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Replication study and mapping of Beninese and Senegalese

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Summary

The LEOPARD project introduces a compact, container-based microgrid solution designed for efficient energy deployment. This containerized solution integrates critical technologies within a standard container, minimizing land use and simplifying environmental assessments. It features pre-installed photovoltaic modules, grid and charger inverters, lithium batteries, and a control and communication device, all housed in standard-sized containers. This design has proven successful in real-world applications in Benin, supporting various energy demands while demonstrating flexibility and efficiency. The deliverable includes interactive maps and Excel spreadsheets for Benin and Senegal, showcasing identified replication sites and their attributes. The maps provide a visual representation of population clusters and pre-identified replication sites, while the spreadsheets allow for detailed data analysis based on factors like grid distance and population size.

Approval

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Replicability Study in Benin and Senegal

WP16 LEOPARD

Version N°1

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Abbreviations and Acronyms

Acronym	Description
AETDGM	Africa Electricity Transmission and Distribution Grid Map
ASER	Senegalese Rural Electrification Agency
CAPEX	Capital Expenditure
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
GOB	Google Open Buildings
JRC	(European Union) Joint Research Centre
LCOE	Levelized Cost Of Electricity
OPEX	Operating Expenditure
OSM	OpenStreetMap
PV	Photovoltaic

Summary

This document provides a comprehensive overview of the LEOPARD project, a key initiative within the LEAP-RE Programme aimed at revolutionizing energy access in West Africa through advanced micro-grid technology. Specifically, the LEOPARD project focuses on deploying a containerized 100% Renewable Energy Source (RES) solution tested in peri-urban and rural areas. This deliverable assesses the replicability potential of the LEOPARD microgrid solution in Benin and Senegal, offering insights into the project's scope, methodologies, results, and recommendations for future improvements.

The LEOPARD Project, a significant endeavour under the LEAP-RE Programme's sixteenth work package, seeks to address the energy access challenges in Africa by deploying an innovative microgrid solution that leverages renewable energy sources. The project targets optimizing local techno-economic benefits and ensuring seamless integration of off-grid solutions with larger grids and national networks. Key objectives include evaluating local energy conditions, designing a containerized RES solution, analysing techno-economic benefits, and identifying replication conditions in Benin and Senegal.

The LEOPARD project introduces a compact, container-based microgrid solution designed for efficient energy deployment. This containerized solution integrates critical technologies

within a standard container, minimizing land use and simplifying environmental assessments. It features pre-installed photovoltaic modules, grid and charger inverters, lithium batteries, and a control and communication device, all housed in standard-sized containers. This design has proven successful in real-world applications in Benin, supporting various energy demands while demonstrating flexibility and efficiency.

The deliverable includes interactive maps and Excel spreadsheets for Benin and Senegal, showcasing identified replication sites and their attributes. The maps provide a visual representation of population clusters and pre-identified replication sites, while the spreadsheets allow for detailed data analysis based on factors like grid distance and population size.

The Levelized Cost of Energy (LCOE) analysis reveals that the economic viability of the microgrid solution in Benin varies significantly with population size and grid length. 144 villages meet the economic viability criteria with a minimum LCOE of 0.302 EUR/kWh in the baseline scenario when the cost of grid investment is considered. Adjusting the diesel share in energy production and considering CAPEX subsidies can significantly enhance economic viability, increasing the number of viable sites up to 196 out of 196 geographically viable sites.

In Senegal, the LCOE analysis has been performed for 3 different types of load curves, associated with varying population sizing and customers distributions. Overall, for each load curve it is possible to identify replication sites in the baseline scenario when considering the cost of grid investment, which varies according to the consumption pattern followed. For instance, LC1 and LC3 present better results than LC2, thanks to a higher energy demand on parity of grid length. With adjustments in CAPEX subsidies, achieving economic viability is feasible for all 321 out of 321 in the case of LC3, 42 for LC2, and 301 for LC1 when the grid investment cost is included in the LCOE calculation. Overall, the LCOE for varies greatly according to the load curve considered and CAPEX incentive envisioned, in the range of 0.160-2.050 EUR/kWh.

The LEOPARD microgrid solution demonstrates significant potential for replicability Benin and Senegal. This deliverable highlights the importance of tailored approaches in different regional contexts to maximize the benefits of renewable energy microgrid solutions.

Overall, the LEOPARD project establishes a promising framework for enhancing energy access through innovative microgrid technologies, with the potential to serve as a benchmark for future RES deployments in Africa.

Keywords

Microgrid, Replication, PV, Battery, Genset, Benin, Senegal, off-grid, LCOE, GIS.

1. Introduction

In this section, a brief introduction to the LEOPARD project and its developed microgrid solution concept is given, together with an overview of this deliverable´s scope and structure.

1.1 LEOPARD Project

The LEOPARD Project, the sixteenth work package of the LEAP-RE Programme, aims to transform energy access in Africa, with a particular focus on West Africa, by leveraging advanced micro-grid technology and automation. It seeks to enhance the deployment of Renewable Energy Sources (RES) through a 100% RES containerized solution, tested in both peri-urban and rural settings. The project will systematically determine local energy access conditions, optimize techno-economic benefits tailored to regional uses, and evaluate the integration of off-grid solutions into larger micro-grids and national grids.

Key objectives include:

- Assessing local energy access conditions at hamlet, village, and regional levels.
- Designing and testing a containerized, RES-based solution.
- Optimizing local techno-economic benefits and user adoption.
- Analysing the impact of integrating off-grid solutions with larger grids.
- Defining conditions for replicability and identifying suitable areas in Benin and Senegal.

Throughout its implementation, LEOPARD will actively promote its goals, findings, and successes to establish itself as a benchmark for RES deployment, guided by the LEAP-RE Communication and Awareness Strategy.

1.2 LEOPARD Microgrid Solution Concept

The LEOPARD project has developed a compact, container-based microgrid solution that integrates essential technologies for efficient microgrid operation within a standard container. This innovative design offers significant advantages. Its small footprint reduces the need for land acquisition and circumvents related environmental and social impact studies. Additionally, the ergonomic design facilitates pre-cabling and equipment setup, while its mobility allows for easy relocation to adapt to changing needs.

Figure 1: The first LEOPARD demonstrator was installed on the Centre Songhaï campus in Benin in 2022.

As part of the project, two types of containers were evaluated. The first, Container-1, is a standard sea freight container, and the second, Container-2, is a locally made pre-manufactured container. Analysis revealed that the locally pre-manufactured container, Container-2, performs better in West Africa, offering improved thermal insulation for approximately 7,000 USD.

The container incorporates a variety of advanced technologies. The photovoltaic (PV) modules used are JAsolar 455 Wc monocrystalline panels (Model JAM72S20-455/MR). The system includes two grid inverters: a Fronius SYMO 8.2-3-M (8 kVA) and a Fronius SYMO 6.0-3-M (6 kVA). It also features three charger inverters, each a Victron Quatro 48V/10000VA/140A (10 kVA), and two charge controllers, the Victron MPPT RS 450/100-Tr (100A each). Energy storage is provided by three BYD lithium batteries, each with a capacity of 15.4 kWh.

The system also includes various distribution boxes: one for connections to loads, one for connections to the public grid which houses the Cerbo GX control and communication device, and one for connections between the PV arrays and other equipment. The entire setup is efficiently packaged in standard containers measuring 6060x2440x2590mm, with a total weight of 2.3 tons. For ease of deployment, the container's building frame is designed to be removable.

This container-based solution has been successfully tested in real-world conditions at the Songhai Centre and the district of Banté in Benin. It supports the energy demands of dormitories, a feed mill, and restaurants, demonstrating its versatility and effectiveness in diverse applications. The compact, portable nature of the container solution makes it well-suited for deployment in various settings, particularly where flexibility and efficiency are paramount.

1.3 Deliverable Scope & Description

This deliverable aims to evaluate the replicability potential of the microgrid solution developed in the LEOPARD project for Benin and Senegal. It specifically addresses the project’s overarching goal of "Defining conditions for replicability and identifying suitable areas in Benin and Senegal”. In particular, the replicability studied is that of a microgrid configuration utilizing the exact same technologies involved in the LEOPARD demonstrators, albeit with the necessary modifications in terms of technological sizing for different population cluster and/or sector expert´s guidance.

The document is structured as follows: Chapter 1 introduces the LEOPARD project and the developed microgrid container solution. Chapter 2 describes the tools and methodology used to assess the replicability potential in Senegal and Benin. Chapter 3 presents the results of the replicability analysis. Chapter 4 explores the study's limitations and offers recommendations for future improvements while summarizing the main conclusions from the analysis.

2. Tools and Methodology

This chapter focuses on describing the tools and methods used to perform the replicability study of the microgrid solution developed within the LEOPARD project.

2.1 Tools Description

This section provides an overview of the tools employed to conduct the analysis of this study. The selection of these tools was driven by their ability to accurately model, simulate, and evaluate the core aspects of the microgrid solution under investigation. Each tool contributes uniquely to the analytical framework, enabling comprehensive assessments of various parameters and their implications on replicability. The following subsections describe each tool's functionality, purpose, and how they integrate into the overall methodology, ensuring a robust and systematic approach to analysing the microgrid's potential in different contexts.

2.1.1 LENI

LENI is intended for use during the screening phase and determines the most suitable rural electrification solution to supply the villages: grid extension, microgrid, or solar home system.

LENI is a methodology developed between 2019 to the present for rapidly scanning a region and identifying population clusters for assessing their suitability for the implementation of an electrification solution.

A comprehensive database of the best available population data is scanned with a configurable clustering algorithm to identify clusters that are suitable in terms of physical size and population.

2.1.2 LCOE Tool

The LCOE Tool developed by EIFER for LCOE calculation offers a time efficient solution for evaluating microgrid projects with a pre-configured set of technologies involved and whose share in meeting the villages energy needs has been specified. Results from LENI and data from users regarding the villages location, population, and grid length can be fed to the tool in order to estimate the LCOE of a potential microgrid project in the area. Users can also manually input a typical 24-hour load curve for different customer categories like residential, commercial, cold storage, and so on and so forth. The tool thus then provides budget estimates for both investment and operating expenditures related to the microgrid system and low voltage network for the selected villages. Technologies integrated in the tool include PV, batteries, diesel generators and inverters so far, although different technologies could be integrated as well. To aid in the financial feasibility of potential replication sites of the solutions developed in the LEOPARD project, the LCOE Tool also estimates the LCOE in EUR/kWh of the microgrid for the specific village, both considering the grid cost in the calculation and without considering it.

2.2 Data Sources

This section outlines the data sources utilized in the presented analysis. These sources provide the foundational information required to evaluate the microgrid solution, encompassing local energy conditions, socio-economic factors, and technical parameters essential for accurate assessment and replication of the proposed microgrid concept.

2.2.1 Input Data to LENI

Several open data sources were used to identify and analyse candidate replication sites. They are listed in this section.

2.2.1.1 Google Open Buildings

The Google Open Building (GOB) dataset is available from download from Google. It contains polygons representing buildings that have been derived from high-resolution satellite imagery, with a focused overage of the global south (Google Research, 2024). Each building feature comes with an associated confidence level, expressed as a fraction between 0 and 1, where a higher value indicated higher confidence of presence of a building. GOB was used in the site clustering methodology as the base features which were clustered to create replication candidate sites.

2.2.1.2 Africa Electricity Transmission and Distribution Grid Map

The Africa Electricity Transmission and Distribution Grid Map (AETDGM) dataset is published by the World Bank and contains line features representing the latest known state of the electricity transmission and distribution grid in Africa (The World Bank, n.d.). While the coverage is not totally complete, there is usually information regarding the voltage level of each line, and whether it is existing or planned. Additionally, there is sometimes some other information, such as the operator and source. AETDGM was used in the site clustering methodology to indicate the straight-line distance of the replication candidate sites to the existing or planned electricity transmission and distribution grid. The AETDGM dataset is shown in Figure 2 and Figure 3, for Benin and Senegal, respectively.

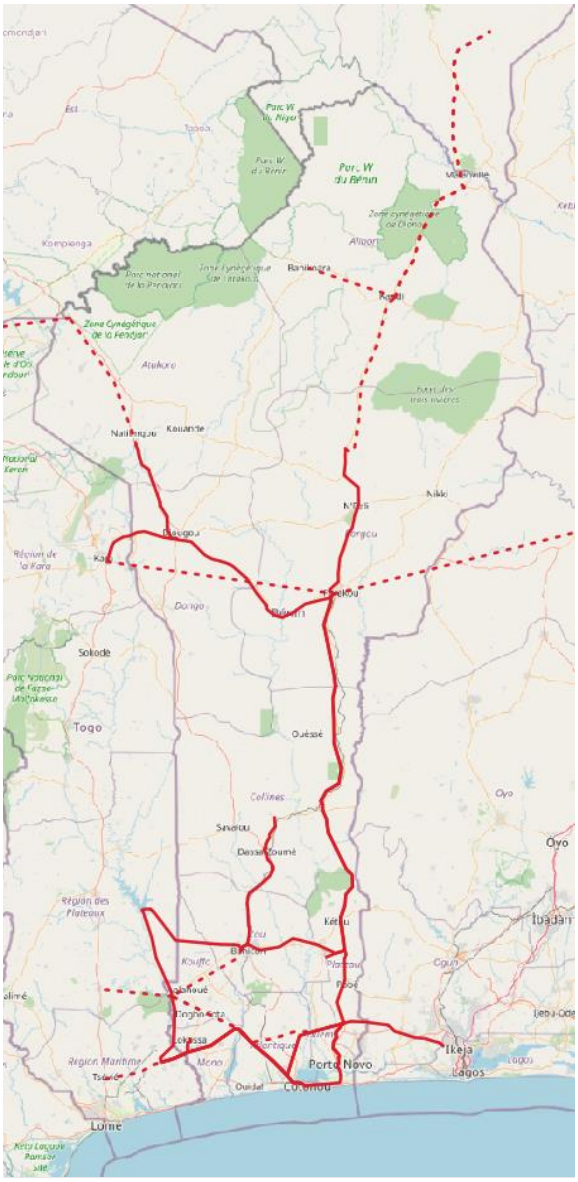

Figure 2: AETDGM dataset for Benin. Solid lines indicate the existing grid, dashed lines indicate the planned grid. Basemap © OpenStreetMap Contributers

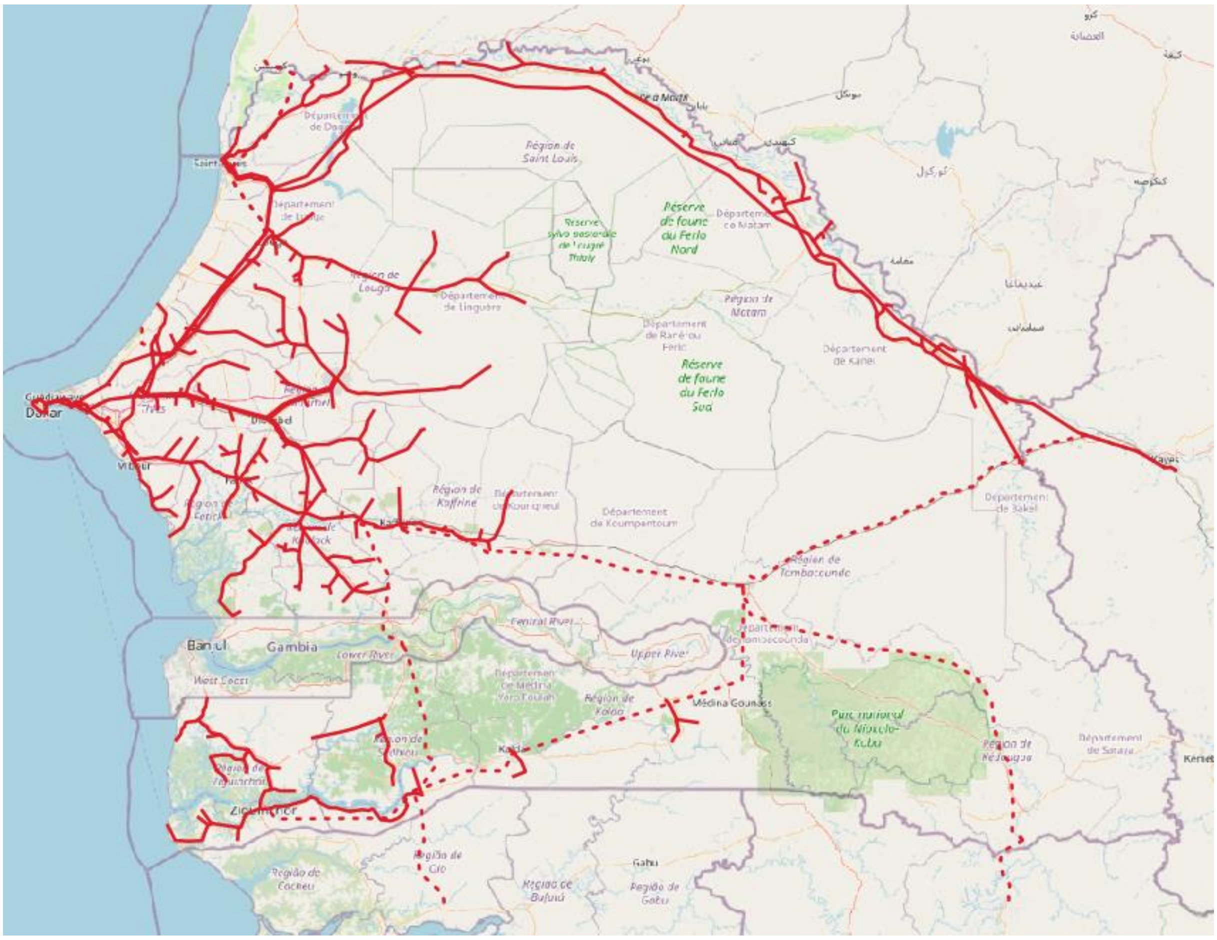

Figure 3: AETDGM dataset for Senegal. Solid lines indicate the existing grid, dashed lines indicate the planned grid. Basemap © OpenStreetMap Contributers

2.2.1.3 OpenStreetMap

OpenStreetMap (OSM) is a long-running open-source project which uses volunteer editors to create and maintain a detailed map the world (OpenStreetMap, n.d.). Its level of detail varies from country to country, but a baseline coverage of roads, streets and place names is generally consistent across the globe. Raw data from OSM can be downloaded from different sources, however data dumps from Geofabrik (Geofabrik GmbH, n.d.) were used in the replication study. Road and street features from OSM were used as input to the "Pathfinder" algorithm (see Estimation of Required Cable Length) to estimate the required cable length of a microgrid.

Features indicating the name of a place were used to provide local context to identified site candidates. Features indicating the presence of a telecommunications tower were also used to indicate a candidate site's distance to such a tower.

2.2.1.4 Mapwith.ai Missing Roads from OpenStreetMap

While OSM's coverage is quite comprehensive, it is not complete, especially in global south countries, such as the target countries for the replication study (Benin and Senegal). Meta (Known at the time as Facebook) has published a catalogue of per-country datasets which contain assumed roads which have been derived from high-resolution satellite imagery (Facebook, n.d.). These features have not gone through the standard review that is typically performed before being integrated into the OpenStreetMap database, but the quality was deemed acceptable for use in the replicability study. The assumed road features were used to supplement the OSM road features when estimating the required cable length of a microgrid with the "Pathfinder" algorithm.

2.2.1.5 Healthcare Facilities in Africa

The approximate locations of health care facilities in Africa have been compiled and published by the European Union Joint Research Centre (JRC) (European Commission Joint Research Centre, 2021). The features contain information about the size, location, electricity access, and various other electricity-related metrics about health care facilities, which may be useful for deciding on a replication site.

2.2.1.6 Pre-Identified Replication Sites

Lists of sites that were pre-selected for replication were provided by other partners. For Benin, a single list of sites was provided in the form of a Microsoft Excel spreadsheet. For Senegal, two lists were provided in the form of Microsoft Excel spreadsheets.

Benin Spreadsheet

This spreadsheet was sent by Leonide Sinsin (ARESS) and forwarded by DPEERR (Department of Energy Planning, Rural Electrification and Regulation in Benin). This list contained, among other information, latitude and longitude coordinates, estimated population, as well as the name of the settlement. This data was integrated into the candidate site identification methodology so that it could be viewed in the context of a country-wide study.

Senegal Spreadsheet #1

This spreadsheet was also provided by ESP (Ecole Supérieure Polytechnique de Dakar in Senegal) via Professor Fadel Kébé. This list was constrained to the "Kaffrine" region of Senegal, and contained various electrification-related metrics, as well as a settlement name and a population estimate, but it did not have any coordinates with which to geolocate the settlement. To overcome this, the names of the settlements and some other context clues from the spreadsheet (such as names of encompassing geographic regions) were used to locate them as effectively as possible, however, in some cases, it was simply not possible to geolocate them. This process was conducted using the "Nominatim" (Nominatim Project, n.d.) geolocation service, as well as Google Maps for some additional refinement. Appendix I shows the pre-identified villages in Kaffrine region in Senegal.

Senegal Spreadsheet #2

This spreadsheet was the data was sent by Professor Fadel Kébé (ESP) and forwarded by the Senegalese Rural Electrification Agency (ASER). This list contained, among other information, latitude and longitude coordinates, estimated population, as well as the name of the settlement. This data was integrated into the candidate site identification methodology so that it could be viewed in the context of a country-wide study. Appendix II shows the 320 pre-identified villages in Senegal.

2.2.2 Input Data to LCOE Tool

Several inputs are required to accurately estimate the microgrid LCOE for a given location and they are presented in the following sections.

2.2.2.1 Geographical and Social Data in Benin

The geographic location of potential replication sites within the target areas of interest, specifically Benin is a crucial input for the LCOE Tool. This information allows us to pinpoint specific villages or clusters of villages for analysis. The microgrid solution is tailored to meet the energy demand of the population size associated with each identified village, making population data essential for accurately estimating the microgrid's Levelized Cost of Energy (LCOE). Moreover, understanding the distribution of consumer types within each village is fundamental, as this affects the load curve and consequently the sizing and cost estimation of the microgrid. The identified energy consumer categories include three types of residential clients (each with distinct energy consumption patterns and peak demands), commercial clients, public clients, productive clients, and a specific category for constant cooling demand, termed "Cooling demand," which pertains to cold storage requirements in the village.

Geographic Data

Regarding the geographical location and population size of the village, these values can either be manually input by the microgrid developer or derived from the outputs of the LENI tool. In contrast, data on the distribution of consumer types must be supplied by the microgrid developers to appropriately size the microgrid according to their specific requirements. Another input that is required is the number of inhabitants per household, which can be specified according to the case considered or inferred by the results of the LENI tool.

In the case of Benin, a total population of 179,779 people is scattered across 195 villages identified. The size of villages, especially in terms of population, can greatly influence the replicability potential of the LEOPARD microgrid solution, thus, it is important to understand how the population is distributed. Figure 4 offers a visual representation of the population status in the identified sites in Benin. The size of the bubbles represents the number of villages within the identified population range. It is evident from the graph that most of the identified sites for replication (101) are on the smaller end of the spectrum, with a population below 500pp. Generally, it can be said that the majority of the identified sites fall onto the lower end of the population sizes within Benin villages, as larger population clusters are rarer. For the sake of easiness to read, the only 3 villages with a population above 6,000 have been excluded from the graph, since it would have been harder to understand the other rather smaller sizes compared to it (See Appendix III for the full graph).

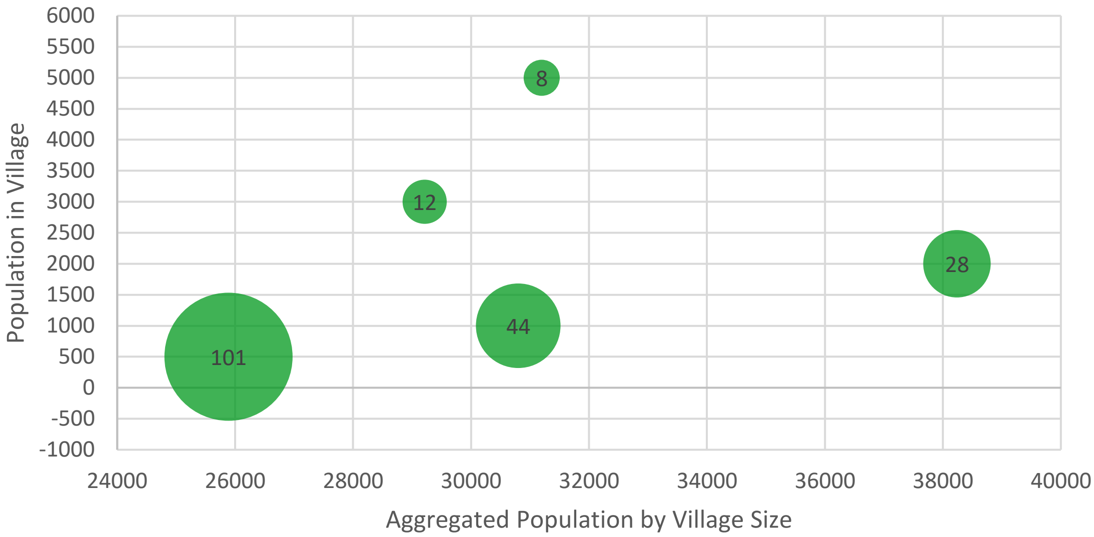

Figure 4: Population distribution by size of village and by number of villages in Benin.

Social Data

In the frame of mind of social data, the distribution of buildings by consumer type in terms of percentages is an input value that needs to be provided by the LCOE Tool user.

In the case of Benin, such input values have been provided by ARESS, a relevant expert in the field of microgrid projects development. Such inputs are presented in Figure 5, where the residential clients differ mainly by the power in W that they consumer, in particular, the residential clients type 1,2, and 3 have an allocated power supply of 30, 192, and 300 respectively. It is evident that the residential client type 2 (192 W peak demand) is the most common type of building for the Beninese case (57%), followed by residential client type 1 (20%). In general, commercial clients still represent a considerable amount of building, with 9%, while the remaining is split almost equally among residential client type 3, public clients, and productive clients.

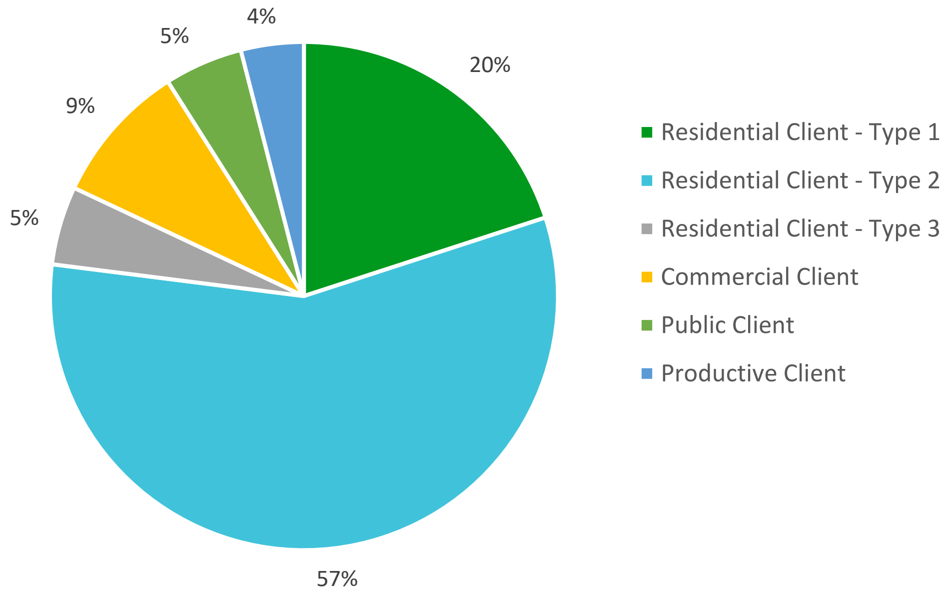

Figure 5: Distribution of Buildings by Type of Client in Benin.

Other social data required concern the overall power consumption of the type of customer, which is a data can be input from the user or provided from available literature, together with the number of inhabitants per household.

In the case of Benin, the peak power required by type of client is presented in Table 1.

Table 1: Peak Power required by type of Client in Benin

Client	Power [W]
Residential Client – Type 1	30.00
Residential Client – Type 2	92.00
Residential Client – Type 3	300.00
Commercial Client	500.00
Public Client	300.00
Productive Client	1,200.00
Street Lighting	200.00
Telecom Tower	2,000.00
Water Pumping	500.00
Cooling Storage	3,600.00

A final social input data required is the number of inhabitants per household, which is set to 8 in the case of Benin according to the (Radboud University - Institute for Management , 2021).

2.2.2.2 Geographical and Social Data in Senegal

The geographic location of potential replication sites within the target areas of interest, specifically Senegal is a crucial input for the LCOE Tool. This information allows us to pinpoint specific villages or clusters of villages for analysis.

The microgrid solution is tailored to meet the energy demand of the population size associated with each identified village, making population data essential for accurately estimating the microgrid's Levelized Cost of Energy (LCOE). Moreover, understanding the distribution of consumer types within each village is fundamental, as this affects the load curve and consequently the sizing and cost estimation of the microgrid. The identified energy consumer categories include four types of clients: **Households**, **Income generating activities** (Shop, Multiservice, Mill, Tailoring, Water pumping and young people's home), **Social and community building** (Cult place, Post and healthcare centre, School) and **Drilling/Borehole**.

Geographic Data

Regarding the geographical location and population size of the village, these values can either be manually input by the microgrid developer or derived from the outputs of the LENI tool. In contrast, data on the distribution of consumer types must be supplied by the microgrid developers to appropriately size the microgrid according to their specific requirements. Another input that is required is the number of inhabitants per household, which can be specified according to the case considered or inferred by the results of the LENI tool.

In the case of Senegal, a total population of 158,683 people is scattered across 321 villages identified (Appendix II: Liste globale des villages du projet ASER 300 villages). The size of villages, especially in terms of population, can greatly influence the replicability potential of the LEOPARD microgrid solution, thus, it is important to understand how the population is distributed. Figure 6 offers a visual representation of the population status in the identified sites in Senegal. The size of the bubbles represents the number of villages within the identified population range. It is evident from the graph that most of the identified sites for replication (191) are on the smaller end of the spectrum, with a population below 1000pp.

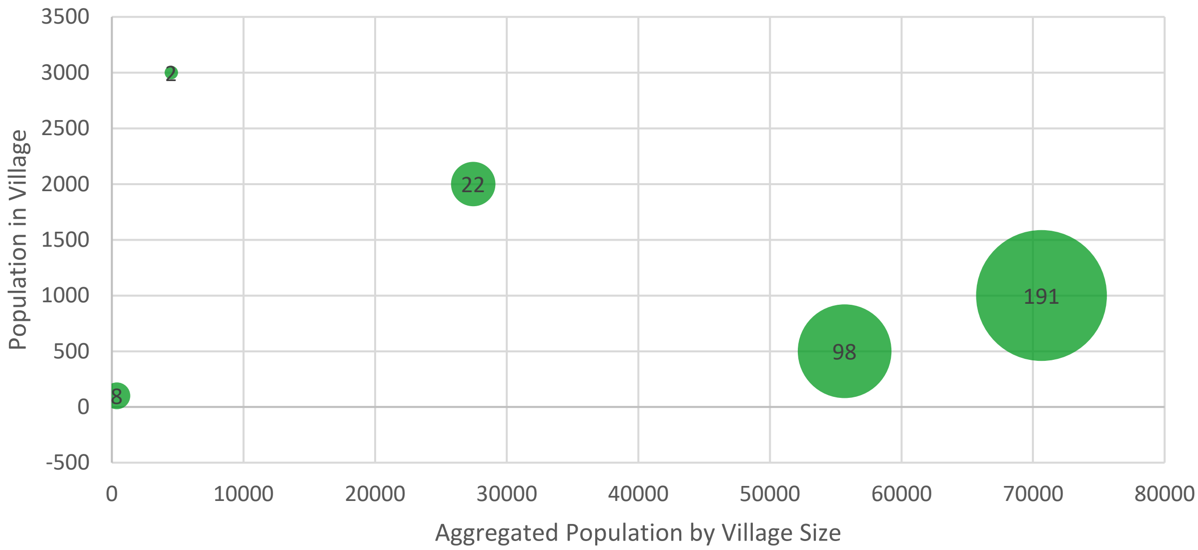

Figure 6: Population distribution by size of village and by number of villages in Senegal.

Social Data

In the frame of mind of social data, the distribution of buildings by consumer type in terms of percentages is an input value that needs to be provided by the LCOE Tool user.

In the case of Senegal, such input values have been provided by Senegalese Rural Electrification Agency (ASER) which is an autonomous unit of the Ministry of Energy, responsible for promoting rural electrification through support to initiatives at national and international level to develop electrification programs based on of the electrification plan defined by the appropriate Minister.

