Draft Pre-Feasibility Report for implementation of solar pumps scheme in Benin

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Table of Contents

List of Figures

List of Tables

1. Executive Summary

- Benin's energy sector is dominated by traditional biomass energy. The use of biofuel and waste represents the highest share—49 percent—of the country's energy balance.
- Electrification rate in Benin is around 32%, whereas urban and rural areas electrified are 59% and 8.3% respectively.
- For its energy needs Benin is majorly dependent on petroleum imports and electricity from neighboring countries. Benin imports 69% of its power requirements from neighboring countries viz, Nigeria, Cote d'Ivoire & Ghana
- Benin has huge untapped renewable energy resources potential with an average solar radiation of 3.9-6.0 kWh/m^2/day
- Ensuring adequate access to electricity and fulfilling energy needs is a key goal of the government.
- Agriculture accounts for 23% of Benin's GDP[1] with 80% of Benin's 10.3 million people earning a living from agriculture. Most are subsistence farmers, growing crops on small family plots. Cotton is Benin's most important cash crop.
- Most agricultural production in Benin is primarily rain fed and in some cases manually irrigated when farms are in close proximity to major water sources.
- Benin has successfully experimented with solar based irrigation projects such as the Solar Market garden Project and portable solar pumps. However, solar contribution to energy mix is still very low at 0.5%.
- As highlighted in this pre-feasibility report, solar powered irrigation systems are potentially the most sustainable option for farmers especially considering the savings on the high diesel expenses and requirement of little/no maintenance.

1 Source: World Bank

2. Introduction

Benin is coastal country in a West Africa with the total estimated installed capacity of 349 MW (2018)[2] with diesel and HFO based plants having 249 MW and hydro based plants having 100 MW of installed capacity. Electrification rate in Benin is around 32%, whereas urban and rural areas electrified are 59% and 8.3% respectively. For its energy needs, Benin is majorly dependent on petroleum imports and electricity from neighboring countries. Benin imports 69% of its power requirements from neighboring countries viz, Nigeria, Cote d'Ivoire & Ghana. The approximate minimum cost of electricity for residential sector in Benin is USD 0.14 – 0.21/kWh. The per capita annual electricity consumption is ~110 kWh, which is very low compared to developing countries.

Benin's energy sector is dominated by traditional biomass energy. The use of bio fuel and waste (wood fuel and charcoal) represents the highest share—49 percent—of the country's energy balance. However, the large majority of the wood fuel and charcoal is harvested/produced in an unsustainable manner to supply to growing urban markets, which accelerates the decline of forest cover. Also, revenues from unsustainable wood harvesting do not benefit local rural populations as they are exploited by professional producers from urban centers. On the demand side, the vast majority of households cook with wood fuel with Liquefied petroleum gas (LPG) use having been limited by high refill costs of bottles (with recent reductions of subsidies), sporadic shortages, restricted distribution networks, and lack of consumer awareness[3].

The power sector in Benin is unbundled and interlinked with that of Togo's. Power generation and transmission for both Benin and Togo have been under the responsibility of the joint Benin-Togo bi-national utility, Communauté Electrique du Bénin (CEB), headquartered in Togo. CEB has been importing about 69 percent of its power from Nigeria, Ghana, and Ivory Coast. Some of CEB's self-generation output comes from thermal generation plants that are fueled by gas imported from Nigeria through the West Africa gas pipeline. CEB supplies both the Togo power distribution utility and the Benin state-owned power distribution utility, Société Béninoise d'Energie Electrique (SBEE), whose installed capacity averaged 240 MW[4].

As per the Intended Nationally Determined Contributions (INDC)[5] submitted to UNFCCC, the country has committed to reduce its carbon emissions by 16.17 % between 2021 -2030. Solar energy in Benin is slowly picking up. Generally health centers, villages, telecommunications etc. are key places where solar has been installed. The country has a National Renewable Energy Policy made in 2018 with focus on Solar Mini grids. However, contribution of Solar Power in energy mix is very minor (0.52%) and the contribution from RE sources including hydro, it is only about 1%. Hence Benin is in the process of focusing on accelerated Solar capacity addition to address the issues of Energy access, Environmental protection and Energy security. The existing Renewable energy policy is being revised which also envisages promotion of Private investment in Grid connected Solar Projects.

Benin has huge untapped renewable energy resources potential. Benin has average solar radiation of 3.9-6.0 kWh/m^2/day[6]. The high value of solar radiation signify great potential for development of solar technologies in the country owing to the abundance of solar insolation. The promotion of solar technology could create conditions, through rapid scale-up of capacity and technological innovation to further drive down costs towards grid parity. Considering the significant dependence on fossil fuel based generation and imported power, localized solar generation can help Benin to reduce the import bills and improve the reliability of power.

2 Source; USAID
3 Source: World Bank
4 Source: World Bank
5 http://www4.unfccc.int/Submissions/INDC/Submission%20Pages/submissions.aspx
6 http://www.reegle.info/countries/benin-energy-profile/BJ

Improving Benin's ability to meet its energy needs, particularly ensuring adequate access to electricity, is a critical goal of the Beninese government to support economic development and foreign investment. Benin depends on Nigeria and Ghana for the majority of its energy. Benin's electricity needs were estimated to be 250 MW in 2016 and are expected to rise to 600 MW by 2020[7].

Recently GE has signed contracts with the government of Benin to help the country to meet growing energy needs while developing self-sustaining electricity systems. GE will supply the country's first advanced distribution management system (ADMS) to increase energy reliability and efficiency. The ADMS will be provide utility with algorithms and predictive analytics to enable grid automation. GE will also upgrade the utility's substations and telecommunication infrastructure at the National Distribution Control Center in Cotonou. The project will help Benin to reduce its energy imports, currently at 85% of the country's total energy demand.

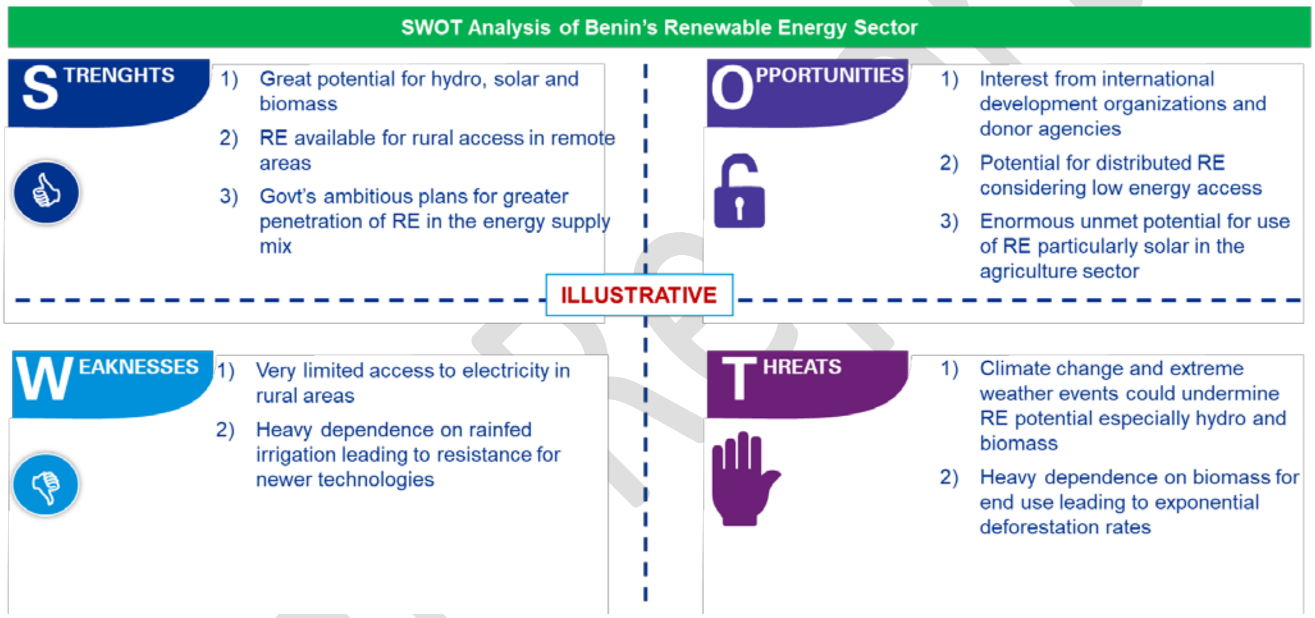


Figure 1: SWOT Analysis of Benin's Renewable Energy Sector

7 Source: export.gov

3. Geography

Benin is situated in West Africa and is bordered to the east by Nigeria, to the north by Niger and Burkina Faso, and to the west by Togo. Benin stretches 700 km from the Bight of Benin to the Niger river. With an area of 112,622 km^2. Benin extends from the Niger River in the north to the Atlantic Ocean in the south, a distance of 700 km with a coastline of about 121 km[8].

