Draft Pre-Feasibility Report for implementation of solar pumps in Senegal

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List of Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AEME	Agence pour l'Economie et la Maîtrise de l'Energie
AFDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
ANER	National Agency for Renewable Energies
ASER	Agence Senegalaise D'Ekectrification Rurale
AUMN	Association des Unions Maraîchères des Niayes
BIO	Société Belge d'Investissement pour les Pays en Développement
CER	Concession d'Electrification Rurale
CFAF	West African franc
cm	Centimetre
CMC	Comprehensive Maintenance Contract
CR	Rural Communities
CRSE	La Commission de Régulation du Secteur de l'électricité
DC	Direct Current
DPF	Development Policy Financing
EBRD	European Bank for Reconstruction and Development
EESL	Energy Efficiency Services Limited
EIB	European Investment Bank
EMI	Equated Monthly Installments
ERIL	Électrification Rural d'Initiative Local
ET_o	Evapotranspiration
EUR	Euros
FAO	Food and Agriculture Organization of the United Nations
FCFA	Central African CFA franc
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoS	Government of Senegal

GWh	Gigawatt hours
Ha/ha	hectare
HFO	Heavy Fuel Oils
HP	Horsepower
IAEA	International Atomic Energy Agency
IDEAS	Indian Development and Economic Assistance Scheme
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IJARET	International Journal of Advanced Research in Education & Technology
IMF	International Monetary Fund
IPPs	Independent Power Producers
IR	Interconnected Grid
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
ITU	International Telecommunication Union
kg	Kilogram
km	kilometre
kV	kilovolt
kWh	kilowatt hour
LoC	Line of Credit
LV	Low Voltage
mm	Millimetre
MPE	Ministry of Petroleum and Energies
MPPT	Maximum Power Point Tracker
MV	Medium Voltage
MW	Megawatt
NDB	New Development Bank
NFP	National Focal Point
NGO	Non-Governmental Organization
NPSH	Net Positive Suction Head
OMVG	Gambia River Basin Development Organisation
OMVS	L'Organisation pour la Mise en Valeur du Fleuve Sénégal
PASER	Rural Electrification Action Plan

PERACOD	Programme pour la promotion des énergie renouvelables, de l'electrifcation rurale et l'approvisionnement durable en combustibles domestiques
PPA	Power Purchase Agreement
PPP	Public-private Partnership
PTB	Petit train de banlieue
PV	Photovoltaic
R&D	Research & Development
RMS	Remote Monitoring Systems
SENELEC	Société nationale d'électricité du Sénégal
SSAAU	Scaling Solar Applications for Agricultural Use
SSLS	Solar Street Lighting System
SWPS	Solar Water Pumping Systems
UL	Underwriters Laboratories
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USD	United States Dollar
VFD	Variable Frequency Drive
Y-o-Y	Year-on-Year

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1. Executive Summary

Background

Senegal is a coastal West African nation located 14 degrees north of the equator and 14 degrees west of the Prime Meridian. The country's total area is 196,190 km^2 of which 192,000 km^2 is land and 4,190 km^2 is water. Senegal is bounded to the north and northeast by the Senegal River, which separates it from Mauritania; to the east by Mali; to the south by Guinea and Guinea-Bissau; and to the west by the Atlantic Ocean. The nation's topography is mainly flat land that lies in the Senegal-Mauritian basin. The country lies at an ecological boundary where semiarid grasslands, oceanfront and tropical rainforest converge.

Senegal has submitted a demand for 4,000 Solar Pumping Systems against the call for Expression of Interest from ISA. The project will be implemented in Niayes (or "Thies") region in Senegal which is spread over an area of 8000 hectares. The demand was given considering 50% of the area with an estimation of one pump per hectare. A pilot project of around 80 solar water pumps has already been implemented by National Agency for Renewable Energies (ANER) in the region.

Senegal's Electricity Sector

At the end of 2018, Heavy fuel oil (HFO) represented 67 percent of the 940 MW of installed capacity and coal 12 percent, with solar and imported hydro power representing the remaining 12 and 9 percent respectively. Coal plant is currently dispatching around 100 MW to the grid as baseload capacity. With the support of the multisectoral reform Development Financing (DPF) (series currently ongoing), government has initiated a phase out of the use of heavy fuel oil for power generation. According to World Bank, by 2025, the installed capacity is expected to have a minimum of 22 percent renewables, (including solar, wind and hydro), 64 percent gas and 8 percent coal.

The installed renewable energy capacity in 2017 stood at 185 MW comprising of 85 MW of solar, 75 MW of hydro and 25 MW of bio-energy sources. While no new hydro power capacity addition took place in the last 5 years, solar power has grown massively from 7 MW in 2013 to about 85 MW in 2017. The government has set up ambitious plan to scale up solar capacity even further to achieve its target of 15% of generation capacity from renewables by 2020.

Senegal's national electricity access rate of 64% is relatively high with over 90% in urban centres but estimated to be about 43.5% in rural areas. The Government of Senegal has set targets to achieve universal electricity access by 2025. The electrification rate is rising as a result of new connections to the main grid and small off-grid projects.

SENELEC also owns about half of the country's generation capacity, with the remainder being owned by independent power producers (IPPs) that generate electricity and sell it to SENELEC. In 1998, given the low rate of rural electrification in the country, the Government of Senegal (GoS) launched the Rural Electrification Action Plan (PASER) and divided the country into 10 concessions for allocation to private sector companies – concessionaires (CER) – who have the monopoly for electricity distribution within their concessions.

Senegal benefits from its strong potential for renewable energies which remains relatively untapped. Solar power represents a massive opportunity for development. Indeed, solar irradiation exceeds 2,000 kWh/m2/year (for Global Horizontal Irradiance) across most of the country. Thus, Senegal has real potential for development and scaling up of photovoltaic projects.

In Senegal, the Ministry of Energy develops and proposes the general policy and applicable standards for the electricity sector to the president. It grants the licenses and concessions within the applicable framework and can withdraw it if needed. The National Agency for Renewable Energies (ANER) is in charge of the promotion and development of renewable energies. The Electricity Sector Regulatory Commission (CRSE) is the independent authority in charge of the regulation of generation, transmission, distribution and sale of electricity. It regulates the sector and determines electricity prices as well as their structuring. The Senegalese Rural Electrification Agency (ASER) oversees rural off-grid projects.

Site Assessment

Thiès is the third largest city in Senegal and lies 72 km east of Dakar on the N2 road and at the junction of railway lines to Dakar, Bamako and St-Louis. It is the capital of Thiès Region and is a major industrial city. It has two coastlines, one in the north with the Grande Côte housing the Niayes vegetable market, one to the south with the Petite Côte, one of the tourist areas of Senegal. Thiès region is divided into 3 departments, 14 communes, 12 arrondissements, 32 communautés rurales and 3 communes d'arrondissement. The project is planned to be carried out in Thiès department of Thiès region which comprises of Kayar, Khombole and Pout communes.

Thiès is a major industrial city and is very well connected with other major cities of Senegal as it is located at the junction of railway lines to Dakar, Bamako and St-Louis. It is situated at 14.7910^{o} N and 16.9359^{o} W. The Railways is used primarily for transporting most of the mineral products, fuels as well as agricultural produce. Thiès also a fair accessibility from the different airports of Senegal – primarily the ones in Thiès and Dakar (international airport). Thiès is situated only 16 km away from the new international airport situated near Diass.

Climate and Rainfall

The temperature typically varies from 16 °C to 35 °C with the average annual temperature of 25.7 °C. The highest temperature on average is reached in June (around 27.6 °C) while the lowest average temperatures (around 23.3 °C) of the year are witnessed in January. In Thiès, the wet season is oppressive and overcast; the dry season is humid, windy, and partly cloudy; and it is hot year-round. The length of the day in Thiès varies over the course of the year. In 2019, the shortest day is December 22, with 11 hours, 15 minutes of daylight; the longest day is June 21, with 13 hours, 0 minutes of daylight.

Soil

Thiès region is characterized by tropical ferruginous soils with sandy, sandy-clay and clay-humus texture; and hydro-morphic soils with a humid texture. The vegetation consists of mainly shrub savanna, filao and classified forests. From a water point of view, the region has significant groundwater, surface water and relatively good quality well water in some areas.

Groundwater Status

Senegal has significant groundwater resources, but the distribution of availability and demand do not match. In Senegal, agricultural and industrial activities affect the quality of surface water and groundwater that undergo also strong alteration due to chemical pollution from industrials effluents and used products in agriculture including pesticides and fertilizers.

Agriculture and Cropping Pattern

The majority of farmers rely on rain-fed crops, though there are slightly over 1,000 square kilometers of irrigated land, out of a total of slightly less than 200,000 square kilometers of land in the country. The majority of farming in Senegal takes place for subsistence, though peanuts, sugarcane, and cotton are important cash crops, and a variety of fruits and vegetables are grown for export and local markets. Gum Arabic (also known as acacia gum) is one of the largest agriculture export product. Peanuts are the most important crop in rural areas, accounting for around 40% of cultivated land and providing employment for around one million people. Millet, sorghum, and rice are major staple food crops. Peanuts, sugarcane, and cotton are important cash crops, and a wide variety of fruits and vegetables are grown for local and export markets. Senegal is a net food importer, particularly for rice, which represents almost 75 percent of cereal imports. Production of food crops does not meet Senegal's needs. The production of major staple food crops covers barely 30% of consumption needs.

The economy of Thiès is essentially based on agriculture, fishing, tourism, industry, mining, handicrafts and trade. Among the productive sectors, agriculture occupies an important place in the economic and social life of the Thiès region. It occupies the majority of the regional population and is the main activity in rural areas. The Thiès region is a major agricultural production center thanks to its numerous hydraulic and soil potential. It mainly comprises three zones with agricultural vocation: (i) the Niayes coastal zone (with market gardening and fruit production); (ii) the central zone (with groundnut, arboricultural and cassava vocation) and (iii) the southern zone (with market gardening and food production).

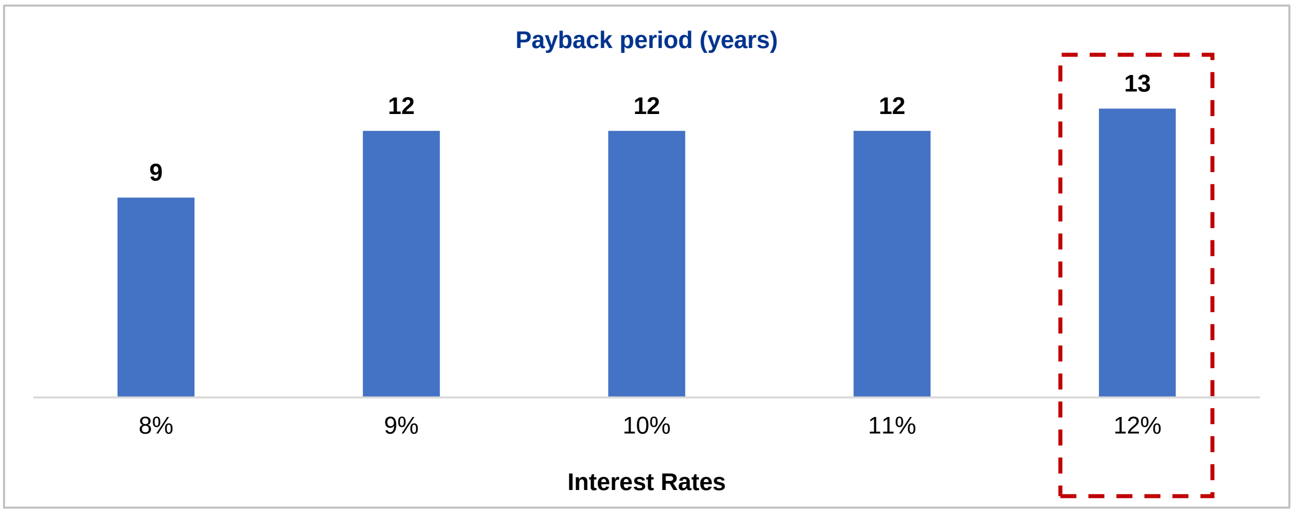
Financial Feasibility

In the base case scenario, it is observed that while the differential in the net cash inflows of solar and diesel pump are minimal, there is substantial difference in the operation and maintenance cost of both pumps. In the first year the total cost of diesel pump is higher due to initial capital expenditure on diesel pump, in the next two years the total cost of solar is higher owing to higher EMI payments scheduled in the first three years of the project. Marked increments are seen in the total cost of both diesel and solar pump in the years of equipment replacement which is on expected lines. For the base case wherein, we have considered the crops of onions and potatoes, a total of 290 hours of operation is required considering the irrigation schedule which leads to a potential saving of CFA 0.10 Million on the diesel costs in the first year.

The payback period for the incremental cash flow of solar compared to diesel is 13 years in the current case being considered. There is a potential of reducing the payback period even further by optimizing the interest rates, crops and capital costs of solar pumps.

Sensitivity Analysis

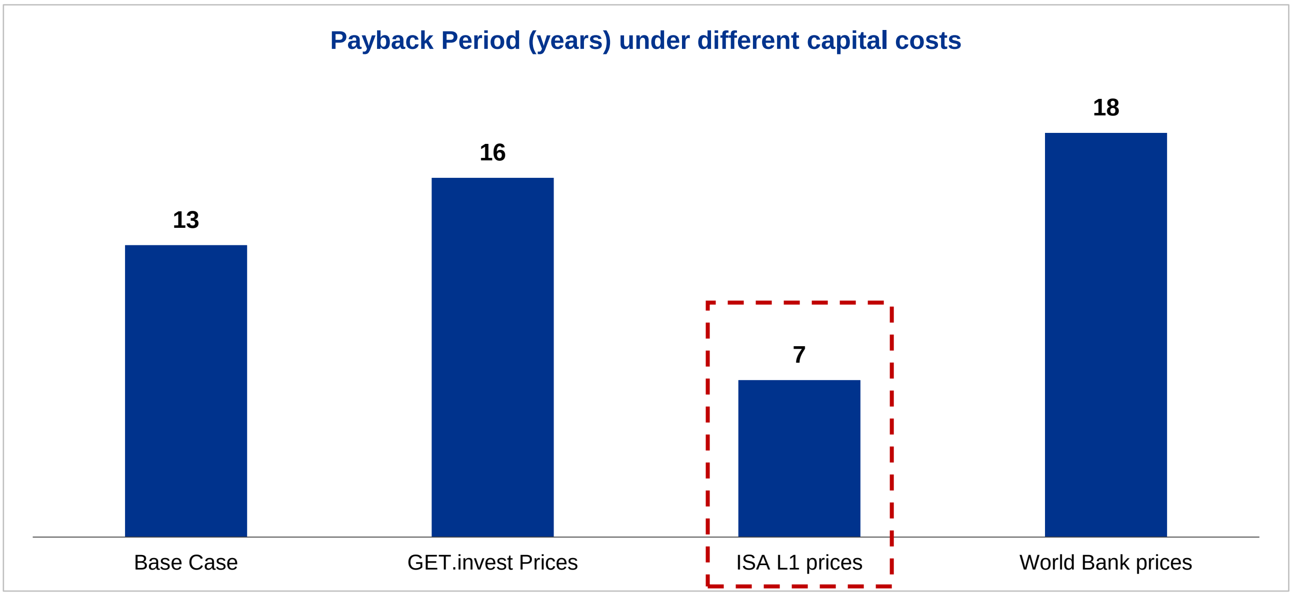
A. Variation in Interest Rate



It can be seen that the payback at the reduced interest rate of 8% is 9 years which is significantly lower as compared to payback of 13 years in base case scenario. It is interesting to note here that increasing the interest rate beyond 8% increases the payback period drastically from 8 years to 12 years. This shows that interest rate of 8% is an important threshold for increasing the viability of the project. ISA can hence facilitate reduced interest rate in Senegal through concessional financing options from multilateral, bilateral and donor agencies.

B. Variation in Capital Costs

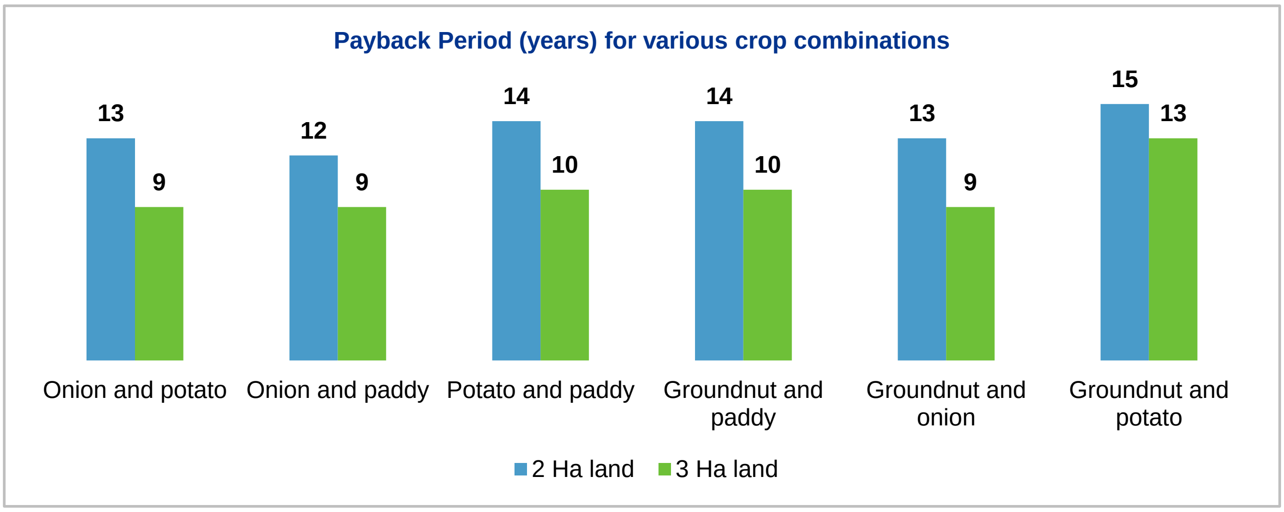
The payback period in the base case scenario is 13 years where the capital cost considered was USD 6500 for a 3 HP pump. This reduces significantly to 7 years with ISA discovered L1 price of USD 3898. The variation in prices in various scenarios is elaborated as below:



As can be seen above, the implementation of solar pumps in Senegal at ISA discovered L1 prices significantly improves the viability of the project. Hence ISA in coordination with ANER can work together for finalizing the business model and implementation plan for executing the project at these prices. The project can also act as a catalyst for reduction of prevailing prices in the local Senegalese market.

C. Variation in Crops

In the Niayes Zone, it is suggested to grow vegetables such as onions and potatoes because of their exceptionally high yield due to ideal climatic conditions. Onions can also be combined with paddy to optimize the returns or groundnut to further reduce the payback period. There is a potential to increase the harvest of groundnut in which occupies a driving position in Senegal's economy. Other benefits can also be realized by growing paddy, currently the consumption of which is highly import driven. Hence, by using solar pumps for paddy, Senegal can reduce the import expenditure leading to forex savings. However, since paddy is a highly water intensive crop, proper and optimal pump sizing should be undertaken to determine the capacity of the pump required for irrigation.



In such situations, increasing the land size of the high value crops can further lead to reduction in payback period. The case in point being the combination of groundnut and onion which has a payback period of 9 years if grown on 3 hectares of land (1.5 hectares each) compared to a payback of 13 years if grown on 2 hectares. Thus, farmers can be encouraged to increase the area under irrigation for maximizing the returns from the project. It is suggested that ANER may carry out detailed study in the Niayes Zone so as to arrive at the optimal crop and land size combination for each of the identified farmers.

2. Background

2.1 About ISA

International Solar Alliance was launched on November 30, 2015 by India and France to implement the Paris Agreement and the ISA Framework Agreement came into force on December 7, 2017. The headquarter agreement with India was signed on June 6, 2018 when the ISA Secretariat acquired a judicial personality under the Framework Agreement. ISA held its first Assembly on October 3, 2018 and the second one is being held on October 31, 2019. To date, 79 countries have signed the Framework Agreement. ISA aims to provide a dedicated platform for cooperation among solar resource-rich countries where the global community, including bilateral and multilateral organizations, corporates, industry and other stakeholders can collaborate and help achieve the aim of increasing the use of solar energy in a safe, convenient, affordable, equitable and sustainable manner.

