Draft Pre-Feasibility Report for implementation of solar pumps scheme in Democratic Republic of Congo

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1. Executive Summary

- Democratic Republic of Congo derives **nearly 95%[1] of its energy supply from biomass**. Owing to the effects of climate change and deforestation, firewood availability in the country is decreasing.
- The Democratic Republic of the Congo (DRC) is the **second largest country in Africa and potentially one of the richest** in the world in terms of **natural resources**.
- Hydropower contributes to **95% of the domestic electricity generation**. Although the Congo River has the potential to generate up to 100,000 megawatts of power, today less than 10% of DRC inhabitants have access to electricity.
- With vast arrays of fertile land, DR Congo is one of the largest agriculturally rich nation in Africa. However, the sector is yet to meet its enormous potential.
- Irrigation is primarily rain fed and is carried out using labor intensive farming techniques.
- Climate change has led to increasing uncertainties regarding rainfall patterns leading to lower yields and dwindling crop productivity.
- **With 80 million hectares (197 million acres) of arable land and 1,100 minerals and precious metals**, the DRC has the resources to achieve prosperity for its people and serve as a catalyst for African economic growth.
- Majority of the farmers rely on **rain and government led large irrigation schemes** to meet their crop water requirements.
- Major international development and funding agencies have increasingly started implementing projects to ensure sustainable agricultural practices and irrigation schemes.
- The **average solar radiation in DR Congo is 5.1 kWh/m2/day.** High solar irradiation in DR Congo is available throughout the year.
- Majority of the farmers have land holding **less than 1 hectare** and therefore small sized pumps shall be more suitable for deployment
- There are limited sources of financing available with the government of DR Congo for solar pumps and external financing through donor agencies, MFIs and DFIs shall be required.

[1] https://www.export.gov/article?id=Congo-Democratic-Republic-Executive-Summary

2. Introduction

The DRC has high energy potential, consisting of non-renewable resources like oil, natural gas, and uranium, as well as renewable energy sources like hydroelectric, biomass, solar, wind, and geothermal power. Hydroelectric power accounts for 95% of domestic power generation[2].

The Democratic Republic of Congo's electricity supply industry is still evolving. The Societé National d'Electricité (SNEL) was established in 1970, as the national institution involved in generation, transmission and distribution. The Electricity Supply Industry (ESI) working structure can be divided into three sectors: production, transmission and distribution. The electricity generation system consists of, majorly, hydropower plants. The national utility transmission lines have been divided into six categories in terms of capacity which are 500KV, 220KV, 132KV, 120KV, 70KV and 55/50KV. Vertical integration describes the relationship or link between the key operational activities within the electricity supply chain, according to the International Energy Agency. Limited grid access has led to over reliance on biomass for energy supply as illustrated in Figure 1.

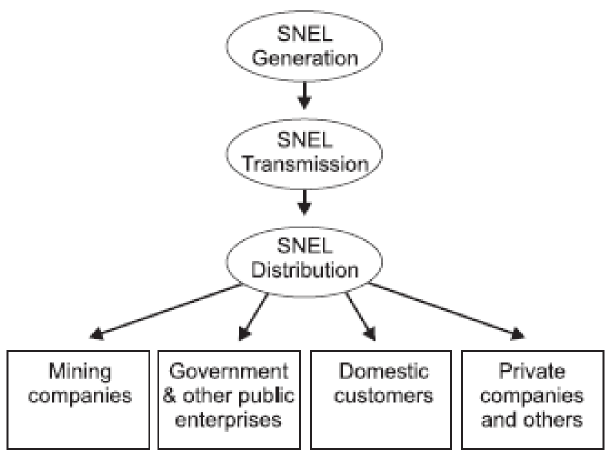

Figure 1: ESI Structure

Source: Journal of Energy in Southern Africa

Following are the key stakeholders in the electricity subsector in DR Congo:

S.No.	Key Stakeholders	Institution
1	Ministry	Ministry of Energy
		Ministry of Agriculture
		Ministry of Rural Development
2	National institutions and policy makers	National Energy Commission
		Société nationale d'électricité (SNEL)
		National Renewable Energies Service (SENEN)
		National Society for Rural Hydraulics (SNHR)

[2] https://journals.assaf.org.za/index.php/jesa/article/view/3261

3	Regulator	Electricity Regulation Authority
4	Governing Policy	Energy Sector Policy Letter 2009
5	Participation in regional energy infrastructure	South African Power Pool (SAPP)
		Central African Power Pool (CAAP)
		East African Power Pool (EAPP)
6	Ownership of sectoral resources and markets	Société nationale d'électricité (SNEL)
		National Congolese Society of Hydrocarbons (SONAHYDROC)
		Services des Enterprises Pétrolières Congolaises (SEP-CONGO)

Table 1 Role of various institutions involved in the electricity sector in Uganda

The total installed capacity was 2.587 MW in 2016[3]. Access to electricity in the rural areas at ~1% which is significantly less than 49% access in urban areas. Biofuels and waste are the largest contributor to energy production followed by hydro as illustrated in Figure 2.

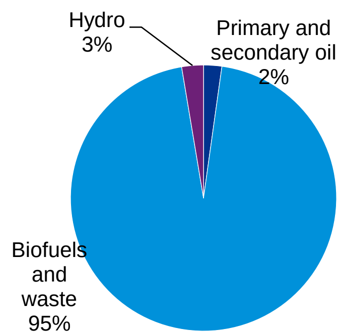

Figure 2: Energy Supply Mix

Source: Energy Charter

The energy consumption is distributed into different categories where the majority is used for residential purposes as illustrated in Figure 3.

