"CLIENT II - International Partnerships for Sustainable Innovation"
LoSENS: LOCAL SUSTAINABLE ENERGY NETWORKS IN SENEGAL

LoSENS

Energy & Climate Protection Master Plan

Balingore Municipality

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COMMUNE DE BALINGORE

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SUBJECT:	***Energy & Climate Protection Master Plan – Balingore***
LOCATION:	Municipality of Balingore, Senegal
CATEGORY:	Knowledge Transfer and Feasibility Assessment
SYNOPSIS:	This report presents the findings of ***Balingore Municipality case study*** as part of ***"Local Sustainable Energy Networks in Senegal"*** project with the objective of developing ***an Energy and Climate Protection Master Plan (ECPMP)***. This ECPMP provides a holistic, comprehensive methodology of planning for Balingore's current and future energy needs as a showcase for further rural regions in Senegal to duplicate. The ECPMP identifies and evaluates the municipality's current energy uses, consumption and actual needs. It identifies inefficiencies and provides concrete demonstration solutions to help the commune achieve greater value based on a feasible and realistic return on investment for the identified projects. The methodology deployed at large is Material Flow Assessment where different site measurements and investigations contribute to the establishment of a base data representative of the status quo for the Municipality of Balingore in all sectors relevant energy.
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BAT	Best Available Technology
CDM	Clean Development Mechanism
COPERES	Business Council of Renewable Energies of Senegal
CRS	Crop Residue Surplus
ECPMP	Energy and Climate Protection Master Plan
GHG	Greenhouse Gas
FAO	Food and Agriculture Organization
IEC	International Electrotechnical Commission
IRENA	International Renewable Energy Agency
KPI	Key Performance Indicator
LCOE	Levelized Cost of Energy
LED	Light Emitting Diode
LHV	Lower Heating Value
LoSENS	Local Sustainable Energy Networks in Senegal
LPG	Liquefied Petroleum Gas
MFA	Material Flow Analysis
PDC	Plan de Développement Communal (Municipal Development plan)
PROMESS	Professionnels pour la Maitrise de l'Energie Solaire et Solidaire (Professionals for Solar and Solidarity Energy Management)
PV	Photovoltaic
RE	Renewable Energy
RPR	Residue-to-Product Ratio
SDG	Sustainable Development Goal
SENELEC	Senegalese National Electrcity Company
SF	Surplus Fraction
SONAGED	Société National de Gestion Intégrée des Déchets (National Integrated Waste Management Company)
SMEs	Small and Medium-sized Enterprises
UCG	Waste Management Coordination Unit
WW	Wastewater
WMC	Waste Management Concept
ZE	Zero Emission

1 Executive Summary

LoSENS project aims to strengthen cooperation between Senegal and Germany in sustainable energy systems, focusing on technical knowledge and technology transfer. Balingore's ECPMP provides a platform for implementing sustainable solutions, while feasibility analysis helps avoid transfer and cooperation difficulties between Africa and industrialized countries.

The ECPMPs highlight local energy system needs and encourage investment in innovative solutions, particularly from Germany. Demonstrations exhibit German solutions in operation, forming a basis for practical training. In Senegal, transfer of technical standards, social acceptance, and system performance are key research questions.

The ECPMP of Balingore municipality is based on the Saint Louis Model. Furthermore, this report issued by conducting a case study which focuses on performing a techno-economic analysis of a photovoltaic to power the three villages of Balingore, Mandégane, and Bagaya situated in Southwest Senegal. Additionally, water distribution is a very crucial concern of the community, thus an efficient and continued pumping system with PV is taken into consideration. Furthermore, to fulfill the energy demand of this rural region, a study of biogas production was analyzed. In general, the techno-economic analysis aims to identify the optimal system configuration according to the available resources, its total net present cost, and savings.

A summary of status quo analysis is demonstrated in the first section to allow for a holistic and comprehensive approach to the energy access problematic in this rural area. In order to start with the development of a data base of all accessible inventories relevant to the energy sector in the defined system boundaries, a survey was conducted in the municipality for the three villages. The second section of this ECPMP presents the strategies and actions to be taken in order to overcome the regional gaps for a sustainable future. The study ends with putting highlighted future recommendations for efficient energy networks guided by a clear set of goals and a compelling vision that reflects the aspirations of the community. By incorporating these goals and vision into the master plan, the village region can lay a solid foundation for an efficient energy network that supports sustainability, resilience, and equitable access to energy for the entire community.

The examination conducted in Balingore municipality clearly indicates that rural areas can undergo development by reducing emissions, specifically 34 t CO_{2eq} annually, through the implementation of a photovoltaic (PV) plant for water pumping. This approach also results in the conservation of 39.1 MWh/a of electrical energy. Additionally, addressing the electrical needs of this region could involve the strategic combination of a solar installation with a biogas plant. This integrated system not only enhances the utilization of organic waste but also generates electrical energy during periods of insufficient solar production. The estimated electricity output from the PV system is 155 MWh/a, leading to an emission reduction of 134 t CO_{2eq} annually. To bridge the energy demand gap of 386 MWh/a, biogas will contribute, requiring 2,396 tonnes per year of biowaste and resulting in a mitigation of emissions amounting to 73 t CO_{2eq} annually.

2 Introduction

In recent times, the call for sustainable development and a swift transition to renewable energy has gained prominence. Rural areas, with untapped potential and unique challenges, offer a significant opportunity for establishing efficient and sustainable energy networks.

Senegal, a focus of the LoSENS project, faces a substantial energy access gap between rural and urban areas, hindering progress toward Sustainable Development Goals (SDGs). Despite utility grid extensions being a viable solution, Senegal grapples with inadequate national production and aged infrastructure, resulting in power outages and economic losses. This leads rural populations to turn to alternative energy sources, increasing dependence on fossil fuels with associated health and environmental risks.

Senegal's energy sector ambitions present business potential for Germany's environmental technology sector. However, introducing German technologies abroad requires country-specific adaptation. The LoSENS project advocates a "pull strategy," fostering local demand for innovative solutions. The project, centered around Balingore in southern Senegal, distinguishes between urban and rural models, tailoring energy-efficient solutions based on varying factors.

The master plan for the rural Senegalese model community (Balingore, Bagaya, and Mandégane) aims to identify needs and implement solutions using sustainable German technologies. Aligning with SDGs 7, 11, 12, and 17, the plan seeks to create a comprehensive framework for sustainable development, addressing global challenges.

The project prioritizes stakeholder engagement for collective efforts, emphasizing collaboration, capacity building, and inclusive decision-making to empower the community. It encourages collaboration among stakeholders, including local governments, energy providers, and community organizations, for successful implementation and long-term sustainability.

Ultimately, the master plan outlines a strategy for transforming the chosen rural area into self-sustaining, energy-efficient communities. It focuses on reducing reliance on fossil fuels and promoting widespread adoption of renewable energy technologies, leveraging natural resources specific to rural regions for an optimized energy network.

3 Methods Applied

The work undertaken in this ECPMP employed two key methods. They are: a.) Material Flow Analysis (MFA) as the base-method and b.) sector specific methods of Clean Development Mechanism (CDM) for greenhouse gas (GHG) impact assessment (*CDM: Documentation*, 2022). In addition, the following five-step general procedure was employed in the assessment and deployment of the aforesaid methods:

I. Identification and definition of the 'system' to be analyzed and characterized by the temporal and spatial boundaries.

II. Data procurement and Material Flow Analysis (MFA) in order to characterize the status quo system.

III. Identification of optimization potentials in order to apply efficient and effective management strategies and technologies (on best available technology [BAT] basis).

NOTE: optimization actions are clearly categorized according to the respective material and energy flows and treated as an individual project for the ease of reference, assessment, and management.

IV. Economic pre-feasibility assessment of the identified improvements/projects.

V. Evaluation of the environmental performance (GHG impact) of the proposed project against the respective status quo.

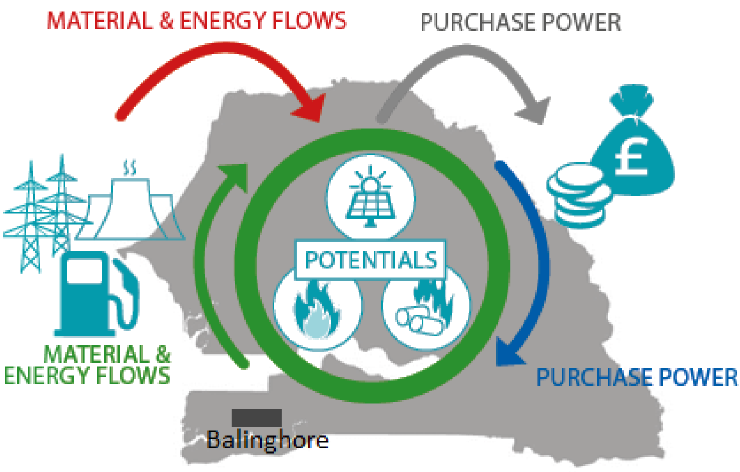


Figure 1 | Material Flow Analysis Vision and Goal Illustration, (© IfaS)

As part of project success controlling, various qualitative and quantitative key performance indicators (KPI) are determined, and the respective degrees of fulfillment are determined. For an evaluation, the respective indicators must be supplemented with target values to be achieved. The determination of concrete target values is closely linked to the individual result values, which are only available after the first steps have been taken in the development of the master plans (current status, future needs and available potential). This is intended to avoid setting unrealistic or too small target values. The determination of the target value is therefore an iterative process. This means that the measurability of the indicators must be considered at an early stage, but a concrete value can only be determined through constant feedback of the respective analysis results.

This master plan focuses on the electrification of the rural municipality of Balingore case study. The rural electrification project contributes to Senegal's target of reaching universal electrification by 2025. This project aims to making it a zero-emission, fully electrified community, using 100% renewable energies powered system with the most competitive Levelized Cost of Energy (LCOE) possible. Other objectives of the project include creating regional added value by employing local fuels and being more independent from fossil fuels, in addition to creating job opportunities in the context of the project for the inhabitants of the villages.

The following are the main work packages of this master plan:

A). WP 1: Status Quo Analysis

a. Describing current situation
b. Using survey by PROMESS
c. Some data also based on PDC or online research
d. Gaps extraction and targets (define key actors)

B). WP 2: Strategies and Actions for Balingore municipality

a. Sustainable public street lighting
b. Solar power potential
c. Water distribution
d. Biogas generation

4 Constraints & Limitations

In the absence of a standardized database with up-to-date data relevant to the energy sector in Balingore municipality, inventories from the municipal services were used in addition to surveys previously conducted in the system boundaries. However, multiple data anomalies were detected during the field inspections to verify data quality and completeness. This includes erroneous recording, calculation errors, misinformation etc. Thus, data verification and collection were done onsite. Note that only example projects (i.e., related to the demonstration projects) are developed representative of each energy and material flow category due to the size of the system boundary, the scale and scope of work, and other constraints in perspective with the deployed resources for this investigation. The work's results clearly show that, in order to accomplish the desired sustainability networks, shift for the municipality of Balingore, the projects could be scaled to encompass 100% of the system boundary.

On the other hand, the project was lunched before the Covid pandemic. Afterward, onsite visits for measurements and installations were affected by the health restrictions. Other constraints were impacting the entire project such communication with some Senegalese stakeholders which leaded to have lack of accurate data.

NOTE: It is important to address these constraints and limitations during the development and implementation of the master plan to enhance its chances of success and to ensure its alignment with the evolving needs of the municipality and its residents.

5 Status Quo Analysis

5.1 Site Description

The rural municipality of Balingore is located in Casamance, southwest of Senegal. It is part of the district of Tendouck, in the department of Bignona, belonging to the region of Ziguinchor (see Figure 2). It encompasses three villages: Balingore which is the capital of the municipality, Mandégane and Bagaya as shown in Figure 3. The municipality spreads over an area of 79.4 km^2 which is equivalent to 10% of the district in terms of area (Commune de Balingore, 2022).