Geographically, Benin can be divided into four main areas from the south to the north. The low-lying, sandy, coastal plain which has a highest elevation of 10 m is, at most, 10 km wide. The plateaus of southern Benin, with an altitude ranging between 20 and 200 m, are split by valleys running north to south along the Couffo, Zou, and Oueme Rivers, an area that has been categorized by the World Wildlife Fund as part of the Guinean forest-savanna mosaic ecoregion. Then an area of flat lands dotted with rocky hills whose altitude seldom reaches 400 m extends around Nikki and Savé. Finally, the Atacora mountain range extends along the northwest border and into Togo with the highest point, Mont Sokbaro, at 658 m.

Benin has fields lying fallow, mangroves, and remnants of large sacred forests. In the rest of the country, the savanna is covered with thorny scrubs and dotted with huge baobab trees. Some forests line the banks of rivers. In the north and the northwest of Benin the Reserve du W du Niger and Pendjari National Park attract tourists eager to see elephants, lions, antelopes, hippos and monkeys. Previously Benin offered habitat for the endangered painted hunting dog, Lycaon pictus although this canid is considered to have been extirpated from Benin, due to human population expansion. Woodlands comprise approximately 31 percent of the land area of Benin.

Figure 2: Benin geographic location

Source: Britannica

Benin has little variation in topography, transitioning from a narrow and somewhat sandy coastal area to a marshy land with lagoons that rise into the La Terre de Barre Plateau. The wooded savannah of the plateau

8 Source: Britannica

continues on into the foot hills of the Atakora Mountains of the northwest, a branch of the Togo Mountains. Benin's highest point is Mt. Sokbaro, which rises 658 m; the lowest point of the country is the Atlantic Ocean at 0 m. From the mountainous northwest, the land slopes down into a broad plain and on to the Niger River valley of the far northeast. Apart from the Niger River, which, with its tributaries the Mékrou, Alibori, and Sota, drains the northeastern part of the country, the three principal rivers in Benin are the Mono, the Couffo, and the Ouémé. The Mono, which rises in Togo, forms the frontier between Togo and Benin near the coast. The Couffo, near which stands Abomey, flows southward from the Benin plateaus to drain into the coastal lagoons at Ahémé. The Ouémé rises in the Atakora Mountains and flows southward for 280 miles; near its mouth it divides into two branches, one draining to the east into Porto-Novo Lagoon and the other to the west into Nokoué Lake. The Atakora Mountains form a divide between the Volta and Niger basins[9].

The southern provinces make up one-fourth of the total area but are inhabited by more than two-thirds of the total population. Many of these people are clustered near the port of Cotonou, which is the focus of the commercial and political life of the country, and Porto-Novo, the official capital. The cultivation of subsistence crops, such as corn (maize), cassava, and yams, is intensive on the outskirts of the towns. The barre region and the Benin plateaus are planted with oil palms, which form the cash crop, as well as with subsistence crops. To the north, the aspect of the countryside changes as savanna vegetation increases and the population diminishes; some areas are uninhabited, except by Fulani nomads. Villages, instead of being encountered frequently as in the south, become scattered[10].

9 Source: Britannica
10 Source: Britannica

4. Climate

Benin is located in the inter-tropical convergence zone and has a tropical savanna climate[11] with average monthly temperatures of 26–31˚C[12]. In the far north the climate is warm semi-arid and temperatures can reach 45˚C. The climate alternates between two sets of powerful winds, the monsoon from the ocean, which brings the cool and wet season, and the Harmattan wind from the Sahara, which blows during the dry season. The effects of the monsoon decrease towards the north of the country, while the Harmattan's impact lessens towards the south of Benin.

Benin has three climate zones[13]:

1. A Sudanian zone, comprised of the departments of Atacora, Alibori and the northern parts of Donga and Borgou. This zone is characterized by a unimodal rainfall profile. The rainfall season is from April to October, with a peak between June and September. The period of vegetative growth in this zone is under 145 days, coinciding with the rainfall season. The mean annual rainfall is under 1,000 mm and the mean relative humidity is 54.9%62. The mean annual temperature is 27.5°C.

2. A Sudano-Guinean zone, comprised of the southern parts of Donga and Borgou, and the northern part of Collines. This zone is characterised by a unimodal rainfall profile peaking between May and October, with a mean annual rainfall of 900–1,100 mm. The period of vegetative growth is about 200 days, during the rainy season. Mean annual temperature varies between 21.2°C and 32.5°C and relative humidity ranges between 45.5% and 87.1%.

3. A Guinean zone, comprised of the southern part of Collines (up to Save), and the departments of Zou, Plateau, Couffo, Mono, Atlantique, Ouémé and Littoral. This zone has a bimodal rainfall profile and the period of vegetative growth is nearly 240 days. The main rainfall season is from April to June and the short rainfall season is from September to November. The mean annual rainfall is 1,200 mm up to 1,400 mm. Mean temperature varies between 25°C and 29°C and the relative humidity between 69% and 97%.

Figure 3: The three climate zones of Benin

The figure below[14] shows the span of the average temperatures in Benin for each month. As can be clearly seen from the temperature pattern, the average temperature range mostly remains flat between 26-27 ^{0}C for the country as a whole despite significant regional variations as detailed above.

11 According to the Köppen climate classification
12 Source: World Bank Climate Change Knowledge Portal
13 Source: FAO
14 Source: http://www.benin.climatemps.com/

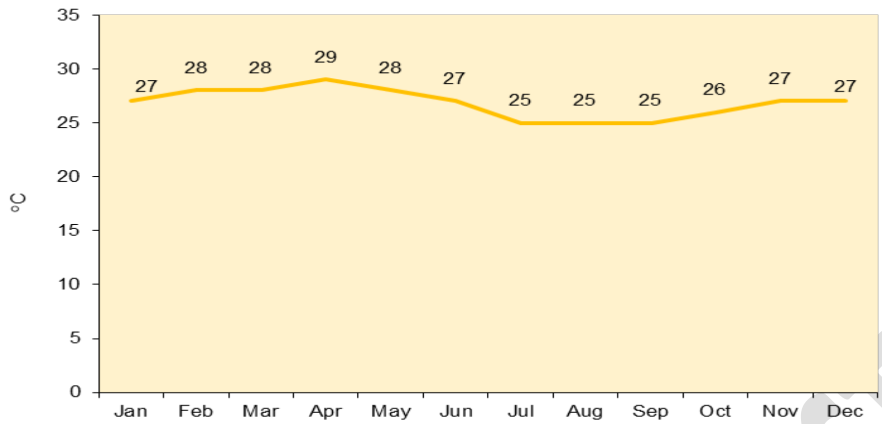


Figure 4: Average temperature pattern in Benin

Source: Clima Temps

In Benin, tropical ferruginous soils are prevalent, covering more than 9 million ha or 82% of the total area of the country; these are the zones with strong agricultural potential covering North Zou and Borgou-South and Centre and southern Atacora.

5. Rainfall

In Benin, the annual rainfall is highly variable, ranging from 700 mm in the north to 1400 mm in the south. Benin receives on average 1339 mm of rainfall per year, or 111.6 mm per month. On average there are 76 days per year with more than 0.1 mm of rainfall or 6.3 days with a quantity of rain per month[15].

Figure 5: Precipitation map of Benin

The principal rainy season is from April to late July, with a shorter less intense rainy period from late September to November. The main dry season is from December to April, with a short cooler dry season from late July to early September. The driest weather is in December when an average of 19 mm of rainfall occurs. The wettest weather is in June when an average of 338 mm of rainfall occurs[16].