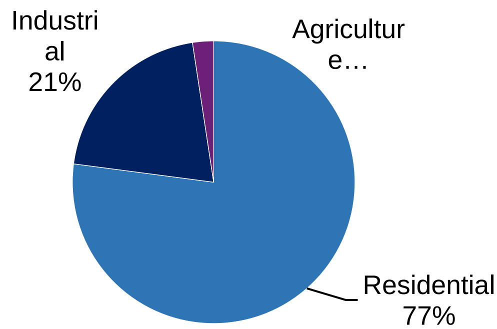

Figure 3: Energy Consumption
Source: World Bank/IRENA

[3] World Bank/Energy Charter

Grid unavailability in rural areas has led to increasing reliance on biomass for meeting the energy needs leading to rapid deforestation

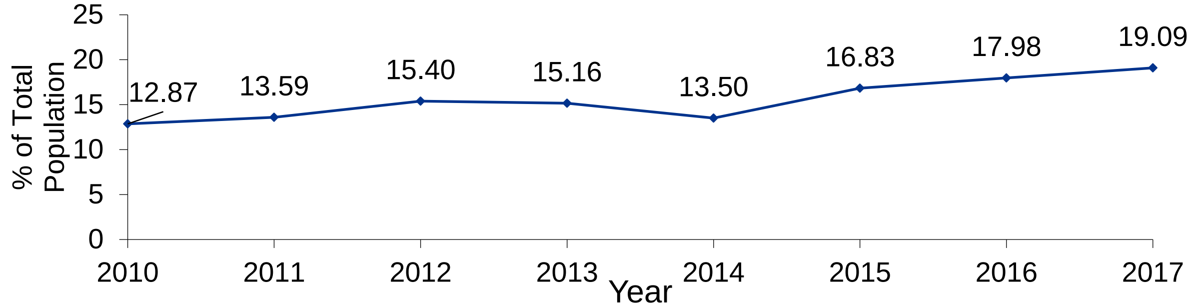

Figure 4 Access to electricity

Farmers primarily depend on rain fed irrigation for meeting their crop water requirements. The country has faced frequent droughts in the recent past and the huge solar potential in the country, with average daily solar insolation of 10-11 hours, can help the farmers develop solar powered irrigation facilities.

3. Geography

Democratic Republic of Congo is located in Central Africa. The nation has a 25-mile (40-km) coastline on the Atlantic Ocean but is otherwise landlocked. It is the continent's second largest country.

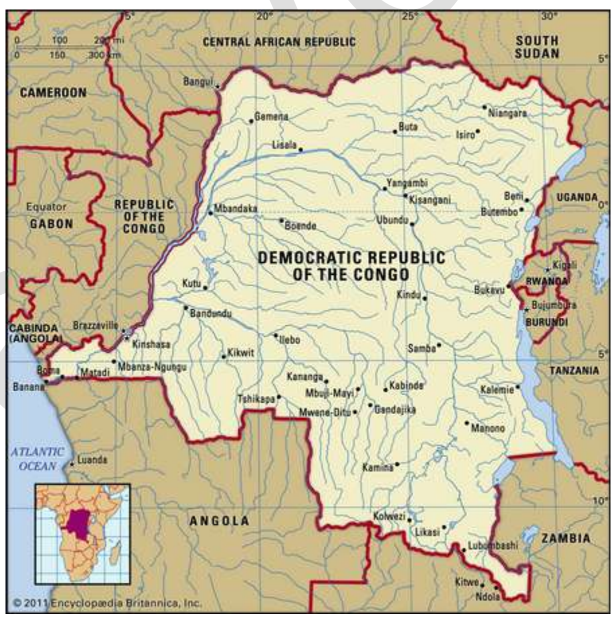

Figure 5: Democratic Republic of Congo Map

Source: Britannica

The capital, Kinshasa, is about 320 miles (515 km) from the source of the Congo River. It is the largest city in central Africa, serving as the official administrative, political, and cultural center of the country. The state is often referred to by its name, the DRC, or Congo (Kinshasa)[4].

[4] https://www.britannica.com/place/Democratic-Republic-of-the-Congo

The nation's major topographic features include a large canyon of the sea, a broad valley, high plateaus, three mountain ranges, and a small coastal plain. The majority of the nation is the central Congo Basin, a broad rolling plain with an average altitude of about 520 meters above sea level. The lowest point on Lake Mai-Ndombe (formerly Lake Leopold) is 1,109 feet (338 metres), and the north's highest point on the Mobayi-Mbongo and Zongo hills is 2,296 feet (700 metres). The basin may once have been an inland sea whose only remains are Lakes Tumba and Mai-Ndombe in the western central region.

