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

Energy & Climate Protection Master Plan

City of Saint-Louis

SPONSORED BY THE
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Birkenfeld, March 28, 2024

SUBJECT:	***Energy & Climate Protection Master Plan – Saint-Louis***
LOCATION:	Saint-Louis, Senegal
CATEGORY:	Knowledge Transfer and Feasibility Assessment
SYNOPSIS:	This report presents the findings of the ***"Local Sustainable Energy Networks in Senegal"*** project in the model region of ***Saint-Louis*** with the objective of developing an ***Energy and Climate Protection Master Plan (ECPMP).*** This ECPMP provides a holistic, comprehensive methodology of planning for Saint-Louis's current and future energy needs as a showcase for further regions in Senegal to duplicate. The ECPMP identifies and evaluates the city's current energy uses, consumption and actual needs. It identifies inefficiencies and provides concrete demonstration solutions to help the commune achieve greater value based on a feasible and realistic return on investment for the identified projects. In the first phase, the status quo of energy use in the city of Saint-Louis is initially quantified and subsequently the technologies and strategies required for the reduction of emissions and environmental impacts toward a Zero Emission shift are investigated through four separate demonstrations projects. The methodology deployed at large is Material Flow Assessment where different site measurements and investigations contribute to the establishment of a base data representative of the status quo for the city in Saint-Louis in all sectors relevant energy.

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The information, data and facts presented are based on up-to-date specialist knowledge as well as our many years of project experience. The preparation of the report and its contents was carried out to the best of our knowledge and belief. Nevertheless, possible errors cannot be ruled out and consequently no guarantee can be given for the correctness.

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List of Abbreviations

AD	Anaerobic Digestion
AEME	National Agency for Energy Efficiency and Management
ANER	Senegalese National Agency for Renewable Energy
ANSD	National Statistics Agency and Demography
APIX	Senegal's Investment State Agency
ASER	The Senegalese Rural Electrification Agency
Bio-CNG	Combined Heat and Power
BMN	Senegal Upgrade Office
CDM	Clean Development Mechanism
CDN	Nationally Determined Contribution
CET	Technical Landfill Center
CF	Cashflow
CH4	Methane
CHP	Combined heat and power
CNCD	National Center for Development Cooperation
CO2	Carbon Dioxide
COPERES	Business Council of Renewable Energies of Senegal
CRSE	The Electricity Sector Regulatory Commission
DM	Dry Matter also knows as Total Solids (TS)
DPEE	Department of Forecasting and Economic Studies
DSCR	Debt Service Coverage Ratio
ECOWAS	Economic Community of West African States
ECPMP	Energy and Climate Protection Master Plan
ECREEE	Center for Renewable Energies and Energy Efficiency of ECOWAS
EIB	European Investment Bank
FCFA	Franc of the French colonies in Africa
FM	Fresh Mass
GEF	Global Environment Facility
GHG	Greenhouse Gas
GHG	Greenhouse Gas
H2S	Hydrogen sulfide
HRT	Hydraulic retention time
IEA	International Energy Agency
IRR	Internal Rate of Return
Kg	kilogram
KTBL	German Association for Technology and Structures in Agriculture
kWel	Electrical power capacity, electric output power
kWhel	Unit of energy, Kilowatt hour electric energy
kWhth	Unit of energy, Kilowatt hours of heat (thermal)
kWth	Thermal power capacity, thermal output power
l	Liter
LED	Light Emitting Diode
LNG	Liquefied Natural Gas (supersaturated; composition: Methane)
LoSENS	Local Sustainable Energy networks in Senegal
LoSENS	Local Sustainable Energy Networks in Senegal
LPDSE	Energy Sector Development Policy Letter
LPG	Liquefied Petroleum Gas (Low Pressure Gas)
MOIC	Multiple on Invested Capital
MPE	The Ministry of Petroleum and Energy

MSW	Municipal Solid Waste
n	Normal cubic meter
NGOs	Non-Governmental Organizations
Nl, Nm3	Normal or cubic meter measured at standard temperature and pressure
Nm3/FM	Normal cubic meter per unit of fresh matter
oDM	Organic Dry Matter also known as Volatile Solids (VS)
OFMSW	Organic Fraction of Municipal Organic Waste
OLR	Organic Load Rate
ONAS	National Sanitation Office of Senegal
PNA	Senegal National Adaptation Plan
PNB-SN	National Biogas Program
PPP	Public Private Partnerships
PRN	Normalized Regrouping Points
PSE	Emerging Senegal Plan
PV	Photovoltaic
RE	Renewable energies
SDE	the Senegalese Waters
SENELEC	Senegal National Electricity Agency
SMEs	Small and Medium-Scale Enterprise
SMIs	Small and Medium-Scale Industries
SOGAS	Management Company of Slaughterhouses of Senegal
SONAGED	National Integrated Waste Management Company
SONES	Société Nationale des Eaux du Sénégal
SONES	National Water Company of Senegal
SP	Pumping Station
SPV	Special Purpose Vehicle
STEP	Station d'Épuration des eaux usées which means a (stabilization pond)
t	Metric tonne, equivalent to 1,000 kg
UCG	Coordination and Management Unit
UGB	Gaston Berger University
WACC	Weighted Average Cost of Capital
WW	Wastewater

1 Executive Summary

Local Sustainable Energy Networks in Senegal (LoSENS) is a project with a strategic response to the pressing global challenges of climate change and the need for sustainable energy solutions. It is supported and funded by the German Federal Ministry of Research & Education (BMBF). This latter lays the foundation for a coordinated and integrated approach towards achieving energy security, reducing greenhouse gas emissions, and promoting environmental stewardship. Its role is to draw an ***Energy & Climate Protection Master Plan (ECPMP)*** for the city of Saint-Louis[1] which is meant to lead the way and kick start development in key sectors such as energy. The development of a master plan in this model region provides the perfect platform to finding adequate solutions to their challenges through the transfer and adaption of German Sustainable Energy technologies and systems.

The project thus pursued the following basic objectives:

- Development of sustainable energy systems
- Market development for export-oriented, innovative German companies (SMEs)
- New model for local/regional energy production and supply

The implementation of technical showcases in the Senegalese context will help to avoid the typical mismatches between Africa and developed countries. In light of that, the LoSENS project has been funded with the specific objective of assessing the potential of Saint-Louis (both existing and future) towards a sustainable energy shift through a science-based, comprehensive methodology with four selected techno-economic studies. Achieving the key objective herein is supported by analyzing different energy intensive sub-sectors in the model region of Saint-Louis. Inter alia, the following topics are carefully examined:

A.) Public street lighting
Assessing the current public lighting and developing a concept to improve the energy and lighting performance for a pilot neighborhood using alternative German market proven technology.

B.) Solar Photovoltaic (PV)
A demonstration PV plant of 100 kWp was built in Gaston Berger University (UGB) with two main objectives: enhancing the understanding of how to successfully develop, finance, construct, and operate solar PV power plants with storage in the Senegalese context.

C.) Energy efficient hydraulic pumping
Assessing and identifying energy savings in the operation of pumps for WW treatment and rainwater drainage.

D.) Biowaste management
Biogas potential analysis of biowaste collected from three different markets.

The investigation carried out for Saint-Louis urban zone (from 01.04.2019 to 30.09.2023) employed Material Flow Analysis (MFA) method as a valuable tool for developing and implementing the ECPMP. MFA enables a comprehensive assessment of material and energy flows within the system, providing insights into resource consumption, waste generation, and

[1] Saint-Louis has been chosen by the project coordinator as a model region because it fits the prior criteria set for selection and due to the commitment of the Commune council to a sustainable energy development as well as the common research links IfaS has with the University of Gaston Berger (UGB)

environmental impacts. By applying the MFA method to the master plan, policymakers and stakeholders can gain a deeper understanding of the current energy and climate landscape, identify inefficiencies, and design targeted interventions for sustainable change. This methodology is coupled with Clean Development Mechanism (CDM) for greenhouse gas (GHG) impact assessment.

A summary of key aspects of the energy sector and its national and local context are summarized in first section to allow for a holistic and comprehensive approach to the energy access problematic in Senegal. This tangible steps in the process of developing an ECPMP, as documented in this report, start with the development of a data base of all accessible inventories relevant to the energy sector in the defined system boundaries. The project then proceeds through several development stages, including status quo analysis of Saint-Louis in order to bring out the main gaps of the city.

The second section of this report enumerates the different methods implemented to conduct the research activities of the project. The project technicalities work package (WP4) examined four different key actors and from which the results are presented in this ECPMP. Moreover, a set of sustainable energy measures are examined for each individual sector and projected to attain short, mid, and long term's objective. Furthermore, this chapter extends its scope to encompass the greenhouse gas (GHG) pathway projections for the upcoming years within the aforementioned sectors. In addition to evaluating the current state and challenges faced by the sectors, an in-depth analysis of the anticipated GHG emissions trajectory will be presented.

The third main section exhibits an economic evaluation and development of an operating model of the previously mentioned projects with regard to relevant key performance indicators (KPI). Based on the assumption of financial resources' local lack and practical know-how, a blueprint for a possible operating model is concretely developed. An analysis of possible institutional and organizational implementation options for projects in the field of renewable energies and energy efficiency was made.

Summing up the results of the four key actors, the findings of the study were largely in accordance with the projected outcomes outlined in the proposal, demonstrating a close alignment between the anticipated and observed results.

As results from taken projects, the energy savings from using efficient lamps can reach 55%. With the installation of the 100 new lamps, 33.86 MWh per year of electrical energy will be reduced and 16.15 t CO_{2e}/a of emissions could be avoided. Concerning the installed 100 kWp PV+Battery system at the UGB, each kilowatt hour produced will cost €0.147. The detailed results of the simulation have been consolidated and shows emissions reduction of 146.3 t CO_{2e}/a. furthermore, by installing efficient wastewater pumps, the city will save 1.49 GWh/a of energy which is equivalent to 51%, and avoid a total amount of 1,334 t CO_{2e}/a. Regarding biogas production from 11,100 t/a of biowaste, the best case scenario was found to be dry anaerobic digestion which will give a benefit of 2.47 GWh/a of electricity, 9,000 t/a of fertilizer, 1,536.3 t CO_{2e}/a of avoided emissions, and 0.18 €/kWh as LCOE.

In order to conduct a conclusive Greenhouse Gas (GHG) balance, an extrapolation was implemented for street lighting to a larger system scale by estimating 1,000 efficient lamps for the city which have 349 MWh/a as energy savings. This electrical savings is equivalent to 1% compared to the total demand of the city. However, leveraging insights from the pilot Photovoltaic (PV) project, a larger 5 MWp will generate approximately 8 GWh annually. The estimated system is anticipated to fulfil 20% of the annual electricity consumption in Saint-Louis. Furthermore, the electrical energy consumption for one year for biogas production and the wastewater pumps efficiency for the city can fulfil 6% and 4% respectively.

In total, the share of the RE production can reach 26% for one year as well as the demand reduction from efficient systems based on the conducted projects are able to reduce 5% from the city total demand. As consequence, the anticipated emission reduction potential for Saint-Louis city will be 11,860 t CO_{2e}/a which represents a 27% reduction from the baseline scenario.

All in all, this ECPMP gives in the last chapters the recommendations for the future scope to let Saint-Louis city change its current status to benefit from reduced energy consumption, decreased CO_2 emissions, and positive environmental impact. Which means, by implementing energy-saving measures, improving efficiency, and adopting sustainable practices, the four key actors can contribute to a greener and more sustainable future.

2 Introduction

In recent years, the importance of sustainable development and the urgent need to transition to renewable energy sources have become increasingly evident. Accordingly, urban areas energy efficiency seeks to engage a systematic approach of optimizing energy use within the densely populated areas to minimize energy consumption, mitigate GHG, and reduce environmental impact. To do so, various strategies should be involved for the implementation of technologies and policies to improve energy performance in buildings, transportation, and infrastructure.

By promoting energy-efficient practices, urban areas can enhance their resilience, reduce greenhouse gas emissions, and create more sustainable and suitable environments for their residents. Likewise, energy efficiency plays a crucial role in addressing climate change, improving air quality, and ensuring the long-term sustainability of cities in the face of growing energy demands and urbanization.

As a targeted country of LoSENS project, Senegal faces a significant energy gap between rural and urban areas. The country's outdated infrastructure and slow development rate contribute to power outages and economic losses. As a result, most populations of the country rely on biomass and fossil fuels, causing toxic exhausts and environmental damage due to greenhouse gas emissions.

To overcome these issues, Senegalese ambitions in the energy sector represent great business potential and bring about a multitude of business opportunities for the environmental technology sector, especially for Germany. However, technologies from Germany cannot be introduced into new foreign markets without country-specific adaptation. A "pull strategy" is recommended, which initially creates a local demand for innovative and sustainable solutions. LoSENS project is developing such a pull strategy in the form of energy and climate protection master plan for rural area. To do so, the chosen model city is Saint-Louis in the northwestern part of Senegal, along the Atlantic Ocean and the mouth of the Senegal River.

The development of such a master plan for the urban Senegalese model community serves to identify concrete needs for action and to implement tailor-made solutions based on the transfer of sustainable German technologies and energy system solutions. Additionally, the master plan targets the needs for action in various municipal fields as well as local decision-makers are sensitized to invest in innovative solutions. It also addresses the interconnected Sustainable Development Goals (SDGs) 7, 11, 12, and 17. By integrating these SDGs, this master plan seeks to create a comprehensive framework that fosters sustainable development and addresses urgent global challenges.

Indeed, the project recognizes the importance of engaging and involving main stakeholders to ensure a collective effort in achieving the goals of reliable energy access and energy efficiency. Through collaboration, capacity building, and inclusive decision-making, the plan aims to empower the community, enhance their livelihoods, and create a sustainable and prosperous future for all stakeholders in Saint-Louis. Additionally, the plan encourages collaboration between various stakeholders, including local governments, energy providers, community organizations, and residents, to ensure a successful implementation and long-term sustainability.

3 Methods Applied

3.1 General Methods

The work undertaken in this ECPMP employed two key methods. They are a.) Material Flow Analysis (MFA) as the base-method and b.) sector specific methods of Clean Development Mechanism (CDM)[2] for greenhouse gas (GHG) impact assessment. In addition, the following five-step general procedure was employed in the assessment and deployment of the aforesaid methods:

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

NOTE: The temporal boundary was set as 2021 which corresponds to the complete availability of material and energy flow data. Whereas the spatial boundary was set as the physical/administrative boundary of the city of Saint-Louis for the regional potential analysis part.

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

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

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

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

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

NOTE: as mentioned above, specific CDM methods—such as AMS-IIL and AM0020 (for Water Pumping Efficiency and Public Lighting)—for the assessment of GHG impact are applied.

Each sector presented in the ECPMP follows the same method. Firstly, the current situation of the sector (status quo) will be explained. Secondly, based on the available data, the baseline scenario will be developed. This does include a short description of assumptions which are considered for the calculations. Thirdly, the details of the appropriate computations are explained.

The study is based on a desktop survey and mainly on online published data, data bases which about the region and country.

In this study, assumptions were made in unclear situations, which resulted from the absence of any required data, documents and records, etc. The scope of the study was to review the energy and GHG emissions.

NOTE: Due to the lack of information specifically for the considered area is the major reason to increase the chance of missing any activities.

[2] CDM, https://cdm.unfccc.int/methodologies/documentation/index.html

3.2 MFA Concept

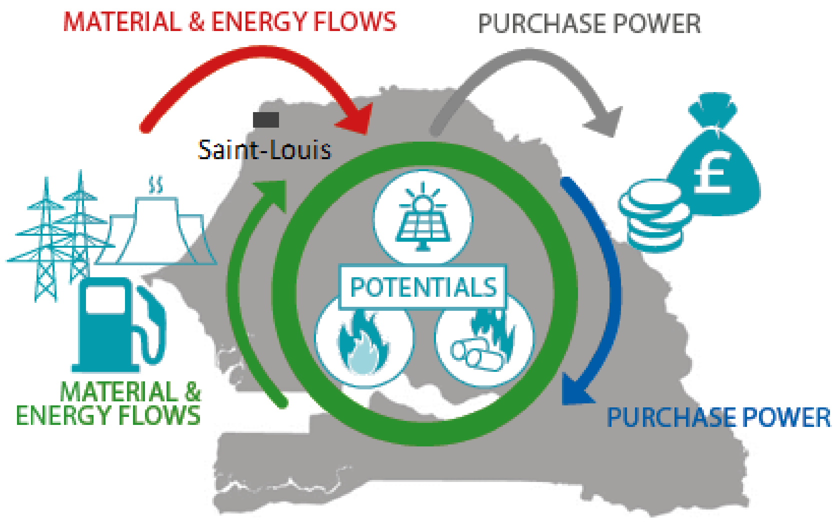


Figure 1 | Material Flow Analysis Vision and Goal Illustration, (© IfaS)

By applying MFA method, the master plan went through:

A.) Establishing a baseline
This involves collecting data on energy consumption, resource usage across sectors, public lighting, wastewater pumps, and waste management.