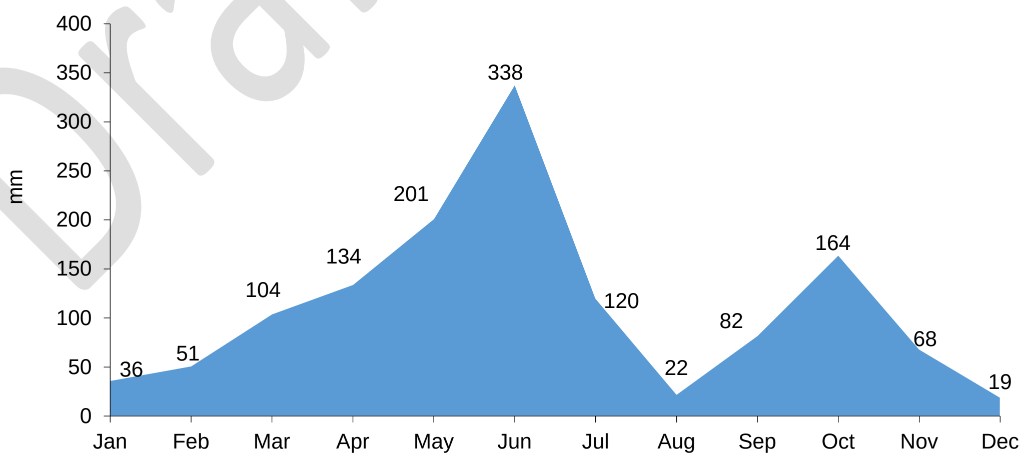


Figure 6: Rainfall pattern in Benin

Source: Clima Temps

[15] World Trade Press
16 Source: http://www.benin.climatemps.com/precipitation.php

6. Agriculture in Benin

Agriculture accounts for 23% of Benin's GDP[17] with 80% of Benin's 10.3 million people earning a living from agriculture. Most are subsistence farmers, growing crops on small family plots. Cotton is Benin's most important cash crop, contributing approximately 35 percent to the country's export revenues and providing an income to roughly three million people. In fact, Benin's export earnings rely on agricultural products, such as cotton, palm oil, cocoa, and coffee, exported to such countries as China, India, and Nigeria.

Most of Benin's rapidly growing population lives in rural areas, where agriculture supports about 70 percent of population's livelihoods, and provides about 80 percent of export income to the economy. Farmers, however, are using a fraction of the country's available land that could be adapted for growing rice. Domestic rice production thus falls short of demand, forcing Benin to rely on imports to make up the difference. To counter this, the Government has made scaling up rice production a priority.

Benin has a large percentage of land that can be considered grassland cover, over 90%, which is the highest percentage of grassland cover in sub-Saharan Africa. Benin's land utilization breaks down into the following components - 25% (2.75 million ha) is in forested zones, 23.5 % (2.585 million ha) is arable land that is now used for agriculture or could be, 8% (880000 ha) is already in permanent crop production, some 4% (440000 ha) is used as permanent pasture for grazing livestock, and the remainder of 39.4% (4.345m ha) is in other uses (urban areas, coastal, roads, etc.). Land utilization crosses categories, with crop stubble feeding ruminants, and grazing taking place in afforested areas.

Livestock is an important component of agricultural production, contributing about 6% of GDP from the husbandry of cattle, goats and sheep, pigs, poultry, grass cutter rodents, and snails. 36% of Benin households engage in some form of raising livestock, and it is particularly important for the North. 87% of households in Alibori Department and 41% of households in Borgou Department depend upon livestock as their main economic activity, and it is very important as an economic livelihood in Donga, Mono, and Zou Departments as well. Estimates of the herd size are as follows - in 2004 stocks were at 1,826,399 cattle, 2,300,000 goats & sheep, 293,000 pigs, and 13,200,000 chickens. Capture fisheries (sea and fresh water) production provides work for 70,000 people and produces 2% of GDP, reaching an estimated high of 40,000 metric tonnes harvested in 2005.

On average, Benin farmers cultivate plots between one and two hectares in size, with 85% of farmers growing corn, 30% cassava, 31% yams, 30% sorghum, and interestingly, only 11% grow cotton, the principal cash crop for the country. The largest plots of farmland are found in Borgou, followed by Atacora, Collines, Alibori, Donga, Plateau, Ouémé, Atlantique, Mono, and Couffo in that order. The leading departments with the highest percentage of households engaged in crops or gardens for food production and income are as follows - Atacora 80%, Alibori 70%, Donga 60%, Collines 54%, Borgou 53%, Couffo 44%, Plateau 40%, and Zou 37%[18].

Agricultural production systems are attached to traditional systems of shifting cultivation, with their own assessments of the level of soil fertility (without the use of soil analysis in laboratories) and face a significant decrease in land reserves due to increased population densities and expansion of cash crops such as cotton. Cotton productivity and profitability have declined in recent years due, in part, to poor management practices - challenges that need to be addressed by the country's decision-makers. Poor infrastructure and flooding, which can wipe out harvests and seed stocks, are just some of the challenges Benin farmers face.

Cotton has high marketing collateral with known prices; other sectors are not organized as food prices are not the object of support and marketing of food products is atomized. This situation means that producers

17 Source: World Bank
18 Source: USDA

tend to use some fertilizer for cotton in favor of food crops. The fertilizer market in Benin is mainly characterized by its segmentation between cotton fertilizers and fertilizer outside of cotton. Private sector participation in the import and distribution of fertilizers is about 30%. According to the stakeholders' forum organized in 2013 in Ghana, the rate of fertilizer use in 2011 in Benin was estimated at about 6.3 kg/ha. The country imported more than 12,000 tonnes (t) of fertilizer in 2011 and more than 1,000 t in 2010. Among the key challenges facing the fertilizer industry in the country is: limited access to credit, small network of distributors of agricultural inputs, poor road and port infrastructure, and an informal intervention fertilizer subsidy. Professional agricultural organizations are weakly involved in the distribution of fertilizers.

Declining soil fertility and the lack of a specialized agency for credit in agriculture are real difficulties experienced by farmers in Benin.

Benin is divided into eight agro-ecological zones[19]. These eight zones can be grouped into three main production systems because of their similarities, particularly in terms of soils and rainfall patterns:

(i) The southern zone, which covers ~13% of the country and is home to more than 60% of the population. Because of this high population density, land is extremely fragmented. Various crops can be grown in the south and agriculture is associated with small ruminants and poultry (Zones 6, 7 and 8).

(ii) A transition zone with reduced population density and less pressure on the land, located in central Benin. Cotton is grown, along with various other crops (Zone 5).

(iii) The Borgou-Atacora zone – which includes the southern Borgou-southern Atacora area, northern Borgo area and Atacora area. The population density of this zone is low. Livestock is often integrated into farming activities (Zones 1, 2, 3 and 4).

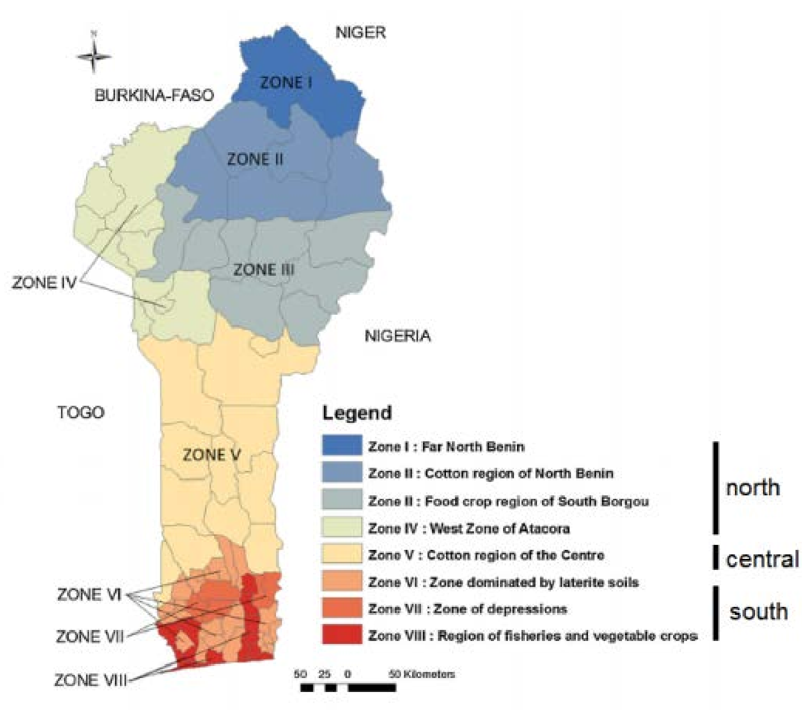


Figure 7: Agro ecological Zones in Benin

19 Source: Akossou, A.Y., Attakpa, E.Y., Fonton, N.H., Sinsin, B. and Bosma, R.H., 2016. Spatial and temporal analysis of maize (Zea mays) crop yields in Benin from 1987 to 2007. Agricultural and Forest Meteorology, 220, pp.177-189.

Despite the overall favorable food security conditions, some vulnerable households still need external food assistance. According to the March 2019 “Cadre Harmonisé” analysis, about 32,000 people (0.27 percent of the population) are estimated to be in need of food assistance from March to May 2019, showing an increase from 8 500 food insecure people in March-May 2018. The increase is explained mainly by the impacts of floods and Fall Armyworm on cultivated areas.