4. Climate

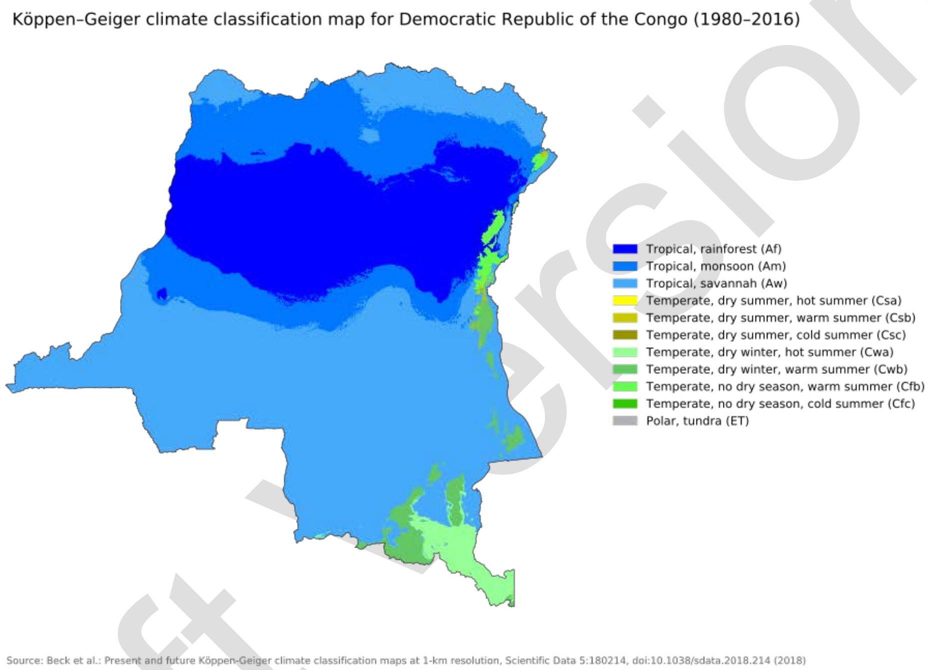

Figure 6: Climate Classification Map

Source: Wikidata

The rainy season stretches from October to May, south of the equator and from April to November, north of the equator. Rainfall is fairly regular all year round along the Equator. Thunderstorms are often intense during the wet season, but they seldom last longer than a few hours. The country's average rainfall is about 1,070 mm (42 in). The Democratic Republic of the Congo is located on the equator, with one-third of the country to the north and two-thirds to the south. The weather is hot and humid in the basin of the river and cool and dry in the southern highlands, with a cold, alpine climate in the Rwenzori.

The figure below shows the Democratic Republic of Congo's average temperature trend. The climate in Congo is classified as tropical. There's a lot less precipitation in winter than in summer. This climate is classified as Aw, according to Köppen and Geiger. Congo's annual average temperature is 24.6 ° C. The average rainfall here is 1686 mm[5].

[5] https://en.wikipedia.org/wiki/Geography_of_the_Democratic_Republic_of_the_Congo

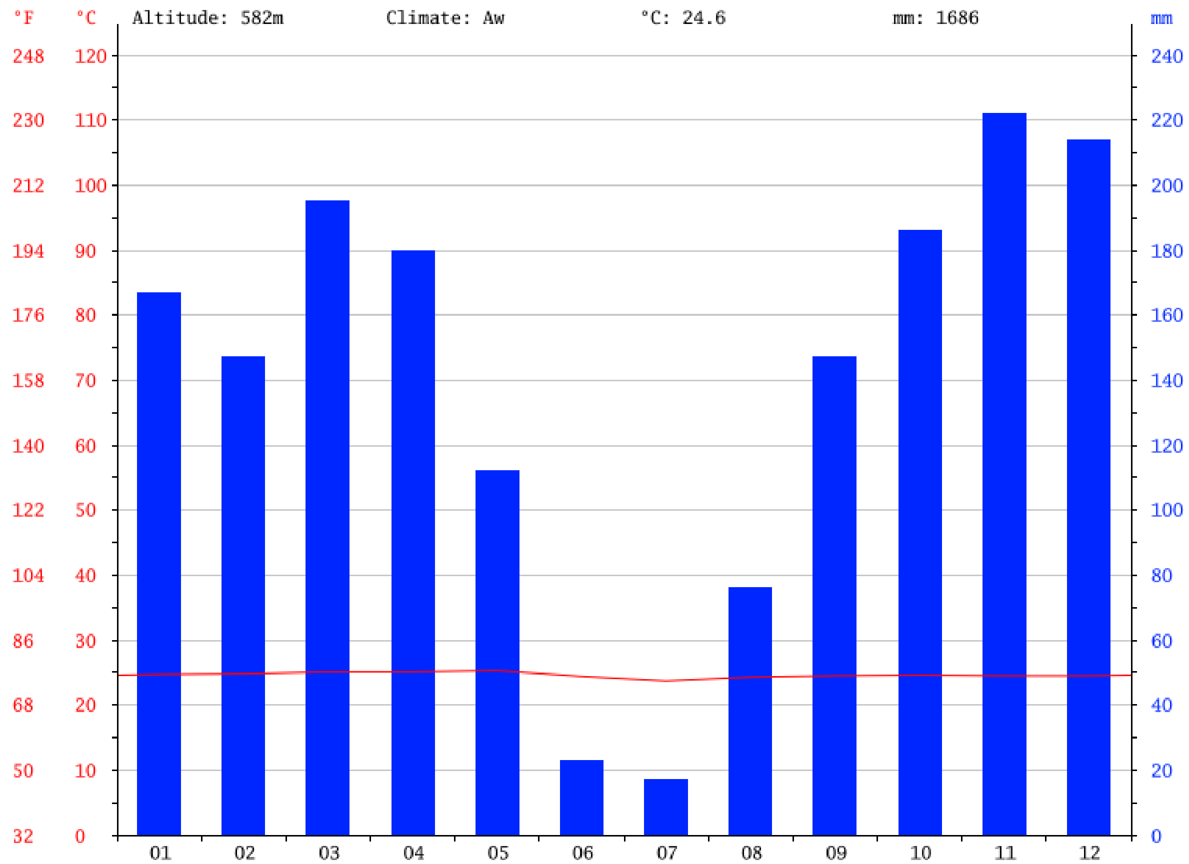

Figure 7: Average Temperature Trend

Source: Climatedata.org

5. Rainfall

The rains are usually in the form of downpour or thunderstorms (DR Congo is the country with the highest number of lightning strikes in the world) usually in the afternoon; in the equatorial zone throughout the year, and in the two tropical regions during the long rainy season.

There is abundant rainfall in the equatorial region, about 1,700/2,000 millimeters (67/78 inches) per year. There are two maxima of precipitation, in the two zenith periods of the sun (that is, when it shines directly overhead in the sky at midday, which happens in late March and late September), and in view of the soil thermal inertia, the months with highest rainfall are typically April-May and October-Nov. The least rainy months are typically January-February and June-July, although there are normally more than 100 mm (4 in) of rain per month. The precipitation falls below 1,000 mm (40 in) per year along the short coastline overlooking the Atlantic Ocean due to the Benguela current which arrives in the region in winter and can prevent the development of rain clouds; on the other hand, the cold current is able to bring a bit of cool air, and to create fog and low clouds[6].

