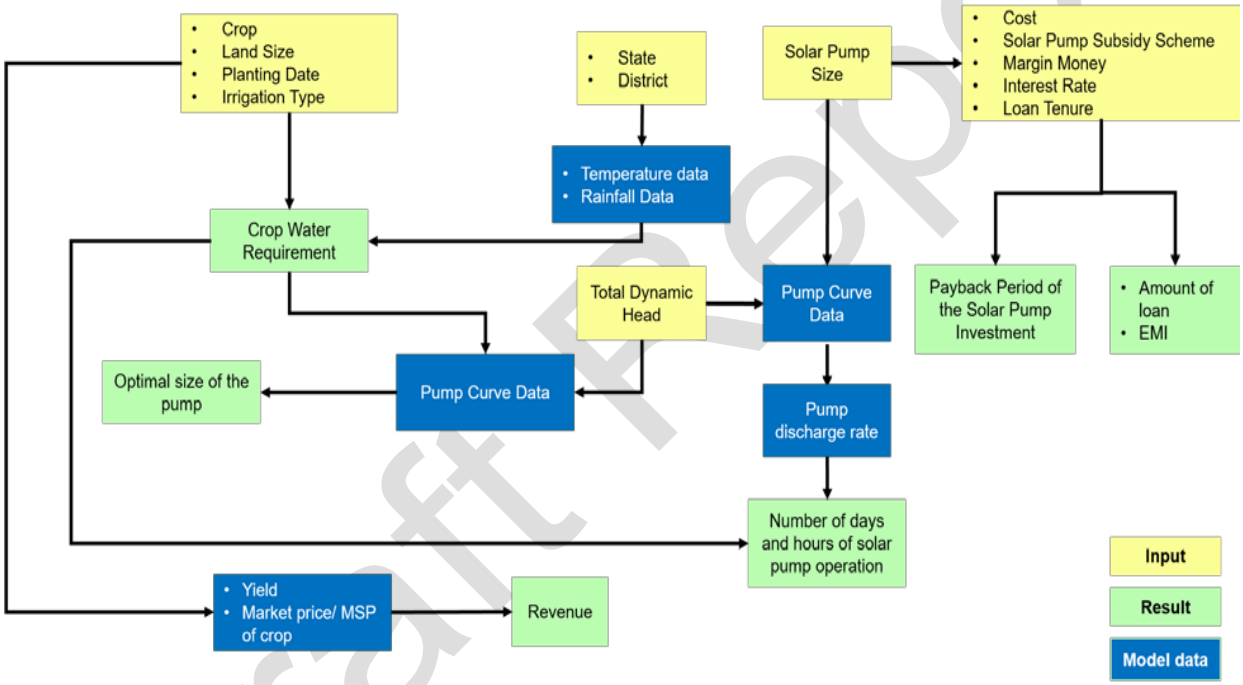


Figure 5: Factors involved in feasibility analysis of solar pump

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[11]:

[11] Review of SWPS - Science Direct

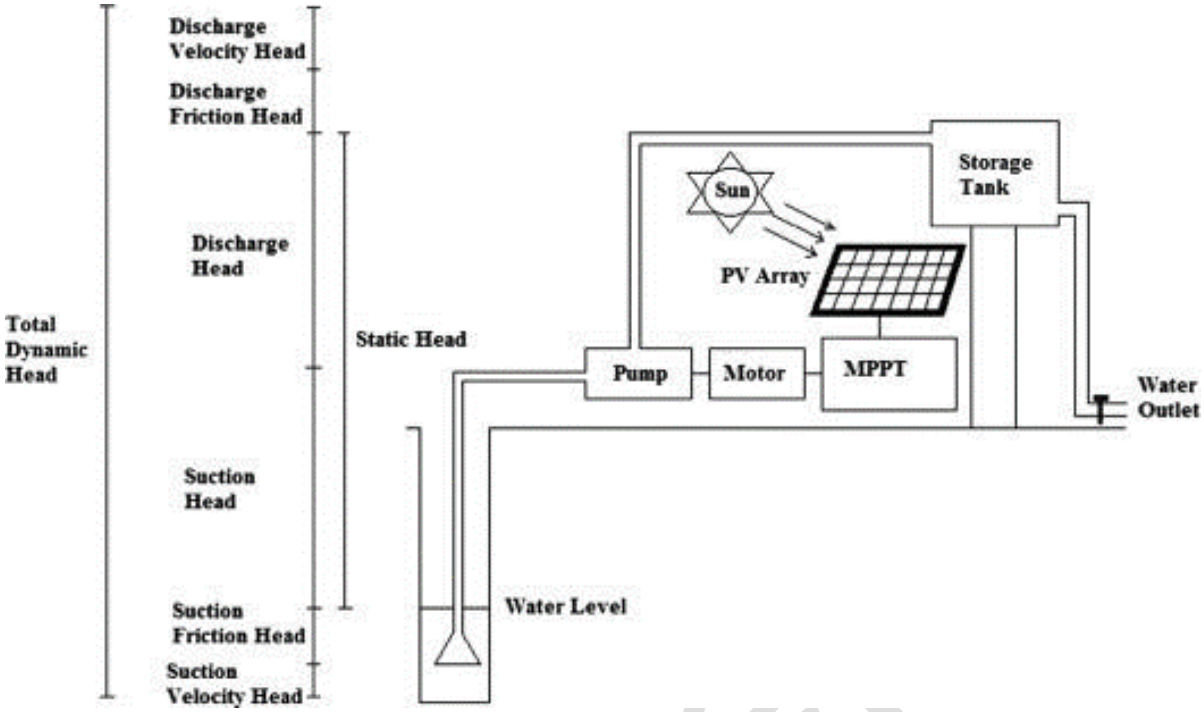


Figure 6: Schematic diagram of total dynamic head of a Solar pump

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[12]. 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[13]:

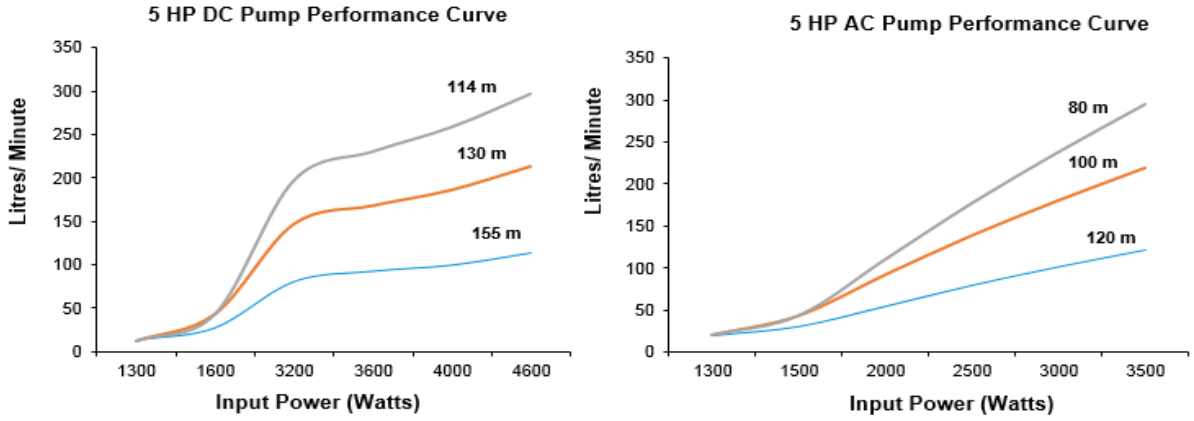


Figure 7: Pump Performance Curves

[12] System Curve and Pump Performance Curve - The Engineering Toolbox
[13] 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)[14]

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[15].

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[16].

4.2 Country Assessment

4.2.1. Connectivity and Accessibility

The Republic of Sudan's road network covers approximately 30,000 km of road, of which 7,000 km are asphalted, 4300 km are gravelled. In addition to urban roads and urban programmes total an additional 1,000 km of paved road.

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

Sudan Railways Corporation is one of the longest railways in Africa. It operates a 4578 km long single line. The railway main route extends from Port Sudan via Atbara to Khartoum with an alternate link between Haya and Sennar via Kassala.

Besides roads and railways, water is also an important transport route in Sudan. The Nile River is the main source of some 5,310 kilometers (3,300 miles) of water transportation routes. There are some ports, including Khartoum, along the Nile and others, including Port Sudan and Sawakin, along the Red Sea. The main sea port is Port Sudan. The country has 4 merchant marine ships.

Major airports are in Khartoum and Port Sudan, and there are some minor airports throughout the country. Of the country's 61 airports, 12 have paved runways. There is 1 heliport.

The distance between key cities of Sudan are given as below:

Khartoum	Capital	El Obeid	Kosti	Port Sudan	Nyala	El Fasher	El Geneina	Kadugli
Khartoum		620	300	1120	1356	1270	1706	1706
El Obeid	620		620	1740	730	642	1078	278
Kosti	300	620		1440	680	880	1700	320
Port Sudan	1120	1740	1440		2420	2420	2770	2040
Nyala	1356	730	680	2420		190	370	980
El Fasher	1270	642	880	2420	190		360	880
El Geneina	1706	1078	1700	2770	370	360		1330
Kadugli	1706	278	320	2040	980	880	1330	

Table 6: Distances from Capital City to Major Towns (km)[17]

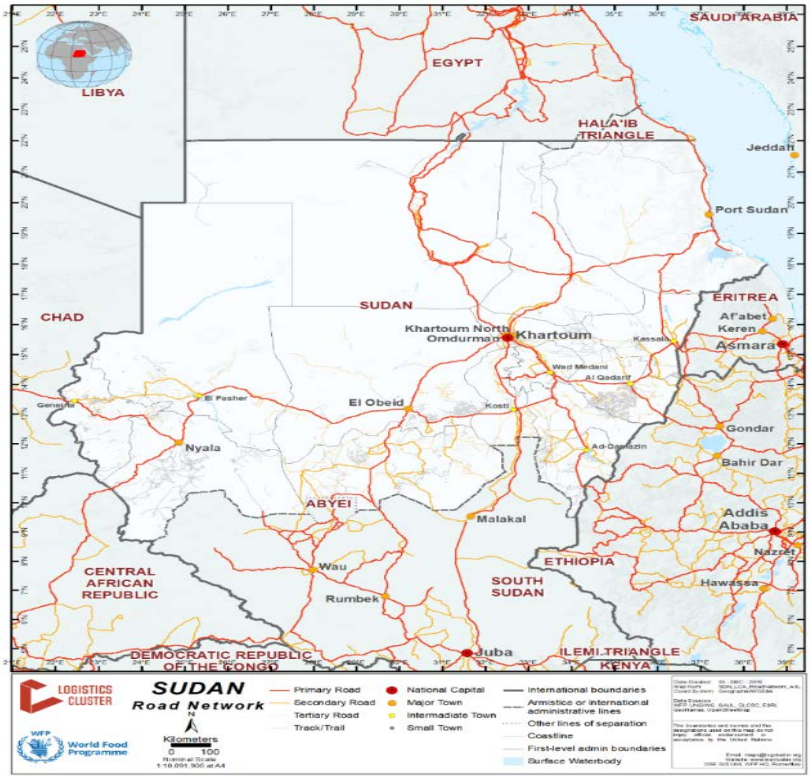


Figure 8: Road Network of Sudan[18]