Three types of typical villages in Senegal have been provided by prof. Fadel Kébé with different distribution of energy demand and different size of population (0-200; 200-1000; >1000 inhabitants).

Figure 7 shows the distribution of daily energy demand of Village **(0 - 200 inhabitants)** by Type of Client in Senegal with a large part the residentials buildings (95%), followed by social and community (4%) and Income generating activities (1%). Income generating activities shown in Table 3 include mainly a shop.

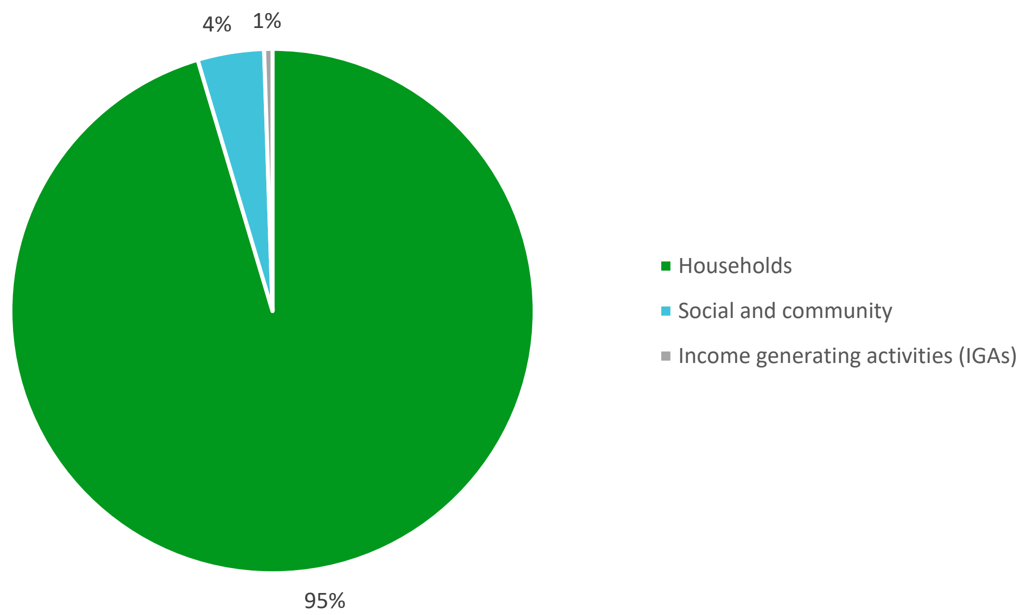

Figure 7: Distribution of Daily Energy demand of a typical Village (0-200 inhabitants) by Type of Client in Senegal.

Table 2: Description of a typical village in Senegal

Region	Fatick
Department	Fatick
Municipality	Fimela
Locality	H1Wandie
Population	216
Households	20
Average household size	11

A final social input data required is the number of inhabitants per household, which is set to 11 according to the data sent by Professor Fadel Kébé.

Table 3: Description of income-generating activities in a typical village (0-200 inhabitants) in Senegal

Income generating activities (IGAs)	
Shop	1
Multiservice	0
Mill	0
Tailoring	0
Water pumping	0
Young people's home	0

Table 4: Description of Social and Community activities in a typical village (0-200 inhabitants) in Senegal.

Social and community	
Cult place	1
Post and healthcare center	0
School	0

In the case of Senegal, the peak power required by type of client is presented in Table 5.

Table 5: Peak Power required by type of Client in a typical village (0-200 inhabitants) in Senegal.

Client	Power [W]
20 Households	1,862.00

Social and community	80.00
Income generating activities	10.00

Table 6: Daily demand in kWh by type of Client in a typical village (0-200 inhabitants) in Senegal

Client	Daily demand in [kWh]
20 Households	16.92
Social and community	0.50
Income generating activities	0.13

Figure 8 shows the distribution of daily energy demand of Village **(200 - 1000 inhabitants)** by Type of Client in Senegal with a large part the residentials buildings (86%), followed by income generating activities (13%) and social and community (1%). Income generating activities shown in Table 8 include productive clients such as Mill, Tailoring, water pumping, etc...

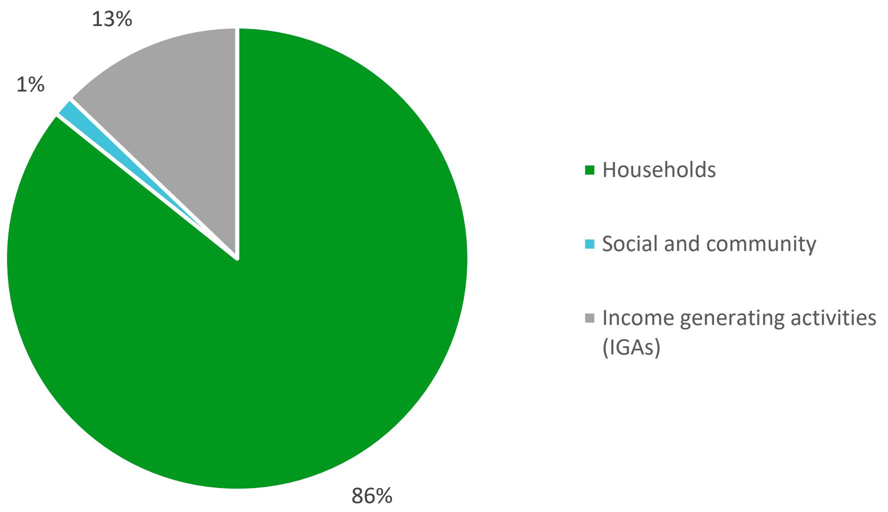

Figure 8: Distribution of Daily Energy demand of a typical Village (200-1000 inhabitants) by Type of Client in Senegal.

Table 7: Description of a typical village (200-1000 inhabitants) in Senegal

Region	Saint-Louis
Department	Podor
Municipality	Dounga-Lao
Locality	Bowde Toudounde
Population	790
Households	113
Average household size	7

A final social input data required is the number of inhabitants per household, which is set to 7 in the case of Senegal according to the (Radboud University - Institute for Management , 2021) and the data sent by Professor Fadel Kébé.

Table 8: Description of income-generating activities in a typical village (200-1000 inhabitants) in Senegal

Income generating activities (IGAs)	
Shop	2
Multiservice	1
Mill	1
Tailoring	1
Water pumping	1
Young people's home	1

Table 9: Description of Social and Community activities in a typical village (200-1000 inhabitants) in Senegal.

Social and community	
Cult place	1
Post and healthcare center	1
School	1

In the case of Senegal, the peak power required by type of client is presented in Table 10.

Table 10: Peak Power required by type of Client in a typical village (200-1000 inhabitants) in Senegal.

Client	Power [W]
113 Households	14,800.00
Social and community	92.00
Income generating activities	300.00

Table 11: Daily demand in kWh by type of Client in a typical village (200-1000 inhabitants) in Senegal

Client	Daily demand in [kWh]
113 Households	145.96
Social and community	2.54
Income generating activities	12.23

Figure 11 shows the distribution of daily energy demand of Village **(more than 1000 inhabitants)** by Type of Client in Senegal with a large part income generating activities (44%) followed by borehole & drilling activities (32%) households (23%) and social and community (1%). Income generating activities shown in Table 13 include productive clients such as Mill, Tailoring etc...

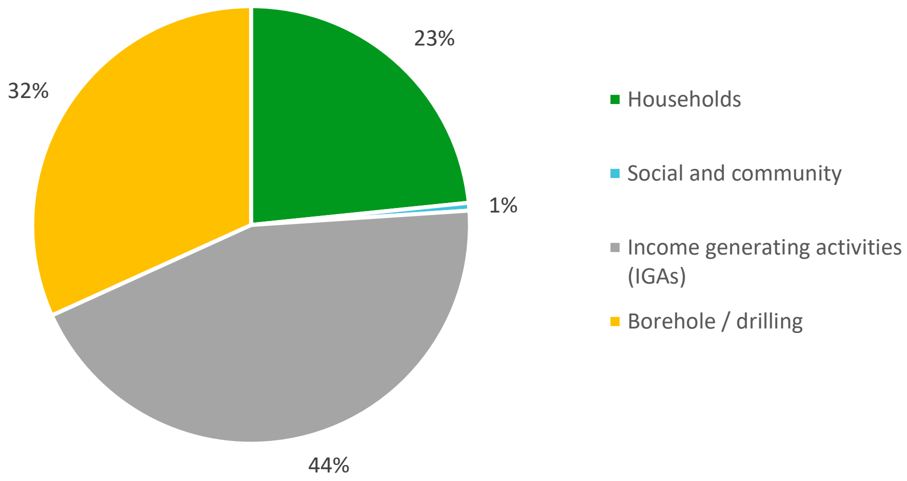

Figure 9: Distribution of Daily Energy demand of a typical Village (more than 1.000 inhabitants) by Type of Client in Senegal.

Table 12: Description of a typical village (more than 1.000 inhabitants) in Senegal

Region	Ziguinchor
Department	Bignona
Municipality	Sindian
Locality	MEDIEDJE
Population	1.458
Households	146
Average household size	10

A final social input data required is the number of inhabitants per household, which is set to 10 according to the data sent by Professor Fadel Kébé.

Table 13: Description of income-generating activities in a typical village (more than 1.000 inhabitants) in Senegal

Income generating activities (IGAs)	
Shop	2
Multiservice	1
Mill	2
Tailoring	2
Water pumping	1
Young people's home	1

Table 14: Description of Social and Community activities in a typical village (more than 1.000 inhabitants) in Senegal.

Social and community	
Cult place	2
Post and healthcare center	1
School	1

In the case of Senegal, the peak power required by type of client is presented in Table 15.

Table 15: Peak Power required by type of Client in a typical village (more than 1.000) in Senegal.

Client	Power [W]
146 Households	13,335.00
Social and community	325.00

Income generating activities	25,246.00
Borehole / Drilling	18,126.00

Table 16: Daily demand in kWh by type of Client in a typical village (more than 1.000) in Senegal

Client	Daily demand in [kWh]
146 Households	120.84
Social and community	3.04
Income generating activities	139.02
Borehole / Drilling	90.75

2.2.2.3 Technical Data

This section provides a detailed overview of the technical data inputs critical for the analysis and configuration of the microgrid solution. These inputs include the technological configuration of the microgrid, the share of energy production by each technology type, the hourly annual energy demand, grid length, and specifications of relevant energy technologies. Accurate and comprehensive technical data is essential to ensure the proper design, sizing, and operational efficiency of the microgrid, allowing us to tailor solutions that meet the specific energy needs of the target areas.

Project Lifetime

The project lifetime is a key parameter in the estimation of the LCOE of a microgrid project. In particular, in the case of Benin, the project lifetime is assumed to be of 20 years, while it is set to 25 years in the case of Senegal.

Technological Microgrid Configuration

To accurately size the microgrid and estimate its Levelized Cost of Energy (LCOE), it is crucial to identify the technologies included in the final design and their respective installed power. The technological configuration can differ from project to project; however, for the LEOPARD project, the containerized microgrid solution integrates photovoltaics (PV), batteries, a diesel generator, and inverters, which facilitate power flow between the PV system and the batteries, as explained in LEOPARD Microgrid Solution Concept of which Figure 10 offers a visual representation.

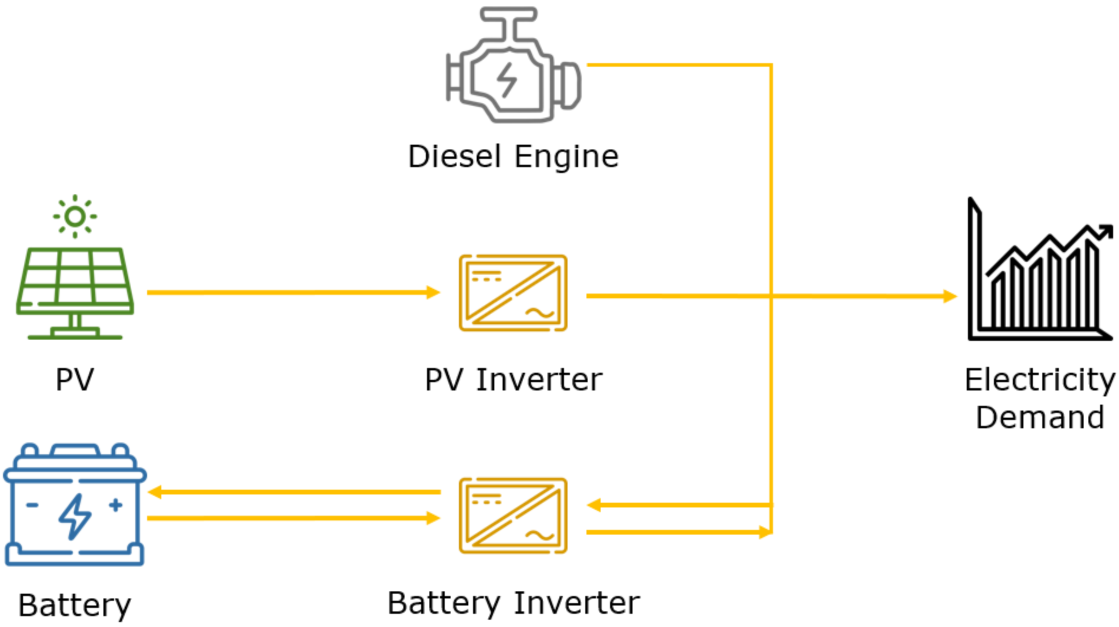

Figure 10: Microgrid Solution Concept Technological Configuration (Image created using Flaticon.com)

The data concerning the respective installed power of the identified technology relative to the peak power demand needs to be provided by the user to the LCOE Tool, this can either be the result of simulations with additional tools, such as the EIFER proprietary tool Memogrid, or the result of field experience gathered over several successful projects.

In the case of the replicability study carried out for Benin, the ratio of installed capacity per technology of the peak power demand is an input provided by ARESS based on their experience with the development of over 300 microgrids. Based on such input values, it is possible to have a clear overview of the share of each technology in terms of total installed power and offers a picture of that for the Benin replicability potential assessment. The majority of the overall installed capacity is represented by batteries with 37%, which are an essential component of the microgrid to avoid solar curtailment and to enhance the use of "free" renewable energy, followed by PV, and battery an PV inverters with 17%, and finally by the diesel generator with 11%. This reflects the willingness to shift towards more sustainable energies in Benin.

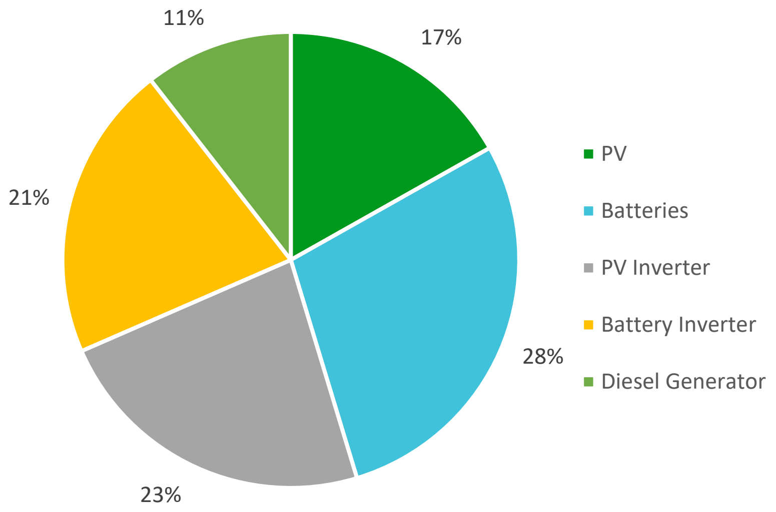

Figure 11: Ratio of Installed Capacity per Technology in the Benin Replicability Assessment

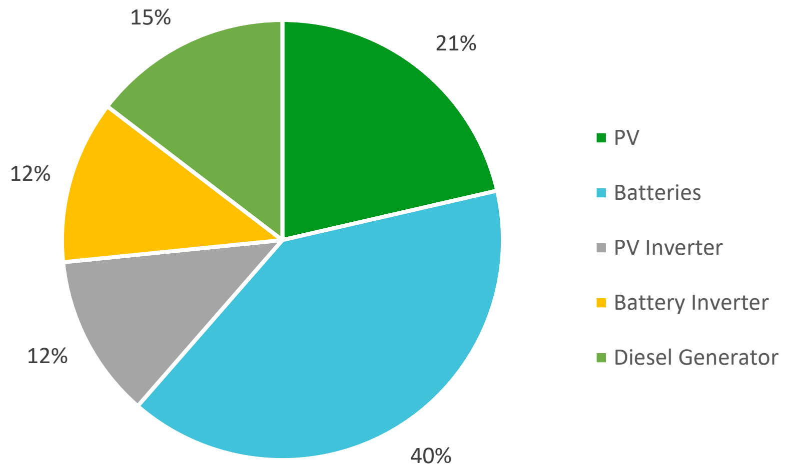

Figure 12: Ratio of Installed Capacity per Technology in the Senegal Replicability Assessment

Another important parameter is the share of diesel-based energy production of the yearly microgrid energy demand. This is an important parameter since it allows to achieve a high share of renewable energy integration.

For the case of Benin the percentage of diesel energy demand coverage is set to 14%. This value can be given as an input from the LCOE Tool user or can be provided through optimization with Memogrid.

In the case of Senegal, the share of diesel production in the overall energy demand covered varies according to the village size between 38-46%.

Relevant Technologies Specifications

As already mentioned in LEOPARD Microgrid Solution Concept, a series of technologies has been selected for the microgrid studies and each comes with some specifications. Therefore, this section aims at shedding light on the technical parameters used to characterize the technologies involved in the microgrid design. For what concerns the diesel generator, Table 17 presents the most relevant technical parameters considered.

Table 17: Diesel Generator Technical Specifications

Parameter	Value	Unit
Nominal Power	Calculated	kW
Diesel Calorific Value	10.700	kWh/litre
Power Production Efficiency	0.163	-
Maximum Power Production Efficiency	0.370	-
Lifetime Benin Lifetime Senegal	10 7	Yr Yr

Regarding the battery, Table 18 offers a representation of the most relevant technical parameters.

Table 18: Battery Technical Specifications

Parameter	Value	Unit
Capacity	Calculated	kWh
Maximum Power In/Out	33.750	kW
Self-discharge Rate	0.100	-
Minimal Level	0.100	-
State Of Charge	0.454	-
Lifetime	10	yr
Battery Deterioration Rate	Not Considered	-

For the inverters, both for the battery and the PV system, the relevant parameters are presented in Table 19.

Table 19: Inverters Technical Specifications

Parameter	Value	Unit
Nominal Power	Calculated	kW
Efficiency	0.945	-
Operating Temperature	25.00	°C
Lifetime	10	yr

For what concerns the PV, relevant parameters are presented in Table 20.

Table 20: PV Technical Specifications

Parameter	Value	Unit
Mounting Type	Fixed	-
Slope and Azimuth	Optimized slope and azimuth for coordinates	-
PV technology	Crystalline Silicon	-
Installed Peak Power	1	kW_p
System Loss	14	%
Lifetime Benin Lifetime Senegal	20 25	Yr Yr

For the estimation of the available power production from PV, the online open access tool PVGIS is used, of which a graphic representation is offered in Figure 13. This tool allows to make calculations on PV systems that are not connected to the electricity grid but use batteries as energy storage. Data can be extracted from PVGIS for the past 10 years and averaged to create a 1-year averaged PV production dataset.

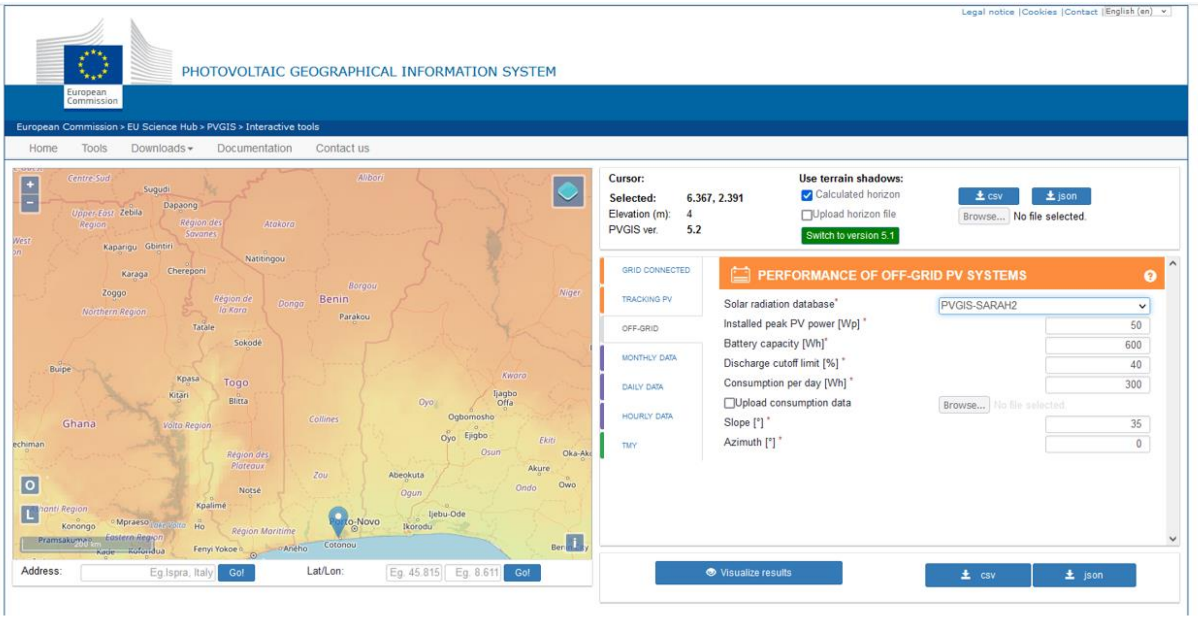

Figure 13: PVGIS tool example (Source: (PVGIS Photovoltaic Geographical Information System, 2024))

Grid Length

A crucial factor in estimating the LCOE of any microgrid project is the length of the cables required, making the grid length in kilometres a vital input for the LCOE Tool. This data is sourced from the LENI tool.

Benin Daily Hourly Load Profile

To determine the optimal size for the microgrid, obtaining a reasonably accurate daily hourly load profile is crucial. This involves inputting hourly energy consumption data from various energy consumers, including building consumers as detailed in the previous section ("Geographical and Social Data"), as well as additional consumers such as street lighting, telecom towers, water pumping, and cooling storage which are included in the LCOE tool.

For the case of Benin, the daily hourly load profile is provided by ARESS, an expert microgrid developing company in Africa, which is a load curve resulting from their available experience on similar projects.

The daily hourly load profile for Benin is presented in Figure 14, Figure 15, and Figure 16, where the difference among them lies in the different type of customers considered. This merely means that the load curve for each of the identified potential replication sites will be the same, although the daily hourly load curve has been split over several graphs for clarity of understanding of the contribution of each major energy user. Considering all the clients or only some of them allows to appreciate the load curve shape built thanks to the expert advice of ARESS. Without considering the telecom tower and the cooling storage demand, which are constant throughout the day, it is possible to observe the true nature of the village residential and commercial load profile. The load curve obtained shows demand peaks between 06.00-11.00, 12.00-14.00, and 16.00-23.00 reaching up to 1.2 kW, while during the nighttime the consumption is mainly represented by street lighting, and it settles around 300 W.

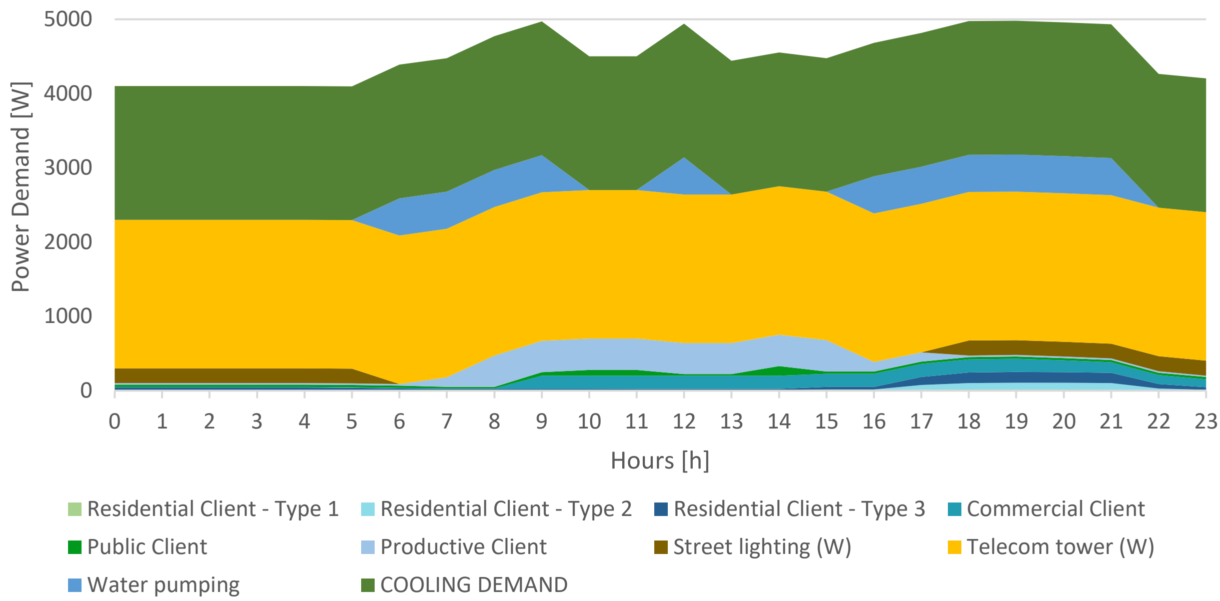

Figure 14: Daily Hourly Load Profile for a Typical Village in Benin

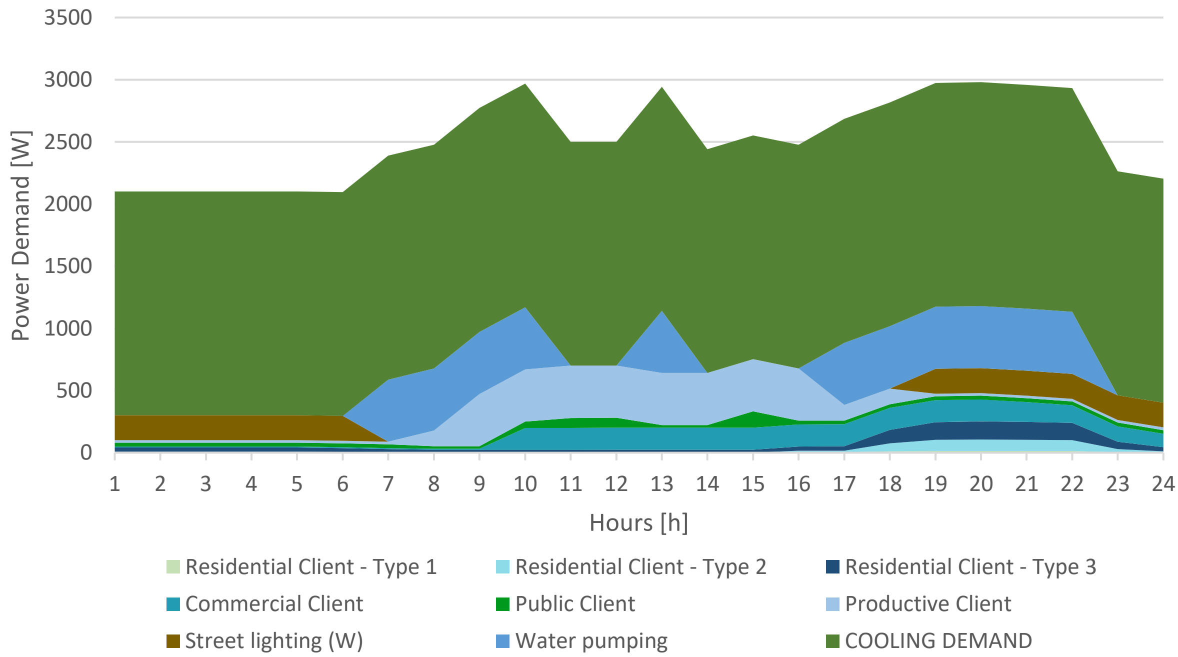

Figure 15: Daily Hourly Load Profile for a Typical Village in Benin without the Telecom Tower

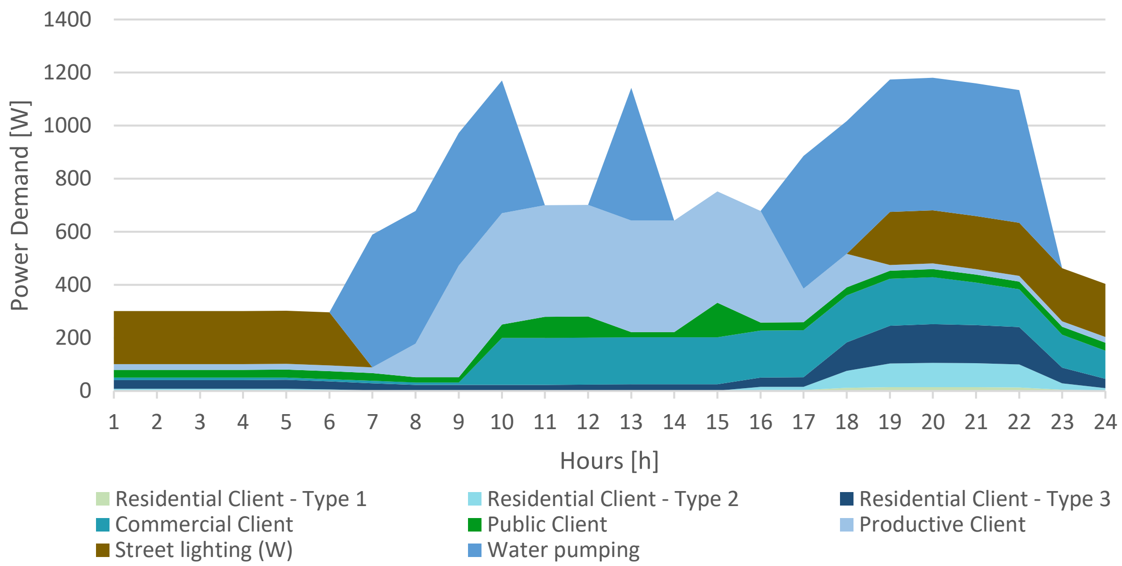

Figure 16: Daily Hourly Load Profile for a Typical Village in Benin without the Telecom Tower and the Cooling Storage

Senegal Daily Hourly Load Profiles

For the case of Senegal, there are 3 daily hourly load profiles provided by CT2S (Professor Fadel Kébé), which are resulting from villages with from 0 to 200 inhabitants, 200 to 1.000 inhabitants and more than 1.000 inhabitants.

The first daily hourly load profile for Senegal is presented in Figure 19 where the difference among them lies in the different type of customers considered in Table 2. Considering all the clients or only some of them allows to appreciate the load curve shape. The load curve obtained shows demand peaks between 21.00-23.00 reaching up to 1.80 kW.

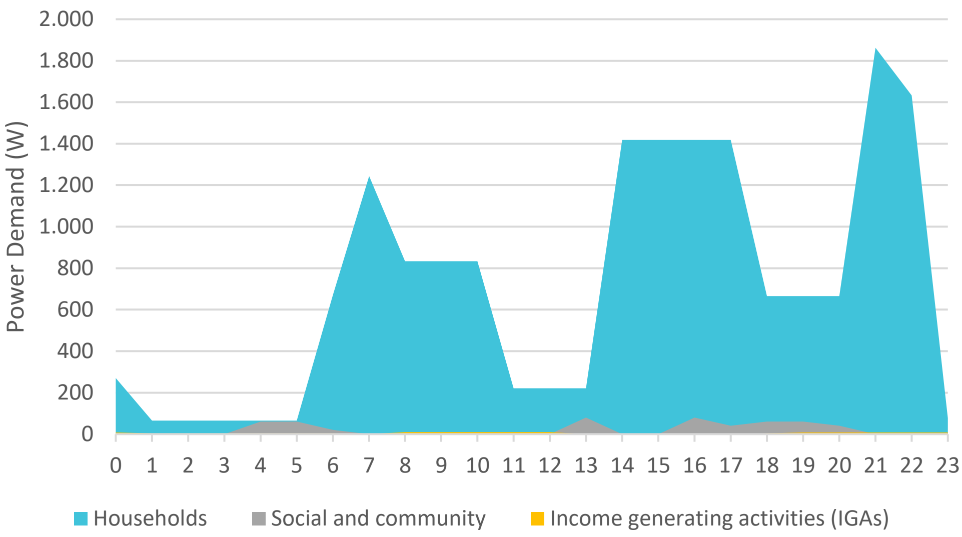

Figure 17: Daily Hourly Load Profile 1 for a Typical Village (0-200 inhabitants) in Senegal.