B.) Identifying Hotspots
The inventory of real situation helps extracting the gaps of the key areas. By pinpointing these hotspots, policymakers can prioritize interventions and allocate resources where they will have the most significant impact.

C.) Setting Targets
Based on the identified hotspots, specific targets and objectives are established. These targets should be measurable, time-bound, and aligned with national and international climate and energy goals.

D.) Developing Intervention Strategies
The MFA method helps in identifying the most effective interventions by analyzing the potential impacts of different strategies on energy efficiency, renewable energy adoption, waste reduction, and carbon emissions mitigation.

E.) Installation and Evaluation
The MFA method is an ongoing process that requires continuous monitoring and evaluation of the implemented interventions.

F.) Iterative Improvement
The MFA method allows for iterative improvement of the master plan by incorporating feedback, lessons learned, and emerging best practices.

3.3 Concept of "Scope"

To support define direct and indirect emission sources, enhance transparency, and give utility to various kinds of associations and distinctive sorts of climate policies and approaches and business objectives, three "scopes" (scope 1, scope 2, and scope 3) are characterized for GHG accounting and reporting purposes (WRI, 2004). In this study at SRT, the focus area is only for scope 1 and 2.

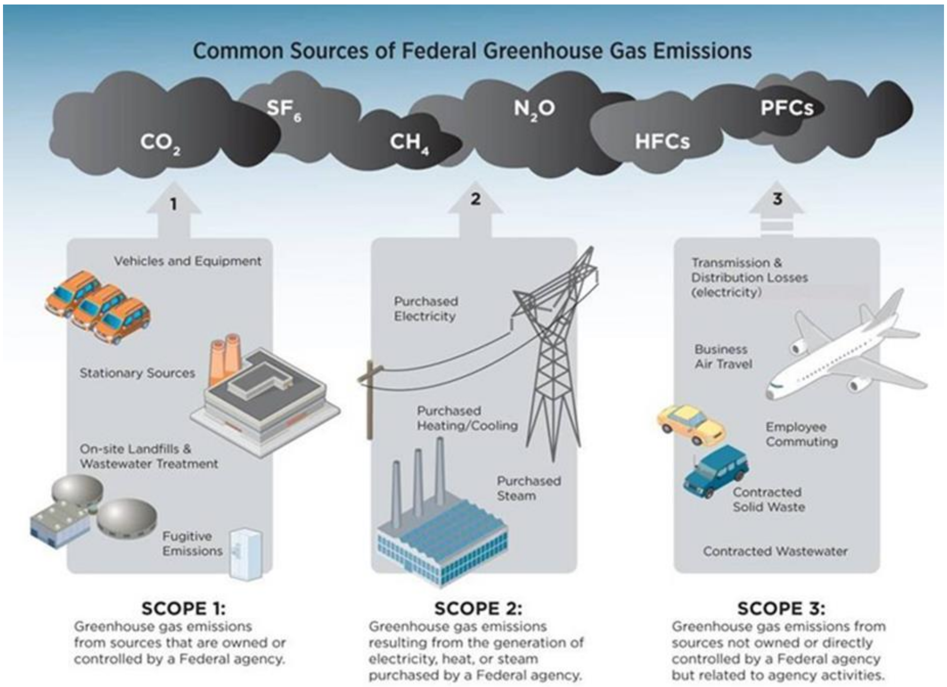


Figure 2 | GHG Emissions Scopes, (Energy.Gov, 2019)

Scope 1: Direct GHG Emissions

Direct GHG emissions occur within the system boundary controlled or owned sources such as fuel combustion from vehicles, industrial processes etc.; Biomass combustions and GHG emissions not covered by the Kyoto Protocol but has to report separately (WRI, 2004).

NOTE: Energy consumption and related GHG Emissions are calculated in scope 1 based on published emissions factors of consumed quantities of commercial fuels (such as oil and gas) and respective Net Calorific values. Published data on 2006 IPCC GHG Guidelines for GHG Inventories are used in this study.

Scope 2: Indirect GHG Emissions Related to Purchased Energy

Scope 2 accounts for the purchased electricity or any form of other energy associated GHG emissions. This is defined as energy that is purchased or otherwise brought into the organizational/community boundary (WRI, 2004).

NOTE: Scope 2 GHG emissions will principally be calculated from recoded electricity consumption and published emission factors.

4 Basic Calculation Variables

Outlined below are the basic assumptions pertinent and calculation variables to the technical and economic calculations.

Currency Exchange Rate:

For the economic calculations of the potential projects, the currency exchange rate of 1 EUR: 656 XOF (West African CFA franc) is used. This is the actual currency exchange rate average during 2022.

Emission Factors for Stationary Combustion:

Below are the emission factors of greenhouse gases endorsed by IPCC to be used in greenhouse gas inventories. The most common emission factors are included in the following Table 1 and Table 2 which are used in IPCC GHG inventory Tier 1 (Default emission factors) (IPCC, 2006).

Table 1 | Emission Factors for Stationary Combustion

FUEL	EMISSION FACTOR		
	CO_2e (kg CO_2e /TJ)	CO_2e (kg CO_2e /l combustible)	CO_2e (kg CO_2e /kWh)
LPG (Household)	63,155	1.61	0.23

Grid Emission Factor:

The selected grid emission factor is the operating margin. The combined margin is the result of a weighted average of two emission factors of the electricity system: the “operating margin” and the “build margin”. The operating margin is the emission factor of the thermal power plants and all plants serving the grid that cannot be characterized as “must run”. The build margin is the emission factor of a group of recently built power plants (WBCSD, 2006). The following factor was used in related calculations which is in the Harmonized Grid Emission factor data set published by UNFCCC[3].

Table 2 | Emission Factors for Purchased Electricity (CO_{2e})

PARAMETER	VALUE	UNIT
Emission Factor	0.87	kg CO_{2e}/kWh

[3] The IFI Dataset of Default Grid Factors Senegal v3.1: https://unfccc.int/documents/437880

5 Constraints & Limitations

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

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

Furthermore, while a master plan provides a blueprint for city development, it may lack strong enforcement mechanisms. Without adequate enforcement and monitoring mechanisms, the realization of the proposed projects and policies may face delays or deviations.

Additionally, comparing the chosen key actors of the pilot projects with the proposal, some unconducted sectors are presented as follows:

A). Solar Thermal Energy:
Due to the limited use of solar thermal energy in the city of Saint-Louis and the absence of data inventory, the potential and viability of using it for particular purposes were not investigated.

B). Energy Efficiency Potential in Trade and Industry:
The project recognizes the value of energy efficiency in households and the public sector, but it does not perform a thorough examination of the potential for energy efficiency in trade and industry. There is no discussion of particulars such compressed air systems, industrial operations, heating and cooling, etc.

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

6 Senegal National Status Quo

6.1 National Energy Context

In Senegal, the state-owned energy operator is Senegal National Electricity Agency (SENELEC)[4]. It is responsible for transmission, distribution and approximately half of the power generation. The remaining demand for primary energy is covered by imports of crude oil. Overall, the electricity production has risen sharply in recent years, whereby the primary energy source has remained oil. Potentials in the field of solar energy have hardly been exploited.

Accordingly, in 2019, the main national electricity ensured by the SENELEC park had a total installed power of 539.94 MW (36.02%) and private producer units had a total capacity of 959.10 MW (63.98%). On the other hand, the total consumed energy each year is around 44 TWh (Panos et al., 2022). This latter is split into several sectors depending on their demand as shown in the figure below (IEA, 2022):

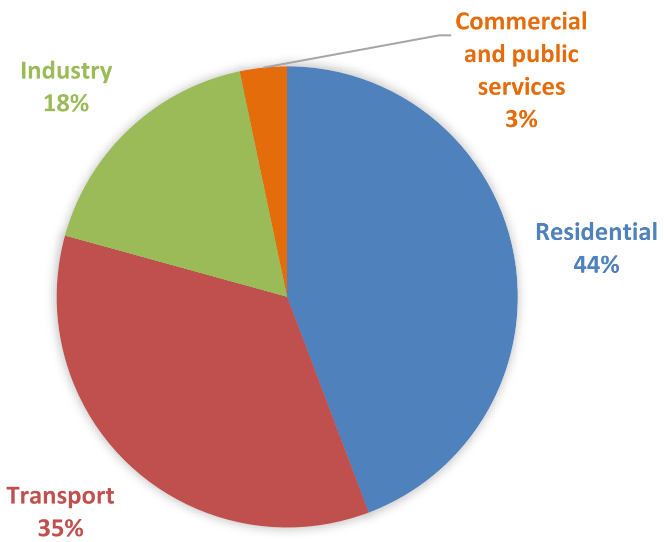


Figure 3 | Energy Consumption by Sector in Senegal 2019

Referring to the world bank database, 70,4% of Senegalese population has access to the electricity that is produced, which means that the left population is suffering from power cuts or even non-electrified households especially in rural areas. In general, the statistics recorded a 273.5 kWh consumed per capita (World Bank, 2023).

NOTE: This poorly maintained electrical network shows that the electricity production is not yet fully sufficient to have a well-balanced electrified country, and this lack leads to other development impacts.

With regard to electricity production, Senegal must therefore face a deficit of production and transport infrastructure that it cannot fill due to lack of sufficient financial means. Moreover, the development of an economy is also accompanied by an increase in the need for hydrocarbons in order to allow the development of the industrial sector.

[4] SENELEC: http://www.senelec.sn/

NOTE: This is why the country, with not having sufficient energy resources, is subject to an increase in its energy bill.

According to the Senegalese National Agency for Renewable Energy (ANER), the energy sector in Senegal has been going through a deep and complex crisis for several years. This has led to malfunctions throughout the sector despite the various strategies and reforms implemented. Therefore, Senegal could not achieve full economic growth without the energy sector that is considered as a major pillar for the development of the economy and for the reduction of social and territorial inequalities. According to the Emerging Senegal Plan (PSE) which is adopted in 2012, the country is led to emergence by 2035 as well as to achieve a sustainable growth of approx. 7% over a period of 10 years. Furthermore, the PSE aims to guarantee wide and reliable access to cheap energy, with targeted and precise objectives (PSE, 2018), aiming at:

- Lowering electricity prices in the sub-region
- Halving the household electricity bill
- Eliminating power cuts and associated losses

Senegal then launched its Senegal National Adaptation Plan (PNA) in 2015, which sets out policies on climate change and in particular the resulting Nationally Determined Contribution (CDN) and aims to strengthen the adaptation and resilience capacities of the sectors of activity that are vulnerable through better planning of actions in the medium and long term at national, local and sectoral level (Sy et al., 2021).

NOTE: Senegal is opting for developing its energetic situation in variant sectors, thus this master plan is providing a model for urban region.

6.2 National Policy Framework

The Senegal country's energy and water sector are governed by multiple actors which are as follow:

- ***The Ministry of Petroleum and Energy (MPE)***
  oversees developing the general policy and standards applicable to the electricity sector.
- ***The Minister of Ecology and Nature Protection***
  is prepared to implement the policy defined by the Head of State in ecology, environmental watch, protection of nature, fauna, and flora, as well as in the area of retention ponds and aquaculture.
- ***The Ministry of Water and Sanitation***
  looks after hydraulic and sanitation fields and its implementation, operation, and maintenance as well as definition of tariff policies for drinking water supply.
- ***The Electricity Sector Regulatory Commission[5] (CRSE)***
  oversees the control of the generation, transmission, distribution, and selling of electricity in terms of their compliance with the legal and regulatory framework in addition to establishing a pricing structure for electricity tariffs.
- ***Senegal National Electricity Agency (SENELEC)***
  is the sole organism responsible for electricity production, transmission, and distribution.
- ***The Senegalese Rural Electrification Agency (ASER)***

[5] CRSE: https://www.crse.sn/

has an aim of developing rural electrification in the country by providing technical and financial assistance to companies and private operators conducting such initiatives (*Senegal - GET.Invest*, n.d.).

- ***The National Agency for Renewable Energy (ANER)***
  was created in order to promote renewable energy projects in Senegal including solar, wind, hydro, tide, and biomass.
- ***The National Agency for Energy Efficiency and Management (AEME)***
  helps put into action the national policy for energy management, promotes and supports projects in energy efficiency practices in all economic sectors.
- ***National Sanitation Office of Senegal (ONAS)***
  is a government agency under the authority of the Ministry of Water and Sanitation and is responsible for sanitation, wastewater and stormwater management.

NOTE: The master plan is based on the data provided by some of the mentioned institutions.

6.3 National Strategies Relevant to Energy Sector in Senegal

The energy industry plays a crucial role in both fostering economic growth and reducing social and geographical disparities. Senegal has adopted a strategic plan for economic and social progress called the Emerging Senegal Plan (PSE). This plan serves as a guiding framework for medium and long-term economic and social policies. Within the PSE, the energy sector is identified as one of the "Foundations of Emergence," aiming to ensure widespread and reliable access to affordable energy by the year 2035. To achieve this objective, the Integrated Electricity Plan is being revitalized. This plan encompasses various initiatives, including the development of energy production from coal, gas, hydropower, solar, and wind sources. The goal is to diversify electricity production and create a balanced energy mix (MFB, 2019).

According to Senegal’s investment state agency (APIX), the country's strategy was set out in the Energy Sector Development Policy Letter (LPDSE 2019-2023) and has the following main objectives (APIX,2018) :

- To ensure a secure supply of sufficient and quality energy to the country.
- To develop access to electricity at lower cost with quality and continuity of service.
- Strengthen the population's access to modern cooking fuels.
- Strengthen governance, regulation, financing, and monitoring-evaluation of the sector.

The PSE's flagship electricity revival project, whose main objectives are to provide sufficient electricity (more than 1,500 MW of installed available capacity), reliably and at a competitive cost (between 0.09 and 0.12 €/kWh), has enabled the implementation of many electricity production projects while developing the energy mix with coal, hydroelectricity, wind, and solar energy in particular. These projects have led to the reduction of the production deficit and reduced the undistributed energy from 44.9 GWh in 2014 to 19.6 GWh in 2018. Over the 2013-2018 period, SENELEC has commissioned 343.9 MW of new capacity, increasing installed capacity from around 800 MW in 2013 to 1,141 MW in 2018 (MFB, 2019).

6.3.1 Energy Efficiency

The launch of the "Sustainable Energy for All" initiative in 2011 highlighted the importance of improving energy efficiency and increasing the share of renewables and clean technologies in the energy mix (MPE, 2015).

The establishment by ECOWAS of the Center for Renewable Energies and Energy Efficiency should make it possible to strengthen policies and programs for energy efficiency and the development of renewable energies in West Africa by 2030. The priorities of this regional policy, defined at the instigation of ECREEE, concern the following areas:

- Efficient lighting
- Achievement of high performance in the distribution of electricity
- Development of standards and labeling of energy-consuming equipment
- Mobilization of financing to mitigate negative environmental externalities
- Sustainable, affordable, and safe cooking

The general measures adopted in Senegal to promote energy efficiency are:

- ***Institutional Frame***
  Focusing on energy management integration, association creations, partnerships establishments, and the development of training and research centers.
- ***Legal and Regulatory Framework***
  Development of energy efficiency standards and enactment of renewable energy laws.
- ***Funding mechanism***
  Concentrating on funding from the Global Environment Facility (GEF), establishment of a financing agreement, and offering bonuses for energy efficiency projects.
- ***Implementing provisions***
  Improving the technical assistance unit and independent experts in energy efficiency.

6.3.2 Renewable energy

Because of the high dependence on imported resources and their impact on climate change, Senegal's national targets for the upcoming years are to scale renewable energies up (20% grid-connected RE generation in 2020, 30% grid-connected RE generation in 2030) and reduce oil consumption. Besides that, it is also helping to boost prospects and job opportunities for young people. Senegal has embarked on a process of promoting renewable energy, energy efficiency and access to energy by developing laws and regulations to allow the private sector to invest in the energy sector with notably the drafting of an Energy Sector Development Policy Letter (LPDSE 2008-2012) which sets the share of renewable energies in the national energy balance at 15% in 2020 (Weiss et al., 2015).

NOTE: The exploitation of the potential of renewable energy in Senegal offers an opportunity for economic activities, creation of qualified jobs (engineers and technicians) and a reduction of GHG emissions linked to energy. The development of renewable energies in Senegal is part of securing the energy supply and reducing dependence on imported fossil fuels.

Additionally, the new energy policy, underpinned by the Energy Sector Development Policy Letter (LPDSE 2012-2017) signed on October 31, 2012, which stems from the analysis of the national and international context and the sectoral vision, pursues the following strategic objectives (MPE, 2015):

- Ensure the country's energy supply in sufficient quantity, under the best conditions of quality and sustainability, and at the lowest cost.
- Carry out energy diversification in order to reduce the country's vulnerability to exogenous hazards, particularly those of the world oil market.
- Promote the development of renewable energies.
- Broaden people's access to modern energy services.
- Promoting energy control and energy efficiency.