The International Solar Alliance (ISA) has been conceived as an action-oriented, member-driven, collaborative platform for increased deployment of solar energy technologies to enhance energy security and sustainable development, and to improve access to energy in developing member countries. In this respect, ISA has been continuously working towards coordinating joint and collaborative efforts for mobilizing more than USD 1000 billion investments in the solar sector thereby facilitating scaling up of solar deployment in various member countries.

As guided by the Framework Agreement of the ISA, the interests and objectives of the ISA are as follows:

1. To collectively address key common challenges to scale up solar energy applications in line with their needs;
2. To mobilize investments of more than USD 1000 billion by 2030;
3. To take coordinated action through programmes and activities launched on a voluntary basis, aimed at better harmonization, aggregation of demand, risk and resources, for promoting solar finance, solar technologies, innovation, R&D, capacity building etc.;
4. Reduce the cost of finance to increase investments in solar energy in member countries by promoting innovative financial mechanisms and mobilizing finance from Institutions;
5. Scale up applications of solar technologies in member countries, and
6. Facilitate collaborative research and development (R&D) activities in solar energy technologies among member countries.

To expand its reach, the ISA has entered into strategic and financial partnerships with the UNDP, the World Bank, the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD), the African Development Bank (AFDB), the Asian Development Bank (ADB), the Asian Infrastructure Investment Bank (AIIB), New Development Bank (NDB), and the Green Climate fund (GCF), IEA, IRENA, Climate Parliament and UNIDO on enhancing cooperation on solar energy deployment to further the mandate of the ISA. The United Nations including its organs are strategic partners of the ISA.
On the request of the ISA, the Government of India has earmarked around US $ 2 billion Line of Credit (LoC) to the African countries for implementation of solar and solar related projects out of its total US $ 10 billion LoC under the Indian Development and Economic Assistance Scheme (IDEAS) to various African and other developing countries. India has set up a project preparation facility which will provide consultancy support to partner countries to design bankable projects.

Following these commitments, India has provided $ 1.4 billion concessional financing to 27 solar projects in 15 developing countries so far. As a co-founding member of the ISA, Government of France through the Agence Française de Développement, has also offered €1000 million for solar projects across ISA member countries. 17 projects have been funded by AFD for approximately Euro 300 million. ISA will similarly persuade other countries to contribute to the cause of solar deployment globally.

ISA is currently working towards coordinating a joint and collaborative effort amongst member countries so that strategies suited to the requirements of individual countries can be formed, and feasible solar technologies can be deployed. ISA is acting as a facilitator to contribute to the solar deployment efforts of individual member country. For this, ISA has formed a framework of programs and initiatives to develop a dedicated approach towards scaling up of various solar technologies. All the Programmes of ISA are member driven. The current programmes of ISA are:

1. Affordable finance at scale
2. Scaling Solar Applications for Agricultural Use (SSAAU)
3. Scaling Solar Mini-Grids
4. Scaling Solar Rooftop
5. Scaling solar supported e-mobility and storage

2.2 About SSAAU Programme

ISA's first programme, Scaling Solar Applications for Agricultural Use (SSAAU), was launched in New York, USA on 22nd April 2016. The SSAAU Programme mainly focusses on decentralized solar applications in rural settings. Major focus areas of the programme include Solar Water Pumping Systems (SWPS), solar drying, solar chilling, solar milling, etc. Other activities under the programme include R&D, capacity building, and developing common standards, facilitate transfer of technology, etc.

More than twenty-one countries namely Bangladesh, Benin, Djibouti, Ethiopia, France, Guinea-Bissau, India, Kiribati, Mali, Mauritius, Niger, Nigeria, Rwanda, Senegal, Seychelles, Somalia, Sudan, Togo, Tonga, Uganda, Vanuatu have been frequently interacting regarding the programme strategy and implementation through the network of NFPs and country representatives via video conferencing. To understand specific requirements of these countries, needs assessment questionnaires have been developed for Solar Water Pumping System (SWPS) and Solar Street Lighting System (SSLS). These questionnaires have been circulated to all participating and signatory countries of the ISA as a first step towards demand aggregation.

The key activities under the SSAAU programme are as under:

S.No.	Category	Key Activities
1	**Demand Aggregation**	• **Obtaining data for demand aggregation models from various member countries** • **Bid process management, fixation of price, identification of manufacturer(s)/ supplier(s) for each of the participating member countries**
2	Country Strategy	• Developing baseline studies and roadmaps for member nations • Constituting global task force for the programme • Facilitating affordable financing for implementation of solar water pumping programme in participating member countries

3	Facilitating Deployment	• Facilitating in setting Standards, Performance Benchmarks, Testing and Certification Protocols through identified test centers • Development of base document for global tendering and best practices for procurement, installation and maintenance • Monitoring and Evaluation
4	Outreach Strategy	• Development of media outreach strategy for the programme • Organization of workshops and seminars for promotion of SSAAU programme

Table 1: Key Activities under SSAAU Programme

As a part of the demand aggregation exercise, ISA has aggregated a demand of 272,579 Nos. of off-grid solar pumps to be implemented across 22 countries spanning 4 different continents. The key objective of the demand aggregation exercise was to bring down the costs of the system so as to enable implementation of viable and bankable solar pumps projects in various ISA countries. The demand aggregation exercise comprised of the following sub-steps:

1. **Needs Assessment:** In collaboration with National Focal Points (NFPs) and Country Representatives, need assessment questionnaires for Solar Water Pumping Systems (SWPS) were circulated to participating member countries
2. **Ascertaining Demand:** The filled in needs assessment questionnaires were used to ascertain demand of solar water pumping systems including information on type, quantity and technical specifications in each of the participating member countries
3. **Demand Validation:** Coordinating with National Focal Points and Country Representatives for obtaining country specific data and information and for validation of demand
4. **International Competitive Bidding for Price-Discovery:** Energy Efficiency Services Limited was hired for management of International Competitive Bidding for price discovery of various types of solar water pumping systems in participating member countries

The results of the demand aggregation exercise are summarized in the figure below:

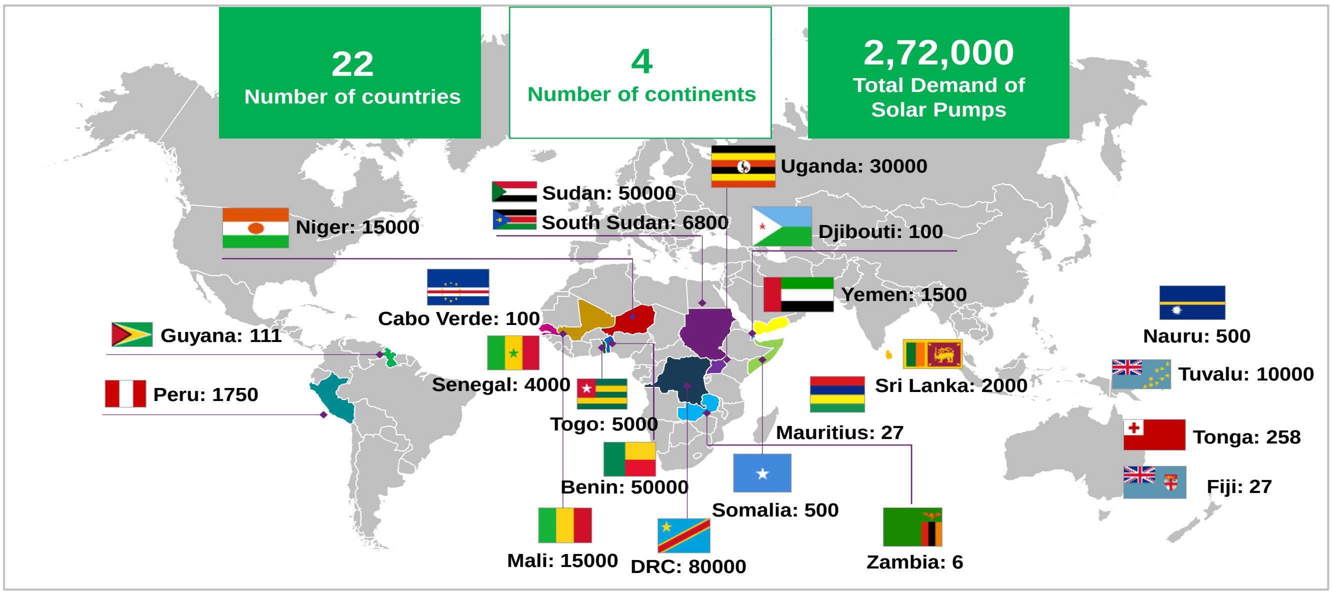


Figure 1: Demand received from various ISA member countries for solar pumps

Subsequent to the demand aggregation exercise, Internal Competitive Bidding was undertaken by EESL on behalf of ISA for price discovery of various types of solar pumps in the participating member countries. The price discovery tender is one of the largest tenders for solar pumping systems globally and is expected to open up huge market opportunity for implementation of solar pump programme in participating member countries. Through this tender, it is expected that local market ecosystem for solar pumps will be developed which will help in greater penetration of technology amongst the farmers. It is envisaged that in the long-run solar pumps would replace the existing diesel pumpsets in these member countries thereby leading to significant reduction in GHG emissions apart from providing a reliable irrigation solution for the farmers. The key features of the International Competitive Bidding for price discovery is summarized as below:

S.No.	Category	Description
1	International Standards for Solar Pumps	• Internationally accepted IEC and UL standards for various solar pump components
2	Technical and Financial Qualifying Criteria	• Technical Qualifying Criteria: Based on experience of supply and installation of solar pump sets and solar power plants • Financial Qualifying Criteria: Based on average annual turnover and net worth
3	Specifications for minimum bidding quantity	• Mandatory to bid for 5 countries with a total bid quantity of at least 27000
4	Two separate bid packages	• Only supply • Supply and Five-Year Comprehensive Maintenance Contract
5	Two stage evaluation process	• Based on technical and commercial evaluation • Award of contract to various bidders based on L1 prices

Table 2: Key features of Internal Competitive Bidding for Price Discovery of Solar Pumps

The price discovery was conducted for two broad services contract namely:

- **Service 1:** Supply, Custom clearance, Local transportation, installation, testing and commissioning of complete system & services at Employer's site of Solar PV based Agricultural Pump Set system
- **Service 2:** Supply Custom clearance, Local transportation, installation, testing and commissioning of complete system at site of Solar PV based Agricultural Pump Set system

The roles and responsibilities of the bidder and the respective member nation as a part of the price discovery tender is summarized in the figure below:

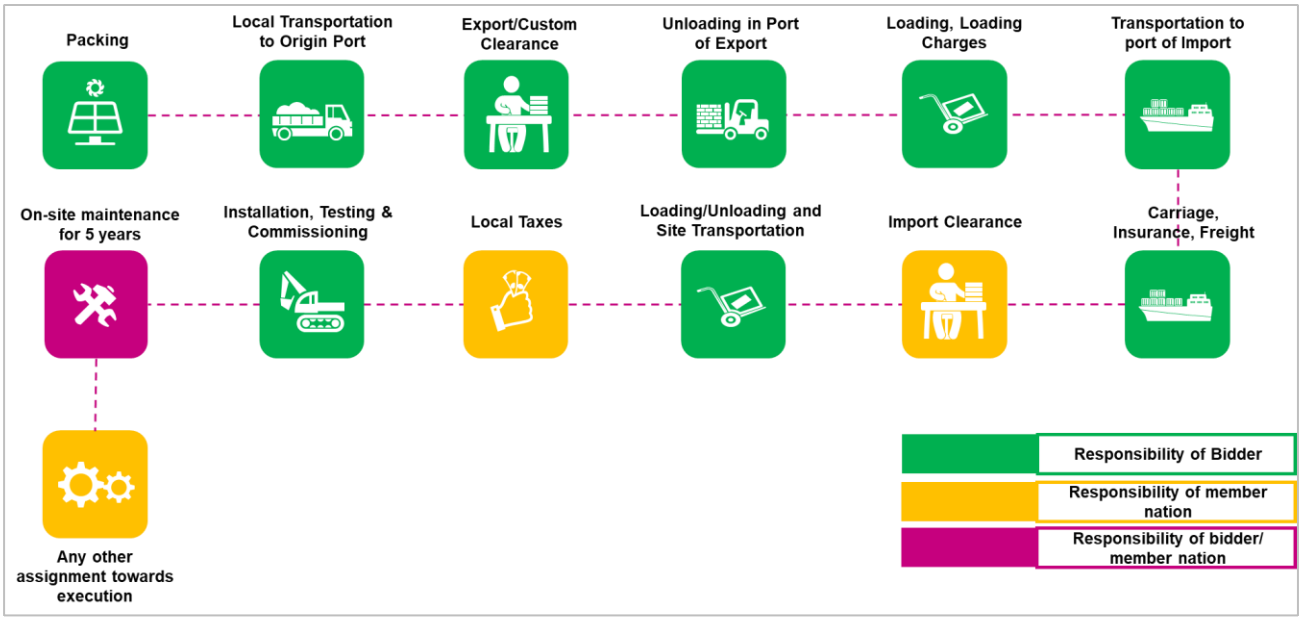


Figure 2: Work Packages and Responsibility Division

Five bidders have participated in the price discovery tender and have submitted the prices for various capacities of solar pumps in the participating member countries. ISA is currently analyzing and evaluating the prices and will subsequently share with the member countries for final decision at their end.

2.3 Senegal's Participation in the Demand Aggregation Exercise

Senegal has submitted a demand for 4,000 Solar Pumping Systems against the call for Expression of Interest from ISA. The project will be implemented in Niayes (or "Thies") region in Senegal which is spread over an area of 8000 hectares. The demand was given considering 50% of the area with an estimation of one pump per hectare. A pilot project of around 80 solar water pumps has already been implemented by National Agency for Renewable Energies (ANER) in the region. Another 100 solar water pumps installation have also been realized by farmers themselves. In response to the demand aggregation submitted by Senegal, ISA Secretariat has engaged consultants for carrying out feasibility study of the projected demand as well as analysis of institutional capacity of stakeholders in the project and division of responsibility thereof. In the same regard, country templates were prepared by the consultants for surveying the institutional and policy framework in Senegal as well as for assessment of potential deployment of solar pumps.

ISA recently concluded mission visit to Senegal to get a 'buy-in' for ISA's solar programmes and to understand the ground level challenges and issues. A five-member ISA Delegation visited Senegal during 30 September 2019 to 4 October 2019 to sensitize the relevant ministries and stakeholders regarding ISA's efforts and also to understand the current on-ground energy scenario to better assist the member country in their various solar initiatives. The mission visits provided critical insights to ISA delegation on various aspects and factors critical to the success of solar water pumping programme. The objectives of the Mission were:

1. **Understand on ground situation in member countries through extensive stakeholder consultations:** During ISA's mission visits, extensive stakeholder consultations were held with

nodal agencies, line ministries, research organization, international development organizations and funding agencies. The meetings were also attended by representatives of energy departments as well as from the embassies. The solar water pumping programme of ISA received great traction from all stakeholders and the line ministries showed their keen interest in collaborating with ISA.

2. **Data Validation:** The relevant data on pricing of solar water pumping systems, water table depth, fuel pricing, and details on policy measures etc. was validated through site visits. The data is being used for undertaking financial feasibility analysis of the project as covered under this report.
3. **Signing of Aide-Memoire:** Post the stakeholder consultations, aide-memoire was signed between ISA representative and respective line ministry. The aid-memoire will serve as the basis for collaboration, fixing roles and responsibilities of various stakeholder for successful implementation of the solar water pumping programme, and for developing country framework.

2.4 Coverage of the report

This report analyzes the feasibility of implementation of solar pumps in the Niayes region of Senegal. The data collected by the ISA delegation during the site visit to Niayes region is used as a basis for arriving at a broad feasibility for installation of solar pumps. Wherever on-ground data was unavailable, data from secondary sources and past studies have been used as a proxy. The sources for such data have been mentioned as a foot-note in the relevant pages of this report. The feasibility analysis has been undertaken keeping the end-user i.e. the farmer in mind and hence relevant cash flows pertaining to the farmer have been used to arrive at a payback period. Wherever site specific data relating to Niayes region was available, relevant analysis have been undertaken to arrive at a high-level technical feasibility for installation of a solar pump. The report also captures sensitivity analysis to assess the feasibility under various scenarios and to understand the key drivers for increasing the viability of the overall project. The key objectives of the report are as below:

1. To assess the feasibility of implementation of solar pumps in Niayes region of Senegal under various scenarios
2. To assist the member country in taking a decision regarding implementation of solar pumps based on prices discovered in the tender
3. To understand the various business models that can be adopted for maximizing the benefits to the end-users
4. To understand the key drivers impacting the feasibility of the project and to subsequently support the member country in undertaking policy decisions for increasing the bankability of the project

3. Introduction

3.1 About Senegal

Figure 3: Map of Senegal

Senegal is a coastal West African nation located 14 degrees north of the equator and 14 degrees west of the Prime Meridian. The country's total area is 196,190 km^2 of which 192,000 km^2 is land and 4,190 km^2 is water. Senegal is bounded to the north and northeast by the Senegal River, which separates it from Mauritania; to the east by Mali; to the south by Guinea and Guinea-Bissau; and to the west by the Atlantic Ocean. The Cape Verde Peninsula is the westernmost point of the African continent. The Gambia consists of a narrow strip of territory that extends from the coast eastward into Senegal along the Gambia River and isolates the southern Senegalese area of Casamance. The capital, Dakar, is the westernmost point of African mainland and is located midway between the mouths of the two rivers – the Gambia and Senegal. It serves as the one of the most important harbors of Africa and is home to the Autonomous port of Dakar which is the ninth largest port of Africa. Dakar also hosts tropical Africa’s leading industrial and service centers. Senegal is popularly known as “Gateway to Africa” as it serves multiple air and maritime travel routes.

The nation’s topography is mainly flat land that lies in the Senegal-Mauritian basin. The country lies at an ecological boundary where semiarid grasslands, oceanfront and tropical rainforest converge.

Elevations greater than 100 meters are only found on the Cape Verde Peninsula and in the southeast of Senegal. The whole country can be divided into 3 structural divisions: The Cape Verde headland on the extreme west with small plateaus of volcanic origin; the southern and eastern parts which include the highest point near Népen Diakha; and a large landmass between Cape Verde and the edges of the massif.

Three principal climate zones are found in Senegal i.e. Coastal, Sahelian, and Sudanic. The coastal zone occurs along a strip of Atlantic coastline about 16 km wide running from Saint-Louis to Dakar. Its winters are cool, with minimum temperatures reaching about 17 °C in January; maximum temperatures in May do not exceed 27 °C. The rains begin in June, reach their height in August, and cease in October. The average annual rainfall is about 500 mm.

Many types of soils are found throughout the country. In the northwest the soils are ochre-colored and light, consisting of sands combined with iron oxide. These soils, called Dior soils, constitute the wealth of Senegal; the dunes they form are highly favourable to peanut cultivation, whereas the soils between the dunes are suitable for other food crops, such as sorghum. In the southwest the plateau soils are sandy clays, frequently laterized (leached into red, residual, iron-bearing soils). The centre and the south of the country are covered by a layer of laterite hidden under a thin covering of sand that affords only sparse grazing during the rainy season. In the Casamance area heavily leached clay soils with a high iron-oxide content predominate, suitable for cultivation regardless of their depth.

3.2 Senegal’s Economy

The Senegalese economy has traditionally revolved around a single cash crop, the peanut. The government, however, has worked to diversify both cash crops and subsistence agriculture by expanding into commodities such as cotton, garden produce, and sugarcane as well as by promoting nonagricultural sectors. The government was successful in making fishing, phosphates, and tourism major sources of foreign exchange at the beginning of the 21st century, although the condition of the transportation and power infrastructure placed limits on the amount of expansion possible.

Agriculture occupies about two-thirds of the economically active population and provides the basis for industry as well. The most important crop has been the peanut, but extensive acreage is also devoted to millet, sorghum, and plants from Old World grasses, grown for fodder. Rice is cultivated both in naturally wet areas and by irrigation, although its large-scale cultivation is restricted to the lower Casamance valley and the lower Senegal River valley below Richard-Toll. In addition, corn (maize), cassava (manioc), beans, and sweet potatoes are grown in significant quantities.