While the GOB aims to diversify its agricultural production, Benin remains underdeveloped and dependent upon the world price for cotton and regional trade. Agriculture policy is set and implemented or influenced by a number of ministries, including the Ministry of Agriculture, Livestock breeding and Fishing (MAEP), Ministry of Industry and Trade, Ministry of Economy and Finances, and the Ministry of Transport and Public Works. Extension services are provided at the Department level through the CerPA (Regional Centres for Agriculture Promotion). Research is carried out at the National Institute of Agriculture Research (INRAB) and the International Institute of Tropical Agriculture (IITA). Partners working with the GOB to improve the agricultural sector include the United Nations Development Programme (UNDP), The World Bank, FAO, United Nations Industrial Development Organization (UNIDO), SNV Benin, the European Union, the German Technical Cooperation (GTZ), Agence Francaise de Développekent (AFD), and many NGOs and initiatives. INRAB is the primary GOB research institution in the agriculture sector.

Benin serves as a delivery corridor for West Africa reaching more than 100 million people in the landlocked countries of Niger, Mali, Burkina Faso, Chad, and the northern states of Nigeria. Benin‘s traditional trade links with the EU, in particular France and Belgium, remain strong. There is presence of Chinese foodstuffs in the open-air markets and supermarkets. Benin’s major trade partners include Nigeria, France, Belgium, Spain, Switzerland, Argentina, Brazil, U.S., China, and the United Arab Emirates (UAE). The major regional trading partners include Niger, Togo, Nigeria, and Burkina Faso. Estimates of annual trade with these countries are extremely hard to determine, but some sources indicate that Benin exports about 15,000 mt of corn and 1,500 mt of rice to Nigeria, 6000 mt of corn to Niger, 1400 mt of corn and 2000 mt of rice to Togo. Vegetables and animals move across these borders in large amounts in regular patterns. In “crisis years” where local crops are under produced, Benin has sourced as much as 9500 mt of corn and 950 mt of rice from Togo, and 6000 mt of rice and 1800 mt of corn from Nigeria[20].

Exports by Quantity, including re-exports	Imports by Quantity	Exports by Value, including re-exports	Imports by Value
Palm Oil	Palm Oil	Palm Oil	Chicken Meat
Cashew Nuts	Refined Sugar	Cashew Nuts	Turkey Meat
Refined Sugar	Chicken Meat	Cotton Lint	Refined Sugar
Cotton Lint	Turkey Meat	Chicken Meat	Palm Oil
Chicken Meat	Wheat Flour	Refined Sugar	Prepared Foods
Cottonseed	Apples	Turkey Meat	Apples
Food Wastes	Wheat	Palm Kernel Oil	Confectionary Sugar
Turkey Meat	Prepared Foods	Cottonseed Oil	Wheat Flour
Cottonseed Cake	Peanut Oil	Cottonseed	Wine
Palm Kernel Oil	Tomato Paste	Cotton Lintner	Whole Milk

Table 1: Top ten leading agricultural exports and imports

Source: FAOSTAT

20 Source: USDA

Benin is signatory to all international trade conventions under the aegis of the WTO and the United Nations Conference on Trade and Development (UNCTAD). Also, Benin is a member of the trade agreement between the European Union, Africa, and Caribbean and Pacific countries (ACP-EU), and the regional and sub-regional economic unions such as the Economic Community of West African States (ECOWAS) and The West African Economic and Monetary Union (WAEMU), and it is party to the African Growth and Opportunities Act (AGOA).

Farmers in Benin face many obstacles to increasing production. They include rudimentary growing systems, limited access to land in the peri-urban production zones, difficulty in obtaining appropriate land title deed or certificate of land occupancy, a lack of adequate credit, 25% or higher post-harvest losses during peak season production, a lack of coordinated groups to aggregate benefits in marketing and distribution, an absence of appropriate packaging systems for products, and an absence of specific vegetable inputs. Producers utilize the chemical fertilizers and pesticides that are only available for cotton on many other crops, as there are few or no alternatives. Farmers also encounter soil issues - 45% report infertile soils are the greatest problem, a lack of moisture was the next greatest soil issue at 34%, degraded soils were seen as problematic by 32%, and flooding was a problem for 25% of farmers.

7. Irrigation

The water resources of Benin include surface and ground water. Most surface water is located in the southern part of Benin, which has 3,048 km of rivers and streams, and 333 km^2 of lakes and lagoons. These water bodies rely on three major water catchments, the Pendjari and Niger water catchments in the north and the coastal water catchment in the south.

- The Pendjari (or Volta) catchment takes its source from the Atacora mountain range, flows north-west then south-west towards the Republic of Togo before reaching the Volta River in Ghana.
- The Niger catchment serves as a 120-km border between Benin and Niger. In Benin, this catchment is made up of three rivers: Mékrou, Alibori and Sota.
- The Coastal catchment includes the largest river of Benin, the Ouémé River, as well as the Mono and Couffo Rivers.

Most production in Benin is primarily rain fed and, in some cases, manually irrigated when farms are in close proximity to major water sources. This dependence results in high seasonal availability of produce and lower prices due to an abundance of produce during the rainy season(s).

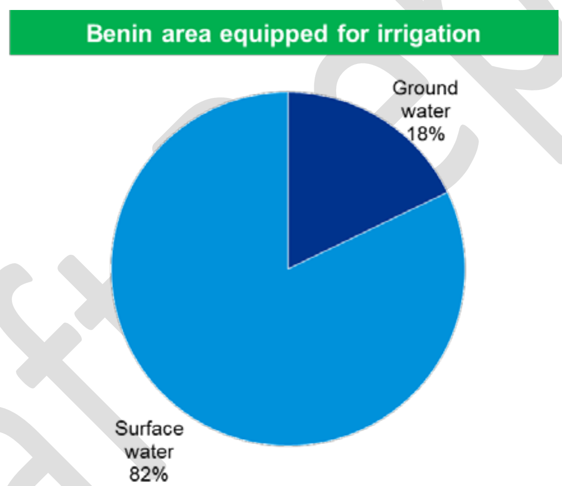


Figure 8: Benin irrigation sources

The total area equipped for irrigation in Benin for irrigation is 12,258 ha. The figures refer to year 2002 and comprise of 10,973 ha in registered schemes and 1,285 ha of equipped lowland[21].

Benin also has about 320,000 ha of irrigable lands, including the Niger valleys (Malanville and Karimama), the Oueme valleys (low valley), and the Mono valleys, of which 205,000 ha of lowlands are favorable to rice cultivation. There are also possibilities given by non-exploited surface waters, including 31,000 ha of lakes and lagoons available and favorable to irrigation.

21 Source: FAO

8. Cropping Pattern

Benin's topography is varied and includes four main geological formations: i) a low-lying, sandy coastal plain; ii) sedimentary shelfs; iii) a crystalline peneplain that covers most of the country and includes many hills; and iv) a mountain range, the Atacora chain in the north-west, which is the only high lying region of Benin, reaching an elevation of 641 m. The spatial variation in climate and different soil properties influence ecological processes. As a result, Benin is divided into three vegetation zones.

- North Benin is comprised of wooded savanna and riverine forests. The vegetation in these parts is broadly categorized as West Sudanian Savanna – typically a hot, dry, wooded savanna composed mainly of large tree species and long "elephant" grass.
- North-central Benin is comprised of dry dense forests, open savanna and riverine forests. The most common tree species in central and north Benin are Isoberlinia doka, Afzelia africana, Khaya senegalensis, Parkia biglobosa, Danielia oliveri, Anogeissus leiocarpus, and Pterocarpus erinaceus.
- South Benin is comprised of a highly dynamic mosaic of forest, savanna and grassland habitats65. The dense forests of this region include species such as Mitragyna spp., Acacia sieberiana, Terminalia spp., Borassus aethiopum, Triplochiton scleroxylon, Acacia seyal, Balanites aegyptiaca and Tamarindus indica. Throughout Benin, narrow strips of forest may be found along watercourses. These "riverine forests" or "gallery forests" include semi-deciduous forest, dry deciduous forest and woodland savanna along rivers or streams. Riverine forests provide crucial ecosystem services such as preventing river bank erosion, reducing flood risk, improving water infiltration and groundwater recharge, and maintaining water quality. Riverine forests also harbor much biodiversity. Although covering only 0.6% of Benin's surface area, riverine forests contain about a third of Benin's estimated 3000 plant species. Overall, approximately 68% of Benin's surface area is covered by forests or woodlands, with only 2.5% covered by dense forests.

Despite localized flooding, favorable weather conditions in 2018 resulted in an above-average cereal crop production of about 2 million tonnes. Production of maize, the main staple cereal, is estimated at about 1.4 million tonnes, nearly 3 percent above the five-year average and 11 percent below the record of the previous year. A record production has been observed for rice, 26 percent above the 2017 harvest and 73 percent above the five-year average levels. Cereal import requirements mostly rice and wheat for human consumption, in 2019 (October 2018/September 2019) are estimated at a high level of 500 000 tonnes, about 16 percent below the previous year and 25 percent above the average due to higher demand for human and industrial use.