[6] https://www.climatestotravel.com/climate/democratic-republic-congo

6. Soil

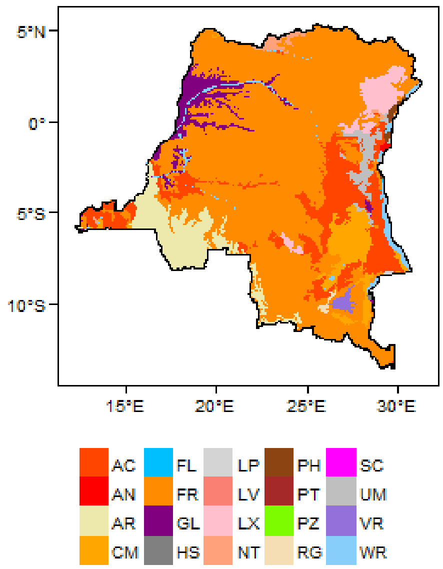

Figure 8: Soil Map

The Congo River is the country's main drainage system, including its 1,336,000-square-mile (3,460,000-square-km) basin. The river rises in the high plateaus of Katanga and flows in a large arc north and then south, crossing the Equator twice. The lower channel flows southwest to drain under Matadi into the Atlantic Ocean. The Congo traverses alluvial lands and swamps along its course and is drained by many lakes and tributaries ' waters. Mai-Ndombe and Tumba are the most important lakes; the major tributaries are the rivers Lomami, Aruwimi, and Ubangi, and those of the great system of the Kasai River. The Lukuga River, moreover, connects the basin with the Western Rift Valley.

Soils are of two types[7]: the equatorial and the drier savanna (grassland). Equatorial soil exists in the central basin's dry, humid lowlands, which receive ample rainfall all year round and are mostly covered by thick forests. This soil is almost fixed in place because of the lack of erosion in the forests. In swampy areas the very thick soil is constantly nourished by humus, the organic material resulting from the decomposition of plant or animal matter. Savanna soil is threatened by erosion, but the river valleys contain rich and fertile alluvial soils. The Great Lakes region's highlands in eastern Congo are partly covered by rich volcanic lava soil. This is the most important agricultural area in the country.

7. Agriculture and Irrigation in Democratic Republic of Congo

The DRC has the bulk of the major assets needed to become a global agricultural force with 80 million hectares of vast arable land, 4 million hectares of irrigated land, and many rivers with substantial fishery reserves. Even though the agricultural sector currently contributes 18 percent of GDP and accounts for over 60 percent of new jobs, it still does not guarantee food autonomy and generate enough revenue and sustainable employment. The main cash crops include coffee, palm oil, rubber, cotton, sugar, tea and cocoa. Food crops also include cassava, plantains, maize, groundnuts and rice. Commercial agricultural production, however, remains small, with many producers engaged in food subsistence farming. In order to cope with food shortages, agro-industrial parks are being established in various areas of the DRC.

Shifting agriculture in the Democratic Republic of the Congo is the traditional form of farming. The native farmer clears two or three acres (about one hectare) in the forest or savanna, cultivates it until the soil's fertility decreases, then moves to another location. Fertilizer, insecticides, and fungicides are not generally available. In the 1930s, a land-settlement policy, called the paysannat scheme, was implemented to increase production by replacing strips of cultivated land with bush and grassland. Nevertheless, since independence, this process has disintegrated due to the lack of management staff and government extension programs and marketing channel disruption. Large modern plantations are often owned,

[7] https://www.britannica.com/place/Democratic-Republic-of-the-Congo

controlled and run by individual Europeans and companies alongside traditional farms. Plant crop yields are two to ten times that of native farms, suggesting possibly the direction of future development.[8]

For the majority of the population, domestic farming is the main source of food and employment. Combined farming, animal husbandry, fisheries and forestry provide jobs for more than three-fourths of the labor force, accounting for more than two-fifths of GDP on average. Although the country is rich in agricultural potential, transportation network deterioration and agricultural services since independence have resulted in a return to subsistence farming and a collapse of market production. Foods like cereals and fish are increasingly being imported. Coffee is the main agricultural export, although much of it is smuggled out of the country; palm oil, rubber and cotton production, once the export economy's main pillars, has become almost negligible.

Cassava (manioc) and rice are the basic food crops in the wet equatorial region. Also important are peanuts (groundnuts), oil palms, and fruit trees, while the main cash crop is robusta coffee. Yams, peas, and sweet potatoes are used as food crops in the eastern highlands, while arabica coffee and tea are products for export. Corn (maize), an important subsistence crop, is widely grown on the southeast, but mainly centered. Vegetable growing is widespread throughout Congo.

In each province, livestock and poultry are held. In the east and south, cattle are raised primarily. Pigs are kept in the west and sheep in the eastern highlands. Other domestic animals include chickens, geese, pigeons, and rabbits. Commercial meat production is limited, however, and the country depends upon imports to fulfill its requirements. A small part of the yearly production of timber is exported for veneering or plywood; most, however, is used locally for fuel. There is some commercial freshwater and ocean fishing. Local hunting, fishing for private consumption, and poaching of wild game are not ordinarily reported in official statistics and are difficult to measure.[9]

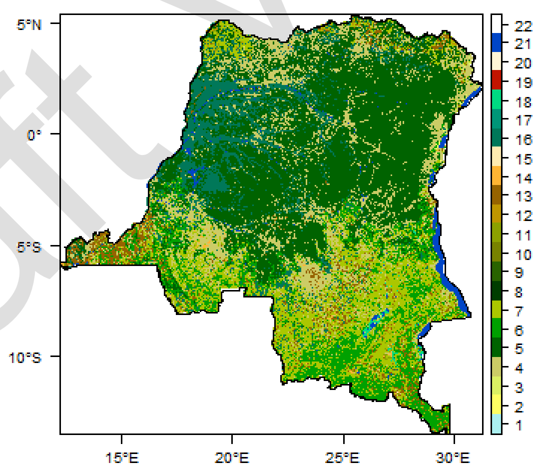

Figure 9: Irrigation Map

The total area under irrigation is 110 Sq. Km and the area of land without irrigation is approximately 249,265 Sq. Km. The total projected requirement is 80,000 solar water pumps of 10 hp. Generally, one Sq. Km requires 250 hp. Therefore, 800, 000 hp is covered in 3200 Sq. Km area. (1 Acre generally requires 1 hp solar water pumping system).