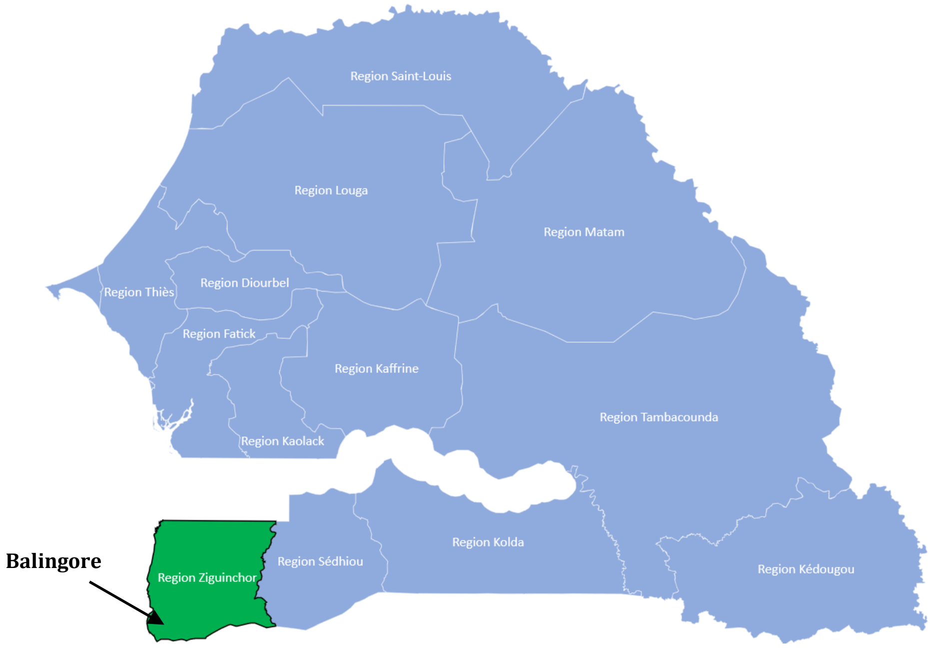


Figure 2 | Location of Ziguinchor Region in Senegal, (© IfaS)

Figure 3 | Three Villages Location of Balingore Municipality, (© Google Satellite Image)

Table 1 describes the climate and population of the Balingore municipality[1]:

Table 1 | Climate and Population of the Balingore Municipality

PARAMETER	VALUE	UNIT
Climate type	Savanna	-
Rainfall	800 - 1700	Mm
Temperatures	18 - 38	°C
Number of inhabitants	7,305	Inhabitants
Population density	69	inhabitants/km^2
Number of households	649	households

Referring to the municipal development plan, the three villages Balingore, Mandégane and Bagaya have respectively 43%, 38.5% and 18.5% of households in the municipality. In order to evaluate the status quo of regarding energy systems, waste management, and household practices in the Balingore municipality, the organization PROMESS[2] (Professionals for the Control of Solar and Solidarity Energy) conducted a survey during March 2023. The mission took 142 households (21.9% out of 649 households) as representative scale of data inventory.

NOTE: Most of the data during the master plan report are taken from the survey done by PROMESS as well as the PDC of Balingore municipality.

The survey showed that families are consisting of approx. 10 individuals per household, Moreover, the average income of a family is 67,629 XOF which is equivalent to €103.09. In these villages, houses exist in small groups. The most common construction materials for houses are concrete and soil bricks and the type of roofs used is zinc, regardless of the construction materials used for the house. Figure 4 displays a view of typical households in the region.

[1] Source : Plan de Développement Communal (Municipal Development plan)-PDC 2022
[2] CEFAIMER/PROMESS : Centre de Formation, d'Application et d'Incubation aux Métiers des Énergies Renouvelables- https://promess-senegal.org/

Figure 4 | Typical house in the Municipality of Balingore, (© IfaS)

The village of Balingore is the largest of all three and has the largest population. Mandégane is 5 km southwest of Balingore, it is second in terms of population. Bagaya is located at about 8 km southwest of Balingore, between Mandégane and Diatock.

The main economic activity in the region is agriculture. Agricultural lands are often plots of less than 1 hectare, independently managed by families or groups of families in a neighborhood. Other more ambitious farmlands of 3 to 8 hectares are being projected with more adapted equipment like solar pumps[3]. Most farms are rice and vegetable farms or mixed farms with orchards.

5.2 Stakeholders

The following represents the stakeholders for the main key actors that are typically involved in LoSENS project of Balingore municipality model:

I. Public lighting:

A). The municipality's technical services

The municipality's technical service was responsible for the provision of some data necessary for the simulation of the PV systems.

B). Population

The present study is aimed at evaluating the feasibility of public lighting. In case of latter system realization however, they will contribute to improving the safety of inhabitants and their properties, and also enhance the freedom to carryout outdoor activities, especially at night and early hours of the morning.

C). Lamp Supplier

[3] Survey conducted for an energy diagnosis in the Balingore municipality.

Lamp Supplier, with its relatively low cost and highly efficient streetlamps are potential lamp supplier in case of the implementation of this project.

D). PROMESS

They carried out surveys and made available information about the status quo of streetlighting in the municipality of Balingore.

II. Water distribution & solar energy

A). **Bonergie**

This company is a potential stakeholder in the provision of solar PV needed by the solar pumps for the pumping of potable water throughout the municipality.

B). PROMESS

As a youth training association in the domain of renewable energies, they are responsible for the continuous training of youth responsible for the monitoring of the PV pumping systems. This ensures continuity in the operation of the pumping systems. They also provided status quo information about the solar PV pumping systems during the design phase.

C). Community members

They are the principal beneficiaries of the water distribution systems.

III. Biogas production from biowaste

A). PROMESS

It helped in gathering data for farms and household waste, type and quantity of biowaste, and waste management methods.

B). Community members

They are the principal beneficiaries of the waste management as well as biogas productions for energy.

NOTE: The implementation of this project will require the consultation and authorization of various government authorities in and out of the Municipality of Balingore.

5.3 Energy Resources and Systems

Introducing reliable and sustainable energy systems for rural areas is essential for promoting economic growth, improving living conditions, and enhancing the overall quality of life for rural communities. By implementing such energy systems, we can address the challenges faced by rural areas in accessing electricity and fuel sources.

This key actor will not only bridge the energy gap but also contribute to environmental sustainability by reducing dependence on fossil fuels and minimizing greenhouse gas emissions. It will empower rural communities, promote inclusive growth, and enable them to participate more actively in social, economic, and technological advancements.

In this regard, the various sources of energy utilized in the municipality of Balingore are solar, firewood, butane gas, charcoal, thermal, diesel, and the grid. The three villages are connected to the grid which is supplied by the National Company of Electricity of Senegal (SENELEC). All the region is electrified, however; few 2% out of 142 households do not use grid electricity because they are simply not able to afford it[4].

The survey shared insights on households' other mean of electricity used in their daily life. Only 7% use photovoltaic system to generate energy. To overcome the electricity bills and financial issues, an observed number of households still relying on candles for illumination. Accordingly, the average cost of the bimonthly invoice for household is 11,909 XOF (€18.30) which is equivalent to approx. 65 kWh.

Upon analyzing the field-collected data, it has been determined that household and other type of buildings within the Balingore municipality consumes around 780 kWh annually. In contrast, the overall electrical energy demand for the entire Balingore municipality is estimated at nearly 541 MWh/a.

The three villages consist of few types of buildings with less energy consumption such as schools, administrative buildings, private enterprises (shops, welder…), and health care centers. However, no large industries are existing in this rural area which means that the energy demand is low compared with urban regions.

Most buildings in the municipality are powered by the grid. Schools use electricity from the grid, while health centers of Balingore and Mandégane have solar PV as principal source and diesel as secondary.

NOTE: The locality experience frequent power outages, and the majority of inhabitants prefer a continues power supply, even if they would have to pay more. Therefore, solar power is highly welcomed by the Balingore community.

On the other hand, the supply of butane gas in the region is very low, therefore firewood and charcoal are the most predominant sources of heat for cooking, with over 70% of households using more than 5 kg of wood per day[4]. Furthermore, food conservation is mainly done with refrigerators or drying. Table 2 demonstrates the statistics of energy consumption in households:

Table 2 | Energy Source for Cooking in Households

PARAMETER	***VALUE[4]***	***UNIT***
Firewood as energy source for cooking	92.3	%
Other fuel types (Butane or Propane, charcoal, etc.) for cooking	7.7	%
Refrigerators usage rate	50	%
Sun drying technic rate	49.3	%

[4] The result is extracted from the survey of 142 households.

NOTE: In the farming sector, most agricultural lands and animal farms have no access to electricity. Referring to the survey, few of them possess solar pumps system as a means of irrigation.

5.4 Public Lighting System

Introducing public street lighting for rural areas is crucial to enhance visibility and ensure safety during nighttime. By implementing this initiative, it is necessary in this master plan to provide a well-lit environment analysis that promotes community well-being and enhances the quality of life for residents. The introduction of public street lighting will not only improve visibility but also contribute to the overall development and modernization of rural areas, making them more attractive for residents, businesses, and visitors alike. An illustration of the presently available streetlight systems is shown in Figure 5.

Figure 5 | Presently available Streetlight Systems, (© IfaS)

The status quo of the three villages consists of 5 principal avenues which possess 95 public lamps and small streets without public lighting. They are all connected to the grid, however; 32% of them are not functioning. Some lamps dates from 2002 and the newest ones are since 2017. As a remark from the survey, the systems are not properly maintained. The following table illustrates the inventory of streetlight systems in some streets of the municipality:

Table 3 | Inventory of Streetlighting System for Some Streets in the Balingore Municipality

VILLAGE	STREET NAME	TARRED / NOT TARRED	TOTAL LAMPS	TOTAL FUNCTIONAL LAMPS	YEAR OF INSTALLATION
Balingore	Etecom-Balimbande	Not tarred	15	05	2002
	Kaouwa	Not tared	30	30	2002
Mandégane	Elegnine	Not tarred	25	5	2017
	Djikess	Tarred	15	10	2017
Bagaya	Etecom-Balimbande	Not tarred	10	10	2002

As type of designing material of the lamps, some are wooden poles and others are with concrete. On the other hand, asphalt and track are the two types of lighted streets' roads. These conditions of streets have a crucial role for the light quality.

NOTE: The majority of non-operating lamps are the ones installed in 2017. The current lamps type and technical sheet are not provided by the municipality.

5.5 Potable Water and Pump Efficiency

5.5.1 Water in Households

Access to clean and safe water is a fundamental necessity for human well-being and development. However, many rural areas around the world face significant challenges in ensuring a reliable and sustainable water supply.

In the three surveyed villages, families live in large houses with sometimes adjacent vegetable gardens. Most of households are relying on unprotected wells or water towers as sources of water and only 32% of them possess a private faucet. However, 17% of houses have non-functional tap water faucet. The average of water consumption per person is 10 liters which gives 150 liters for the whole family. Accordingly, the water bill is approx. 3,500 as average (€5.33).

Furthermore, a remarkable number of families stock rainwater in reservoirs as a secondary source of water that is typically used for various purposes, including laundry, household chores, bathing, drinking, and irrigation. It is mainly used during periods of tap-water shortages.

In fact, the water extracted from wells or stored in water towers is not totally clean. It's important to note that maintaining the quality of water from these sources is crucial, and regular testing and treatment may be necessary to ensure it is safe for consumption. In this regard, the consumers of these villages add bleach/chlorine to water or filter it through a cloth.

Throughout the year, some households experience periodic water shortages. Below are some of the reasons:

Table 4 | Reasons for Water Shortage

REASON	HOUSEHOLDS RATE (%)
Water not available at source	74
Source not accessible	20
Water too expensive	2
Others	4

5.5.2 Water Towers

In terms of hydraulics, according to PDC, the municipality has three functional boreholes, two of which have water towers located in Balingore and Mandégane. The third water tower is under construction at Balingore Farm.

Apart from the boreholes, the water supply in the municipality is ensured by a network of traditional wells (144 of which 65 functional), improved wells (26 of which 21 functional) and wells equipped with pumps (05 functional).

The two towers Mandégane and Balingore get their sources from bore holes with the use of electric pumps. The tower in Balingore is powered by a diesel generator, while that of Mandégane is operated by both PV and diesel generators. However, due to inadequate maintenance, the PV system is out of service. The technical datasheets of the pumps are as well not available. Below is an illustration of a presently available water tower.

Figure 6 | Presently Available Water Tower, (© IfaS)

The two towers can be described as follows:

1. ***Water tower of Balingore:***
   It covers the village of Balingore with a volume of 100 m^3 - the corresponding well is 117 m deep and powered with a 25 m^3/h pump. It consists of an auxiliary 27.5 kW diesel generator powers the pump when there is a grid blackout. However, it is old and poorly maintained. The capacity of the pump is 9.2 kW and consumes approx. 20 L/month with a price of 15,000 XOF (€23).

2. ***Water tower of Mandégane:***
   It covers the remaining two villages: Mandégane and Bagaya and has a volume of 100 m^3. It is powered by a small PV plant (10 kWp) coupled with a diesel generator and operated by a local cooperative financed by every house connected to the water tower (1,000 XOF – 1.5 €/house). This operation costs cover fuel, labor, and maintenance. The capacity of the pump is 7.5 kW and consumes approx. 1,050L/month with a price of 687,750 XOF (€1,048).

5.6 Wastewater and Latrine Sanitation Status Quo

In rural areas where proper sanitation systems are lacking, the disposal of wastewater poses significant challenges. Due to the absence of centralized sewer systems, rural households often resort to haphazard methods for wastewater disposal. Some common practices in Balingore municipality include:

- Open defecation
- Pit latrines (with slab and without slab/open pit)
- Uncontrolled greywater discharge

Referring to the survey, the wastewater generated from the daily life is thrown next to the free space of the houses because of the no drainage network for wastewater and rainwater.

With regard to individual sanitation, the number of households with modern latrines remains very low. Most of the existing latrines are of the traditional type which are in the yard with bottomless pits. These latter ones have not been emptied 5 years ago.