Benin cereal production (000 tonnes)

Cereal	2013-17 average	2017	2018 (e)
Maize	1,390	1,617	1,428
Rice (paddy)	258	361	458
Sorghum	118	140	128
Others	25	26	28
Total	**1,790**	**2,144**	**2,042**

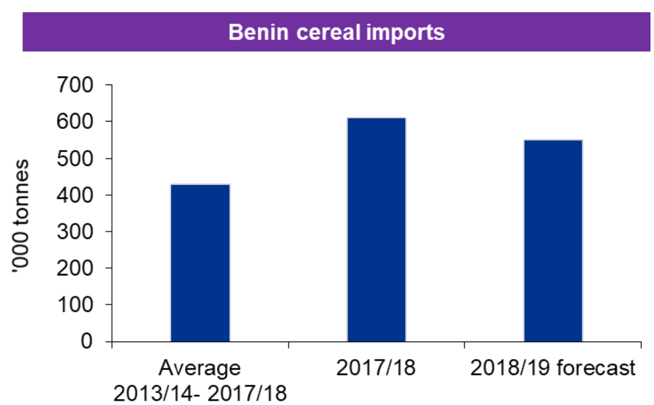


Figure 9: Benin's cereal production and cereal imports
Source: FAO

The typical cropping calendar and production areas for Benin is shown below:

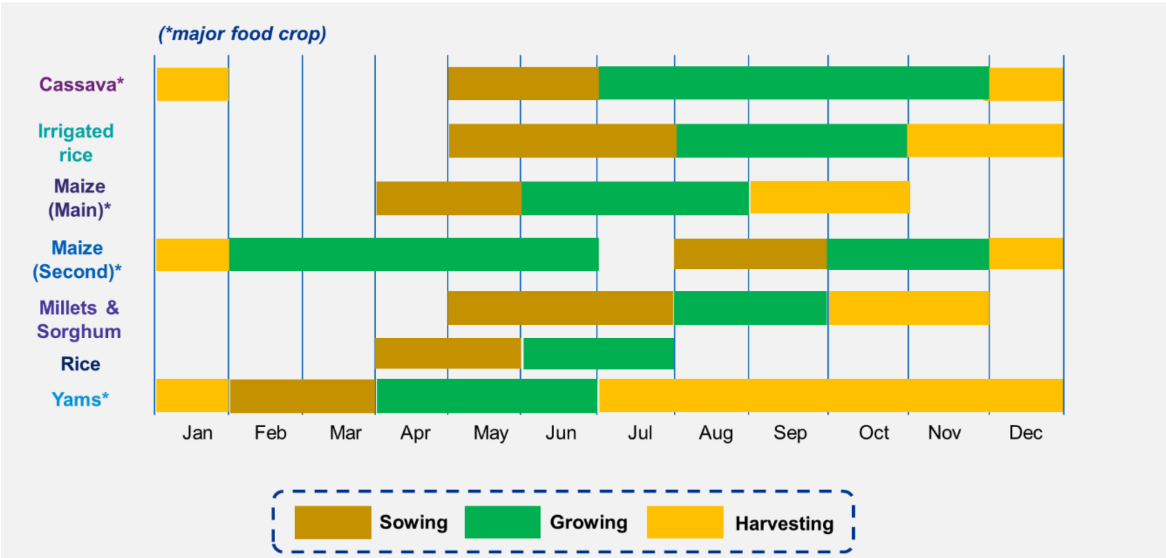


Figure 10: Cropping calendar for major crops in Benin

Source: FAO

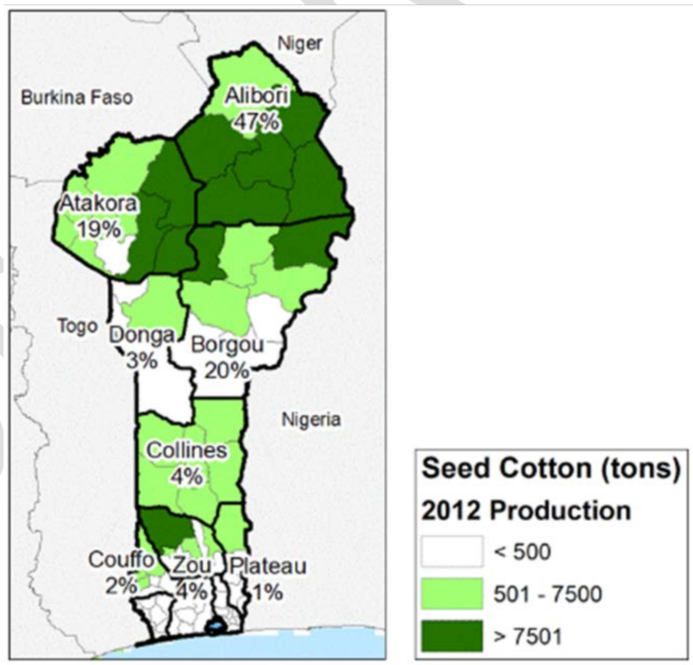


Figure 11: Production areas of cotton in Benin

Source: United States Department of Agriculture

9. Background to solar water pumping in Benin

Most production in Benin is primarily rain fed and, in some cases, manually irrigated when farms are in close proximity to major water sources. This dependence results in high seasonal availability of produce and lower prices due to an abundance of produce during the rainy season(s).

Benin also has about 320,000 ha of irrigable lands, including the Niger valleys (Malanville and Karimama), the Oueme valleys (low valley), and the Mono valleys, of which 205,000 ha of lowlands are favorable to rice cultivation. There are also possibilities given by non-exploited surface waters, including 31,000 ha of lakes and lagoons available and favorable to irrigation. The irrigated areas is ~4% of the total irrigation.

In 2017, some companies have installed 41 Solar PV systems and 71 Solar Water Pumping systems (Details to be furnished by NFP). Besides, Benin has successfully experimented with solar based irrigation schemes such as:

(i) The Solar market garden project

The project combines solar-powered pumps with drip irrigation systems to provide a cost-effective and environmentally friendly way to pump water for irrigation from nearby rivers and underground aquifers. The Solar Market Garden concept creates a safety net for the dry season, reducing environmental and health vulnerability, and providing a reliable base income for women farmers. To date, there are 11 half-hectare-sized Solar Market Gardens, with 30-40 women working in each. Solar energy powers a well pump to water gardens through a drip irrigation system. One garden supplies two tonnes of produce monthly. Twenty percent is for home consumption; the balance is sold, generating a profit of USD 7.50 weekly for each woman vendor. The Solar Market Garden project has replaced diesel generators with solar pumps, avoiding a minimum of 0.86 tonnes of carbon emissions annually per garden, and provided a means for the most vulnerable in Sub-Saharan Africa to adapt to future water shortages resulting from climate change.

(ii) The SISAM project

The SISAM project aims to improve solar irrigation solutions in Burkina Faso, Togo and Benin. The project plans to co-construct and disseminate a solution to improve access to smallholder irrigation in the following areas: Technical optimization, financial accessibility, Maintenance, Environmental impact. It favors a participatory approach of local stakeholders for the design of the solution supported by a transfer of skills to local stakeholders. The new solution will provide as much as necessary differentiated devices according to local contexts of intervention. The objectives of the project are that local actors in the solar pumping sector (microfinance institutions, distributors, installers, institutional representatives, local technical services, farmers, groups, local partners, etc.) are strengthened in their capacity to offer vegetable growers a new and improved Solar Irrigation Solution proven to support the acquisition, maintenance, efficient use and management of solar pumping systems. Further the objectives are that agricultural production and income of vegetable growers operating small private or collective farms (<1 ha) are increased in 3 regions (1/country) perennially following the provision and/or acquisition of irrigation systems by solar pumping

While the penetration of using pumps as a means of irrigation is slowly gaining pace through the use of innovative business models, there are still concerns regarding the sustainability of such practices. The country primarily depends on oil imports to meet its needs and extensive and increased use of diesel in agriculture will only worsen the economic situation. There is a twin need of bringing more area under irrigation and at the same time increase the energy access in rural areas, both of which are abysmally low for a rapidly growing population of Benin. Irregular rainfall and political instability have left as many as four million people lacking water, both for drinking and agriculture purposes. In this context, both government and international development organizations are investing in projects involving installation of solar powered irrigation systems. The solar powered irrigation systems offer the dual benefit of improving access to irrigation as well as electricity, without relying on grid expansion.

Furthermore, innovative business models such as using portable solar pumps are also being implemented on a pilot basis drawing inspiration from other successful projects executed in Kenya, Ethiopia and Malawi.