[17] Sudan – Logistics Cluster
[18] Sudan – Logistics Cluster

4.2.2. Climate and Rainfall

In Northernmost Sudan, Northerly winds prevail for most of the year, and rainfall is rare. To the South of this the seasons are characterized by the North-South oscillation of the boundary between moist Southerly air and dry Northerly air. In winter the North winds of the tropical air mass blow across Sudan. These winds are relatively cool and dry and usually bring no rain. Sometime around May, the moist southerly air of the Southern maritime air mass moves northward across the country. Because of this, Central and Southern Sudan have rainy seasons, the total lengths of which vary according to their latitude.

Sudan is a hot country. The central and eastern areas have the highest mean annual temperatures, typically ranging from mid 30°C to high 30°C. In the West and Northwest of the country, the highest mean temperatures generally range from low to mid 30°C. The highest temperatures normally occur just before the rainy season. The mean minimum temperatures in most of the country range from low to mid 20°C; in the West and Northwest, mean minimum temperatures are a little lower, ranging from high 10°C to low 20°C.

From January to March, the country is under the influence of the dry northeasterly. There is practically no rainfall countrywide except for a small area in northwestern Sudan in where the winds have passed over the Mediterranean bringing occasional light rains. By early April, the moist south westerly have reached southern Sudan, bringing heavy rains and thunderstorms. By July the moist air has reached Khartoum, and in August it extends to its usual northern limits around Abu Hamad, although in some years the humid air may even reach the Egyptian border. The flow becomes weaker as it spreads north. In September the dry northeasterly begin to strengthen and to push south and by the end of December they cover the entire country. Yambio, close to the border with Zaire, has a 9 months rainy season (April-December) and receives an annual average of 1,142 millimeters; Khartoum has a 3 months rainy season (July-September) with an annual average rainfall of 161 millimeters; Atbarah receives showers in August that produce an annual average of only 74 millimeters[19].

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	26.6	26.5	26.8	27.2	27.1	26.7	26.3	26.7	27.6	28.2	28	27.1
Min. Temperature (°C)	22.6	22.6	22.7	22.8	22.6	21.8	21	21	21.7	22.6	23	22.6
Max. Temperature (°C)	30.6	30.5	30.9	31.6	31.6	31.6	31.7	32.4	33.5	33.8	33.1	31.6
Precipitation / Rainfall (mm)	270	217	213	136	112	70	42	27	39	73	145	242

Table 7: Temperature Variation in Sudan[20]

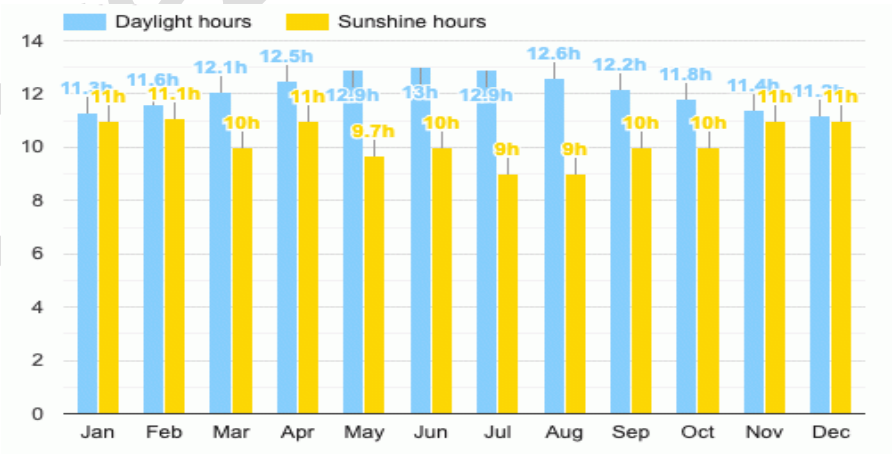


Figure 9: Sun hours in Khartoum region[21]

[19] U.S. Library of Congress
[20] Sudan: Climate Data
[21] Khartoum, Sudan - Weather Atlas

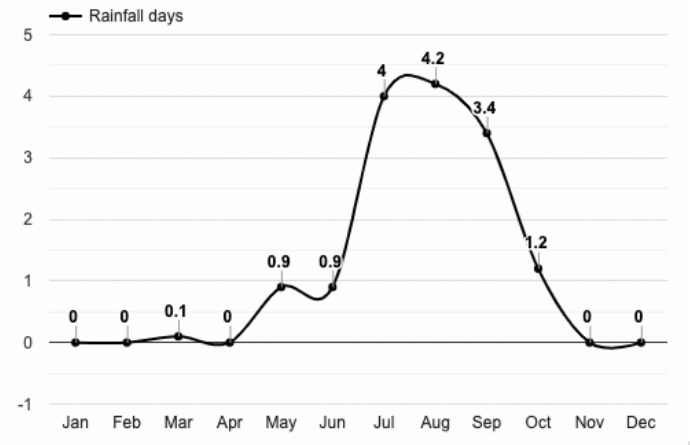


Figure 10: Precipitation Days over the year in Khartoum region[22]

4.2.3. Soil Pattern

The surface of the deserts in the north and northeast are either bare rock, a mantle of bare waste, or sandy expanses of mobile dunes known as ergs. In the semiarid zone of north-central Sudan, the layer of rock waste is slightly modified to form immature soils; in the Qawz region, soils are brownish red and of low fertility. Alluvial soils occur at the desert deltas of the Gash and Barakah rivers, along the White and Blue Niles, and in the alluvial plains of the many small rivers radiating from the Marrah Mountains. The alkaline soils of the south-central plain are heavy cracking clays. The soil of the Gezira plain south of Khartoum is deep-cracking uniform clay that has been deposited during the annual inundations of the Blue Nile[23].