NOTE: The households with no latrines are still using old methods such as a round hole is dug protected with wood

5.7 Waste Generation and Management

5.7.1 Agricultural and Farm Residues

Agriculture is the main economic activity of Balingore municipality, thanks to the existence of a vast cultivation area as shown in Figure 7. Common agricultural crops produced in the locality include vegetable (onion, tomatoes etc.), fruits (mangoes, oranges, bananas, etc.) and the main speculations are peanuts and rice.

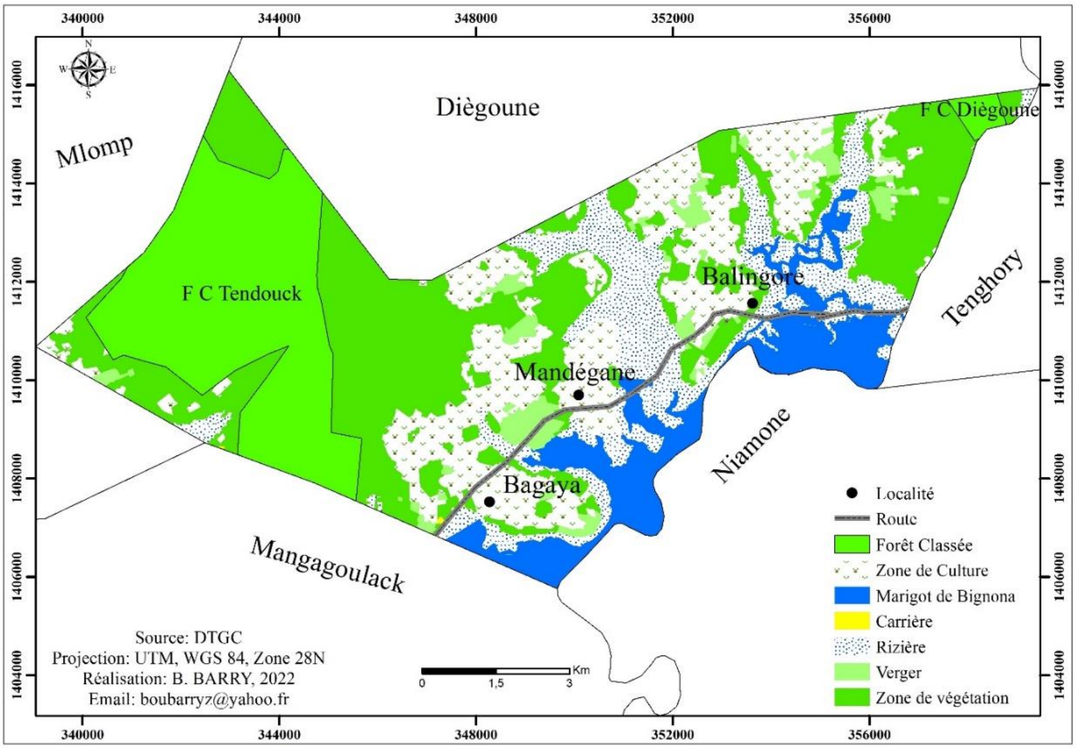


Figure 7 | Agricultural Land Distribution Map of Balingore Municipality, (© PDC)

Market gardening provides substantial income to households and is practiced in agricultural blocks. In addition to fruit tree growing which is also developing with the establishment of orchards on the plateau lands.

In fact, the three villages have an interesting production from agriculture. Referring to the survey, its waste is used for compost and from 15 farms just one which use the incineration or biogas. Some data are not answered by the farmers which means that it is not available, or it is not used currently (How many cattle, are all cattle in one place, how do you gather the manure, livestock for dairy or meat...). Accordingly, two of those farms generate 1.4 tonnes per year of mixed agricultural waste and most of it is from mangos. In general, the regional agricultural waste consists principally of some remains of these food crops. This waste is composted by more than 95% of farmers and used as fertilizers.

There exists however a farmer in the Balingore village, who produce over 73 ton/a of vegetables and uses the waste for biogas production. The most common types of animals reared are fowls and goats.

NOTE: Crop drying for conservation is an essential practice to preserve agricultural produce and prevent spoilage or post-harvest losses.

5.7.2 Livestock Residues

The livestock is an activity practiced in Balingore municipality by agro-pastoralists and is essentially traditional and extensive. The livestock is made up of cattle, sheep, donkeys, goats and poultry as shown in Table 5. Despite favorable conditions for its development (abundance of fodder, vast grazing area), the activity is faced with difficulties related to feeding and watering livestock, especially in the dry season, the frequency of epizootics and of parasitism.

Table 5 | Total Livestock in Three Villages of Balingore Municipality in 2022

LIVESTOCK	BALINGORE	BAGAYA	MANDÉGANE
Cattles	730	415	523
Sheep	350	26	262
Donkeys	14	7	13
Goats	728	569	885
Poultry	1,444	1,304	4,930

The villages practice extensive and traditional animal rearing and most of livestock are not breaded but are free to roam around compounds.

NOTE: The manure from animal breeding is not specified for its usage.

5.7.3 Household Waste

The municipality does not have a system for collection as well as treatment of household waste. It is generally composed of kitchen waste (rice, vegetables...), animal waste, and waste from trees. This means that the villages generate 100% biowaste. Besides that, each household generates 3.65 tonnes per year.

From the survey, 73% of households give the waste every day to animals from their small-scale farming. Furthermore, the inhabitants of the three villages do not use bins to store solid waste and consequently, they dump it in the courtyard of the concession, pit and street as means of disposal.

NOTE: As the municipality does not possess a public dump, the occupants burn the waste.

5.8 Main Disparities: Energy, Waste, and Public Lighting

This chapter delves into the critical gaps and challenges that plague the municipality of Balingore, highlighting the pressing issues surrounding energy availability, the management of waste, and the illumination of public spaces.

Based on the survey conducted and the PDC report from municipality's mayor, some rooms for improvement are mentioned below:

A). Gaps in energy resources and energy systems

Despite the relatively high electrification rate of the municipality (about 98%), there still exist a few households without access to electricity. This is mostly because of their inability to afford the electricity price. Furthermore, the source of energy is still not sustainable, and its cost is relatively high.

Moreover, the electricity self-sufficiency ratio of the inhabitants is very low with almost every inhabitant being dependent on the central grid system. This creates a high level of dependence on the grid, causing the majority of households and buildings to be in blackout in case of grid failure.

B). Gaps in public lighting

While the main streets of the municipality are lit, there are no streetlights in secondary roads and footpaths. This makes it difficult for inhabitants to walk around the villages, particularly during night hours. Moreover, the streetlight systems are very old, less efficient, not properly maintained, and hence are highly defective.

With the grid being their only source of energy, every street is in blackout in case of grid failure. Also, some of the streetlight poles are made up of wood rather than more durable materials such as concrete or metals. This reduces the system's lifetime thereby necessitating a higher frequency of maintenance.

C). Gaps in water and water resources management

Due to the presence of many wells in the region, water is relatively available. However, approx. third of the population surveyed have access to potable water from faucets. On one hand, the treatment of water is still an issue for the villages. On the other hand, water tower nee sustainable and efficient supply of energy for water pumps. Accordingly, the solar PV system installed in one of the towers is non-functional due to poor system maintenance.

D). Gaps in biowaste and wastewater management:

The municipality of Balingore does not possess a wastewater treatment system. There is no proper drainage system for rainwater, and household wastewater is simply discharged to the environment. This leads to the stagnation of wastewater, resulting in pollution and land contamination. It is also a breathing ground for harmful insects. Another major challenge faced by the inhabitants is the absence of modern latrines. Pit latrines are the most common types of latrines used in the Balingore municipality which have never been emptied in the last 5 years. This waste accumulation causes precarious hygienic conditions in the villages.

There exists no waste collection system for household and agricultural waste. Household waste is dumped in house yards and on the streets. Additionally, the manure of livestock is not well collected.

In general, LoSENS project master plan for Balingore municipality focuses on the main key actors' disparities as shown in Figure 8 which concerns sustainability and environment protection from the population habits of the three villages.

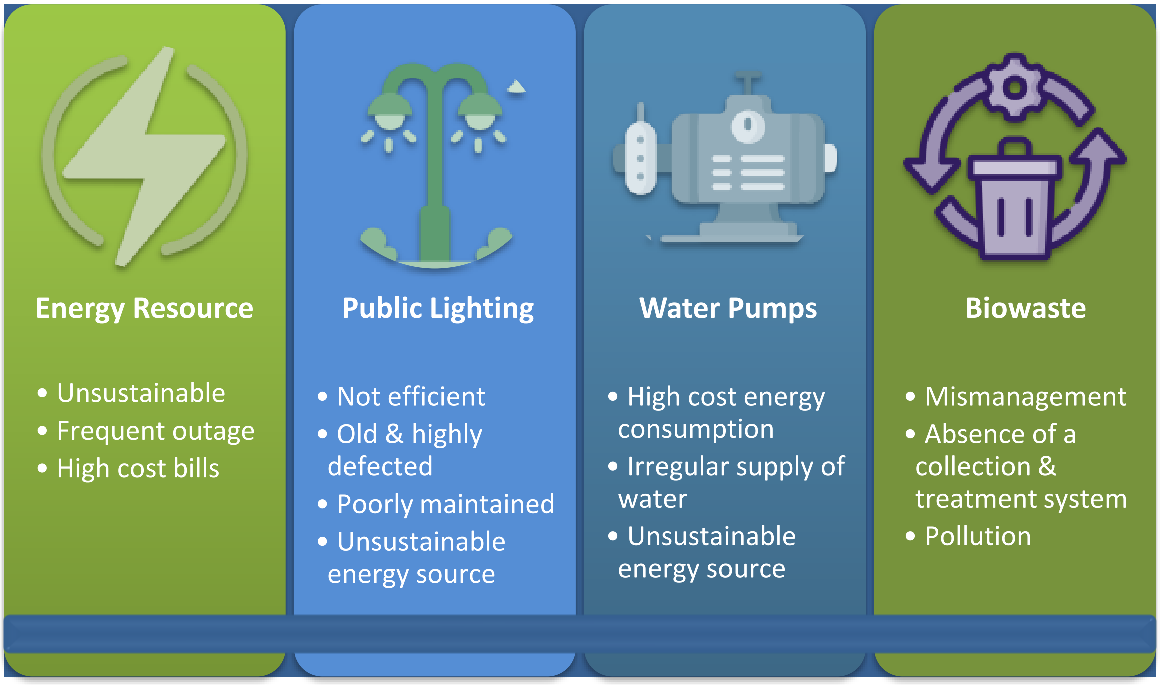


Figure 8 | Four Main Sectors Gaps in Balingore Municipality, (© IfaS)

NOTE: Despite the virous infrastructures in the Balingore municipality regarding energy systems, public lighting, potable water, waste management, there is still great room for improvement. In addition, referring to PDC report, the lack of finance and the lack of awareness are the main factors hindering the further development of the infrastructures needed for the provision of better utility services.

6 Strategies and Actions for Balingore Municipality

From the concluded disparities of the three villages, many inhabitants need to use extra energy sources like solar PV or diesel. This inadequate supply of energy by the grid also constitutes a barrier for the economic growth of the municipality in the sense that it discourages prospect companies who might be interested to carry out their activities in the region. This problem can be resolved by the creation of decentralized electricity systems like rooftop solar PV and biogas.

The regional potentials of the municipality of Balingore are illustrated below.

Table 6 | Regional Potentials per Sector of the Balingore Municipality

SECTOR	*REGIONAL POTENTIALS*
Energy Resources and systems	• Senegal receives about 9 hours of sunlight per day (*Senegal Climate | Sunheron*, 2022). • The organic waste produced by the inhabitants are still non-utilized. If properly harnessed, can be used to generate electricity through biogas production. The resulting fluent could also be used as fertilizer. • The population is willing to forgo fossil fuels and switch to renewable energy in case it could consistently meet up their electricity demand.
Public Lighting	• The existing streetlight systems are a foundation which can be used for further improvement at a lower cost. • SENELEC electricity provision and other local companies with professional experience.
Potable water	The availability of fresh underground water in the region.
Waste management	• The recycling of the waste produced by the municipality represents not only economic potential, but also an energy potential for the municipality. • The willingness of the population to dispose of a better waste management system.

6.1 Sustainable Public Street Lighting

6.2 Assessment of the Current Street Lighting Network in Balingore

6.2.1 Inventories

A mission was carried out by the association "Une lumière dans la Rue". This mission took place in the municipality of Balingore with the objective of carrying out an energy diagnostic. The street lighting network was one of the sectors to be analyzed. Table 7 summarizes the streets visited during the mission.

Table 7 | Balingore Street Lighting Network Data

STREET NAME	*ENEBANE-FOUTAMA*	*ETECOM-BALIMBANDE*	*KAOUWA*	*ELEGNINE*	*DJIKESS*
Pavement	Bitumen	Unpaved	Unpaved	Unpaved	Bitumen
Number of streetlights	10	15	30	25	15
Defective	0	10	0	15	5
Connected to the network	10	15	30	25	15
Year of commissioning	2002	2002	2002	2017	2017
Range(m)	90	45	90	90	90
Type of layout	One-way Layout	One-way Layout	One-way Layout	One-way Layout	One-way Layout
Pole type	Wood and concrete	Wood and concrete	Wood and concrete	Wood and concrete	Wood and concrete

The streetlights in the municipality of Balingore are positioned on the upper or lower side of one lane, depending on the obstacles encountered, such as trees. The poles are either wooden or concrete, as shown in Figure 9 below. Pavements are sometimes asphalt-covered, or just paved.