Funding Agency	Implementing Partner	Project Title	Project Description
Nordic Climate Facility	Solar Electric Light Fund (SELF)[22]	Solar Market Garden project	The project combines solar-powered pumps with drip irrigation systems to provide a cost-effective and environmentally friendly way to pump water for irrigation from nearby rivers and underground aquifers. To date, there are 11 half-hectare-sized Solar Market Gardens, with 30-40 women working in each.
Various	Various	The Hunger Project	The Hunger Project has been working in Benin since 1997 and is currently empowering community partners in 19 epicenter areas to end their own hunger and poverty. Through its integrated approach to rural development, the Epicenter Strategy, The Hunger Project is working with community partners to successfully access the basic services needed to lead lives of self-reliance and achieve internationally agreed-upon markers of success, such as the Millennium Development Goals.
French Development Agency (AFD) and French Environment and Energy Management Agency (ADEME)	Practica Foundation	SISAM	The project aims to improve solar irrigation solutions in Burkina Faso, Togo and Benin. The project plans to co-construct and disseminate a solution to improve access to smallholder irrigation

Table 2: Projects in Benin

Further, many of multi-lateral institutions like World Bank, European Union, AFD, MCA, ECOWAS are supporting Benin through Technical Assistance as well as Project funding. World Bank has been supporting Benin for Electrical network augmentation. Recently the Bank approved ROGEP (Regional Off grid Electrification Programme) to promote private sector funding in off grid solutions in 19 Countries in west African Region and Benin is one of them. Apart from promotion of Bio gas Stoves, GIZ has been supporting the Solar sector market development in the Country through an incentive scheme for private entrepreneurs for small systems for home lighting. The specifications are prescribed through Lighting Global Porgramme.

22 https://unfccc.int/climate-action/momentum-for-change/women-for-results/selfs-solar-market-gardens

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.
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

Term	Description
	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.
Diaphragm pump	The diaphragm pump is used for pumping small volumes of water from 100/120m depth. The pump needs regular maintenance (diaphragm replacements, cleaning). If the diaphragm breaks the motor chamber gets wet. The pump can run dry.[23]

Table 3: Key technology terms in a solar powered irrigation system

23 Ministry of Mines and Energy (Namibia), UNDP, GEF

11. Experience and Perceptions

1. Theft: This is a problem for both PVP 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[24].

24 Ministry of Mines and Energy (Namibia), UNDP, GEF

12. Recent Solar Pumps Uptake and Pricing

Information to be furnished by Benin NFP (if any)

13. 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.

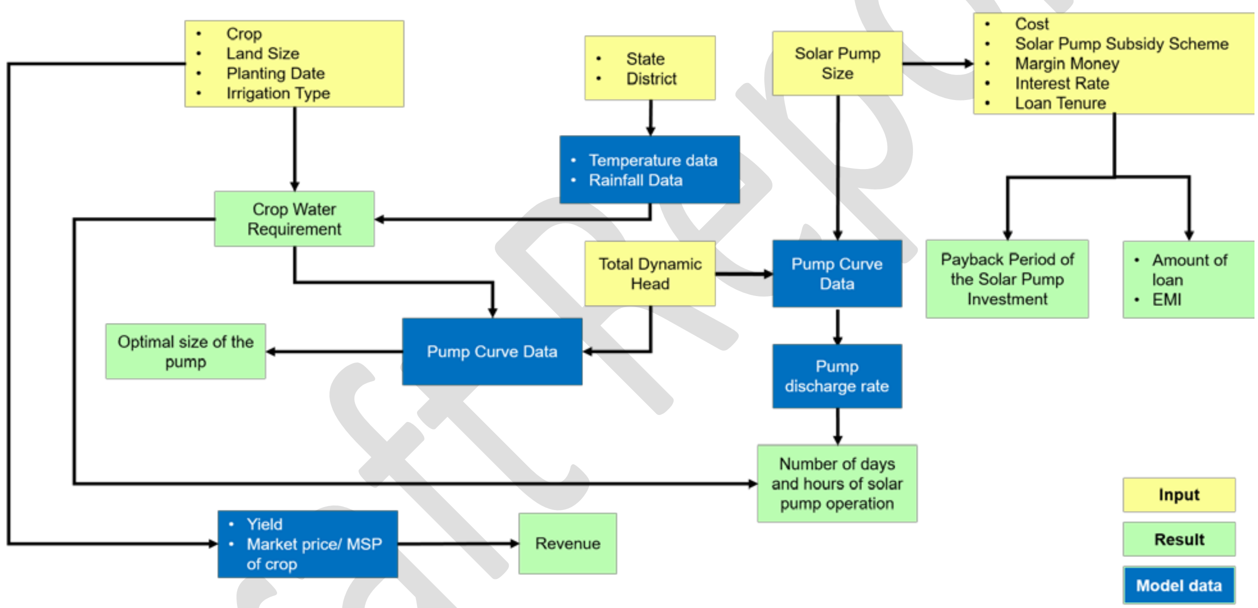


Figure 12: Factors involved in feasibility analysis of a solar powered irrigation system

13.1 Technical Feasibility Analysis

13.1.1 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 Benin[25].

25 Source: Global Solar Atlas

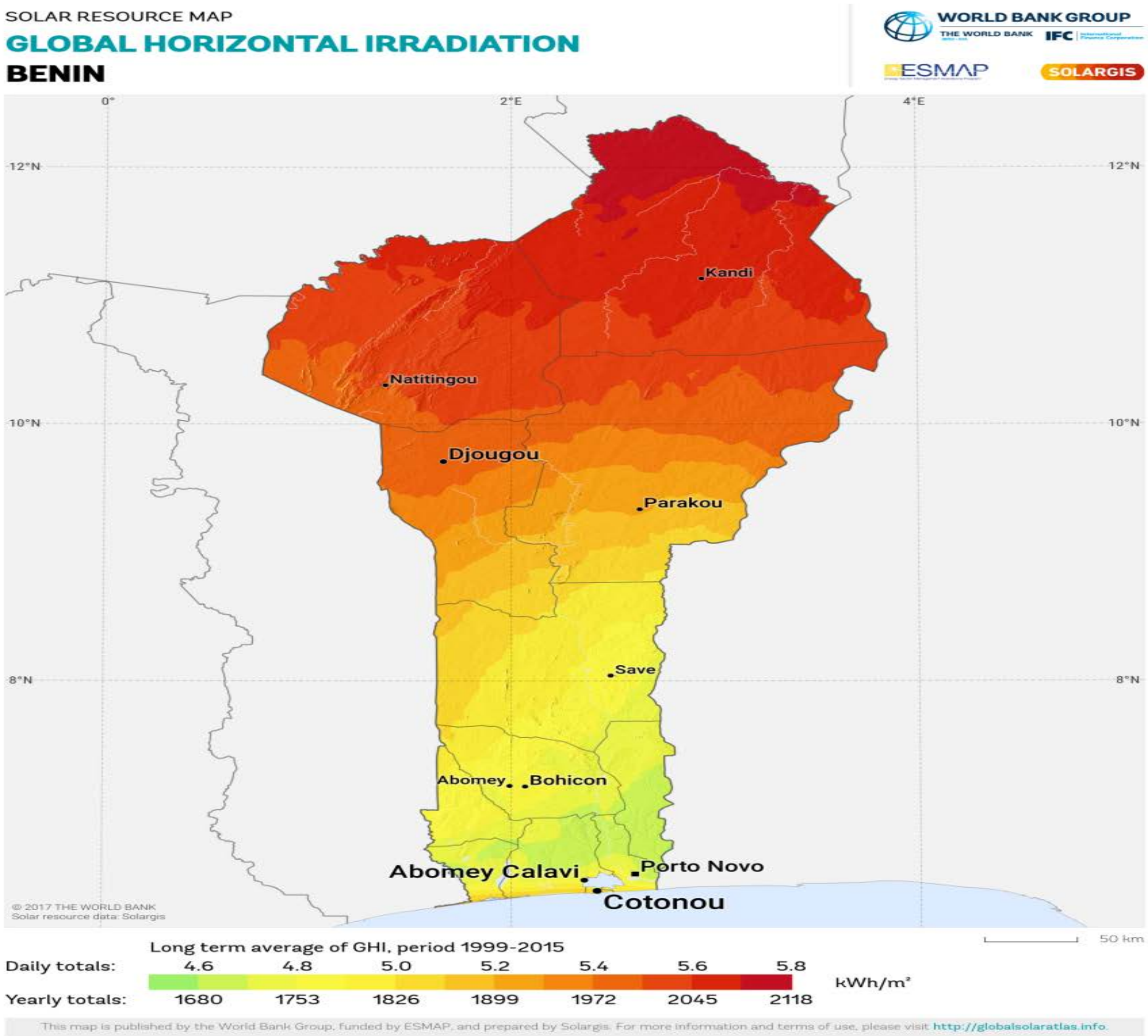


Figure 13: Solar Resource Map of Benin

Benin has average solar radiation of 3.9-6.0 kWh/m^2/day[26]. As clearly indicated from the above, the North part of the country particularly in the warm desert areas particularly around and north of Natitingou and Kidai, the GHI values vary between 5.4-5.8 kWh/m^2 while in the Southern part it is less than 5.0 kWh/m^2. The high value of solar radiation signify great potential for development of solar technologies in the country owing to the abundance of solar insolation. The utilization of solar energy can further be increased by utilization automatic/ manual trackers to ensure maximum absorption of solar irradiance by the panel surface.