Furthermore, the definition of an energy management policy depends both on the energy challenges of the country but also on the international experience accumulated on the various measures. Thus, the energy management policy in Senegal is based on the following four (4) main levers that should be exploited simultaneously to achieve the targeted energy consumption reduction objectives:

A). Provisions of Governance
B). Economic and Financial provisions
C). Implementation provisions
D). Energy management action programs

With the National Energy Strategy, the state's objective is to increase the penetration rate of renewable energies in the electricity mix by issuing approvals to promoters wishing to resell electricity from renewable sources to SENELEC, which will have to conduct a stability study of its electricity network for the integration of renewables into its production facilities.

NOTE: All in all, as Senegal is not an oil producer, the option is to bet on a diversification of energy sources by integrating those of renewable origin whose exploitable potential is proven. Additionally, solar energy is the best-distributed and most important source throughout the territory, even if there is considerable potential for the other sectors, in particular wind power, biomass, and hydropower.

6.3.3 Industry

According to IEA, the consumption by sector for industry was reaching 17.4 % of the national total energy consumption (IEA, 2022). The development of an economy is also accompanied by an increase in the need for hydrocarbons in order to allow the development of the industrial sector. This is why Senegal, not having such resources, is subject to an increase in its energy bill. Improving energy efficiency by reducing energy consumption is one of the new axes formulated by the Senegalese government. This is indeed weighed down by a fleet of aging industrial equipment, with high consumption. In addition, the objective is also to promote low-consumption tools, always with the aim of reducing energy consumption (Belkas et al., 2017).

Given the very low availability of information on this energy consumption item, only one energy-saving action was studied: raising industrial awareness of the simplest energy conservation techniques (insulation, sealing and setting parameters). The deployment of this measure will only go through the implementation of energy audits which will make it possible to detect these sources of savings (PSE, 2018). Additionally, industries such as agribusiness, mining and fertilizer production are equally important sectors. Improving energy systems would modernize these sectors.

The strategy to develop the industrial sector is related to the real situation gaps. As it is important to emphasize the interest shown by industrialists in energy efficiency measures. In fact, the observation made by the Senegal Upgrade Office (BMN) highlights the following (BMN, 2022):

- Energy accounts for 5 to 15% of the turnover of industrial companies in the food or plastics industry.
- Up to 15% of the bill can be valued solely by maintenance and energy management actions such as electricity bill optimization, maintenance, adequate regulation of equipment.
- Investments to replace production tools, increase capacity, move or bring them into compliance, are generally an opportunity for companies to improve their energy efficiency and integrate Renewable Energies.

6.3.4 Transportation

Senegal's energy accounting shows that its economy is based on the massive use of biomass in the residential sector and fossil fuels in the production of electricity and the transport of goods and people. According to the International Energy Agency (IEA), the energy consumption for transportation sector in 2019 is taking 35% from the total production (IEA, 2022).

In proportion to a study conducted in Alioune DIOP University, Senegal's energy usage pattern reveals a heavy reliance on biomass for residential purposes and fossil fuels for electricity generation and transportation of goods and people. A significant proportion of the country's energy consumption is attributed to the transportation sector by 30%, with road transport dominating the field and accounting for nearly all of its energy usage with 95%, mostly 80% from diesel and 20% of gasoline sources. The heavy dependence on imported fuels negatively impacts the nation's economy, and the use of low-quality diesel exacerbates pollution and health concerns. Analyzing data from 2000 to 2013 indicates a growing trend in energy consumption and a shift towards road-based transportation, which raises crucial questions about the need to decarbonize the economy, achieve energy independence, and embrace cleaner energy solutions in the transport sector (Bertrand & Ibrahima, 2014).

In future Senegalese strategy, urban mobility and the development of a sustainable transport system will be a priority. The European action will aim at the restructuring of public transport in Dakar, on the basis of the structuring projects of the Regional Express Train, and the Bus Rapid Transit. Road improvements, construction of bus depots, renewal/expansion of the bus fleet with more environmentally friendly engines (gas, electric) and upgrade of passenger service (with digital solutions), with integrated pricing in particular, are planned. The European intervention, in cooperation with the World Bank, will aim to guarantee a strong positive environmental impact, through funding for the public sector as well as support for private operators (Amadou et al., 2018).

NOTE: Transportation mainly through the use of fossil fuels in vehicles is a major contributor to climate change due to the significant release of carbon dioxide. To address this, there's an urgent need to shift away from fossil fuels. Adopting cleaner alternatives like electric vehicles powered by renewable energy, promoting public transportation, cycling, walking, and implementing policies for energy-efficient infrastructure are essential steps to reduce the environmental impact of transportation and foster a more sustainable and climate-friendly future.

6.4 National System Characterization

6.4.1 Existing Sustainable Energy Systems

In terms of energy, Senegal is characterized by a strong dependence on imports, especially of oil. With regard to biomass consumption (firewood, charcoal, bagasse and peanut shell), their use remains the main cooking energy despite the strong degradation of the resource in this Sahelian region such as Saint-Louis (GERES, n.d.).

However, the region offers significant energy potential, in particular solar and wind. The biomass from agricultural residues and animal waste are still under-exploited.

In general, the main energy sources are not sustainable. The following graph demonstrates the different resources which has minimal percentages of used renewable energies, (Panos et al., 2022):

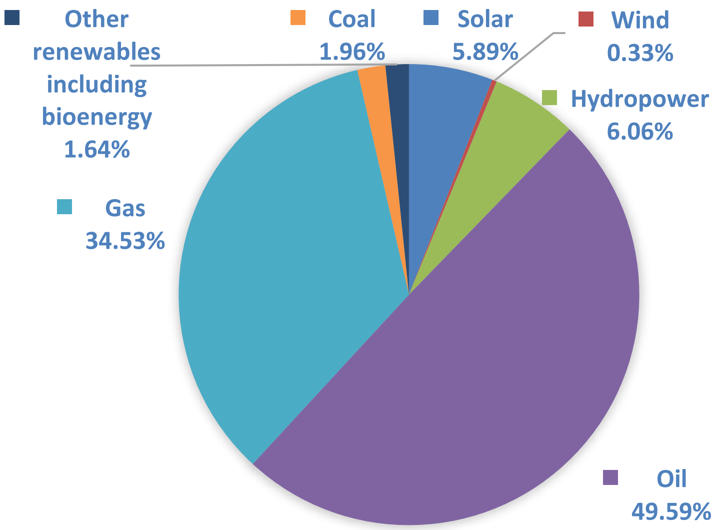


Figure 4 | Electricity Production by Source in Senegal 2021

Overall, few sustainable energy projects are existing in Senegal. Similarly in the region of Saint-Louis, crucial potentials are existing, however, they are not well exploited. The main sources and projects are described as follow (MPE, 2015):

A). Biogas

The use of biogas as an energy source was initiated in Senegal in 1977 in Ndiouck Fissel in the district of Thiadiaye in the Fatick region with the installation of two biodigesters. The year 1989 was marked by the creation of biogas production units at the Cambérène wastewater treatment plant and at the SERAS (currently named SOGAS) in Thiès. In December 2009 with the National Biogas Program (PNB-SN), more than 500 domestic biodigesters were installed in rural areas, ranging in size from 4 to 18 m³. The 10 m³ biodigester is the most common with a rate of 60%.

NOTE: The problem is the unfollow and lack of maintenance to keep the plants with good regular production.

B). Hydroelectricity:

The Manantali dam on the Senegal River is the main hydroelectric facility. With a capacity of 200 MW, its electricity production is divided between Senegal (33%), Mauritania (15%)

and Mali (52%). Potential sites exist on the foothills of the Fouta Djallon on the Guinean border for small hydroelectricity (power less than 100 kW).

C). Wind energy:

The data available in Senegal show a relative weakness of the winds in the country with the exception of the Dakar-Saint-Louis axis where in Potou an annual average of 6.4 m/s at 70 m and 5.8 m/s in Cayar. There are pumping wind turbines in the Niayes market gardening area. In addition, some wind farm projects are existing in Senegal, including:

- Taïba Ndiaye wind project (158.7 MW), (Eva rassoul, 2018).
- Léona wind farm project (50 MW), (GEM wiki, 2023).
- Saint-Louis wind farm project (15MW), (Elhadji SYLLA, n.d.).

NOTE: Despite the importance of other planned projects, the use of wind energy is still low.

D). Solar energy:

Senegal has an average solar irradiation of 5.7 kWh/m^2/d for an average duration of 3,000 hours. The installed photovoltaic (PV) capacity was 2.86 MWp in 2012, equivalent to 0.3% of the total electricity production capacity. The number of subscribers per region is greater in Fatick than other regions.

NOTE: There exist recurring issues in current infrastructures, including frequent equipment breakdowns, lack of local expertise in maintenance, ineffective financial governance, and frequent power outages causing losses. The financial burden of equipment renewal and maintenance is a common challenge.

Overall, the electrification rate stood at 67% in 2018. However, significant geographical discrepancies exist nationwide: 88.5% of urban households have access to electricity, whereas only 54% of rural households do. Additionally, approximately 68% of villages, totaling 585 localities, lack access to electricity, whether through the centralized grid or decentralized solutions (GERES, n.d.).

6.4.2 Existing Wastewater and Waste Management Systems

6.4.2.1 Wastewater Management

According to the National Center for Development Cooperation (CNCD), access to drinking water remains a problem in Senegal for certain populations, particularly those in poor neighborhoods and rural areas. Many localities do not yet have running water at home and get their supplies from wells and public standpipes.

As far as sanitation (drainage) is concerned, it remains inaccessible. The results of a recent social situation survey carried out by the Department of Forecasting and Economic Studies (DPEE) indicate that in the first quarter of 2018, only 26.8% of Dakar households had access to sanitation.

To ensure the harmonious development of Urban Hydraulics and Sanitation, the State of Senegal proceeded in 1995 with the institutional reform of this sector. This reform split the Senegalese National Water Exploitation Company, which was responsible for the entire urban water sector, into three entities:

- National Water Company of Senegal (SONES)
- Senegalese Waters (SDE)

- National Office of Senegal (ONAS)

Investments in the liquid sanitation sector are the responsibility of the Senegalese State. However, other actors intervene, in particular the populations and Non-Governmental Organizations (NGOs). The intervention of populations and NGOs is especially felt in the management of domestic wastewater. Thus, at the country level, the vast majority of current wastewater treatment systems are installed by the populations themselves; these are always individual systems that often do not meet the standards in force in the field of individual sanitation.

The ONAS of Saint-Louis is responsible for a vast network of wastewater and rainwater. The wastewater network, which was only 50,000 meters long in 2008, is estimated at 79,000 meters in 2012 and the extensive rainwater network of 26,893 meters in 2012 has increased for the same period by 112% (ANSD, 2015).

In Saint-Louis there exist two systems:

A). The collective system

It dates from the 1940s and originally only concerned the island. In 2007, the service rate was 30% (3,271 connections). There are other facilities: 6 pumping stations; 35 km of sewers; a lagoon station with an area of 70,000 m^2, corresponding to a capacity of 35,000 inhabitants. Special efforts have been made in Léona, Diamaguène and Ndar Toute. However, some neighborhoods do not yet have connections to the sewer (ATELIERS, n.d.).

B). The autonomous system

Households are using septic tanks which some are connected to the network and others not. Each year, this system encounters major emptying problems, in particular due to the rising of the groundwater. The poorly drained surfaces are estimated at 162 hectares. The rainwater sewerage network is dilapidated and not very functional. In the urban restructuring project of the Pikine district, two types of rainwater evacuation channels have been built in concrete: a superficial air channel free and a channel under the sidewalk (ATELIERS, n.d.).

Indeed, during the rainy season, neighborhoods that do not have sufficient collection and evacuation networks are flooded for several months, which causes the rise of used effluent from septic tanks and the flotation of waste and household waste (PSEAU, 2014).

NOTE: The emergence of the problem of rainwater management in Senegal results from a multiplicity of climatic, economic, and institutional events, which have led populations to migrate to areas that are now highly exposed to the risk of flooding.

6.4.2.2 Waste management

Senegal, like most other countries in the Global South, is facing high population growth, accompanied by rapid urbanization. These trends go hand in hand with changing consumption patterns, which lead to an increase in levels and types of waste. In Senegal, the average daily volume of urban solid waste is around 8,664.4 tonnes, consisting mainly of fine materials around 50 %, particularly sand. Municipal solid waste per capita is around 0.5 kg a day (giz, 2021).

In the regional capitals, the State intervenes in support of the municipalities through the Coordination and Management Unit (UCG), an agency of the Ministry of Urban Planning UCG. Previously, its actions were more focused on one-off operations to clean up garbage dumps. However, over the past two years, they have become more structured and linked to door-to-door collection from households, the voluntary delivery of garbage to the Normalized Regrouping Points (PRN) set up in the districts, sweeping and the regular removal of street bins.

However, the work started a few years ago is still unfinished. To accelerate the process of preserving the urban environment in Senegal, a project for the promotion of integrated management and the economy of solid waste was officially launched in 2021. The latter, which will be implemented in 138 municipalities, has the objectives, among other things, of improving solid waste management, boosting recovery, and proposing areas for reform (AUTRETERRE, 2021).

In medium-sized municipalities, State intervention remains ad hoc. It is especially marked by operations to eradicate wild deposits, at the request of municipal authorities or in the run-up to major events in their regions. However, many municipalities say they do not benefit from state support and the lack of financial resources leads to serious shortcomings in waste management. This is what has led to the proliferation of community initiatives carried out by civil society organizations committed to contributing or even carrying out the task of collecting and transporting waste themselves, very often to unauthorized sites.

In general, there are two types of streams in Senegal:

A). Domestic solid waste streams

The processing of solid waste generated by households is not regulated in Senegal. Primary waste collection is carried out using carts and tricycles. Throughout the country, primary collection is an informal activity and is not part of the official public service management system.

NOTE: Collected household materials and recovered waste from dumps are sold to manufacturers like aluminum foundries, blacksmiths, and garment makers, or to intermediaries who stock them for resale. Some waste items, like jars and bottles, are cleaned and directly resold, while others, such as food scraps, paper, and cardboard, are used as animal feed.

B). Industrial solid waste streams

At large scale, waste depends on operations and ordinary industrial waste such as plastics, paper, and cardboard. The former is either reused internally or transported to dedicated facilities or dump sites. Special or hazardous industrial waste, due to its potential danger, is managed separately through a well-defined process agreed upon by the relevant companies, often outlined in a memorandum of understanding between them.

NOTE: There exists a local industry for each kind of waste although the level of recycling or reuse varies according to the type of waste.

7 Status Quo Analysis of Saint-Louis

In this master plan, the information presented regarding the status quo of Saint-Louis is derived from various sources, with a significant portion of the data and insights coming from the associated reports (Work package (WP4)). These reports have been integrated into the overall project to provide a comprehensive model analysis.

The ECPMP strategically prioritizes public street lighting, solar power, wastewater pumping stations, waste management, and biogas, reflecting a comprehensive approach to urban development. Public lighting enhances safety and minimizes energy use, while solar integration aligns with renewable energy goals, reducing the city's carbon footprint. Optimizing wastewater pumping station efficiency is vital for resource conservation and environmental protection. Waste management initiatives emphasize commitment to community well-being through reduction and recycling. Exploring biogas aligns with circular economy objectives, aiming to reduce dependence on traditional fossil fuels. This integrated approach aims to create a sustainable urban environment, meeting present needs while safeguarding the prosperity of future generations.

7.1 Site Model Description

The region of Saint-Louis has several divisions which consist of urban and rural areas. In this ECPMP the main urban model is based on the municipality of Saint-Louis. According to the National Statistics Agency and Demography (ANSD), the regional population of Saint-Louis was 1,063,542 inhabitants in 2019 which is 6.6% of national community (Peuple et al., n.d.). Referring to the management master plan of solid waste from the municipality of Saint-Louis division (2014), the census data boasts a diverse population of approximately 201,300 residents in both rural and urban zone.

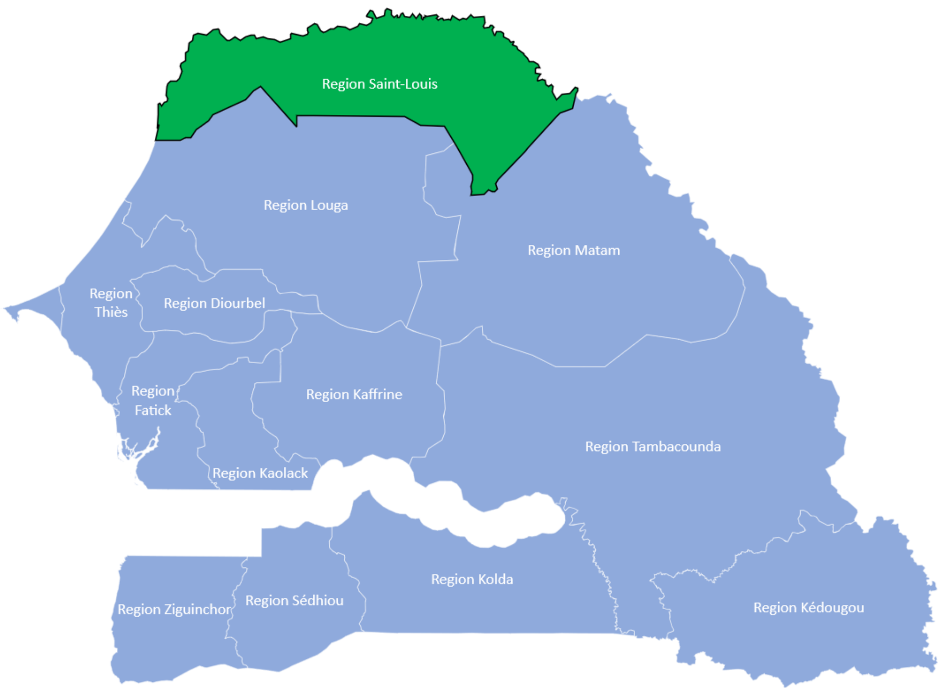


Figure 5 | Regional Map of Senegal and Saint-Louis Municipality, (© IfaS)

Saint Louis is a historical city located in northern Senegal, at the mouth of the Senegal River. Its geographical features and potential in energy make it an interesting location in terms of renewable energy sources.