With a coastline of 718 km, the fisheries sector makes a significant contribution to the economy in Senegal. Capture production was 395,400 tonnes of marine fish and 30,000 tonnes of freshwater fish in 2015. The sector contributed 1.8 percent to the GDP in 2015 and provided more than 53,100 direct and an estimated 540,000 indirect jobs, mainly in artisanal fishing and processing. 147 decked fishing vessels were reported in 2015 with most being between 30-45 meters, length overall. A significant artisanal, undecked fleet of 8,053 powered vessels and 1,430 unpowered were also reported[1]. Senegal is by far a net exporter of fish and fishery products, with exports reaching USD 353 million in 2015 and imports valued only USD 20 million in the same year[2].

With an estimated real GDP growth of about 7.0%, down slightly from 7.2% in 2017. Senegal is amongst the fastest growing economies in Africa. The primary sector expanded by 7.8% in 2018, driven by agriculture and related activities. The secondary sector recorded 6.9% growth, driven mainly by mining subsectors, agrofood, and construction. The tertiary sector saw 6.7% growth, reflecting strong performance by the retail segment. On the demand side, real GDP growth was driven by 9.5% growth in gross fixed capital formation, 7.7% growth in intermediate consumption, and 6.7% growth in final consumption. Fiscal management resulted in a deficit of 3.5% of GDP in 2018, up from 3% in 2017, financed mainly by issuing Eurobonds. The total external debt–to-GDP ratio was 62.9% in 2018, down from 64.2% in 2017, but the risk of debt overhang remains low. Inflation was 1.4% in 2018, up slightly from 2017, reflecting a favorable agricultural season and prudent monetary policy. The current account deficit improved from 7.3% of GDP in 2017 to 6.9% in 2018 due to increased agricultural and fisheries exports and lower imports. The terms of trade improved by 4.1%[3].

Country	Expected Economic Growth Rate- 2019 (%)
Ethiopia	8.5%
Côte d'Ivoire	7%
Rwanda	7.8%
Ghana	7.6%
Senegal	**6.7%**
Benin	6.3%
Kenya	6.1%
Uganda	6.1%
Burkina Faso	6.1%
Guinea	5.9%
Tanzania	6.6%

Table 3: Expected Economic Growth Rate of select African Countries[4]

The sectoral breakdown of GDP shows the predominance of the tertiary sector. Activities in the services sector accounted for nearly 60% of total value added between 2000 and 2015. The primary sector only accounts for 16% of GDP over the same period. The weight of the secondary sector in value added has been consistent since 2000, at around 23%. Within the tertiary sector, trade (18%), post and telecommunications (9%), financial services (3%) and government services (9%) were the main drivers of growth[5]. Senegal has made significant progress in infrastructure, including transport, electricity, and water sectors. For example, the country has today about 864 MW of installed generation capacity, up from only 540 MW in 2010. Senegal currently spends around USD 911 million per year on infrastructure[6].

[1] **Britannica**
[2] **Food and Agriculture Organization of the United Nations (FAO)**
[3] **African Development Bank Group**
[4] **Source: IMF**
[5] **International Telecommunication Union (ITU), 2016**
[6] **World Bank**

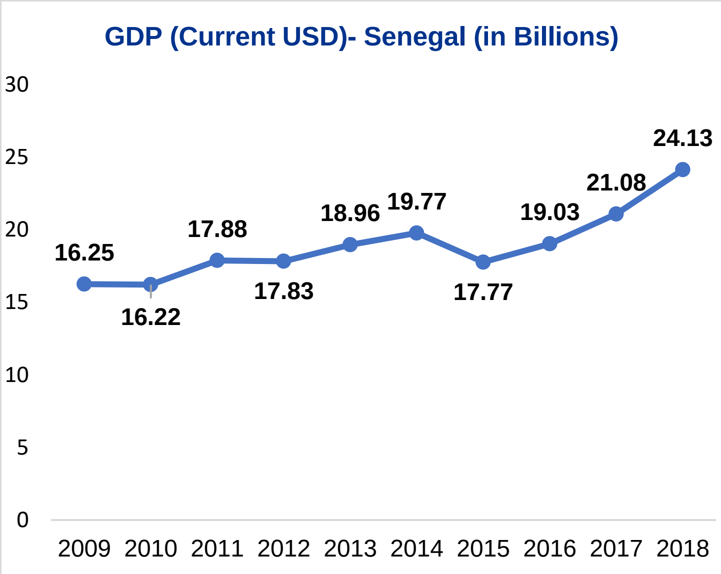


Figure 5: GDP Trend (in current USD) for Senegal

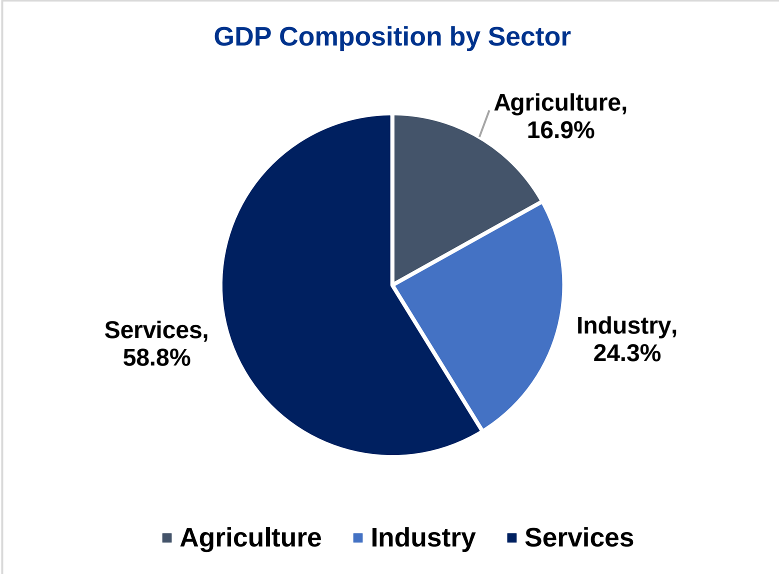


Figure 4: GDP Composition by Sector (2018)

3.3 Overview of Power Sector in Senegal

Senegal's source for electricity generation is overwhelmingly diesel and gas, which both need to be imported. Power demand has been growing throughout the last decade, and in tandem with upbeat economic forecasts it is expected to increase further in the next few years. Installation of new coal and diesel generation and exploitation of newly discovered offshore gas reserves is foreseen to keep up with rising demand. In addition, there is political will to have 15% of generation capacity from renewables by 2020, with regulations that have been promulgated since the signature of the first Energy Sector Development Policy Letter aiming in this direction.

Senegal's national electricity access rate of 64% is relatively high with over 90% in urban centres but estimated to be about 43.5% in rural areas[9]. The Government of Senegal has set targets to achieve universal electricity access by 2025. The electrification rate is rising as a result of new connections to the main grid and small off-grid projects. However, consumers and businesses connected to the grid still have to contend with highly unstable and unreliable electricity supply, leading to revenue and productivity losses for firms and the economy as a whole[10].

In 2016, due to low oil prices, the tariff was close to being cost reflective. However, as oil prices increased by 40 to 50% the following year, the cost of electricity services increased in Senegal given that it is 67% of installed capacity is based on HFO fired generation (83% of energy generated is from HFO). Consequently, the subsidy requirements soared to 1.1% of GDP in 2018. Government was reluctant to increase tariffs to cover this fiscal burden due to affordability concerns– as electricity tariffs in Senegal ($0.19 c/kWh) are close to double the global average. The recent decrease in international oil prices might contribute to reduce fiscal pressures. For instance, for an oil barrel of USD 65, tariff compensation to SENELEC would reduce to CFAF 111

[7] World Bank
[8] CIA World Factbook
[9] USAID
[10] GET.invest

billion (0.8% of GDP) in 2019. However, the power sector in Senegal remains vulnerable to price shocks as each additional dollar increase in oil price would increase the compensation by around CFAF 2.3 billion. As part of power sector reforms, government intends to promote a structural shift in the energy mix to improve the financial sustainability of the sector[11].

[12][13]

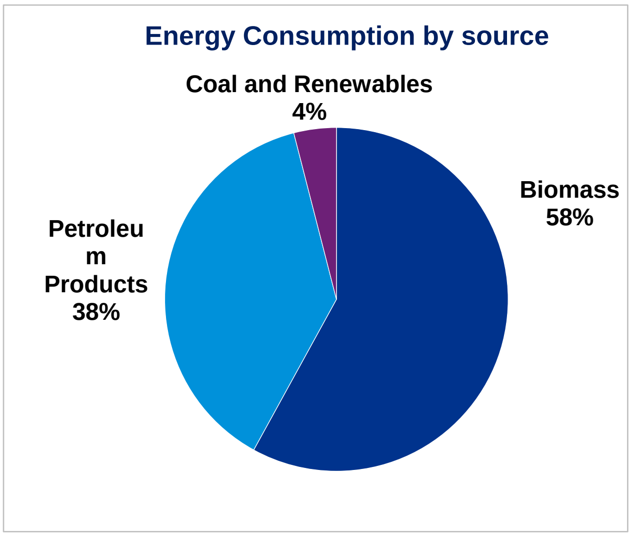


Figure 7: Energy Consumption by source

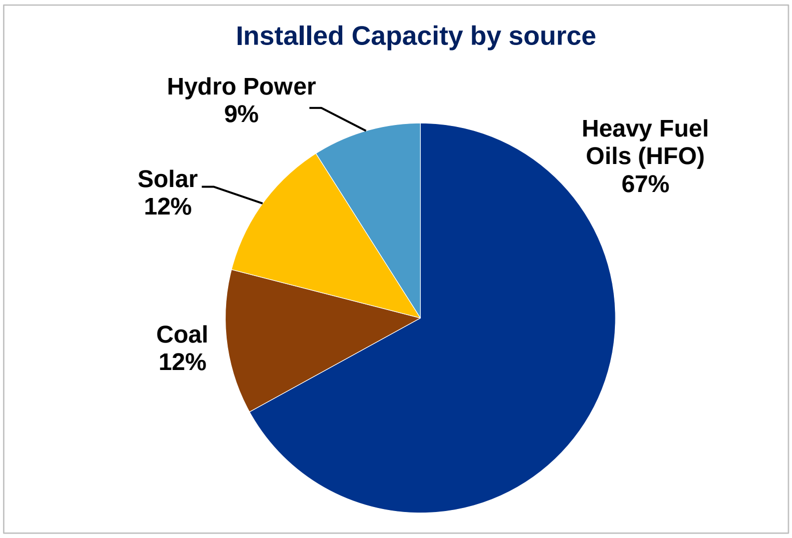


Figure 6: Installed Capacity by source

SENELEC also owns about half of the country's generation capacity, with the remainder being owned by independent power producers (IPPs) that generate electricity and sell it to SENELEC. In 1998, given the low rate of rural electrification in the country, the Government of Senegal (GoS) launched the Rural Electrification Action Plan (PASER) and divided the country into 10 concessions for allocation to private sector companies – concessionaires (CER) – who have the monopoly for electricity distribution within their concessions. 6 out of 10 concessions have been awarded to private stakeholders, which have encountered numerous barriers delaying their connection progress. SENELEC remains the major electricity service provider in rural areas, covering 96 percent of clients compared to CERs' 4 percent and was recently awarded the remaining 4 concessions.

3.3.1 Electricity Generation

At the end of 2018, Heavy fuel oil (HFO) represented 67 percent of the 940 MW of installed capacity and coal 12 percent, with solar and imported hydro power representing the remaining 12 and 9 percent respectively. Coal plant is currently dispatching around 100 MW to the grid as baseload capacity. With the support of the multisectoral reform Development Financing (DPF) (series currently ongoing), government has initiated a phase out of the use of heavy fuel oil for power generation. According to World Bank, by 2025, the installed capacity is expected to have a minimum of 22 percent renewables, (including solar, wind and hydro), 64 percent gas and 8 percent coal. The share of coal in the mix will be substantially reduced thanks to the recent natural

[11] **World Bank**
[12] **World Bank**
[13] **EnDev**

gas discoveries in Senegal and the development of renewable energies together with increased in imported hydropower. Furthermore, Senegal is modernizing its long-term planning and dispatching capabilities, and will be able to absorb higher levels of renewable energy over time through reinforcing the grid and adopting new methods to integrate variable renewable energy as technology further develops.

Senegal benefits from its strong potential for renewable energies which remains relatively untapped. Solar power represents a massive opportunity for development. Indeed, solar irradiation exceeds 2,000 kWh/m2/year (for Global Horizontal Irradiance) across most of the country. Thus, Senegal has real potential for development and scaling up of photovoltaic projects. Senegal demonstrates good potential for other sources of renewable energy along the northern coastline between Dakar and Saint-Louis. In a study by the Senegal Meteorological Service, wind velocities between 5.7 and 6.1 m/s were observed in this area. This potential will be exploited through the 158.7 MW Taiba N'Diaye wind farm which is currently under construction. The electricity output will be sold to Senelec under a 20-year PPA. Senegal also benefits from hydropower's strong potential through the Senegal River which is exploited by the Senegal River Basin Development Authority. Finally, Senegal has good potential for biomass thanks to important agricultural waste and agribusiness by-products (rice husks, bagasse, cotton stalks, etc.). The estimated potential for biomass generation is around 2,900 GWh.

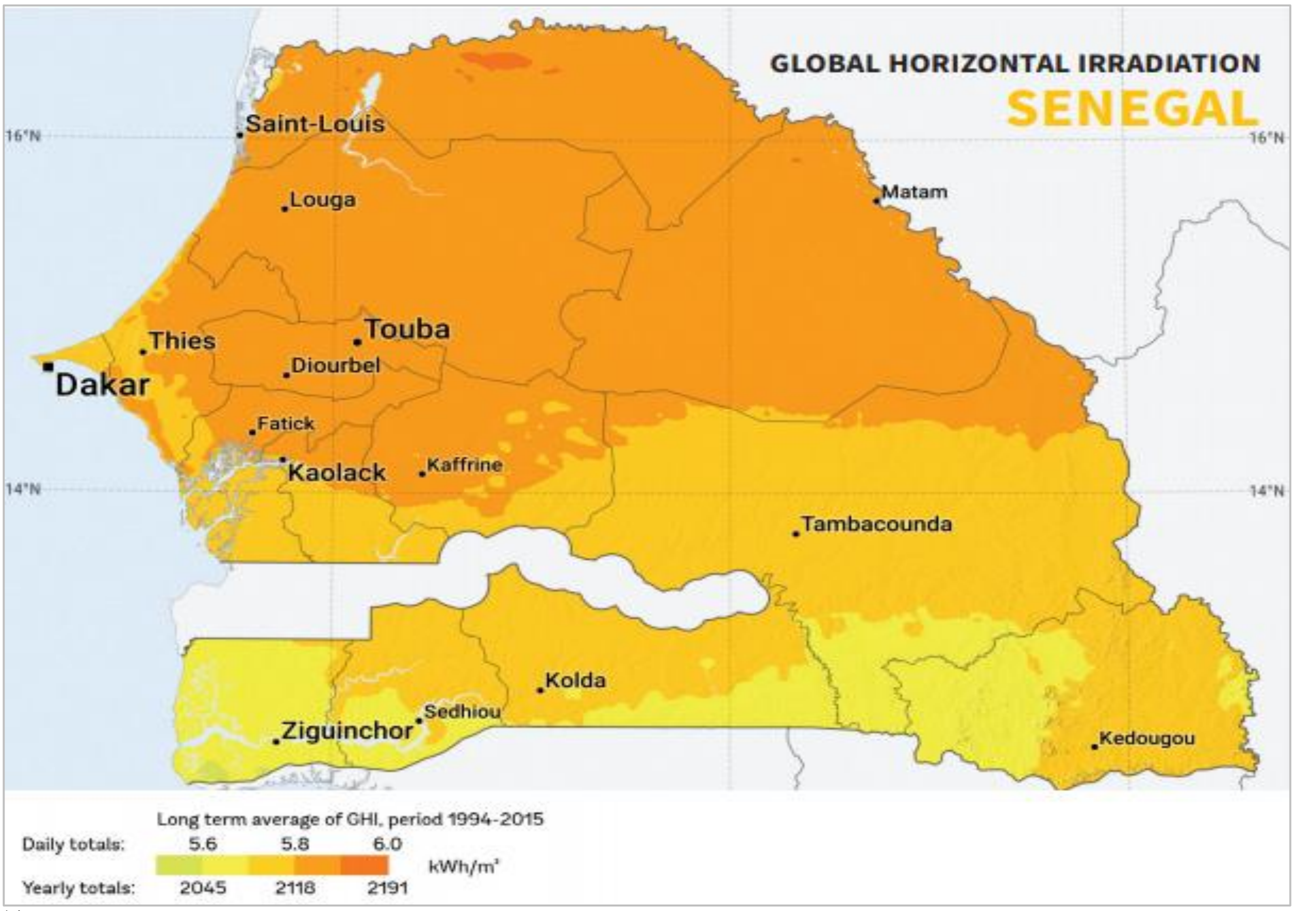


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Figure 8: Global Horizontal Irradiation for Senegal

[14] **Source: World Bank, Solargis, 2017**

Senegal's strategic master plan for electricity generation outlines how Senegal intends to more than double the generation capacity from around 940 MW to 2.5 GW by 2030, through a reliance of a mix of domestic gas and imported hydropower for baseload power generation, which will be supplemented by as much intermittent renewable energy (from solar and wind) that the nascent grid can absorb[15]. Accelerating the deployment of solar and other renewable energy, remains a strategic pillar for the sector. In addition to the 40 MW which they have commissioned in 2016, SENELEC has planned 323 MW of grid-connected solar capacity by 2023. Together with 158.7 MW expected from wind energy by 2020, the country will surpass its renewable energy targets.

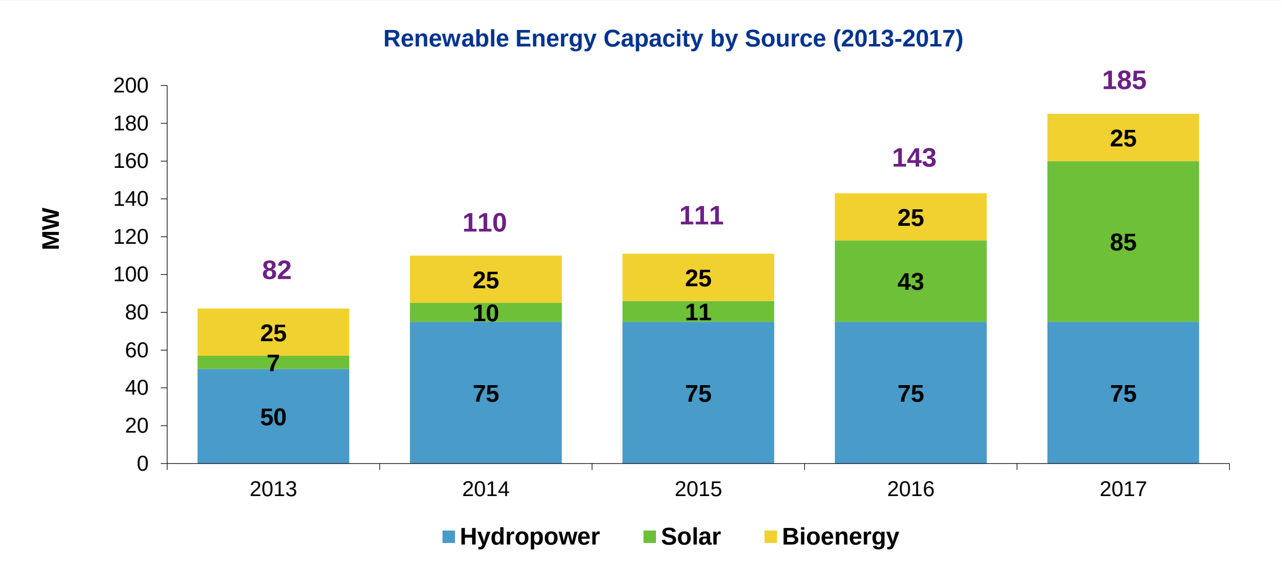


Figure 9: Renewable Energy Capacity by Source

The installed renewable energy capacity in 2017 stood at 185 MW comprising of 85 MW of solar, 75 MW of hydro and 25 MW of bio-energy sources. While no new hydro power capacity addition took place in the last 5 years, solar power has grown massively from 7 MW in 2013 to about 85 MW in 2017. The government has set up ambitious plan to scale up solar capacity even further to achieve its target of 15% of generation capacity from renewables by 2020.