Pole spacing varies between 45 and 90 m, and most are connected to the Sénélec network. Some lamps are faulty; a malfunction that is not always remedied in time, as indicated by the public lighting technician for the municipality of Balingore, Mr. Yafaye Diedhiou.

This lighting network was installed over 20 years ago, and the luminaires used range from halogen lamps to LEDs. The latter model fits in with Senegal's plan to eradicate halogen lamps from its territory in favor of LEDs. To this end, the municipality of Balingore has received a donation of 200 LED lamps from the government. These lamps, which have a power of 100 W, are barely sufficient to cover the municipality's needs, since according to data gathered from the mayor, Mr. SANE Youssouph, around 2,000 additional lamps will be required in the municipality. The next step will be to find an alternative lamp that will reduce consumption in the locality, while lighting the streets in accordance with international lighting standards.

Figure 9 | Balingore Street-Lighting System, (© IfaS)

6.2.1.1 Design Parameters

The design parameters include the information needed to simulate the roads concerned. The streets in Balingore have been grouped into two categories: trunk roads and pedestrian roads. Their dimensions and pavements are shown in Table 8 below.

Table 8 | Characteristics of Roads

CHARACTERISTIC	TRUNK ROAD	PEDESTRIAN ZONE	UNIT
Street width	12	3	m
Number of lanes	2	1	-
Pavement	Bitumen	Unpaved	-
Height of lamppost	12	12	m

a. Choice of Road Lighting Class

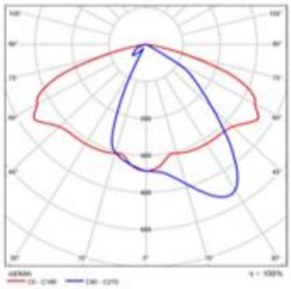
The lighting classes of the streets studied were selected according to the EN13201:2015 model. The methods used to define the lighting class have not changed and remain the same as those used for the municipality of Saint-Louis. Trunk roads and sidewalks are classified as "M4" and "P6" respectively. Pedestrian zones, on the other hand have been grouped in class "P5".

b. Luminaire Catalog:

The simulations were carried out using LED luminaires only. Lanz lamps, with unchanged characteristics were also used in this case. To compare this model with that of other manufacturers such as AEC and Philips, three other lamps were used.

Figure 10 | Technical Data for AEC and Philips Lamps, (© IfaS) shows the characteristics of the lamps.

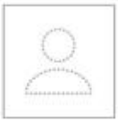
Pas encore partenaire DIALux - I-TRON 1 B 2W8 STU-W 22.50-1M

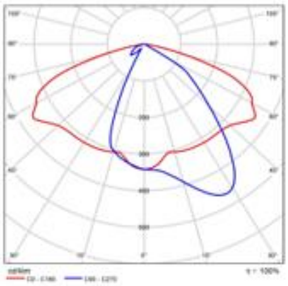


CRL polaire

Article n°	I-TRON 1 B 2W8 STU-W 22.50-1M
P	29.0 W
Φ_{Lampe}	2970 lm
$\Phi_{Luminaire}$	2970 lm
η	100.00 %
Rendement lumineux	102.4 lm/W
CCT	2200 K
CRI	70

Pas encore partenaire DIALux - I-TRON Zero B 2W8 STU-W 3.3-2M

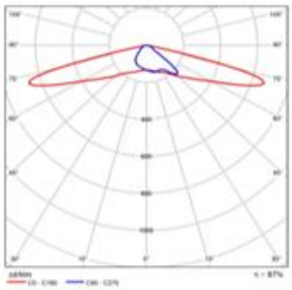




CRL polaire

Article n°	I-TRON Zero B 2W8 STU-W 3.3-2M
P	36.0 W
Φ_{Lampe}	4680 lm
$\Phi_{Luminaire}$	4680 lm
η	100.00 %
Rendement lumineux	130.0 lm/W
CCT	3000 K
CRI	70

Philips - BGP291 T25 1 xLED51-4S/730 DM50



CRL polaire

P	35.0 W
Φ_{Lampe}	5200 lm
$\Phi_{Luminaire}$	4511 lm
η	86.74 %
Rendement lumineux	128.9 lm/W
CCT	3000 K
CRI	70

Figure 10 | Technical Data for AEC and Philips Lamps, (© IfaS)

6.2.2 Simulation results

6.2.2.1 Results for a Trunk Road

Unlike Saint-Louis, where the roads are wider and only Lanz lamps have provided satisfactory results, Balingore has narrower pavements, making it easier to choose the right luminaire.

Champ d'évaluation (M4)		Route principale Balingore Lanz (M4)		Route principale Balingore Philips LED (M4)		Route principale AEC (M4)		Route principale AEC 2 (M4)	
Lm	[cd/m²]	✓ ≥ 0.75	0.54 ✗	✓ ≥ 0.75	0.50 ✗	✓ ≥ 0.75	0.28 ✗	✓ ≥ 0.75	0.44 ✗
Uo		✓ ≥ 0.40	0.86 ✓	✓ ≥ 0.40	0.75 ✓	✓ ≥ 0.40	0.78 ✓	✓ ≥ 0.40	0.78 ✓
Ul		✓ ≥ 0.60	0.79 ✓	✓ ≥ 0.60	0.78 ✓	✓ ≥ 0.60	0.81 ✓	✓ ≥ 0.60	0.81 ✓
TI	[%]	✓ ≤ 15	7 ✓	✓ ≤ 15	7 ✓	✓ ≤ 15	3 ✓	✓ ≤ 15	3 ✓
REI		≥ 0.30	0.81	≥ 0.30	0.91	≥ 0.30	0.75	≥ 0.30	0.75
Champ d'évaluation (P6)		**Trottoir 2 (P6)**		**Trottoir 2 (P6)**		**Trottoir 2 (P6)**		**Trottoir 2 (P6)**	
Em	[lx]	✓ ≥ 2.00 ≤ 3.00	5.87 ✗	✓ ≥ 2.00 ≤ 3.00	5.00 ✗	✓ ≥ 2.00 ≤ 3.00	3.69 ✗	✓ ≥ 2.00 ≤ 3.00	5.82 ✗
Emin	[lx]	✓ ≥ 0.40	3.27 ✓	✓ ≥ 0.40	4.12 ✓	✓ ≥ 0.40	2.86 ✓	✓ ≥ 0.40	4.51 ✓
Esc,min	[lx]	✓ ≥ 0.20	1.52 ✓	✓ ≥ 0.20	2.27 ✓	✓ ≥ 0.20	0.75 ✓	✓ ≥ 0.20	1.18 ✓
Ev,min	[lx]	✓ ≥ 0.60	2.12 ✓	✓ ≥ 0.60	2.47 ✓	✓ ≥ 0.60	0.68 ✓	✓ ≥ 0.60	1.07 ✓
Champ d'évaluation (P6)		**Trottoir 1 (P6)**		**Trottoir 1 (P6)**		**Trottoir 1 (P6)**		**Trottoir 1 (P6)**	
Em	[lx]	✓ ≥ 2.00 ≤ 3.00	5.87 ✗	✓ ≥ 2.00 ≤ 3.00	5.00 ✗	✓ ≥ 2.00 ≤ 3.00	3.69 ✗	✓ ≥ 2.00 ≤ 3.00	5.82 ✗
Emin	[lx]	✓ ≥ 0.40	3.22 ✓	✓ ≥ 0.40	4.13 ✓	✓ ≥ 0.40	2.85 ✓	✓ ≥ 0.40	4.50 ✓
Esc,min	[lx]	✓ ≥ 0.20	1.76 ✓	✓ ≥ 0.20	2.28 ✓	✓ ≥ 0.20	0.78 ✓	✓ ≥ 0.20	1.23 ✓
Ev,min	[lx]	✓ ≥ 0.60	2.51 ✓	✓ ≥ 0.60	2.56 ✓	✓ ≥ 0.60	0.78 ✓	✓ ≥ 0.60	1.23 ✓

Figure 11 | Results of the Simulation of a Trunk Road in Balingore, (© IfaS)

Figure 11 shows the results for the four lamp types used. With the exception of luminance "Lm" and average illumination "Em", all three lamps meet the requirements of the EN13201:2015 standard. While “Lm” falls short of the recommended value, Em exceeds the specified value, so sidewalks will be brighter. To ensure uniform longitudinal illumination, the spacing between roadway posts must be 30 m.

6.2.2.2 Results for a Pedestrian Zone

Like the sidewalks on the main road, the pedestrian zones will be brighter than average. Figure 12 shows the simulation results for these areas. Apart from the average illuminance, the requirements of EN13201:2015 are met. The distance between the poles (60 m) must be taken into account.

Champ d'évaluation (P5)		zone piétonne Lanz (P5)		zone piétonne Philips LED (P5)		zone piétonne AEC	
TI	[%]	≤ 30	6	≤ 30	6	≤ 30	3
Em	[lx]	✓ ≥ 3.00 ≤ 4.50	7.97 ✗	✓ ≥ 3.00 ≤ 4.50	5.16 ✗	✓ ≥ 3.00 ≤ 4.50	6.56 ✗
Emin	[lx]	✓ ≥ 0.60	7.13 ✓	✓ ≥ 0.60	4.68 ✓	✓ ≥ 0.60	4.64 ✓
Esc,min	[lx]	✓ ≥ 0.60	1.71 ✓	✓ ≥ 0.60	1.83 ✓	✓ ≥ 0.60	0.75 ✓
Ev,min	[lx]	✓ ≥ 1.00	2.44 ✓	✓ ≥ 1.00	2.70 ✓	✓ ≥ 1.00	1.02 ✓

Figure 12 | Results of the Balingore Pedestrian Zone Simulation, (© IfaS)

Improving the quality of light while reducing energy consumption is a goal for every municipality. However, the costs associated with these measures should be considered.

6.2.2.3 Economic evaluation

The economics of any project remain a sensitive and uncertain area. If market prices vary from region to region, inflation cannot be accurately predicted, which further complicates the calculation of profitability.

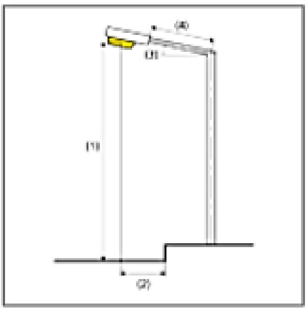
The costs of installing 100 high-quality LEDs, which were planned for the city of Saint-Louis in Senegal, formed part of the basis for assessing the costs of a public lighting project in Senegal, taking into account the import of the lamps and the associated customs clearance costs.

Unlike Saint-Louis, where the lamps will be replaced, the streets of the municipality of Balingore are not yet fully lit. The resulting economic calculation can therefore be applied to other streets in Senegal. Details of these calculations can be found in section 6.2.3

6.2.2.4 Implementation: Technical data, Angle of Inclination

To obtain the results presented above, the construction parameters shown in the figure below must be respected. The parameters for the roadway are at the top, with a 50 m spacing between the posts, while those for the pedestrian zones are at the bottom, with a 60 m spacing between the posts.

Espacement poteau	50.000 m
(1) Hauteur point d'éclairage	12.000 m
(2) Saillie au point lumineux	-1.500 m
(3) Inclinaison de bras	0.0°
(4) Longueur de bras	0.500 m
Heures de services annuelles	4000 h: 100.0 %, 36.0 W



Espacement poteau	60.000 m
(1) Hauteur point d'éclairage	12.000 m
(2) Saillie au point lumineux	0.500 m
(3) Inclinaison de bras	0.0°
(4) Longueur de bras	0.500 m
Heures de services annuelles	4000 h: 100.0 %, 36.0 W

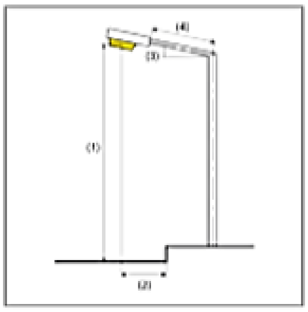


Figure 13 | Installation Parameters, (© IfaS)

6.2.3 Transferring Simulation Results to Other Locations in Senegal

The research carried out and the information obtained from the Saint-Louis municipality's public lighting department led to the conclusion that there are no standards specific to Senegal, which regulate public lighting. Each municipality is responsible for ensuring that the streets in its area are well lit.

As the aim of any standard relating to street lighting is to ensure that roads are well lit, thereby guaranteeing the safety of road users, the European standard for street lighting, EN13201: 2015 was considered as part of the LoSENS project. This does not specify the type of luminaire to be used but governs the illuminance parameters that must be maintained; these parameters are the same for streets belonging to the same class.

Street classes are not geographically limited but depend on the construction and use of the pavement and/or sidewalk. Streets with identical classes can therefore be found in different regions of Senegal, and their lighting should therefore meet the same criteria set by the standard. In this way, the simulation results obtained with the DIAlux software for the municipality of Saint-Louis and Balingore can form the basis for improving the lighting quality of the corresponding streets in Senegal or can be applied directly to previously unlit streets.