Saint-Louis has the following characteristics (see Figure 6):

- ***Coastal Location***
  Situated along the Atlantic Ocean coast, providing easy access to marine resources and potential for offshore wind energy generation.
- ***River System***
  Located at the mouth of the Senegal River, which offers opportunities for hydropower generation and irrigation.
- ***Islands and Estuaries***
  Known for its scenic islands, such as the Île de N'Dar, which could be utilized for renewable energy projects and ecotourism.
- ***Flat Terrain***
  Facilitating the installation of solar panels and the development of solar power farms.

Figure 6 | Entire Saint-Louis City Boundary, (Google Earth Satellite Image)

The concentrated population of the city, despite its significant density and the presence of vast open spaces within the region, can be attributed to intricate urban planning, economic opportunities, and social dynamics. The urban area is limited geographically and is densely populated in comparison with the city surface.

7.2 Stakeholders

The following represents the stakeholders for the main four key actors[6] that are typically involved in LoSENS project of Saint-Louis model master plan:

I. Public lighting:

A). The municipality's technical services

[6] The four main key elements of the LoSENS project are: public streetlight, solar power, wastewater pumping stations, waste management.

The municipality's technical services are not only responsible for the smooth operation of the lighting system, but they are also an important partner in the LoSENS project, working closely together to ensure its realization.

B). Lanz GmbH

Known for its high-quality LEDs, Lanz GmbH is a specialist in the field of lighting in general. Its knowledge in this field has enabled the team to gain an insight into the evolution of LED technology, facilitating a clear understanding of the technical parameters of the lamps that could be used in the LoSENS project.

C). Population

Public lighting benefits both road users and local residents. Some areas of Diamaguene are under- or even unlit. Installing a new, more efficient lighting system will make the population feel safer at night, and encourage night-time activities, as some shopkeepers are afraid of walking at night because of the unlit areas they use to get to their homes. At a minimum, this outcome is the product of a survey conducted along General Avenue de Gaulle in Saint-Louis.

II. Solar power:

A). The municipality

Although the new 100 kWp solar system will not directly benefit the municipality of Saint-Louis, this mini power plant will increase the installed power of photovoltaic systems in the region.

B). KLE Energie GmbH

Known for its experience in solar energy field KLE GmbH is a specialist who has strongly contributed to the realization of the mini solar power plant at Gaston Berger University. Its technical support was a great help in sizing the system, writing the specifications and providing technical support.

C). Gaston Berger University

The roof of building A of Gaston Berger University is where the new mini solar power plant with a storage system will be installed. The energy produced will be directly consumed within the university and will thus make it possible to take another step towards the energy transition.

D). Business Council of Renewable Energies of Senegal (COPERES)

It is an organization that works to increase renewable energy in Senegal. Thanks to numerous meetings organized, it has shown itself to be very useful both technically and administratively; COPERES has indeed followed and accelerated the process aimed at obtaining the authorization to build the photovoltaic system. His invaluable advice has also led to financial savings. The sharing of technical data specific to Senegal made it possible to properly prepare the specifications.

III. Municipal waste:

A). Le Partenariat

It is an association of international solidarity, which acts as a mobilizer and supporter of the various technical and financial institutional partners in order to achieve development in the region of Saint-Louis. This organization is also of the main and most important stakeholders of this project, as they have realized many projects in the region of Saint-

Louis and provided great help in terms of studies conducted and contacts of people in the city.

B). GIZ Senegal

It is a German development agency operating in Senegal that works closely with the Senegalese government, civil society organizations, and other stakeholders to support sustainable development initiatives. It often involves capacity building, technical assistance, policy advice, and the promotion of innovation and best practices. Its role was to help in provision of contacts as well as data collection.

C). The Waste Management Coordination Unit (UCG)

This organization is responsible for waste collection and management. By working closely with local authorities, civil society organizations, technical and financial partners, and the local population, the UCG aims to improve waste management in Saint-Louis and promote sustainable and environmentally friendly practices. It was beneficial at the beginning of LoSENS to introduce the city waste collection system in addition to current situation.

D). SONAGED

National Integrated Waste Management Company, which is responsible for waste collection, transportation, and disposal after taking over from the UCG in 2022.

E). The merchants and vendors in the markets

They are important to consider as they will be the primary suppliers of organic waste from the three markets.

IV. Wastewater pumping stations:

A). Municipality of Saint-Louis

The city government is responsible for the overall management of wastewater pumping stations. They are responsible for ensuring that the stations are properly maintained and that they comply with environmental regulations.

***B).* ONAS (Wastewater utility)**

The wastewater utility is responsible for the day-to-day operation of the wastewater pumping stations. They ensure that the pumps are functioning properly, that the wastewater is being pumped efficiently, and that any issues with the stations are quickly addressed. It is the source of data provided to LoSENS project.

***C).* Kocks Consult GmbH**

Partner provided the full comprehensive solution to develop an efficient pumping station for the model city.

***D).* Water Technology Company**

A company for technical service and industrial maintenance, was charged of onsite measurements.

***E).* Community members**

They rely on these stations to ensure that their wastewater is properly disposed of and that it does not contaminate the environment. They may also be concerned about the noise and odor generated by these stations and may provide feedback to the city government regarding any issues they may encounter.

***F).* Environmental regulators**

Environmental regulators are responsible for ensuring that the wastewater pumping stations comply with environmental regulations. They monitor the stations and assess their impact on the environment, such as water quality and air emissions. They may also provide guidance to the municipality and other stakeholders on how to improve the operations of the pumping stations.

7.3 Public Street Lighting

The status quo of the street lighting network in Saint-Louis was assessed through an inventory provided by the municipal utilities. This inventory contained an exhaustive list of all lighting units in the city. For each light point, the inventory indicated the neighborhood and street where it is installed and the date of installation, as well as other attributes related to the light cabinet, bulb type and date of installation, wattage rating, ballast and igniter types, type of mounting and bracket, and pole height.

Unfortunately, not all of the above information was available for all districts in the city. A representative district (Diamaguène) with the most complete data was chosen, in order to develop a methodology that could then be applied to all other districts in the city. According to this inventory, the district has a total of 155 lighting units installed along 27 streets. The exact location of each lighting point, as well as the type of diffuser, the type of equipment, were missing, and the inventory was not up to date. In an attempt to locate the luminaires, the span was calculated and compared to the width of the road, but discrepancies were found, and a further inventory was required.

The second inventory made it possible to record the exact location of the luminaires, and to update the data from the first inventory. The inventory was carried out in collaboration with a student trainee from the University of Gaston Berger of Saint-Louis. The geographic information system for mapping application "Google My Maps", was used for this purpose. A map of Diamaguène was created, on which the location of each luminaire in the neighborhood was recorded using a GPS. The material needed to document the inventory was prepared in advance. This consists of an instruction document on how to proceed with data collection and an Excel spreadsheet to record the necessary data. The data recorded included the type of luminaire, its power rating, manufacturer, operational status, the height and material of the pole, daytime and nighttime photographs of the luminaires, which allowed the operational status of the luminaires to be verified as well as their physical appearance.

The inventory revealed the complexity of the street lighting network in the district and the city. According to the surveys, the district has 149 installed lighting units, compared to 155 units recorded in the first inventory. Table 3 summarizes the results of the inventory in terms of the type and number of luminaires of each technology on site, and Figure 10 shows the lighting levels in two different streets of the neighborhood.

Table 3 | Luminaire Type and Power Rating (Diamaguène)

TYPE OF LUMINAIRE	POWER (W)	NUMBER OF UNITS	NUMBER OF OPERATIONAL UNITS
HPS (Sodium lamps)	70	104	70
HPS	100	5	3
HPS	Unknown	1	-
Mercury vapor lamp	125	3	3
Mercury vapor lamp	Unknown	1	1
LED	80	16	16
LED	60	17	17

Figure 7 | Lighting Environment in Diamaguène, (© IfaS)

NOTE: Further information are joined to this master plan in WP4a.

7.4 Solar Power

The energy sector is a key area for development in Senegal in general and in the city of Saint-Louis in particular. The lack of real data makes it difficult to carry out any study that might lead to the development of an energy concept that would enable the regions concerned to benefit from local added value. Some data dating from 2017 and forecasts for 2025 have been collected and grouped together in the table below.

Table 4 | Household Electricity Consumption in Saint-Louis Region in 2017 and Forecast for 2025, (Le Partenariat, 2020)

DEPARTMENT	AVERAGE CONSUMPTION PER HOUSEHOLD [kWh]	YEAR 2017		YEAR 2025	
		NUMBER OF HOUSEHOLDS	CONSUMPTION IN KWH	NUMBER OF HOUSEHOLDS	CONSUMPTION IN KWH
Dagana	110	24 330	2 676 300	29 943	3 293 730
Podor	110	19 841	2 182 510	24 419	2 686 090
Saint-Louis	147	33 331	4 899 657	41 022	6 030 234
Région	122	77 502	9 758 467	95 384	12 010 054

While the amount of electrical energy consumed by households in the city of Saint-Louis was 9.7 GWh, this will rise to almost 12 GWh by 2025. This growth will be due to the increasing population and the growing number of electronic devices in households.

In 2018, the electrification rate in the city of Saint-Louis was 67%, or 21.5% less than in Senegal as a whole, if only urban areas are considered (GERES, n.d.). This shortfall could be compensated for by solar energy, thereby helping to preserve the environment. In the agricultural sector, a 604 kWp solar power plant should be able to supply a 2,000 hectares farm (Afrik21, 2023). This improvement in Senegal's energy mix is also being felt at the University of Gaston Berger in Saint-Louis, where several small photovoltaic systems have already been installed. The table below gives an overview of the installed capacity.

Table 5 | Existing Photovoltaic Systems at the UGB

LOCATION	[kWc]	STORAGE SYSTEM	OPERATING DATE	TARGETS
Computer centre	07	4 Batteries of 12 V, 100 Ah	-	Empowerment of the IT server room
CEA MITIC[7]	07	-	-	Stand-alone computer server room
UFR SAT	06	-	-	Autonomous physics and IT practical work rooms
Building I (UFR SAT)	3,15	-	20th avril 2022	Training for students enrolled in the Renewable Energies master's program and, above all, guaranteeing continuity of service in practical work (PT) laboratories

[7] African Center of Excellence in Mathematics, Computer Science and TIC (CEA MITIC)- (Information and Communication Technologies).

As the data collected from the chairman of the 2ISC committee, Mr. Amsata NDIAYE, shows, not only are effective measures being taken to enable the UGB to become energy self-sufficient, but emphasis is also being placed on practical training for students. A total of 23.15 kWp (kilowatt peak) has been installed at Gaston Berger University. SENELEC only intervenes when this production is insufficient to supply the loads. The 3.15 kWp solar system, the components of which were acquired thanks to the STAIRE project[8], covers the electricity demand of the "IL01" physics laboratory in building "I". An extension of this project is planned to supply the teachers' offices in the vicinity of this laboratory.

NOTE: Further information are joined to this master plan in WP4b.

7.5 Wastewater Pumping Stations

Among the main targeted fields to be developed is the wastewater systems. The current situation in Saint-Louis shows that there exists almost 12 wastewater station and 17 of rainwater stations. According to ONAS, the pumping stations are all functional (wastewater and rainwater). However, the pumps are undersized as the number of inhabitants of the city is increasing.

The Saint-Louis wastewater network was carried out in several phases of work (ONAS, 2016):

- ***A). Initial Stage:*** The network established during the colonial era was primarily concentrated at the island level.
- ***B). Subsequent Stage:*** Implemented based on the master plan created in 1981, this phase involved the improvement of certain areas, including Ndar Tourte, Sor Nord, Balacoss, Diamaguène, HLM, Léona, and some residences in Ndiolofène. Italian cooperation primarily funded this phase, which encompassed the construction of the central discharge station (SP 14) depicted in Figure 8 and the pipeline leading to the lagooning station.

Figure 8 | Pumping Station SP14, (© IfaS)

Another issue of the current situation is having other waste inside pumping stations of wastewater which can lead to several problems as shown in Figure 9.

[8] Strengthening Aquaculture Industry through Renewable Energy

Figure 9 | Discharge chamber of Leona (Right) and Goxu Mbacc (Left) Pumping Stations station Full of Waste, (© IfaS)

In Senegal, the rainy season typically occurs between June and October. During this time, the country experiences increased rainfall and higher humidity levels. Generally, the rains begin in the southern part of the country in June and gradually progress northward, reaching the northern regions by July or August. The heaviest rainfall usually occurs between August and September.

According to ONAS data inventory, the pumping stations have a remarkable increase of water during the period of August and October, for instance SP 14 reached in October 2021 a volume of 109,130 m^3.

Moreover, the type of pumps in Saint-Louis stations is submersible. These pumps are commonly used in wastewater applications due to their design that allows them to be submerged directly in the wastewater. Figure 10 demonstrates a nonfunctional exemplary pump.

Figure 10 | Low Efficient and Nonoperating Pump, (© IfaS)

From the 29 pumping stations, LoSENS project focused more on the priority and biggest stations to conduct the measurement and extract the efficiency analysis. The six stations have more data availability and are represented as follows (location is shown in Figure 11):

Table 6 | Main Six Pumping Stations and Their Average Volume of Collected Effluents

MAIN PUMP STATIONS	*AVERAGE WW VOLUME (m^3/month) 2020*	*AVERAGE WW VOLUME (m^3/month) 2021*
WASTEWATER		
SP 14	87,235	64,888
SP 4	18,758	10,753
SP 2	11,076	12,473
RAINWATER		
Leona	16,828	50,596
Ile Nord	8,390	4,255
Goxu Mbacc	86	212

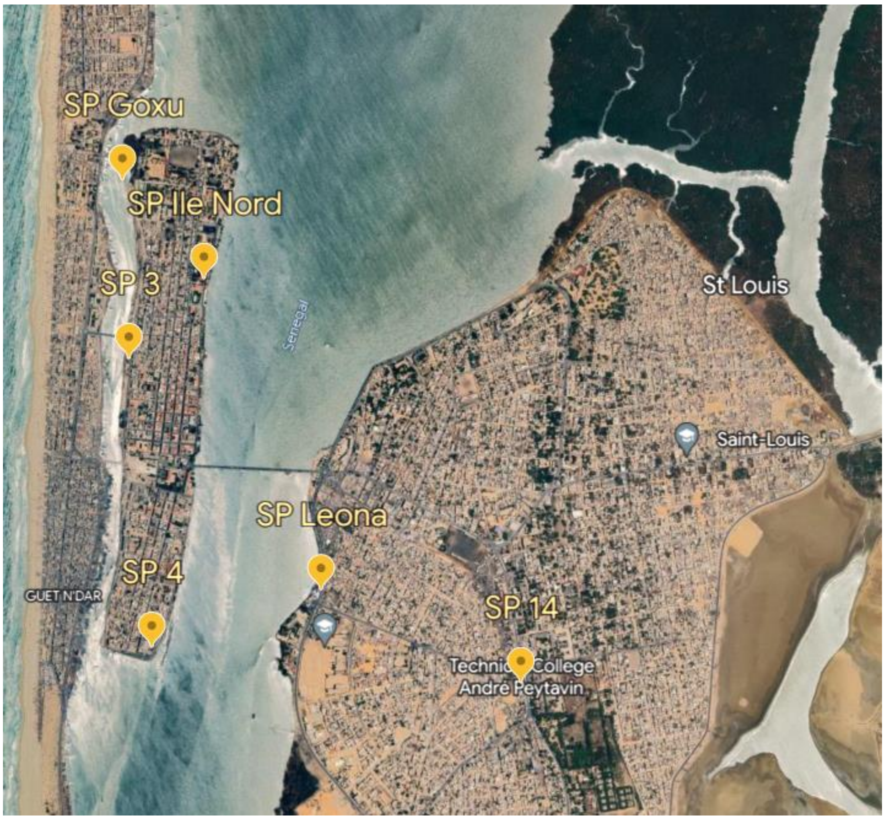


Figure 11 | Priority Pumping Stations Location in Saint-Louis, (Google Earth Satellite Image edited by IfaS)

From the summary map in Figure 12, the collected rainwater in each individual pumping station is directly discharged to the river. On the other hand, the wastewater has a connection between all stations which let the effluents to be gathered in the main lagooning station. Afterward, WW is not treated, and this raw sewage is dumped in the river which flows into the ocean.