The country's soils can be divided geographically into 3 categories. These are:

- The sandy soils of the Northern and West Central areas
- The clay soils of the Central region, and
- The laterite soils of the South

Less extensive and widely separated, but of major economic importance, is a fourth group consisting of alluvial soils found along the lower reaches of the White Nile and Blue Nile rivers, along the main Nile to Lake Nubia, in the delta of the Qash River in the Kassala area, and in the Baraka Delta in the area of Tawkar near the Red Sea in Ash Sharqi State.

Agriculturally, the most important soils are the clays in central Sudan that extend from west of Kassala through Al Awsat and southern Kurdufan. Known as cracking soils because of the practice of allowing them to dry out and crack during the dry months to restore their permeability, they are used in the areas of Al Jazirah and Khashm al Qirbah for irrigated cultivation. East of the Blue Nile, large areas are used for mechanized rain fed crops. West of the White Nile, these soils are used by traditional cultivators to grow sorghum, sesame, peanuts and cotton. The southern part of the clay soil zone lies in the broad floodplain of the upper reaches of the White Nile and its tributaries, covering most of upper Bahr al Ghazal states. Subject to heavy rainfall during the rainy season, the floodplain proper is inundated for four to six months and a large swampy area is permanently flooded; adjacent areas are flooded for one or two months. In general this area is poorly suited to crop production, but the grasses it supports during dry periods are used for grazing.

4.2.4. Groundwater Status

Groundwater is more readily available than other water resources during the long dry season of winter. At least 80% of the population depends almost entirely on groundwater for agriculture. Away from the Nile basin and

[22] Khartoum, Sudan - Weather Atlas
[23] Sudan - Britannica

other non-Nilotic river wells, groundwater is the only source of water. Available groundwater is 900BCM, with an annual recharge of 1,563 billion cubic metres (BCM)

The Nubian Sandstone Aquifer System is shared by Sudan, Egypt and Libya. It is recharged from the Nile in Sudan. With an area of almost 29% of Sudan, the system is the country's most important aquifer. All the major aquifers and their annual recharge and abstractions are shown in Table below.

Aquifer	Storage (km^3)	Annual recharge (km^3)	Annual abstraction (km^3)
Nubian sandstone	503	0.381	0.086
Um Ruwaba	22	0.582	0.04
Gezira	38	0.100	0.005
Alluvial deposits	1	0.500	0.096
Total	**564**	**1.563**	**0.227**

Table 8: Annual recharge and annual abstraction from major aquifers in Sudan[24]

Harnessing rainwater and floods are not widely practiced, and water harvesting is poorly developed. Rainwater is used to cultivate around 35 million feddans of sorghum and millet subsistence and semi-mechanized rain-fed agriculture. Most of the rainwater evaporates, although some recharges groundwater or run-off in seasonal streams.

At the watershed level, Sudan comprises seven main basins as shown in Figure below.

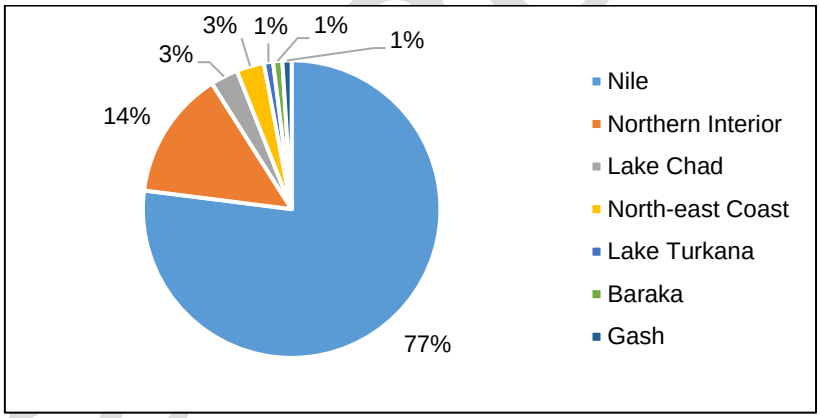


Figure 11: Areas of Sudan's basins (%)[25]

4.2.5. Agriculture and Cropping Pattern

Agriculture production is the cornerstone to Sudan's economy. The country is blessed with a wealth of 300-400 million acres of fertile land. Nearly 1/3rd of the GDP comes from Agriculture. More than 1/3rd of the national workforce is engaged in agriculture and agroprocessing industries. Dams have been built throughout the country that divert nearly 60% of the water resource to sustaining the agricultural sector. Though there are also farms that are solely dependent on the abundance of rain to maintain a good yield, the country has embarked on a massive campaign to improve the irrigation system from the labyrinth of rivers and lakes to supply the resource to these farmers. Despite the tangible role of agriculture, the enormous agricultural potential that gives promise for agriculture to take lead in the country's economic growth and livelihood improvement has not been adequately exploited. Arable land[26] of 17.1 million ha made about only 16% of the

[24] Water Resources in Sudan - Fanack Water
[25] Water Resources in Sudan - Fanack Water
[26] Land under temporary agricultural crops, pasture, gardens and fallow

agricultural area; which signals high potential for agricultural expansion. Although South Sudan's secession reduced the former Sudan's total land area by about a quarter and increased the area classified as arid from 65% to 90% of total area, three-quarters of the former agricultural land area still remains in the country and the cultivated area remains almost unchanged[27].