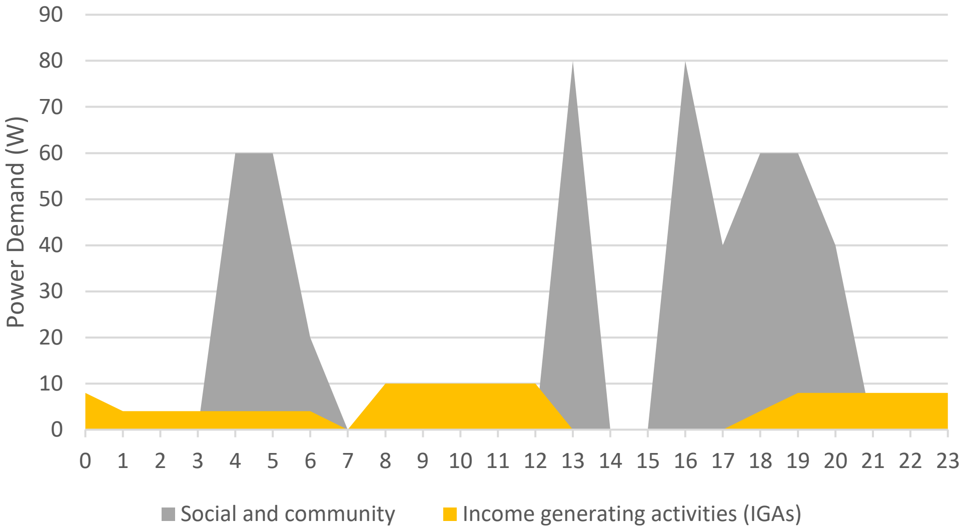

Figure 18: Daily Hourly Load Profile 1 for a Typical Village (0-200 inhabitants) in Senegal without households.

The second daily hourly load profile for Senegal is presented in Figure 19 where the difference among them lies in the different type of customers considered in Table 7. The load curve obtained shows demand peaks between 21.00-23.00 reaching up to 15.10 kW.

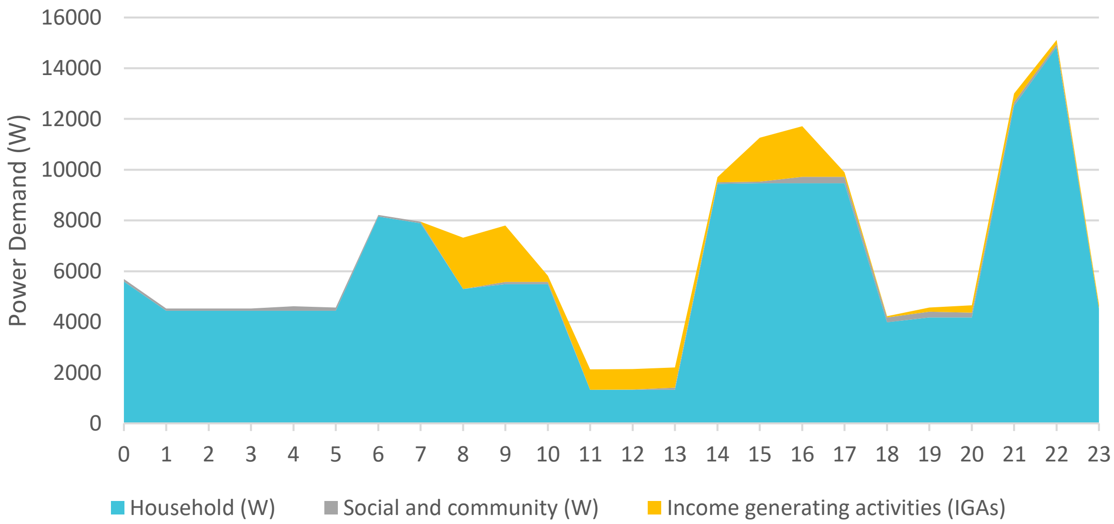

Figure 19: Daily Hourly Load Profile 2 for a Typical Village (200 -1000 inhabitants) in Senegal.

The third daily hourly load profile for Senegal is presented in Figure 20 where the difference among them lies in the different type of customers considered in Table 12. The load curve obtained shows demand peaks between 11.00-12.00 reaching up to 25.50 kW.

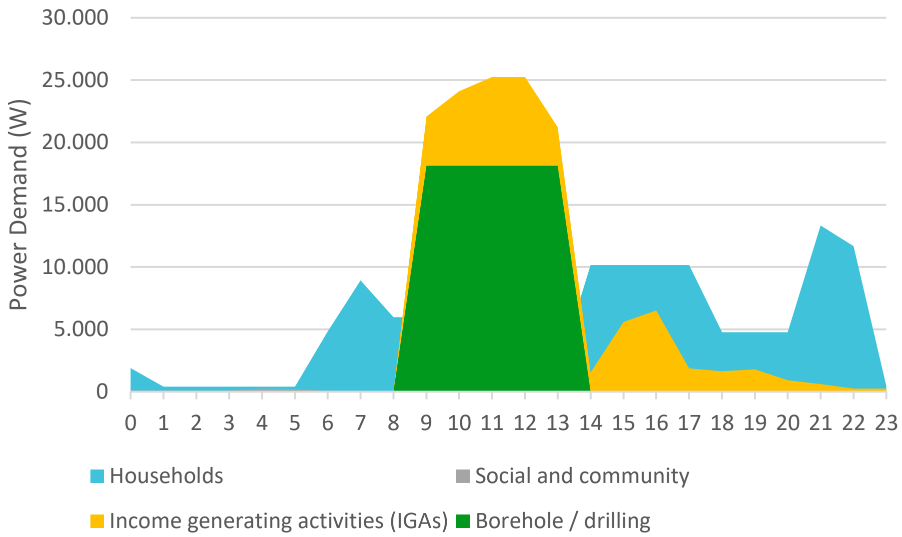

Figure 20: Daily Hourly Load Profile 3 for a Typical Village (more than 1000 inhabitants) in Senegal.

2.2.2.4 Economic Data

In assessing the economic feasibility and performance of a project (closely linked to its replicability), several key financial parameters are crucial. These parameters include:

- Capital Expenditure (CAPEX), which represents the initial investment costs for purchasing and installing equipment.
- Operating Expenditure (OPEX), encompassing the ongoing costs of operation and maintenance, including fuels costs, reflecting the expenses associated with energy sources.
- The Discount Rate which is used to calculate the present value of future cash flows.
- And the Inflation Rate that adjusts these values to reflect changes in purchasing power over time.

Together, these economic parameters provide a comprehensive view of the financial viability and cost-efficiency of the project.

For what concerns the CAPEX, the investment cost of each component considered in the Senegalese case in the LCOE Tool is presented in Table 21 and it comprises of the labour cost associated with each component. Such data were provided as input from ROGEAP data sent by Prof Fadel Kébé (CT2S), from a Senegal case study GET Invest done in 2020, from ARESS based on their previous experience with similar projects. It is evident that the major investment cost for the microgrid is represented by the grid itself and, in terms of technologies involved, PV and batteries account for the highest investment costs.

Table 21: Investment Cost of Microgrid Components including Labour Cost for Senegal

Component	CAPEX	Unit
PV***	450.00	EUR/kW
Battery*	385.97	EUR/kWh
PV Inverter*	222.10	EUR/kW
Battery Inverter*	297.48	EUR/kW
Diesel Generator**	300.00	EUR/kW
Grid*	24,485.00	EUR/km

*ARESS data

** ROGEAP data sent by Prof Fadel kébé (CT2S)

*** Senegalese feasibility study GET Invest.

Regarding the OPEX, data for the maintenance and operation of the PV, battery, and inverters system needs to be provided by the user or through external simulation tools, as well as OPEX related to the diesel generator, which includes operation and maintenance and an average fuel price.

Table 22 offers a summary of the OPEX values used for the Senegal replicability study. It is evident that the major OPEX costs for the Benin case are related to the operation of the PV, battery, and inverts system and to the price of fuel, while the operation and maintenance of the diesel generator can be considered relatively cheap.

Table 22: Operation and Maintenance Cost of Microgrid Components for Senegal

Component	OPEX	Unit
PV, Battery, and Inverter System*	0.198	EUR/kWh/yr
Diesel Generator**	0.11	EUR/kWh/yr
Fuel**	0.107	EUR/kWh/yr

The discount and degradation rate are, as explained previously, necessary for a meaning representation of the cash flows over the project lifetime, thus, they must be input by the LCOE Tool user. The discount rate used in the LCOE Tool for the Benin and Senegal case is 8%, while the degradation rate is set to 1.5%.

Table 23: Investment Cost of Microgrid Components including Labour Cost for Benin

Component	CAPEX	Unit
PV	397.28	EUR/kW
Battery	385.97	EUR/kWh
PV Inverter	222.10	EUR/kW
Battery Inverter	297.48	EUR/kW
Diesel Generator	224.40	EUR/kW
Grid	24,485.00	EUR/km

Regarding the OPEX, data for the maintenance and operation of the PV, battery, and inverters system needs to be provided by the user or through external simulation tools, as well as OPEX related to the diesel generator, which includes operation and maintenance and an average fuel price.

Table 22 offers a summary of the OPEX values used for the Benin replicability study. It is evident that the major OPEX costs for the Benin case are related to the operation of the PV, battery, and inverts system and to the price of fuel, while the operation and maintenance of the diesel generator can be considered relatively cheap.

Table 24: Operation and Maintenance Cost of Microgrid Components for Benin

Component	OPEX	Unit
PV, Battery, and Inverter System	0.198	EUR/kWh/yr
Diesel Generator	0.020	EUR/kWh/yr
Fuel	0.107	EUR/kWh/yr

The discount and degradation rate are, as explained previously, necessary for a meaning representation of the cash flows over the project lifetime, thus, they must be input by the LCOE Tool user.

The discount rate used in the LCOE Tool for the Benin and Senegal case is 8%, while the degradation rate is set to 1.5%.

2.3 Methodology

In this section, the methodology used both for the LENI tool and the LCOE Tool to perform their respective analyses is described.

2.3.1 LENI Methodology

The methodology specific to LENI is described in this section.

2.3.1.1 Creation of Single Database

The data sources indicated in the "Data Sources" section were filtered to only include the target countries (Benin and Senegal) and were loaded into a PostGIS-enabled PostgreSQL database. Such a database is appropriate for storing large amounts of geographic data so that it can be filtered, queried, and analysed (PostgreSQL Global Development Group, n.d.) (PostGIS Project Steering Committee, n.d.).

2.3.1.2 Selection of Clustering Algorithm

To provide a consistent list of candidate sites, it was decided to select a single clustering algorithm which could transform the individual GOB features into discrete clusters for further analysis. It was critical that the algorithm be able to generate clusters which accurately reflect the unique sizes and shapes of settlements, and to work consistently for the entirety of the study areas (Benin and Senegal). Out of a myriad of clustering algorithms, the "Density-Based Spatial Clustering of Applications with Noise" (DBSCAN) was selected. The main strengths of this algorithm are well-suited to the problem at-hand:

- It does not need a pre-specified number of clusters.
- It can generate clusters of differing sizes, even within the same clustering operation.
- The generated clusters are more "organic" in that they more precisely reflect the boundaries of the locations of the clustered features.

These advantages can be visualized in Figure 21 which compares the output of a DBSCAN clustering operation to the (arguably more popular and well-known) K-means algorithm. Indeed, in the figure, there are outputs from other clustering algorithms present, however DBSCAN is already implemented in the analysis environment (PostGIS) and was suitable for the purposes of the replicability study.

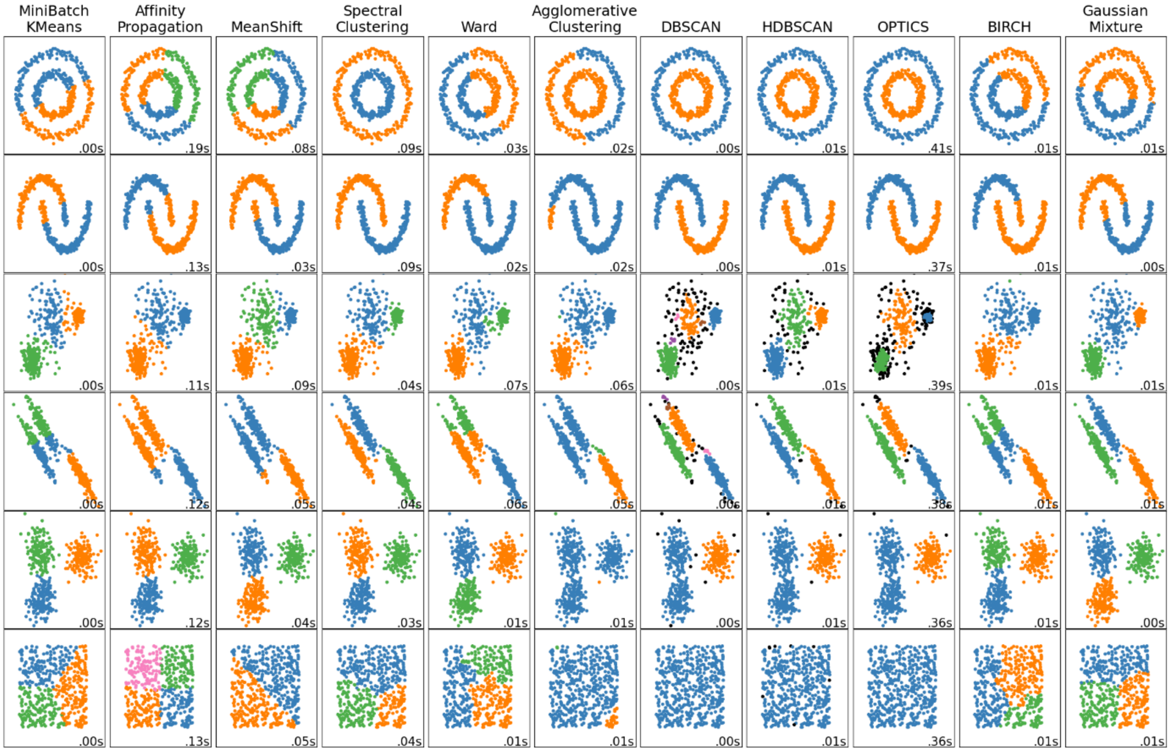

Figure 21: Outputs of various clustering algorithms demonstrating the relative advantages of using DBSCAN to other algorithms. From (Scikit-learn developers, n.d.)

A full description of the DBSCAN algorithm is out of the scope for this report, so suffice it to say that it uses two parameters, "epsilon" and "minpoints" (short for "minimum number of points"). A random feature is selected from the input dataset, and a local search is conducted to find any other nearby features. If one is found, they are aggregated into a cluster, and the process is repeated. Clusters that "grow" into each other are merged into a single cluster. The "epsilon" parameter represents this distance between features, and the "minpoints" parameters indicates a minimum threshold for number of features in a cluster for it to be considered a true cluster, and not just random noise that is ultimately filtered out of the returned cluster set. A far more detailed description can be found in the original paper (Ester, Kriegel, Sander, & Xu, 1996).

2.3.1.3 Creation of Population Clusters

The DBSCAN algorithm described in the previous section was used to identify population clusters in the selected countries (Benin and Senegal). Using each country as a study area, DBSCAN was applied to the GOB dataset. The GOB features were filtered such that only features with a confidence value of 0.75 (75%) or higher were included. Values of "150" and "25" were used for the "epsilon" and "minpoints" parameters. These values effectively mean that a population cluster must contain at least 25 buildings, for which, each building must be no more than 150 meters away from another building. These values were settled upon based upon experimentation directly on the dataset and were found to most consistently return appropriately sized and shaped clusters. A "concave hull" operation (PostGIS Project Steering Committee, ST_ConcaveHull, n.d.) was then performed on the resultant clusters to define an approximate boundary which would best approximate the shape of each population cluster, and a 150-meter buffer has been applied to create a more natural, approximated cluster boundary which would also include the surrounding area, as the settlement naturally tapers off into non-settled areas.

Figure 22 shows this procedure happening in stages on a small sample area. In step one, the GOB features are raw and unclustered. In step two, the DBSCAN clustering algorithm has been applied with the specified parameters. In Step 3, the concave hull and 150-meter buffer is applied. These are the population clusters that are used as the basis for the rest of the methodology.

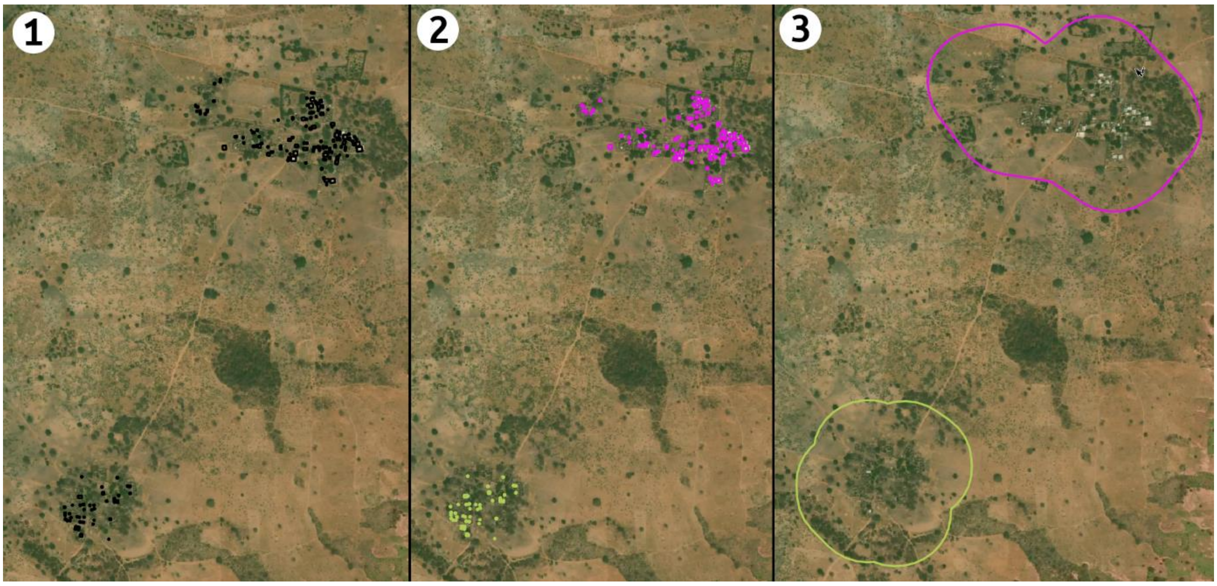

Figure 22: Application of the DBSCAN clustering methodology on the Google Open Buildings dataset. Basemap provided by (Mapbox, n.d.)

Using the lists of pre-selected candidate sites from Pre-Identified Replication Sites, it was determined if there were any pre-selected candidate sites which had not been found by the clustering algorithm. If there were any, the DBSCAN algorithm was re-applied with more permissive clustering parameters, only in the local area of the missing settlement. More precisely, the "epsilon" parameter was doubled to "300" and the "minpoints" parameter was dropped to zero. After applying this post-processing step, nearly all of the pre-identified sites were located and had an appropriate cluster generated for them. In the few cases where it still did not find a cluster, it was simply due to apparent mistakes in the table, as there are very few or no buildings at all near the coordinates of the table row in question.

2.3.1.4 Contextualization of Identified Clusters

The generated set of population clusters was then contextualized to include various pieces of information. These pieces of information were added to each cluster by finding related nearby features from other datasets and writing their names, as well as the distance between them, into the cluster. These contextual properties include:

- Settlement name(s) as found by "place" features in OSM.
    - (More than one place name can sometimes be found, as a cluster naturally forms around two "place" features that are in very close proximity)
- Distance to national grid, using the AETDGM dataset.
- Distance to a telecommunication tower, using OSM features that are tagged as such.
- Distance to health care facility, as per the EU JRC Healthcare Facilities dataset.

- Estimated population, calculated with the following assumptions:
    - There are on average 8 people per dwelling.
    - There are on average 3 roofs per dwelling (to account for nearby many features in the GOB dataset that are just sheds)

2.3.1.5 Estimation of Required Cable Length

The "Pathfinder" algorithm was originally created by Meta (known at the time as Facebook) and was originally used for identifying existing high-voltage transmission infrastructure in Africa (Gershenson, Rohrer, & Lerner, 2019). It was repurposed to automatically draw local microgrid networks which would connect the buildings in each cluster to a hypothetical, relatively centralized production facility. The lines drawn by the algorithm are biased to follow the existing streets from the OSM and Mapwithai datasets. In this way, a general estimation can be made about the required cable length for a settlement.

The lines drawn by the algorithm are not considered precise enough for the planning of a real network, and so they are not included in the result so as not to imply that they are a fully optimized and reliable network layout configuration. The intent of this step was to provide a general estimate of the necessary size of the network to serve all the local denizens.

The length of the lines drawn by the Pathfinder algorithm were summed and stored as a property of each cluster.

Figure 23 shows the result of a typical pathfinder algorithm result using a sample cluster. The green diamond represents an assumed, centralized production facility. The red circles are generated from the GOB dataset. The cyan lines are the result of the Pathfinder algorithm.

Figure 23: Results of the Pathfinder algorithm, used to estimate a cable length required to deploy a replicated microgrid.

2.3.1.6 Combination with Pre-Identified Sites

The provided lists of pre-identified sites were then overlaid onto the generated population clusters, so that they can be viewed in the overall context of all the population clusters generated by this replication study.

This was done by checking if the coordinates in each list of pre-identified sites intersected the boundary of an identified population cluster. For any row whose coordinates did not intersect with a boundary, a local search distance of one kilometre was applied to try and find a nearby cluster. After this refinement, there were only a handful of unmatched pre-identified sites. However, closer inspection indicates that there may be issues in these lists, as some coordinates are for locations for which there is very little or no visible settlement, when viewing local satellite imagery. This is explored more in Quality Assessment.

2.3.2 LCOE Tool Methodology

This section is dedicated to the step-by-step explanation of the methodology followed to derive the microgrid LCOE for a selected village with a provided load curve and with a pre-determined set of technologies and energy production shares.

2.3.2.1 Assumptions

A brief list of key assumptions for the LCOE tool is provided here:

- The daily hourly load profile is replicated for the whole here; thus, it is assumed that no changes in the energy consumption patter occur for different seasons or different day of the week, e.g. weekdays vs weekends.
- The distribution of buildings by type of client is assumed to be the same for all the villages analysed, although this may differ.
- In particular, a telecom tower, water pumping, street lighting and cold storage are always assumed to be present in each village for the Benin case.
- The initial microgrid investment is performed in year 1 and subsequentially in year 11 as the lifetime of some technologies comes to an end.

2.3.2.2 Step-by-step Methodology

In this section, step-by-step methodology for the calculation of the LCOE for a selected village is presented.

Data Input

As explained in Data Sources, a series of inputs are required for the LCOE Tool to correctly calculate the LCOE of the microgrid. In this frame of mind, the first step is to provide the necessary Geographical and Social Data to the LCOE Tool, which include:

- Estimated population.
- Distribution of building by type of client
- Peak power demand by type of client.
- Number of inhabitants per household.

The first value can either be provided by the user or estimated thanks to LENI, while the latter three need to be provided by the user or it will be defaulted to literature values.

In the case of Benin, the estimated population is the result of the comparison between the LENI results, the data provided by the microgrid developer ARESS, and a satellite image check to understand which of the two values (either LENI or provided data) is more realistic for the identified village. The distribution of building and the peak power demand by type of client are also provided by ARESS. The number of inhabitants per household is derived from the literature.

A similar methodology has been followed for Senegal, where the input data has been provided by Professor Kebe.

Other inputs required are the technical data associated with the technologies selected for the microgrid configuration and with the demand side of the microgrid, like:

- Technology specific parameters: efficiency, minimum size, operating temperatures, etc.
- Ratio of installed capacity to peak power demand per technology & share of diesel production
- Estimated grid length.
- Daily hourly load profile.

For the technology specific technical parameters, these can either be provided or defaulted to standard and literature values, while the ratio of installed capacity to peak power demand per technology can either be provided by the user or the values can be the result of a microgrid optimization process with EIFER´s proprietary tool Memogrid.

For the case of Benin and Senegal, values related to technical parameters have been defaulted to standard and literature values, while the ratio of installed capacity per technology to peak power demand was provided by ARESS. The grid length fed to the LCOE Tool is a result of LENI, while the daily hourly load profile is a combination of literature values and information provided by ARESS.

The final sets of inputs required concerns the Economic Data, which again can be either be provided or defaulted to literature values. These inputs include:

- CAPEX for selected technologies and grid
- OPEX for selected technologies and fuel cost
- Discount rate.
- Inflation rate.

In the case of Benin and Senegal, said values have been provided by ARESS and correspond to the values presented in Economic Data.

Calculation Step

After all the required data has been input, it is time to go through the calculation step.

The **number of buildings in a cluster** is calculated as:

$$Number\ of\ Buildings\ in\ a\ Cluster = \frac{Estimated\ Population}{Number\ of\ Inhabitants\ per\ Household}$$

This allows to have an idea of the number of buildings in a potential microgrid site given its population.

Then, the **number of buildings by type of client** is calculated as:

$$Number\ of\ Building, i = Number\ of\ Buildings\ in\ a\ Cluster * Distribution\ of\ Building, i$$

Where *i* is the index that varies amongst the different types of buildings presented in Geographical and Social Data.

Then the **peak power demand per hour** is calculated as the sum of the building demands by type of client in said hour as:

$$Peak\ Power\ Demand\ per\ Hour, j = \sum_{i} Number\ of\ Building, i * Power\ Demand, i\ @\ Hour, j$$

Where *Hour,j* represents one of the 24 hours of the day and the *Power Demand,i* is provided by the daily hourly load profile input for the different type of clients.

Then, the **maximum daily power demand** is calculated as the sum over the day of the peak power demand per hour, as:

$$Maximum\ Daily\ Power\ Demand = \sum_{j} Peak\ Power\ Demand\ per\ hour, j$$

From the maximum daily power demand, it is possible to **size the microgrid components** thanks to:

$$Installed\ Power, i = Maximum\ Daily\ Power\ Demand * (\frac{Installed\ Capacity}{Peak\ Power\ Demand})_i$$

So, for each component *i*, it is possible to calculate the installed power with the provided ration of component installed capacity over peak power demand.

Then, the **yearly power demand by type of customer** is calculated as the sum of the daily power demand of a specific customer over a full year:

$$Yearly\ Demand\ by\ Type\ of\ Customer, i = Number\ of\ Buidling, i * \sum_j Power\ Demand\ @\ hour, j * 365$$

Where *i* represents again the index that varies amongst the different types of buildings presented in Geographical and Social Data.

This allows to calculate the **yearly power demand for the microgrid** installation:

$$Yearly\ Microgrid\ Demand = \sum_{i} Yearly\ Demand\ by\ Type\ of\ Customer, i$$

Then the calculation can move onto the economic parameters. The first one that is calculated is the **investment cost** of each component with:

$$Investment\ Cost, i = Installed\ Power, i * CAPEX, i$$

Where the investment cost of each component is calculated thank to the input CAPEX provided in Economic Data.

The **overall microgrid investment cost** is given by:

$$Investment\ Cost\ Microgrid = \sum_{i} Investment\ Cost, i$$

This cost however does not include the **cost of the grid**, which is calculated separately as:

$$Investment\ Cost\ Grid = Estimated\ Grid\ Length * CAPEX_{grid}$$

Where both parameters are required data inputs.

For what concerns the OPEX calculation, this is divided into Maintenance Costs and Operation Cost, where the latter basically corresponds to fuel costs associated with diesel purchase.

The **OPEX maintenance** can be calculated as follows:

$$OPEX_{maintenance} = Installed\ Power_{PV} * OPEX_{maintenance}^{PV\ system} + OPEX_{maintenance}^{diesel} * Yearly\ Demand\ Covered\ by\ Diesel$$

Where the *OPEXs* are inputs provided by the user and the ***Yearly Demand Covered by Diesel*** is calculated as:

$$Yearly\ Demand\ Covered\ by\ Diesel = \ Yearly\ Microgrid\ Demand * Share\ of\ Diesel\ Production$$

Where the Share of Diesel Production is a value given as input from the user.

Then the **OPEX operation** is calculated based on the cost of fuel as:

$$OPEX_{operation} = \frac{Yearly\ Demand\ Covered\ by\ Diesel}{\eta_{diesel}} * \ LHV_{diesel} * Fuel\ Cost$$

Where η_{diesel} represents the diesel generator efficiency, LHV_{diesel} is the Lower Heating Value of the fuel, and *Flue Cost* is the price of diesel in EUR/l. All are input parameters provided by the user to the model.

The **overall microgrid OPEX** can then be calculated as:

$$OPEX_{microgrid} = OPEX_{maintenance} + OPEX_{operation}$$

Finally, the **microgrid LCOE** can be evaluated as:

$$LCOE = \frac{\sum_{t=0}^{T}(Investment\ Cost\ Microgrid_t + OPEX_{microgrid,t})/(1+r)^t}{\sum_{t=0}^{T} Yearly\ Microgrid\ Demand_t * (1-d)^t/\,(1+r)^t}$$

Where T is the project lifetime, t is the year, r is the discount rate, and d is the degradation rate, which are all values required as inputs. Values for discount and degradation rates for Benin and Senegal used in this replicability study are set to 8% and 1.5% respectively.

3. Results

In this section, the main findings of the replicability study, both from the LENI tool and the LCOE tool are presented.

3.1 Results from LENI

The results of this replication candidate site methodology have been packaged as three offline, interactive web maps and corresponding Microsoft Excel spreadsheets. There is one interactive map and one spreadsheet for Benin, and two of each for Senegal, because there were two separate, pre-identified site lists for Senegal.

3.1.1 Interactive Map

An interactive map has been produced using the results of the methodology. The map is opened in a web browser, and then the user can pan, zoom, and interact with features on the map. A choice between various basemaps can be toggled (OpenStreetMap, OpenStreetMap Humanitarian and Mapbox Satellite). It should be noted that while the data is stored locally, the basemaps require an internet connection to function properly.

On the map, there is a layer of blue and green polygons. A blue polygon indicates a population cluster that has been generated and contextualized using the described methodology. A green polygon indicates the same kind of population cluster, but one that has been matched to a pre-identified replication site.

There is also a layer of green and orange map markers. The green markers contain a checkmark icon and indicate the location a of pre-identified replication candidate site that has been successfully matched to a generated population cluster. The orange markers contain a question mark icon and indicate the location of a pre-identified replication candidate site that was not able to be matched to a generated population cluster.

There are other contextual layers which can be toggled on and off using the layers icon in the top right. They include:

- Existing electricity transmission and distribution grid
- Health care facilities
- Telecommunication towers

Finally, a search bar in the top right allows the user to search for place names. Only place names that are present in the map's data will be searched, and it is possible to locate place names from both the clustering methodology and from the lists of pre-identified replication candidate sites.

Figure 24 shows an example of the interactive map, displaying the described layers and features.

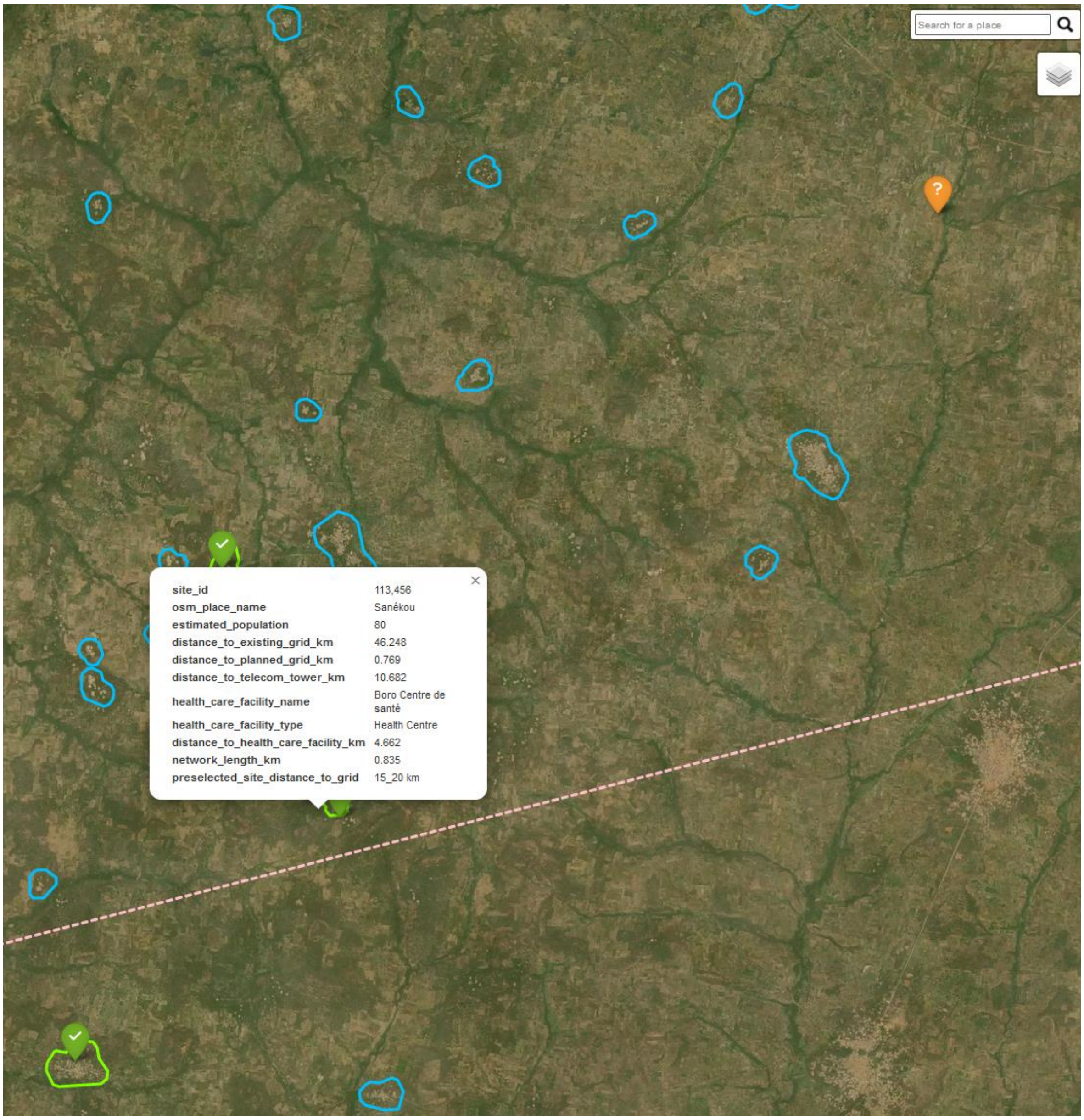

Figure 24: View of the interactive web map deliverable.