Due to lack of access to data, it was not possible to count the number of luminaires installed in Senegal, or the length of streets not yet lit, making it impossible to estimate the cost of lighting all the streets in Senegal. The characteristics of the LEDs to be used by the various municipalities are also difficult to determine. In the following, we'll look at the cost of installing LEDs from different manufacturers.

The capital costs of installing 100 LEDs in Saint-Louis were used to calculate the annual cost of a lamp of this type; customs duties and transport costs were not taken into account, nor were maintenance costs, which were assumed to be identical Table 9 shows the parameters used to estimate the cost of installing an LED.

Table 9 | Parameters for calculating the cost of installing 100 high-quality LEDs 300 km from Dakar, Senegal.

LAMP	*HIGH-POWER LED 1*	*HIGH-POWER LED 2*	*CONVENTIONAL LED*	*UNIT*
Number of lamps	1	1	1	-
Power	0.036	0.036	0.06	kW
Functioning time	4,392	4,392	4,392	h
Price	0.27	0.27	0.27	€/kWh used
Lamp costs	*429*	*255*	*139*	*€*

The costs applied to LED 1 are the actual project costs. It was impossible to receive a non-binding quotation from other manufacturers such as Philips. A meeting with the manufacturers of LED 2 provided access to the price of a 60 W lamp. This came to €150. This price was retained for the 36 W lamps used in the simulations. It is clear, however, that these 36 W lamps would actually cost less than the above-mentioned price. The wattages of the various LEDs have also been grouped together in Table 9 This information was used to calculate the cost of each type of luminaire over a 15-year life. The graphs in Figure 14 show the discrepancies.

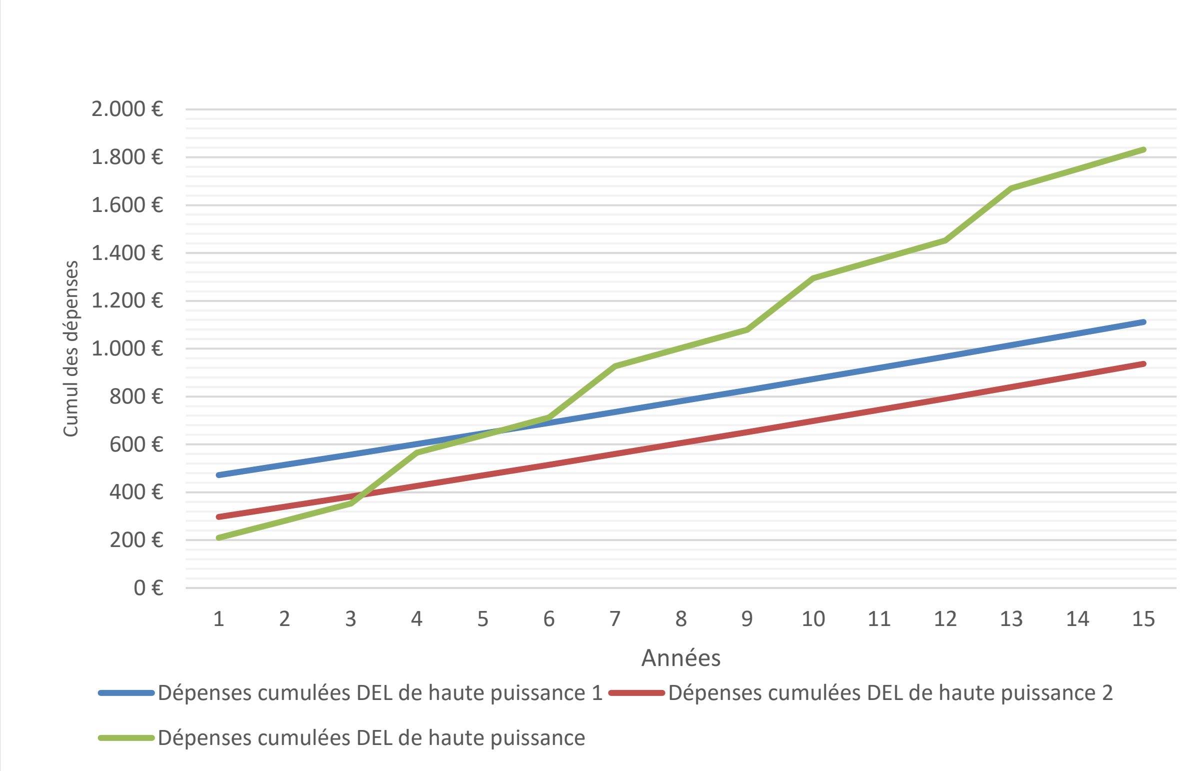


Figure 14 | Comparison of Cumulative Expenditure on LED Installation, (© IfaS)

The 15-year duration was chosen following a conversation with experts in the field of public lighting, who attest that a high-quality LED luminaire could operate for at least 15 years if properly maintained. While investments are made once for LEDs 1 and 2, which are initially more expensive than the LEDs sold in Senegal, every 2 years it would be necessary to invest to buy new lamps, if these are bought locally and at low cost, as the technician from Balingore town hall pointed out. In these calculations, one investment will be made every 3 years instead of two.

After 3 years, the cumulative expenditure on LEDs purchased in Senegal exceeds that on LEDs 2. It will take almost 6 years for them to equal the expenditure on LEDs 1. This shows that the starting price of high-quality LEDs is certainly high, but they are profitable in the long term, especially as LEDs of over 60 W are currently installed in Senegal, whereas one of 36 W would suffice for better lighting quality.

The public lighting market will remain difficult in Senegal as long as no specific specifications are made for the LEDs desired on the market.

6.3 Solar Power Potential

6.3.1 Method

A survey that allowed for the collection of the necessary data for the drafting of the Master Plan, as part of the LoSENS project, was conducted by the PROMESSE team in Balingore. The collected information provides a current state of the quantity and quality of waste produced in this region, the size of households, and energy consumption. The focus of this section of the report will be on the latter, i.e., energy consumption.

The electricity consumption of approximately 142 households and most of the public buildings has been recorded, allowing for the calculation of the consumption of all households in the region which is 649 households. The electricity demand of public buildings, which were easy to account for, has also been considered to estimate the total consumption of Balingore.

The data collected in the field have been analyzed, and it appears that a household in the locality of Balingore municipality consumes approximately 780 kWh per year, while nearly 541 MWh of electrical energy would cover the demand of the municipality of Balingore. These two consumption figures served as the basis for simulating photovoltaic systems with the aim of making this energy available.

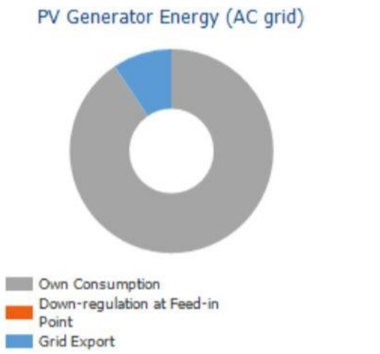
6.3.2 Result

6.3.2.1 Result for the Municipality

To meet the electrical demand of this region, it would be necessary to install a capacity of 323 kWp on approximately 1,435 square meters. In order to ensure a continuous energy supply, a storage system would need to be coupled with this system, which can be quite costly. To address this issue, a solar PV system has been sized in such a way that the production is completely consumed, eliminating the need for expensive storage. 80 tonnes of CO_2 will be avoided thanks to this system.

PV System

PV Generator Output	99,90	kWp
Spec. Annual Yield	1.700,82	kWh/kWp
Performance Ratio (PR)	87,58	%
PV Generator Energy (AC grid)	169.974	kWh/Year
Own Consumption	153.972	kWh/Year
Down-regulation at Feed-in Point	0	kWh/Year
Grid Export	16.002	kWh/Year
Own Power Consumption	90,6	%
CO_2 Emissions avoided	79.859	kg / year



Appliances

Appliances	540.000	kWh/Year
Standby Consumption (Inverter)	62	kWh/Year
Total Consumption	540.062	kWh/Year
covered by PV power	153.972	kWh/Year
covered by grid	386.090	kWh/Year
Solar Fraction	28,5	%

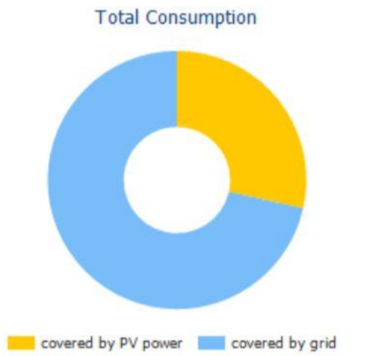


Figure 15 | Result of the System

Only 28.5% of the electrical demand is covered by the solar system if the storage system is not taken into account. The remaining 71.5%, which is mostly consumed at night, will be covered by the storage system. However, due to the low cost of electricity in Africa, this kind of combination is not very cost-effective. That's why it would be wise to combine a solar installation with a biogas plant to not only valorize organic waste but also generate electrical energy when solar production falls below demand.

Approximately 100 kWp capacity would be needed for almost 100% of the production to be consumed without much excess being stored in the public grid.

An economic assessment was conducted for a 100 kWp system on 444 square meters. This system would cost approximately €184,530 per year, including maintenance costs of around €4,530 per year. With an internal rate of return of 9%, this investment would generate approximately €20,000 per year over 20 years. Figure 2 illustrates the annual financial flow. It would take nearly 9.5 years to cover the expenses related to the construction of the photovoltaic system. It's important to note that the unit price of the produced energy would be €0.091, which is less than the current electricity price, which is at least €0.14 for households in the first tier.

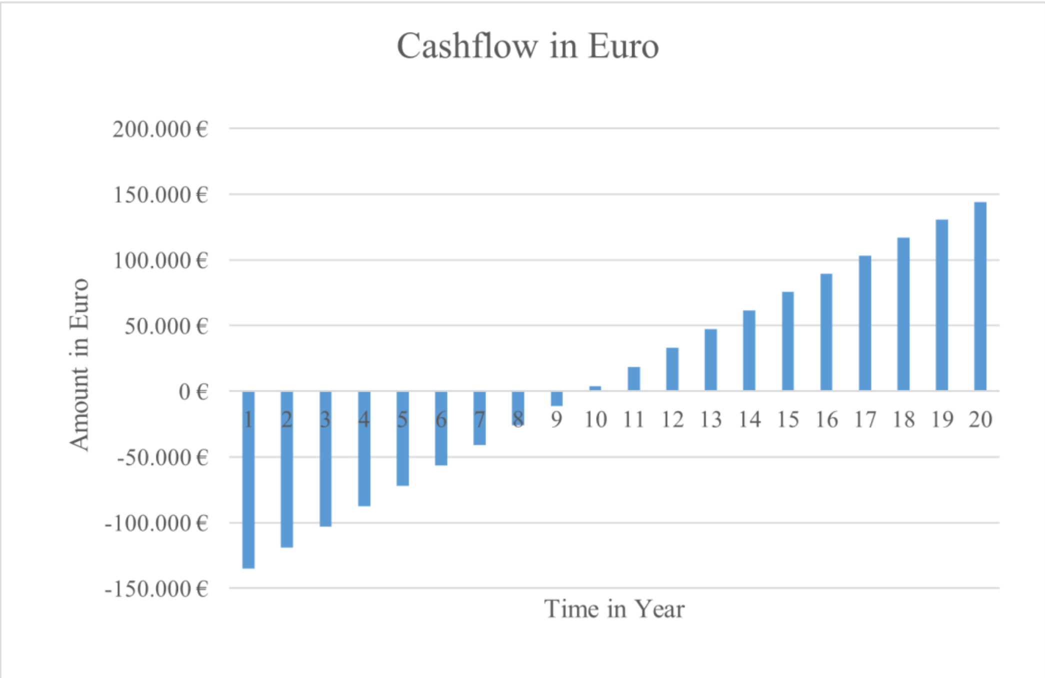


Figure 16 | Cashflow of A 100 kWp Solar PV System Without a Battery

Table 10 | Estimation of Annual Production, Energy Performance Coefficients, and Emission Reduction

PARAMETERS	VALUE	UNIT
PV Installation		
PV Generator Capacity	100	kWp
Annual Specific Yield	1,700.82	kWh/kWp
Installation Performance Ratio (PR)	87.58	%
PV Generator Energy (AC Grid)	169,974	kWh/a
Direct Self-Consumption	153,972	kWh/a
Avoided CO_2 Emissions	133,956	kg/a

6.3.2.2 Result for the Houshold

According to a survey, the household energy needs amount to 780 kWh per year. Assuming a specific yield of 1,684 kWh/kWp for a PV installation (based on the results of simulations with PV*SOL), a PV installation with a capacity of 0.485 kWp would be sufficient to cover this consumption, provided that a corresponding battery is available, and the grid remains operational. Additionally, PV modules connected to the grid are out of service when the grid fails. Since there is no feed-in tariff for electricity generated from renewable sources in Senegal, a grid-connected PV installation (without a battery) would not be profitable (-€404 over 20 years) because only 329 kWh is directly consumed, corresponding to an installed power of about 200 Wp. The remaining 522 kWh are injected into the grid for free.