Irrigated area in Sudan is estimated at some 3.84 million acres, of which federal schemes total 2.88 million acres are being implemented in Gezira, Rahad, Souki, and New Halfa[28]. Sudan grows a variety of crops that includes cereals i.e. wheat, millet, corn and rice, oil seeds i.e. sesame, groundnuts and sunflower, beans, chickpeas and lentils. Others include cotton, sisal hemp and fodder crops. Horticulture crops includes vegetables such as onions, tomatoes, okra, potatoes, watermelon and cucumber and other tropical and equatorial fruits.

There are four distinct subsectors in Sudanese agriculture: modern irrigated farming, most of which is carried out with mechanized equipment on a large scale with the help of government investment; mechanized rain-fed crop production, traditional rain-fed farming and livestock raising. Large scale irrigation accounts for only nine percent of the cultivated land area but it receives the lion's share of agriculture spending. The Govt. of Sudan's Agriculture Revival Programme (ARP), during 2008-2011 received 87% of Agriculture Bank of Sudan lending[29].

The typical cropping calendar in Sudan for major crops is shown in the figure below.

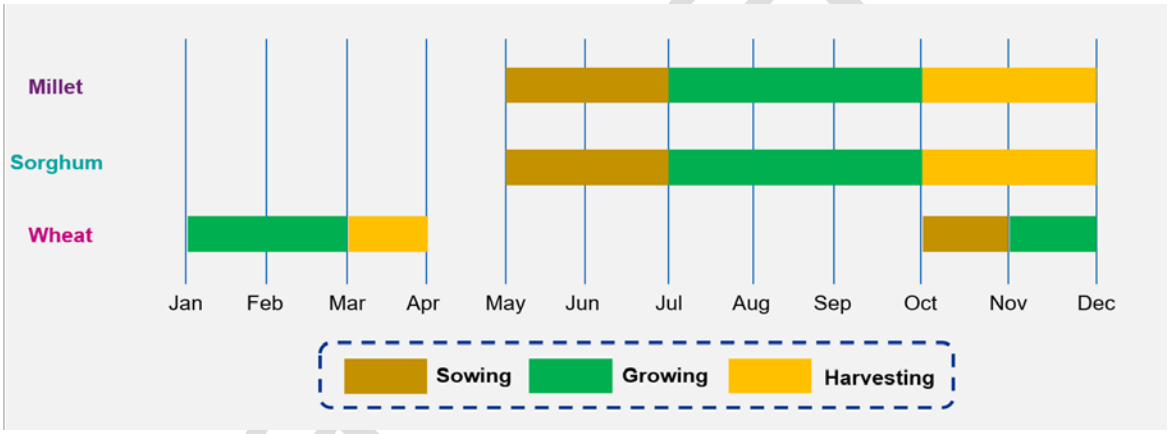


Figure 12: Cropping calendar for major crops in Sudan[30]

[27] Food and Agriculture Organization
[28] Crop and Food Supply Assessment Mission - FAO
[29] Abdelgani, Hassan: The Impact of Agricultural Research
[30] Country Briefs - FAO

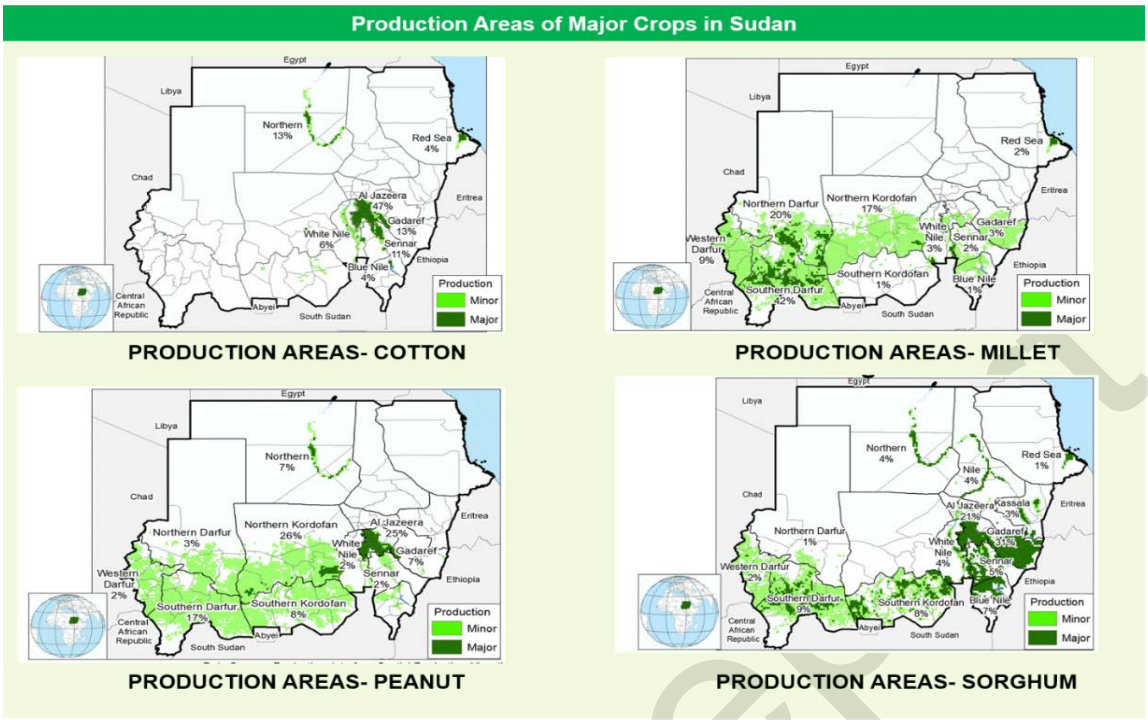


Figure 13: Production Areas of Major Crops in Sudan[31]