26 http://www.reegle.info/countries/benin-energy-profile/BJ

13.1.2 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.

13.1.3 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[27].

13.1.4 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.

13.1.5 Total Dynamic Head

[28]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.

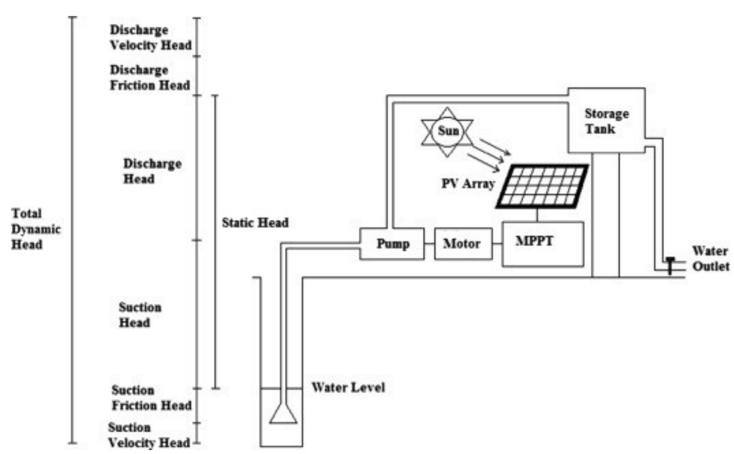


Figure 14: Total Dynamic Head of a solar pump

27 Sun-Connect News
28 ScienceDirect.com

13.2 Financial Feasibility Analysis

13.2.1 Payback Period Analysis

Indicative Inputs

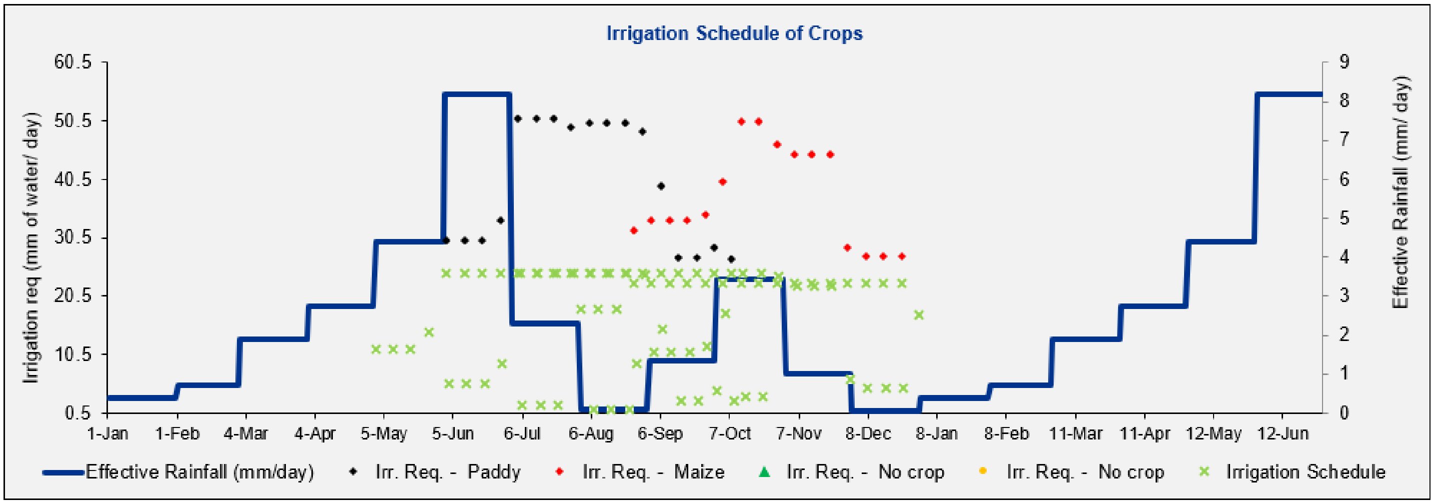
S.No.	Particulars	Unit	Value	Source
1	Crop to be Irrigated		Rice, Maize	
2	Land Size	hectares	0.5 (for each crop)	
3	Planting date		As per cropping calendar	
4	Irrigation type		Flood: Lined canal supplied	
5	Selected Size of Solar Pump	HP	3	
6	Total dynamic head inclusive of friction losses	meters	40	
7	Cost of Solar Pump	USD	4044	
8	Subsidy	%	0%	
9	Margin Money	%	10%	
10	Loan Amount	%	90%	
11	Interest Rate	%	12.98%	Trading Economics
12	Loan Tenure	years	10	
13	Cost of diesel pump per HP	USD	56	FAO
14	Cost of diesel	USD/litre	1.09	Published reports and articles
15	Hike in diesel prices (y-o-y)	%	3%	Based on global averages
16	Inflation rate	%	5.3%	Trading economics
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[29]

Indicative Crop Water Requirement[30]

Total Crop Water Requirement (m^3)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	-	-	-	-	-	866	1759	1176	558	904	683
Annual crop water requirement (m^3)						5961					

29 The toolkit developed by KPMG for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was used to undertake the analysis.
30 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 arrived at once data has been obtained from the respective nations.

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

Indicative Outputs

S.No.	Particulars	Unit	Value
1	Amount of subsidy	USD	0
2	Amount of loan to be availed	USD	3640
3	Yearly installment towards loan repayment	USD	670
4	Monthly installment towards loan repayment	USD	56
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	82
6	Number of hours of solar pump operation required	Hours	558
7	Number of days of solar pump operation required	Days	70
8	**Incremental payback of solar pump w.r.t. diesel pump**	**years**	**9**

14. 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 4: Advantages of solar powered irrigation

15. Key Stakeholders

Organization/ Agency	Role
Ministry of Energy, Water and Mines (Ministère de l'Energie, de l'Eau et des Mines, MEEM)	MEE is the major government agency responsible for sector development planning, policy making, and the development and oversight of electricity expansion programs. MEE is also responsible for electricity regulation
Ministry of Economy and Finance (MEF)	The Ministry of Economy and Finance is responsible for the design, implementation, monitoring and evaluation of the State's general economic, financial and monetary policy, as well as for constitution and conservation of land and real estate assets of the state.
Ministry of Agriculture	The key objective of the ministry is to define policies relating to Agriculture, Breeding Fisheries, Forestry and Natural Resources, Agricultural Research, Rural Legislation, Rural fitting and Cleansing, Promotion of Rural Youths and Women Activities, Packaging of agricultural products and to other closely related sectors.
Ministry of Decentralization and Local governance (MDGL)	Nodal ministry responsible for overall supervision, coordination and implementation of social development projects. MDGL works very closely with international funding agencies especially World Bank.
Communauté Electrique du Bénin (CEB)	CEB is the state-owned electricity company of Benin and Togo. The CEB is in charge of production, distribution and the import of electricity in both countries, and is jointly owned and managed by Benin and Togo. The CEB is responsible for development of the electricity infrastructure of both countries.
Benin National Power Utility (Société Beninoise d'Electricité et d'Eau, SBEE)	SBEE is largely involved in the distribution of electricity within the national territory of Benin. The SBEE is also responsible for the development and upgrade of the interconnection of the North Togo/North Benin networks.
Benin Agency for Rural Electrification and Energy Control (ABERME)	ABERME is responsible for the implementation of policies in the field of rural electrification. ABERME aims to implement a wide spectrum of energy efficiency measurements in Benin. The agency has divided the country into 15 rural electrification concessions and has offered tenders to private sector actors.
Authority for Regulation of Electricity (ARE)	Authority for Regulation of Electricity (ARE) is Electricity Regulator of Benin, set up in 2009 through a Decree by Government of Benin to take care of public interest, provide quality power and regulate cost of power supply
Bureau of Analysis of Investigation	Bureau of Analysis of Investigation works closely with government of Benin in drafting and finalizing renewable energy policies
African Development Bank (AfDB)	Cooperation between the African Development Bank and Benin dates back to 1972. Financing provided by the Bank since that date amounts to UA 709 million, corresponding nearly to FCFA 550 billion, and covering several areas. The Bank's investments in this country are as follows: transport, 27.8 per cent; agriculture, 26.3 per cent; multi-sector, 18.8 per cent; social sector, 15.8 per cent, electricity, water, sanitation and communication, 10.5 per cent; finance 0.5 per cent and industry 0.3 per cent.
United States Agency for International Development (USAID)	In Benin, USAID's programming has a strong emphasis on the health sector, but also includes activities that combat corruption, reduce violence against women and girls. USAID's work in Benin is complemented by regional USAID programs that strengthen the country's agricultural sector.
Millennium Challenge Corporation (MCC)	MCC is an independent U.S. foreign aid agency created in 2004 to promote economic growth, open markets, and increased living standards in select countries. The MCC aims to modernize Benin's electricity distribution infrastructure to expand capacity and improve reliability. Compact funding will improve the grid in Cotonou, Benin's economic capital, add distribution around planned photovoltaic plants, and establish a modern distribution control center. MCC is assisting the Government of Benin to establish a