Last year, President Macky Sall inaugurated the largest solar power plant in West Africa, Senergy 2, which boasts a 20 MW capacity, delivered by 75,000 PV panels and aims to provide electricity to 160,000 people. Funded by GreenWish Africa – a consortium comprised of local and international investors – the plant was built in eight months by Omexom, a subsidiary of the French power giant Vinci Energies. Since then, Senegal has inaugurated three new plants: Senergy (30 MW), Ten Merina (30 MW) and Malicounda (22 MW). Furthermore, French company Engie, together with its partner Meridiam and sovereign fund Fonsis, has constructed two new solar plants in the country, featuring a capacity of 20 MW each. Both plants are part of the Scaling Solar initiative by the World Bank, which aims to unlock private investment in solar power markets. The 'one stop shop' program aims to make privately funded grid-connected solar projects operational within two years and at competitive tariffs.

In July, an agreement was signed for the funding of two new solar power plants, within the Scaling Solar initiative, for a total investment of $42 million. With a total capacity of 60 MW, these power plants will be the seventh and eighth in the country and will produce electricity for 600,000 people.

[15] **World Bank**

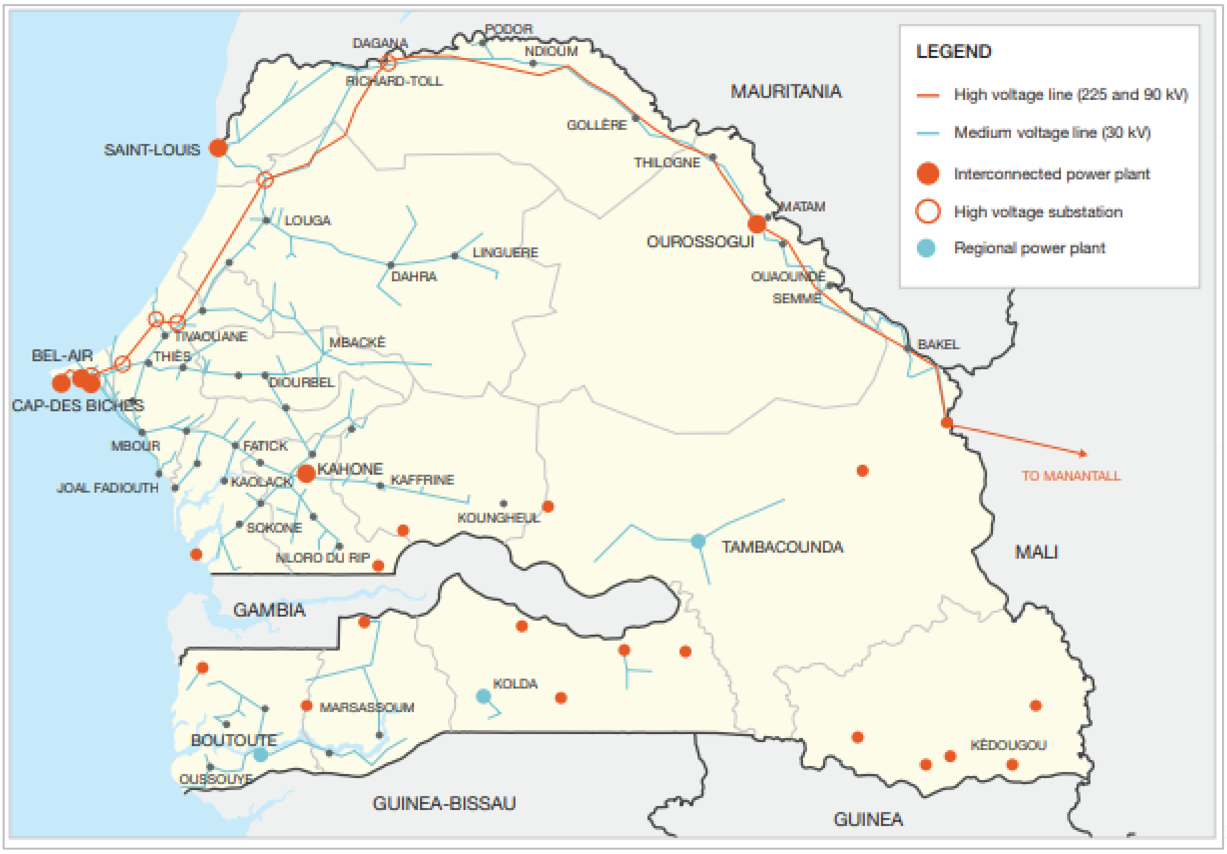
The plants will be funded by French development organisation, Proparco, the European Investment Bank and the International Finance Company[16]. Other solar projects in operation include:

1. The Senergy II solar plant in Bokhol was the first important solar installation in Senegal, with an installed capacity of 20 MW. It was launched in October 2016 and was the biggest plant in West Africa at the time. The installation is composed of 77,000 solar panels and supplies electricity to 9,000 households and cost FCFA 17 billion (EUR 25.9 million), financed by the French platform GreenWish Partners through the investment vehicle GreenWish Africa REN. 45% of the project equity is held by Senegalese investors including the Caisse des Dépôts et Consignations du Sénégal. Vinci Energies was in charge of construction and operation.
2. The Malicounda solar plant was inaugurated in November 2016 by Senelec and a group of Italian investors, including Solaria, which financed the construction for an amount of FCFA 20 billion. The plant has 86,000 panels and a capacity of 22 MW. It provides energy to 9,000 households.
3. The Senergy solar plant in Santhiou-Mékhé is one of the biggest in Africa with a capacity of 30 MW. Beginning production in June 2017, the park is composed of 92,000 solar panels and can supply electricity to 300,000 households according to Senelec, which signed a PPA with Senergy PVSA. This solar farm is the result of a public-private partnership (PPP) including the French fund Meridiam (53%), the Fonds souverain sénégalais (32%), Solairedirect—an Engie subsidiary, which built and operates the park—(15%), Senergy PVSA and Proparco (15 %). Proparco financed 80% of this project through a FCFA 22 billion loan, the total investment being estimated at FCFA 27 billion.
4. The Ten Merina 30 MW solar plant was launched in January 2018. This project was carried by Meridiam (85%) in a partnership with Eiffage and Solairedirect. The investors obtained a € 34.5 million loan from Proparco and the Société Belge d'Investissement pour les Pays en Développement (BIO) for a total cost estimated to EUR 43 million. It should bring electricity to 226,500 inhabitants[17].

3.3.2 Electricity Transmission

In spite of the increasing number of IPPs, Senelec still holds a monopoly on the transmission and distribution of electricity. The distribution system comprises a 7,627km medium-voltage (MV) network at 6.6 kV and 30 kV, a low-voltage (LV) network with a total length of 6,761km as well as 13 high-voltage (HV)/HV and 3,511 MV/LV (30 and 6.6 kV) substations. The transmission network consists of 225 kV and 90 kV lines totaling 6,761 km in length. There have been instances of infrastructure issues leading to frequent shutdowns, and transmission losses are estimated at around 19%. Reserve capacity presently is insufficient, causing frequent (scheduled or unscheduled) outages of whole districts, while transmission losses, old thermal power plants and increasing oil prices result in high average production costs[18].

[16] Africa Oil & Power
[17] SolarPower Europe
[18] GET.invest



[19]

Figure 10: Production and Distribution Network of Senegal

A transmission system is used for electricity exchanges across the country and for electricity supply to big industrial companies. Commonly known as the Interconnected Grid (IR), it is mainly located in the western area of the country, especially in the Dakar area, in which energy consumption is the highest. However, the IR is growing towards the centre of the country in anticipation of the interconnection with the future 225 kV grid of OMVS (Senegal River Basin Development Authority) and OMVG (Gambia River Basin Development Authority). Except for this line, electric transmission is done through a grid of 90 kV and 30 kV lines coupled with transformer station HV/MV.

Via its Omexom energy transition brand, VINCI Energies has won the Société d'Electricité du Sénégal (Senelec) contract to install five new extra high voltage transformer stations, nearly 200 km of overhead and underground EHV transmission lines, over 100 distribution substations in various parts of the country and a regional load dispatch centre. The project is part of Senelec's transmission and distribution grid expansion, reinforcement and reliability enhancement programme (the 2016-2020 Strategic Plan). The €197 million project will take 36 months to complete and involves the cities of Dakar, Diass, Diamniadio, Thiès, Kounoune, Tobène and Tambacounda. The contract is fully financed by a banking pool made up of French and Senegalese lenders and is backed by the French authorities via a BPI Assurance Export guarantee and the Senegalese authorities via a Ministry of Economy, Finance and Planning guarantee.

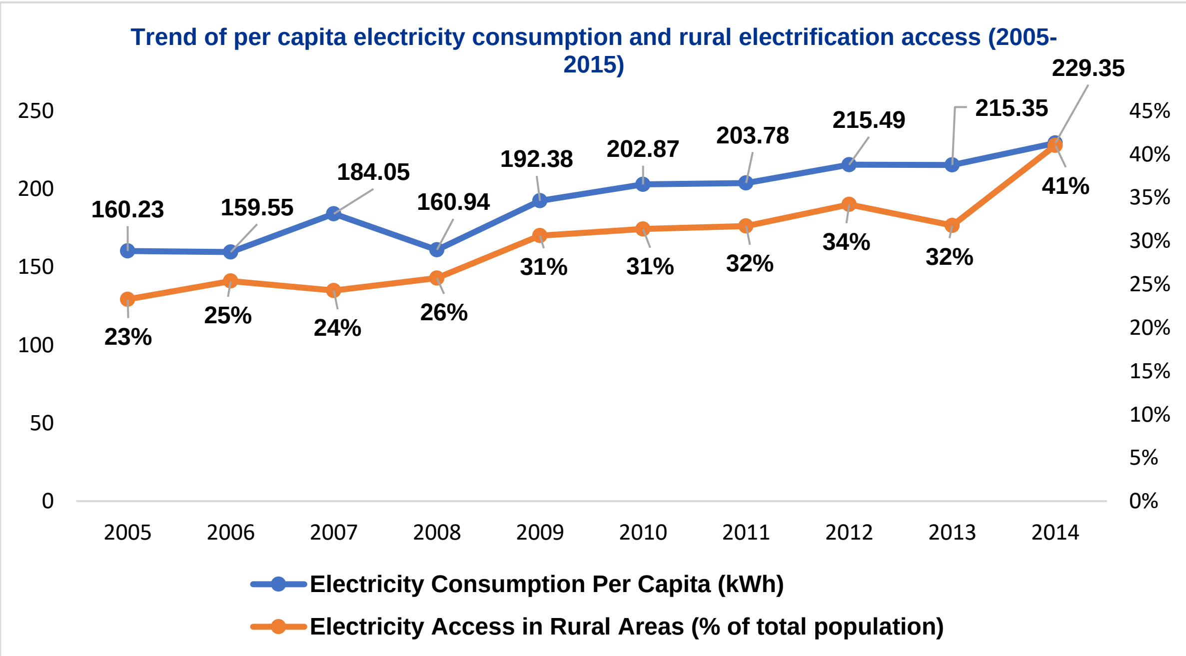
[19] **Source: CRSE**

The project will enhance the reliability of the Senegalese electricity grid. In Dakar, it will give the strategic city-centre neighbourhoods three new sources of supply. An extra high voltage transformer station will be built to secure the power supply in the new suburb of Diamniadio. A second transformer station will be installed in the city of Thiès to secure the electricity supply of several towns in the vicinity. Lastly, the contract covers reinforcement of the distribution grids in Dakar, Tambacounda, Kounoune, Diamniadio and Thiès[20].

3.3.3 Electricity Distribution

While significant progress has been made in increasing the number of IPP power projects in Senegal, the per capita electricity consumption has grown only marginally. The per capita electricity consumption was about 160 kWh in 2005 which improved to only 229 kWh in 2015, a growth rate of 4% Year-on-Year (Y-o-Y).

The main reason of this imbalance is wide disparity in electrification rates in rural areas. While Senegal has almost achieved full electrification in urban areas (90 percent), rural access remains low at an estimated 43 percent, hindered by inadequate infrastructure and high tariffs. Basic social services (health centers, schools, etc.) are also often not electrified. Regional disparities are also prevalent with regions such as Kaffrine, Kolda, Kédougou with rural access rates estimated at between 9 and 12 per cent, while others such as Diourbel and Thiès feature rural access as high as 55 and 76 per cent respectively. In 2016, professional uses accounted for 54% of consumption, while domestic and public lighting accounted for 44% and 2% respectively[21].



[22]

Figure 11: Trend of per capita electricity consumption and rural electrification access in Senegal

Rural electrification policy runs as a concession program (Concession d'Electrification Rurale or CER) whereby ten distinct rural electrification concession areas can be awarded to bidders in a

[20] Global News Wire
[21] HAL Archives
[22] Source: World Bank

competitive tender. Local initiatives for rural electrification can also be supported. Senegal is divided into ten CER, which are granted to private operators selected by international bids. Operators oversee technical studies, acquisition and installation of supply equipment, operation, maintenance and replacement as well as billing and client management during the duration of the Concession (25 years). Among the ten CER, six concessions have already been granted and the remaining four are temporarily under the supervision of several Interim Delegate Supervisors. The national electrification strategy has determined that 95% of the connections will come from grid extensions that will require about 180 MW of additional supply into the SENELEC network by 2025. In addition, one of the key constraints to accelerate the increase of electricity access has been the high cost of electricity and its related affordability issue, especially in rural areas. The shift to lower carbon energies including domestic gas and renewable energy will also entail a reduction of electricity generation costs, allowing to facilitate the objective of achieving universal access.

The entire distribution of electricity in Senegal is carried out by Senelec. Senelec's Medium Voltage distribution network (2015) is composed of: 9,102.24 km of medium voltage lines (6.6 kV and 30 kV); 8,376.75 km of low voltage lines (0.4 kV) and 4,819 MV/LT. The Low Voltage distribution network includes 7,812.517 km of overhead lines and 564.233 km of underground lines[23]. The regulator, CRSE, publishes on a quarterly basis, the maximum allowed revenues for SENELEC to cover their costs and, by comparing this figure with the revenue given the current level of tariffs, demonstrates any tariff revenue shortfall. As a result, it calculates the corresponding tariff adjustment, or the level of budgetary 'compensation' needed to cover the additional costs not covered by revenues from electricity sales. The government then has the option of adjusting the tariffs accordingly or compensating the utility. Budgeting of the required tariff compensation by the government is not consistently or fully implemented, resulting in payments arrears, particularly when the amounts are significant[24].

Tariff Categories (Low Voltage)	Cost of Electricity (CFAF/ kWh)			Fixed Monthly Premium (CFAF/ kWh)
	1st Tranche	2nd Tranche	3rd Tranche	
Domestic Use				
Domestic Low Power	90.47	101.64	112.65	
Domestic Medium Power	96.02	102.44	112.02	
Professional Use				
Professional Low Power	128.85	135.68	147.68	
Professional Medium Power	129.81	136.53	149.24	
Prepayment (WOYOFAL)				
Domestic Low Power	90.47	101.64	101.64	
Domestic Medium Power	96.02	102.44	102.44	
Professional Low Power	128.85	135.68	135.68	
Professional Medium Power	129.81	136.53	136.53	
High Power Use	**Off-peak hours**	**Peak hours**		
Domestic High Power	86.30	120.81		869.21
Professional High Power	103.36	165.38		2607.63
Public Lighting	118.16			3007.21[25]

Figure 12: Low Voltage Electricity Tariff Schedule since May 2017

[23] SolarPower Europe
[24] World Bank
[25] Source: Senelec, 2018

3.3.4 Institutional Framework

In Senegal, the Ministry of Energy develops and proposes the general policy and applicable standards for the electricity sector to the president. It grants the licenses and concessions within the applicable framework and can withdraw it if needed. The National Agency for Renewable Energies (ANER) is in charge of the promotion and development of renewable energies. The Electricity Sector Regulatory Commission (CRSE) is the independent authority in charge of the regulation of generation, transmission, distribution and sale of electricity. It regulates the sector and determines electricity prices as well as their structuring. The Senegalese Rural Electrification Agency (ASER) oversees rural off-grid projects. The details of key stakeholders along with their roles and responsibilities is provided in the table as below:

S.No.	Stakeholder	Role
1	Ministry of Petroleum and Energies (MPE)	Ministry of Energy that oversees the energy sector, including the renewable sub-sector. Its key role includes: • Policy making body for the energy sector including renewables • Nodal ministry for coordination and implementation of RE projects
2	National Agency for Renewable Energies (ANER)	Government agency created in 2013, to promote and develop renewable energies in all forms: solar, wind, biomass, hydropower, and tidal. ANER has focused more on SHS and public areas electrification given ASER's focus on village-level mini-grids.
3	CRSE (La Commission de Régulation du Secteur de l'électricité)	Regulator that oversees licensing, operation, and sales of electricity. This includes setting tariffs and monitoring concession contracts.
4	Senelec (Société Nationale d'Electricité)	SENELEC is the vertically-integrated national utility created in the 1998 power sector reforms. It is the largest electricity generator, and the only concessionaire for on-grid transmission and distribution. It has a monopoly over the purchase and sale of wholesale electricity.
5	ASER (Agence Sénégalaise d'Electrification Rurale)	ASER is an independent agency responsible for providing electricity companies and individuals with the technical and financial assistance needed to support rural electrification initiatives. ASER is developing the electrification programs decided on the basis of the rural electrification plan defined by the Minister in charge of Energy.
6	AEME (Agence Nationale pour l'Economie et la Maitrise de l'Energie)	AEME participates in the implementation of policies in the areas of energy, environment and sustainable development. It provides companies, local authorities, public authorities and the general public with expertise and advice. It helps finance and implement projects in the areas of sustainable energy usage and energy efficiency.
7	PERACOD (Programme pour la Promotion des Energies Renouvelables, de l'Electrification Rurale et de l'Approvisionnement Durable en Combustibles Domestiques)	PERACOD is implemented by GIZ, a German technical cooperation organization. The objective of PERACOD is to contribute to the sustainable improvement of the rural population's access to energy services. The focus is on renewable energies, especially on solar systems and the sustainable use of non-fossil fuels.[26]

Table 4: Role of key stakeholders in Senegal's Power Sector

[26] **Inputs from ISA Mission Visit and HAL Archives**

Senegal benefits from the strong support of international organizations. The World Bank provides support to Senegal for its National Rural Electrification Program 2015 – 2025. In addition, Senegal is a beneficiary of Power Africa, an American program launched by Barack Obama in 2013, which aims at improving access to a reliable and less costly energy. USAID is working with Senegal's Ministry of Energy to assess Senegal's rural electrification efforts and come up with recommendations to accelerate the process. The agency also provides transaction advisory to private sector off-grid companies and rural concession holders in order to help them in developing their activities and strengthening their business models. Development Finance Institutions also represent a major source of financing and support for the renewable energy sector in Senegal. As mentioned above, Proparco took part in the financing of two major solar plants over the past years. GIZ, a German development agency also provides support to Senegal in the development of renewable energy and energy efficiency projects[27].