4.2.6. Agricultural Policy Framework and Strategy

Based on Sudan's long-term strategy 2007-2032, the government has formulated its Five-year Plan 2015-2019. Beside addressing improvements in many macroeconomic indicators, the Plan encourages private sector investment and industrial progress including agricultural agroprocessing for many products including sugar, vegetable oil, flour, hides and textiles. Raising agricultural productivity in both crop and livestock sectors to international levels and reducing agricultural production costs formed an important objective. The government aims within the agricultural sector to reduce the trade balance gap and achieve a tangible increase in the supply of food commodities to reduce their prices and reduce people's livelihood burdens. It is envisaged that the agricultural sector grows at 6.8% on average. Policies set in the plan include the continuation of institutional reform by restructuring the Ministry of Agriculture and Forests as well as the administration of the irrigated agricultural schemes along with establishing bodies to the run agricultural activities in the Nile states (Northern, River Nile, Sennar and White Nile). Modern production systems are planned to be introduced in all of the existing irrigation schemes in addition to the development of agriculture in the traditional and mechanized rainfed sectors and provision of needed infrastructure such as roads, water and improved seeds. Further, policies include expansion in field water harvesting and supplementary irrigation in the traditional rainfed sector. The livestock sector is foreseen for increasing livestock numbers and enhancing the output of various livestock products.

[31] United States Department of Agriculture

Current Strengths	Current Weaknesses (opportunities for change)
• Vast areas of cultivable agricultural land • Sufficient water resources to meet agricultural requirements • Huge livestock resource potential and sizeable fish resources • Network of agricultural faculties across the country in all agricultural specializations • Generations of trained manpower • Adoption of federal system of government encourages participation of local authorities • Planned improvement of rural infrastructure to encourage free-market mechanisms • Strategic geographical location in Neat East and North Africa region • Commitment and political will for sustainable socio-economic rural development	• Fragile state of national economy • Low levels of crops, livestock, fisheries and forestry productivity • Outdated agriculture and natural resources policies; and lack of policy coordination • Agricultural plans lack scientific and operational approaches • Poor condition of existing rural infrastructure (lack of public and private investment) • Lack of quality control, and sanitary, phytosanitary and food safety procedures • Lack of strict measures to apply regional and international agreements • Deep-rooted rivalries between professional and trade union organizations • Insecurity and tenuous peace, especially in areas of high potential for agricultural production
Potential Opportunities	**Potential Threats**
• Realization of peace and stability • Possibility of increased oil and gold production to finance infrastructure and manufacturing • Change towards a more open economy • Public awareness that agriculture is the main source of rapid and balanced economic growth • Potential for more efficient utilization of Sudan's share of River Nile waters • Application of small- and large-scale water harvesting technologies • Utilization of forward and backward linkages between agriculture and industry (value chains) • Strategic location of Sudan for agricultural trade (vis à vis Near East, North Africa and Europe)	• Rapid population growth • Continuous deterioration of the country's natural resource base • Escalation of political and tribal conflicts • 85 % of animal resources depend on pastoral and transhumant systems of production • Increasing risk of transboundary plant and animal pests and diseases • Climate change and variability (i.e. dry spells, droughts, heavy rainstorms, floods, etc.) • Institutions and procedures that control public funds not suitable for financing agriculture • Soaring prices of food and agricultural inputs

Figure 14: SWOT table for Sudanese Agricultural Sector[32]

4.2.7. Irrigation

Almost 90% of the arable land in Sudan is rain fed. Climate change and rainfall variability, water scarcity and the inaccessibility of other water sources have contributed to crop failures making it difficult for small-scale family farmers to maintain adequate livelihoods, particularly in the Kassala region in the eastern part of Sudan[33].

Crops were previously irrigated by shadufs (hand-operated water pump) and sequia (animal-driven water-wheel), which are now almost entirely replaced by small irrigation pumps. Traditional irrigation is still practiced

[32] Plan of Action (2015-2019) - FAO
[33] Nuclear applications in Agriculture - Joint FAO/IAEA Programme

on the floodplains of the main Nile downstream of Khartoum, as well as over substantial areas along the White and Blue Nile and the Atbara river. Irrigation systems in modern irrigation include surface, sprinkler and localized irrigation systems. Spate irrigation is practiced in the Gash Delta with water from the Mareb-Gash River; in the Toker Delta with water from the Baraka River, and to a lesser extent in Abu Habil. In spate irrigation, water from the seasonal streams is captured and redirected by diverting structures and canals to flood wide areas of arable land. The crop grows on residual moisture in the soil and no irrigation is needed. Sometimes two crops are grown in one season.

In pre-2011 Sudan, in 2000 only about 43 percent of the total area equipped for irrigation, were irrigated owing to deterioration of the irrigation and drainage infrastructures. Most irrigation schemes are large-scale and were up to recently managed by para state organizations known as Agricultural Corporations. They have now been transferred to water users, while small-scale schemes are owned and operated by individuals or cooperatives[34].

The importance of the irrigated agriculture is evidenced in 2011, when it corresponded to 11 percent of the cultivated area but produced over 25 percent of the total cereals production of Sudan with almost 1.5 million tons of irrigated cereals. In addition to cereals (mainly sorghum, wheat and millet, and to a lesser extent maize and rice), the main irrigated crops are cotton, fodder, groundnuts, vegetables, sugarcane and in a lesser extent sunflower, roots and tubers. In spate irrigation, the same crops are grown except for the cash crops (cotton, groundnuts, and sugarcane). The irrigation sector is of crucial importance for the country due to its reliable production, contrarily to rain fed agriculture, in particular in drought years.