[8] https://www.export.gov/article?id=Congo-Democratic-Republic-Agricultural-Services-AGS
[9] https://www.britannica.com/place/Democratic-Republic-of-the-Congo/Economy#ref40800

8. Cropping Pattern

Agriculture employs approximately 70% of the population and produces 40% of GDP. The nation has been estimated to have over 120 million ha of land suitable for agriculture, but currently only an estimated 10% of the land is being used. The country's three primary agro-ecological areas are as follows: (i) the Congo alluvial plain in the centre; (ii) the terraced plateaux in the south and north of the central basin; and (iii) the high altitude massifs (up to 5,000 m) in the east and north-east. Although there are great opportunities for irrigation, rain-fed agriculture is mainly prevalent. Of a total four million hectares, only 13,500 ha with sugar cane and rice are irrigated. The productivity of the crops is poor as plant cultivation follows traditional system including slash-and-burn agriculture. Most farmers do not use fertilizers, plant protection measures, and improved machinery and farm implements.[10]

Although there are great opportunities for irrigation, rain-fed agriculture is mainly prevalent. Of a total four million hectares, only 13,500 has for sugar cane and rice are irrigated. The plant productivity is poor as crop cultivation follows a traditional system, including slash-and-burn agriculture. Many farmers do not use fertilizers, plant protection measures, or new machinery and farm implements. Cassava, plantains & banana, mangoes / mangosteens, corn, groundnuts, and roots and tubers are the most important crops in terms of value. Cassava, sugarcane, maize, roots and tubers, plantains, tomatoes, groundnut, and paddy are the major crops in terms of production. Certain crops like rice, peas, papaya, palm oil, sugarcane, pine apple, avocados, chilies, pepper, and pulses are also grown by farmers.

The typical cropping calendar for Democratic Republic of Congo is provided below:

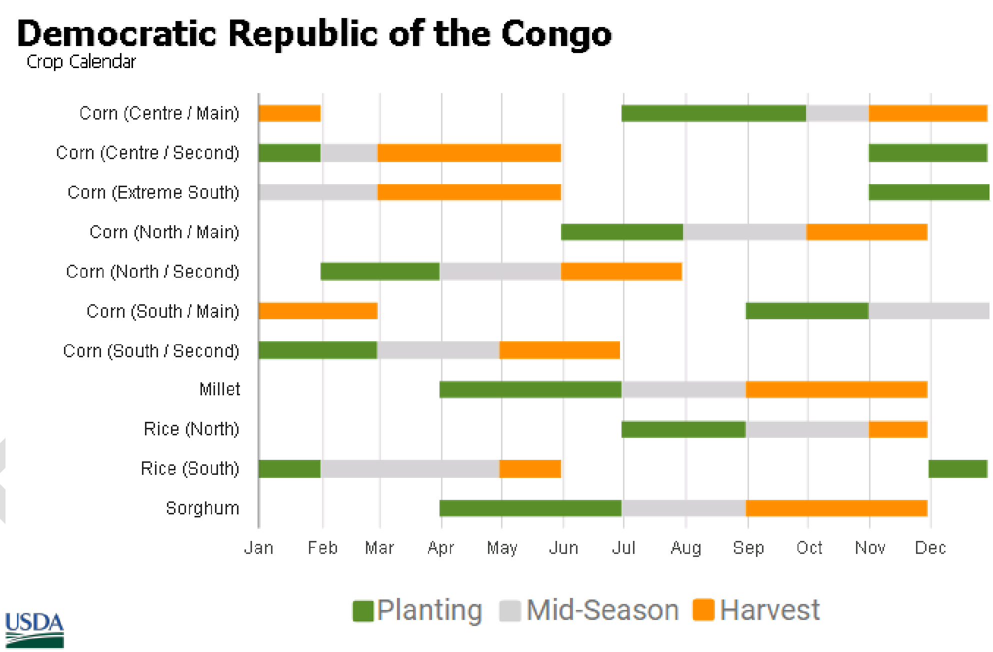

Figure 10: Cropping Calendar

Source: USDA

[10] https://www.export.gov/article?id=Congo-Democratic-Republic-Agricultural-Services-AGS

9. Background to solar water pumping in Democratic Republic of Congo

The Democratic Republic of Congo has submitted a demand of 80,000 solar water pumping systems. The ISA mission team discussed the potential of solar water pumping system for irrigation & drinking water and the likely transformational change it will bring to agricultural/ social sector by ways of increased productivity, higher income for farmers and drinking water to rural/semi urban communities. The Country templates have been shared with the National Focal Point to consider submitting their demand for Solar Pumping Systems. Additionally, ISA team shared with NFP and Ministry of Agriculture about its initiatives in conducting a price discovery bid through Energy Efficiency Services Ltd for 272,579 Solar Pumping Systems based on aggregated demand from 22 Member Countries. It is expected that there shall be a significant reduction of price through demand aggregation. The Democratic Republic of Congo has expressed interest in the program and the Ministry of Electricity and Hydraulic Resources will be coordinating with the concerned Ministries and Departments for implementation of aggregated demand of solar pumps which can be used for irrigation, drinking water and sanitation purposes to cover agriculture, health and education sector.