The overarching institutional framework in Senegal's Power Sector is illustrated as below:

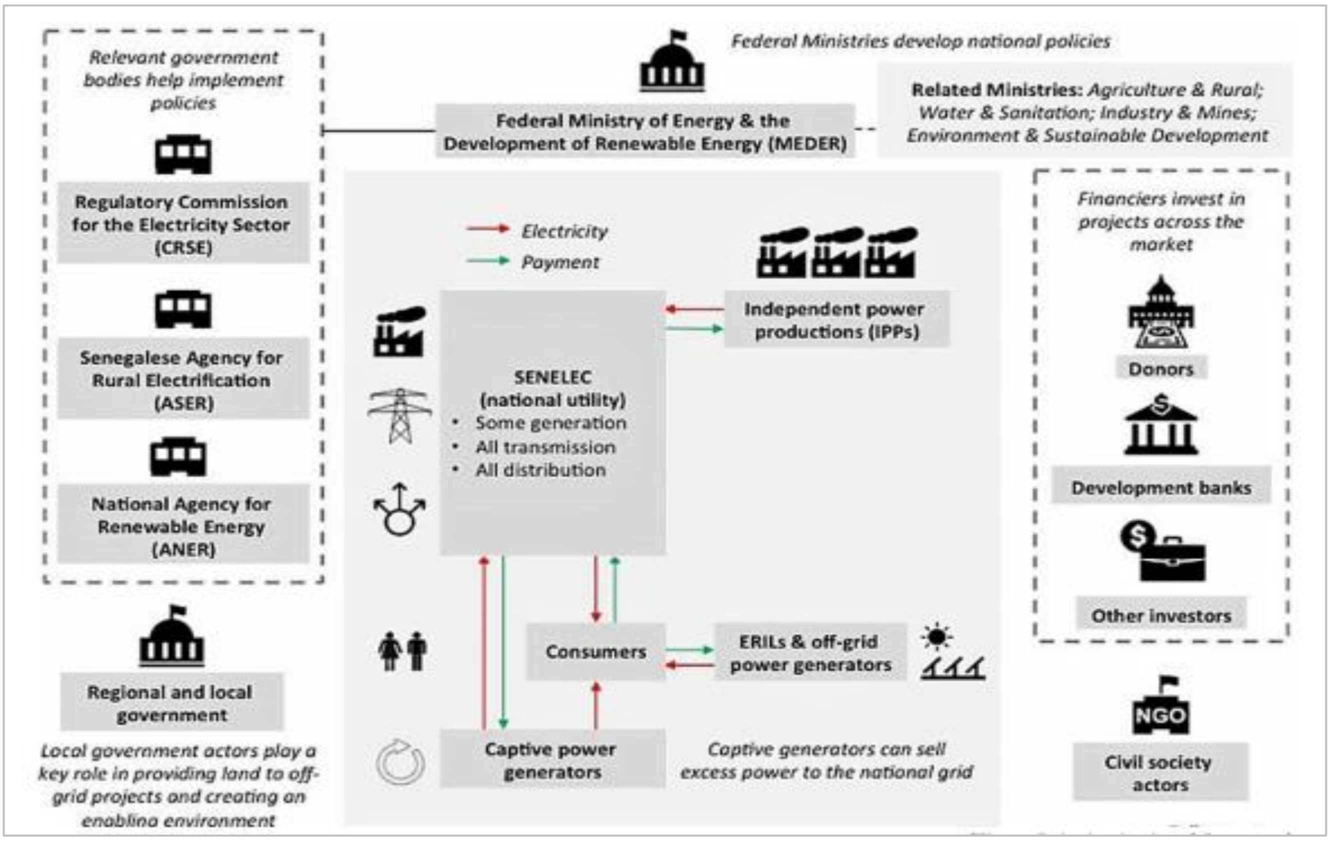


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Figure 13: Overarching Institutional Framework in Senegal

[27] SolarPower Europe
[28] Source: World Bank

4. Technical Feasibility Assessment

4.1 Assessment Criteria

The feasibility of a solar powered irrigation system depends on a wide array of factors ranging from geographic parameters such as temperature, rainfall, water table depth to site specific parameters such as cropping pattern, land size, planting date, irrigation technique etc. Any feasibility analysis of a solar powered irrigation system would involve both the technical feasibility and the financial feasibility. The technical feasibility would analyze the site-specific conditions to determine whether such system can be installed considering the different technical aspects such as solar irradiance, size availability, panel size, tracking systems, water table depth etc. The technical feasibility would also provide recommendations on the ideal pump size and type considering the dynamics of the site. Once technical feasibility for a given system is established, the costs involved, and the expected returns are calculated using financial feasibility analysis. The below figure summarizes the interplay of various parameters involved in technical and financial feasibility analysis.

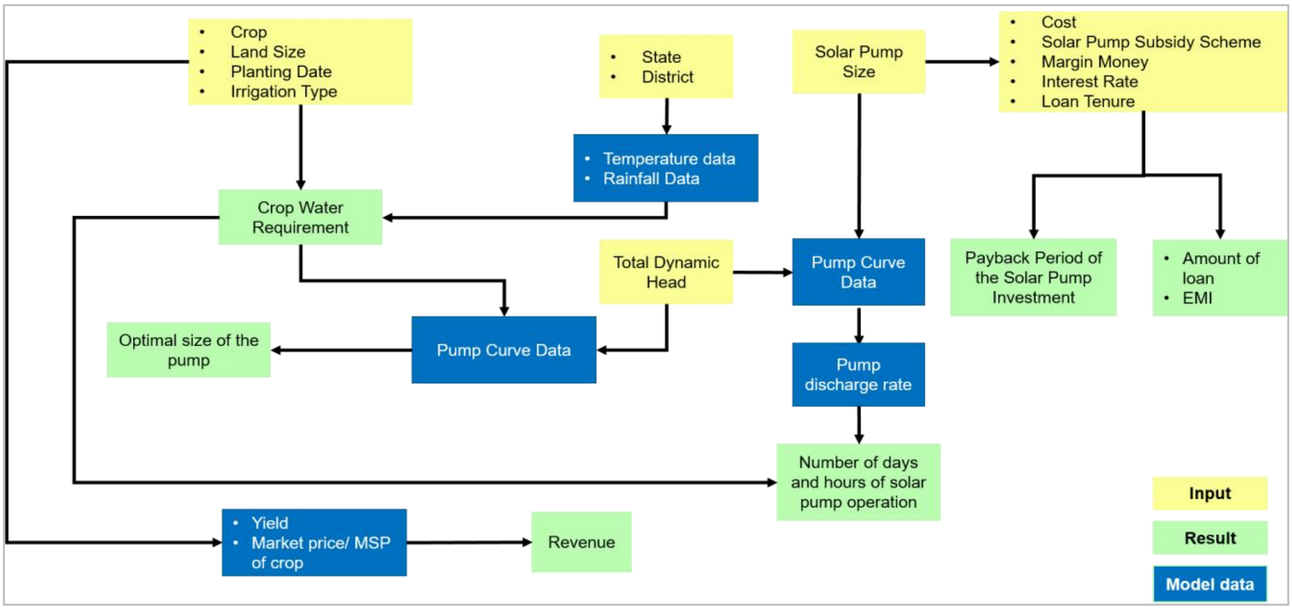

Figure 14: Factors involved in feasibility analysis of solar pump

4.1.1 Total Dynamic Head

The total dynamic head is a very important parameter of a solar pumps which determines the various head losses that the pump must overcome. It is a summation of the suction head, discharge head and the friction losses. The total dynamic head and the desired flow rate of the system are applied to the pump performance curve, which is used for proper pump selection based on required electrical power input and optimum efficiency.

The static head, discharge head and the total dynamic head is explained through the image below[29]:

[29] ScienceDirect.com

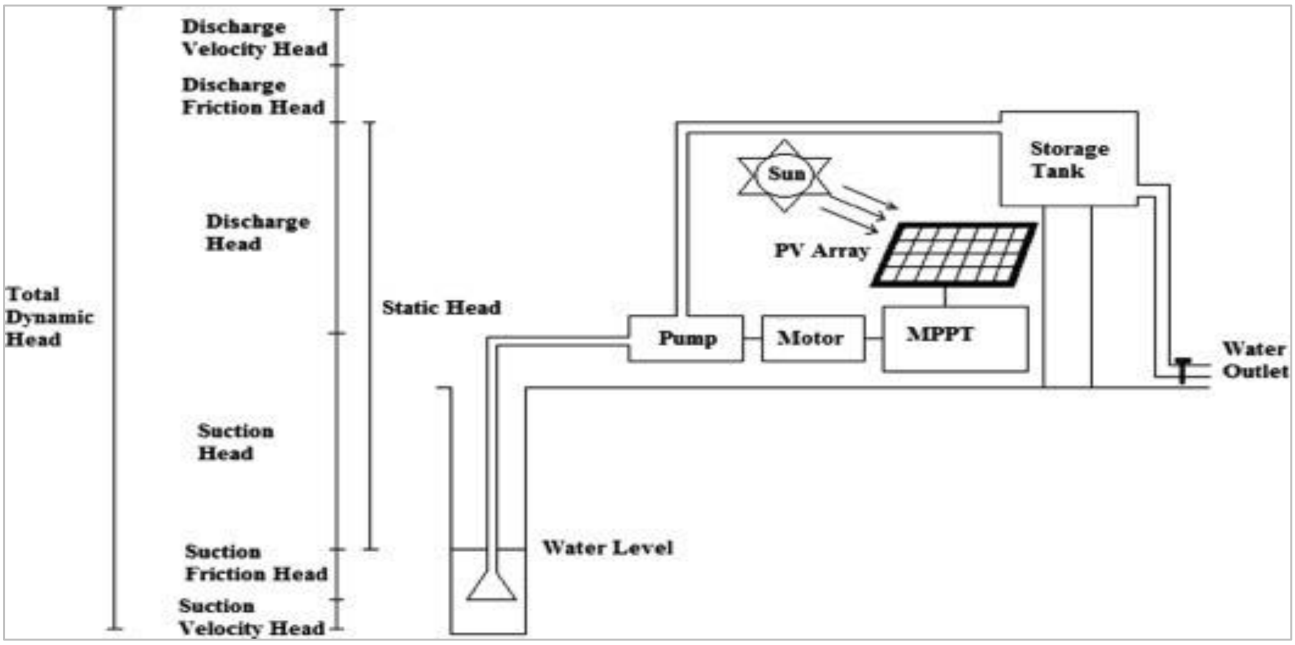

Figure 15: Total Dynamic Head of a solar pump

4.1.2 Pump Curves

The pump characteristic is normally described graphically by the manufacturer as the pump performance curve. Other important information for a proper pump selection is also included - like efficiency curves, NPSHr curve, pump curves for several impeller diameters and different speeds, and power consumption[30]. The performance curve indicates the variation in the discharge rate of a pump with a change in required head and input power. The pump curves are analyzed to determine the optimal size of a solar pump for a given manufacturer and also to assess whether the system will be able to the peak demand requirements of the farmer. The performance curves for a 5 HP AC and 5 HP DC pump is shown as below[31]:

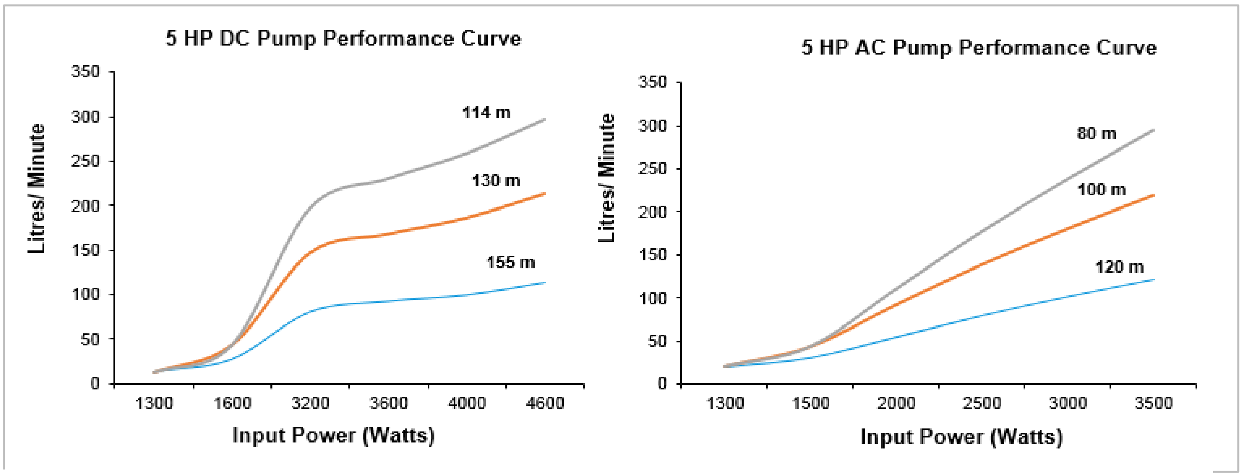

Figure 16: Pump Performance Curves

[30] The Engineering Toolbox
[31] Shakti Pumps (DC pump: 5 DCSSP 2700/3600/4600; AC pump: SSP 5000-100-11)

4.1.3 Crop Water Requirement

The crop water need is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally. The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need mainly depends on:

- **the climate:** in a sunny and hot climate crops need more water per day than in a cloudy and cool climate
- **the crop type:** crops like maize or sugarcane need more water than crops like millet or sorghum
- **the growth stage of the crop:** fully grown crops need more water than crops that have just been planted.

The below table showcases the effect of various climatic factors on the crop water requirement:

Climatic Factor	Crop Water Requirement	
	High	Low
Temperature	Hot	Cool
Humidity	Low (Dry)	High (Humid)
Windspeed	Windy	Little Wind
Sunshine	Sunny (no clouds)	Cloudy (no sun)[32]

Table 5: Effect of major climatic factors on crop water requirement

The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind. The influence of the climate on crop water needs is given by the reference crop evapotranspiration (ETo). The ETo is usually expressed in millimetres per unit of time, e.g. mm/day, mm/month, or mm/season. ETo is the rate of evapotranspiration from a large area, covered by green grass, 8 to 15 cm tall, which grows actively, completely shades the ground and which is not short of water[33].

4.1.4 Pump Sizing

Oversizing would incur unnecessary costs, and under sizing would lead to insufficient performance. This is why each component needs to be properly designed and sized to meet the specific requirements of the project. It is the only way to guarantee reliability and system durability to achieve the desired performance. Similarly, when sizing a solar system, it is recommended to use the 'worst month method'. By sizing the systems for the month with most adverse conditions in the year, it will be ensured that water supply will be enough for all the other months. The worst

[32] Food and Agriculture Organization of the United Nations (FAO)
[33] Food and Agriculture Organization of the United Nations (FAO)

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[34].

4.2 Site Assessment- Thiès

4.2.1 Thiès

Thiès is the third largest city in Senegal and lies 72 km east of Dakar on the N2 road and at the junction of railway lines to Dakar, Bamako and St-Louis. It is the capital of Thiès Region and is a major industrial city. It has two coastlines, one in the north with the Grande Côte housing the Niayes vegetable market, one to the south with the Petite Côte, one of the tourist areas of Senegal. Principally the main passageway between the peninsula and the rest of the country, the region of Thies has received a communication route connected to the first rail line and new road infrastructure. The coastal communities dependent on fishing, growing crops and coastal tourism for subsistence. The interior of the region was the peanut basin. Phosphates are also mined there.

Figure 17: Location of Thiès in Senegal

[34] **Sun-Connect News**

Figure 18: Administrative divisions in Thiès

Thiès region is divided into 3 departments, 14 communes, 12 arrondissements, 32 communautés rurales and 3 communes d'arrondissement. The project is planned to be carried out in Thiès department of Thiès region which comprises of Kayar, Khombole and Pout communes. The details of administrative devision of the region is as shown below:

Department	Commune	Arrondissement	Rural Communities (CR)	Population (as per Census 2011)
M'bour	M'bour, Joal-Fadiouth, Nguekokh, Ngaparou, Popenguine-Ndayane, Saly, Somone, Thiadiaye	Fissel, Séssène, Sindia	Fissel, Ndiaganiao, Nguéniène, Sandiara, Séssène, Malicounda, Diass, Sindia	668,878
Thiès	**Kayar, Khombole, Pout**	**Thiès Nord, Thiès Sud, Keur Moussa, Notto, Thiénaba**	**Diender Geudj, Fandène, Keur Moussa, Notto, Tassette, Ndiayène Sirah, Thiénaba, Ngoudiane, Touba Toul**	**667,814**
Tivaoune	Tivaouane, Mboro, Meckhe	Méouane, Médina Dakhar, Niakhène, Pambal	Méouane, Taïba Ndiaye, Darou-Khoudoss, Koul, Mérina Dakhar, Pékesse, Nbayène, Ngandiouf, Niakhène, Thilmakha, Chérif Lo, Mont Rolland, Notto Gouye Diama, Pambal, Pire Gourèye	452,172

Table 6: Administrative divisions of Thiès

4.2.2 Connectivity and Accessibility

Thiès is a major industrial city and is very well connected with other major cities of Senegal as it is located at the junction of railway lines to Dakar, Bamako and St-Louis. It is situated at 14.7910º N and 16.9359º W. The Railways is used primarily for transporting most of the mineral products, fuels as well as agricultural produce. Thiès also a fair accessibility from the different airports of Senegal – primarily the ones in Thiès and Dakar (international airport). Thiès is situated only 16 km away from the new international airport situated near Diass. As Thiès is strategically situated on the transportation axe of the country and has a fair connectivity via road, railways, waterways and airways, it has been quickly developing as an extension of the congested Cap-Vert Peninsula and is therefore, attracting industrial investments, both from the domestic as well as international markets.

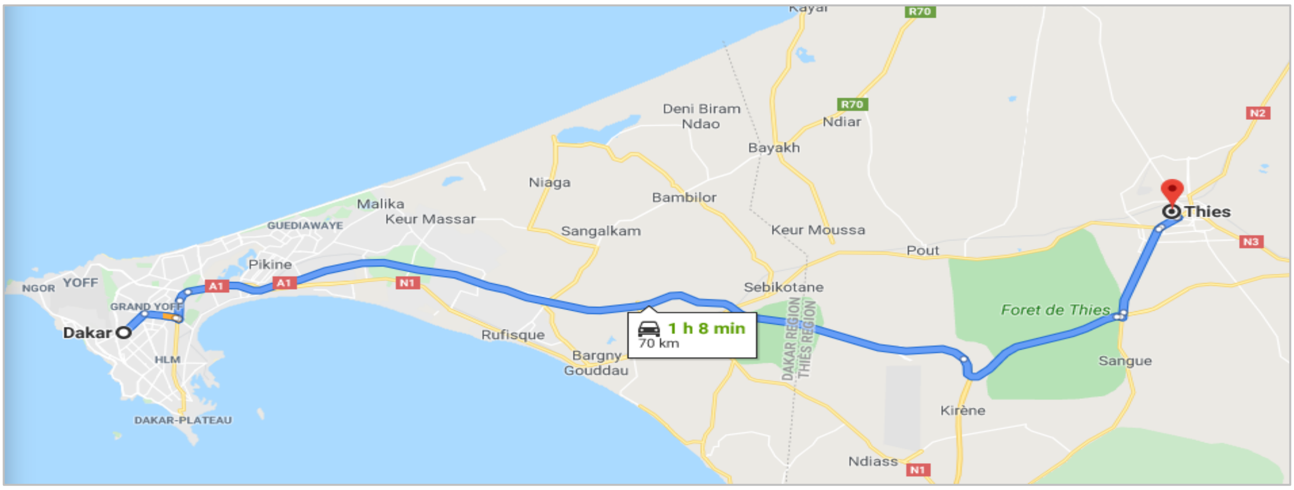

Figure 19: Connectivity between Dakar and Thiès

Thiès controls access to Dakar from the inside of the country through a path situated between two plateaus, currently covered by a protected forest. It is connected to Dakar through the N2 road and is also one of the major interjections on the Dakar Niger Railway Network. Post the development of new airport in Ndiass, Thies enjoys robust connectivity and access to both air and water transport. It is situated 28 km from Bliase Diagne International Airport and about 70 km from Port De Dakar, the major West African port. The Petit train de banlieue (PTB) provides regular commuter services between Dakar railway station and Thies via Thiaroye and Rufisque.