A new simulation of a PV installation with an installed capacity of 200 Wp is carried out to assess profitability if the injected electricity is reduced or zero.

In Senegal, the cost for installing a 1 kWp PV system without a battery range from €1,600 to €2,000. For small installations, the average price of €1,800 will be applied at this level, as in the previous simulation. This results in an investment of €360, with approximately €9 in annual expenses. While not all of the produced energy is consumed, such a project would be profitable. Approximately €40 could be saved each year, resulting in a cumulative cash flow of €457 over 20 years. The payback period would be 7.5 years.

From the previous simulations, it becomes clear that solar energy can be produced at a lower cost in Senegal, even though the price per kilowatt-hour considered so far (€0.14) is the lowest in Senegal, specifically for the "tier 1."

In this regard, it's worth looking at a bill from SENELEC, the electricity provider in Senegal. Figure 3 provides an example of a calculation for a maximum connection of 6 kW, which corresponds to the smallest and cheapest household connection in Senegal. Electricity costs are established every two months or quarterly. The bill includes tiers (in green), consumption per tier (in red), specific prices per tier (in yellow), municipal tax (in blue), meter rental fees (in white), VAT (in black), and the total cost (in orange).

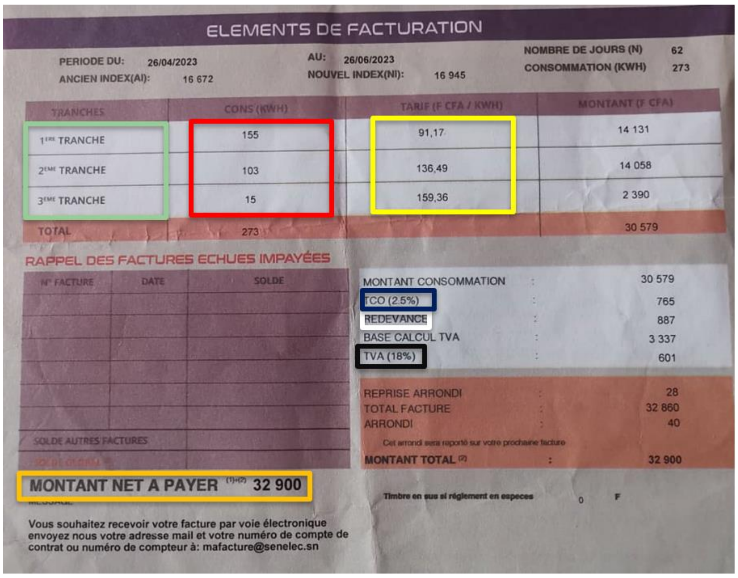


Figure 17 | Electricity Bill for the Household "Anonymous" in Mboro, Senegal, (© IfaS)

With the exception of the tax, all the data for the household "Anonymous" have been aggregated for 3 years. Table 2 illustrates one year's worth of data.

Table 11 | Consumption and Specific Cost Per Tier

PERIOD 2016 – 2017							
			1. Tranche	2. Tranche	3. Tranche	Meter Rental Fees and Meter Maintenance Fees	Paid
25.10.2016	28.12.2016	Consumption per tier [kWh]	160	28	0	918	21,650
		Cost per tier [XOF]	106.44	114.2	117.34	-	-
28.12.2016	22.02.2017	Consumption per tier [kWh]	140	29	0	808	16,810
		Cost per	90.47	101.64	112.65	-	-

		tier [XOF]					
22.02.2017	25.04.2017	Consumption per tier [kWh]	155	21	0	891	17,450
		Cost per tier [XOF]	90.47	101.64	112.65	-	-
25.04.2017	04.07.2017	Consumption per tier [kWh]	175	29	0	1,002	20,250
		Cost per tier [XOF]	90.47	101.64	112.65	-	-
04.07.2017	28.08.2017	Consumption per tier [kWh]	137	43	0	787	17,970
		Cost per tier [XOF]	90.47	101.64	112.65	-	-

The evolution of prices per tier over the past three years is illustrated in Graph 4. After the first two months, the prices for the first tier remained almost constant. In the second-to-last year, the costs for tiers 2 and 3 increased by about 10 XOF (€0.015) compared to the previous year. Since December 29, 2023, the household "Anonyme" has been paying approximately 24 XOF more for each kilowatt-hour in the first tier and 35 XOF more for the second tier.

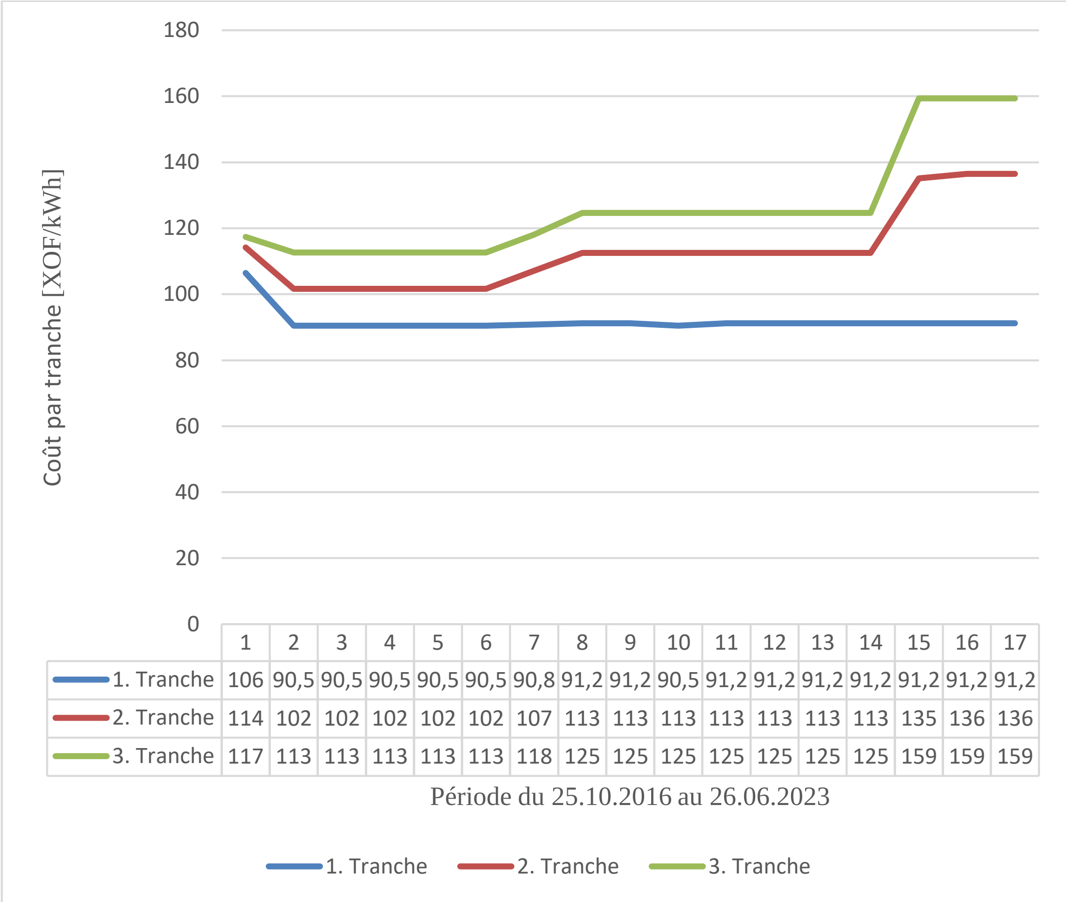


Figure 18 | Change in Price Per Tier Over the Period from 10/25/2016 to 06/26/2023, (© IfaS)

Even though the majority of the consumption is still attributed to tier 1, and the consumption levels are two to three times higher than those in tier 2 (as seen in Table 11), the distribution of costs is completely different.

Table 12 | Annual Consumption Per Tier.

	1. TRANCHE	2. TRANCHE	3. TRANCHE	SUM OF ALL	UNIT
2016 – 2017	907	243	7	1,157	kWh
2019 – 2020	931	450	80	1,461	kWh
2022 – 2023	924	507	83	1,514	kWh

The rapid increase in prices for tiers 2 and 3 has a significant impact on the total costs (as shown in Figure 5). From 10/23/2019 to 06/26/2023, they contributed to more than 50% of the total costs. From 10/25/2016 to 10/23/2017, they represented only 21% of the total costs.

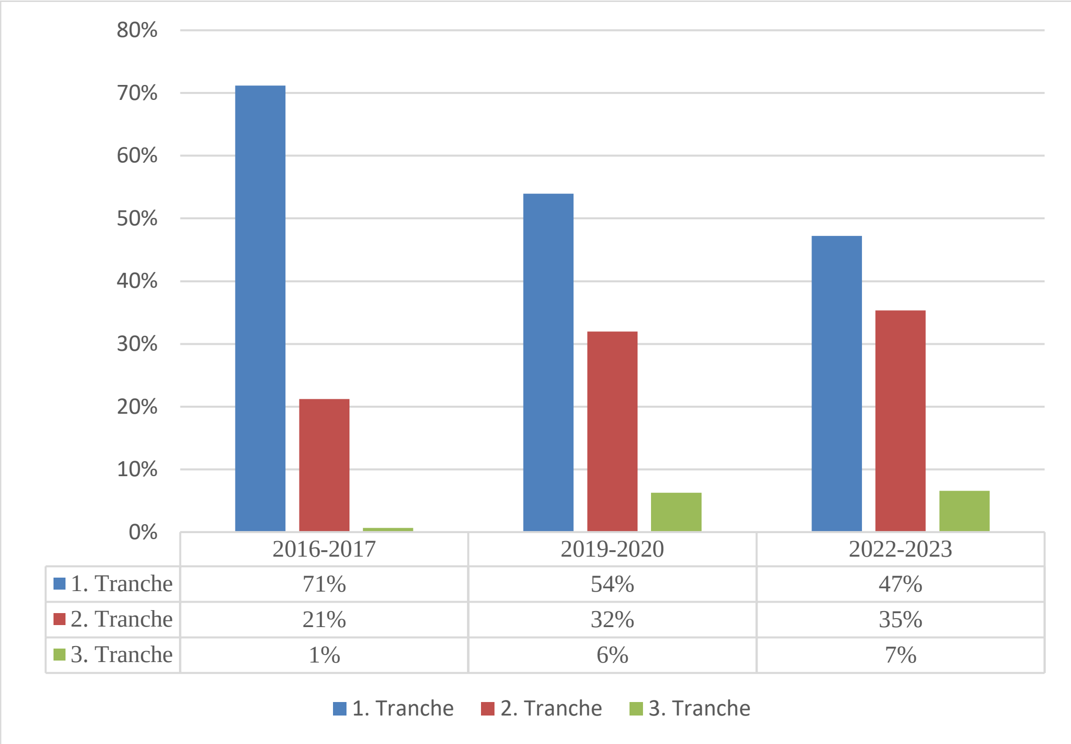


Figure 19 | Distribution of Electricity Costs for the "Anonymous" Household Over the Period from 10/25/2016 To 06/26/2023 Per Tier and Per Year, (© IfaS)

The expenses incurred by the "Anonymous" household for each kilowatt-hour over the past three years are provided in Table 13. For the three years, this amounts to more than the €0.14 considered in the calculations for Balingore. The assumption is that electricity costs increase by 1% per year, which is less than the 5% in the previous year and/or the 10% in the year before that.

Table 13 | The Specific Prices Paid by the Household "Anonymous" Over the Last Three Years and the Price Increase.

PERIOD	*PRICE IN €/kWh*	*CHANGE COMPARED TO THE PREVIOUS YEAR (%)*
2016 – 2017	0.1566	-
2019 – 2020	0.1641	5
2022 – 2023	0.18	10

The new simulation with PV*SOL will demonstrate the potential savings that the household "Anonymous" would achieve if the average electricity price increased by 1% per year (initial price of €0.18 per kWh).

The average electricity consumption of the household "Anonymous" over the past three years is 1,378 kWh per year. To meet this demand, a 1 kWp installation would be sufficient, unless the system is not grid-connected. For an off-grid system, it would require 24 kWh of storage capacity, three 5 kW battery inverters, three 3 kW inverters (DC), and a total of 6 kWp PV modules. Running a 1 kWh battery in Senegal costs around €1,400. The sole purchase price of the batteries for this system would be approximately €33,600. Over the past few years, household "Anonymous" has paid about €231, which, when accumulated over 20 years (the lifespan of a PV installation), would amount to around €4,620. For this household, it would be a very expensive "continuous" energy supply. The calculation is different if a 0.5 kWp PV installation is grid-connected. The system is profitable even if only 60.6% of the energy produced is consumed. This would allow to save approximately 463 kg of CO_2 that could be be emitted into the atmosphere.

With an average savings of about €84 per year, the payback period is approximately 12 years. The remaining energy produced is injected into the grid for free, a problem that, in addition to grid fluctuations, hinders the development of the solar sector in Senegal. These results demonstrate that electricity produced by a PV installation in Senegal is cheaper than that offered by SENELEC.