Organization/ Agency	Role
	policy, strategy, master plan and regulatory framework for off-grid electrification, along with a grant fund to support clean off-grid services. Those services include critical public infrastructure, mini-grids, household systems, and energy efficiency.
Food and Agriculture Organization of the United Nations (FAO)	FAO has been established in Benin since 29 December 1977. The projects have focused, inter alia, on integrated rural development in certain regions, agricultural diversification, the development of farming systems, the development of decentralized storage systems, the development of small-scale fisheries, the promotion of private irrigation, inventories, studies and development of lowlands, the promotion of harnessed culture and rural crafts.
Federal Ministry for Economic Cooperation and Development, Germany	The agency is funding the Program of Accompanying Research for Agricultural Innovation (PARI) which brings together partners from Africa, India and Germany to contribute to sustainable agricultural growth and food and nutrition security in Africa and India as part of One world, No Hunger Initiative (SEWOH) by the German government
Climate Investment Funds (CIF)	CIF is supporting Benin in designing a SREP (Scaling Up Renewable Energy Program in Low Income Countries) investment plan to help accelerate electricity generation through various renewable energy technologies. It will focus on the specific institutional, financial, and economic barriers to scaling up bioenergy, hydro, solar, and wind energy.
European Union (EU)	European Union (EU) is working in areas of Energy, Agriculture, Governance and Justice in Benin. EU has earmarked 100 Million Euros for Energy sector development in Benin. EU is working with West African Power Pool, a cooperation of the national electricity companies in Western Africa, for improving transmission infrastructure in these nations.
World Bank	The World Bank has approved a $60 million International Development Association (IDA) Scale-Up Facility credit to help the Republic of Benin improve energy services through the improvement of the operational performance of its national distribution utility, SBEE, the expansion of electricity access to peri-urban areas of Cotonou, Porto-Novo, Parakou and Natitingou, and the promotion of community-based management of forest resources.
French Development Agency (AFD)	French Development Agency (AFD) has a team is working based out of Benin. AFD have been supporting Benin for last 20 years and assisting Benin in association with EU for last 3 years. They have been supporting Government of Benin for policy and regulatory frameworks. AFD has been co-financing with EU 25 MW Solar PV project in Benin. (AFD funding of 50 Million Euros as a low interest loan and EU 10 Million Euros as a grant). Presently the bidding process for the selection of contracting agency is in progress and is planned to commence the work in 2020. Further, AFD is also supporting 3 projects for augmentation of distribution network
Global Environment Facility (GEF)	GEF has undertaken 67 projects in Benin involving GEF Grant Funding of USD 268 Million, in the areas of land degradation, climate change and biodiversity.

Table 5: Key stakeholders in Benin

16. Recommendations

Benin has submitted a demand of 50,000 solar water pumping systems as part of ISA's Demand Aggregation activity under the Scaling Solar Applications for Agriculture Use (SSAAU) programme. A five-day mission visit with delegates from ISA and KPMG was undertaken to understand the existing ground level scenario in Benin and to validate the demand. During the discussions, it was noted that while Benin has participated in the programme, the details of the location, sizing and other aspects of demand estimation has not been worked out by the respective Ministry. This report, hence 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 costing of solar pumps, applicable taxes etc.) are required from the relevant Ministry so as to support the country in developing a bankable project. The details of the information requested from the Ministry is provided in Annexure A.

Further, it is expected that the outcome of Price Discovery International Competitive Bid being carried out by ISA for Solar Agricultural Pumps will be finalized by November 2019 and the country specific rates for various categories of pumps will be informed to Benin. The same may be examined and if acceptable, Benin may enter into a contract with the selected bidder(s). The prices discovered will also help Benin in ascertaining a benchmarking price for various capacities of solar water pumping systems for future projects.

Annexure A

Key questions

1. Basic Information

The country profile and ISA link with the country (NFP, Ministry, etc.):

- Name and contact details National Focal Point (designation, postal address, E Mail, Telephone, Whatsapp Number – of NFP)

- Nodal Ministry/Department responsible for implementation of solar water pumping systems and its structure (state level, provincial level & district level, etc.)

2. Country profile:

The country's present statistics about energy and agriculture:

- Total area of country (in Square kilometers)
- Total area under agriculture (in Square kilometers/hectare)
- Energy scenario of the country (may attach sheet for details)
- The crop pattern and number of crops per year
- Existing irrigation methods/techniques (canal, sprinkler, drip irrigation, any other.)
- Existing farming techniques/methods (individual, community based, co-operative, commercial, any other.)
- Average land holding of the farmers (in hectares)
- Number of farmers with land holding of
  (a) _ (less than or equal to) 1 Hectare
  (b) 1 – 2 Hectare
  (c) _ (greater than or equal to) 2 Hectare

3. Technology

Aspects related to pumping systems

- Number of agricultural pumps already installed in the country (number of diesel pumps/ electricity run pumps) (# number)

- What was the approach adopted for determination of number of solar pumps including area wise distribution or crop wise distribution?

- What are the types of solar pumps required in the country (off-grid, grid connected, etc.)?
- The capacity of pumps required for installation (normal range is 3, 5, 7.5, 10 hp; AC/DC; Surface, submersible.)?
- Data availability for ground water, recharging rate and water table level?
- If data for ground water is not available, any proposal to assess the water availability by the country?
- Who are the existing players in the diesel/ grid connected pumps?
- Is there are service delivery mechanism for irrigation? If yes, what is the model and what are the typical charges paid by the farmers?

4. Policy/Finance

- What is the current funding mechanism for financing government based irrigation projects? How much of it is spent by the government exchequer? What are the typical lending rates for these projects?
- What is the sources of funding for existing pump sets? Does the farmer take loans from banks or does government provides subsidy/ financing for the same?
- Whether any financial assistance is available in the country to support SWPS programme
- If financial assistance is available, what is the pattern and model of implementation?
- What could be the modality of implementing the programme if there is no financial assistance available by the government?
- Which are the financial institutions/banks active in the area of SWPS implementation?
- Any international cooperation available for financing of SWPS/solar projects?
- Any Foundations/ Non-Government Organizations active in the country to support the SWPS/solar programme?

5. Existing ecosystem for solar pumps

- Has there been prior pilot projects implemented for solar pumps in the country? If yes, how has been the experience/ challenge etc.?
- What is the estimated utilization of solar pumps by farmers practicing subsistence farming?
- What is the level of theft/ security for solar technology in general and solar pumps in particular?
- What is the custom/import duties/ taxes on various solar pump components?
- What are the requirements from international/ national solar pump suppliers to do business in the country? Is there any mandatory requirement of setting up of project office for solar pump supplier?
- Which are existing solar pump suppliers in the country?
- What is the general awareness levels of the farmers regarding solar technology in general and solar pumping technology in particular?
- What are the views of the state on implementation of solar pumps programme and possible business models?

6. Project feasibility

- What are the prevalent interest rate for RE projects in the country?
- What is the cost of diesel pump per HP?
- What is the cost of diesel?
- What are the living expense of the farmer (as a % of crop revenue)?
- What is the month on month crop water requirement?
- How many days in a year does a farmer typically use a pump set?

7. Project implementation

- What are the required timelines for delivery of solar pumps?
- What is the implementation plan for solar pumps including agency to be involved, human resource capabilities, training requirements, phase wise implementation etc.
- Have the sites been identified for solar pump implementation? If yes, can these be shared on the map?
- What are the areas where ISA can facilitate the implementation of solar pumps?

8. Others

- Any other information the country would like to share that shall facilitate the implementation of solar pumps?