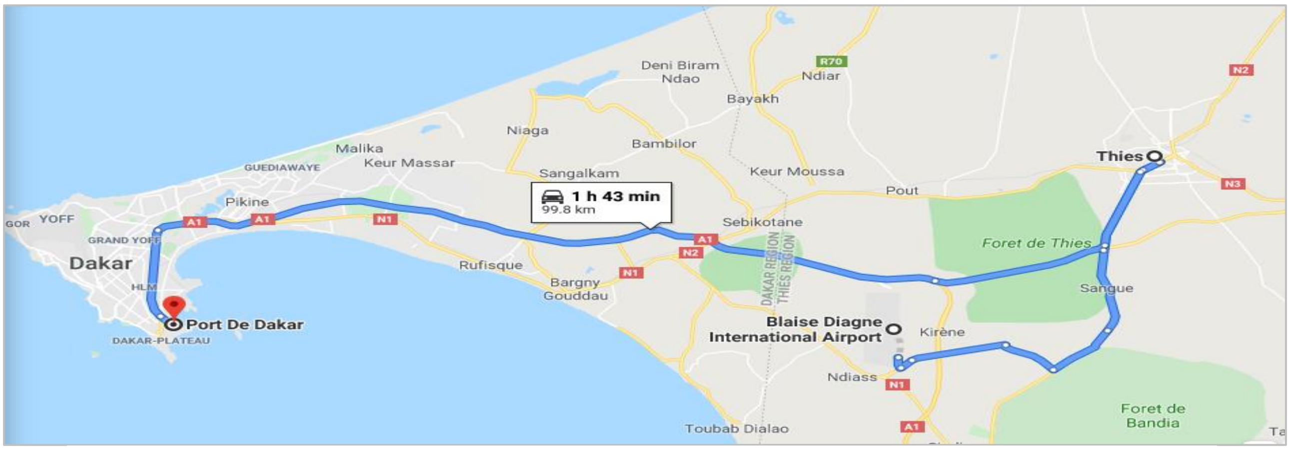

Figure 20: Connectivity of Thies with Blaise Diagne International Airport and Port de Dakar

4.2.3 Climate and Rainfall

The climate in Thiès is referred to as a local steppe climate . It remains hot all year round with a little rainfall. This location is classified as BSh by Köppen and Geiger[35]. The temperature typically varies from 16 °C to 35 °C with the average annual temperature of 25.7 °C. The highest temperature on average is reached in June (around 27.6 °C) while the lowest average temperatures (around 23.3 °C) of the year are witnessed in January. The climate of the region is subject to the influence of the maritime trade winds and the harmattan. Thiès witnesses fast but dry winds for more than 6 months (November to June) in a year with average speeds of more than 9.7 miles per hour.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (ºC)	23.3	23.9	25.1	25.1	25.9	27.6	27.3	26.6	26.8	27.1	26.1	23.4
Min. Temperature (ºC)	15.3	16.2	17.1	17.8	19.4	22.2	23.1	22.8	22.6	21.9	19	15.9
Max. Temperature (ºC)	31.3	31.6	33.1	32.5	32.5	33	31.6	30.5	31.1	32.4	33.3	30.9

Figure 21: Temperature Variation in Thiès

In Thiès, the wet season is oppressive and overcast; the dry season is humid, windy, and partly cloudy; and it is hot year-round. The length of the day in Thiès varies over the course of the year. In 2019, the shortest day is December 22, with 11 hours, 15 minutes of daylight; the longest day is June 21, with 13 hours, 0 minutes of daylight.

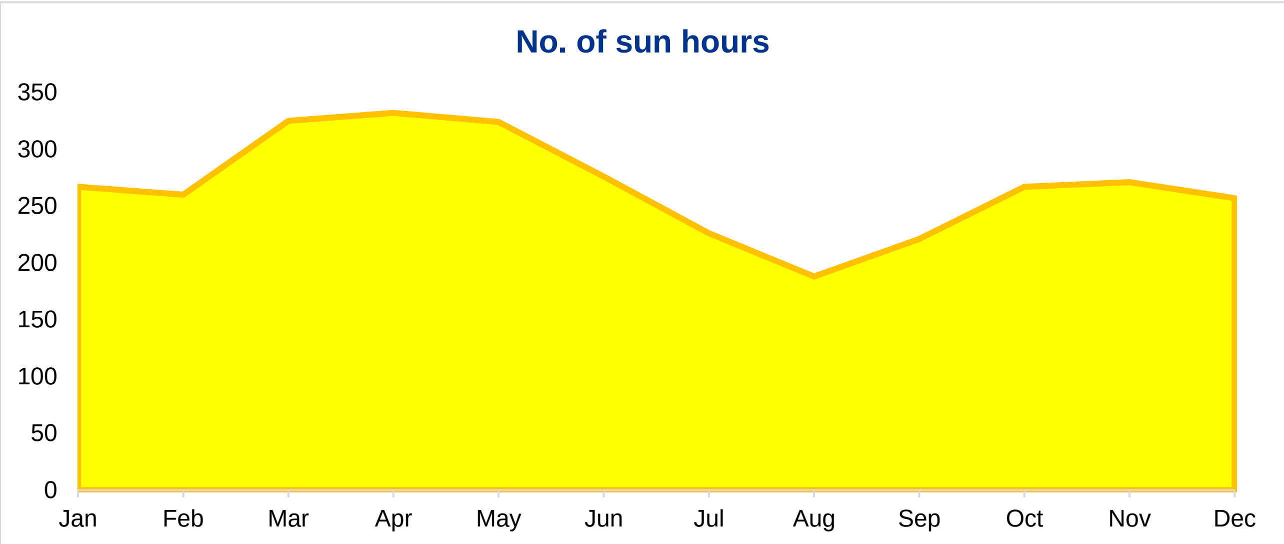

Figure 22: No. of sun hours in Thiès region

[35] **Hot semi-arid climates (type "BSh") tend to be located in the 20s and 30s latitudes of the (tropics and subtropics), typically in proximity to regions with a tropical savanna or a humid subtropical climate. These climates tend to have hot, sometimes extremely hot, summers and warm to cool winters, with some to minimal precipitation.**

[36] **Horizon Documentation**

Thiès faces extreme seasonal variations in monthly rainfall. It has dry months for more than 9 months in a year and receives about 503 mm of precipitation annually. The least amount of rainfall occurs in March while the most precipitation in Thiès occurs in the month of August. The variation in precipitation between driest and wettest months is 194 mm with average humidity of about 78%[37].

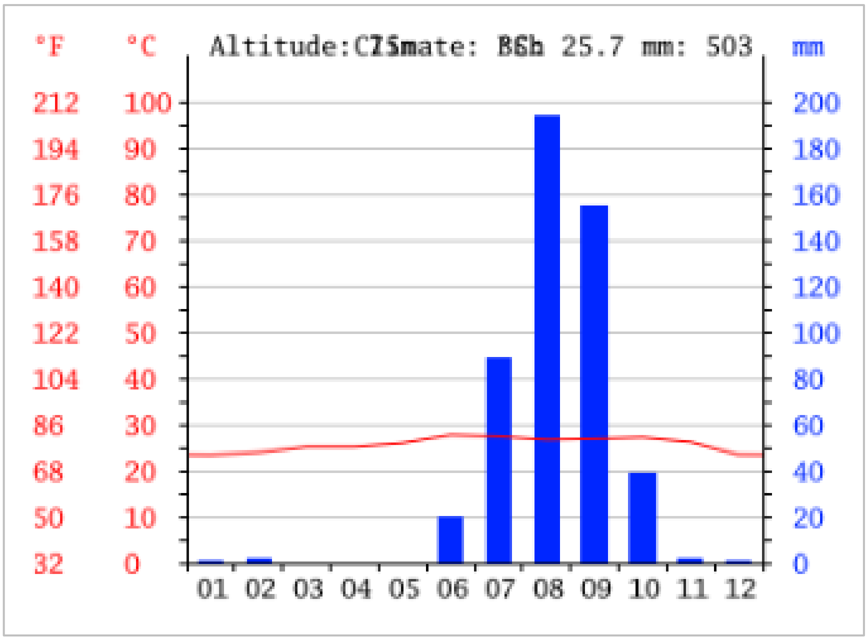

Figure 23: Climate and Rainfall pattern in Thiès region

4.2.4 Soil Pattern

The soils of the Sénégal and Saloum river valleys in their middle courses are alluvial and consist of sandy loams or clays. Near the river mouths the soils are salty and favourable for grazing. Similar conditions are associated with the Gambia and Casamance rivers, except near their mouths the banks are muddy, whereas their upper courses have sandy clay soils.

Many types of soils are found throughout the country. In the northwest the soils are ochre-coloured and light, consisting of sands combined with iron oxide. These soils, called Dior soils, constitute the wealth of Senegal; the dunes they form are highly favourable to peanut cultivation, whereas the soils between the dunes are suitable for other food crops, such as sorghum. In the southwest the plateau soils are sandy clays, frequently laterized (leached into red, residual, iron-bearing soils). The centre and the south of the country are covered by a layer of laterite hidden under a thin covering of sand that affords only sparse grazing during the rainy season. In the Casamance area heavily leached clay soils with a high iron-oxide content predominate, suitable for cultivation regardless of their depth[38].

Thiès region is characterized by tropical ferruginous soils with sandy, sandy-clay and clay-humus texture; and hydro-morphic soils with a humid texture. The vegetation consists of mainly shrub

[37] **Climate-Data.org**
[38] **Britannica**

savanna, filao and classified forests. From a water point of view, the region has significant groundwater, surface water and relatively good quality well water in some areas.

4.2.5 Groundwater Status

Senegal has significant groundwater resources, but the distribution of availability and demand do not match. This means that some groundwater systems are over exploited, leading to groundwater depletion: this has been observed in the Palaeocene and Maastrichtian in the Diass aquifer system. Large-scale irrigation in alluvial valleys (Senegal, Saloum and Casamance) may also act to gradually increase the salinity levels in soil water, surface water systems and/or aquifers. The effects are most pronounced under arid conditions but also with the use various anthropogenic pollutants (fertilizers, domestic, industrial and agricultural effluents etc.). In addition, the using brackish water or treated waste waters for irrigation in Niayes area (north coastline) may promote salinization of the underlying groundwater system in particularly around of large cities like Dakar. It is assumed that the groundwater salinization because of irrigation is restricted to the first meters to tens of meters below the groundwater table in sands dunes (Niayes area). Groundwater salinization effects of these processes will be rather localized.

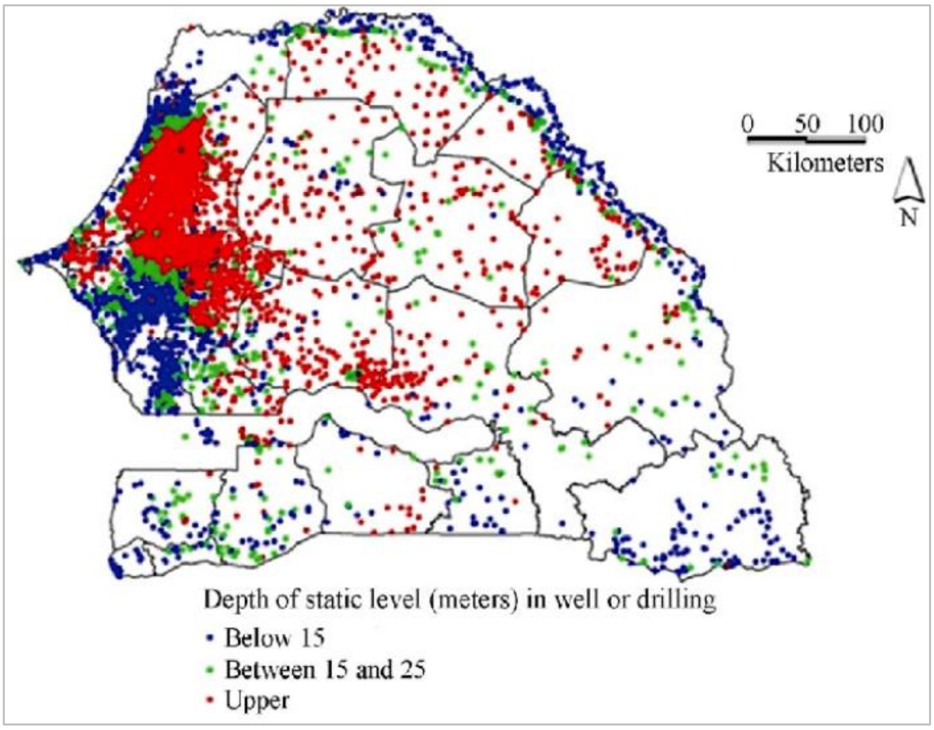

Figure 24: Map of water table depth[39]

In Senegal, agricultural and industrial activities affect the quality of surface water and groundwater that undergo also strong alteration due to chemical pollution from industrials effluents and used products in agriculture including pesticides and fertilizers. This depends on several factors: soil characteristics, irrigation, crops performed, regulation deficiencies, illiteracy of farm operators and funding facility of chemical inputs. These are sensitive problems in areas such as Senegal River Delta, Dakar, Mbour and Fatick etc. The studies carried out in the Senegal delta showed that the

[39] **ResearchGate**

river and distributaries channels are affected by mineral pollution from private irrigation discharges in the alluvial plain of Djeuss, pumping stations discharges of Ndong and Gaela on the Gorom channel and high mineralized drainage water discharge of sugar company in Guiers Lake.

Annual Freshwater Withdrawal (2013)	**2.611 Million m^3**
Annual Freshwater Withdrawal for Agriculture	**92.98%**
Annual Freshwater Withdrawal for Domestic Use	**4.412%**
Annual Freshwater Withdrawal for Industry	**2.611%**
Rural Population with Access to Improved Water Source	**60.3%**
Urban Population with Access to Improved Water Source	**92.5%**

Table 7: Groundwater withdrawal in Senegal[40]

4.2.6 Solar Irradiance

Senegal benefits from its strong potential for renewable energies which remains relatively untapped. Solar power represents a massive opportunity for development. Indeed, solar irradiation exceeds 2,000 kWh/m^2/year (for Global Horizontal Irradiance) across most of the country. Thus, Senegal has real potential for development and scaling up of photovoltaic projects. The highest solar radiation is around 2233 kWh/ m^2/year, whereas Saint-Louis which is in the Northern part of the country has 2179 kWh/m^2/year. Central part of the country has solar radiation of 2160 kWh/m^2/year while eastern part receives 2127 kWh/m^2/year. The highest global horizontal irradiance is in Dakar and Thies[41].

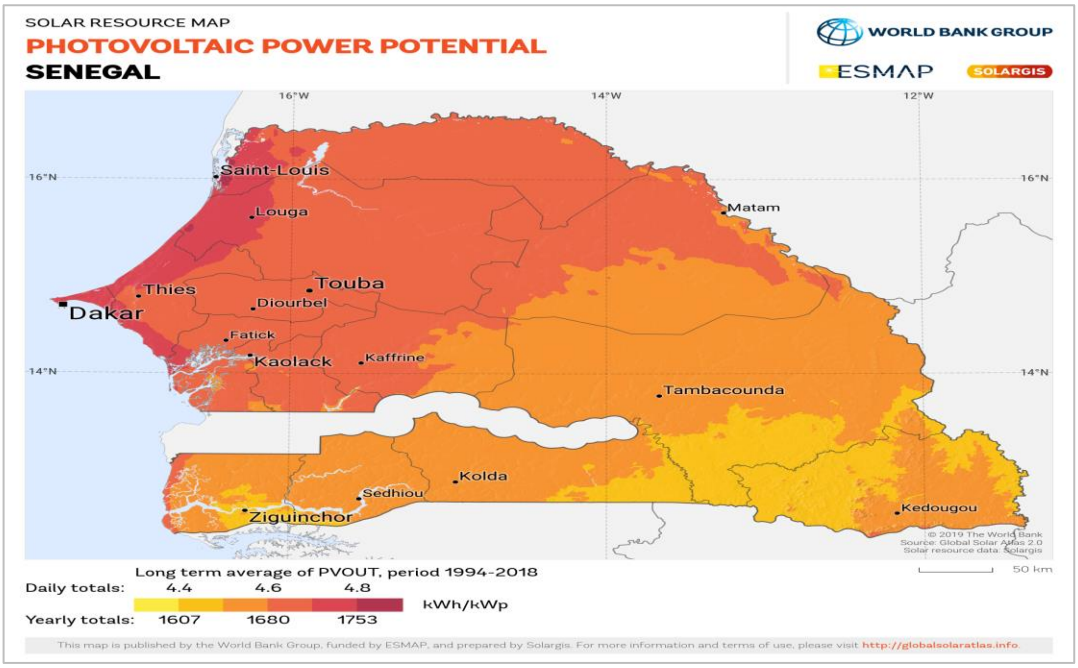

Figure 25: Photovoltaic Power Potential in Senegal

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40 International Atomic Energy Agency (IAEA)
41 International Journal of Advanced Research in Education & Technology (IJARET)

4.2.7 Agriculture and Cropping Pattern

The majority of farmers rely on rain-fed crops, though there are slightly over 1,000 square kilometers of irrigated land, out of a total of slightly less than 200,000 square kilometers of land in the country. Available surface water and runoff water provide potential to greatly expand irrigated agriculture. Senegal faces many barriers to agricultural production. First, the majority of Senegal's landmass lies within the Sahel region and is thus is arid (receiving 300-350 mm of rain per year) and extremely prone to drought. The Casamance region, south of Gambia, experiences more rainfall (1000-1500 mm per year); it is therefore an important agricultural area, but it lacks greatly in infrastructure and transportation. Soil quality throughout Senegal is generally poor, serving as an additional barrier to agricultural production[42]. And lastly, climate change trends have placed a strain on farmers: mean annual rainfall has been decreasing by 10-15 mm per decade and mean annual temperature has increased by 0.9°C since 1960, now hovering around 28 °C[43].

The majority of farming in Senegal takes place for subsistence, though peanuts, sugarcane, and cotton are important cash crops, and a variety of fruits and vegetables are grown for export and local markets. Gum Arabic (also known as acacia gum) is one of the largest agriculture export product. Peanuts are the most important crop in rural areas, accounting for around 40% of cultivated land and providing employment for around one million people. Millet, sorghum, and rice are major staple food crops.

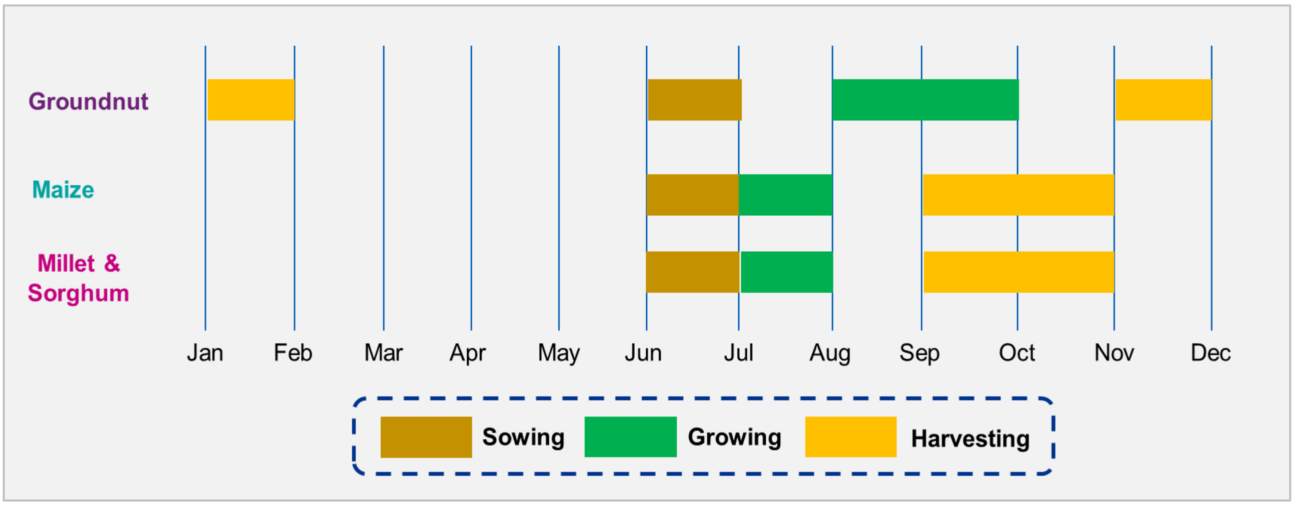

Figure 26: Cropping Calendar of Senegal[44]

As seen above, several of Senegal's major crops are sown between June and July, coinciding with the country's three-month rainy season (which runs slightly longer in southern regions). The "lean season," during which food insecurity is highest, coincides with the sowing season. Growing and harvesting take place during the dry season, which runs from September through May (October-April in the south).