The distribution of crop cultivation over the main farming types indicated the wide prevalence of traditional rain-fed (58%) and sizeable mechanized rain-fed cropping (33%). Irrigated farming though smaller in area, was quite significant in terms of total value of production and contribution to country's GDP relative to other sectors as depicted in the table below:

Sub-sector	Share of area (%)	Share of GDP (%)
Irrigated	9	11.3
Traditional rain-fed	58	6.3
Mechanized rain-fed	33	1.4

Table 9: Average shares of main agriculture sub-sectors in area and GDP[35]

4.2.8. Solar Irradiance

Sudan lies within a high sunshine belt which gives Sudan an enormous ambulance in solar energy potential. The majority of Sudan land area receive solar irradiance greater that 2,400 kWh/m^2/year. The average daily solar energy received on a horizontal surface is about 5.5-7 kWh/m^2/day.

[34] Evolution of irrigation development - FAO
[35] Mechanism of poverty incident in agricultural sector of Sudan

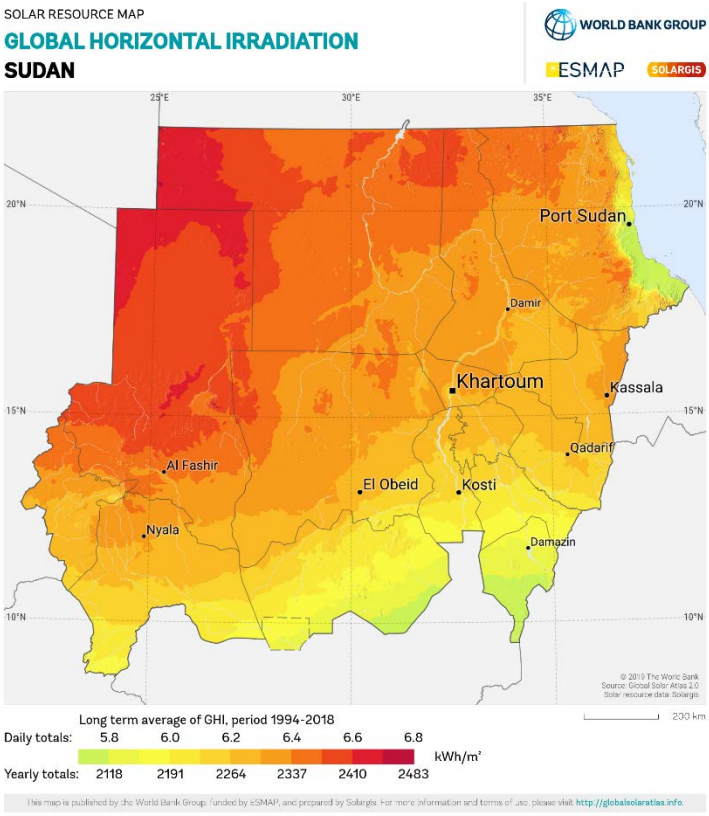


Figure 15: Global Horizontal Irradiation for Sudan[36]

[36] Solar resource maps - Solar GIS

5. Financial Feasibility Analysis

5.1 Indicative Inputs

S.No.	Particulars	Unit	Value		Source
1	Crop to be Irrigated		Wheat, Millet		
2	Land Size	hectares	0.5 (for each crop)		
3	Planting date		As per cropping calendar of Sudan		
4	Irrigation type		Flood: Lined canal supplied		
5	Annual average yield of crop	Kg/hectare	Wheat	2,759	FAOSTAT
			Millet	445	
6	Market Price	USD/quintal	Wheat	65	FAO: Food Price Monitoring and Analysis
			Millet	86	
5	Selected Size of Solar Pump	HP	5		
6	Total dynamic head inclusive of friction losses	meters	140		
7	Cost of Solar Pump	USD	5,135 [37]		Average of L1 prices discovered in ISA tender for various categories of 5 HP pumpsets (AC, DC, Submersible and surface mounted)
8	Subsidy	%	0 %		
9	Margin Money	%	10 %		
10	Loan Amount	%	90 %		
11	Interest Rate	%	16.7 %		Last data available from World Bank is till 1988; hence 1988 data is considered
12	Loan Tenure	years	8		
13	Cost of diesel pump per HP	USD	115		
14	Cost of diesel	USD/litre	0.20		Published reports and articles
15	Hike in diesel prices (y-o-y)	%	3%		Based on global averages
16	Inflation rate	%	63.29 %		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[38]