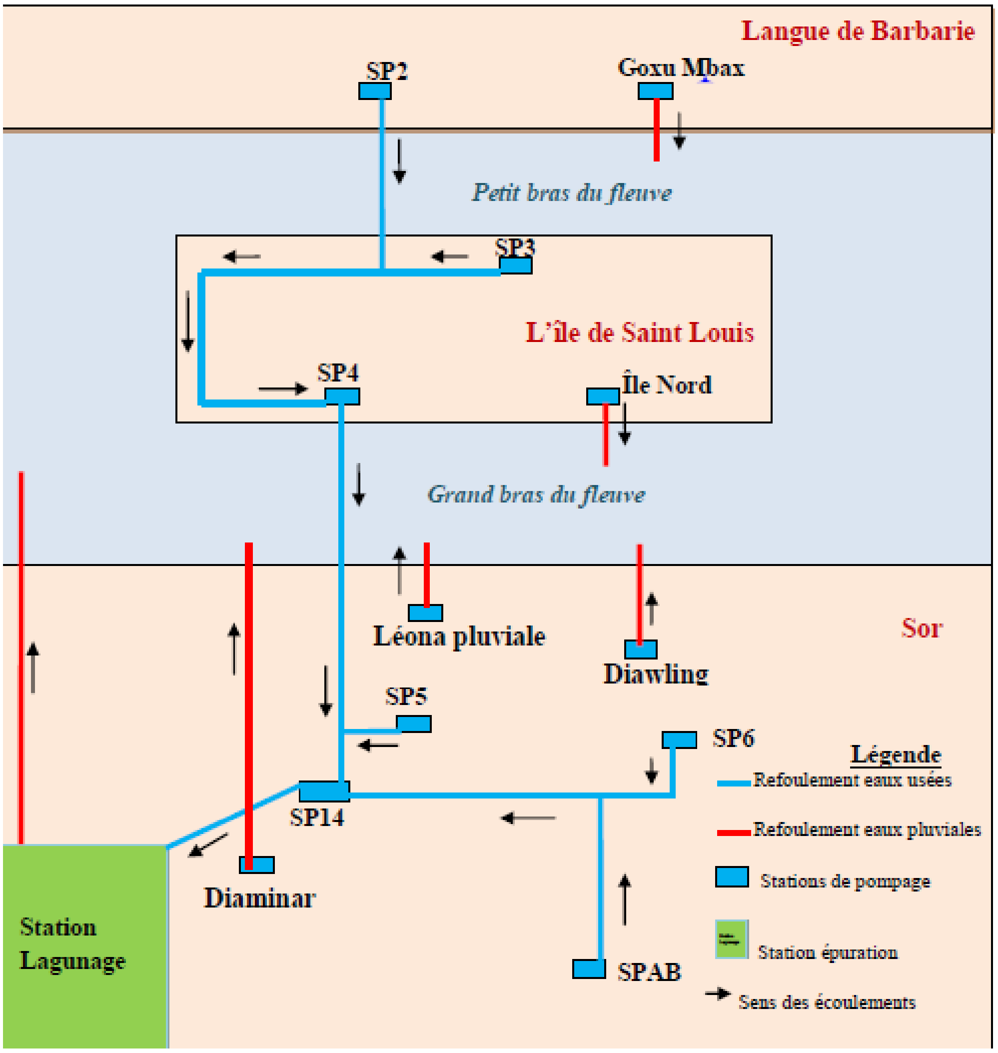


Figure 12 | Summary Map of Main Pumping Stations in Saint-Louis, (ONAS)

NOTE: The sewage treatment plant as shown in Figure 12 is in planned to be re-established in next years. The wastewater generated from the pumping stations is directly dumped in the river.

The current situation shows the inefficient system of the pumping stations, the high energy consumption, and the mismanagement of wastewater and rainwater reuse. Accordingly, Leona and SP 14 which have mostly the highest amount of collected wastewater. Because of old infrastructure, the stations do not include a digital system to collect data automatically.

NOTE: Further information are joined to this master plan in WP4c.

7.6 Waste Management and Biogas

Solid waste management in Saint-Louis is a complex issue, with challenges such as inadequate infrastructure, low awareness of waste reduction, contamination of existing landfills, and issues related to informal waste collection. The Senegalese government, local authorities, and civil society organizations are working to improve waste management in Saint-Louis. Awareness campaigns, training, and capacity-building initiatives are being implemented to encourage the population to adopt more sustainable waste management practices, such as waste sorting and recycling.

A quick overview of the public cleaning sector of the city of Saint-Louis highlights the following context (Rouyat et al., n.d.):

- In 1992, within the framework of the study carried out with the support of the "LILLE Saint-Louis" partnership, the Nord Pas-de-Calais Region and the French Ministry of Cooperation, the latter had retained in its priorities a project collection and evaluation of household waste.
- The CETOM project (Collection, Evaluation and Treatment of Household Waste) was created in 1994. Its objective is to put in place a new waste management strategy by introducing into practice the use of soft technologies (animal traction and high intensity labor).
- The test phases began in 1994 in a few districts of the municipality and led to the establishment of an organization of cleaning committees in these gradually.
- This approach is accompanied during the evolution of the project by the mobilization of various partners around the main objective of improving the management of waste.

Waste collection and management in Saint-Louis is handled by the waste management coordination unit (UCG) which is an initiative to offer unemployed educated women job opportunities. The UCG is responsible for waste collection, transportation, and disposal. Since June 2022, the National Waste Management Company (SONAGED: Société National de Gestion Intégrée des Déchets) took over the role of UCG in Saint-Louis.

The waste generated is collected in big bins and containers and deposited at certain collection points "sites-relais" around the city. Then, big trucks collect the waste from the different collection points and transport it to a landfill called "Centre d'Enfouissement technique (CET)" outside of the city of Saint-Louis. The Senegalese ministry in charge of environment started a program to construct engineered landfills or CETs in 11 cities in Senegal. One of them is the dumpsite of the municipality of Saint-Louis, located in the community of Gandon. This CET, which lays over an area of 2.5 ha, was constructed so that the waste is disposed of without polluting the environment following the international standards. However, due to some logistic problems the CET lost its accreditation, and it is now just like a normal landfill.

Once the waste is disposed of in the collection points (see Figure 13), small children and scavengers come and pick the biowaste such as fruits and vegetables waste and take it, whether to feed their domestic animals or sell it to other farmers. This leaves very small to inexistent amounts of biowaste that could reach the CET.

Figure 13 | A Bin Filled with Mixed Waste from Sor Market, (© IfaS)

On the site of the landfill, there are various children and women (see Figure 14) who, once the truck pours the waste, start manually sorting the waste to collect hard plastics or metals and sell it to people who are interested. For the LoSENS project, the focus will be only on the organic waste as it has a higher potential to be used for biogas production.

Figure 14 | Waste Dumping at the CET of Gandon, (© IfaS)

In the effort of satisfying the energy demand of the growing population, Senegal has been implemented since 2009, the national domestic biogas program (PNB- SN). This program aims at installing domestic biogas digesters more 52,000 digesters between 2021 and 2030 across the whole country[9].

Le Partenariat participates in the bioenergy production projects by working with agropastoral households under the scope of the PNB. Along with the commune of Saint-Louis and other local NGOs, Le Partenariat installed many biogas digesters in the region of Saint-Louis. So far, there are 73 biogas digesters projects in Saint-Louis installed within the framework of the PNB. 55 of these

[9] Senegal's National Domestic Biogas Programme (PNB-SN), Climate Focus, 2020

digesters are already installed and 18 are still under construction. Figure 15 shows the location of some of these biodigesters.

NOTE: All the installed biogas plants visited during the trip to Saint-Louis were not operating due to lack of maintenance.

Figure 15 | Installed Biogas Plants in Saint-Louis, (© IfaS)

NOTE: Further information are joined to this master plan in WP4d.

7.7 Main Gaps

From the status quo of Saint-Louis, the analysis brings into attention several economic, social, and environmental problems related to energy production, public streetlights, waste management, and wastewater pumps. Here are some of these problems:

I. Public Street Lighting:

A). Social and technical problem

As mentioned above, a well-lit road contributes to the wellbeing of its users and the surrounding population. Many streets in Saint-Louis are not lit, and even when they are, some poles are in very poor conditions. In addition, tree branches prevent the light from spreading in all directions, and the lamps are defective. Apart from the above-mentioned problems, the spacing between poles is not uniform, and neither is the size of the poles. This has a considerable influence on light distribution.

B). Economic and environmental problem

The inventory carried out in the Diamaguène district revealed that the halogen lamps installed are based on outdated technologies, and that their wattages are very high compared with LEDs, which also provide better lighting. The energy consumption of these halogen lamps is consequently high, increasing the municipal bills as well as the CO_2 emissions balance.

II. Solar Power:

A). Social and technical problem

The recurring load shedding, which can be observed, testifies to the instability of the network in Senegal, even in Saint-Louis. SENELEC in its annual report also highlights the losses and theft during the transport of energy. If households suffer from these cuts, students at Gaston Berger University suffer as much, because some courses that are given in the evening are very often canceled.

B). Economic and environmental problem

Renewable energy projects are associated with very high costs. Even if it is profitable in the long term, the investment costs are not within everyone's reach. This form of clean energy will also limit emissions caused by the use of fossil fuels.

III. Wastewater Pumping Stations:

A.) Technical and technology problems

Accessibility: Wastewater pumps stations are located in hard-to-reach zones, making it challenging for maintenance personnel to perform regular efficiency checks and inspections.

Frequency: Regular efficiency checks are crucial, but the frequency of inspections is limited and this affect the accuracy of data inventory.

Data collection: Gathering accurate data for pump efficiency checks was difficult, especially the pump station which lacks modern monitoring and data logging systems.

Aging infrastructure: Older pump stations have outdated equipment and is not performed optimally, making it harder to achieve high efficiency levels.

Maintenance delays: Limited resources or bureaucratic procedures can lead to delays in pump maintenance and repairs, impacting pump efficiency and overall system performance.

Energy consumption: Wastewater pump efficiency is closely tied to energy consumption. High energy demands can result from inefficient pumps, but assessing efficiency solely based on energy use might not capture other factors affecting pump performance.

B.) Environmental problems

Clogging and risk of pump failures: Solid waste and debris are accumulated in the pumping station's equipment, such as screens, pumps, and pipelines, causing clogging. This reduces the station's efficiency and may lead to equipment malfunction, requiring frequent maintenance and repairs.

Environmental Pollution: The absence of sewage treatment system as well as the discharging untreated or inadequately treated wastewater into a river are a significant environmental concern.

NOTE: To address these limitations, the municipality of Saint-Louis and wastewater management authorities should invest in modern monitoring systems, predictive maintenance techniques, and regular staff training to optimize pump efficiency and extend the life of the wastewater infrastructure.

IV. Waste and Biogas Plant:

A). Economic problems

High costs of waste management: Collecting, treating, and disposing of waste require significant financial resources. The high costs of waste management can burden local authorities and limit funds available for other important economic investments.

Lack of adequate infrastructure: Saint-Louis may face a lack of adequate waste management infrastructure, such as treatment facilities, sanitary landfills, and recycling facilities. This can result in inefficiencies in waste management and additional costs for disposal.

B). Social problems

Impact on public health: Inadequate waste management can have detrimental effects on public health. Improperly managed waste can contribute to the spread of diseases. Waste bins are the perfect place for rodents such as rats to eat and the more rats there are, the higher the chances of spreading dangerous diseases. Exposure to harmful chemicals, and contamination of water resources poses risks to the health of local residents.

Informal employment and precarious working conditions: In some cases, informal waste collection may be practiced by individuals facing economic vulnerability. These informal jobs can be hazardous to the workers' health, with exposure to hazardous waste, challenging working conditions, and limited income.

C). Environmental problems

Environmental pollution: Inadequate waste management can lead to air, soil, and water pollution. Untreated or improperly disposed waste can release toxic substances and contaminate local ecosystems, posing threats to biodiversity and the natural environment.

Impact on coastal ecosystems: In Saint-Louis, located along the Atlantic Ocean, poor waste management can contribute to coastal erosion and pollution of beaches and marine ecosystems. This can have negative consequences for fishing, tourism, and fragile coastal ecosystems.

NOTE: It is important to implement effective waste management measures such as selective collection, recycling, biogas production, and waste reduction awareness. This can help address these economic, social, and environmental problems related to waste management in Saint-Louis while promoting a more sustainable circular economy.

In general, LoSENS project master plan for Saint-Louis city focuses on the main key actors' disparities as shown in Figure 16 which concerns sustainability and environment protection from the population habits.

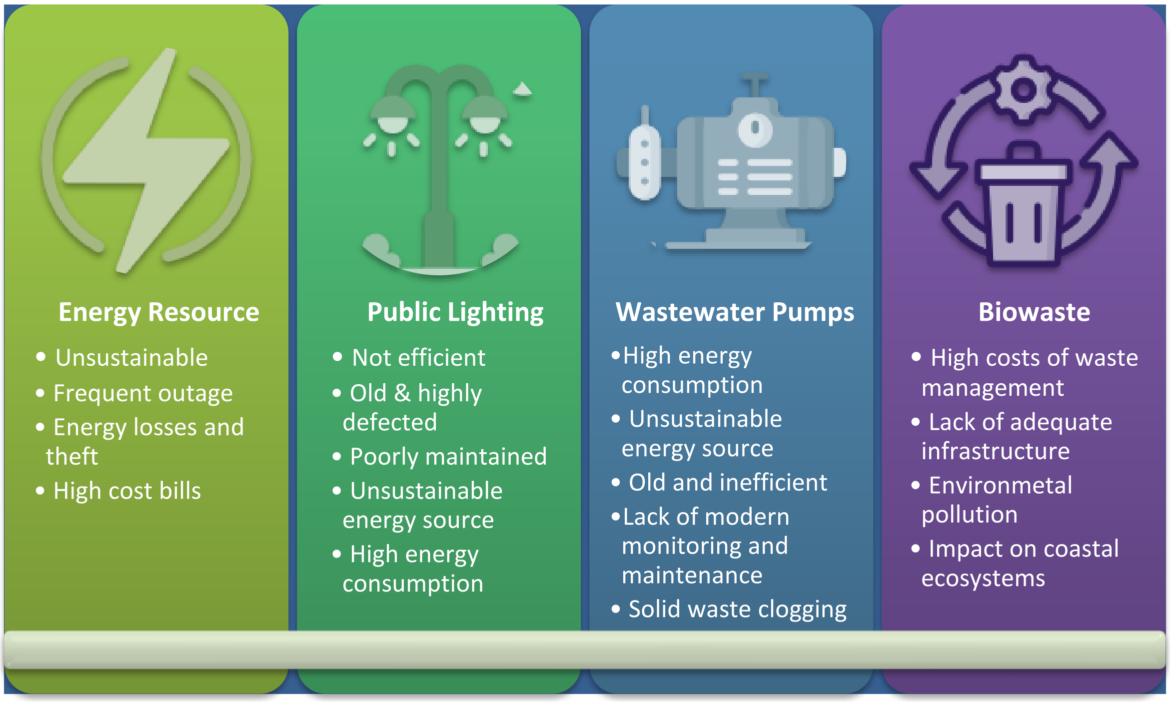


Figure 16 | Four Main Sectors Gaps in Saint-Louis City, (© IfaS)

8 Strategies and Actions for Saint-Louis

The preceding chapter focused on energy sinks gaps within the master plan, it has been thoroughly assessed the current state of energy consumption and identified critical areas for improvements. Now, the focus is on the chapter of potentials and solutions, the vision is to unlock a greener, more sustainable future. This chapter aims to present a comprehensive array of innovative and pragmatic solutions that hold the key to bridging these identified gaps and creating a transformative impact.

NOTE: The given potentials of Saint-Louis city are resulted from project technicalities Work package (WP4) that explains in detail the followed steps and outcomes.

8.1 Public Lighting Efficiency Potential

8.1.1 Project Demonstration and Planning

The aim of this part of the master plan is to optimize the public lighting system in the city of Saint-Louis, Senegal. 100 high-quality LEDs will replace 100 halogen lamps in the city.

Collaboration with the city council's technical department was necessary in order to better plan the progress of the project and obtain more information on the important elements to be taken into consideration. As a result, several working sessions had to be held, at which the working method was defined.

To better prepare for the installation phase of the 100 Lamps, a prototype was installed (Figure 17). This also enabled the familiarization with the realities on the field. The success of this installation as well as the quality of the light produced had a positive impact on the neighboring population and the lamp was appreciated by the technical service of the public lighting who requested that a part of the lamps be installed on the avenue Général de Gaulles, which is considered as the showcase of Saint-Louis. Moreover, the energy saving would be greater at this level, since the lamps installed there have a power of 125 W each, that is 3,750 W for the 30 Nikkon lamps installed along this street.

Figure 17 | Prototype of the Lanz lamp Installed at the Intersection of DG 14 and DG 21 in the Diamaguène District of Saint-Louis, (© IfaS)

8.1.2 Methodology and Analysis

First of all, it is important to stress that the EN 13201: 2015 standard was used to assess the quality of public lighting on the streets selected.