3.1.2 Excel Spreadsheet

For each interactive map, there is an associated Microsoft Excel spreadsheet. These spreadsheets contain all the same data as their corresponding interactive maps. The user can user them to filter based on various attributes, such as distance to existing transmission and distribution grid, distance to health care facilities, estimated population, etc., to fit specialized needs for an arbitrary replication project.

Given the open-ended nature of Microsoft Excel spreadsheets, these spreadsheets should sufficiently serve as the starting point for any further analysis of the generated candidate replication sites when selecting one or more sites for a replication study.

3.1.3 Quality Assessment

When comparing the results of the clustering methodology to the lists of pre-identified sites, some notable issues arose. The first issue is that, in the Benin spreadsheet, there are eight sites that could not be identified using the clustering methodology. closer inspection of these pre-identified sites yields that there are extremely few, or no buildings whatsoever at the location specified by the row's coordinates in this excel file. Most pre-selected sites were, however, consistent with the clustering methodology, as seen in Figure 25.

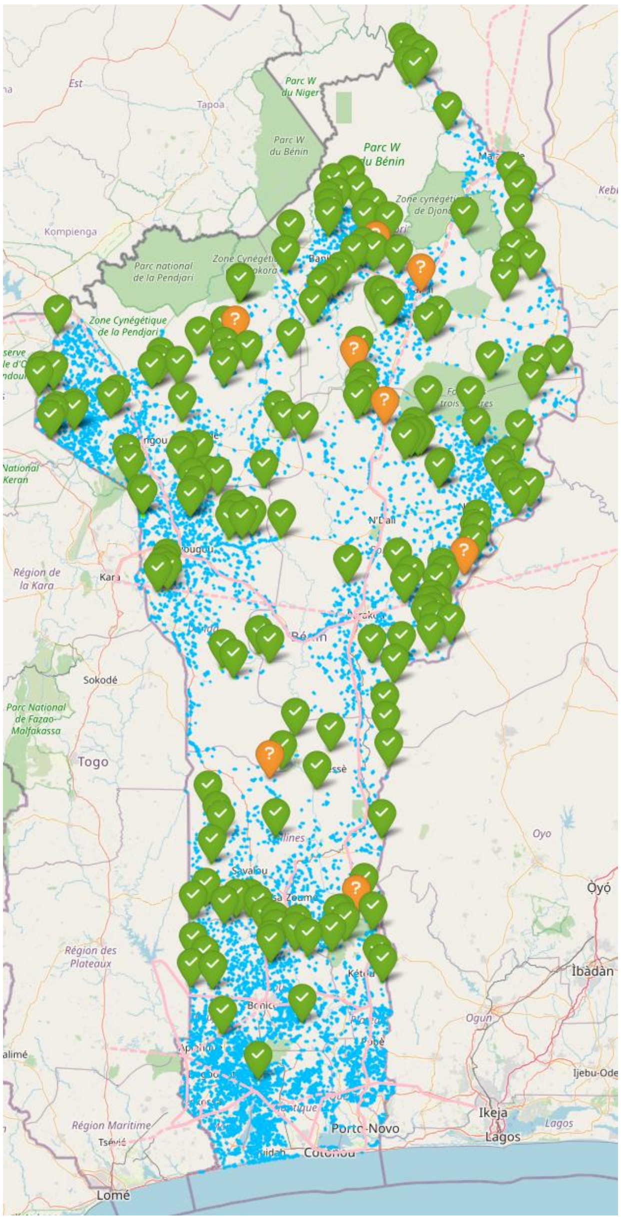

Figure 25: Identified sites in Benin

A particularly illustrative example of such a site is "Egbedje", in Benin, seen in Figure 26. The pre-identified sites data claims that this is a settlement of 3309 people, yet its location shows only a few buildings.

Figure 26: Dubious pre-identified site "Egbedje", claiming to have over 3000 inhabitants, yet having only a few buildings visible on satellite imagery.

The second issue is that, in Senegal spreadsheet #1, there are eight pre-identified sites with coordinates which are clearly outside of the country's borders. Seven of these are even located over the Atlantic Ocean. It is likely that there are some mistakes in the coordinates column which place them in these erroneous locations. These sites were kept in the final output for the sake of completeness, but it should be noted regardless. Outside of these problematic exceptions, all pre-identified sites were successfully identified in the clustering methodology.

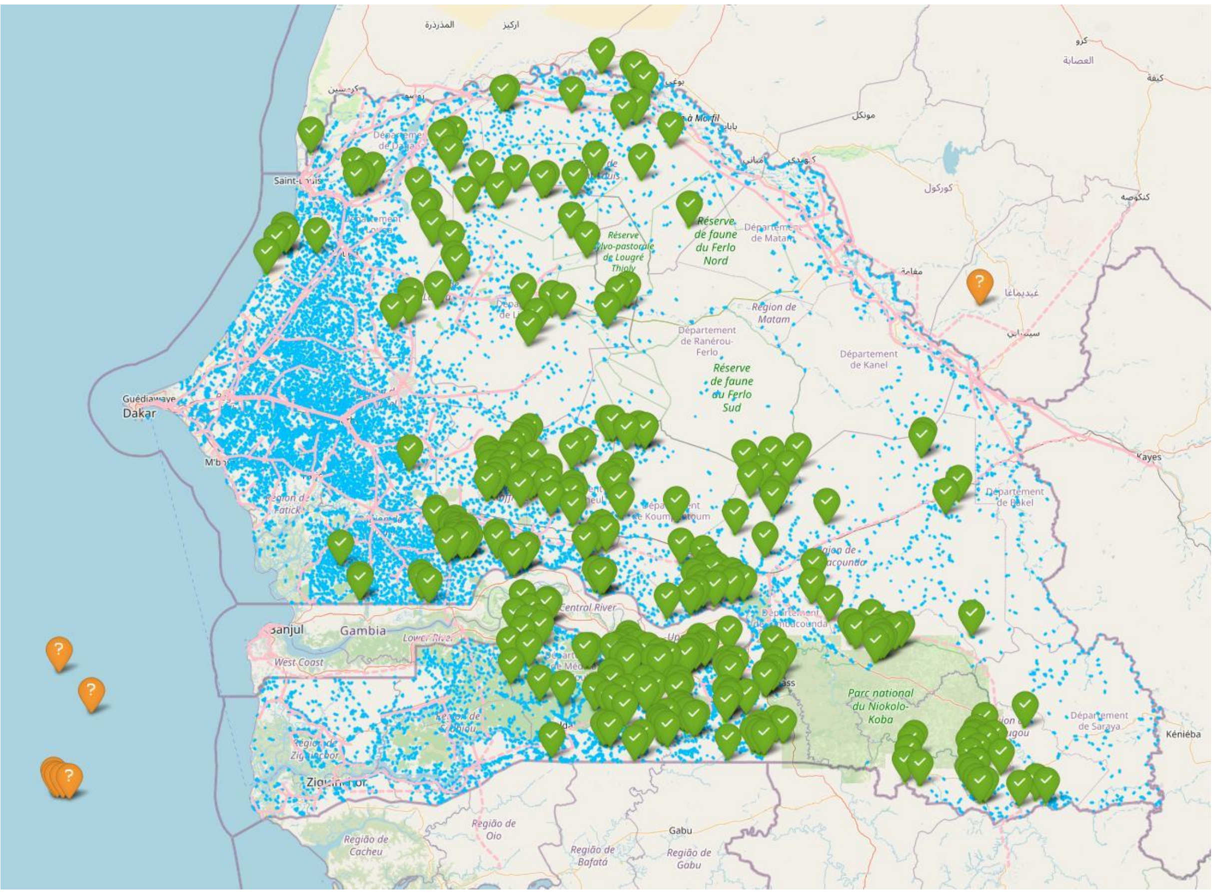

Figure 27: Erroneous pre-identified sites in Senegal

3.2 Results from LCOE Tool

The LCOE tool results shed light on the link between village size, both in terms of population and of location, and LCOE of a microgrid project, therefore aiding in selecting an economically viable location for replicability of the LEOPARD microgrid solution.

3.2.1 Microgrid LCOE analysis for Benin

In this section, the focus is on presenting the results for replicability in Benin. As mentioned in this chapter´s introduction, the LCOE provides a clear overview of whether a certain location is feasible for the replication of the solution developed within the LEOPARD project.

In this frame of mind, it is important to understand how the LCOE correlates to population size and to the estimated grid length of the microgrid to identify the possible best candidates for replication.

3.2.1.1 LCOE as a function of Site Population

As it is to be expected, the LCOE of the microgrid solution is directly dependent on the population size, as shown in Figure 28. It is clear that the LCOE of the microgrid tends to increase as the population size increases as a higher investment cost in terms of technology size is required to supply the electricity demand. It is however important to notice that the LCOE presented in Figure 28 does not account for the grid length of the microgrid, but only for the specific technological investment and operational expenditures, as this allows to have a clearer view of the correlation between microgrid technology sizes and population sizes. Overall, the microgrid LCOE varies from a minimum of 0.345 EUR/kWh for a population size of 40 people to a maximum of 0.478 for a population of 12,429 people.

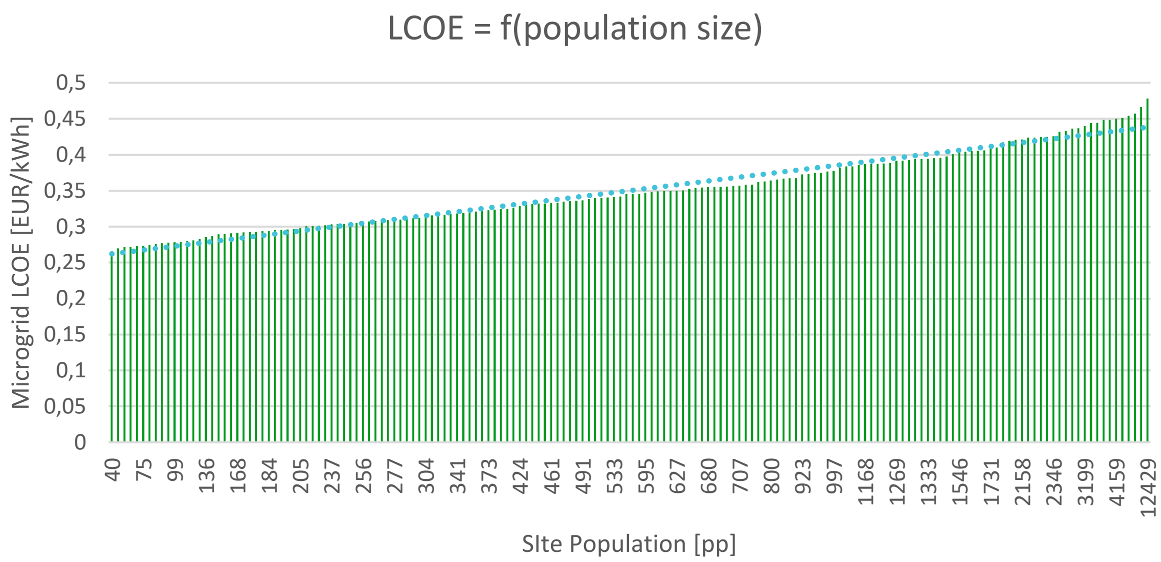

Figure 28: LCOE as a function of Population Size in Benin (Diesel Share 14%, no grid investment considered)

Considering that the LCOE for a microgrid project to be considered economically viable in Benin is 0.40-0.47 EUR/kWh, 195 of the identified villages meet such criteria, which means all but the site with the highest population.

3.2.1.2 LCOE as a function of Grid Length

As it could be expected, the LCOE including the cost of the grid increases with larger grid installations, as shown in Figure 29. The few "off-trend" cases are specific case in which the considered site are particular sparse villages, thus having a considerable grid length which results in a higher investment in terms of capital. As foreseeable, the LCOE considering the grid investment is higher than the one presented in "LCOE as a function of Site Population", as it varies between 0.302 and 0.802 EUR/kWh, with an average of 0.478 EUR/kWh.

Considering that the LCOE for a microgrid project to be considered economically viable in Benin is 0.40-0.47 EUR/kWh, 144 of the identified villages meet such criteria.

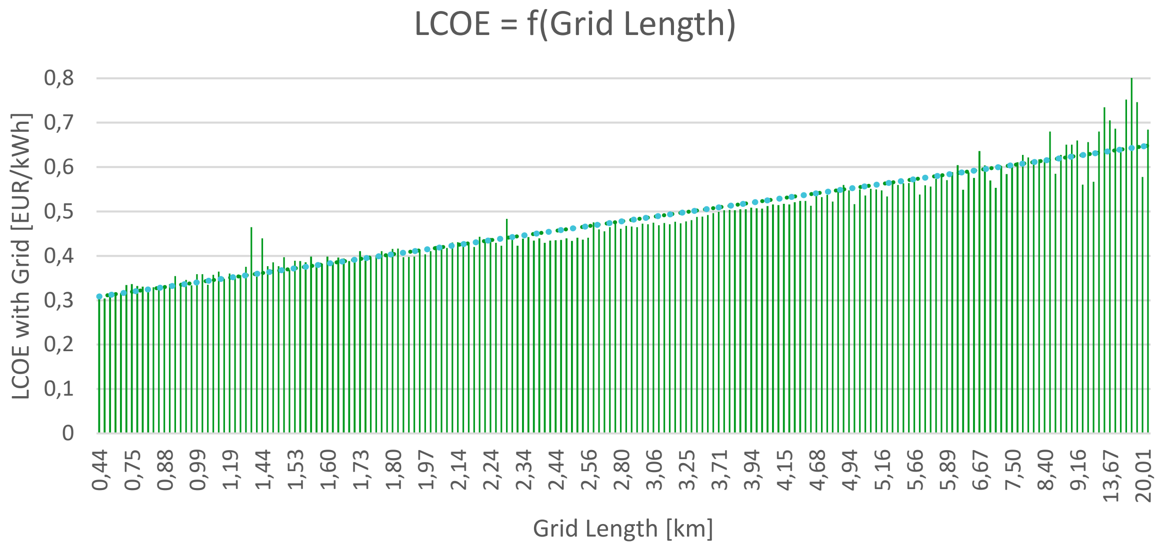

Figure 29: LCOE as a function of Grid Length in Benin (grid investment cost considered).

3.2.1.3 LCOE Sensitivity Analysis

Generally, the average LCOE value (without considering the grid investment) found in the replicability study settles around 0.350 EUR/kWh for Benin, which is within the range of the number considered economically viable of 0.40-0.47 EUR/kWh. However, as shown in previous paragraphs, when the cost of the grid is included, 52 of the pre-identified sites have an LCOE higher than the reference range. Many reasons could be the cause of a higher LCOE:

- Incorrect load curve estimations, which would be mainly due to the assumption that each village presents the same building distributions, and the exact same need for water pumping, telecom tower, street lighting and cold storage, without them being referred to the population size.

- A potential non optimal ratio of installed capacity per technology over peak power demand. From the results of EIFER´s Microgrid optimization tool Memogrid, it is evident that microgrid with a higher penetration of diesel generation results in lower LCOEs. For instance, a microgrid with a share of electricity generation from diesel over 24.7% allows to reach LCOEs below 0.20 EUR/kWh (Sanfilippo, et al., 2023).

- No subsidies have been considered yet in the calculation of the LCOE, however, according to Beninese microgrid developer ARESS, usually a CAPEX subsidy of 30-50% can be applied.

Effect of ratio of installed technologies

It is interesting to note that when the diesel share of produced energy is changed to 24.7% instead of 14%, a number that is closer to the results from Memogrid optimization, and the necessary rescaling in terms of ratio of installed capacity per technology is applied, it is possible to reach much lower LCOEs in line with the provided target of 0.40-0.47 EUR/kWh, as shown in Figure 28. In this case, the LCOE varies between 0.160 EUR/kWh and 0.227 EUR/kWh, which is fully within the target range. This is due to the saving on the higher investment cost on technologies such as PV and batteries, which represents the highest budget consumers in the microgrid installation.

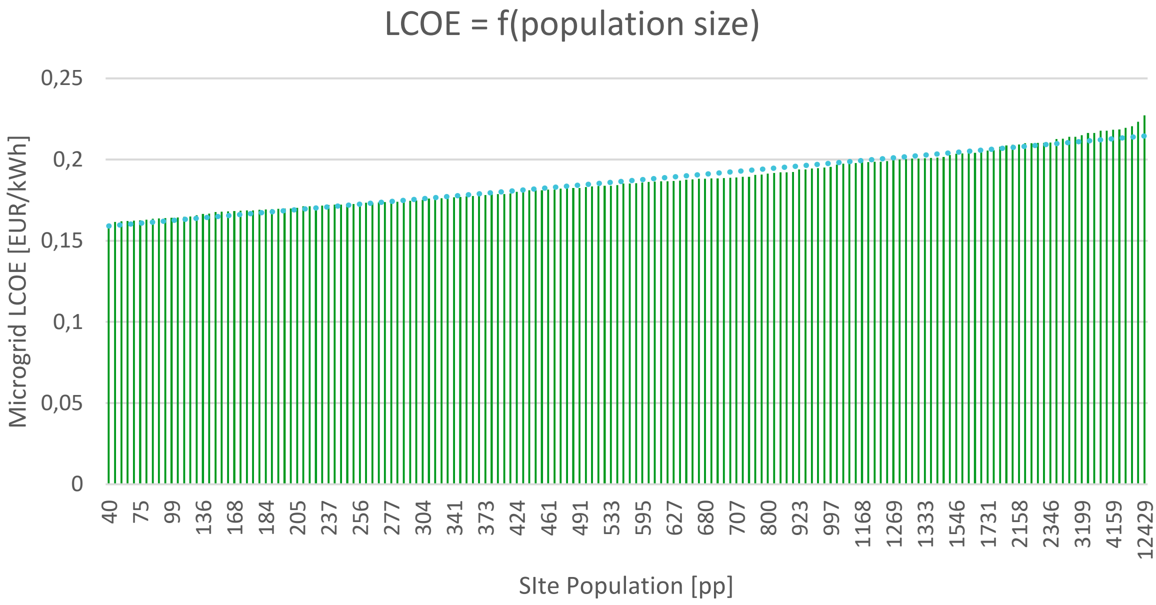

Figure 30: LCOE as a function of Population Size in Benin (Diesel Share 24.7%, no grid investment cost considered)

With this simple modification, the number of identified sites that meet the LCOE requirements is 196 out of 196 identified. It is however important to highlight that the LCOE here observed refers to the calculation without considering the grid cost.

Figure 31 presents the LCOE when the cost of the grid is considered, as a function of the grid length. In this case, the LCOE varies between 0.348-0.868 EUR/kWh, with an average of 0.518 EUR/kWh. The number of villages meeting the criteria if the energy produced from the diesel is increased to 24.7% and the cost of the grid investment is considered is 61.

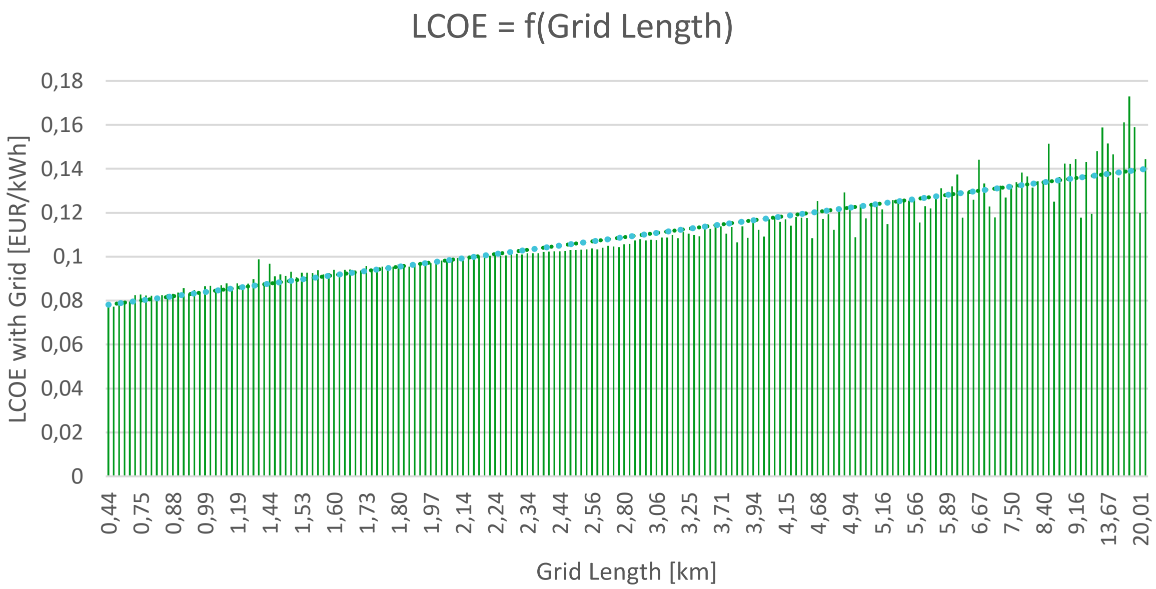

Figure 31: LCOE as a function of Grid Length in Benin (Diesel Share 24.7%, grid investment cost considered)

Effect of CAPEX subsidies

In this section, the effect of CAPEX subsidies on the microgrid LCOE, both with and without considering the grid investment, is explored. The CAPEX subsidy in this sensitivity analysis is applied to the technology related investment cost at year 1 and at year 11, and to the grid related investment.

First, the effect of CAPEX subsidies on the LCOE is considered in the case in which the investment cost of the grid is not taken into account. A CAPEX subsidy variation between 30-50% has been analysed and the findings are presented in Table 25. As it is to be expected, the higher the CAPEX subsidy, the higher the number of villages that meet the criteria for economic viability (LCOE = 0.40-0.47 EUR/kWh).

Table 25: CAPEX subsidy sensitivity analysis on LCOE without grid in Benin

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.351	0.637	0.458	121
40%	0.316	0.567	0.410	162
50%	0.281	0.497	0.362	192

A similar sensitivity can be performed when the grid investment is considered, and its results are presented in Table 26. In a similar manner, the higher the CAPEX subsidy, the higher the number of villages that meet the criteria for successful replication, although the number of sites is lower than the one in which the cost of the grid is not considered, as that results in a higher investment and thus a higher LCOE.

Table 26: CAPEX subsidy sensitivity analysis on LCOE with grid in Benin

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.380	0.835	0.546	48
40%	0.341	0.735	0.485	87
50%	0.302	0.634	0.424	131

From the CAPEX sensitivity analysis, it is possible to conclude that, if available, incentives in terms of CAPEX discount aid greatly into the economic viability of a microgrid project in Benin.

3.2.2 Microgrid LCOE analysis for Senegal

In this section, the focus is on presenting the results for replicability in Senegal. As mentioned in this chapter´s introduction, the LCOE provides a clear overview of whether a certain location is feasible for the replication of the solution developed within the LEOPARD project.

In this frame of mind, it is important to understand how the LCOE correlates to population size and to the estimated grid length of the microgrid to identify the possible best candidates for replication.

3.2.2.1 LCOE as a function of Site Population – Load Profile 1

As it is to be expected, the population size has no impact on the LCOE, given the distribution of client shown in Figure 7: Distribution of Daily Energy demand of a typical Village (0-200 inhabitants) by Type of Client in Senegal. : residentials buildings (95%), followed by social and community (4%) and Income generating activities (1%). It is however important to notice that the LCOE presented in Figure 32 does not account for the grid length of the microgrid, but only for the specific technological investment and operational expenditures, as this allows to have a clearer view of the correlation between microgrid technology sizes and population sizes. Overall, the microgrid LCOE varies from a minimum of 0.35 EUR/kWh for a population size of 496 people to a maximum of 0,385 for a population of 499 people.

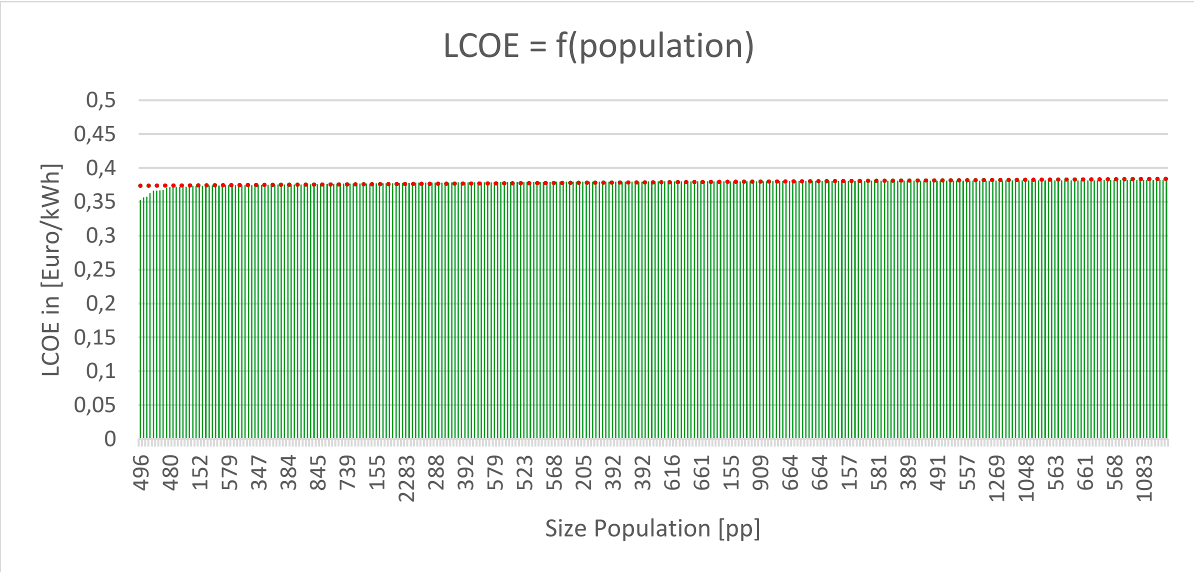

Figure 32: LCOE as a function of Population Size in Senegal (Diesel Share 45%, no grid investment considered)

3.2.2.2 LCOE as a function of Grid Length - Load Profile 1

As it could be expected, the LCOE to increase with lengthier grid installations, as shown in Figure 33. The few "off-trend" cases are specific case in which the considered site is a particular dense village, thus having a short grid length but a high energy demand which results in a higher investment in terms of technologies. As foreseeable, the LCOE considering the grid investment as well is higher than the one presented in LCOE as a function of Site Population, as it varies between 0.449 and 3.074 EUR/kWh, with an average of 0.855 EUR/kWh.

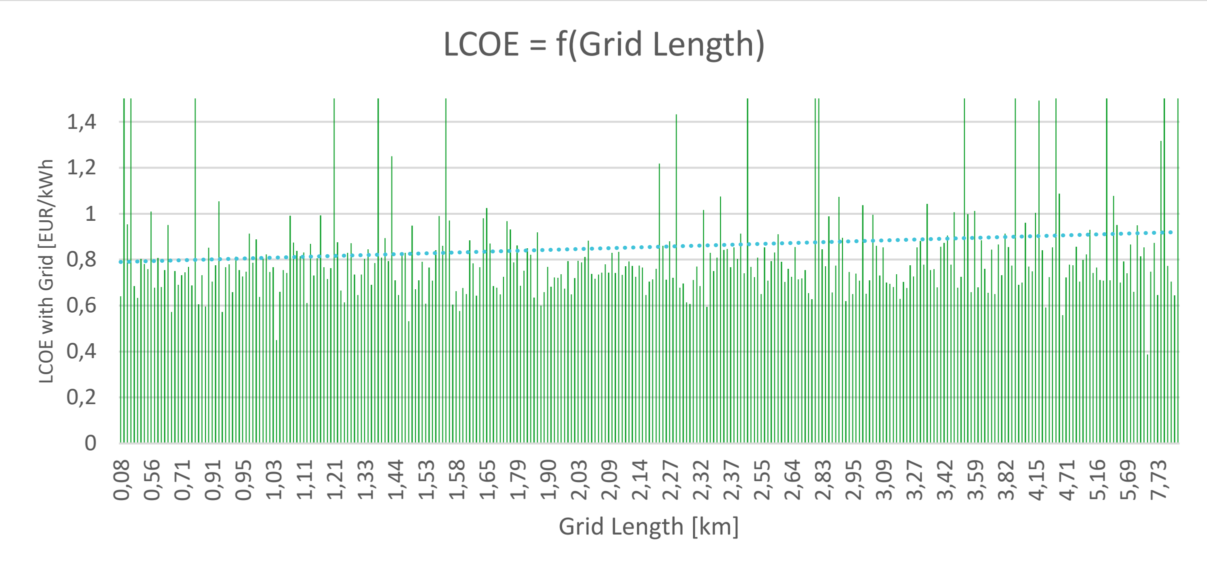

Figure 33: LCOE as a function of Grid Length in Senegal (grid investment cost considered)

3.2.2.3 LCOE as a function of Site Population - Load Profile 2

As it is to be expected, the population size has no impact on the LCOE, given the distribution of client shown in Figure 8 : residentials buildings (86%), followed by Income generating activities (13%) and social and community (1%). It is however important to notice that the LCOE presented in does not account for the grid length of the microgrid, but only for the specific technological investment and operational expenditures, as this allows to have a clearer view of the correlation between microgrid technology sizes and population sizes. Overall, the microgrid LCOE varies from a minimum of 0.334 EUR/kWh for population size of 496 people to a maximum of 0,427 for a population of 683 people.

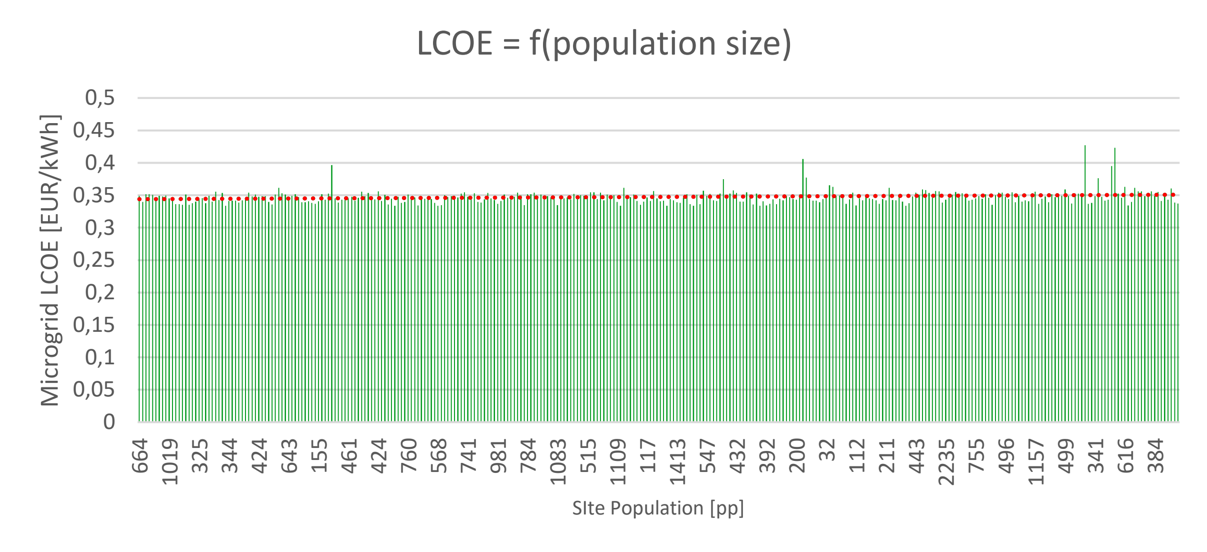

Figure 34: LCOE as a function of Population Size in Senegal (Diesel Share 46%, no grid investment considered)

3.2.2.4 LCOE as a function of Grid Length - Load Profile 2

As it could be expected, the LCOE to increase with lengthier grid installations, as shown inFigure 35. The few "off-trend" cases are specific case in which the considered site is a particular dense village, thus having a short grid length but a high energy demand which results in a higher investment in terms of technologies. As foreseeable, the LCOE considering the grid investment as well is higher than the one presented in LCOE as a function of Site Population, as it varies between 0.357 and 1.148 EUR/kWh, with an average of 0.510 EUR/kWh.