Peanuts, sugarcane, and cotton are important cash crops, and a wide variety of fruits and vegetables are grown for local and export markets. Senegal is a net food importer, particularly for rice, which represents almost 75 percent of cereal imports. Production of food crops does not meet

[42] USAID
[43] World Bank
[44] Food and Agriculture Organization of the United Nations (FAO)

Senegal's needs. The production of major staple food crops covers barely 30% of consumption needs. Only in years of favorable rainfall does the country approach self-sufficiency in millet and sorghum, the basic staples with rice[45].

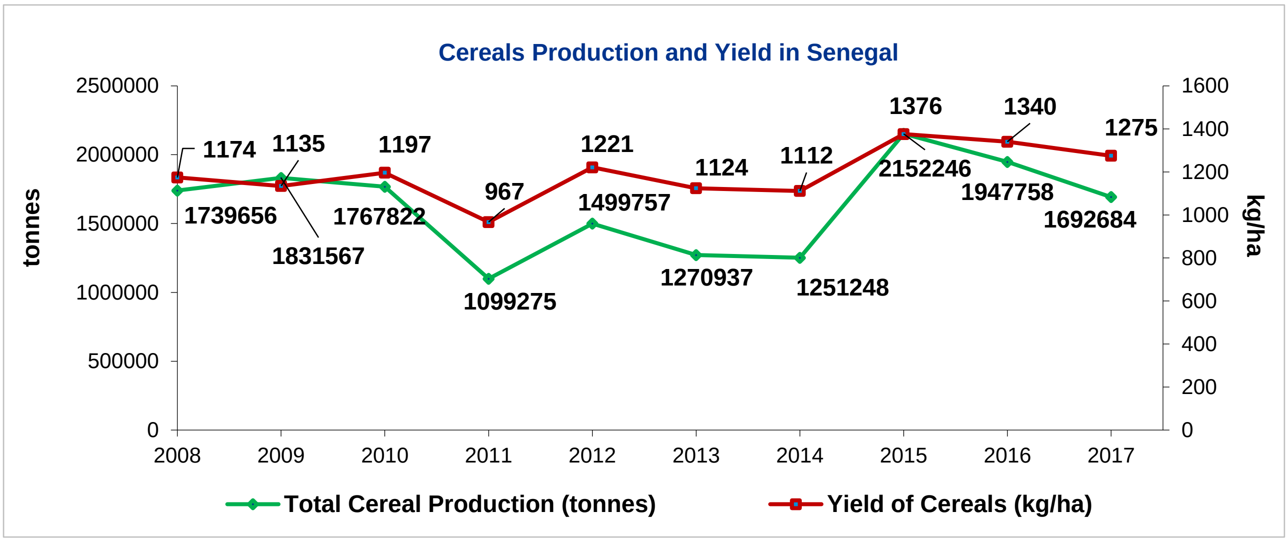

Figure 27: Cereal Production and Yield in Senegal[46]

Due to favourable rainfall conditions and timely provision of inputs by the Government, the 2018 cereal production is estimated at about 2.8 million tonnes, about 55 percent above average and 14 percent above last year's record. The major increases were observed in rice paddy and maize production. The good performance of the season is also explained by the increased access of factors of production, including the certified seeds and inputs which led to an increase in cultivated areas of 3 percent compared to 2017/18 and 22 percent compared to the average of the last five years. This has also contributed to increase the yields compared to the average of the past five years. To cover domestic demand, the country relies heavily on rice imports, which account for approximately half of the total domestic cereal requirements. On average, the country imports about 2 million tonnes of cereals, including about 1.2 million tonnes of rice and 0.5 million tonnes of wheat.

Peanut production accounts for around 40 percent of cultivated land, taking up about million hectares, and provides employment for as many as one million people. Although the peanut sector's contribution to foreign exchange earnings has dropped below those of fishing and mining, peanuts continue to play an important role in the overall economy as the main cash crop for many rural Senegalese farmers. Peanuts are processed locally, and prices of processed peanut oil and other peanut products are set by a government-controlled commission. Production of unshelled peanuts varies widely because of periodic drought, and production is frequently underreported because of unauthorized sales to processors in neighboring countries[47].

[45] **Senegal agriculture situation country report**
[46] **Food and Agriculture Organization of the United Nations (FAO)**
[47] **Senegal agriculture situation country report**

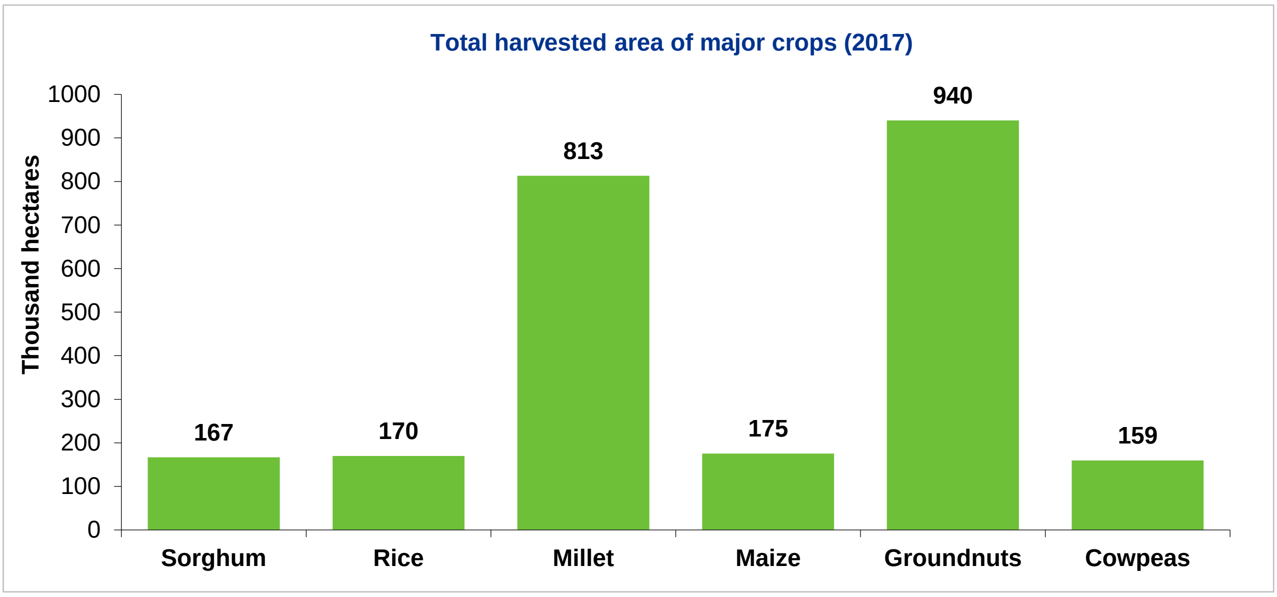

Figure 28: Total harvested area of major crops (2017)[48]

The economy of Thiès is essentially based on agriculture, fishing, tourism, industry, mining, handicrafts and trade. Among the productive sectors, agriculture occupies an important place in the economic and social life of the Thiès region. It occupies the majority of the regional population and is the main activity in rural areas. The Thiès region is a major agricultural production center thanks to its numerous hydraulic and soil potential. It mainly comprises three zones with agricultural vocation: (i) the Niayes coastal zone (with market gardening and fruit production); (ii) the central zone (with groundnut, arboricultural and cassava vocation) and (iii) the southern zone (with market gardening and food production).

The key crops grown by the farmers in the Niayes zones include mainly potatoes, tomatoes, onions, and carrots, etc. As the transportation hub of a productive agricultural hinterland – rice, peanuts, manioc, millet, and fruit, the city is a leading livestock-trading and meat-packing center. The Niayes zones have about 20,000 farmers for 8,000 hectares under cultivation. Fossil energy-based irrigation sources has led to low income levels of farmers and hence sustainable business models needs to be deployed.

[48] Food and Agriculture Organization of the United Nations (FAO)

5. Financial Feasibility Assessment

5.1 Proposed Project at a Glance

Senegal has submitted a demand for 4,000 Solar Pumping Systems against the call for Expression of Interest from ISA. The project will be implemented in Niayes (or "Thies") region in Senegal which is spread over an area of 8000 hectares. The demand was given considering 50% of the area with an estimation of one pump per hectare. A pilot project of around 100 solar water pumps has already been implemented by National Agency for Renewable Energies (ANER) in the region. Another 100 solar water pumps installation have also been realized by farmers themselves.

ISA recently concluded mission visit to Senegal to get a 'buy-in' for ISA's solar programmes and to understand the ground level challenges and issues. A five-member ISA Delegation visited Senegal during 30 September 2019 to 4 October 2019 to sensitize the relevant ministries and stakeholders regarding ISA's efforts and also to understand the current on-ground energy scenario to better assist the member country in their various solar initiatives. The ISA Delegation also visited a solar pump installation in Niayes zone wherein a farmer was using a 3 HP pump mainly for growing vegetables such as onions, tomatoes and potatoes. A diesel pump was also used as a backup irrigation option at a time of low solar radiation and for contingency situations. During the visit, detailed discussions were also held with a local farmer association namely Association of Niayes Vegetable Trade Unions (AUMN) who provided valuable insights and data points regarding the operation of the solar pump.

Figure 29: Pictures from the solar pump site visit in Niayes Zone

The data and information as provided during the site visit has been used as a basis for calculating feasibility in the base case scenario. The financial feasibility of solar pumps in the Niayes zone of Senegal has been captured by estimating incremental and cumulative cashflows thereby calculating the simple payback period achieved under different practical scenarios.

The proposed project details are as under:

S.No.	Particulars	Value
1	**Location**	Niayes zone located in Thies administrative division
2	**Financing**	Self-financing by farmers facilitated through a medium-term loan from a local agriculture bank. However, other alternative financing means may also be explored
3	**Facilitating agency**	National Agency for Renewable Energies (ANER)
4	**Crops**	Mainly vegetables
5	**Pump Size**	To be estimated but currently farmers are using solar pumps of sizes varying between 1-3 HP in the Niayes Zone
6	**Buyer of produce**	Senegalese companies marketing local produce, other local buyers
7	**Number of pumps**	4000
8	**Total land area**	4000 hectares
9	**Business Model**	Currently, the farmers are using solar pumps for their own individual use. However, other innovative models such as irrigation water as a service and community-based models may be explored
10	**Water table depth**	6-15 meters below ground level
11	**Advantages of implementing solar pump project in Niayes zone**	Appropriate weather conditions, optimum water table depth and close proximity to buyers
12	**Current solar pump penetration in the region**	Currently, there are 200 solar pumps in the region and around 80 solar pumps were installed through support from ANER
13	**Taxes**	Information on taxes to be shared by ANER. However, as per secondary research and news articles, the government has exempted customs, taxes and value added tax on solar water pumps
14	**Crop Insurance**	Available from local bank and is generally 2-3% of the system cost
15	**Other Information**	The water in the Niayes zone contains iron and hence robust pumps are needed for irrigation

5.2 Base Case Scenario

5.2.1 Inputs

S.No.	Particulars	Unit	Value
1	Pump Capacity (Diesel and Solar)	HP	3
2	Pump rating in kW	kW	2.24
3	Cost of solar pumping system	USD	6500
4	Cost of solar pumping system	CFA	3823365
5	Cost of diesel pump per HP	CFA	800
6	Price of diesel	CFA/litre	550
7	Pump cost as a % of total cost (in case of solar pump)	%	12%
8	VFD cost as a % of total cost (in case of solar pump)	%	12%
9	Interest Rate (for solar pump loan)	%	12%
10	Loan Tenure (for solar pump loan)	Years	3
11	Total Land Size	Hectares	2
12	Crops Grown		Onions, Potatoes
13	Land Size for Onions	Hectares	1
14	Land Size for Potatoes	Hectares	1
15	Plantation dates		June
16	No. of cropping seasons	Nos.	1
17	Average Yield for Onions	tonnes/hectare	35
18	Average Yield for Potatoes	tonnes/hectare	27.5
19	Market Price for Onions	CFA/kg	175
20	Market Price for Potatoes	CFA/kg	200
21	Replacement period of diesel pumpset	Years	9 years
22	CMC period for solar pump	Years	5
23	Replacement period of pump in case of solar pump	Years	9
24	Replacement period of VFD in case of solar pump	Years	11
25	Inflation Rate	%	3.90%

In the base case, it is assumed an individual farmer is using a 3 HP solar pump to irrigate a 2 hectares land for growing onions and potatoes (1 hectares each). The financing is supported by a local bank at an interest rate of 12% with a repayment period of 3 years. The case is a zero-subsidy scenario wherein there is no envisaged contribution from the government or from the facilitation agency. The entire capital cost is financed through bank loan with no upfront payment. We have considered onions and potatoes as the crops since the farmers in the Niayes Zone predominantly grow vegetables. There are approximately 20,000 farmers spread across 8000 hectares of land in the region with one pump being installed for each hectare. Almost every farmer has either a diesel pump or solar pump installed in his/ her field. Considering the same, we have compared the economics of diesel pump viz. a viz. a solar pump and calculated the simple payback period based on the cumulative cash flows. We have assumed 100% equity contribution from farmers for purchase of diesel pump. In the base case, yield improvement due to solar pumps has not been considered but the same has been analyzed in the sensitivity analysis as detailed below.

5.2.2 Projected Cash Flows

Cash Flows for Diesel Pump

Particulars	Unit	Year 1	Year 6	Year 11	Year 16	Year 21	Year 25
Revenue from crops-Onions	Million CFA	6.13	7.42	8.98	10.87	13.16	15.34
Revenue from crops-Potatoes	Million CFA	5.50	6.66	8.06	9.76	11.82	13.78
Capital Cost	Million CFA	1.57	-	-	-	-	-
Cost of diesel	Million CFA	0.10	0.12	0.14	0.16	0.18	0.21
Maintenance Cost	Million CFA	0.08	0.10	0.12	0.14	0.17	0.20
Net Inflow	Million CFA	9.87	13.86	16.79	20.34	24.63	28.71

Cash Flows for Solar Pump

Particulars	Unit	Year 1	Year 6	Year 11	Year 16	Year 21	Year 25
Revenue from crops-Onions	Million CFA	6.13	7.42	8.98	10.87	13.16	15.34
Revenue from crops-Potatoes	Million CFA	5.50	6.66	8.06	9.76	11.82	13.78
EMI Repayment	Million CFA	1.59	1.59	1.59	-	-	-
Maintenance Cost	Million CFA	-	0.02	0.02	0.03	0.03	0.04
Replacement Cost of pump	Million CFA	-	-	-	-	-	-
Replacement Cost of VFD		-	-	0.46	-	-	-
Net Inflow	Million CFA	13.22	14.06	16.56	20.61	24.95	29.08

5.2.3 Key Findings

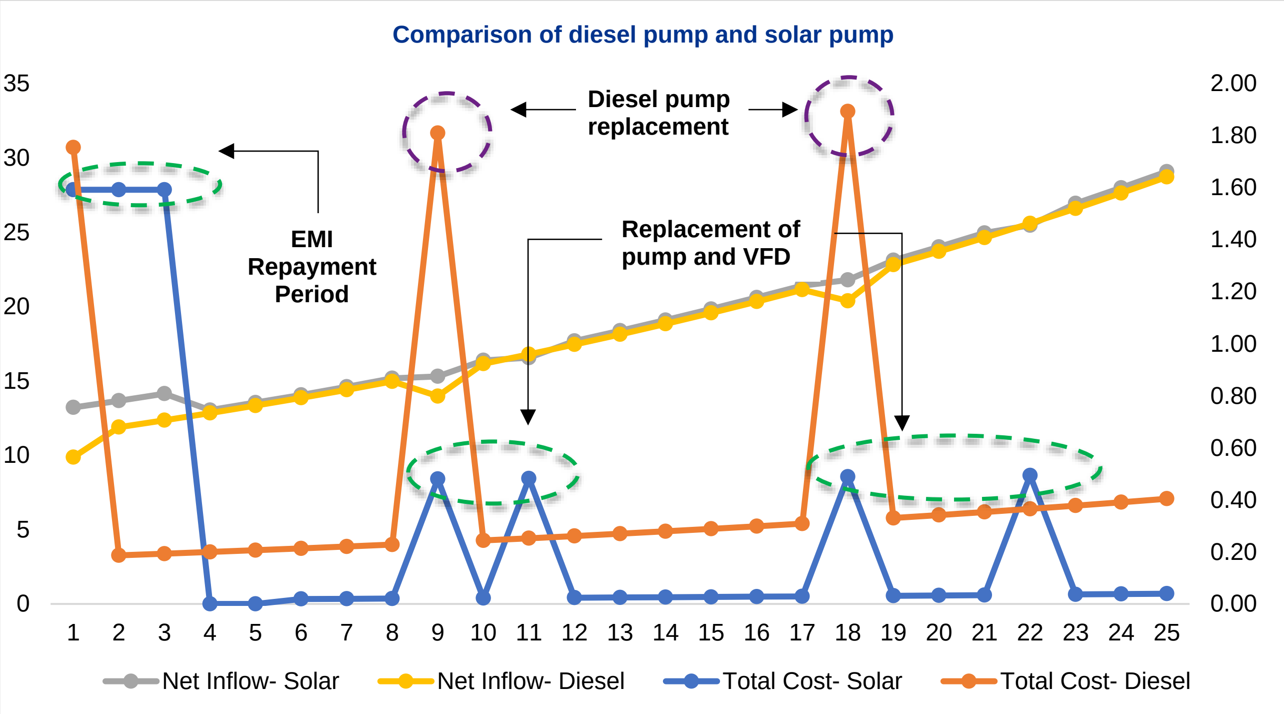

Figure 30: Comparison of diesel and solar pump in base case scenario

In the base case scenario, it is observed that while the differential in the net cash inflows of solar and diesel pump are minimal, there is substantial difference in the operation and maintenance cost of both pumps. In the first year the total cost of diesel pump is higher due to initial capital expenditure on diesel pump, in the next two years the total cost of solar is higher owing to higher EMI payments scheduled in the first three years of the project. Marked increments are seen in the total cost of both diesel and solar pump in the years of equipment replacement which is on expected lines. For the base case wherein, we have considered the crops of onions and potatoes, a total of 290 hours of operation is required considering the irrigation schedule which leads to a potential saving of CFA 0.10 Million on the diesel costs in the first year.

The payback period for the incremental cash flow of solar compared to diesel is 13 years in the current case being considered. There is a potential of reducing the payback period even further by optimizing the interest rates, crops and capital costs of solar pumps. These three drivers have been separately analyzed in the sensitivity section as detailed below. Further, in the base case we have considered no yield improvements due to solar due to which net inflows of both solar and diesel are almost similar; but in practical situations it can be expected that with higher yields in case of solar pumps, the gap of net inflows in both cases would be significant higher. This has been elaborated in the subsequent sections.

5.3 Sensitivity Analysis

5.3.1 Variation in Interest Rates

In case of non-subsidy or debt-equity hybrid models, the interest rate plays a major role in determining the feasibility of the system. In case of a solar water pumping system, since the operational cost of the pump is nearly negligible, the only major financial burden that farmer has to undergo is repaying the debt in the form of equated monthly installments. In case of Senegal, it is observed that the interest rate of 12% is significantly higher as compared to other countries in the region like Togo (5.1%), Niger (5.1%), Mali (5.1%), Benin (5.1%) and Ethiopia (8%)[49]. Since there is no subsidy or financial support being provided by the government, it is imperative for sound development of financial markets especially in the rural areas so as to provide concessional financing to the farmers. In many countries, lending rates for agriculture are significantly lower as compared to normal lending rates in a bid to boost agriculture productivity.