Moreover, it was necessary to draw up an inventory of the situation in Saint-Louis. A representative neighborhood, Diamaguène, was chosen for this purpose. Based on the data collected, it was found that 110 of the 150 lamps identified were in operation.

DIALux simulation software was used to simulate the current lighting situation in the region. To do this, several parameters were required. These are shown in Figure 18.

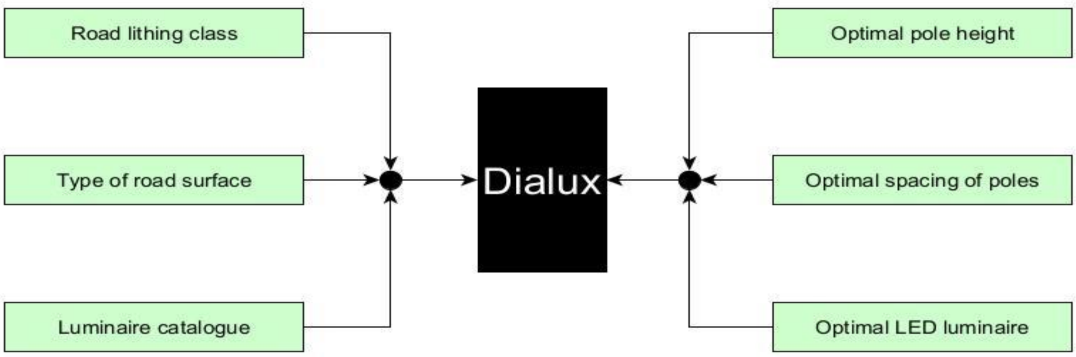


Figure 18 | Simplified Interface of DIALux Simulation Software, (© IfaS)

The lighting classes of the streets studied were selected according to the EN 13201: 2015 model. These classes vary depending on whether the street is DG 25, Avenue Général de Gaulle or National 2 (N2), which justifies the fact that the recommendations of the CIE are different for each of these classes. The following table shows the classes used along this work and the location of application. Apart from DG 25 and Avenue Général de Gaulle, both the "C" class for conflict areas and the "M" class for motorized areas can be assigned to National Road 2 (N2), since the latter, due to its length, crosses several cities with different characteristics and users.

Table 7 | Overview of Lighting Classes According to EN 13201

LIGHTING CLASS	*PLACE OF APPLICATION*
P	Lighting classes P1 to P7 are used for pedestrian areas, cycle paths, representative streets, residential streets, parking roads, car parks, school grounds, hard shoulder areas and other non-traffic road areas etc. Example: DG 25 Street
C	Lighting classes C0 to C5 are applied in the same way as classes M, but in this case for roads with conflict areas like road intersections, junctions, traffic circles, traffic jams at junctions, streets with pedestrians and cyclists, shopping streets and business streets, including underpasses and stairs. Example: Avenue Général de Gaulle, N2
M	Lighting classes M1 to M6 apply to roads with medium to high traffic speeds. Example: the N2

The number of the appropriate lighting class is based on the options selected for each parameter (speed, road users...) and is given by the following equation (Medway, n.d.):

$$\textit{Number of lighting class} = 6 - (\textit{sum of weighting factors of selected options})$$

8.1.3 Feasible Potential

8.1.3.1 Result for DG 25

After introducing the road parameters and the type of luminaire currently used along DG 25 in the Diamaguène district of Saint-Louis, the spacings between poles were defined. In spite of the irregular spacings noted in some places, a distance of 30 m was set. Although this street does not have sidewalks, they were inserted during the simulation, in order to better represent the DG 25 street and its luminaries, which are not always located at the edge of the roadway. This offset of the house poles was materialized by a two-meter (2 m) sidewalk on each side of the roadway.

The following figure shows the results obtained after the simulation. These show that the average horizontal illuminance and the minimum horizontal illuminance are respected on the sidewalk 1, while the pavement and sidewalk 2 would be poorly illuminated, thus not meeting the requirements of EN 13201: 2015. Looking closely at these results and taking into account that a NIKKON lamp with a power of 98.16 W instead of 70 W, as in reality, was installed in some places (because the 70 W model could not be found in DIALux), it is clear that these results would have been worse with a 70 W lamp and undoubtedly below the recommendations of the standard over the entire width of the road.

	Taille	Calculé	Consigne	Contrôlé
Trottoir 1 (P3)	E_{moy}	7.98 lx	[7.50 - 11.25] lx	✓
	E_{min}	1.87 lx	≥ 1.50 lx	✓
	$E_{v,min}$	0.05 lx	≥ 2.50 lx	✗
	$E_{sc,min}$	0.19 lx	≥ 1.50 lx	✗
DG-25 (P3)	E_{moy}	7.41 lx	[7.50 - 11.25] lx	✗
	E_{min}	1.44 lx	≥ 1.50 lx	✗
	$E_{sc,min}$	0.04 lx	≥ 1.50 lx	✗
	$E_{v,min}$	0.06 lx	≥ 2.50 lx	✗
	TI[1]	4 %	-	-
Trottoir 2 (P3)	E_{moy}	1.41 lx	[7.50 - 11.25] lx	✗
	E_{min}	0.58 lx	≥ 1.50 lx	✗
	$E_{v,min}$	0.06 lx	≥ 2.50 lx	✗
	$E_{sc,min}$	0.17 lx	≥ 1.50 lx	✗

(1) pour information, ne fait pas partie de l'évaluation

Figure 19 | Results for Evaluation Field (NIKKON lamp), (© IfaS)

In order to correct this deficiency in light quality, the NIKKON luminaires were initially replaced with those from Lanz, this while maintaining the pole arrangement. Although the requirements of EN 13201: 2015 are only partially met, these results are, with one exception, better than those obtained with the NIKKON lamps. Especially since the minimum illuminance (respected when using Lanz lamps) is a difficult factor to optimize.

Although better, the results obtained with the Lanz lamps can be optimized by changing the pole arrangement. For the two previous simulations, a "one-lane layout" was used. The poles (6.5 m high) were placed on one side of the street with a spacing of 30 m and an arm tilt of 5°. For optimization, a spacing of 38 m between the poles (10 m high) was preferred, as well as an arm inclination of 10°. In addition to these modifications, a "staggered arrangement" was chosen. In this new configuration, the luminaires are present on both sides of the roadway.

For a better comparison, the results of these three simulations were entered into the Table 8.

Table 8 | Comparison of Results for the Different Evaluation Fields (DG Street 25)

DG Street 25 (P3)		Current situation	Simulation with the Lanz lamp	Simulation with the Lanz lamp
Manufacturer		NIKKON	Lanz	Lanz
Lamp		S0070	RALEDLAMP III V1, 3000K, asymmetrical, 36Watt	RALEDLAMP III V1, 3000K, asymmetrical, 36Watt
Type of lamp		Halogène	LED	LED
Power		98,6 W	36 W	36 W
Pole spacing		30 m	30 m	38 m
Total luminous flux		4764 lm	5372 lm	5373 lm
Arm tilt		5°	5°	10°
Height of light point		6,5 m	6,5 m	10 m
Type of layout		One way layout	One way layout	Two-way staggered layout
Evaluation criteria				
Pavement 1	**Setpoint**	**Outcome**	Outcome 1	Optimization
Eav	[7,5 - 11,25] lx	7,98 lx	6,69 lx	7,65 lx
Emin	>= 1,5 lx	1,87 lx	3,02 lx	5,28 lx
Esc,min	>= 1,5 lx	0,19 lx	0,63 lx	3,08 lx
Ev,min	>= 2,5 lx	0,05 lx	0,24 lx	3,74 lx
DG-25	**Setpoint**			
Eav	[7,5 - 11,25] lx	7,41 lx	9,48 lx	11,07 lx
Emin	>= 1,5 lx	1,44 lx	4,58 lx	9,31 lx
Esc,min	>= 1,5 lx	0,04 lx	0,24 lx	3,36 lx
Ev,min	>= 2,5 lx	0,06 lx	0,38 lx	4,82 lx
Pavement 2	**Setpoint**			
Eav	[7,5 - 11,25] lx	1,41 lx	2,99 lx	7,63 lx
Emin	>= 1,5 lx	0,58 lx	1,07 lx	5,22 lx
Esc,min	>= 1,5 lx	0,17 lx	0,42 lx	2,44 lx
Ev,min	>= 2,5 lx	0,06 lx	0,41 lx	2,84 lx

8.1.3.2 Estimated Savings

The inventory carried out in the Diamaguène district as well as for the new airport area provided information on the power of the various lamps installed. It follows that the 100 lamps to be replaced consume a total power of 7,730 W. Once replaced, this power will decrease by about 55% (4,238 W).

With the installation of the 100 new lamps, 33.86 MWh per year of electrical energy will be reduced, which will also limit the emissions of CO_2 and other fine particles released during the production of electrical energy. Thus, 16.15 t CO_{2e} could be saved per year by replacing 100 lamps. This energy saving will allow the municipality of Saint-Louis to save approximately 3.3 million CFA francs per year (4,967 €/a), without taking into account the possible increase in the price of electricity as well as the gains related to the "carbon price" (see Table 9).

Table 9 | Calculation of Savings Related to The Replacement of 100 Lamps

DESIGNATION	UNIT	STATUS QUO	OPTIMISATION
Power	W	7,730	3,492
Time of use per year	h/a	4,380	4,380
Energy consumed	MWh/a	33.86	15.29
Emission factor	kg CO_{2e}/kWh	0.87[10]	
CO_{2e} emission	t CO_{2e}/a	22.82	10.31
Cost per kWh (public lighting)	€	0.27[11]	
Total cost	€/a	9,059	4,092
Energy savings	MWh/a	18.56	
Savings per year	€/a	**4,967**	
CO_{2e} reduction per year	t CO_{2e}/a	**16.15**	

8.1.4 Installation and Monitoring

8.1.4.1 Lamps Localization

Because of its proximity to the stadium, the Mosque and to one of the important markets in the city of Saint-Louis, the Diamaguène neighborhood, where the quality of light was very poor has been chosen for the installation of the lamps. Figure 20 shows the number of 97 lamps that was planned to be replaced on each street.

[10] The IFI Dataset of Default Grid Factors v3.1
[11] Source : https://www.senelec.sn/grille-tarifaire

Figure 20 | Selected Streets for Lamp Replacement[12], (© IfaS)

NOTE: It was planned to install some of the lamps (30) on Avenue Général de Gaulles, as requested by the municipality's director of technical services, Mr. Sine Ali. Delays in the LoSENS project have not affected the plans of Saint-Louis town council, which has other projects planned for this road. The lights initially planned for this stretch of road were installed in the Diamaguène district (90 lamps) and near the new Saint-Louis airport (10 lamps) in Bango as the light quality was not up to standard and there was a great deal of uncertainty.

Figure 21 and Figure 22 demonstrate the localization of the 100 installed lamps:

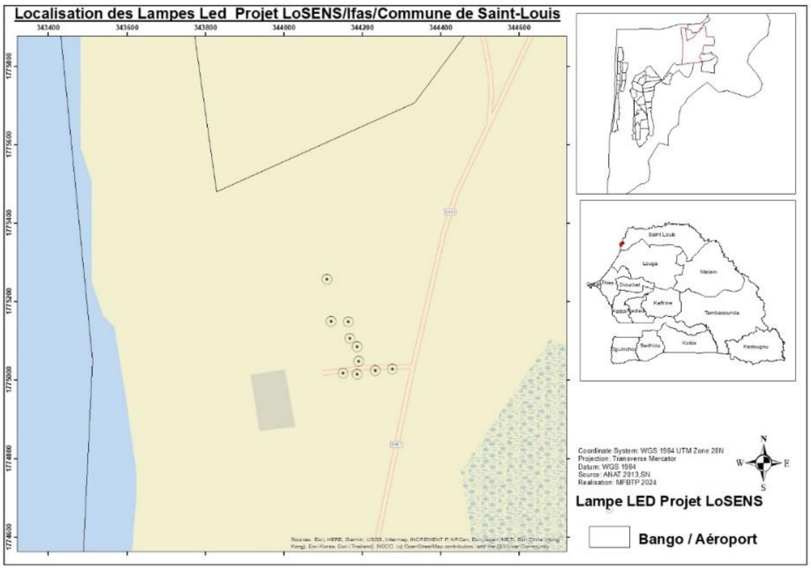


Figure 21 | Position of the Lamps in the Bango Neighbourhood-New Airport, (© IfaS)

[12] Edited plan from Google Maps.

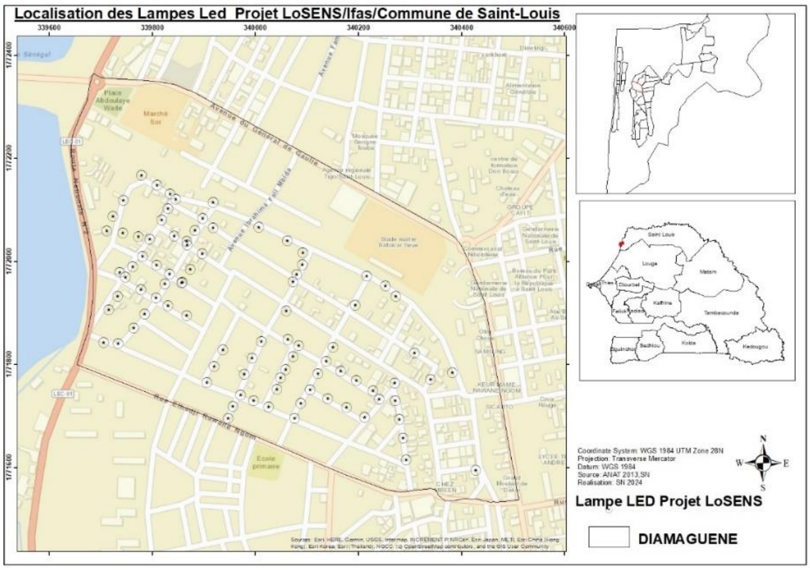


Figure 22 | Position of the Lamps in the Diamaguène Neighbourhood, (© IfaS)

8.1.4.2 Lamps Installation

To achieve the results described above, not only must the lamps in the various streets be replaced, but certain building regulations must also be observed. These are summarized in Figure 23 and Figure 24.

Mastabstand	30.000 m
(1) Lichtpunkthöhe	6.500 m
(2) Lichtpunktüberhang	1.500 m
(3) Auslegerneigung	5.0°
(4) Auslegerlänge	1.496 m
Jährliche Betriebsstunden	4000 h: 100.0 %, 36.0 W

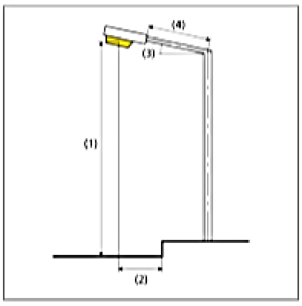


Figure 23 | Installation Settings on the "DG 25 Road"

Mastabstand	50.000 m
(1) Lichtpunkthöhe	12.000 m
(2) Lichtpunktüberhang	-3.500 m
(3) Auslegerneigung	0.0°
(4) Auslegerlänge	1.500 m
Jährliche Betriebsstunden	4000 h: 100.0 %, 36.0 W

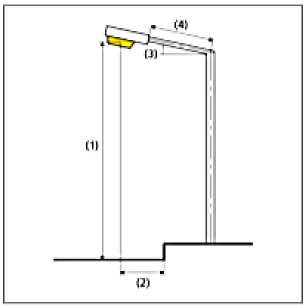


Figure 24 | Installation Settings on the "Avenue Général de Gaulles Road", (© IfaS)

The installation steps of a prototype of the Lanz luminaire selected as part of this project were installed in the city of Saint-Louis in Senegal in February 2022.

Once the lamp cuffs had been manufactured, they were wired up before being installed. The installation was not carried out on the streets initially planned, as can be seen in Figure 25. Nevertheless, the quality of the lighting was better than that of the halogen lamps. While around

5 lux could be measured directly 7 m below the pole, at least 25 lux was measured below the new lamps.

Figure 25 | A Few Installation Steps in Diamaguène, (© IfaS)

Figure 26 documents the relevant work steps for installing and commissioning the luminaire:

Figure 26 | Images of the Installation Steps of a Prototype of the Lanz Luminaire in February 2022 in the Diamaguène District of Saint-Louis, (© IfaS)

A direct comparison at the same location of the light quality before and after installation is unfortunately impossible, as the installation location was not predefined in advance. The condition of the post, its location (intersection) and the presence of a small business (shop) opposite justify this choice. Nevertheless, it can be concluded from Figure 27 that the junction of the streets "DG 14" and "DG 21" are better lit after installation (2 &3) than before (1).