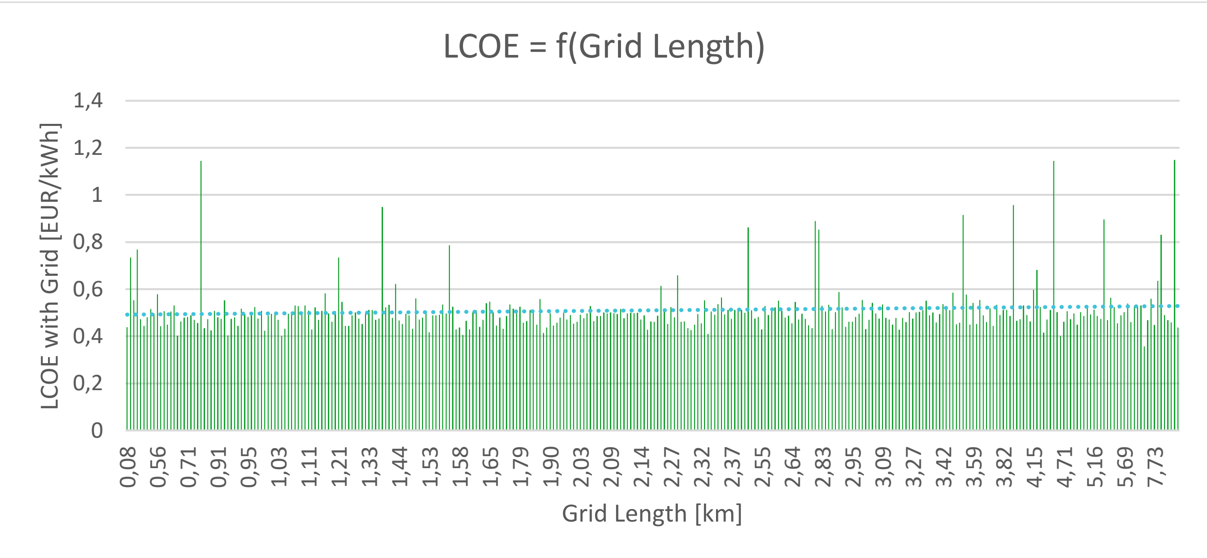

Figure 35: LCOE as a function of Grid Length in Senegal (grid investment cost considered)

3.2.2.5 LCOE as a function of Site Population - Load Profile 3

As it is to be expected, the LCOE of the microgrid solution is directly dependent on the population size, as shown in Figure 9. It is clear that the LCOE of the microgrid tends to increase as the population size increases as a higher investment cost in terms of technology size is required to supply the electricity demand. It is however important to notice that the LCOE presented in Figure 36does not account for the grid length of the microgrid, but only for the specific technological investment and operational expenditures, as this allows to have a clearer view of the correlation between microgrid technology sizes and population sizes. Overall, the microgrid LCOE varies from a minimum of 0.336 EUR/kWh for a population size of 499 people to a maximum of 0,446 for a population of 75 people.

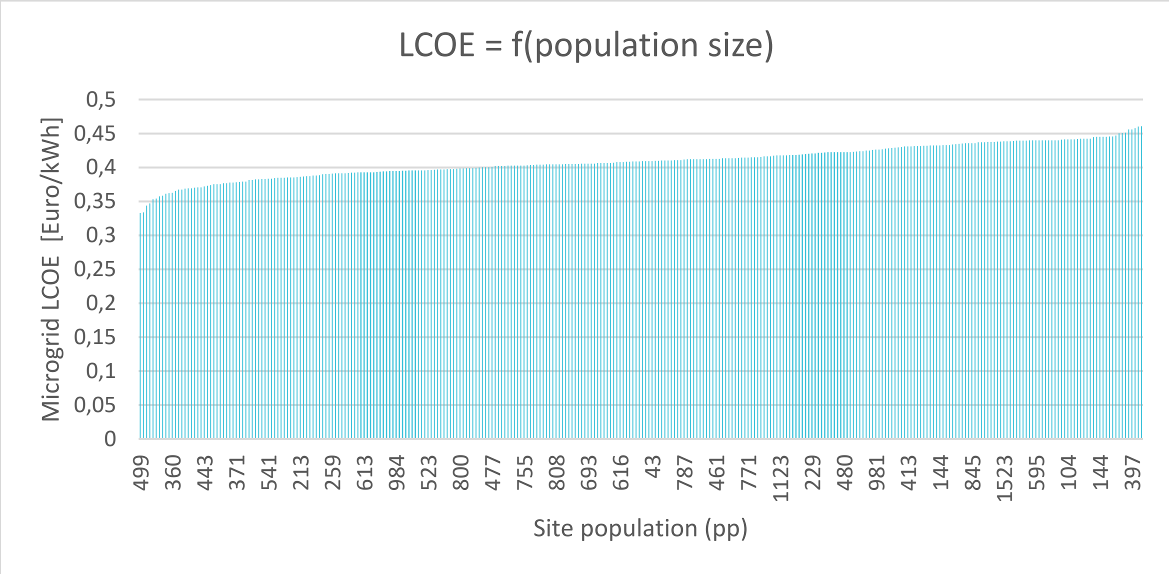

Figure 36: LCOE as a function of Population Size in Senegal (Diesel Share 38%, no grid investment considered)

3.2.2.6 LCOE as a function of Grid Length - Load Profile 3

As it could be expected, the LCOE to increase with lengthier grid installations, as shown inFigure 37. The few "off-trend" cases are specific case in which the considered site is a particular dense village, thus having a short grid length but a high energy demand which results in a higher investment in terms of technologies. As foreseeable, the LCOE considering the grid investment as well is higher than the one presented in LCOE as a function of Site Population, as it varies between 0.382 and 0,741 EUR/kWh, with an average of 0.498 EUR/kWh.

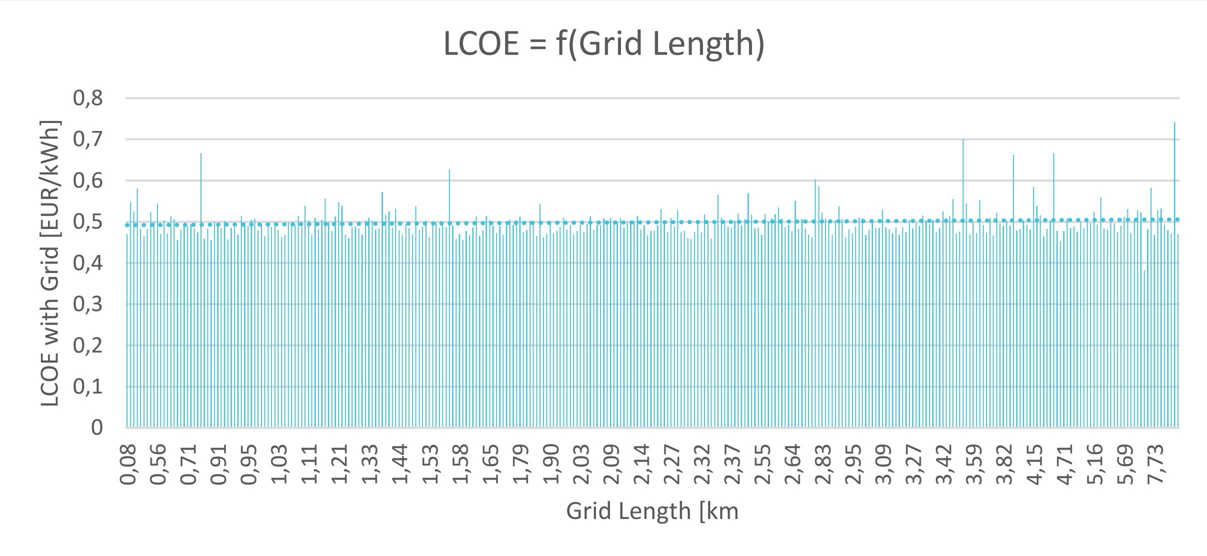

Figure 37: LCOE as a function of Grid Length in Senegal (grid investment cost considered)

3.2.2.7 LCOE sensitivity analysis

To compare the results obtained for replicability in Senegal with the ones already presented for Benin, a similar sensitivity analysis is conducted. For the case of Senegal, no replication sites, either considering the investment cost associated with the grid or without considering it, are found economically viable if no additional measures are considered.

Like previous chapters, the reasons for a lack of economic viability can be several:

- Incorrect load curve estimations, which would be mainly due to the assumption that each village presents the same building distributions, and that the load curve provided did not present differentiations among different type of residential consumers.

- A potential non optimal ratio of installed capacity per technology over peak power demand. From the results of EIFER´s Microgrid optimization tool Memogrid, it is evident that microgrid with a higher penetration of diesel generation results in lower LCOEs. For instance, a microgrid with a share of electricity generation from diesel over 24.7% allows to reach LCOEs below 0.20 EUR/kWh (Sanfilippo, et al., 2023). The benefits from increasing the share of energy produced by the diesel generator up to 45% further lower the expected microgrid LCOE.

- No subsidies have been considered yet in the calculation of the LCOE, however, a CAPEX subsidy of 30-50% can be assumed to compare the results to the ones generated for Benin.

Effect of ratio of installed technologies

As the Senegalese case already presents a quite high share of diesel generation in their overall energy production (from 38% for a village above 1,000 inhabitants to 46% for villages below 200 inhabitants), in the interest of better environmental outcomes in the long run, it was decided to not perform a sensitivity analysis on increasing the diesel share in this case.

Effect of CAPEX subsidies

As mentioned, to compare both replicability study, it may be interesting to dwell with the possibility of benefitting from similar CAPEX subsidies, thus, this section explores the possibility of introducing a 30-50% CAPEX subsidization for the microgrid project in Senegal. This analysis has been performed for all three considered load curves. It is important to bear in mind when analyzing the following results that the sensitivity analysis has been performed applying the microgrid design for the three different load curves to all the pre-identified 321 sites. This was done in order to reduce calculation times and to provide insights for future population growth.

<u>Village below 200 inhabitants – Load Curve 1</u>

First, the effect of CAPEX subsidies on the LCOE is considered in the case in which the investment cost of the grid is not taken into account. A CAPEX subsidy variation between 30-50% has been analysed and the findings are presented in Table 27. As it is to be expected, the higher the CAPEX subsidy, the higher the number of villages that meet the criteria for economic viability (LCOE = 0.40-0.47 EUR/kWh). Without considering the cost of the grid, with a CAPEX incentive as low as 30%, all 321 sites are found to be economically viable for replication, with higher CAPEX incentives contributing to lowering the LCOE prices but not adding extra sites for replication. Interestingly, all 321 sites for LC1 are found to be replicable even without CAPEX incentives when not considering the investment cost for grid installation and adding a CAPEX incentive only helps in lowering the LCOE price.

Table 27: CAPEX subsidy sensitivity analysis on LCOE without grid in Senegal (0-200 inhabitants)

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.313	0.366	0.323	321
40%	0.306	0.356	0.315	321
50%	0.298	0.345	0.308	321

A similar sensitivity can be performed when the grid investment is considered, and its results are presented in Table 28. Before any CAPEX subsidies are taken into consideration, only 98 of the 321 pre-identified sites are found to be economically viable when the investment cost of the grid installation is accounted for. In this case, a 30% CAPEX incentive helps to reach economic viability for 290 sites, while increasing above 30% does not help too much in terms of additional sites. It is indeed interesting to notice that even with a 50% CAPEX subsidy, it is still not possible for all 321 pre-identified sited to be economically viable, as the maximum reachable number is 305. The villages that won´t be economically viable even with a 50% CAPEX incentive when the cost of the grid installation is considered are sparse villages in which significant cable length is required to connect all consumers, thus making the overall grid investment prohibitive.

Table 28: CAPEX subsidy sensitivity analysis on LCOE with grid in Senegal (0-200 inhabitants)

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.359	0.749	0.422	290
40%	0.345	0.682	0.400	301
50%	0.331	0.615	0.378	305

From the CAPEX sensitivity analysis, it is possible to conclude that, if available, incentives in terms of CAPEX discount aid into the economic viability of a microgrid project in Senegal, albeit leaving out from the economic viability villages in which extensive grid length is required to connect all the customers.

<u>Village between 200-1,000 inhabitants – Load Curve 2</u>

Similarly, the effect of CAPEX subsidies on the LCOE is considered in the case in which the investment cost of the grid is not taken into account. A CAPEX subsidy variation between 30-50% has been analysed and the findings are presented in Table 29. As it is to be expected, the higher the CAPEX subsidy, the higher the number of villages that meet the criteria for economic viability (LCOE = 0.40-0.47 EUR/kWh). In the case of LC2, before any CAPEX subsidies opportunity is considered, 314 sites would be economically viable. Without considering the cost of the grid, with a CAPEX incentive as low as 30%, all 321 sites are found to be economically viable for replication, with higher CAPEX incentives contributing to lowering the LCOE prices but not adding extra sites for replication.

Table 29: CAPEX subsidy sensitivity analysis on LCOE without grid in Senegal (200-1,000 inhabitants)

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.331	0.353	0.351	321
40%	0.323	0.344	0.341	321
50%	0.315	0.334	0.332	321

A similar sensitivity can be performed when the grid investment is considered, and its results are presented in Table 30. Without considering CAPEX incentives, only 2 sites meet the economic viability criteria previously defined. In this case, a 30% CAPEX incentive does not provide substantial help in reaching economic viability, as only 3 sites are found to be suitable. Increasing the CAPEX subsidy does help in increasing the number of villages for replication to up to 42 with a 50% CAPEX incentive, however, this number is still considerably much lower than the pre-identified 321 sites. The main explanation behind the worse results when compared to Load Curve 1 (LC1) most likely lies in the fact that the provided microgrid design from C2TS in terms of technology sizing has been optimized to supply LC1. Therefore, keeping the same technology to peak power ratio for different village sizes and load curve shape may hinder the economic viability of cases that vary much in terms on inhabitants and of consumption pattern. Another unusual point is the one of a village with relatively low population (80 inhabitants), resulting in a LCOE above 2 EUR/kWh even with a CAPEX subsidy of 30%. This is due to the rather high cable length for such a small village.

Table 30: CAPEX subsidy sensitivity analysis on LCOE with grid in Senegal (200-1,000 inhabitants)

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.454	2.050	0.628	3
40%	0.428	1.797	0.579	8
50%	0.402	1.544	0.530	42

From the CAPEX sensitivity analysis, it is possible to conclude that, if available, incentives in terms of CAPEX discount aid into the economic viability of a microgrid project in Senegal, albeit not much when the investment cost of the grid is accounted for.

Village above 1,000 inhabitants – Load Curve 3

Firstly, the effect of CAPEX subsidies on the LCOE is considered in the case in which the investment cost of the grid is not taken into account. A CAPEX subsidy variation between 30-50% has been analysed and the findings are presented in Table 31. As it is to be expected, the higher the CAPEX subsidy, the higher the number of villages that meet the criteria for economic viability (LCOE = 0.40-0.47 EUR/kWh). Before any CAPEX subsidies are considered, all 321 sites are found to be already economically viable for LC3. Without considering the cost of the grid, with a CAPEX incentive as low as 30%, all 321 sites are found to be economically viable for replication, with higher CAPEX incentives contributing to lowering the LCOE prices but not adding extra sites for replication.

Table 31: CAPEX subsidy sensitivity analysis on LCOE without grid in Senegal (1,000 inhabitants)

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.177	0.414	0.369	321
40%	0.171	0.399	0.356	321
50%	0.166	0.384	0.343	321

A similar sensitivity can be performed when the grid investment is considered, and its results are presented in Table 32. Without considering CAPEX incentives, 41 sites are found to be economically viable if the cost of grid installation is accounted for. In this case, a 30% CAPEX incentive helps to reach economic viability for 296 sites, while increasing above 30% results in 321 out of 321 sites available for replication. In this case, LC3 performs better than LC1 and LC2 in terms of replicability.

Table 32: CAPEX subsidy sensitivity analysis on LCOE with grid in Senegal (1,000 inhabitants)

CAPEX Subsidy	$LCOE_{min}$ [EUR/kWh]	$LCOE_{max}$ [EUR/kWh]	$LCOE_{mean}$ [EUR/kWh]	Sites for Replication
30%	0.403	0.490	0.423	296
40%	0.386	0.463	0.407	321
50%	0.368	0.436	0.386	321

From the CAPEX sensitivity analysis, it is possible to conclude that, if available, incentives in terms of CAPEX discount aid into the economic viability of a microgrid project in Senegal.

3.2.3 Replicability Conclusion based on LCOE

In the case of **Benin**, it is possible to conclude that, without considering CAPEX incentives and a reshaping of the technological microgrid configuration, 195 sites out of 196 pre-identified ones meet the requirements for economic viability when the cost of the grid is not included in the LCOE calculation. While that number lowers to 144 sites if the investment cost for the microgrid project is accounted for in the overall LCOE.

However, when changing the share of electricity produced by the diesel generator from 14 to 24.7%, the number of sites meeting the economic requirements increases to 195 if the grid investment is considered, and to 196 out of 196 if the grid investment is not considered.

If instead of changing the share of diesel generated electricity, the possibility of taking advantage of CAPEX subsidies as little as 30% improves the economic viability of the project, with the best possible economic result achieved for a CAPEX subsidy of 50%. Although all 196 pre-identified sites are found to be economically viable with the lowest CAPEX incentive considered (30%), increasing the CAPEX incentive helps to lower the overall LCOE, thus potentially resulting in a higher revenue stream for the implementer.

Figure 38 & Figure 39 offer a visual representation of the identified sites that are considered to be geographically, technically, and economically viable for the LEOPARD microgrid concept replication in Benin. In particular, the colored dots represent the different variations performed in terms of diesel share and capex incentives. The red is associated with the replication sites that are economically viable without any CAPEX incentives nor changes to the diesel penetration in the microgrid.

In the case of Figure 38, the light blue dots represent the sites that would be viable if a 24.7% diesel share is considered. The green dot represents the additional site that would be viable (additional to the already identified red and light blue dots) if a CAPEX subsidy of 30% is granted.

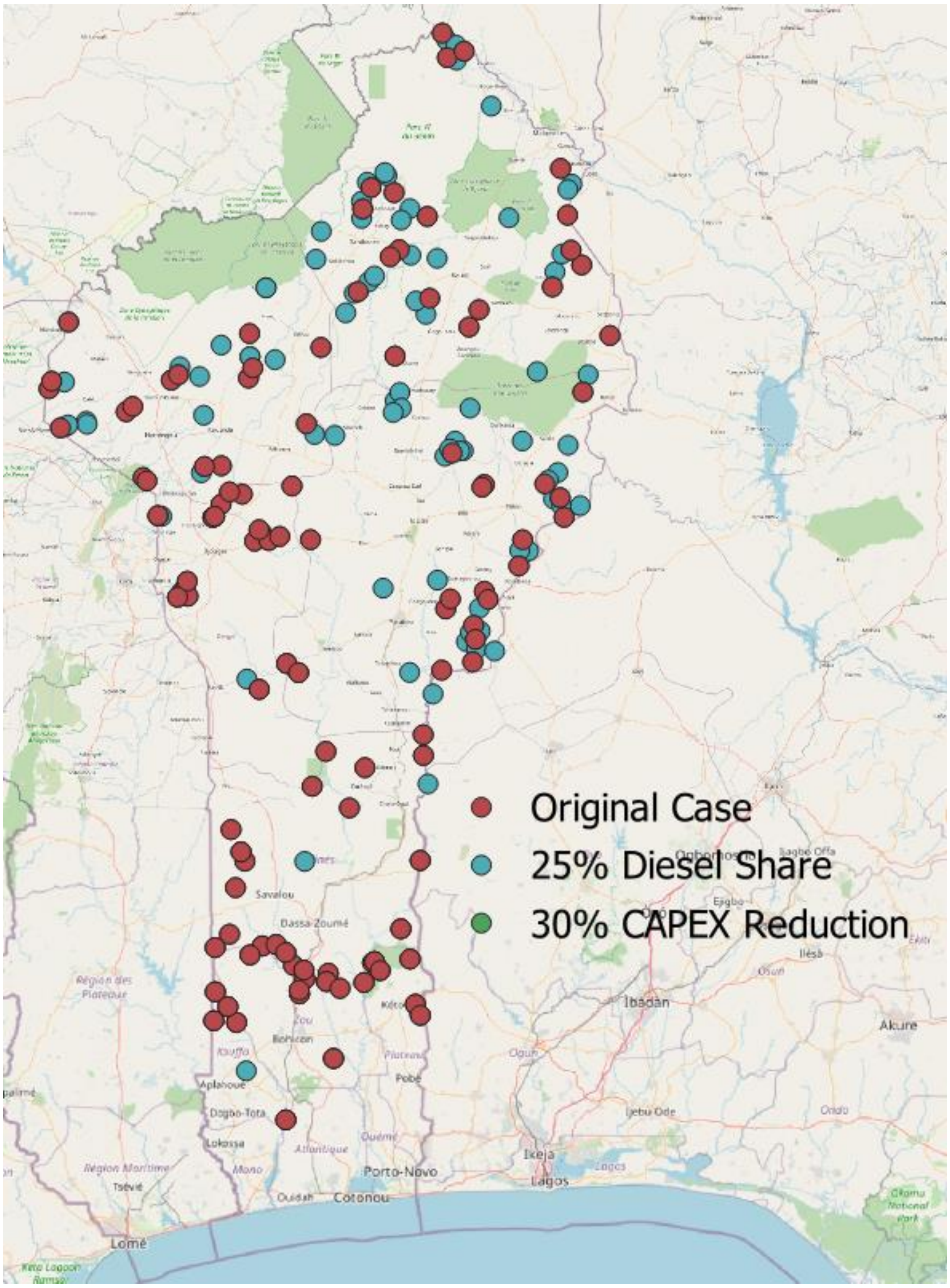

Figure 38: Replication Sites for Benin based on LCOE results including the investment cost of the Grid.

Similarly, but with some minor differences, in the case of Figure 39, the red dots represent the sites that would be available without considering the cost of the grid investment and without considering any change in the electricity generation or CAPEX subsidy. The light blue dot represents the additional site that would be viable if a 30% CAPEX discount is included, or a 25% diesel share is considered.

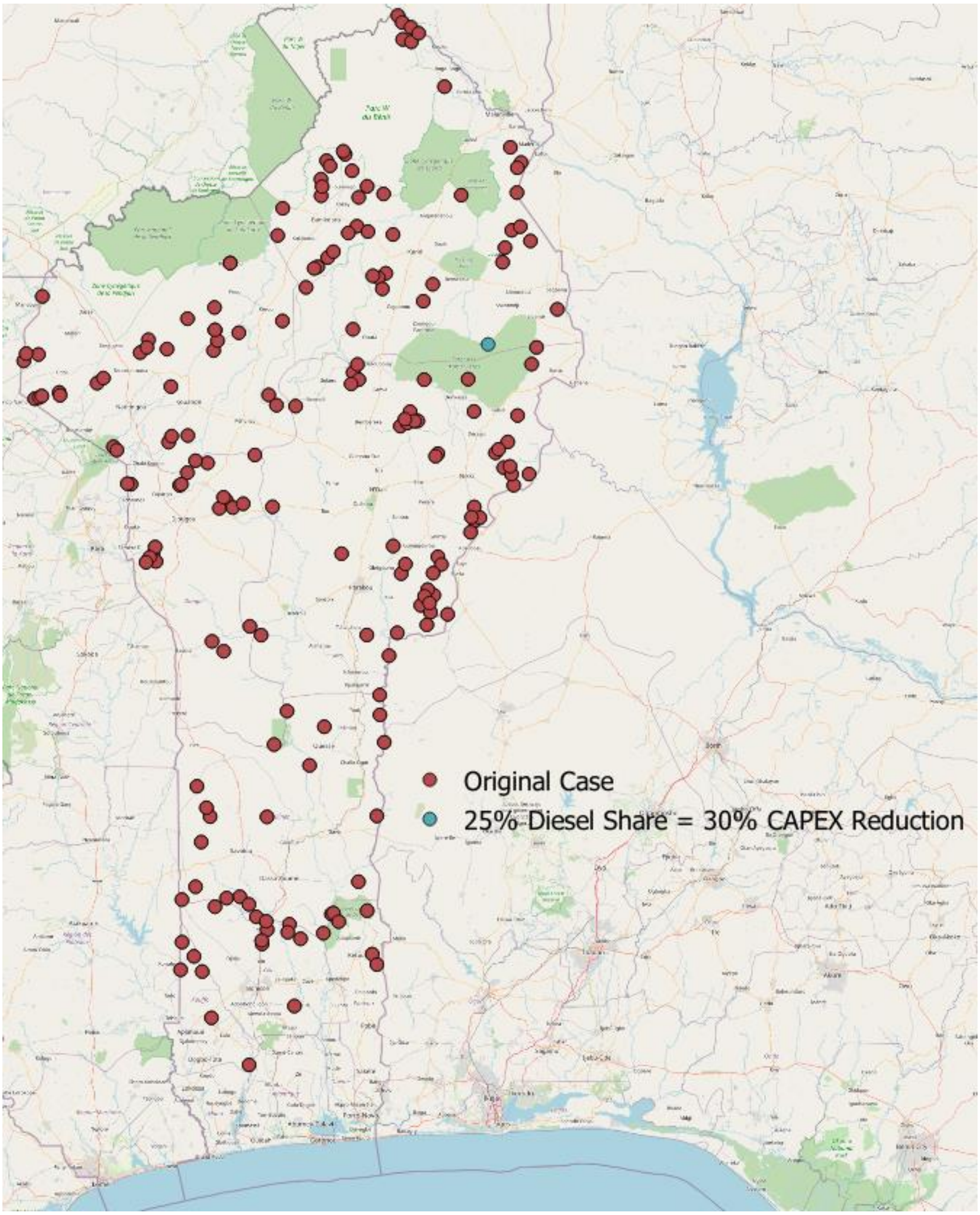

Figure 39: Replication Sites for Benin based on LCOE results without including the investment cost of the Grid.

The replicability analysis carried out for the microgrid solutions in **Senegal** reveals several crucial insights, also thanks to the 3 different load curves presented. To recap, the first load curve (LC1) is representative of Senegalese villages with a population below 200 inhabitants, LC2 of a village with 200-1,000 inhabitants, and finally LC3 of villages with a population above 1,000. In the Senegal replication study, no increasing share of diesel variation has been taken into consideration given the already rather high diesel share (30-46%) as seen in Senegal LCOE sensitivity analysis. A sensitivity analysis has then been performed on the assumption of CAPEX incentives varying between 30-50%, in line with the assumptions considered for the Beninese case and in order to make the replicability in both countries comparable.

Although each load curve considered for the Senegalese case results in slightly different outcomes for the economic viability of the 321 pre-identified sites, generally, as it is to be expected, a higher CAPEX incentive results in a higher number of villages that are found to be economically viable.

In particular, for LC1, even without considering the opportunity for investment incentives, all sites are found to be economically viable if the cost of grid installation is not considered, thus, the red dots in Figure 40 that represent the economically viable sites for Senegal for LC1 coincide with the 321 pre-identified sites. CAPEX incentives in this case only contribute to improving the economic success of the project, rather than adding additional sites to the list of those economically viable.

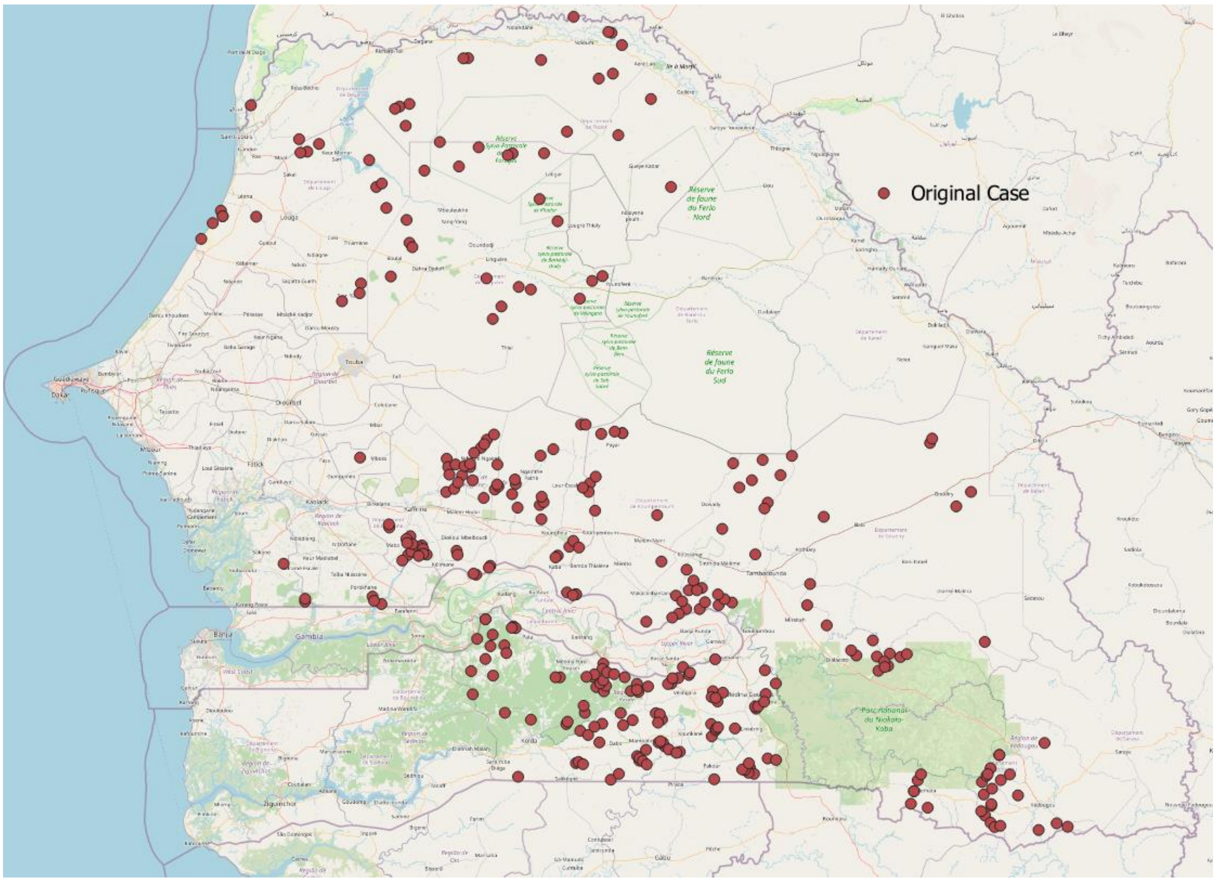

Figure 40: Replication Sites for Senegal based on LCOE results without including the investment cost of the Grid for LC1.

When considering the grid investment cost though, the situation changes for LC1 and Figure 41offers a visual representation of the CAPEX based sensitivity analysis results. The red dots represent the sites that would be economically viable if no CAPEX incentives were to be considered (98), while the blue dots represent the additional sites that would be viable with a 30% CAPEX incentive (290), the green dots represent the additional sites that would be viable with a 40% CAPEX incentive (301), and finally the yellow dots represent the additional sites that would be viable with a 50% CAPEX incentive (305). In the case of LC1 it results impossible to have all the 321 pre-identified sites viable even with a 50% CAPEX incentive. This may be due to the significant grid length of some of the identified villages.