10. Solar pump Technology Overview

A PVP (Photo Voltaic Pump) typically consists of the following main components:

1. **Photovoltaic array:** An array of photovoltaic modules connected in series and possibly strings of modules connected in parallel.
2. **Controller:** An electronic device which matches the PV power to the motor and regulates the operation, starting and stopping of the PVP. The controller is mostly installed on the surface although some PVPs have the controller integrated in the submersible motor-pump set:
   - DC controller: usually based on a DC to DC controller with fixed voltage set point operation.
   - AC controller (inverter): converts DC electricity from the array to alternating current electricity often with maximum power point tracking.
3. **Electric motor:** There are a number of motor types: DC brushed, DC brushless, or three phase induction and three phase permanent magnet synchronous motors.
4. **Pump:** The most common pump types are the helical rotor pump (also referred to as progressive cavity), the diaphragm pump, the piston pump and the centrifugal pump. Some years ago there were PVP models on the market that operated with batteries and a conventional inverter. However it was soon realized that the cost savings on the pump did not make up for the overall substandard efficiency and the higher maintenance cost due to battery replacements. Instead it became clear that it is more economical to rather store water in a reservoir than electricity in a battery bank.

There are currently three pumping configurations commonly utilized in Africa:

- **DC drive with positive displacement pumps**. This consists of four pump technologies: Diaphragm pump driven by brushed DC motor, Helical rotor pump driven by brushless DC motor, Helical rotor pump driven by surface mounted brushed DC motor, Piston pump driven by surface mounted brushed DC motor
- **AC drive powering a submersible induction motor/centrifugal pump unit**
- **AC drive powering a three phase permanent magnet synchronous motor**. This category consists of: Positive displacement helical rotor pump, Centrifugal pump

The above technologies have specific features which make them suitable for particular applications. Some of the other key technology terms useful for understanding the functioning of a solar powered irrigation system are described in detail as per the table below.

Term	Description
Array Voltage	Some of the pumping systems have high array voltages. This has the advantage that the array may be further from the borehole without significant voltage drop (dependent on cable size and current). Array positioning may be important where there is potential for theft.
AC Motors	The motor operates on alternating current; the direct current produced by solar panels gets converted to AC using the inverter. The conversion from DC to AC leads to loss of power from generation to consumption. AC motors gain importance in applications where higher output/head combinations are required.
DC Motors	DC motors reach efficiencies of up to 80% and are therefore significantly more efficient than sub-kW three phase motors which have efficiencies in the region of 60% to 65%.
Brushless DC Motors	This combines the high efficiency of DC motors with low maintenance as opposed to brushed DC motors which require regular brush replacement (approximately every one to two years – head and quality dependent).
Three phase permanent magnet motors	This similarly combines the high efficiency of permanent magnet motors with low maintenance.
Positive displacement vs. Centrifugal pump	Positive displacement pumps have a better daily delivery than centrifugal pumps when driven by a solar PV system with its characteristic variable power supply. This is due to the considerable drop in efficiency of the centrifugal pump when operating away from its design speed. This is the case in the morning and the afternoon of a centrifugal pump driven by a PV array, unless that array tracks the sun (which is why centrifugal PVPs effectiveness improves more with a tracking array than a positive displacement PVP). The efficiency curve of a positive displacement pump is flatter over a range of speeds. However the efficiency of positive displacement pumps decreases with the shallowness of the borehole (the constant fixed friction losses become a more significant part of the power it takes to lift water). Therefore it is not surprising that both Grundfos and Lorentz use centrifugal pumps for applications where the lift is less than 20 to 30m but switch to positive displacement pumps for deeper wells.
Surface pump	Surface pumps are installed at ground level to lift water from shallow water sources such as shallow wells, ponds, streams or storage tanks. Surface pumps can also be used to provide pressurized water for irrigation or home water systems. These pumps are suitable for lifting and pumping water from a maximum depth of 20 meters.
Submersible pump	Submersible pumps installed where there is a requirement for the submerged in the fluid to be pumped These pumps can be used in areas where water is available at a greater depth and where open wells are not available. Typically the maximum recommended depth these systems can pumps is 50 meters.

Table 2 Key technology terms in a solar powered irrigation system

11. Experience and Perceptions

1. **Theft**: This is a problem for both PVP (Photo Voltaic Pump) and diesel pumping but very costly for the PVP systems due to the main portion of the capital cost being vested in the solar PV modules.
2. **Variable water demand:** Diesel pumps can pump water on demand. PVPs do not have that flexibility. A hybrid system such as solar diesel would present an attractive solution, however at a higher cost.
3. **Supply security:** PVP is considered to have less redundancy, is more difficult to repair and is susceptible to lightning strike. Diesel pumping has a more solid service infrastructure and is considered more reliable. The hybrid pumping solutions would improve supply security.
4. The diesel system is considered more flexible (flexible in moving a diesel engine to another borehole).
5. Diesel fuel is part of an existing infrastructure and the owner is able to do the minor service on the engine himself. PVP technology requires knowledge of mechanics, electrical and electronics thus making the user/operator dependent on specialized service which is often only available in Windhoek.
6. PVP are perceived to pump insufficient water.
7. **Corrosion** is a problem for both diesel and solar pumps.
8. The environmental impact of diesel pumps includes carbon emissions, possible borehole contamination, and threat to borehole sustainability. PVPs can be seen as a resource protection if it is designed for the maximum sustainable yield of the borehole.
9. The operation of PVPs is quiet.
10. PVPs are perceived to be expensive.
11. Many users on commercial farms combine the need for starting the diesel pump the opportunity for inspecting fences, checking on livestock and other farming activities. However, if a PVP is used then the frequency of these trips over the farm decrease[11].

12. Feasibility Analysis

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.