6.4 Water Distribution

6.4.1 Project Demonstration

In this project, the aim is to implement a solar photovoltaic (PV) power plant to provide sustainable and reliable energy for water towers located in a rural area. Water towers are crucial for supplying clean and safe water to the community, and by integrating solar power, the project seeks to enhance the efficiency and sustainability of this essential infrastructure.

A project of PV plant for Balingore municipality was introduced by Bonergie[5], a company in Senegal based in Dakar which supplies solar products. The suggestion of the PV plant is based on two cases: one for Mandégane and the other for entire municipality.

The objective of this solar energy is:

- ***A). Renewable energy integration and energy independence***
  This reduces the dependency on traditional fossil fuel-based energy sources, thereby decreasing the carbon footprint of the water supply system.
- ***B). Cost savings***
  Implementing a solar PV plant can result in long-term cost savings by reducing operational expenses associated with purchasing and transporting fuel for generators.
- ***C). Environmental impact***
  The project contributes to the reduction of greenhouse gas emissions and other environmental pollutants associated with traditional energy sources.
- ***D). Community empowerment and educational outreach***
  The project serves the local community by improving the quality and accessibility of water supply services. Alongside it aims to educate the community about renewable energy, energy conservation, and the benefits of sustainable practices.
- ***E). Collaboration and stakeholder engagement***

[5] PV supplier: https://bonergie.com/en/

The project seeks to involve local stakeholders, government agencies, community members, and relevant experts in the planning, execution, and monitoring phases.

NOTE: By achieving these objectives, Balingore municipality will be a model to other rural areas in terms of improving energy access, water supply reliability, and environmental sustainability through the integration of solar power technology.

According to the PV panels, a reservoir of 5,000 Liters is suggested to be among the project of Bonergie. It is a large storage tank designed to collect and store water. It serves as a buffer, allowing the system to collect water during times of plenty (rainy season or when the water source is active) and store it for use during times of scarcity. The reservoir ensures a continuous supply of water even when the water source isn't producing water consistently.

6.4.2 Proposal Project

Referring to Bonergie provided data, the PV plant could be installed for two cases Mandégane village as well as the municipality of Balingore. The following table presents the energy production of water distribution with investment costs for both scenarios:

Table 14 | KPIs for Mandégane Water Tower PV Plant

PARAMETER	***VALUE***	***UNIT***
PV power capacity	0.25	kW
Energy production	402	kWh/a
Lifespan	20	a
Total investment	1,803,625	XOF
	2,749	€
OPEX	1,650	€
TOTEX	4,399	€
LCOE	0.55	€/kWh
Avoided emissions	0.35[6]	t CO_2/kWh/a

[6] Referring to the International Financial Institutions Technical Working Group on Greenhouse Gas Accounting (IFI TWG), the emission factor with all sources of energy is 0.87 kg CO_2 /kWh.

With the components proposed, PV plant for pumping water in Mandégane will be possible to produce approximately 402 kWh of electrical energy per year with a specific annual yield of 1,608.16 kWh/kWp and an OPEX of 3% per year.

Table 15 | KPIs for Balingore Municipality Water Tower PV Plant

PARAMETER	VALUE	UNIT
PV power capacity	0.405	kW
Solar panels	60	unit
Total PV power capacity	24.3	kW
Energy production	39,078	kWh/a
Lifespan	20	a
Total investment	13,898,704	XOF
	21,187	€
OPEX	12,712	€
TOTEX	33,899	€
LCOE	0.04	€/kWh
Avoided emissions	34	t CO_2/kWh/a

With the components proposed, PV plant for pumping water in Balingore municipality will be possible to produce approximately 39.1 MWh of electrical energy per year. Consequently, the reduction of emissions will lead to the avoidance of 34 t CO_2/kWh annually.

Additionally, the reservoir of 5,000 Liters will have an investment of 885,000 XOF (€1,328).

NOTE: The investment cost is planned to be paid by several parties: the municipality, the population who will benefit from the project, and the investors.

6.5 Biogas Generation

6.5.1 Overview

In rural Senegal, residents primarily rely on natural resources for their daily energy needs, including firewood, agricultural residues, dry manure, and charcoal. The energy these materials provide is essential for them, to use in cooking and meal preparation. However, this heavy reliance on plant biomass has severe repercussions on the local environment, leading to deforestation, reduced soil fertility, and contributing to global climate change. The woody species are being depleted leading to deforestation and bushfires.

Furthermore, household health is significantly compromised by using plant biomass. Gaseous pollutants emitted from burning wood and charcoal, such as carbon monoxide, sulfur dioxide, nitrogen oxides, and hydrocarbons, can cause chronic bronchitis, lung cancers, cardiovascular, and eye diseases.

To alleviate these challenges, solutions that protect women and children from health risks and improve household living conditions are imperative. Implementing bio-digesters in rural areas such as Balingore could provide such a solution, offering an energy source tailored to the local context and within reach of project beneficiaries, while also promoting environmental conservation.

The recovery of household waste for biogas production in rural areas in Senegal is a topic of interest, especially given the country's growing energy demands and waste management challenges. Therefore, using the results obtained in the study done on Saint-Louis as an example of an urban area in Senegal, a projection with adaptations was conducted in Balingore as an example of a rural area in the same country.

In the commune of Balingore, 70% of households consume firewood daily for cooking purposes. Based on the survey conducted in the region of Balingore in Senegal. The survey findings indicate that households, on average, consume approximately 5 kg of firewood daily. To validate and ensure this figure was not an underestimate, many literature sources were checked. A recent study corroborates that for a household comprising 15 members, the daily firewood consumption averages 5.5 kg, which translates to 0.4 kg per person(Aïdara A Lamine et al., 2021). This means that in the case of households of Balingore that have on average 10 people each, around 4 kg of firewood would be needed daily for cooking. In order to be on the safe side, considering the quality of wood and the long cooking time as most of the household prefer the traditional way of cooking which takes a long time, 5 kg of daily firewood consumption will be used as it is the value obtained by the survey.

The total number of households in Balingore amounts to 649 households. These households are home to 7,305 inhabitants. This leads to a total of 1,184 tonnes of firewood demand per year. For optimal combustion and efficient energy extraction, it is generally recommended that firewood have a moisture content of less than 20%. Given Senegal's climate, with a distinct wet season and dry season, the moisture content of firewood can fluctuate based on the time of year and the method of storage. Firewood collected or cut during or shortly after the rainy season would typically have higher moisture content than wood that has been left to dry during the dry season. In this case, a dry wood with a moisture content less than 20% is considered in the calculations, which has a net calorific value of 5 kWh/kg(FAO, n.d.).

6.5.2 Proposal for Balingore

Two scenarios for the utilization of biogas produced from organic waste collected from households could be proposed for Balingore. These scenarios are presented in the following paragraphs:

Scenario 1: Direct Utilization of Biogas for Cooking

One viable method to harness the potential of organic waste is to convert it into biogas for direct cooking applications. Firstly, organic waste is systematically collected from households and sent to centralized or several decentralized biogas digesters. Upon digestion, the biogas produced is stored in designated gas storage facilities, ensuring a steady and continuous supply. To distribute the biogas, it is piped directly to households or community cooking centers. To facilitate this, households are either equipped with new biogas stoves or modifications are made to existing stoves to use biogas. Utilizing biogas as a primary cooking fuel could significantly curb the village's reliance on firewood or charcoal, thereby addressing environmental concerns such as deforestation.

Scenario 2: Biogas Utilization in a Combined Heat and Power (CHP) Unit

The third scenario proposes a dual-benefit solution by deploying a Combined Heat and Power (CHP) unit. After the initial collection and digestion of organic waste to produce biogas, the gas is then channeled into a CHP unit. This sophisticated system is designed to produce electricity while simultaneously capturing heat. The generated electricity can cater to the energy needs of the village, while the captured heat has versatile applications, such as household heating, water heating, or warming community facilities like schools and clinics. By simultaneously delivering electricity and heat from a single energy source, this scenario presents a holistic and efficient energy solution that can address a broad spectrum of the village's energy demands.

6.5.3 Scenario 1

6.5.3.1 Defining the Cooking Energy Demand of the Households

In the case of Balingore, scenario 1 was inspected first which resulted in the following outcomes. Based on the findings obtained from the survey conducted in the municipality of Balingore, the total thermal energy from firewood used for cooking amounts to 5,922 MWh/a as shown in

Table 16.

Table 16 | Calculation of Total Annual Cooking Demand

CALCULATING THE COOKING DEMAND	VALUE	UNIT
Number of households	649	
Average number of people per household	10	People
Average wood consumption per household	5	kg/day
Total wood consumption per year	1,184	tonnes/a
Thermal energy content in dry wood	5[7]	kWh/kg
Total thermal energy content for cooking in Balingore	5,922	MWh/a

However, cooking with firewood is different than cooking with gas or electricity as the efficiency of firewood stoves is much lower. Also, considering that the energy from firewood is affected by several factors such as the humidity and quality of the wood. Therefore, another approach was selected to estimate the energy needed for cooking which is focused on the normal energy used daily for cooking. From literature, a household of 4 people would need 1.3 kWh/day of energy for cooking in South Africa. Therefore, for a household of 10 people in the case of Balingore, a total of 3.25 kWh/day. Therefore, the total annual energy needed for cooking for the 649 households is 770 MWh/a (Table 17).

Table 17 | Calculating the Energy Needed for Cooking

CALCULATING THE COOKING DEMAND	VALUE	UNIT
Energy needed for cooking per day for a household of 10 people	3.25[8]	KWh/household/day
Total annual energy needed for cooking for the 649 households	770	MWh/a

6.5.3.2 The Potential Energy from the Existing Households Organic Waste

To check if the existing biowaste amount is enough to cover the needs for cooking, some calculations were performed as will be explained in the following paragraphs. From the results of the survey, the total organic waste collected from households amounts to 2,369 tonnes/a. This quantity will generate around 1,310 MWh/a of thermal energy as displayed in Table 18.

[7] Source: (FAO, n.d.)
[8] Source: (Batchelor, 2015)

Table 18 | Calculation of the Existing Biowaste Energy Potential

EXISTING BIOWASTE ENERGY POTENTIAL	VALUE	UNIT
Annual organic waste per household	3.65	tonnes/a
Total amount of organic waste in Balingore	2,369	tonnes/a
Specific biogas production	89.2	m^3/ton
Total amount of biogas	211,301	m^3/a
Thermal energy content of biogas	6.2[9]	kWh/m^3
Total thermal energy	1,310	MWh/a

Considering that the people will directly use the energy produced in biogas stoves. There will not be many losses during the treatment of the gas as only desulphurization process will take place using activated carbon adsorption. Activated carbon is commonly used as a desulphurisation technique through adsorption to remove hydrogen sulphides (H_2S) which are toxic to human health and harmful to the environment if released(Fachagentur Nachwachsende Rohstoffe, 2012). Using the treated biogas directly after treatment for cooking in the stoves will only be affected by the efficiency of the stoves used for cooking. The most efficient biogas cooking stoves are the one with a cyclone shape as shown in the picture of Figure 20. This type of stoves proved to have the highest efficiency according to comparative study that was done in 2016 with 58.42% efficiency compared to other types. Therefore, considering this efficiency, the energy that will be used for cooking will be around 765 MWh/a.

Figure 20 | Cyclone shape biogas cooking stove (Syamsuri et al., 2015)

[9] Source: (*AQPER*, n.d.)

Table 19 | Energy Potential used During Cooking with Biogas Stove

CALCULATING THE ENERGY POTENTIAL	VALUE	UNIT
Efficiency of a biogas stove cyclone	58.42[10]	%
Energy potential from household waste used for cooking with biogas stove	765.34	MWh/a

A comparison of the energy demand and the potential energy from biowaste of Balingore shows good results as the energy potential will cover about 99% of the total cooking energy demand (Table 20). The 1% left could be covered by other energy sources such as agricultural residues or animal manure.

Table 20 | Cooking Energy Demand vs the Potential Energy

COOKING DEMAND COVERED	VALUE	UNITS
Cooking energy demand	770	MWh/a
Energy obtained from existing waste potential	765	MWh/a
Energy deficit	5	MWh/a
Percentage covered	99	%

6.5.3.3 Potential Energy from Agricultural Waste

In order to cover the cooking demand deficit, other sources for biomass were considered in the municipality of Balingore. Based on the survey results, agricultural waste in Balingore is comprised mainly of mango waste and it amounts to 1.4 tonnes/a. This quantity is estimated to yield around 6.87 MWh per year of thermal energy, as outlined in

[10] Source: (Syamsuri et al., 2015)

Table 21. However, considering literature insights and practical experience, the digestion of mango seeds is a time-intensive process and may not align with the immediate energy requirements. Consequently, this option will be excluded from further consideration.