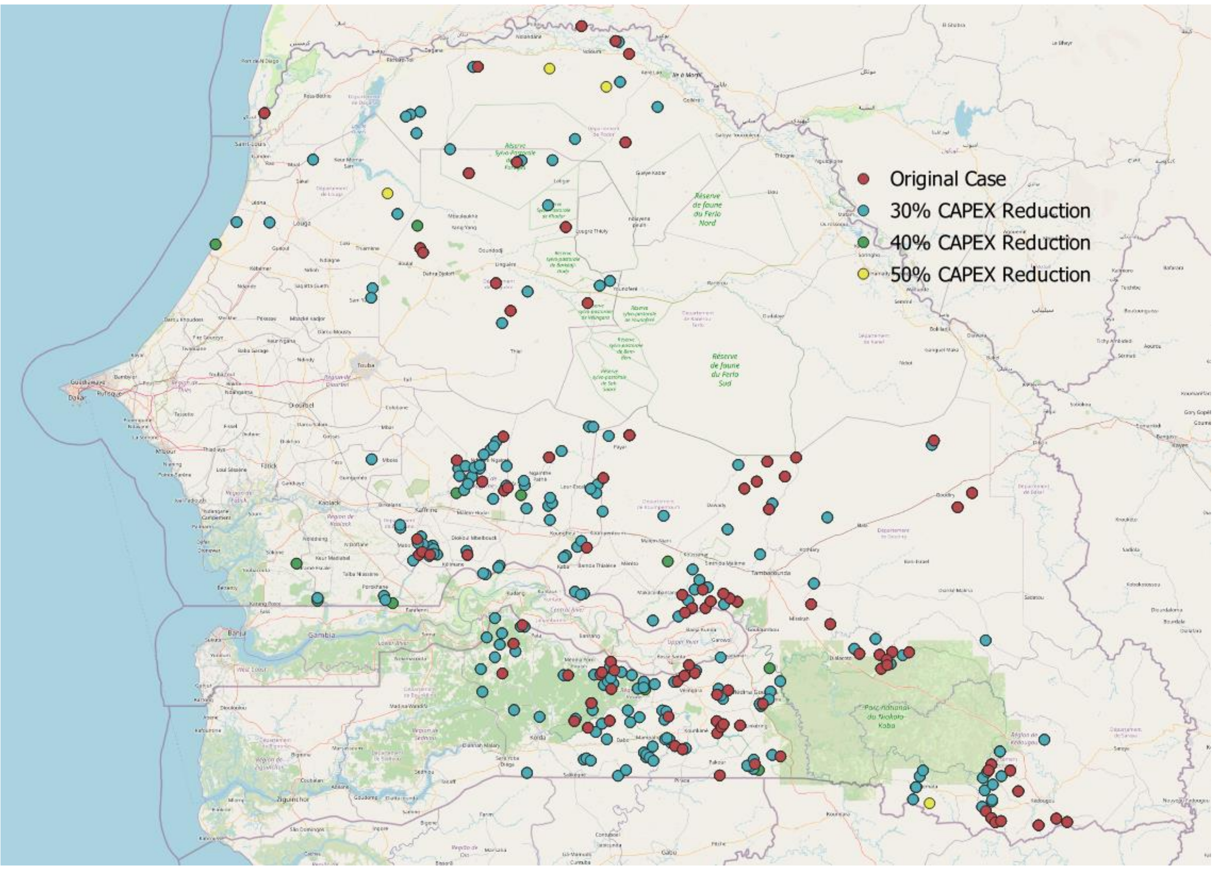

Figure 41: Replication Sites for Senegal based on LCOE results including the investment cost of the Grid for LC1.

A similar analysis can be carried out for LC2. In the case of LC2, if no investment discount and grid associated cost are not considered, 314 sites are found to be economically viable and are represented by the red dots in Figure 42. A CAPEX incentive as small as 30% already achieves to add all the additional sites to reach the total of 321 pre-identified locations for replicability, which are represented by blue dots. Any further CAPEX incentives only help with improving the projects economics, but don´t add any extra sites.

If the grid investment cost is accounted for, the situation of LC2 appears to be rather different than for LC1. This is most likely due to the fact that the grid length required to connect the villages is the same for each of the modelled load curves, but what changes is the energy demand. Thus, a lower energy demand but the exact same grid length leads to a much worse LCOE for LC2 when the cost of the grid investment is factored in. These results are to be expected from a mathematics point of view if the methodology described in Step-by-step Methodology is applied, as the denominator reduces drastically, while the grid cost at the numerator remains the same. With that being said, 2 villages are found to be replicable with no CAPEX incentives (represented by red dots in Figure 43), the number grows to 3 when a 30% CAPEX discount is available (blue dots), to 8 with 40% (green dots) and 42 with 50% (yellow dots). Again, no matter the amount of CAPEX discount, it is not possible for all 321 LC2 villages to be economically viable.

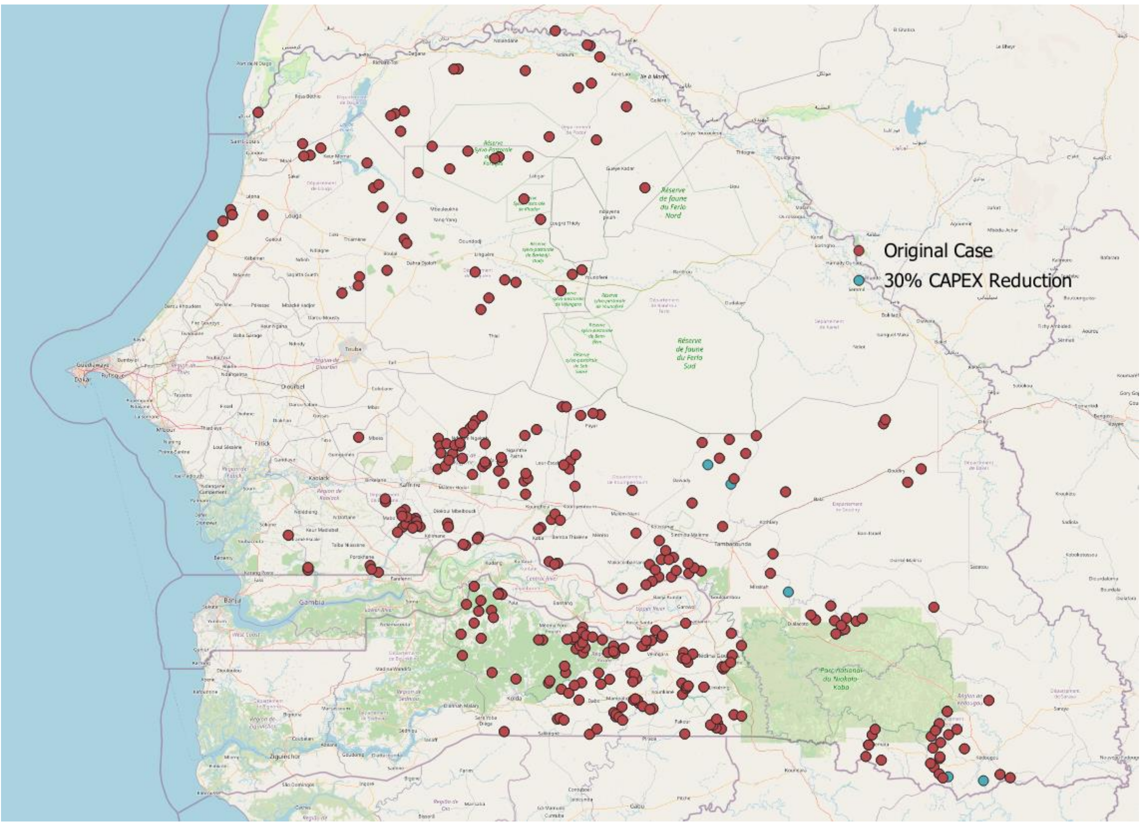

Figure 42: Replication Sites for Senegal based on LCOE results without including the investment cost of the Grid for LC2.

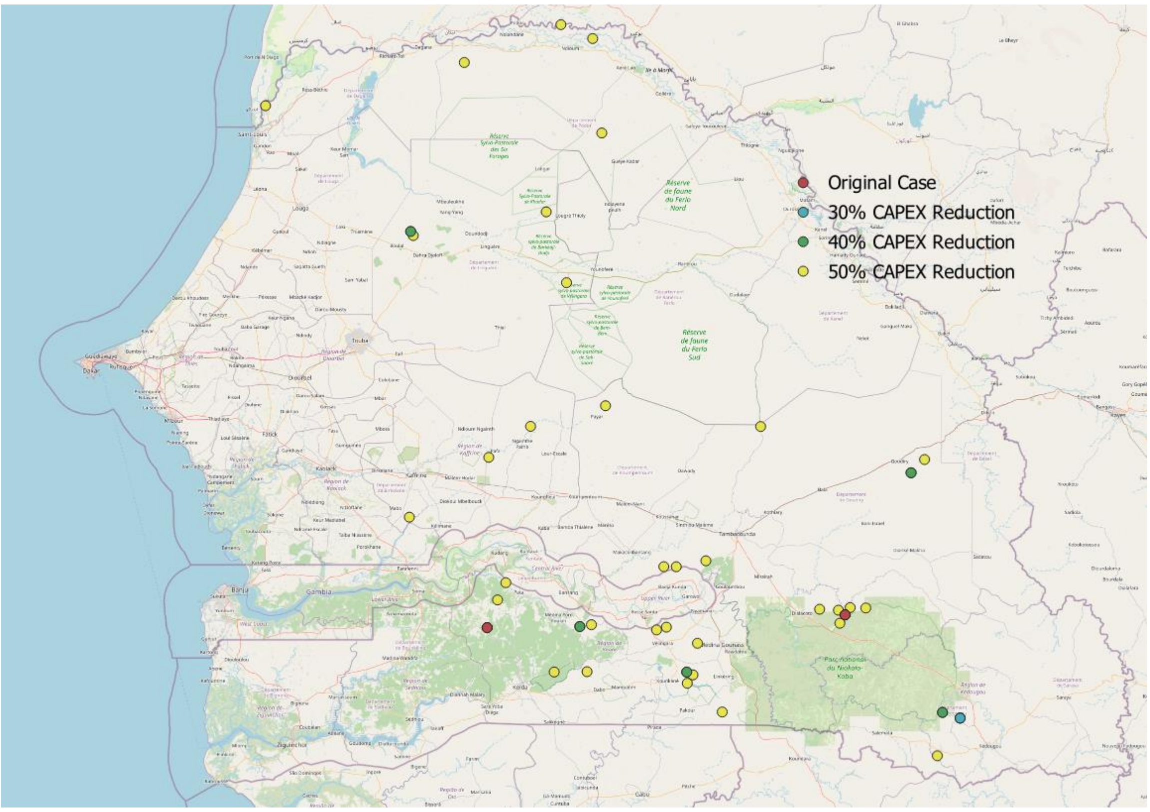

Figure 43: Replication Sites for Senegal based on LCOE results including the investment cost of the Grid for LC2.

LC3 constitutes a bit of a different situation when compared to the previous two. In this case, all 321 pre-identified sites are viable from the get-go when the investment cost associated with the grid is not considered and are represented by red dots in Figure 44. When CAPEX incentives are considered, this help increasing the economic profitability of the microgrid project, but do not add any additional sites.

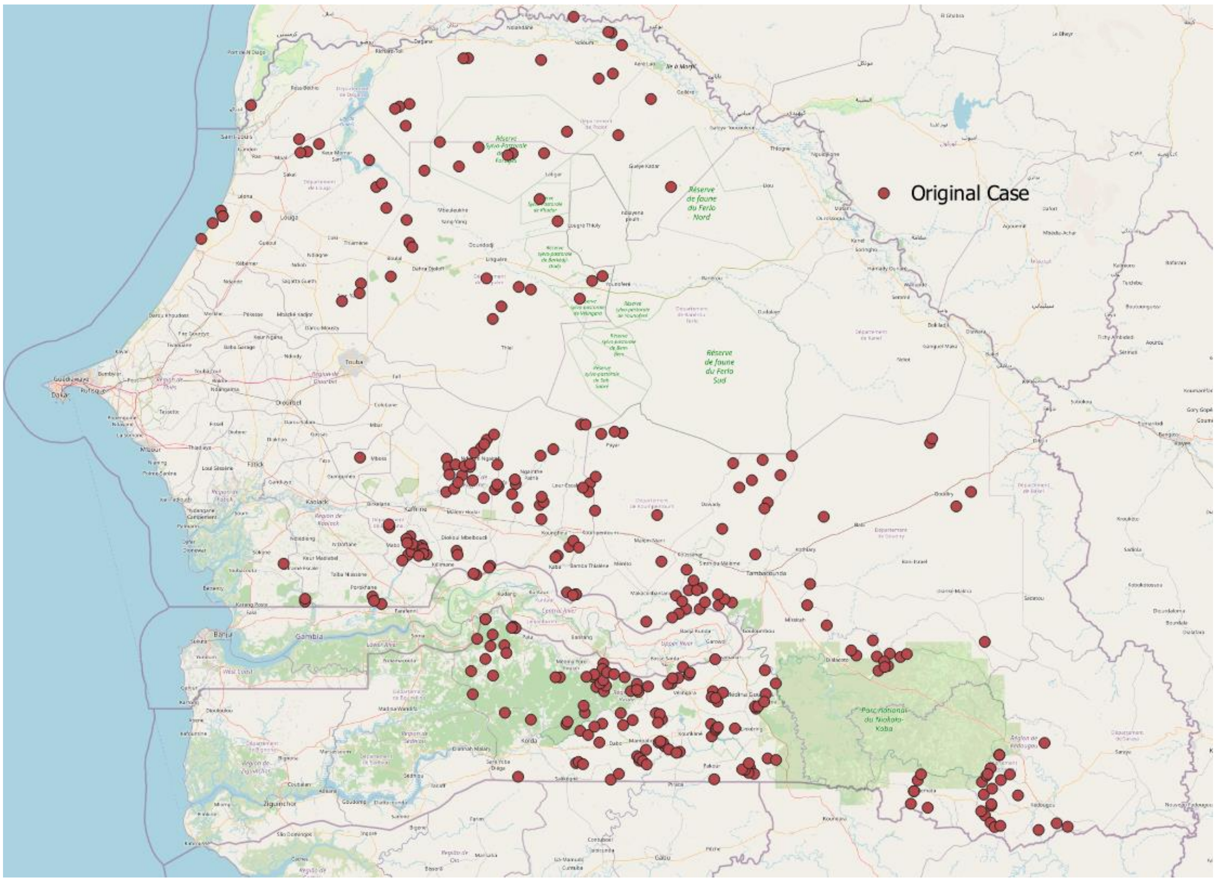

Figure 44: Replication Sites for Senegal based on LCOE results without including the investment cost of the Grid for LC3.

Since LC3 presents a much higher energy consumption when compared to the other examined load curves, but the grid length remains the same for all of the 321 identified villages, then in this case the LCOE values are comparably lower, as to be expected, and it allows to achieve much better results in terms of replicability. As a matter of fact, even without considering any CAPEX incentives, when the investment cost of the grid is considered for LC3, 43 sites are already found to be replicable and are represented by red dots in Figure 45. Although this number is still lower than the similar case for LC1, as the microgrid design was optimized for such a village size, better results are achieved when CAPEX subsidies are considered. A small CAPEX incentive of 30% allows for 296 sites to be economically viable (represented by the blue dots), and 321 when a 40% reduction is considered (green dots). Increasing the CAPEX subsidy beyond this point will only aid in the economic profitability but will not add any extra sites to the viable ones. In the case of LC3 it is therefore possible for all 321 pre-identified sites to be economically viable with a CAPEX subsidy of 40%.

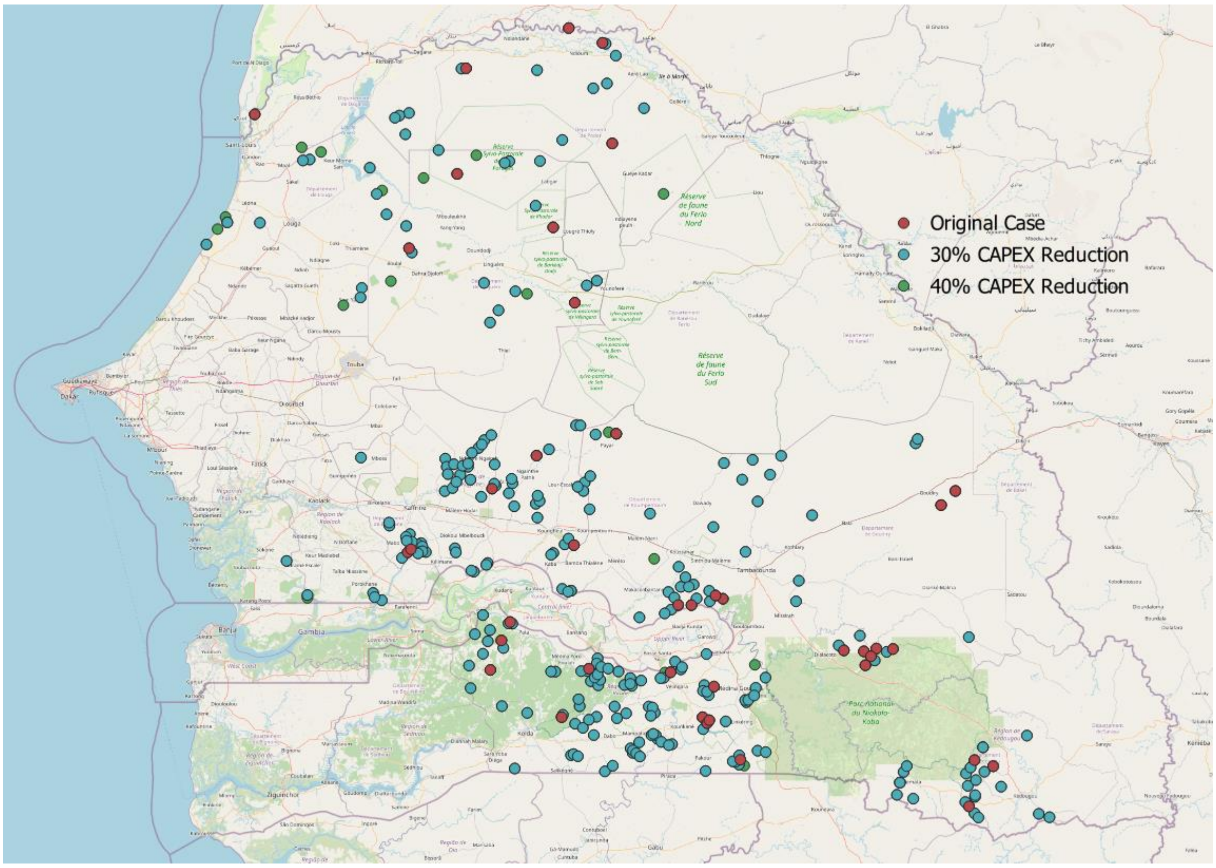

Figure 45: Replication Sites for Senegal based on LCOE results including the investment cost of the Grid for LC3.

4. Conclusion

This chapter aims at shedding light on the main conclusions drawn from the replicability analysis carried out in this study and critically reviewing its limitations, while providing suggestions for further development.

4.1 Limits & Recommendations for Future Work

As mentioned throughout the report, several limitations have been identified in the replicability study and the overall methodology applied. For instance, a reference daily hourly load profile is replicated for each day of the year without considering seasonal and weekday variations. This approach can lead to inaccurate load profile estimations, resulting in either over-sizing or under-sizing the microgrid. Over-sizing can lead to higher-than-necessary investments, while under-sizing can result in unmet demand. Therefore, it is advisable to account for load profile variations between weekdays and weekends, as well as overall energy consumption changes based on average outdoor temperatures. Ideally, the hourly load profile should be based on data from microgrid projects in locations with similar population consumption patterns and climates.

Another limitation is the lack of differentiation between villages. Although this analysis serves as a first step in assessing replicability potential, future work should include a more precise building distribution related to the specific site to ensure a more accurate LCOE estimation. For example, some villages may not require as large a cold storage facility as the one envisioned for Benin, especially if their population is smaller than the average village size considered. Significant differences in cold storage size will heavily impact the LCOE obtained.

Additionally, further sensitivity analysis could be performed to understand the impact of changes in the load profile and building distribution by client type on the LCOE. The sensitivity analysis in this study focuses on changes in the energy share produced by the diesel engine or changes in the CAPEX subsidy. However, combining these two analyses could lead to the best possible replication results.

4.2 Replicability Study Conclusion

A country-wide replication study has been conducted for the LEOPARD microgrid project in Benin and Senegal. The study results have yielded an easy-to-use set of interactive maps and spreadsheets, which may serve as the basis for future decision-making regarding suitable sites for replicating the LEOPARD microgrid demonstrator sites. The study incorporates existing lists of pre-identified sites for the target countries, combining them with the results of a country-wide analysis using open data sources. This allows the end user to analyse and interpret the list in the context of the entire country rather than being limited to the pre-identified sites.

The analysis of the LCOE for microgrid solutions highlights a direct relationship between LCOE and population size. Larger populations necessitate greater technological investments, resulting in higher LCOE values. Additionally, LCOE increases with grid length due to the additional costs associated with extended infrastructure, making economic viability challenging under these conditions. Adjustments in the energy mix, particularly increasing the diesel share from 14% to 24.7%, significantly improve economic viability for the Benin case. Similarly, a 30% CAPEX subsidy enhance viability both in Benin and Senegal, however, higher CAPEX subsidies mainly aid in the increasing the potential revenue streams for the microgrid deployer rather than adding additional sites to the list of viable ones.

Future work should refine load profiles to reflect seasonal and weekly variations and incorporate site-specific assessments to improve LCOE accuracy. A combination of adjustments in diesel energy share and CAPEX subsidies could further optimize the economic feasibility of microgrid replication in Benin and Senegal. Overall, the replicability analysis is grounded in a strong mathematical methodology that has effectively pinpointed various potential sites for replication, ensuring they are geographically, technically, and economically viable. While there is still room for improvement, the authors are confident in the results presented in this report.

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Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. The European Union can not be held responsible for them.

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7. Appendix

Appendix I: Input data Senegal #1

Nom	Département	Région	Population	Nombre de ménage hors boutique et collectif	Nombre de points de connexion	Consommation journalière village (kWh)	Distance par rapport au réseau
Doyly	BIRKILANE	Kaffrine	697	63	70	50,2333	15
Hamdalaye Mbeuleup	BIRKILANE	Kaffrine	702	45	52	33,94425	11
Keur Aly Khady	BIRKILANE	Kaffrine	543	49	59	45,4335	11
Keur Birame	BIRKILANE	Kaffrine	981	98	109	62,6305	20
Keur Djiby	BIRKILANE	Kaffrine	997	79	83	58,3133	30
Keur Ngatta	BIRKILANE	Kaffrine	820	80	93	61,35225	32
Koumpeul Wolof	BIRKILANE	Kaffrine	960	76	87	70,48405	18
Ndiayene Mbeuleup	BIRKILANE	Kaffrine	400	13	18	8,345	31
Ndiobene Gouye	BIRKILANE	Kaffrine	625	25	30	18,715125	65
Ndiobene Taiba	BIRKILANE	Kaffrine	1075	70	83	58,02395	30
Hane Thiekene Darou Salam	BIRKILANE	Kaffrine	953	51	61	39,5715	9
Talla	BIRKILANE	Kaffrine	400	12	17	20,61025	13
Darou Mady Diallo	KAFFRINE	Kaffrine	650	34	42	32,00425	40
Dioly Keur Mote - Dioly Mbaba	KAFFRINE	Kaffrine	550	62	71	53,941	15
Kelimane Gouye	KAFFRINE	Kaffrine	412	35	47	47,04855	21
Lanel	KAFFRINE	Kaffrine	746	81	91	63,24675	20
Louba	KAFFRINE	Kaffrine	1056	67	72	70,359	66
Medina Diery	KAFFRINE	Kaffrine	717	50	57	45,34125	66
H1 Ngedene	KAFFRINE	Kaffrine	1134	81	92	72,29755	45
Ngoye Mady Boury	KAFFRINE	Kaffrine	647	60	65	60,11525	59
Panthiang 1	KAFFRINE	Kaffrine	1163	46	53	36,575	60
Panthiang 2	KAFFRINE	Kaffrine	1213	48	61	37,103	13
BOUDIOUGUEL	KOUNGHEUL	Kaffrine	834	0	10	101,481	10
COURA YORO SIDY	KOUNGHEUL	Kaffrine	560	53	59	36,18275	10
Darou Kaffate	KOUNGHEUL	Kaffrine	1225	112	123		15
Darou Koung Koung	KOUNGHEUL	Kaffrine	714	38	57	86,94025	15
Darou Thiamene	KOUNGHEUL	Kaffrine	550	43	52	52,37725	15
Dimangueune Ndame	KOUNGHEUL	Kaffrine	588	42	45	54,55075	10
Hamdallah Thiamene	KOUNGHEUL	Kaffrine	671	57	67	57,76225	21
Kaffate	KOUNGHEUL	Kaffrine	1157	130	153		12
Coura Ndiaridiofa-Koura Foutaye	KOUNGHEUL	Kaffrine	537	37	42	32,99525	15
Lougué Yama	KOUNGHEUL	Kaffrine	778	47	56	79,55625	9
Maka Katal	KOUNGHEUL	Kaffrine	693	28	35	21,5515	9

g from the European Union’s Horizon 2020
m under Grant Agreement 963530.

Mbayéne Elimane	KOUNGHEUL	Kaffrine	408	28	35	31,30925	16
Médina Fass	KOUNGHEUL	Kaffrine	641	35	50	78,3263	11
Medina Ndiayene	KOUNGHEUL	Kaffrine	588	43	51	69,68075	45
Medina Tobéne	KOUNGHEUL	Kaffrine	674	73	79	73,837	20
Missirah Keur Omar Sarr	KOUNGHEUL	Kaffrine	786	62	65	99,52075	9
Ndiaye Counda 1	KOUNGHEUL	Kaffrine	470	44	54	42,65575	15
Sobel Hamdallahi	KOUNGHEUL	Kaffrine	400	53	59	34,43275	17
Taiba Ndioufene	KOUNGHEUL	Kaffrine	1167	49	58	77,56825	7
Taneme	KOUNGHEUL	Kaffrine	359	72	77	66,229	30
Tawfekh Saloum	KOUNGHEUL	Kaffrine	782	44	52	84,75005	12
Touba Mbowene	KOUNGHEUL	Kaffrine	416	38	45	50,81375	35
Alouky Ndoucoumane	MALEM HODDAR	Kaffrine	900	43	54	35,01725	15
Bode	MALEM HODDAR	Kaffrine	875	55	66	100,16325	11
Darou Diene	MALEM HODDAR	Kaffrine	600	40	46	70,5248	11
Diacksao Saloum	MALEM HODDAR	Kaffrine	1159	61	69	93,97855	30
Dianke Kao	MALEM HODDAR	Kaffrine	800	46	56	58,081	15
Djiddah	MALEM HODDAR	Kaffrine	600	40	43	42,56975	32
Hamdalaye Delby	MALEM HODDAR	Kaffrine	624	42	50	36,854	18
Hamdallah	MALEM HODDAR	Kaffrine	410	40	45	51,11425	31
Khourou Ndiobene	MALEM HODDAR	Kaffrine	500	54	60	50,884	65
Lewe	MALEM HODDAR	Kaffrine	889	80	86	67,084	30
Medina Fass	MALEM HODDAR	Kaffrine	990	58	67	107,00225	9
Madina Mbaye	MALEM HODDAR	Kaffrine	900	33	39	24,8594	13
Medina Ndiaye	MALEM HODDAR	Kaffrine	1080	48	54	62,2095	40
Nawrene	MALEM HODDAR	Kaffrine	1205	82	94	62,3688	15
Ndiote Mor Coumba	MALEM HODDAR	Kaffrine	684	38	47	53,993	21
Diganete Peulga	MALEM HODDAR	Kaffrine	450	22	23	8,62825	20
Touba Ngueyene	MALEM HODDAR	Kaffrine	875	46	58	153,589	66
Belel Djiga	MALEM HODDAR	Kaffrine	1200	65	76	110,66475	66
Mbane	MALEM HODDAR	Kaffrine	555	51	56	99,69325	45
Taif Ndioum	MALEM HODDAR	Kaffrine	350	41	47	48,58775	59
Thioyi Ndioum	MALEM HODDAR	Kaffrine	965	41	57	115,22	60

Appendix II: Input data Senegal #2

This project has received funding from the European Union's Horizon 2020
Research and Innovation Program under Grant Agreement 963530.

N	REGION	DEPARTEMENT	COMMUNE	VILLAGE	Longitude (degre)	Latitude (degre)	POPulation des villages
1	KAFFRINE	KAFFRINE	MEDINATOUL SALAM 2	Darou Mady Diallo	-15,222025	13,758542	650
2	KAFFRINE	KAFFRINE	MEDINATOUL SALAM 2	Kelimane Gouye	-15,235767	13,764100	412
3	KAFFRINE	KAFFRINE	MEDINATOUL SALAM 2	Panthiang 1	-15,146460	13,804437	1163
4	KAFFRINE	KAFFRINE	MEDINATOUL SALAM 2	Panthiang 2	-15,153624	13,794748	1213
5	KAFFRINE	KAFFRINE	DIAMAGADIO	Dioly Keur Mor - Dioly Mbaba	-15,506228	13,892748	550
6	KAFFRINE	KAFFRINE	DIAMAGADIO	Touba Nguettene (H1 Ngedene)	-15,529681	13,855877	1134
7	KAFFRINE	KAFFRINE	DIAMAGADIO	Louba	-15,524679	13,862263	1056
8	KAFFRINE	KAFFRINE	DIAMAGADIO	Médina Diéri	-15,321504	13,861538	717
9	KAFFRINE	KAFFRINE	DIAMAGADIO	Ndiock	-15,326327	13,882728	415
10	KAFFRINE	KAFFRINE	DIAMAGADIO	NGouye Madi Bouri	-15,505275	13,867386	647
11	KAFFRINE	KAFFRINE	DIAMAGADIO	Passy Ndialakh	-15,487045	13,863245	547
12	KAFFRINE	BIRKILANE	MBEULEUP	Ndiayène Mbeuleup	-15,595422	13,944152	400
13	KAFFRINE	BIRKILANE	MBEULEUP	Ndiobène Gouye	-15,591231	13,923066	625
14	KAFFRINE	BIRKILANE	MABO	Keur Djiby	-15,586595	13,861336	997
15	KAFFRINE	BIRKILANE	MABO	Koumpeul Wolof	-15,617482	13,831998	960
16	KAFFRINE	KAFFRINE	BOULEL	Lanel	-15,379548	14,360853	3215
17	KAFFRINE	BIRKILANE	NDIOGNICK	Daga Biram (Keur Birame)	-15,574371	13,958670	981
18	KAFFRINE	BIRKILANE	SEGREGATA	Keur Aly Khady	-15,688913	14,019805	543
19	KAFFRINE	BIRKILANE	SEGREGATA	Keur Nghatta	-15,687115	14,003697	820
20	KAFFRINE	BIRKILANE	MBEULEUP	Hamdalaye Mbeuleup	-15,562773	13,917834	702
21	KAFFRINE	BIRKILANE	MBEULEUP	Roukhane Thiékène Darou Salam	-15,512191	13,910495	953
22	KAFFRINE	BIRKILANE	MBEULEUP	Ndiobène Taiba	-15,530353	13,903448	1075
23	KAFFRINE	BIRKILANE	MBEULEUP	Talla	-15,561911	13,897907	400
24	KAFFRINE	BIRKILANE	MABO	Ndoyly	-15,568600	13,877745	697
25	KAFFRINE	MALEM HODDAR	DAROU MINAM II	Darou Diéne	-15,178381	14,436259	600
26	KAFFRINE	MALEM HODDAR	DAROU MINAM II	Madina Mbaye	-15,164825	14,459481	900

g from the European Union’s Horizon 2020
m under Grant Agreement 963530.