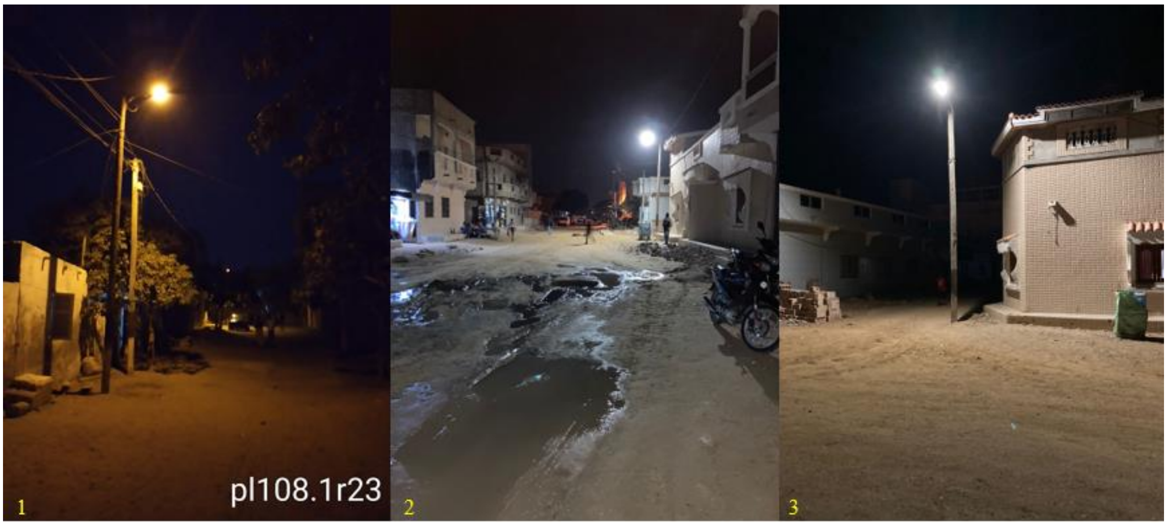


Figure 27 | Comparison of Light Quality Before and After Installation, (© IfaS)

Regardless of the type of installation and the light sources used, many parameters influence the quality of light. These are country-specific and cannot be generalized. Streetlights are installed with an "electrical ballast" unless the latter is already integrated into the light source. Ballasts are used for current limitation (ensuring constant currents and voltages at the output) and may contribute to dimming the luminaire (if it is an electronic ballast) (*Vorschaltgeräte | Licht.De*, n.d.). These components typically break down after a certain time (depending on the loads) and must therefore be replaced.

8.2 Solar Energy Potential

8.2.1 Project Demonstration and Planning

The potential of solar energy remains unexploited in several regions of Africa. As part of the LoSENS project, an analysis will be made of the potential for solar energy in urban and rural areas of Senegal. The solar system at the UGB will be used to analyze medium-sized consumers connected to the SENELEC network.

The LoSENS project is a pilot project in Saint-Louis. The installation of a photovoltaic (PV) system as part of this project remains a test, which will allow us to confront the realities on the ground, to understand how such a system works, etc. The information gathered during the monitoring phase will provide a solid database for the sizing of a larger system, which will bring Gaston Berger University in particular closer to energy empowerment, as well as other universities and cities in Senegal in general.

The 100 kWp PV system will cover part of the energy demand of Building A. This system will be sized in such a way that, in the event of load shedding, part of the installed solar modules will continue to supply energy to the pre-selected premises of the said building; To do this, the modules will be connected to a battery-powered inverter. In addition to this component, the following elements will be connected to the PV system:

- Inverters: for the transformation of direct current from solar modules into alternating current.

- A battery storage system of up to 100 kWh: for the storage of excess energy produced.
- A resale meter and a bidirectional meter: to analyze the flow of energy.
- A junction box: for the connection of a circuit, as well as the distribution of the electrical circuit to different devices (sockets, lighting, etc.).

8.2.2 Methodology and Analysis

PV*SOL is a powerful tool used for the simulation of photovoltaic systems. It makes it possible to simulate such systems connected to an electrical consumer and the grid and/or a storage system with or without islanding. PV*SOL's diverse database gives the user a free choice to integrate the desired components (modules, inverter, etc.). of a desired producer) to the simulation. The advantage of such a database is that it is instantly updated. However, the results are not obtained without any prior information. Before the choice of components, the surface area available for installation, the location of the construction of the system, the orientation of the building on which the system will be built, etc. are all necessary data.

According to measurements made on google maps, building "A" has a length of 74.7 m and a width of 12.24 m, i.e., an area of approximately 914 m^2 available to accommodate the PV system. Regarding the orientation of the modules, the south direction has an advantage since a module oriented in this direction receives solar radiation all day long. The orientation of the building does not favor this arrangement; For this reason, the modules were oriented towards the south-west and north-east, i.e., an orientation of 238° and 58° respectively. Compared to Western countries, the angle of elevation of the γ gamma sun is large enough at the equator, as well as in Senegal where the project will be carried out. As a result, the modules do not need to be high enough.

8.2.3 Feasible Potential

8.2.3.1 Yield Prediction and Amount of CO_2 Avoided

The results that will be presented in this section are those expected from the simulation that was done before the call for tenders. It will be possible to produce approximately 168,126 kWh of electrical energy per year, i.e., a specific annual efficiency of 1,608.16 kWh/kWp and a coefficient of performance[13] from 83.64%.

Let Alpha (α) be the sum of the direct own consumption and the consumption covered by the battery system. The rate of self-consumption is the ratio of Alpha and the total production of the solar system. The solar coverage rate, on the other hand, is the ratio between alpha and total consumption of the building. It is predicted to be 61.2%, while the share of own consumption will be 78.8%.

The detailed results of the simulation have been consolidated in the Table 10. It shows that around 146,269 kg CO_{2e} could be avoided per year.

Table 10 | Estimated Annual Production, Energy Performance Factors and Emission Reductions

[13] Ratio between the actual energy output of the PV system and the expected power based on solar radiation and panel area.

PARAMETERS	VALUE	UNIT
PV system		
PV Generator Power	104.52	kWp
Specific Annual Return	1,608.16	kWh/kWp
Facility Coefficient of Performance (PR)	83.64	%
Yield drop due to shading	0.8	%/a
PV Generator Energy (AC Grid)	168,126	kWh/a
Direct own consumption	76,521	kWh/a
Charging the batteries	56,014	kWh/a
Resold energy	35,591	kWh/a
Share of own consumption	78.8	%
Avoided CO_2 emissions	146,269	kg/a
Consumers		
Total building consumption	200,000	kWh/a
Standby Power Consumption (UPS)	42	kWh/a
Covered by the network	77,591	kWh/a
Autarky	61.2	%

8.2.3.2 Comparison of Results with Other Sources

There are various software programs, including PV*SOL, that can be used to simulate photovoltaic systems.

In this work, the results obtained with PV*SOL are compared with data from Solargis and Renewables ninja. After the simulation with PV*SOL, it follows that 224 PV modules will be built at the LSU. This corresponds to a total module area of 489.68 m^2. Since the tracks of the PV modules do not contain PV cells, about 0.5 cm has been subtracted from the original length. In this hypothesis, the total surface area is 486.17 m^2. This figure is multiplied by the specific efficiency of 2,120 kWh/(m^2*a), the efficiency of the module and the system utilization rate of 78% (LACHHEB et al., 2021). This results in an annual output of 162,268 kWh (Medway, n.d.). Another alternative to calculating the efficiency would be to take the product of the installed capacity

(100.8 kWp) and the specific efficiency of 1,753 kWh/(kWp*a). The resulting output is 176,702 kWh. The average of these two yields was considered a result with Solargis.

The results of the three sources mentioned above are compared in Table 8.

Table 11 | Results of the Simulation with PV*SOL and Renewables Ninja and Results of the Calculation with Solargis Data

DESIGNATION	*VALUE*	*UNIT*
Solargis		
Rendement_1 (with installed power)	176,702	kWh/a
Rendement_2 (with total area)	208,248	kWh/a
Yield Correction (Surface with Cells Only)	206,754	kWh/a
System Utilization Rate	78	%
Efficiency 2 with plant utilization rate	161,268	kWh/a
Average Yield	**168,985**	kWh/a
Specific Yield	**1,753**	kWh/(kWc.a)
PV*SOL		
Annual return	**168,126**	kWh/a
Specific Yield	**1,608**	kWh/(kWc.a)
Renewables ninja		
Annual return	**189,280**	kWh/a

In Table 12, the influencing parameters are listed next to the results to better understand the differences. The "Comments" column deserves special attention here.

Table 12 | Comparison of the Results of PV*SOL, Solargis und Renewables Ninja

SPRING	DESIGNATION	VALUE	UNIT	COMMENT
PV*SOL	Annual return	168,126	kwh	Any losses (due to dust, wiring, wiring, weathering, etc.) are taken into account here. The modules are tilted and receive only a portion of the total solar radiation.
	Specific Yield	1,608.16	kWh/kWp	
	Radiation on module surfaces	1,942	kWh/m^2	
	Tilt of the modules	10	°	
Solargis	Annual return	168,985	kwh	The degree of load of the system components influences the efficiency. Solargis does not take this into account. It is also calculated in part with the maximum horizontal radiation and maximum efficiency of the module. The inclination and orientation of the module are neglected. For this reason, this efficiency would be higher, although the utilization rate of the system used is only 78%.
	Specific Yield	1,753	kWh/kWp	
	Specific Yield	1,753	kWh/(kWp*a)	
	Horizontal Radiation	2,120	kWh/(m^2*a)	
Renewables ninja	Annual return	189,280	kWh/a	The south orientation of the solar modules, as set during the simulation with Renewables ninja, is advantageous because the installation is lit all day and therefore provides a better yield. A south-east or north-west orientation as at the UGB was impossible. Casualties were also overlooked in this simulation.
	Horizontal Radiation	1,963	kWh/(m^2*a)	
	Tilt of the modules	10	°	
	Losses	0	%	

Despite the differences, the results of Solargis and PV*SOL are very comparable. This proves that the installation at the LSU has been well designed. Even though the results with Renewables ninja seem quite high, they are almost identical to the others (PV*SOL and Solargis). Yields with Renewables ninja are 13% higher than PV*SOL. The technical losses (system utilization rate) of a PV system vary between 10% and 20%[14]. The calculated 13% is within this range and can be attributed to the facility utilization rate overlooked by Renewables ninja.

[14] Fraunhofer Institute for Solar Energy Systems ISE, Current facts about photovoltaics in Germany.

8.2.3.3 Economic Evaluation

The parameters and assumptions of the Table 13 are used for the calculation of economic performance indicators. To determine the operating costs (maintenance, operating and insurance costs) of a PV installation, it is recommended to take an annual amount of 1.5% of the investment and a service life of 20 years. In this work, it is assumed that the annual operating costs amount to 2% of the investment. Insurance costs are presented separately, up to 1% of CAPEX, and electricity costs come from a Gaston Berger University bill. It is also assumed that these costs increase by 1% per year, as shown by the Table 13 .

Table 13 | Parameters for Cost Calculation

PARAMETER	*VALUE*	*UNIT*
Operating Expense Rates	2	%
Increase in operating costs	1	%
Insurance Fee Rates	1	%
Rising insurance prices	1	%
Rising electricity prices	1	%
kWh price	0.21	€
Annual kWh production	168,126	kWh/a
Amount of kWh production in 20 years	3,362,520	kWh

The Table 14 shows the annual composition of the cash flow over the service life of the PV system. For the sake of clarity, some years have been masked. Thanks to the PV system that will be built at the UGB, each kilowatt hour produced will cost €0.147. The internal rate of return associated with CAPEX and OPEX is 8%.

Table 14 | Economic Analysis for a 100 kWp System with Batteries in €

PARAMETER	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
PV System Cost	**-151,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cost of the storage system	**-120,898**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cost of Ownership	-5,438	-5,492	-5,547	-5,603	-6,376	-6,440	-6,505	-6,570
Insurance	-2,719	-2,746	-2,774	-2,801	-3,188	-3,220	-3,252	-3,285
Charged Costs	-280,055	-288,293	-296,614	-305,018	-422,234	-431,894	-441,651	-451,506
Feed-in tariff	0	0	0	0	0	0	0	0
Power Generation	160,816	160,012	159,212	158,416	148,422	147,680	146,942	146,207
Savings	34,555	34,726	34,552	34,379	32,210	32,049	31,889	31,730
Annual Cashflows	**-245,500**	**26,487**	**26,231**	**25,975**	**22,646**	**22,389**	**22,132**	**21,875**
Cumulated Cashflows	-245,500	-219,013	-192,782	-166,807	147,573	169,962	192,095	213,970
LCOE	**0.147 €/kWh**							

The Figure 28 shows the accumulated cash flow as well as the payback period of the installation. The latter is about 10.5 years.

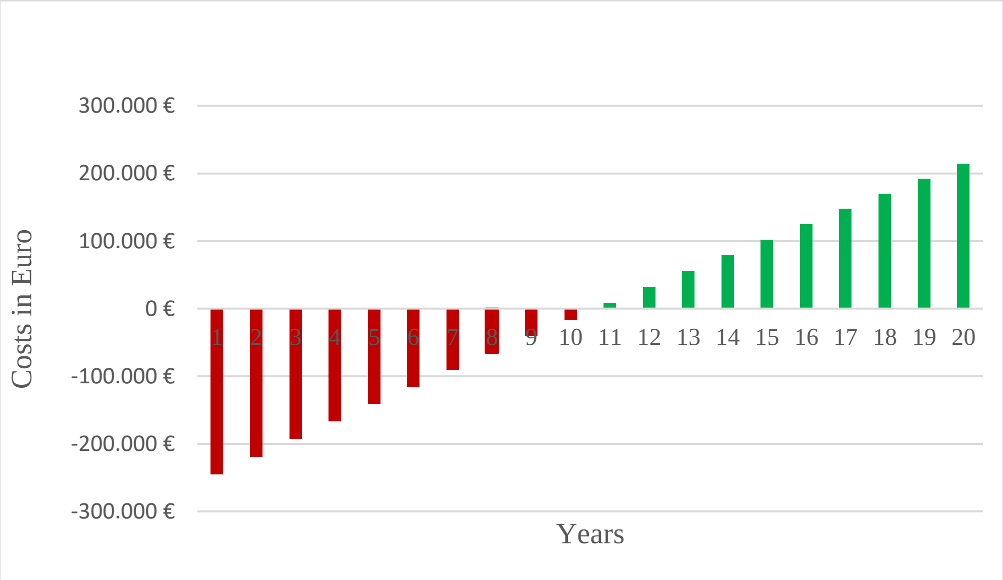


Figure 28 | Flow of Money from a PV System with Batteries over the Life of Use, (© IfaS)

The payback time of the system without storage with 100% self-consumption will be around 5.5 years, while the LCOE (cost price of one kilowatt hour) would be reduced to €0.082. Such a system will be more cost-effective with an internal rate of return of 22.96%.

8.2.4 PV Plant at UGB

In the second half of 2023, Bonergie has successfully installed the PV plant for UGB-Building A (see Figure 29). during this period, many students from the Interuniversity Master in Renewable Energies program[15] Master Interuniversitaire en Energies Renouvelables (MIER) had participated in the installation of a state-of-the-art photovoltaic (PV) plant at the heart of our academic hub (see. Figure 30).

The purpose of integrating students in this activity is learning how the PV plant seamlessly integrates with the university's existing infrastructure. Furthermore, the reason is not only generating clean energy but also cultivates a new generation of environmentally conscious and skilled individuals.

Figure 29 | PV Plant Installed in Building A at UGB, (© IfaS)

[15] MIER: Master Interuniversitaire en Energies Renouvelables-Interuniversity Master in Renewable Energies. https://www.ugb.sn/sat/index.php/90-sat/143-master-energies-renouvelables

Figure 30 | Technical Chamber of PV Plant with the Participation of Students and Technicians, (© IfaS)

NOTE: The installation of the photovoltaic (PV) system at UGB has been underway, but numerous delays have affected the timeline. The monitoring phase will continue after the end of the project so that long-term data series can be created. UGB is moving closer to sustainable energy solutions with the installation of the PV system, and every effort is being made to overcome any obstacles that may arise. When the system is well maintained, it will strengthen the university's commitment to green energy techniques.

8.3 Wastewater Pumps Efficiency Potential

One of the key actors of LoSENS project in Saint-Louis to be developed is wastewater pump efficiency. It is crucial for reducing energy consumption, lowering operational costs, minimizing environmental impact, ensuring system reliability, and meeting regulatory requirements. By focusing on pump efficiency, wastewater treatment facilities can optimize their operations, improve resource utilization, and contribute to a sustainable and effective wastewater management system.

8.3.1 Project Demonstration and Planning

In this master plan, wastewater pump stations are targeted to be more efficient in the future. From the first stage of the project, ONAS provided the main data and details regarding the stations and their current situation. The objective of this analysis is to develop an energy efficiency method where less energy is consumed to attain the same amount of useful output. As a result, there are opportunities for changing the current situation at all levels of energy use as well as the amount of pumped water. The project was based on the following stages:

Figure 31 | Efficient Pump Management Work Package Stages, (© IfaS)

The project had two active partners who helped to conduct the analysis of pumping stations in Saint-Louis in particular for six priority ones. One partner is Water Technology; a company for technical service and industrial maintenance, was charged of onsite measurements. On the other hand, the main partner of LoSENS project is Kocks Consult GmbH; provided the full comprehensive solution to develop an efficient pumping station for the model city.