5.2 Indicative Crop Water Requirement [39]

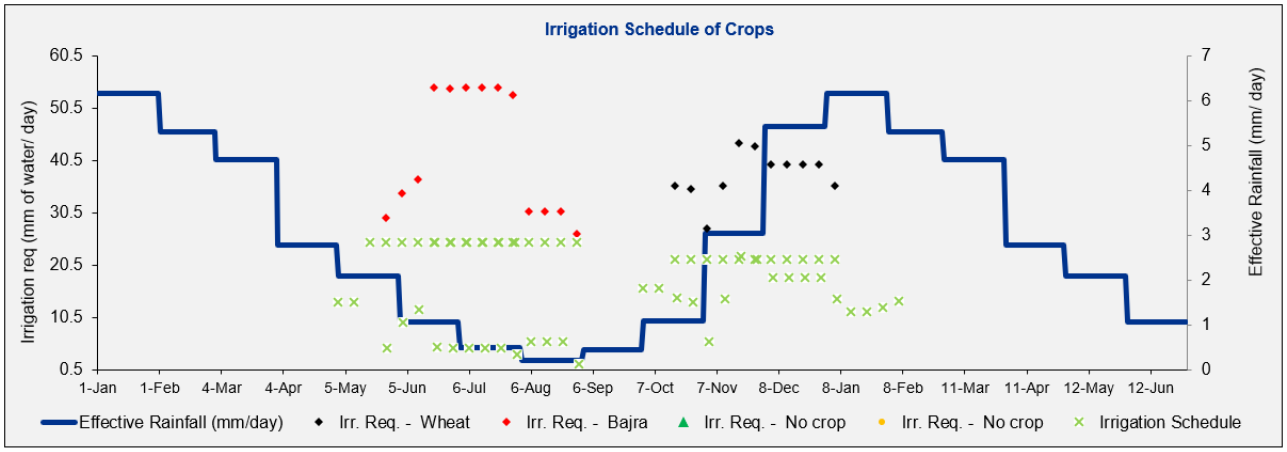
Total crop water requirement (m^3)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	-	-	135	885	1,284	807	11	453	380	43
Annual crop water requirement (m^3)				3,998							

[37] 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

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

[39] 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	4,621
3	Yearly installment towards loan repayment	USD	1,088
4	Monthly installment towards loan repayment	USD	90.7
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	8.26
6	Number of hours of solar pump operation required	Hours	913
7	Number of days of solar pump operation required	Days	130
8	Incremental payback of solar pump w.r.t. diesel pump	years	8

Sudan has submitted demand for 50,000 Nos. solar water pumping systems. At an average price of USD 5134.75 per 5 HP pumpset[40], Sudan requires financing of USD 256.74 million to roll out deployment of 50,000 Nos. solar water pumping systems across the country.

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

6. Key Stakeholders

Organization/ Agency	Role
Ministry of Water Resources, Irrigation and Electricity (MoWRIE)	Nodal ministry for implementing water, irrigation and electricity related projects in the country. Implementation partner for majority of international development organizations. • Designing & providing of the water engineering projects, and making correction, approval of engineering designs, and supervision on its implementation. • Managing, operating and maintenance of the irrigation services facilities in the projects. • Conducting scientific research in the field of water hydrology, irrigation equipment, rivers and flood water, sediment and all concerning development, renewing, operation of irrigation & water resources facilities. • Setting up policy & plans for developing, renewing and water use rationalization of water resources development. • Setting up policies, programs and projects for developing drinking water to rural and urban area in the international standard. • Setting up polices & regulations concerning energy generation from several sources and its transmission , distribution , approval of general plans & programs of electricity and make use of its projects and the following up of its implementation. • Developing of using alternative energies in electricity production. • Setting up policies, plans and programs related to alternative energies, raising the contribution of its techniques in national energy balance, encourage investment, make use of unutilized sources and following – up the related development and scientific researches.
Ministry of Agriculture and Forestry	The Sudan Country Programming Framework is co-owned by the Ministry. The role of the ministry includes development of agriculture with an aim to reduce poverty, increase the economic growth and achieve sustainable development in the country. The ministry is also the nodal contact ministry for projects and research funded by Food and Agriculture Organization (FAO). The ministry is jointly executing the Gezira Irrigation Project.
Ministry of Finance & Economic Planning	Ministry of Finance and Economic Planning is the main body which is responsible for managing the national economy and orients it to achieve its aims and purposes according to state philosophy, strategy, social and economic programs. Its roles include drawing up strategies, economic and financial management policies and development programs. The ministry is jointly executing the Gezira Irrigation Project.
UNDP and UCHA	Both UNDP and UCHA are executing solar powered irrigation projects in Sudan in coordination with nodal ministries and NGOs. UNDP programme has been one of the first such being implemented in the region. The project starts with a pilot phase of installing 28 solar pumps covering the 7 localities of the Northern State focusing primarily on installation in agricultural areas that are not accessible by the National Electrical Grid. The UCHA project is being implemented in West Darfur.
Global Environment Facility (GEF)	GEF has funded large scale irrigation projects in Sudan along with 'Solar for Agriculture' programme in coordination with UNDP. The other portfolio of projects include development of irrigation infrastructure, rehabilitation projects and electrification of irrigation pumpsets.

7. Recommendations

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

1. **Number and type of pumps**: Sudan has submitted demand for procurement of 50,000 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. **Location of pumps:** In the initial phase, it is advisable to select few concentrated areas and install the solar water pumps in order to have a good demonstration effect. For example, solar pumps may be installed at Juba and Shabelle Rivers area where farmer user groups have been formed and are already paying for water irrigation facilities provided by Government of Sudan. If the solar water pumps are scattered across different areas, it will lead to high transportation and maintenance costs. Also, the installation of solar water pumps in a concentrated area will help in better visibility and strong impact of the programme**.**
3. **Financing:** There are limited sources available for the government of Sudan 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 Sudan 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 Sudan under the ISA's programme.
6. **Ecosystem availability:** Though Ministry of Energy and Water Resources has already implemented solar water pumping systems for drinking water, the solar ecosystem is not well developed in the country. Therefore availability of local manpower for solar and pumps may be a challenge during the initial phase of implementation. However initial training on the operations and maintenance aspects of the solar pumps will mitigate the challenge to an extent.

8. 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 Sudan. 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 Sudan 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 Sudan, 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 Sudan 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 Sudan basis field reports and feedback from farmers, suppliers / installers and government agencies.