27	KAFFRINE	MALEM HODDAR	NDIOUM NGAINTH	Bélel Djiga	-15,126287	14,486252	1200
28	KAFFRINE	MALEM HODDAR	NDIOUM NGAINTH	Léwé	-15,284076	14,322810	889
29	KAFFRINE	MALEM HODDAR	NDIOUM NGAINTH	Mbané	-15,254814	14,317617	555
30	KAFFRINE	MALEM HODDAR	NDIOUM NGAINTH	Taif Ndioum	-15,232701	14,391724	350
31	KAFFRINE	MALEM HODDAR	NDIOUM NGAINTH	Thioyi Ndioum	-15,196048	14,417727	965
32	KAFFRINE	MALEM HODDAR	NDIOUM NGAINTH	Darou Mbané	-15,254443	14,334418	1113
33	KAFFRINE	MALEM HODDAR	NDIOBENE SAMBA LAMO	Khourou Ndiobene	-15,108163	14,330225	500
34	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Alloucky Ndoucoumane	-15,382149	14,187860	900
35	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Bodé	-15,371390	14,317987	613
36	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Diaksao Saloum	-15,332186	14,330840	1159
37	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Dianké Kao	-15,365429	14,278563	800
38	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Diganté (Diganete Peulga)	-15,318840	14,237261	450
39	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Hamdalaye Delby	-15,240924	14,248782	624
40	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Navarène (Nawrene)	-15,339508	14,204435	1205
41	KAFFRINE	MALEM HODDAR	DIANKE SOUF	Ndioté Mor Coumba	-15,297152	14,274842	684
42	KAFFRINE	MALEM HODDAR	SAGNA	Djiddah 1	-15,102845	14,216979	600
43	KAFFRINE	MALEM HODDAR	SAGNA	Hamdalaye 1 (Hamdallah)	-15,109782	14,227266	410
44	KAFFRINE	MALEM HODDAR	SAGNA	Médina Fass	-15,181497	14,157324	990
45	KAFFRINE	MALEM HODDAR	SAGNA	Touba Ngueyene	-15,122124	14,200965	875
46	KAFFRINE	KOUNGHEUL	GAINTHE PATHE	Boudiourguel	-15,014359	14,253189	834
47	KAFFRINE	KOUNGHEUL	GAINTHE PATHE	Touba Mbowène	-15,010113	14,229760	416
48	KAFFRINE	KOUNGHEUL	MAKA YOP	Darou Thiamène	-15,029627	14,177013	550
49	KAFFRINE	KOUNGHEUL	MAKA YOP	Taiba Ndioufène	-15,000213	14,106844	1167
50	KAFFRINE	KOUNGHEUL	GAINTHE PATHE	Medina Ndiayene	-14,877447	14,376733	588
51	KAFFRINE	KOUNGHEUL	IDA MOURIDE	Diamaguene Ndame	-14,585099	14,091268	588

52	KAFFRINE	KOUNGHEUL	IDA MOURIDE	Hamdallay Thiamène	-14,860650	14,135351	671
53	KAFFRINE	KOUNGHEUL	IDA MOURIDE	Missirah Keur Omar Sarr	-14,872633	14,046441	786
54	KAFFRINE	KOUNGHEUL	LOUR ESCALE	Coura Ndiaridiofa-Koura Foutaye2	-14,619490	14,188685	537
55	KAFFRINE	KOUNGHEUL	LOUR ESCALE	Coura Yoro Thidy	-14,650557	14,210823	560
56	KAFFRINE	KOUNGHEUL	LOUR ESCALE	Sobel Hamdallaye	-14,612519	14,233325	400
57	KAFFRINE	KOUNGHEUL	RIBOT ESCALE	Darou Koung Koung	-14,808866	14,410180	714
58	KAFFRINE	KOUNGHEUL	RIBOT ESCALE	Lougué Yama	-14,659692	14,538195	778
59	KAFFRINE	KOUNGHEUL	RIBOT ESCALE	Tawfekh Saloum	-14,636052	14,537608	782
60	KAFFRINE	KOUNGHEUL	FASS THIEKENE	Darou Fana	-14,671446	13,899788	591
61	KAFFRINE	KOUNGHEUL	FASS THIEKENE	Maka Katal	-14,701659	13,934415	693
62	KAFFRINE	KOUNGHEUL	FASS THIEKENE	Mbayéne Elimane	-14,797083	13,848372	408
63	KAFFRINE	KOUNGHEUL	FASS THIEKENE	Médina Fass	-14,722737	13,903713	641
64	KAFFRINE	KOUNGHEUL	FASS THIEKENE	Ndiaye Counda 1	-14,785136	13,857839	470
65	KAFFRINE	KOUNGHEUL	MAKA YOP	Tanème	-14,871271	14,163380	359
66	KAFFRINE	KOUNGHEUL	MAKA YOP	Medina Tobéne	-14,881189	14,120605	674
67	FATICK	FOUNDIOUGNE	NIORO ALASSANE TALL	Manssassou	-16,138058	13,633169	702
68	FATICK	FOUNDIOUGNE	KEUR SALOUM DIANE	Keur Katime Gueye & Keur Bakar S	-16,252933	13,815272	375
69	KAOLACK	GUINGUINEO	WACK NGOUNA	Afe Keur Hamady Diagne SARR	-16,138151	13,617898	560
70	KAOLACK	GUINGUINEO	NDIAGO	Keur Niokhor	-15,843595	14,366717	505
71	KAOLACK	GUINGUINEO	MEDINA SABAKHE	Keur Samba Couta	-15,729035	13,605571	278
72	KAOLACK	NIORO DU RIP	POROKHANE	Bouli Boky	-15,776915	13,644534	420
73	KAOLACK	NIORO DU RIP	POROKHANE	Keur Diatta	-15,768532	13,622615	606
74	KOLDA	VELINGARA	Linkéring	Akane	-13,660918	12,800423	879
75	KOLDA	VELINGARA	Linkéring	Boumoune samaye	-13,616163	12,792769	639
76	KOLDA	VELINGARA	Kandia	Dialaka	-14,194651	13,188844	969

77	KOLDA	VELINGARA	Sinthing Koundara	Gambisara	-13,942132	13,318084	946
78	KOLDA	VELINGARA	Némataba	Hamdalaye Almamy	-14,114836	13,277656	478
79	KOLDA	VELINGARA	Sinthing Koundara	Hamdalaye Malang Touré	-13,954206	13,151690	436
80	KOLDA	VELINGARA	Paroumba	Kathilaty	-13,797221	12,743439	589
81	KOLDA	VELINGARA	Paroumba	Kolo	-13,734136	12,720350	827
82	KOLDA	VELINGARA	Némataba	Koumera	-14,076585	13,248016	355
83	KOLDA	VELINGARA	Sinthing Koundara	Mballocounda	-13,900926	13,143972	612
84	KOLDA	VELINGARA	Paroumba	Médina Bouré	-13,763937	12,726070	406
85	KOLDA	VELINGARA	Kandia	Medine Elhadji Sory	-14,301498	13,175991	823
86	KOLDA	VELINGARA	Medina Gounass	Missira Fourath	-13,617384	13,191759	1116
87	KOLDA	VELINGARA	Pakour	Panangar	-13,946947	12,691704	757
88	KOLDA	VELINGARA	Medina Gounass	Rabat	-13,712179	13,072338	680
89	KOLDA	VELINGARA	Kandiaye	Saré Aly	-13,963650	12,979973	429
90	KOLDA	VELINGARA	Boncontu	Saré Boussodié	-13,836218	12,957418	891
91	KOLDA	VELINGARA	Kandia	Sinthiang Saby	-14,176788	13,191183	891
92	KOLDA	VELINGARA	Kandiaye	Takoudiala	-14,131788	12,835374	587
93	KOLDA	KOLDA	BAGADADJI	Afia Samba	-14,664638	12,944880	152
94	KOLDA	KOLDA	DABO	Alalon Samba	-14,547119	12,981970	653
95	KOLDA	KOLDA	MEDINA CHERIF	Darou Salam Sadio	-14,245119	12,883832	271
96	KOLDA	KOLDA	MAMPATIM	Diankancounda	-14,384436	13,000590	335
97	KOLDA	KOLDA	MEDINA CHERIF	Diyabougou Khadry	-14,235100	12,890449	386
98	KOLDA	KOLDA	COUMBACARA	Gnandindya	-14,457810	12,719962	476
99	KOLDA	KOLDA	MEDINA CHERIF	Kéréwane Bocar	-14,248127	12,987489	315
100	KOLDA	KOLDA	COUMBACARA	Kondior	-14,501087	12,689679	261
101	KOLDA	KOLDA	MEDINA CHERIF	Lingayel Kassoum	-14,190830	12,848186	315
102	KOLDA	KOLDA	MEDINA CHERIF	Macina Seny	-14,221647	12,883302	235

103	KOLDA	KOLDA	MEDINA EL-HADJI	Medina Alpha Sadio	-14,997366	12,704970	429
104	KOLDA	KOLDA	DIALAMBERE	Ngoudoumane	-14,562236	12,884156	377
105	KOLDA	KOLDA	MEDINA CHERIF	Ninkidji	-14,227062	13,004184	681
106	KOLDA	KOLDA	MAMPATIM	Pidiro	-14,312301	12,845557	643
107	KOLDA	KOLDA	MEDINA CHERIF	Saré Hamady (saré diata)	-14,260013	13,036942	319
108	KOLDA	KOLDA	MAMPATIM	Sare Kanta	-14,329246	12,786957	495
109	KOLDA	KOLDA	MEDINA CHERIF	SareMaounde	-14,213575	12,864921	398
110	KOLDA	KOLDA	MAMPATIM	Sare Ndiayla	-14,359796	12,812842	469
111	KOLDA	KOLDA	MAMPATIM	Sare Simali	-15,067843	13,039040	441
112	KOLDA	KOLDA	MEDINA CHERIF	Saré Yoba Niama	-14,238745	13,031555	326
113	KOLDA	KOLDA	DIALAMBERE	Velingara Yele	-14,447970	13,037321	448
114	KOLDA	MEDINA YORO FOULA	Bouroucou	Aïnomady	-15,248930	13,256248	282
115	KOLDA	MEDINA YORO FOULA	Kerewane	AÏNOUMANE	-15,172100	13,526494	540
116	KOLDA	MEDINA YORO FOULA	Kerewane	AÏNOUMANE_kéréwane	-15,172100	13,526494	412
117	KOLDA	MEDINA YORO FOULA	Kerewane	DAROU KHOUDOSS	-15,070665	13,390797	995
118	KOLDA	MEDINA YORO FOULA	Bouroucou	DAROU PAKATHIAR	-15,145594	13,386180	847
119	KOLDA	MEDINA YORO FOULA	Kerewane	DIABA SENEGAL	-15,216559	13,424200	560
120	KOLDA	MEDINA YORO FOULA	Ndorna	Djifing Coly	-15,240237	13,135457	211
121	KOLDA	MEDINA YORO FOULA	Dinguiraye	Doboncounda	-14,545996	13,267767	569
122	KOLDA	MEDINA YORO FOULA	Badio	Dioulanguél Boutang	-14,426407	13,224400	1120
123	KOLDA	MEDINA YORO FOULA	Niaming	Fandana-Sinthiang Koncorou	-14,631252	13,226541	148
124	KOLDA	MEDINA YORO FOULA	Bouroucou	FASS NDIENGUENE	-15,131381	13,232968	1042
125	KOLDA	MEDINA YORO FOULA	Dinguiraye	Francounda	-14,598071	13,227205	122
126	KOLDA	MEDINA YORO FOULA	Fafacourou	Kandialang	-14,483467	13,240356	532
127	KOLDA	MEDINA YORO FOULA	Kerewane	KOEL NIORO	-15,133362	13,446233	765
128	KOLDA	MEDINA YORO FOULA	Badion	Linguédie	-14,361228	13,189612	682
129	KOLDA	MEDINA YORO FOULA	Dinguiraye	Médina Koyri	-14,541399	13,208599	667

130	KOLDA	MEDINA YORO FOULA	Dinguiraye	Médina Malafi	-14,521402	13,249699	666
131	KOLDA	MEDINA YORO FOULA	Dinguiraye	Médina Pathé (Sinthiang Diarra Sov	-14,541218	13,295177	496
132	KOLDA	MEDINA YORO FOULA	Niaming	Médinatoul Mounawara	-14,773743	13,223876	782
133	KOLDA	MEDINA YORO FOULA	Dinguiraye	Sangoulé	-14,578265	13,172806	831
134	KOLDA	MEDINA YORO FOULA	Dinguiraye	Sare Bacary	-15,031276	13,482104	309
135	KOLDA	MEDINA YORO FOULA	Fafacourou	Diamsylla (Saré Dickel)	-14,639962	13,038871	416
136	KOLDA	MEDINA YORO FOULA	Bourouco	Sare Yoro Sy	-15,172331	13,319334	1104
137	KOLDA	MEDINA YORO FOULA	Dinguiraye	Sinthiang Babou Dème	-14,557265	13,191979	915
138	KOLDA	MEDINA YORO FOULA	MEDINA YORO FOULAh	Sinthiang Diabel Baldé	-14,797177	13,224321	251
139	KOLDA	MEDINA YORO FOULA	Dinguiraye	Sinthiang Ifra	-14,589227	13,239336	693
140	KOLDA	MEDINA YORO FOULA	Fafacourou	Sinthiang Yoro Diamanka	-14,526780	13,179580	681
141	KOLDA	MEDINA YORO FOULA	Kéréwane	Touba Kelimane	-15,059987	13,350277	757
142	LOUGA	LINGUERE	Téssékèré	BOCKY THIAO	-15,208570	15,970510	154
143	LOUGA	LINGUERE	Barkèdji	DIOUMANAME ELHADJI	-14,600880	15,281405	473
144	LOUGA	LINGUERE	Syer	DJILALY	-15,794955	15,904458	507
145	LOUGA	LINGUERE	Téssékèré	GANIMAYEL BAKARNABE	-15,314079	15,871716	356
146	LOUGA	LINGUERE	Téssékèré	GANIMAYEL BISNABE	-15,416492	15,997530	248
147	LOUGA	LINGUERE	Labgar	KADAR	-14,882511	15,703645	309
148	LOUGA	LINGUERE	Mboula	LOUMBY ARABOBE	-15,499055	15,850303	136
149	LOUGA	LINGUERE	Barkèdji	LOUMBY DOULO	-14,545299	15,306236	325
150	LOUGA	LINGUERE	Thiargny	NIERI	-15,086666	15,149165	195
151	LOUGA	LINGUERE	Boulal	PATOUDE	-15,678772	15,304077	280
152	LOUGA	LINGUERE	Dodji	PORAM	-14,785766	15,589117	361
153	LOUGA	LINGUERE	Thiargny	TOUBA BEBEL	-15,133157	15,084538	464
154	LOUGA	LINGUERE	Doumga Lao	TOURGUENOUL	-14,286137	16,218681	561
155	LOUGA	LINGUERE	Boulal	WENDOU NDAMARY 2	-15,578836	15,478166	293
156	LOUGA	LINGUERE	Boulal	WENDOU SEBE	-15,563813	15,455548	253
157	LOUGA	LINGUERE	Ouarkhokh	Khogue	-15,166363	15,294412	813

158	LOUGA	KEBEMER	Sam yabal	BOUCHERA	-15,846145	15,217726	283
159	LOUGA	KEBEMER	Thiéppe	NDAM-NDAM PEULH	-16,399736	15,612879	416
160	LOUGA	KEBEMER	Sam yabal	NDIAKHATE	-15,940531	15,176143	331
161	LOUGA	KEBEMER	Sam yabal	NDIKY LARY	-15,838896	15,267903	384
162	LOUGA	LOUGA	Gandé	BOGAL NDIAYENE	-15,702842	15,657957	312
163	LOUGA	LOUGA	Gandé	GADD MBELOGNE	-15,756794	15,765741	260
164	LOUGA	LOUGA	Keur Momar Saar	KEUR IBRA BINTA	-16,063476	15,987654	936
165	LOUGA	LOUGA	Sakal	KEUR MANDIAYE BAKARY	-16,162808	15,942738	464
166	LOUGA	LOUGA	Sakal	RIMBA SYLLA	-16,125963	15,947878	1053
167	LOUGA	LOUGA	Gandé	THIONKE PEULH	-15,727230	15,784122	550
168	LOUGA	KEBEMER	Thieppe	keur ALDIOUMA WOURY&Nayel D	-16,579147	15,615259	137
169	LOUGA	KEBEMER	Thieppe	KEUR OUSMANE ROUGUI & KEUR	-16,579147	15,615259	58
170	SAINT LOUIS	PODOR	Aere Lao	DIOUTH MELEL	-14,460794	16,033040	820
171	SAINT LOUIS	PODOR	Boké Dialoubé	GUIRWASS	-14,178403	15,766067	525
172	SAINT LOUIS	PODOR	Fanaye	BELEL bogal	-15,290183	16,427765	153
173	SAINT LOUIS	PODOR	GAMADJI SARE	YOLI	-14,858296	15,940068	265
174	SAINT LOUIS	DAGANA	Diama	AL WATHIAM	-16,428091	16,186480	408
175	SAINT LOUIS	DAGANA	Fanaye	DIALLY	-15,265242	16,429173	632
176	SAINT LOUIS	DAGANA	Fass Ngom	NIASSENE	-16,169928	16,012123	1717
177	SAINT LOUIS	DAGANA	Mbane	Sobolnabe Bely Namary	-15,632033	16,179904	207
178	SAINT LOUIS	PODOR	Guedé village	ALANA	-14,874354	16,419466	180
179	SAINT LOUIS	PODOR	Mbane	MBELOGNE GOUDI	-15,579193	16,193425	202
180	SAINT LOUIS	PODOR	Gamadji Saré	WOURO ABDOUL SIRE	-14,735498	16,051094	150
181	SAINT LOUIS	PODOR	DODEL	DIOLBORTOL	-14,514116	16,563327	174
182	SAINT LOUIS	PODOR	DODEL	H15 PéLé mamadou Diamody	-14,489932	16,349245	118
183	SAINT LOUIS	PODOR	DODEL	H20 PETE OBAK	-14,565272	16,323893	193

184	SAINT LOUIS	PODOR	GAMADJI SARE	MOUNDOU WAY	-14,699981	16,641199	308
185	SAINT LOUIS	PODOR	DODEL	TOULEL MAMA	-14,497079	16,558730	194
186	SAINT LOUIS	DAGANA	Mbane	Dialba Nabé Bely Namary	-15,656466	16,168566	408
187	SAINT LOUIS	PODOR	DODEL	MBOROBE	-14,441268	16,495965	587
188	SAINT LOUIS	DAGANA	Mbane	Sarre Lamo Nguelefoul	-15,599221	16,081167	848
189	TAMBACOUN	TAMBACOUNDA	Niany Toucouleur	Kalela	-14,083314	13,677477	494
190	TAMBACOUN	TAMBACOUNDA	NETEBOULOU	Medina Dialoube	-13,433906	13,709958	356
191	TAMBACOUN	TAMBACOUNDA	NDOGA BOUBACAR	Soutouyba Peulh	-13,923526	13,600089	714
192	TAMBACOUN	TAMBACOUNDA	NDOGA BABACAR	Sinthiou Koulykan	-13,927203	13,655874	603
193	TAMBACOUN	TAMBACOUNDA	NDOGA BABACAR	Sinthiou El Mody Ba	-14,024818	13,579656	557
194	TAMBACOUN	TAMBACOUNDA	NDOGA BABACAR	Marcounda	-14,039626	13,677519	294
195	TAMBACOUN	TAMBACOUNDA	NDAGA BABACAR	bambacko	-13,996646	13,615268	472
196	TAMBACOUN	TAMBACOUNDA	MAKACOULIBATANG	Sinthiou Sambarou Djaba Sow	-14,136514	13,555518	405
197	TAMBACOUN	TAMBACOUNDA	MAKACOULIBATANG	Sare Ely	-14,171979	13,535239	703
198	TAMBACOUN	TAMBACOUNDA	MAKACOULIBATANG	Sare Diame	-14,311070	13,513877	436
199	TAMBACOUN	TAMBACOUNDA	MAKACOULIBATANG	Mbane Kalido	-14,151604	13,649346	598
200	TAMBACOUN	TAMBACOUNDA	MAKACOULIBATANG	Dialassaba Sarakhoule	-14,097802	13,580021	670
201	TAMBACOUN	TAMBACOUNDA	MAKACOULIBATANG	Dialassa Peulh et Sare Eli Dien	-14,119014	13,619800	429
202	TAMBACOUN	TAMBACOUNDA	KOUSSANAR	Toubere Diaobe	-13,531241	14,375706	358
203	TAMBACOUN	TAMBACOUNDA	Koussanar	Sinthiou Mamadou	-13,812876	14,211659	247
204	TAMBACOUN	TAMBACOUNDA	Koussanar	Sinthiou Demba niamba	-13,745607	14,249304	247
205	TAMBACOUN	TAMBACOUNDA	Koussanar	SAM	-13,688213	14,354461	247
206	TAMBACOUN	TAMBACOUNDA	Koussanar	NGALLA BOUDE	-13,727145	13,863981	183
207	TAMBACOUN	TAMBACOUNDA	KOUSSANAR	KELA ET LAMA	-13,660619	14,132908	426
208	TAMBACOUN	TAMBACOUNDA	KOUSSANAR	BOKILOTHIE(Wouro Hama)	-13,846089	14,337146	508
209	TAMBACOUN	TAMBACOUNDA	KOUSSANAR	Bohe Baledji (Bokilothi)	-13,592091	14,275514	1114

210	TAMBACOUN	TAMBACOUNDA	KOUSSANAR	Balla	-13,678476	14,102667	273
211	TAMBACOUN	TAMBACOUNDA	KAHENE	Ndiobenne 1	-14,704006	13,651469	600
212	TAMBACOUN	TAMBACOUNDA	Kahene	Medina Thiekene & Fadiya Tening	-14,735768	13,666028	475
213	TAMBACOUN	KOUMPETOUM	KAHENE	Medina Kaneme (Konte peulh)	-14,687449	13,656359	541
214	TAMBACOUN	KOUMPETOUM	KAHENE	Medina Kaneme (Konte wolof)	-14,687449	13,656359	1131
215	TAMBACOUN	TAMBACOUNDA	Dialacoto	Tambacoumbaboulou	-13,097968	13,416278	171
216	TAMBACOUN	TAMBACOUNDA	DIALACOTO	Sounatou	-13,037095	13,306058	246
217	TAMBACOUN	TAMBACOUNDA	DIALACOTO	Madina Fouga	-12,950275	13,329784	485
218	TAMBACOUN	TAMBACOUNDA	DIALACOTO	Massadala	-13,016469	13,283636	369
219	TAMBACOUN	TAMBACOUNDA	DIALACOTO	Gamon	-12,915992	13,344833	259
220	TAMBACOUN	TAMBACOUNDA	Dialocoto	Diakhaba Peulh	-13,076237	13,332226	146
221	TAMBACOUN	TAMBACOUNDA	DIALACOTO	Bantakountou	-13,067900	13,258009	551
222	TAMBACOUN	TAMBACOUNDA	DIALOCOTO	Ainoumany	-13,034592	13,277739	338
223	TAMBACOUN	TAMBACOUNDA	DIALOCOTO	Sitaouma	-13,007164	13,347265	203
224	KEDOUGOU	KEDOUGOU	Dimboli	Bowal	-17,960371	12,499474	267
225	KEDOUGOU	KEDOUGOU	Dimboli	DIANKERY	-12,113542	12,461587	321
226	KEDOUGOU	KEDOUGOU	Dimboli	Maleme	-17,909806	12,470008	191
227	KEDOUGOU	KEDOUGOU	Dimboli	Malinda	-17,956381	12,477514	423
228	KEDOUGOU	KEDOUGOU	Dimboli	Roundé Barra	-12,054535	12,443651	366
229	KEDOUGOU	KEDOUGOU	Bandafassi	Samal	-12,513561	12,677860	432
230	KEDOUGOU	KEDOUGOU	Dimboli	Barra	-12,210107	12,426538	162
231	KEDOUGOU	KEDOUGOU	Dimboli	KAFORY	-17,939820	12,475247	588
232	KEDOUGOU	KEDOUGOU	Dimboli	Magnafe	-17,869410	12,462564	213
233	KEDOUGOU	KEDOUGOU	NINEFACHA	Assoni	-12,504151	12,612090	657
234	KEDOUGOU	KEDOUGOU	NINEFACHA	Baraboy	-12,412568	12,687648	38
235	KEDOUGOU	KEDOUGOU	NINEFACHA	Baya	-12,467339	12,464976	307
236	KEDOUGOU	KEDOUGOU	NINEFACHA	Lakanta Soukouta	-12,467356	12,749682	360

237	KEDOUGOU	KEDOUGOU	NINEFACHA	Manda Thies	-12,482576	12,719241	351
238	KEDOUGOU	KEDOUGOU	NINEFACHA	Wourydje	-12,415087	12,448732	405
239	KEDOUGOU	KEDOUGOU	Tomboronkoto	Bagnomba	-12,364150	12,717168	425
240	KEDOUGOU	KEDOUGOU	Tomboronkoto	Magnankanti	-12,420496	12,818837	483
241	KEDOUGOU	KEDOUGOU	NINEFACHA	Khourou ngoto	-12,489018	12,709887	265
242	KEDOUGOU	KEDOUGOU	NINEFACHA	Thiamalele	-12,459526	12,642851	365
243	KEDOUGOU	KEDOUGOU	Tomboronkoto	Kanamere	-12,178624	12,881323	491
244	KOLDA	VELINGARA	MEDINA GOUNASS	AINEMADY	-13,671088	13,137235	615
245	KOLDA	VELINGARA	NEMATABA	BADIARA CAMPEMENT	-14,170779	13,219196	306
246	KOLDA	VELINGARA	NEMATABA	BAGAYOGO	-14,139932	13,220332	505
247	KOLDA	VELINGARA	PAROUMBA	BODORA	-13,782825	12,739828	440
248	KOLDA	VELINGARA	BONKONTO	DAROU SALAM MAMADOU	-13,960541	12,916105	513
249	KOLDA	VELINGARA	MEDINA GOUNASS	DEMBACOUNDA	-13,729125	13,071201	288
250	KOLDA	VELINGARA	MEDINA GOUNASS	FASS	-13,675950	13,260582	670
251	KOLDA	VELINGARA	BONKONTO	HAMDALAYE BARKA	-13,929502	13,097960	281
252	KOLDA	VELINGARA	PAROUMBA	KAOLACK SECKOU	-13,761763	12,775482	196
253	KOLDA	VELINGARA	NEMATABA	KOULANDIALA	-14,082796	13,235849	555
254	KOLDA	VELINGARA	KANDIAYE	MAREWE ABDOU I ET II	-13,938755	12,948162	220
255	KOLDA	VELINGARA	KANDIAYE	MAYAL ROUNDE	-13,935726	12,958132	259
256	KOLDA	VELINGARA	PAROUMBA	MEDINA BOBO	-13,755964	12,751973	528
257	KOLDA	VELINGARA	MEDINA GOUNASS	MEDINA DIAM	-13,722634	13,060220	670
258	KOLDA	VELINGARA	BONKONTO	NETERE PAKANE	-13,927102	12,963658	186
259	KOLDA	VELINGARA	MEDINA GOUNASS	PASSOUNGOU	-13,679848	13,096324	271
260	KOLDA	VELINGARA	KANDIAYE	THIANCOLY (SARE SADIO)	-14,149515	12,830169	323
261	KOLDA	VELINGARA	KANDIAYE	THIOMOLOCK DIAM ET SARE YER(	-13,939911	13,116232	522

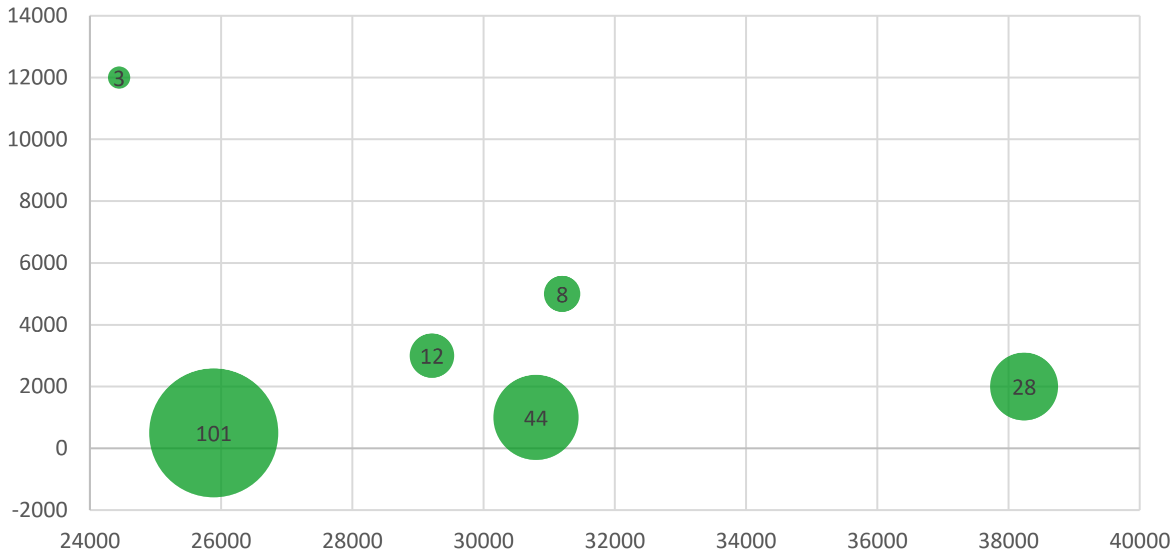
262	KOLDA	VELINGARA	KANDIAYE	THIOMOLOCK TOMBO	-13,961051	13,121083	470
263	KOLDA	KOLDA	DIALAMBERE	FODE BAYO ET BANTANKILING WA	-14,434915	12,974425	430
264	KOLDA	KOLDA	BAGADADJI	KADIAL ET MAOUNDE DIOUMA	-14,687526	12,776266	276
265	KOLDA	KOLDA	MAMPATIM	SARE DEMBAYEL	-14,346785	12,802347	910
266	KOLDA	KOLDA	MAMPATIM	SERE NDIOBO	-14,348154	12,789283	334
267	KOLDA	KOLDA	DIALAMBERE	SINTHIANG COURTIBE & SINTHIAN	-14,589144	12,966232	306
268	KOLDA	KOLDA	BAGADADJI	SINTHIANG DEMBAROU	-14,650037	12,770694	492
269	KOLDA	KOLDA	BAGADADJI	SINTHIANG IBRAHIMA NIMA & SIN	-14,673570	12,782218	388
270	KOLDA	KOLDA	BAGADADJI	SINTHIANG SIRING ET SINTHIANG	-14,622438	12,922992	204
271	KOLDA	KOLDA	MAMPATIM	WAKILARE TOBO	-14,308777	12,769343	591
272	KOLDA	MEDINA YORO FOULA	BIGNARABE	DAYBATOU BACOR	-14,739139	12,980162	325
273	KOLDA	MEDINA YORO FOULA	BIGNARABE	GALLOUYELE DEMBE	-14,732441	12,992436	603
274	KOLDA	MEDINA YORO FOULA	FAFACOUROU	MEDINATOUL SALAM	-14,646356	13,075722	552
275	KOLDA	MEDINA YORO FOULA	BADION	NEMATABA TENING	-14,352996	13,148021	232
276	KOLDA	MEDINA YORO FOULA	BADION	PIAYE BOURE	-14,393507	13,152650	879
277	KOLDA	MEDINA YORO FOULA	BADION	SARE DEMBA SOW	-14,361677	13,159039	209
278	KOLDA	MEDINA YORO FOULA	KEREWANE	SARE MAMADOU ANNA ET SINTHI	-15,010995	13,480533	929
279	KOLDA	MEDINA YORO FOULA	KEREWANE	SARE SAMETA	-15,022379	13,489014	329
280	KOLDA	MEDINA YORO FOULA	FAFACOUROU	SINTHIANG DIADIE	-14,537954	13,150835	470
281	KOLDA	MEDINA YORO FOULA	BIGNARABE	SOSSOUTOU	-14,928902	13,003028	630
282	TAMBACOUN	BAKEL	BELE	WALIDIALA	-12,448536	15,317347	274
283	TAMBACOUN	GOUDIRY	BOUTOUCOUFARA	SINTHIOU SALIF	-12,498559	13,408550	439
284	TAMBACOUN	GOUDIRY	BOYNGUEL BAMBA	BOGAL	-12,572271	14,188623	1021
285	TAMBACOUN	GOUDIRY	GOUMBAYEL	BOFOULOU	-13,344652	13,494739	156
286	TAMBACOUN	GOUDIRY	KOULOR	SIBOR	-13,360709	14,059223	621
287	TAMBACOUN	GOUDIRY	KOUSSAN	THIECKE	-12,651073	14,113317	280