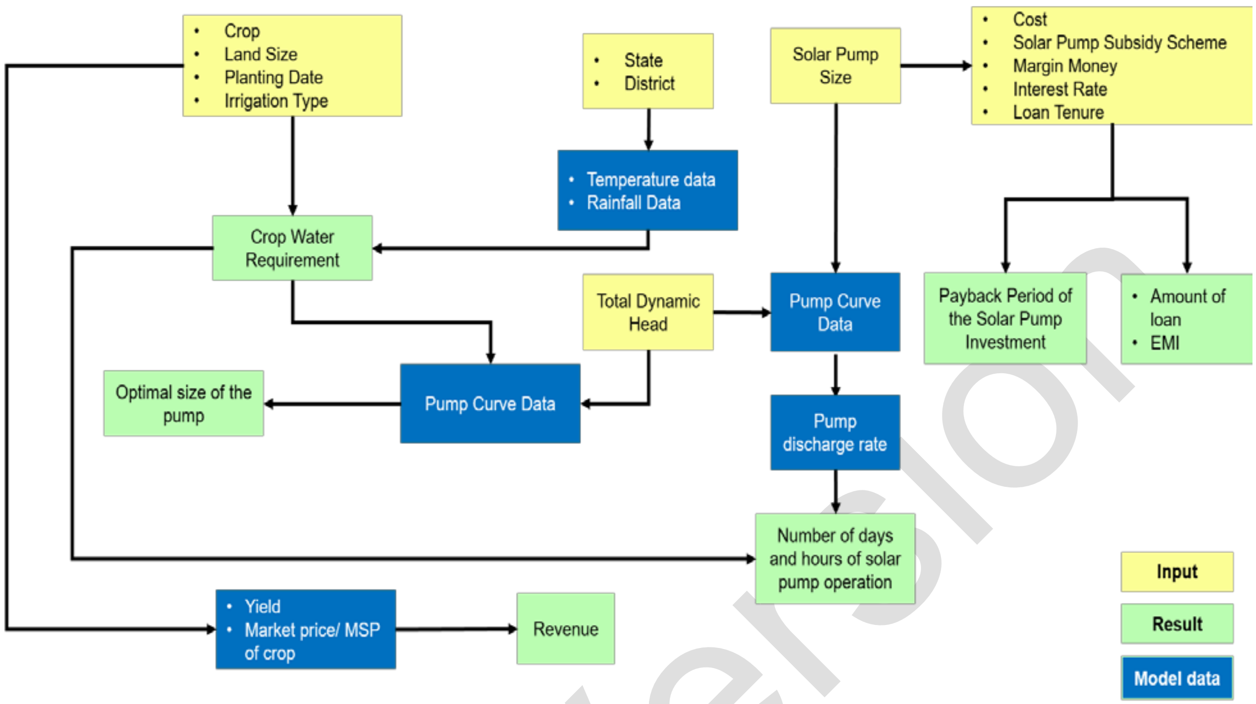

Figure 11: Technical and Feasibility Analysis

12.1 Technical Feasibility Analysis

12.1.1 Solar Irradiance

The efficiency of solar panels and consequently the solar energy output depends on three factors: the intensity of the solar radiation flux; the quality and the operating temperature of the semiconductor in use and the operating temperature of the semiconductor cell. Though the two latter factors may somehow, in one way or the other, be altered and improved; the intensity of the solar radiation flux however, to a great extent, is simply a given natural resource. The actual level of solar irradiance depends on the latitude and local climatic conditions. Annual solar irradiance, for instance in northern Europe is different from that noted within the sub-Saharan region. The below figure shows the long term global horizontal irradiance over Democratic Republic of Congo.

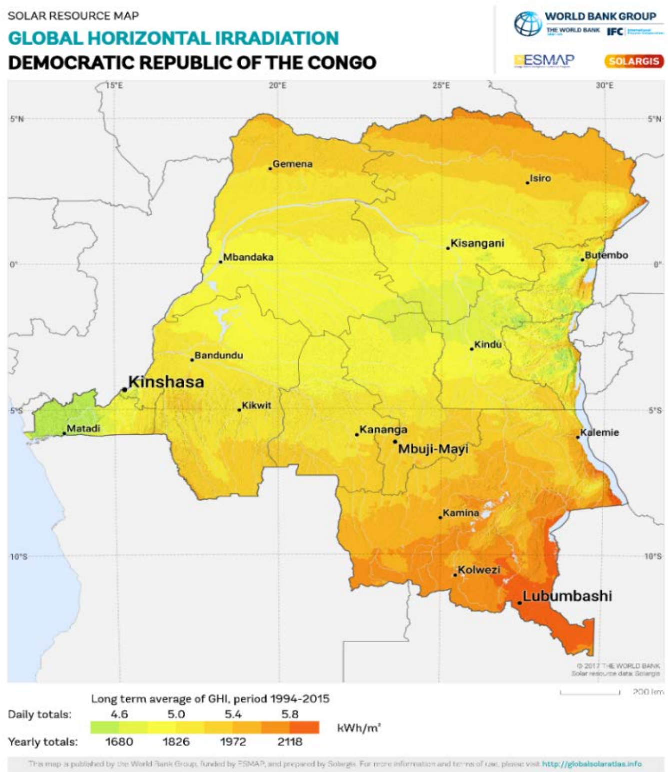

Figure 12: Solar Irradiation Map

The average solar radiation in Democratic Republic of Congo is 5.1 kWh/m^2/day. Existing solar data clearly indicate that the solar energy resource in Democratic Republic of Congo is high throughout the year. Grid connected Utility Scale Solar could play a big role in future addition of electricity installed capacity. Hydro resources could help in balancing the intermittence of solar generation.

12.1.2 Pump Location

The pump should be located in an enclosed room called a pump pit or a pump house. Surface pumps are not water proof and need to be kept away from water and protected from environmental conditions to prolong their lifetime and reduce maintenance requirements. Distance between the pump and the PV panels should be kept to a minimum to reduce voltage drop in the cables. Increased distance causes harmonics and would require a harmonics filter to avoid damages to the pump and the inverter/controller.

12.1.3 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, and 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.

12.1.4 Water Demand

Water demand is the major factor affecting the size of the pumping system. For solar systems it is calculated as a daily consumption rate (m^3/day). The storage capacity is the volume of water that need to be stored to ensure sufficient and continuous supply of water to end users. Storage tanks usually range in a volume of between 1 to 5 days of daily water requirements, depending on the location and the usage patterns

12.1.5 Total Dynamic Head

[12]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.