Table 21 | Energy Potential from Agricultural Waste

ENERGY POTENTIAL FROM EXISTING AGRICULTURAL WASTE	VALUE	UNIT
Agricultural waste (mostly from Mango)	1.40	tonnes/a
HV of mango stone/seed	17.66[11]	MJ/kg
Conversion	4.91	kWh/kg
Total thermal energy from mango waste	6.87	MWh/a

6.5.3.4 Potential Energy from Animal Manure

The other option is animal waste, based on the report sent by the mayor of Balingore and the survey conducted in the region, the households raise some animals such as cows, chicken, sheep, and goats. Since it is difficult to collect the manure of chicken, goats, and sheep, only cow manure will be considered in this case. The total number of cows obtained after questioning 142 households in the region of Balingore was around 138 as shown in Table 22. This number will be used to estimate the energy potential from cow manure.

Table 22 | Number of Animals in the Households Questioned During Survey

ANIMAL NUMBERS IN 142 HOUSEHOLDS OF BALINGORE	VALUE
Chicken	970
Goats	274
Sheep	79
Cattle	138

In Balingore and Africa, traditional cattle-raising methods pose challenges for efficient cow dung collection. The herding method consists of letting the cattle graze over large areas, making it difficult to centralize and collect cow dung systematically. Additionally, the communal nature of grazing lands and the absence of controlled feeding practices limit the accessibility of cow dung for collection. Cattle are often allowed to roam freely, feeding on open pastures, which results in

[11] Source: (Perea-Moreno et al., 2018)

a more scattered distribution of dung across the landscape. These decentralized and nomadic cattle-raising methods create obstacles for collecting and harnessing cow dung as a valuable resource for energy and agricultural purposes, hindering the potential for more organized and sustainable waste management practices. Therefore, in this scenario, it is assumed that only 40%(Tucho & Nonhebel, 2017) of produced dung will be collected, which is during the time when the cattle is in the barns of the house. Considering a dry dung output per head of 0.7 ton/a(Tucho & Nonhebel, 2017) and knowing that the total number of cows is 138 from the survey, the estimated annual cow dung quantity that could be collected will be around 39 tonnes. The biogas yield of cow dung is 281 m^3/ton, this gives an energy potential of 67 MWh/a as presented in Table 23.

Table 23 | Energy Potential from Cattle Manure

ENERGY POTENTIAL FROM EXISTING CATTLE MANURE	VALUE	UNIT
Total number of animals	138	Cow
Dry dung output ton/head/a	0.7[12]	t/head/a
Percentage of collection of manure	40%[12]	
Biogas Yield Factor m^3/t	281[12]	m^3/t
Annual biogas yield m^3	10,858	m^3/a
Energy potential MWh/a	67	MWh/a

When using biogas produced from cow dung in cooking with a stove efficiency of 58%, the energy that will be available for cooking will amount to 39 MWh/a. This energy is more than enough to cover the 5 MWh of energy for cooking left after using household biowaste (

[12] Source: (Tucho & Nonhebel, 2017)

Table 24).

Table 24 | Energy Potentials from Household Waste and Cow Manure used During Cooking with Biogas Stove

CALCULATING THE ENERGY POTENTIALS USED FOR COOKING	VALUE	UNIT
Efficiency of a biogas stove cyclone	58.42[10]	%
Energy potential from household waste used for cooking with biogas stove	765	MWh/a
Energy potential from cow manure used for cooking with biogas stove	39	MWh/a

6.5.4 Scenario 2

Implementing a Combined Heat and Power (CHP) unit for electricity and heat generation using household waste in the villages of Balingore, Senegal, represents a sustainable and integrated approach to energy production. In this system, household waste is utilized as feedstock for the CHP unit. The process involves the combustion of waste to produce both electricity and heat simultaneously. The electricity generated can be used to meet the local energy demand, addressing electricity deficit at night in the villages. Simultaneously, the heat produced during the combustion process can be harnessed for various applications, such as small-scale activities of drying mangoes and fish. This approach not only addresses the energy needs of the community but also provides an environmentally friendly solution for waste disposal, contributing to waste-to-energy initiatives.

The annual electrical energy needed to cover the demand of the municipality of Balingore amounts to 541 MWh. After installing PV panels, the annual electricity covered would be 155 MWh. Since no batteries will be used, there will be a deficit of 386 MWh which is needed for the nighttime as explained in

Table 25. This scenario investigates using household waste as feed for a CHP to see if it will cover the electrical energy deficit.

Table 25 | Electrical Energy Profile of the Municipality of Balingore

CALCULATING THE ELECTRICITY DEFICIT	***VALUE***	***UNIT***	***SOURCE***
Total electricity demand	541,000	kWh/a	From survey
Electricity covered by PV	154,676	kWh/a	From PV*SOL
Electricity deficit	386,324	kWh/a	Calculated

The electric and thermal efficiencies of the CHP unit will be the same as the ones suggested by Ökobit company in their feasibility study of the city of Saint-Louis. Therefore, in this scenario, the electric and thermal efficiency of the CHP are 41.6% and 42.7% respectively (

). This would provide a potential electric energy of 545 MWh/a, which is more than enough to cover the energy deficit of the

CALCULATING THE ELECTRIC AND THERMAL ENERGIES	***VALUE***	***UNIT***
Electric efficiency of CHP	41.6	%
Thermal efficiency of CHP	42.7[13]	%
Potential electric energy	545	MWh/a
Potential thermal energy	559	MWh/a

municipality (Table 27). As for thermal energy produced, it will amount to 559 MWh/a, which can be used as heat to dry the mangoes and the fish instead of buying expensive gas bottles.

Table 26 | Electric and Thermal Energies Produced by The CHP Unit

CALCULATING THE ELECTRIC AND THERMAL ENERGIES	***VALUE***	***UNIT***
Electric efficiency of CHP	41.6[13]	%
Thermal efficiency of CHP	42.7[13]	%
Potential electric energy	545	MWh/a
Potential thermal energy	559	MWh/a

[13] Source: (Greentec, 2023)

Table 27 | Electricity Covered

CALCULATING THE ELECTRICITY COVERED	VALUE	UNIT
Electricity deficit in Balingore	386	MWh/a
Electrical energy obtained from existing waste potential	545	MWh/a
Percentage covered	141	%

Each of these scenarios carries its own set of advantages. However, their successful implementation would depend on establishing an effective waste collection system, ensuring regular maintenance of equipment, and possibly training local residents to operate and manage the biogas facilities. Converting to either one of these scenarios will save around 73 tCO_2/a of carbon emissions every year which results from the emissions of household organic waste.

7 Sustainable Development Goals Implementation

Implementing a project in a rural area in line with the agenda 2030 for Sustainable Development involves addressing specific challenges and opportunities unique to rural settings. In this regard, the sustainable rural energy project in Balingore municipality, Senegal, aims to address various Sustainable Development Goals (SDGs) including Goal 7 (Affordable and Clean Energy), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), and Goal 17 (Partnerships for the Goals). Figure 21 demonstrates the main contributions of LoSENS project in Balingore municipality to reach the SDGs:

Figure 21 | Main SDGs Contributions, (© IfaS)

Overall, LoSENS project plays a vital role in contributing to multiple SDGs (7, 11, 12, and 17) by promoting clean energy, enhancing urban development, fostering responsible consumption, and encouraging collaborative partnerships to create a more sustainable and prosperous future for the villages and their residents.

8 Conclusion & Future Recommendations

This master plan for an efficient and renewable energy network in rural areas aims to unlock the vast potential of rural regions to become sustainable, self-sufficient, and resilient communities. By embracing renewable energy sources, improving energy efficiency, and engaging local stakeholders, we can pave the way for a greener future, while also stimulating economic growth, creating job opportunities, and enhancing the quality of life in rural areas. This master plan serves as a roadmap to guide the transformation of rural areas into beacons of sustainable energy, contributing to a global transition towards a low-carbon and resilient society.

From the key actors' analysis, the following are future recommendation that could enhance the development of Balingore municipality situation:

8.1 Public Lighting Efficiency

The market for street lighting will remain difficult in Senegal as long as the desired characteristics of LEDs are not specified in the market. If there are no standards to which manufacturers or sellers must comply, a subjective choice is always made when choosing luminaires for street lighting, which is not always the best because, in addition to good quality lighting, it is also important that the bulbs ensure a long life with constant illuminance. It is therefore important to familiarize with the data sheets of the luminaires. For a better representation of this problem, for example, a 100 W LED of €31.61 from the Internet is considered. This has a service life of 10,000 hours, is made of aluminium and is operated with an AC voltage of 220 V. There is no relevant information that can be gleaned from the product data. The excerpt from the data sheet of another LED, which costs €150, lists the following specifications:

1. Power 36 W
2. Service life: > 100,000 h with a 10% reduction in performance after 100,000 h
3. Operating voltage: 220 V – 240 V
4. Surge protection: 10 kV
5. Operating temperature: -40 °C / +55 °C
6. Storage temperature: -40 °C / +80 °C
7. References: EN 60598-1, EN 60598-2-3, EN 62471, EN 55015, EN 61547, EN 61000-3-2, EN 61000-3-3, EN 60598-1, EN 60598-2-3, EN 62471, EN 55015, EN 61547, EN 61000-3-2, EN 61000-3-3
8. LED current: 60 mA

The data sheets of these products can be found in the appendix:

- DIN EN 55015 provides information on the limit values and measurement methods for radio interference from electrical lighting equipment.
- EN 62471: This is where the luminaire is tested for photobiological hazards such as eye damage.
- EN 61000-3-2: Electronic equipment that has an input current of less than 16 A and is connected to a low-voltage mains causes harmonics, causing overheating of transformers, cables, motors, generators and capacitors. This standard regulates the limits of harmonic currents.

These goals of the standard prove that it makes a difference whether a manufacturer's product complies with it or not. The specification of the LED current also plays an important role, as in the event of faults in the grid, as is common in Senegal, the luminaires are operated at a very lower current.

In addition to these technical aspects that are directly related to the quality of the lamp, it is important to note that a lighting system must be maintained regularly.

To this measure, which determines the lifespan of the lamps, the poles must be very well installed (straight, the distance between the poles must be regular, the distances from the road regular and many others).

The aim with is LEDs is next to better lighting, energy saving. It should therefore not be forgotten that thanks to technological advances, a lamp of about 40 W that is of good quality can produce enough light to meet the requirements of lighting standards for roads with standard dimensions.

8.2 Solar Energy

The solar market in Senegal is also affected: Although anyone is allowed to operate a PV system in Senegal, the fact that it is not allowed to feed energy into the grid obliges system owners to install a battery with the PV system. Financially, this is unprofitable for private consumers, as the price of electricity and consumption in the country are low. In addition to subsidies, new laws are needed to promote the spread of renewable energies (tax breaks, feed-in tariffs, etc.). In addition, expert staff is essential, as the grid fluctuations in Senegal are putting a brake on the development of the solar industry. Another aspect to scrutinize is statistics that are rarely published or do not exist. For a good analysis and better planning of a PV system, load profiles (exact consumption data) are necessary.

8.3 Biogas

Introducing biogas as a primary energy source in rural areas like Balingore, Senegal, requires a multi-faceted approach, given the complexities involved. The transition from traditional energy sources, like firewood and charcoal, to biogas requires infrastructural, societal, and educational changes. Some to the recommended modifications are listed below:

1. Infrastructure Development:

- **Biogas Digesters**: Establish centralized or decentralized biogas plants, depending on the scale of the project and availability of resources. Centralized plants serve multiple households while decentralized ones might serve individual homes or clusters of homes.
- **Storage Facilities**: Create storage solutions for the biogas produced, ensuring there is a continuous supply even when production fluctuates.
- **Distribution System**: For centralized systems, develop a network of pipes to distribute the biogas directly to households.

2. Modification of Household Appliances:

- **Cooking Stoves**: Current stoves that use firewood or charcoal would need to be replaced or modified to work with biogas.
- **Heating Systems**: If biogas is to be used for heating purposes, appropriate modifications or installations would be required.

3. Education and Training:

- **Usage Training**: Households would need guidance and training on how to use biogas efficiently and safely.
- **Maintenance Knowledge**: Regular maintenance of biogas digesters and related infrastructure is essential. Training a subset of the community can ensure local expertise is available.
- **Awareness Campaigns**: Promote the benefits of biogas, such as its eco-friendliness and cost-effectiveness, to ensure community buy-in.

4. Financial Mechanisms:

- **Funding the Transition**: Initial setup costs for biogas production and distribution can be high. Secure funding through governmental schemes, NGOs, or public-private partnerships.
- **Subsidies or Loans**: Offer subsidies or low-interest loans to households for stove replacement or modifications.

5. Waste Collection and Management:

- **Systematic Collection**: Establish a systematic organic waste collection process from households to ensure a steady supply to the digesters.
- **Waste Segregation**: Educate households about the importance of segregating organic waste from other waste to ensure efficient biogas production.

6. Monitoring and Feedback:

- **Monitoring Systems**: Regularly monitor the efficiency and safety of the biogas system.
- **Feedback Mechanisms**: Establish channels for households to report issues or provide feedback, ensuring continuous improvement.

7. Sociocultural Considerations:

- **Engaging Community Leaders**: Work with local leaders to gain trust and ensure the community is on board.
- **Respecting Traditions**: Understand and address any traditional or cultural apprehensions about switching to biogas.

Successful integration of biogas in the households of Balingore will depend not only on technological adaptations but also on community engagement, ensuring that the benefits of biogas are tangible and recognized by all.

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