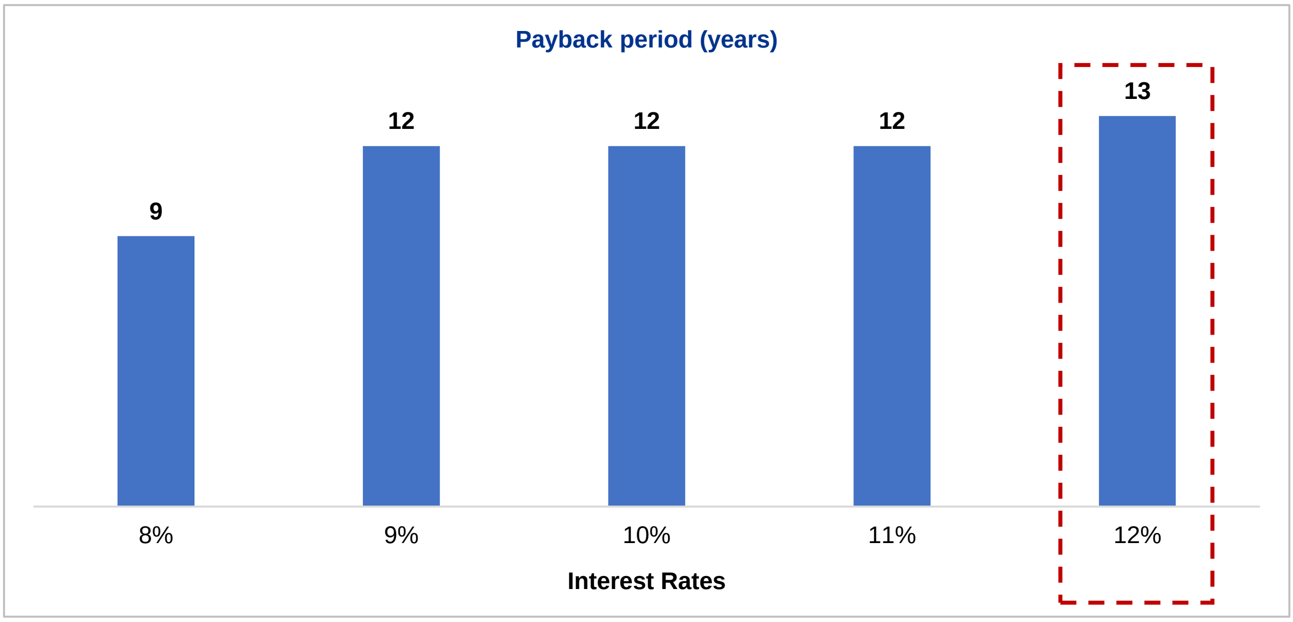

Figure 31: Variation in payback period with change in interest rates

It can be seen that the payback at the reduced interest rate of 8% is 9 years which is significantly lower as compared to payback of 13 years in base case scenario. It is interesting to note here that increasing the interest rate beyond 8% increases the payback period drastically from 8 years to 12 years. This shows that interest rate of 8% is an important threshold for increasing the viability of the project. ISA can hence facilitate reduced interest rate in Senegal through concessional financing options from multilateral, bilateral and donor agencies.

Another interesting insight from sensitivity analysis shows that if we replace the 3 HP by a 2 HP pump and analyze the sensitivity, the variation in payback period with interest rates is almost negligible. The payback period in case of a 2 HP pump, and keeping all other parameters constant is 9 years for an interest rate of 8-12%. Hence, in a situation where concessional financing options

[49] World Bank

are not available, farmers may be encouraged to use a 2 HP instead of 3 HP pump subject to sufficient meeting of their crop water requirements.

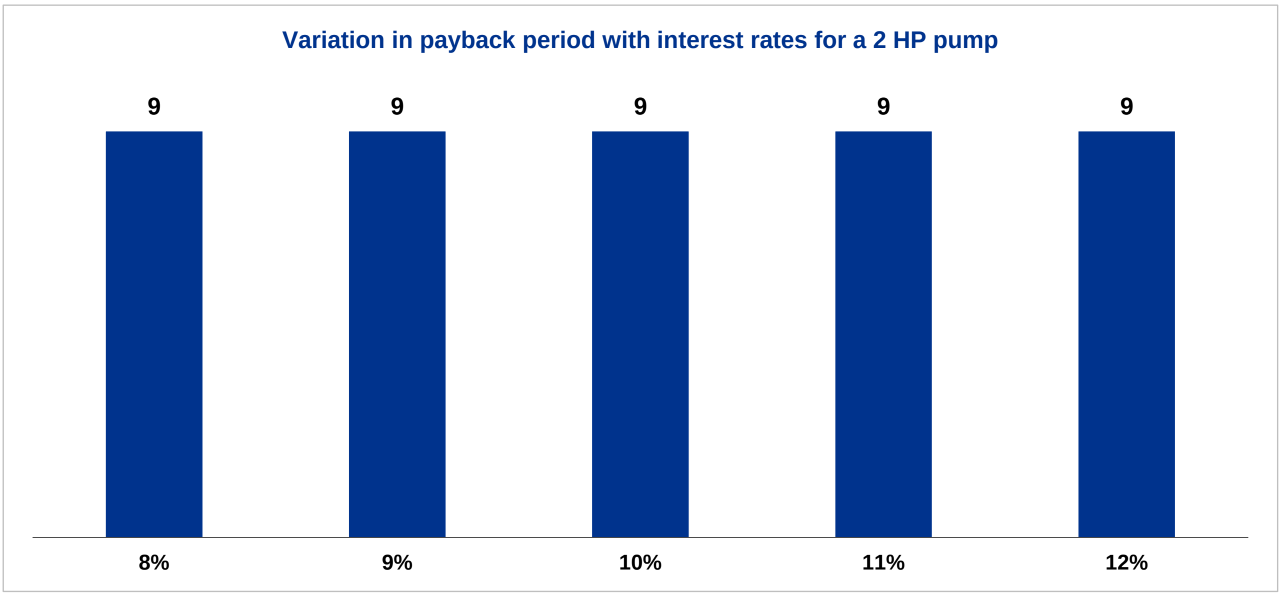

Figure 32: Variation in payback period with interest rate for a 2 HP pump

5.3.2 Variation in Capital Cost

High capital cost of a solar pump is one of the most critical barriers hampering the adoption of the technology. Especially in the African region where the markets for solar pumps are not developed yet, the costs of solar pumps are exceptionally high leading to their limited off-take. During the ISA Mission Visit, the capital cost as shared by the farmers was USD 6500 for a 3 HP solar pump. However, there is a huge variation in cost of a solar pump as obtained from secondary research and other sources. The costs of solar pumps as obtained from various sources is summarized as below:

S.No.	Pump Size (HP)	Cost (USD)	Source
1	0.1	669	GET.invest Market Insights
2	1	4252	GET.invest Market Insights
3	5	10595	GET.invest Market Insights
4	3	6500	Data collected during site visit
5	0.5 (Africa Sun)	2519	World Bank
6	0.4 (Lorentz)	1819	World Bank
7	0.2 (Difful)	1542	World Bank
8	0.2 (Mini Volanta)	2236	World Bank
9	0.8 (Solar Tech)	2206	World Bank
10	1	2621	L1 prices discovered in the ISA tender
11	2	2941	L1 prices discovered in the ISA tender

S.No.	Pump Size (HP)	Cost (USD)	Source
12	3	3898	L1 prices discovered in the ISA tender
13	5	5044	L1 prices discovered in the ISA tender
14	7.5	7492	L1 prices discovered in the ISA tender
15	10	9533	L1 prices discovered in the ISA tender

Table 8: Prices of solar pump in Senegal

As seen above, the prices discovered in the International Competitive Bidding conducted by ISA are almost 30-40% lower than the prevailing local market costs. This signifies huge potential for increasing the project viability since reduced capital costs will have a significant bearing on the payback period. The payback period in the base case scenario is 13 years where the capital cost considered was USD 6500 for a 3 HP pump. This reduces significantly to 7 years with ISA discovered L1 price of USD 3898. The variation in prices in various scenarios is elaborated as below:

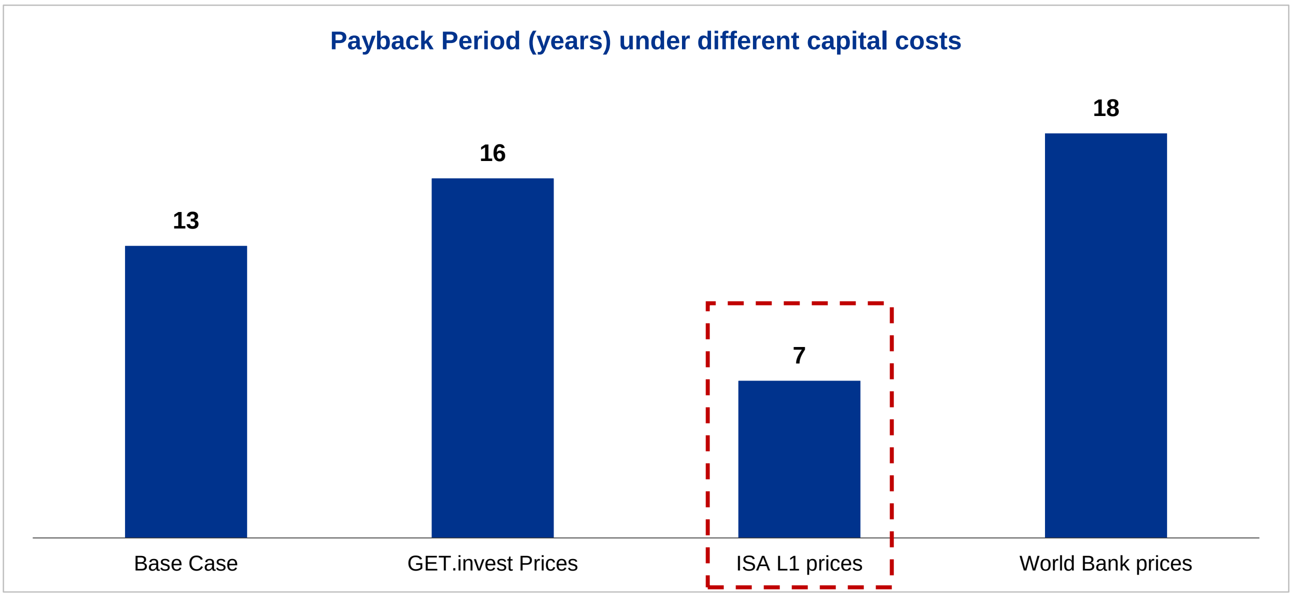

Figure 33: Variation in payback period with change in capital cost

As can be seen above, the implementation of solar pumps in Senegal at ISA discovered L1 prices significantly improves the viability of the project. Hence ISA in coordination with ANER can work together for finalizing the business model and implementation plan for executing the project at these prices. The project can also act as a catalyst for reduction of prevailing prices in the local Senegalese market.

5.3.3 Variation in Crops

With the advent of solar pumps, it is generally observed that due to reliable irrigation supply, efficiency of irrigation improves thus leading to improved crop productivity. Past studies have shown yield improvement in the range of 5-10% in case of solar pumps compared to diesel. The yield improvement if incorporated in the analysis, leads to significant improvement in the payback period owing to the increased incremental revenue due to higher crop produce. The payback period reduces from 13 years in the base case scenario to 5 years at 2% yield improvement and 3 years at 10% yield improvement.

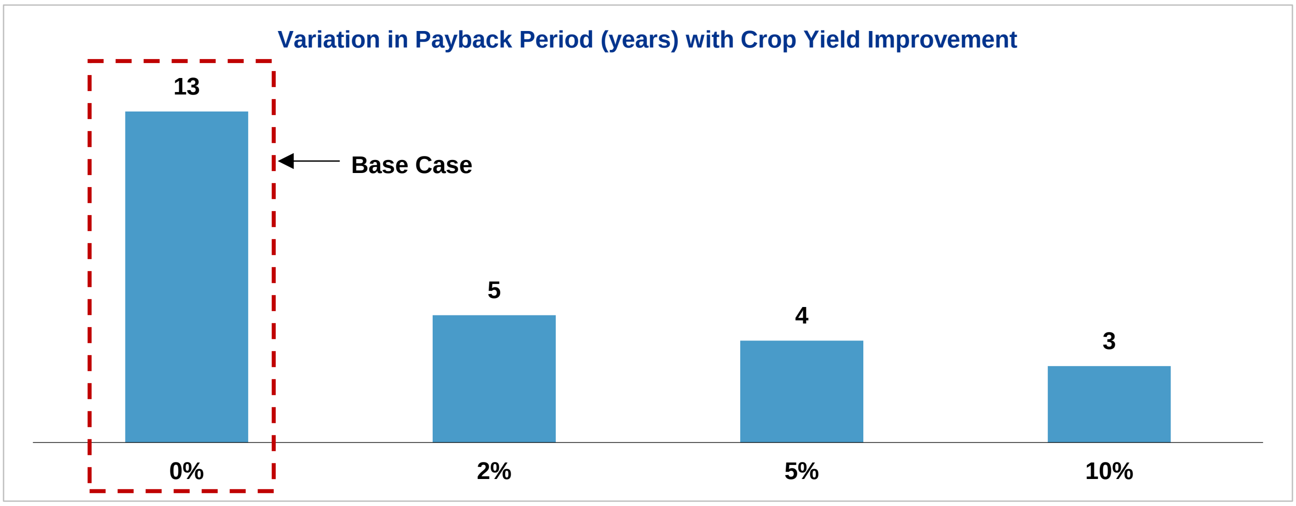

Figure 34: Variation in Payback Period with change in Crop Yield Improvement

Even with changes in the type of crops grown by the farmer, the payback period changes significantly. It is generally recommended to grow horticulture crops along with solar pumps for maximizing the profitability of the overall project. In the Niayes Zone, it is suggested to grow vegetables such as onions and potatoes because of their exceptionally high yield due to ideal climatic conditions. Onions can also be combined with paddy to optimize the returns or groundnut to further reduce the payback period. There is a potential to increase the harvest of groundnut in which occupies a driving position in Senegal's economy. Other benefits can also be realized by growing paddy, currently the consumption of which is highly import driven. Hence, by using solar pumps for paddy, Senegal can reduce the import expenditure leading to forex savings. However, since paddy is a highly water intensive crop, proper and optimal pump sizing should be undertaken to determine the capacity of the pump required for irrigation.

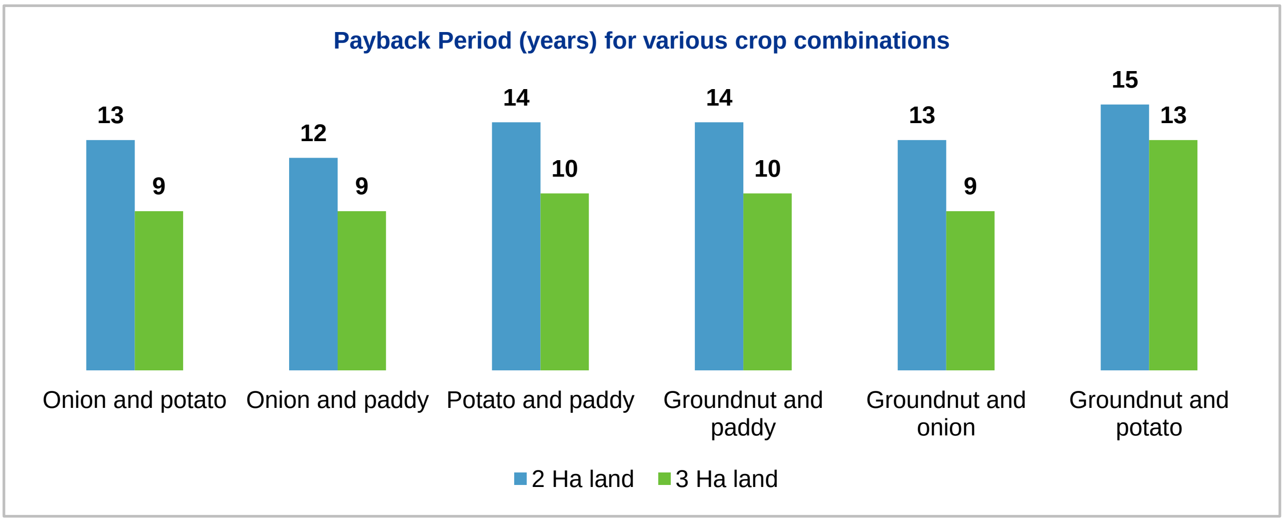

Figure 35: Payback Period for various crop combinations

In such situations, increasing the land size of the high value crops can further lead to reduction in payback period. The case in point being the combination of groundnut and onion which has a payback period of 9 years if grown on 3 hectares of land (1.5 hectares each) compared to a payback of 13 years if grown on 2 hectares. Thus, farmers can be encouraged to increase the area under irrigation for maximizing the returns from the project. It is suggested that ANER may carry out detailed study in the Niayes Zone so as to arrive at the optimal crop and land size combination for each of the identified farmers.

6. Recommendations

Based on the results of the technical and financial feasibility assessment and other prevalent local conditions, the key recommendations for implementation of solar pumps in Senegal is as follows:

1. Feasibility

It is observed that implementation of solar pump initiative in Niayes Zone of Senegal is economically viable and implementable. Niayes Zone boasts of ideal climatic conditions, vicinity to buyers, and low water table depth which makes the region ideal for installation of solar pumps. Further, the region is ideal for growing vegetables which has significantly higher yield and thus opportunity for enhancing farmer's income. The market in and around Niayes is fairly developed and established and hence the crop produce is already ready with all the required market linkages. The payback period observed is 13 years in base case scenario and there are many options to optimize this even further by selecting the right combination of crops and land size.

2. Optimal Pricing

The ISA discovered prices are 30-40% lower than the current prevailing prices and has a payback period of 7 years which is significantly less than that of 13 years in case of base case scenario. While detailed analysis on the applicable taxation has not been carried out, there is a possibility of lower payback period even with minor taxes on solar equipment. However, it is recommended to keep the taxes at the bare minimum so as to optimally utilize the returns from the lower ISA discovered L1 prices.

3. Adequate Pump Sizing

The optimal size selection of a pump is extremely important for analyzing project viability since it determines the number of hours of required operation as well as the irrigation schedule. Lower of higher size of solar pumps may lead to under/ over utilization of pumps leading to operational issues and exploitation of ground water. Hence, it is recommended that ANER carried out detailed analysis and research for assessing the required pump sizing for each of the individual farmers. Further, since the water in the Niayes Zone contains Iron, hence robust pumps designed for high stress situations are required for implementation in the fields.

4. Training and Capacity Building

The solar pump market is still at a very nascent stage especially in Africa and hence there is need of increasing the awareness of the technology through capacity building and training sessions. The Niayes Zone in Senegal has a fairly developed penetration of solar pumps with 200 solar pumps already being installed on ground by ANER and farmers. Still, it is recommended to strengthen this further by organizing regular training and knowledge building sessions with the farmer. ANER, having already overseen the pump installations earlier, can act as a nodal agency for facilitating the same.

5. Monitoring and Verification

Robust processes need to be incorporated and established for regular monitoring of solar water pumping systems. It has been observed that in many countries solar pumps are not being utilized to their full potential due to low and inadequate asset utilization. In some cases, there has been significant jump in groundwater extraction due to overutilization. These instances need to be closely observed to ensure that the local ecosystem is not hampered as a result of solar pump installation. Remote Monitoring Systems (RMS) needs to be in place to ensure regular collection of usage data. Farmers can also be encouraged to grow better/ high value crops based on the data collected from the site. Thus, there is an opportunity for overall strengthening of the business model through robust monitoring mechanisms.

6. Business Model

As can be seen from the analysis above, a reduction in the rate of interests gives a lower payback period to the farmers. Hence, alternate financing mechanisms or concessional financing from bilateral and multilateral funding agencies can be explored to reduce the lending rate for the farmers as it is comparatively high in Senegal as compared to other countries. Further, some demonstration pumps can be set up where farmers can be shown the viability of growing the higher value crops with better yield improvements. The production of groundnut, which is one of the most important agricultural crops of Senegal, can also be improved by utilizing the solar pumps owing to improved yields and availability of a reliable water supply. It is recommended that ANER acts an implementing agency for the entire program as they have the experience of implementing other similar programs in the past and has good local knowledge and understanding of the various profiles of the farmers, markets and other local conditions of the region required for the implementation of the program. Initially, only a few pumps may be set up in the pilot mode which can be then scaled up to 4000 pumps as requested by Senegal.