13. Advantages of solar powered irrigation

Socio-economic advantages		Environmental advantages
Farm level	National level	
Financing and cost of solar panels continue to drop, making SPIS economically viable and competitive with other sources of energy.	Potential for job creation in the renewable energy sector.	No greenhouse gas emissions.
Rural electrification and access to renewable energy, especially in remote areas.	Contribution to rural electrification and renewable energy targets.	Potential for adaptation to climate change by mobilizing groundwater resources when rains fail or rainfall patterns are erratic.
Independence from volatile fuel prices and unreliable and costly fuel supplies.	Reduced dependence on energy exports. Energy subsidies for fossil fuels can be reduced while offering an alternative to farmers and rural communities whose livelihoods would otherwise be negatively affected.	Potential for improving water quality through filtration and fertigation systems. Less pollution resulting from inadequate fuel handling from diesel pumps.
Potential for increasing agricultural productivity and income due to improved access to water.	Food security may be improved if introduction of SPIS is accompanied by changes in irrigation technologies and agricultural practices.	
Potential for income diversification due to multiple uses of energy (e.g. feed-in to grid, lighting, cooling) and water (e.g. livestock watering, domestic uses).	Rural development through improved access to water and energy.	
Reduced cost for water pumping in the long run. If system is being modernized for pressurized irrigation, increases in energy costs are offset through the use of solar energy.		
Potential time saving due to replacement of labour intensive manual irrigation, which can lead to other income-generating activities. Women and/or		

children might profit from time not spent on watering anymore.		

Table 3 Advantages of solar powered irrigation

14. Key Stakeholders

Organization/ Agency	Role
Ministry of Electricity and Hydraulic Resources (MEHR)	Ministry for coordination and implementation of solar related projects. Assess the requirements for solar mini grids and solar rooftop projects and monitor their implementation.
Ministry of Finance	The Ministry's mandate cuts across all sectors of Government. Not only is it entrusted with the formulation of sound economic and fiscal policies, but it also mobilizes resources for the implementation of government programs and ensure that all public resources are disbursed as appropriated by Parliament and accounted for in accordance with national laws and international best practice. Their role is to mobilize and approve the financing for solar related projects in Democratic Republic of Congo
Ministry of Foreign Affairs and Regional Integration (MOFARI)	The Ministry of Foreign Affairs (MOFA) is a cabinet-level government ministry responsible for the implementation and management of Democratic Republic of Congo's foreign policy and international activity
Ministry of Agriculture (MoA)	Government Ministry charged with creating an enabling environment in the Agricultural Sector. It is commonly known as Ministry of Agriculture and carries out its role by enhancing crop production, improving food and nutrition security, widening export base and improved incomes of the farmers. The Ministry is the overseer of the Agricultural sector where it formulates, reviews and implement national policies, plans, strategies, regulations and standards and enforce laws, regulations and standards.
African Development Bank (AfDB)	AfDB is supporting a number of projects in the country in the area of energy, agriculture, transportation, water supply and sanitation through financial and knowledge support.
USAID	USAID supports Democratic Republic of Congo's efforts to address weather-related impacts on agriculture through access to reliable climate data, development of effective climate policies, and research and education. USAID works with civil society organizations to build institutional capacity and support political advocacy on a wide variety of human rights and development issues.
World Bank	World Bank is supporting a number of projects in Democratic Republic of Congo in the area of energy, agriculture, education, transportation, water and sanitation.
UNDP	UNDP is executing projects in Democratic Republic of Congo in coordination with nodal ministries and NGOs.

Table 4 Key stakeholders in Democratic Republic of Congo

15. Recommendations for implementation

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

1. **Number and type of pumps**: Democratic Republic of Congo has submitted demand for procurement of 80,000 solar water pumps. Considering the low levels of electricity access especially in rural areas, off-grid pumps are required.
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. If the solar water pumps are scattered across different areas, it will lead to high transportation and maintenance costs. It is important to have the installation of solar water pumps in a concentrated area for better visibility and strong impact of the programme**.** Port Mombasa and Port Dar es Salaam could be the preferred ports for reaching the Eastern Port of the Democratic Republic of Congo. Port Motodi will be the preferred port for reaching the western port of the Democratic Republic of Congo and Pot Lobito (Angola) could also be an option to reach the centre of the country.
3. **Financing:** There are limited sources available for the government of Democratic Republic of Congo 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 may be 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 2. 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 Democratic Republic of Congo are very limited and farmers have relied on rain 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 pumps. Initially these activities may be undertaken by i-STARCs to be developed in Democratic Republic of Congo under the ISA's programme.
6. **Ecosystem availability:** Solar ecosystem is to some extent developed in the country and there are retail stores in rural areas available for the solar panels. Therefore availability of local manpower for solar and pumps should not be a challenge. However initial training may be required on the operations and maintenance aspects of the solar pumps.

16. Proposed next steps

1. **Pre-feasibility report:** The pre-feasibility report may be shared with NFP, Democratic Republic of Congo for any further suggestions or inputs.
2. **Bid for solar pumps and price discovery:** The bidding shall be completed for 2, 72,000 solar pumps basis the demand aggregation undertaken by ISA and price be discovered for solar pumps in the participating countries including Democratic Republic of Congo.
3. **Financing arrangement:** Government of Democratic Republic of Congo with ISA may explore suitable sources of financing for 80,000 solar pumps.
4. **Capacity building:** Post bid process and financing arrangement, capacity building of farmers and knowledge development of local technicians may be initiated by pump suppliers and through i-STARCs
5. **Implementation scale:** Considering solar pumps have not been deployed at a major scale in Democratic Republic of Congo, implementation may be initiated initially in a concentrated area for better visibility and strong impact of the programme which may further may be scaled to the country level. The roadmap for the same may be prepared by Government of Democratic Republic of Congo in consultation with ISA.
6. **Field preparation:** Boring activities may also be suitably initiated by farmers in the area where the solar pumps are planned to be initially implemented.
7. **Supply and project monitoring:** Regular project monitoring for supply and installation of pumps may be undertaken by ISA and NFP Democratic Republic of Congo basis field reports and feedback from farmers, suppliers and government agencies.