288	TAMBACOUN	GOUDIRY	SINTHIOU MAMADOU BO	SIWABE	-12,791363	14,442503	553
289	TAMBACOUN	GOUDIRY	SINTHIOU MAMADOU BO	SOWOL	-12,780251	14,465288	578
290	TAMBACOUN	KOUMPETOUM	KOUTHIABA WOLOF	BOUSTANE	-14,581728	14,267679	662
291	TAMBACOUN	KOUMPETOUM	PASS KOTO	BARINABE	-14,229942	13,826720	389
292	TAMBACOUN	KOUMPETOUM	PASS KOTO	BOULIMANGA PEULH	-14,252842	14,068188	301
293	TAMBACOUN	KOUMPETOUM	PAYAR	BELEL DIAMAL PEULH	-14,480261	14,501445	159
294	TAMBACOUN	KOUMPETOUM	PAYAR	DAROU MINAME	-14,552270	14,489657	884
295	TAMBACOUN	TAMBACOUNDA	DIALOCOTO	BANTACOLY	-13,186192	13,337736	271
296	TAMBACOUN	TAMBACOUNDA	DIALOCOTO	BANY PELLY SISAO	-14,013115	13,689332	271
297	TAMBACOUN	KOUMPETOUM	PAYAR	LOUMBY TRAVAUX	-14,438948	14,493546	613
298	TAMBACOUN	KOUMPETOUM	PAYAR	DAROU RAHMANE PETEL OUOLO	-14,438948	14,493546	314
299	TAMBACOUN	TAMBACOUNDA	DIALAKOTO	TENGUETO	-13,214084	13,364248	358
300	TAMBACOUN	TAMBACOUNDA	KOUSSANAR	MBOULE (DIMBO)	-13,904468	13,996481	924
301	TAMBACOUN	TAMBACOUNDA	NDOGA BABACAR	SARE THILEL	-13,449132	13,599747	438
302	TAMBACOUN	TAMBACOUNDA	NODOGA BABACAR	GOUBOU COUNDA (SARE BONDJI)	-13,892392	13,630920	528
303	TAMBACOUN	TAMBACOUNDA	NODOGA BABACAR	NGOLEL MANDING (BOUNTOUNK	-14,095109	13,784369	835
304	TAMBACOUN	TAMBACOUNDA	NODOGA BABACAR	SINTHIOU SAMBA DIOULKA	-14,058028	13,728098	514
305	TAMBACOUN	TAMBACOUNDA	NETEBOULOU	SARE NIAMA I	-13,851721	13,613403	460
306	KEDOUGOU	KEDOUGOU	BANDAFASSI	NIANGUE	-12,320526	12,607627	314
307	KEDOUGOU	KEDOUGOU	TOMBORONKOTO	MANIANKANTY	-12,420514	12,818828	528
308	KEDOUGOU	SALEMATA	Dare Salam	INGUATHITIQUE	-12,840079	12,717671	186
309	KEDOUGOU	SALEMATA	Dare Salam	THIANGUETO LEYBAR	-12,857553	12,686569	329
310	KEDOUGOU	SARAYA	BEMBOU	BARABIRY	-17,739577	12,963011	644
311	KEDOUGOU	SARAYA	KHOSSANTO	BEROLA ET MEDINA BEROLA	-17,929331	13,198966	644
312	KEDOUGOU	SARAYA	SABADOLA	DIALOKOTOBA	-12,877612	12,629374	603
313	KEDOUGOU	KEDOUGOU	NINEFECHA	Village De DONGOL NIALBY	-12,497451	12,502105	328

314	KEDOUGOU	KEDOUGOU	NINEFECHA	MATAKOUSSI	-12,517675	12,524883	515
315	KEDOUGOU	KEDOUGOU	NINEFECHA	NAMEL1	-12,464502	12,553120	159
316	KEDOUGOU	KEDOUGOU	NINEFECHA	NAMEL 2	-12,463293	12,562054	164
317	KEDOUGOU	KEDOUGOU	NINEFECHA	WOUNTGOURE	-12,446047	12,442322	277
318	KEDOUGOU	SALEMATA	DAR SALAM	BAKOUAKA (Missirah)	-12,803929	12,543281	277
319	KEDOUGOU	SALEMATA	ETHIOLO	EBARACK	-12,877612	12,629374	324
320	KEDOUGOU	SALEMATA	ETHIOLO	MBONG PEULH	-12,894103	12,563960	398
321	LOUGA	KEBEMER	THIEPPE	RONY NDEUG 1	-16,693946	15,498345	362
322	LOUGA	KEBEMER	THIEPPE	LOUGY THIOMBE	-16,588609	15,643879	138
323	LOUGA	KEBEMER	THIEPPE	YODI SAYORO	-16,632580	15,579637	308
324	LOUGA	LUINGUERE	BARKEDJI	BOURACK	-14,993947	15,250259	274
325	LOUGA	LUINGUERE	BARKEDJI	GASSEL OUROBE	-14,667086	15,189587	411
326	LOUGA	LUINGUERE	BARKEDJI	LOUMBY KOYLE	-14,929277	15,236849	230
327	LOUGA	LUINGUERE	KAMB	NAWEL OUROBE	-15,594471	15,596066	368
328	LOUGA	LUINGUERE	TESSEKERE FORAGE	LOUMBI YORO 1	-15,052433	15,929874	209
329	LOUGA	LUINGUERE	TESSEKERE FORAGE	LOUMBI YORO 2	-15,027021	15,938784	267

Appendix III: Benin

Population distribution by size of village and by number of villages in Benin



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Provided Sites Locations for Benin

N°	TYPE	DEPARTEMENT	COMMUNE	ARRONDISSEMENT	NOM DE L'UNITE ADMINISTRATIVE	DISTANCE PAR RAPPORT AU RESEAU MOYENNE TENSION	EFFECTIF DE LA POPULATION EN 2020	Latitude	Longitude
1	URBAIN	ALIBORI	BANIKOARA	BANIKOARA	KORI-GUIGUIRI	10_15 km	1723	2,4143	11,4264
2	RURAL	ALIBORI	BANIKOARA	FOUNOUGO	GAMMERE-ZONGO	10_15 km	1963	2,5813	11,5598
3	RURAL	ALIBORI	BANIKOARA	FOUNOUGO	KANDERO-KOTCHERA	15_20 km	3972	2,5401	11,6459
4	RURAL	ALIBORI	BANIKOARA	FOUNOUGO	KANDEROU-YABADOU	10_25 km	14677	2,5388	11,6597
5	RURAL	ALIBORI	BANIKOARA	FOUNOUGO	SAMPETO	20_20 km	10642	2,442	11,6165
6	RURAL	ALIBORI	BANIKOARA	FOUNOUGO	YANGUERI	10_15 km	4159	2,6615	11,4783
7	RURAL	ALIBORI	BANIKOARA	FOUNOUGO	YINGNIMPOGOU	10_15 km	3318	2,4617	11,5387
8	RURAL	ALIBORI	BANIKOARA	GOMPAROU	GNAMBANOU	10_15 km	7839	2,4107	11,5157
9	RURAL	ALIBORI	BANIKOARA	GOMPAROU	SIONKPEKOKA	10_15 km	2016	2,4195	11,4765
10	RURAL	ALIBORI	BANIKOARA	GOMPAROU	TIGANSON	10_15 km	2462	2,6089	11,2657
11	RURAL	ALIBORI	BANIKOARA	GOUMORI	BONTE	10_15 km	6318	2,1778	11,2189
12	RURAL	ALIBORI	BANIKOARA	GOUMORI	SAKASSINNOU	15_20 km	2567	2,3968	11,0673
13	RURAL	ALIBORI	BANIKOARA	KOKEY	SONWARI	20_25 km	9155	2,7525	11,4042
14	RURAL	ALIBORI	BANIKOARA	KOKEY	YAMBEROU	10_15 km	5079	2,6189	11,4183
15	RURAL	ALIBORI	BANIKOARA	OUNET	BONIKI	15_20 km	3924	2,4492	11,0984
16	RURAL	ALIBORI	BANIKOARA	OUNET	KIHOUHOU	15_20 km	3948	2,3756	11,0415
17	RURAL	ALIBORI	BANIKOARA	OUNET	KPEBOROGOU	15_20 km	4649	2,4803	11,1313
18	RURAL	ALIBORI	BANIKOARA	SOMPEREKOU	BOURIN	10_15 km	4171	2,561	11,2277
19	RURAL	ALIBORI	BANIKOARA	SOMPEREKOU	BOUYANGOU	10_20 km	3826	2,6783	11,2947
20	RURAL	ALIBORI	BANIKOARA	SOROKO	MEKROU	15_20 km	10554	2,2055	11,3594
21	RURAL	ALIBORI	GOGOUNOU	BAGOU	GARAGORO	10_15 km	3472	2,5896	10,7184

...g from the European Union's Horizon 2020
...m under Grant Agreement 963530.

22	RURAL	ALIBORI	GOGOUNOU	GOUNAROU	DAGOUROU	15_20 km	6772	3,0195	10,8885
23	RURAL	ALIBORI	GOGOUNOU	GOUNAROU	LAFIAROU	10_15 km	1746	2,968	10,8505
24	RURAL	ALIBORI	GOGOUNOU	WARA	KALE	10_15 km	3280	2,5621	10,6718
25	RURAL	ALIBORI	KANDI	DONWARI	DININ	10_15 km	8387	2,8051	11,2214
26	RURAL	ALIBORI	KANDI	SAM	BIKONGOU	10_15 km	1316	2,7647	10,9409
27	RURAL	ALIBORI	KANDI	SAM	GBINDAROU	10_15 km	1237	2,7248	10,9902
28	RURAL	ALIBORI	KANDI	SAM	TANKONGOU-DAGOUROU	10_15 km	613	2,7461	10,9344
29	RURAL	ALIBORI	KANDI	SAM	TERI	10_15 km	3860	2,6936	11,001
30	RURAL	ALIBORI	KANDI	SONSORO	ALIBORI-YANKIN	15_20 km	6804	2,6678	11,2373
31	RURAL	ALIBORI	KARIMAMA	BOGO-BOGO	KOFOUNON	10_15 km	12774	3,0827	12,0067
32	RURAL	ALIBORI	KARIMAMA	MONSEY	BAKO-MAKA	25_30 km	3328	2,8289	12,3824
33	RURAL	ALIBORI	KARIMAMA	MONSEY	BONGNAMI	15_20 km	20811	2,8565	12,258
34	RURAL	ALIBORI	KARIMAMA	MONSEY	FANDOGA	25_30 km	840	2,8488	12,3516
35	RURAL	ALIBORI	KARIMAMA	MONSEY	GOUMBITCHIGOURA	15_20 km	859	2,9002	12,3218
36	RURAL	ALIBORI	KARIMAMA	MONSEY	LOUMBOU-LOUMBOU	10_15 km	4237	2,9028	12,2457
37	RURAL	ALIBORI	KARIMAMA	MONSEY	MACHAYAN-MARCHE	10_15 km	579	2,9453	12,2907
38	RURAL	ALIBORI	MALANVILLE	GAROU	GAABO	10_15 km	3786	3,4323	11,6815
39	RURAL	ALIBORI	MALANVILLE	GUENE	MONKOLLE	10_15 km	9504	3,1726	11,4306
40	RURAL	ALIBORI	MALANVILLE	MADECALI	GODJEKOARA	30 km +	6242	3,4755	11,4434
41	RURAL	ALIBORI	MALANVILLE	MADECALI	KOUARA-TEDJI	10_15 km	522	3,4996	11,6035
42	RURAL	ALIBORI	MALANVILLE	MADECALI	MELAYAKOUARA	15_20 km	3699	3,4784	11,5761
43	RURAL	ALIBORI	SEGBANA	LIBANTE	GOUNGBE	10_15 km	2913	3,6999	10,6741
44	RURAL	ALIBORI	SEGBANA	LIBOUSSOU	TOUNGA-ISSA	25_30 km	3199	3,5496	11,1867
45	RURAL	ALIBORI	SEGBANA	LOUGOU	GANDOLOUKASSA	20_25 km	3703	3,4119	11,1547
46	RURAL	ALIBORI	SEGBANA	LOUGOU	GBEKAKAROU	10_15 km	2118	3,3998	11,0746
47	RURAL	ALIBORI	SEGBANA	LOUGOU	GUENELAGA	30 km +	4614	3,4505	11,2405

48	RURAL	ALIBORI	SEGBANA	LOUGOU	KAMANAN	31 km +	2419	3,4958	11,264
49	RURAL	ALIBORI	SEGBANA	SOKOTINDJI	MOROU	20_25 km	12429	3,3203	10,6385
50	RURAL	ATACORA	BOUKOMBE	DIPOLI	DISSAPOLI	10_15 km	577	0,8601	10,3147
51	RURAL	ATACORA	BOUKOMBE	DIPOLI	KPERINKPE	10_15 km	1269	0,8838	10,3498
52	RURAL	ATACORA	BOUKOMBE	KOUSSOUCOINGOU	TIPAOTI	10_15 km	2316	1,2842	10,1319
53	RURAL	ATACORA	COBLY	DATORI	TCHAMONGA	10_15 km	1430	0,7961	10,552
54	RURAL	ATACORA	COBLY	KOUNTORI	OROUKOUARE	10_15 km	962	0,9948	10,3796
55	RURAL	ATACORA	COBLY	KOUNTORI	OUKPINTIHOUN	10_15 km	970	0,997	10,3646
56	RURAL	ATACORA	COBLY	KOUNTORI	SERHOUNGUE	10_15 km	2150	0,8975	10,3633
57	RURAL	ATACORA	COBLY	TAPOGA	GNANGOU	10_15 km	2682	0,8807	10,5829
58	RURAL	ATACORA	COBLY	TAPOGA	KOLGOU	10_15 km	920	0,8065	10,5877
59	RURAL	ATACORA	KEROU	BRIGNAMARO	BAGOUBAGOU	10_15 km	2716	1,9673	10,6993
60	RURAL	ATACORA	KEROU	FIROU	YIROUBARA	20_25 km	1642	1,8965	10,8347
61	RURAL	ATACORA	KEROU	KOABAGOU	GNAMPOLI	30 km +	6937	1,9224	11,0694
62	RURAL	ATACORA	KEROU	KOABAGOU	YINSIGA	30 km +	1410	1,9222	11,0678
63	URBAIN	ATACORA	KEROU	KEROU	KEDAROU	10_15 km	5979	2,2016	10,7624
64	URBAIN	ATACORA	KEROU	KEROU	MANOU	10_15 km	8118	2,3308	10,9411
65	RURAL	ATACORA	KOUANDE	BIRNI	GORGOBA	10_15 km	1621	1,5849	10,1142
66	RURAL	ATACORA	KOUANDE	GUILMARO	BORO	15_20 km	2080	1,8368	10,7129
67	RURAL	ATACORA	KOUANDE	GUILMARO	SERI	20_25 km	4333	1,6893	10,7734
68	RURAL	ATACORA	KOUANDE	GUILMARO	KEDEKOU	20_25 km			
69	RURAL	ATACORA	KOUANDE	GUILMARO	FOO-MAMA	25_30 km	3001	1,8362	10,8334
70	RURAL	ATACORA	KOUANDE	GUILMARO	GOUTERE	10_15 km	3242	1,8296	10,6035
71	RURAL	ATACORA	KOUANDE	GUILMARO	KPIKIRE KOKA	15_20 km	1321	1,8528	10,6556
72	RURAL	ATACORA	KOUANDE	OROUKAYO	KPANKPANKOU	10_15 km	3057	1,6895	10,1508
73	RURAL	ATACORA	KOUANDE	OROUKAYO	OROUGBENI	10_15 km	1356	1,6018	10,1472
74	RURAL	ATACORA	MATERI	TANTEGA	TAMPANGA	10_15 km	1935	0,9002	10,8903

75	RURAL	ATACORA	NATITINGOU	TCHOUMI-TCHOUMI	KOUTIE TCHATIDO	10_15 km	2621	1,3061	10,0735
76	RURAL	ATACORA	NATITINGOU	KOTOPOUNGA	KAMPOUYA	10_15 km	1177	1,5968	10,4102
77	RURAL	ATACORA	OUASSA-PEHUNCO	TOBRE	GAMBINOU	10_15 km	4875	2,1294	10,3673
78	RURAL	ATACORA	OUASSA-PEHUNCO	TOBRE	NINGOUSSOUROU	10_15 km	2150	2,1715	10,3129
79	RURAL	ATACORA	TANGUIETA	COTIAKOU	DAGUIMAGNINNI	10_15 km	5037	1,4762	10,6619
80	RURAL	ATACORA	TANGUIETA	COTIAKOU	PEMOMBOU	10_15 km	3549	1,43	10,5916
81	RURAL	ATACORA	TANGUIETA	TAIACOU	KOUTCHOUNTCHOUNG OU	10_15 km	2665	1,1975	10,4309
82	RURAL	ATACORA	TOUKOUNTOUN A	KOUARFA	BOUYAGNINDI	15_20 km	3958	1,5779	10,6115
83	RURAL	ATACORA	TOUKOUNTOUN A	TAMPEGRE	TCHANHORTA	10_15 km	1551	1,2326	10,4565
84	RURAL	ATACORA	TOUKOUNTOUN A	TOUKOUNTOUNA	FATIYA	15_20 km	1795	1,4689	10,6194
85	RURAL	BORGOU	BEMBEREKE	BEROUBOUAY	BOURATEBE	15_20 km	2970	2,5866	10,4857
86	RURAL	BORGOU	BEMBEREKE	BEROUBOUAY	SOMBOUAN-PARIS	10_15 km	3096	2,6099	10,5289
87	RURAL	BORGOU	BEMBEREKE	BOUANRI	BORO	20_25 km	5321	1,8368	10,7129
88	RURAL	BORGOU	BEMBEREKE	BOUANRI	GANDO-BOROU	10_15 km	2842	2,8444	10,1996
89	RURAL	BORGOU	BEMBEREKE	BOUANRI	GBEROU-DABA	10_15 km	4308	2,9351	10,2283
90	RURAL	BORGOU	BEMBEREKE	BOUANRI	GUERA-NKALI-TASSI	15_20 km	2965	2,893	10,2786
91	RURAL	BORGOU	BEMBEREKE	BOUANRI	KASSAROU	10_15 km	707	2,8805	10,2162
92	RURAL	BORGOU	BEMBEREKE	BOUANRI	KASSAROU GNEL BABI	10_15 km	833	2,9186	10,2233
93	RURAL	BORGOU	BEMBEREKE	BOUANRI	SISSIGOUROU	10_15 km	2078	2,8688	10,2374
94	RURAL	BORGOU	BEMBEREKE	GAMIA	DANTCHA	10_15 km	2012	2,6185	10,4478
95	RURAL	BORGOU	BEMBEREKE	GAMIA	TIMBOURE	10_15 km	4580	2,577	10,4252
96	RURAL	BORGOU	KALALE	BASSO	BANAGBASSON	15_20 km	5498	3,5819	10,6199
97	RURAL	BORGOU	KALALE	DUNKASSA	BATIN	20_25 km	5999	2,974	10,4477
98	URBAIN	BORGOU	KALALE	KALALE	SEGBANA	10_15 km	7490	3,5547	10,5297
99	URBAIN	BORGOU	KALALE	KALALE	WOBADJE	10_15 km	10811	3,4803	10,2595

100	RURAL	BORGOU	KALALE	PEONGA	KORODJI	10_15 km	9146	3,2073	10,4469
101	RURAL	BORGOU	N'DALI	BORI	ANGARADEBOU	30 km +	4703	3,2414	10,2796
102	RURAL	BORGOU	N'DALI	BORI	BIO-SIKA	30 km +	4851	2,1522	9,7706
103	RURAL	BORGOU	N'DALI	GBEGOUROU	SINAWOURAROU	10_15 km	2310	2,8041	9,5578
104	RURAL	BORGOU	N'DALI	SIRAROU	GANDOU-NOMBA	10_15 km	3699	2,5233	9,519
105	RURAL	BORGOU	NIKKI	TASSO	CHEIN-TASSO	10_15 km	1889	3,245	9,7674
106	URBAIN	BORGOU	NIKKI	NIKKI	BAROUGOUROUSSI	10_15 km	851	3,3593	10,0573
107	URBAIN	BORGOU	NIKKI	NIKKI	BELLE	15_20 km	7688	3,4274	10,1164
108	URBAIN	BORGOU	NIKKI	NIKKI	BOO	10_15 km	1191	3,4061	9,9799
109	URBAIN	BORGOU	NIKKI	NIKKI	GOURE-GBATA	10_15 km	1596	3,377	10,0754
110	RURAL	BORGOU	NIKKI	OUENOU	GNEL KIRADJE	10_15 km	2797	3,4587	9,8872
111	RURAL	BORGOU	NIKKI	OUENOU	GNELSANDA	10_15 km	1273	3,4462	9,9445
112	RURAL	BORGOU	NIKKI	OUENOU	GOSSODJI-GOURE-BAABA	20_25 km	6098	3,5425	9,9427
113	RURAL	BORGOU	NIKKI	OUENOU	GOURE-BAABA	15_20 km	1628	3,4387	9,9856
114	RURAL	BORGOU	NIKKI	SEREKALE	MOUSSOURE	10_15 km	2214	3,0459	10,0537
115	RURAL	BORGOU	NIKKI	SEREKALE	YAO-GOUROU	10_15 km	1655	3,0328	10,0422
116	RURAL	BORGOU	NIKKI	TASSO	FO-DAROU	15_20 km	1140	3,2463	9,6957
117	RURAL	BORGOU	NIKKI	TASSO	GAH-GBEROU	15_20 km	3553	3,2743	9,7119
118	RURAL	BORGOU	NIKKI	TASSO	TANAKPE	15_20 km	1572	3,2309	9,7166
119	RURAL	BORGOU	PERERE	GNINSY	ASSAGNAHOUN	10_15 km	1495	3,1727	9,5631
120	RURAL	BORGOU	PERERE	GNINSY	DIGUIDIROU	10_15 km			
121	RURAL	BORGOU	PERERE	GNINSY	KOUKOUMBOU	10_15 km	1419	3,0463	9,5014
122	RURAL	BORGOU	PERERE	GNINSY	SANEKOU	15_20 km	4284	3,067	9,4582
123	RURAL	BORGOU	PERERE	GNINSY	SOMBIRIKPEROU	15_20 km	2043	3,225	9,6328
124	RURAL	BORGOU	PERERE	GUINAGOUROU	BANIGOUROU	15_20 km	2131	2,9309	11,1208
		BORGOU	PERERE	GUINAGOUROU	BOUGNANKOU	10_15 km			
125	RURAL	BORGOU	PERERE	GUINAGOUROU	GBANDE	10_15 km	1712	2,8425	9,4134

		BORGOU	PERERE	GUINAGOUROU	GOUNKPARE	10_15 km			
126	RURAL	BORGOU	PERERE	GUINAGOUROU	NANIN	10_15 km	1536	2,8709	9,4597
127	RURAL	BORGOU	PERERE	GUINAGOUROU	OGAMOIN	15_20 km	2970	3,0204	9,4157
128	URBAIN	BORGOU	SINENDE	SINENDE	GUESSOU-BANI-PEULH	10_15 km	2469	2,279	10,3048
129	RURAL	BORGOU	TCHAOUROU	KIKA	BONWOUBEROU	15_20 km	2158	2,9542	9,2437
130	RURAL	BORGOU	TCHAOUROU	KIKA	BOUAY	10_15 km	3140	2,7321	10,391
131	RURAL	BORGOU	TCHAOUROU	KIKA	CAMP-ZATO	25_30 km	2305	3,0255	9,2978
132	RURAL	BORGOU	TCHAOUROU	KIKA	GOUROUBARA	25_30 km	1751	3,0064	9,2055
133	RURAL	BORGOU	TCHAOUROU	KIKA	KPEWONKOU	20_25 km	2198	2,8226	9,0962
134	RURAL	BORGOU	TCHAOUROU	KIKA	NANNONROU	20_25 km	1391	2,9913	9,3259
135	RURAL	BORGOU	TCHAOUROU	KIKA	SONNA	20_25 km	1315	2,9756	9,2903
136	RURAL	BORGOU	TCHAOUROU	KIKA	TANGUE	30 km +	1553	3,0996	9,1932
137	RURAL	BORGOU	TCHAOUROU	KIKA	TOUROU-SOUANRE	20_25 km	851	3,0014	9,2535
138	RURAL	BORGOU	TCHAOUROU	KIKA	WARANKPEROU	25_30 km	2968	2,9876	9,1388
139	URBAIN	BORGOU	TCHAOUROU	TCHAOUROU	KPATAKO	10_15 km	1364	2,7311	8,7631
140	URBAIN	BORGOU	TCHAOUROU	TCHAOUROU	YAMBOUAN	10_15 km	1546	2,7837	8,9714
141	RURAL	BORGOU	TCHAOUROU	TCHAOUROU	GBEKPANIN	10_15 km	2769	2,6601	9,0825
142	RURAL	COLLINES	BANTE	BOBE	FOMON	15_20 km	6187	2,1587	8,4959
143	RURAL	COLLINES	BANTE	BOBE	SOULA	10_15 km	2509	2,0888	8,4404
144	RURAL	COLLINES	BANTE	GOUKA	KAMALA-IDJOU	10_15 km	1346	1,8111	8,1094
145	RURAL	COLLINES	BANTE	LOUGBA	GOTCHA	15_20 km	3157	1,7393	8,2719
146	RURAL	COLLINES	DASSA-ZOUME	KPINGNI	ZOUGOUDO	20_25 km	3700	2,0617	7,5713
147	URBAIN	COLLINES	DASSA-ZOUME	PAOUINGNAN	AGBOGBOME	15_20 km	1741	2,469	7,5859
148	URBAIN	COLLINES	DASSA-ZOUME	PAOUINGNAN	ZOTEDJI	15_20 km	2005	2,2418	7,5306
149	RURAL	COLLINES	GLAZOUE	OUEDEME	ATEGUEDJI	10_15 km	1318	2,1217	8,1167
150	RURAL	COLLINES	OUESSE	GBALIN	AZRAOU	15_20 km	3973	2,2289	8,6753
151	RURAL	COLLINES	OUESSE	KILIBO	OLOUNI-NGBE	10_15 km	1811	2,7545	8,5068

152	RURAL	COLLINES	OUESSE	KILIBO	OWOLAFE	15_20 km	1850	2,733	8,6557
153	RURAL	COLLINES	OUESSE	LAMINOU	WODJI	10_15 km	6009	2,3509	8,3804
154	RURAL	COLLINES	OUESSE	ODOUGBA	N'GBEHOUEDO-ROUTO	10_15 km	5735	2,4303	8,5922
155	RURAL	COLLINES	SAVALOU	DJALOUKOU	GBAGLODJI	15_20 km	1626	1,9006	7,6722
156	RURAL	COLLINES	SAVALOU	DJALOUKOU	MONFIO	10_15 km	1286	1,7323	7,7323
157	RURAL	COLLINES	SAVALOU	DOUME	BEBIANI	10_15 km	1922	1,7619	7,9712
158	RURAL	COLLINES	SAVALOU	DOUME	IDJOU	10_15 km	1067	2,6859	7,3692
159	RURAL	COLLINES	SAVALOU	GOBADA	ABIADJI-SOGOUDO	10_15 km	2186	1,9782	7,6728
160	RURAL	COLLINES	SAVALOU	GOBADA	ZANKPE-HOUESSINHOUE	10_15 km	3082	2,0222	7,6386
161	RURAL	COLLINES	SAVALOU	OTTOLA	ALLE	10_15 km	1937	1,791	8,1572
162	RURAL	COLLINES	SAVE	OKPARA	SANDEHOU	10_15 km	1691	2,7152	8,1133
163	RURAL	COUFFO	APLAHOUE	ATOMEY	AGBOTAVOU	10_15 km	3827	1,6504	7,2863
164	RURAL	COUFFO	APLAHOUE	ATOMEY	COUFFOKPA	15_20 km	4697	1,7692	7,278
165	RURAL	COUFFO	APLAHOUE	ATOMEY	DOUSSO	10_15 km	2671	1,6595	7,4346
166	RURAL	COUFFO	APLAHOUE	ATOMEY	LANHOUETOMEY	10_15 km	3397	1,7237	7,3586
167	RURAL	COUFFO	APLAHOUE	GODOHOU	KOGBETOHOUE	10_15 km	2722	1,8217	7,024
168	URBAIN	DONGA	BASSILA	BASSILA	ADJIMON	20_25 km	2733	2,0274	9,1293
169	URBAIN	DONGA	BASSILA	BASSILA	APPI	10_15 km	3962	1,8226	9,0509
170	RURAL	DONGA	BASSILA	BASSILA	DOGUE	20_25 km			
171	RURAL	DONGA	BASSILA	BASSILA	IGBOMAKRO	20_25 km			
172	RURAL	DONGA	BASSILA	MANIGRI	MODOGUI	15_20 km	6172	1,8842	8,9969
173	RURAL	DONGA	BASSILA	MANIGRI	TEKE-TEROU	20_25 km	4779	2,0881	9,0808
174	URBAIN	DONGA	COPARGO	COPARGO	GALORA-YABAGA	10_15 km	2631	1,6854	9,9505
175	URBAIN	DONGA	COPARGO	COPARGO	SATIEKA-GBAMDI	10_15 km	1390	1,644	9,8815
176	URBAIN	DONGA	COPARGO	COPARGO	TCHAKLERO-YARAOU	10_15 km	2227	1,6503	9,9012
177	RURAL	DONGA	COPARGO	ANANDANA	KOUBENEBENE	10_15 km	939	1,3806	9,8966
178	RURAL	DONGA	COPARGO	ANANDANA	N'DAM	10_15 km	1157	1,3694	9,9085

179	URBAIN	DONGA	COPARGO	COPARGO	DJESSOUKOU	10_15 km	1041	1,6509	9,9963
180	URBAIN	DONGA	COPARGO	COPARGO	GOSSINA	10_15 km	4496	1,7981	10,0041
181	URBAIN	DONGA	COPARGO	COPARGO	YAOURA	10_15 km	2646	1,7294	10,0147
182	RURAL	DONGA	DJOUGOU	BARIENOU	BORTOKO	15_20 km	2346	1,9007	9,799
183	RURAL	DONGA	DJOUGOU	BARIENOU	DONGA	15_20 km			
184	RURAL	DONGA	DJOUGOU	BARIENOU	FOYO	15_20 km			
185	RURAL	DONGA	DJOUGOU	BARIENOU	GAOUNGA	20_25 km			
186	RURAL	DONGA	DJOUGOU	BARIENOU	TIMBA				
187	RURAL	DONGA	DJOUGOU	BARIENOU	TOKO TOKO	25_30 km			
188	RURAL	DONGA	DJOUGOU	BARIENOU	GNONRI	10_15 km	2271	1,8604	9,7622
189	RURAL	DONGA	DJOUGOU	BARIENOU	KOKOSSIKA	15_20 km	3569	1,9338	9,7651
190	RURAL	DONGA	DJOUGOU	BARIENOU	POTOKOU	25_30 km	5473	1,9906	9,7823
191	RURAL	DONGA	DJOUGOU	KOLOCONDE	BOUNGOUROU	15_20 km	8411	2,0546	10,046
192	RURAL	DONGA	DJOUGOU	KOLOCONDE	TEWAOU	10_15 km	2137	1,8832	9,8203
193	URBAIN	DONGA	OUAKE	SEMERE 1	ATCHANKPA-KOLAH	10_15 km	993	1,5068	9,5173
194	URBAIN	DONGA	OUAKE	SEMERE 1	KOUBLY	10_15 km	1307	1,5182	9,4807
195	URBAIN	DONGA	OUAKE	SEMERE 1	MAMI	10_15 km	1760	1,5127	9,5529
196	RURAL	DONGA	OUAKE	SEMERE 2	AGUE-GARBA	10_15 km	1124	1,4826	9,501
197	RURAL	DONGA	OUAKE	SEMERE 2	ITCHELLI	10_15 km	1809	1,4635	9,4714
198	RURAL	PLATEAU	KETOU	ADAKPLAME	AGONLIN-KPAHOU	10_20 km	2805	2,4814	7,5907
199	RURAL	PLATEAU	KETOU	ADAKPLAME	AGUIGADJI	10_15 km	2805	2,4323	7,4819
200	RURAL	PLATEAU	KETOU	ADAKPLAME	KOZOUNVI	10_15 km	4115	2,5088	7,5442
201	URBAIN	PLATEAU	KETOU	IDIGNY	EGBEDJE	20_25 km	3309	2,5734	7,6933
202	URBAIN	PLATEAU	KETOU	IDIGNY	IDJEDJE-GAMBIALA	25_30 km	2494	2,6156	7,7607
203	URBAIN	PLATEAU	KETOU	IDIGNY	IWESSOUN	10_15 km	1953	2,6627	7,6036
204	RURAL	PLATEAU	KETOU	OKPOMETA	OGOUNOU	10_15 km	2200	2,7187	7,3147
205	RURAL	ZOU	DJIDJA	DAN	HANAGBO	10_15 km	2395	2,0934	7,4244

206	RURAL	ZOU	DJIDJA	HOUTO	CHIE	10_15 km	939	1,6576	7,6637
207	RURAL	ZOU	DJIDJA	MONSOUROU	YAGBANOUGON	15_20 km	1905	1,8362	7,6334
208	RURAL	ZOU	DJIDJA	SETTO	MAGASSA	15_20 km	2507	2,1205	7,5017
209	RURAL	ZOU	DJIDJA	SETTO	NONTCHEDIGBE	15_20 km	2584	2,1152	7,5468
210	RURAL	ZOU	DJIDJA	SETTO	TOKEGON	10_15 km	1729	2,0923	7,444
211	RURAL	ZOU	ZAGNANADO	BANAME	AKOHAGON	20_25 km	2770	2,2324	7,4883
212	RURAL	ZOU	ZAGNANADO	BANAME	MASSAGBO	10_15 km	3756	2,3023	7,453
213	RURAL	ZOU	ZOGBODOMEY	KOUSSOUKPA	LOKOLI	10_15 km	557	2,0211	6,7749
214	RURAL	ZOU	ZOGBODOMEY	KOUSSOUKPA	TCHIHEIGON	10_15 km	1715	2,2682	7,0904