NOTE: It is important to note that conducting a comprehensive efficiency analysis of wastewater pumps in Saint-Louis requires specialized engineering expertise and collaboration with relevant stakeholders, such as wastewater treatment authorities, pump manufacturers, and energy experts.

8.3.2 Methodology and Analysis

In more details, the methodology consists of examining the existing pumping stations situation with all their measurements and comparing them with a new guideline of new pumps that are more efficient. The outcome of this analysis is the savings of energy as well as the avoided emissions. In the absence of monitored energy data, the efficiency rate and power consumption had to be calculated based on the provided data. Accordingly, the measurements included the flowrate, pressure, and electrical parameters.

Analyzing the efficiency of wastewater pumps in Saint-Louis city required a comprehensive assessment of various factors. On one hand, the master plan focused on one example largest pump station of the city. On the other hand, the left list of pumping stations was examined by extrapolation the same methodology used by Kocks Consult GmbH with modifications.

8.3.2.1 Kocks Consult GmbH Methodology

Following the initiation of the project, a comprehensive approach was formulated to evaluate the existing pumping stations. This involved identifying opportunities for energy conservation and conducting an economic assessment to guide decision-making and potential investments.

The basic procedure for achieving the project goals is explained by the following graphic in Figure 32:

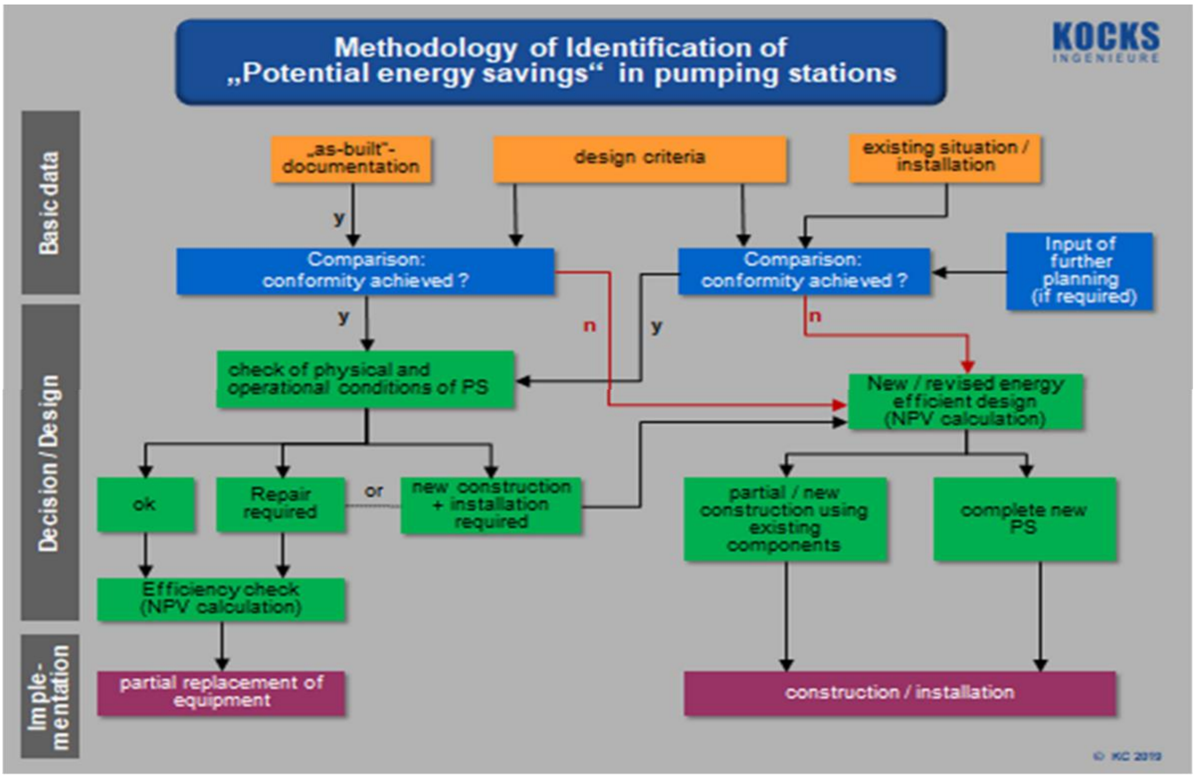


Figure 32 | Methodology for Technical and Economical Assessment of Pumping Stations, (© Kocks Consult GmbH)

8.3.2.2 Extrapolation of Pump Efficiency Methodology

The evaluation of pump efficiency is crucial due to the high energy demand associated with pump-set installations. This is a fundamental part of LoSENS Project technicalities to identify optimization opportunities. This write-up presents a step-by-step methodology for calculating hydraulic power, pump efficiency, net energy saved when installed new pump and CO_2 abatement potential based on the provided data.

1. Gathering required data and assumptions.
2. Calculate hydraulic power.
3. Calculate pump efficiency.
4. Selection of new pump from KSB[16].
5. Check for net save in energy and CO_2 abatement potential based on theoretical consumptions.

NOTE: The detailed methodology with equations is represented in WP4 report.

8.3.3 Feasible Potential

The analysis was driven by two example paths, one is regarding the pumping station that has all inventory data eligible for efficiency evaluations, and the other is regarding the total estimated evaluation for the city pumping stations including the stations that have a lack of data provision as well as not measured.

[16] KSB SE & Co. KGaA: a German multinational company produces pumps and valves. The company has facilities, sales teams, and service units across all continents.

8.3.3.1 SP 14 Evaluation

A). Energy Potential

According to the technical details of the individual pumping stations selected for measuring, SP 14 and SP Ile Nord have the biggest energy consumption. Thus, these units basically represent the biggest potential for energy savings. Yet, as described by Kocks Consult GmbH, also the results of the measurements for these 2 pumping stations are not plausible.

For the determination of a potential for energy saving, SP 14 was chosen as an example. There the nominal duty point meets the performance curve.

Given the flow rate and power measurements, the total pump efficiency is approximately 13%, whereas the efficiency at the nominal duty point, based on the performance curve, should be around 70%.

NOTE: The curves are taken from the pump producer with its model.

Firstly, the measurement results of pump 1 (P1) in SP 14, concerning flow rate and power (see

Table 15), are accurate and reliable for the analysis. However, the head measurement appears questionable, as it is significantly lower than the initially indicated value, only approximately 1/3 (13.5 m instead of 38.7 m). Consequently, a head of 30 m is assumed for the analysis.

Table 15 | SP 14 Technical Data

PARAMETERS	UNIT	NOMINAL DUTY POINT	ASSUMPTION
Flow rate	l/s	90	44
Head	m	38.7	30
Power	kW	47	43.5
Efficiency	%	72	30
Operating hours	h/a	1,354[17]	2,770[18]
Electrical consumption	kWh/a	63,648	120,495
Calculated flow rate	m^3/a	438,768	438,768

NOTE: With these values, as a result the reduced flow rate led to an overall pump efficiency of approx. 30%.

[17] Calculated operating time for "nominal duty point".
[18] Operating time existing pumping station from ONAS data.

Comparing the "nominal duty point" with the conditions as assumed above, a "fictious" potential for energy saving can be identified as follows:

Table 16 | SP 14 Energy Savings Results

PARAMETERS	UNIT	VALUE
Potential for energy savings	kWh/a	56,847
	%	47

NOTE: The total electrical consumption as indicated by the operator is approx. 158,000 kWh/a which is very high than the calculated value

B). Investment Projection

Based on Kocks Consult Gmbh analysis, expenses for yearly maintenance and servicing are calculated as follows:

- 0.5%/a of the investment costs for construction technology
- 2.5%/a of the investment costs for mechanical and electrical equipment

The project cost present values are determined based on a term of 25 years and an annual real interest rate of e.g., 3%. Replacement investments after a term of 12.5 years accounted for 67% of the costs of mechanical and electrical engineering.

The interest rate to be chosen depends on the economic conditions of the project and shall be defined by the owner/operator.

NOTE: A detailed report from Kocks Consult GmbH is joined to this master plan.

Two variant data assumptions were taken to compare and evaluate Different technical solutions–either for new construction or renovation of facilities. The manpower has only low influence on net present value, thus it is nearly similar for both variants. Variant 1 has continuing operation with the existing equipment with no changes and a replacement of pumps by new, effective pumps after 12.5 years. Variant 2 has directly a replacement of pumps (only) by new, effective pumps meeting the duty point.

Regarding the NPV general assumptions are made as follows:

- Costs for electrical power is 0.30 €/kWh[19].
- No price increase for the replacement of the pumps as foreseen in variant 1.
- Total term (lifetime) considered to be 25 years.

[19] It is also confirmed by ONAS for high tension consumption as SP14.

The following table summarizes the sum present value at real interest rate of 3%:

Table 17 | Sum Present Value for SP 14 in Two Different Variables

PARAMETERS	***VARIANT 1***		***VARIANT 2***	
	Nominal Cost €/a	***Present Value €***	***Nominal Cost €/a***	***Present Value €***
Investment cost	0	0	96,000	96,000
Re-Investment[20]	96,000	66,345	64,320	44,451
Operation cost (3;12,5)	36,149	372,221	-	-
Operation cost (3;12,5)	19,094	196,615	-	-
Operation cost (3;25)	-	-	19,094	332,494
Total present value		**635,200**		**473,000**

NOTE: The result of calculation shows that a timely replacement of the 3 pumps of SP 14 would be an economical solution for this pumping station.

8.3.3.2 Total Evaluation

In order to analyses the efficiency of the other pumping stations based on the measured data as well as Kocks' methodology, an n evaluation is made by choosing two scenarios of calculations regarding the main parameter which is the head of the pump:

1. ***Scenario 1:*** Considering the uncertainty surrounding the pressure measurement, where the originally indicated value is different than measured value. An adjustment is made in head to account for the possibility of reduced performance and efficiency over time. This assumption assumes a consistent relationship between head and pump performance across the pumps being analyzed.
2. ***Scenario 2:*** In this scenario, it is assumed that the measured head on the site corresponds to the actual head of the pump.

NOTE: Both scenarios were examined to assess the variation in pump efficiency between the old and new pumps. Moreover, the best scenario was chosen based on a suitable justification provided in the subsequent section.

[20] Re-Investment IKR (67% of the first Investment M+E) after 12.5 years.

The following is a summary of the SP 4 pump's assumed and calculated data in tabular form for both the scenario:

Table 18 | Results from SP 4 Example

PARAMETERS	UNIT	OLD PUMP – SCENARIO 1		OLD PUMP – SCENARIO 2		NEW PUMP	
PUMP		**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
Change in pump efficiency	%	28.9	28.9	58.4	58.4	-	-
Annual energy consumption	kWh/a	**7,232.9**	**7,558.4**	**7,232.9**	**7,558.4**	**5,051.1**	**5,278.5**
Total energy savings potential	kWh/a	**4,461.7**					
Percentage of energy savings potential	%	**30.2**					
Total CO_2 abatement potential	t CO_{2eq}/a	**3.9**					

From the provided table, it is evident that the change in pump efficiency varies significantly between the two scenarios. This variation can be attributed to the significant difference in head considerations for each scenario. However, despite the drastic difference in efficiency change, both scenarios yield the same energy saving potential and CO_2 abatement potential. This outcome is primarily due to the consideration that the power absorbed by the pump remains the same in both scenarios.

NOTE: The above methodology is followed for all pumps to get energy saving potential and CO_2 abatement potential.

The same scenarios and methods were extrapolated for the other priority pumps in the city of Saint-Louis (see WP4). The summary of performance parameters is shown as follows:

Table 19 | Priority Pumping Stations Performance

PUMPING STATION	*TOTAL ENERGY SAVINGS POTENTIAL (kWh/a)*	*PERCENTAGE OF ENERGY SAVINGS POTENTIAL (%)*	*TOTAL CO_2 ABATEMENT POTENTIAL (t CO_{2eq}/a)*
SP 14[21]	60,036	49.9	52.23
Ile Nord	-2,044	-76.2	-1.78
Goxu Mbacc	52.5	41.3	0.05
SP 3	-7,145	-22.2	-6.22

SP Ile Nord and SP 3 pump stations currently exhibit negative energy savings due to the disparity between the current pump's absorbed power and the intended absorbed power. The pump's operation deviates from its rated conditions, resulting in a lower absorbed power. However, operating the pump under its intended rated conditions will increase the absorbed power while simultaneously improving its efficiency and reducing maintenance requirements. This will ultimately enhance the pump's overall performance.

As result of the efficient pump management work package, Table 20 below shows total energy saving potential and CO_2 abatement potential for all pumps in Saint-Louis:

Table 20 | Performance Data for all Provided Pumps in Saint-Louis

PARAMETERS	*UNIT*	*VALUE*
Total energy saving potential	GWh/a	**1.49**
Total energy savings percentage	%	**51**
CO_2 abatement potential	t CO_{2eq}/a	**1,334**

The assumed current efficiency of 5% for all the other pumps is based on the realistic average efficiency of priority pumps in the given system. It is reasonable to consider this efficiency value since these pumps generally operate under comparable conditions and exhibit similar performance characteristics.

Furthermore, the operating hours for all other pumps was assumed to be 2,000 hours per annum based on the same methodology discussed above. Importantly, when considering the installation of a new pump with the same model as the old pump, the efficiency range between 50 to 75% is anticipated. This range accounts for potential improvements in the new pump's design and engineering, resulting in higher efficiency compared to the existing pumps.

[21] Due to KSB's inability to provide an appropriate submersible pump for the specified operating conditions, a suitable alternative pump from FLYGT pumps is being considered for the pump station.

The significance of replacing the pumps, even with new pump models of higher efficiency, lies in the substantial electricity demand reduction and CO_2 abatement potential that can be achieved. The efficiency improvement from 5% to a range of 50 to 75% indicates a significant reduction in energy consumption and, consequently, a noteworthy decrease in greenhouse gas emissions.

8.4 Waste-to-Energy Potential

8.4.1 Project Demonstration and Planning

Biogas plants have emerged as a promising solution to address multiple environmental and socioeconomic challenges. In cities like Saint-Louis in Senegal, which faces a set of regional challenges, the adoption of biogas from organic waste can be transformative. Such an initiative can revolutionize waste management, introduce a renewable energy source, and present health and environmental conservation benefits. Many projects of biogas plants installations were realized in different cities in Senegal. The goal of LoSENS project is to do a technical feasibility study for the treatment of biogenic waste using biogas technology in the city of Saint-Louis and exploring the digestate potential to be used as a high value product fertilizer in the agricultural activities. All the calculations performed in the study are based on the population of 201,300 inhabitants.

The main partner of this project to help realize the feasibility study of a biogas plant is a German company called ÖKOBIT GMBH[22]. They are considered biogas experts as a leading figure in the biogas industry, with a legacy of over 250 projects both domestically and internationally. Renowned for constructing technically advanced and substrate-flexible biogas and biomethane plants, the company tailors its solutions to match the unique conditions of each client's site. With a dedicated team of engineers, economists, and environmental technicians, ÖKOBIT GmbH emphasizes both environmental sustainability and economic efficiency. Their comprehensive approach spans from consultation and profitability analyses to full turnkey plant construction, ensuring optimal quality and safety standards, all while fostering close partnerships with clients and staying actively involved in industry research and standards development.

8.4.2 Methodology and Analysis

There are two scenarios in this study (Biogasworld, n.d.):

1. ***Dry anaerobic digestion (Dry AD):***

Solids Content: This method is typically used for substrates with a high solid content, usually between 20% and 40%.

Application: Because of its ability to handle high solids content, Dry AD is suitable for the treatment of the organic fraction of municipal solid waste (OFMSW) and agricultural wastes (AW).

Methane Yields: The methane yields for this method range between 0.2 and 0.6 m^3/kg of volatile solids (VS). The actual yield, however, can vary based on the nature of the feedstock and the specific configuration of the digestion system.

[22] ÖKOBIT GmbH (Greentec Service): https://www.oekobit-biogas.com/en/oekobit/

Advantages: The process requires less water and can handle contaminants (like plastics) more easily than wet AD. It can also lead to a reduction in reactor size and decrease energy input for heating, as less water needs to be heated.

Challenges: Mixing and handling high solid content can be a challenge, and this method might require more frequent maintenance due to wear and tear.

2. ***Wet anaerobic digestion (Wet AD):***

Solids Content: Wet digestion is used for substrates with a lower solids content, typically less than 15%.

Application: It's typically used for sludges like those produced in wastewater treatment plants or liquid manures.

Methane Yields: Methane yields in wet AD systems can vary, but they are generally influenced by the nature of the feedstock, temperature, and system configuration.

Advantages: Wet AD systems are typically easier to mix and pump. The process is well-established with a large amount of operational data available.

Challenges: Requires a greater volume of water, which can increase the energy required for heating. Contaminants in the feedstock can lead to operational issues.

Comparison Criteria	Wet Digestion	Dry Digestion
Input material	maximum 20% dry matter	20-40% dry matter
Water consumption	Dilution may be necessary	Percolat renewal
Process stability	Easier to intervene in the case of biological malfunction	Need to manage several digestors simultaneusly
Heat need	20 to 30% of the heat produced	Lower need for thermally insulated installations
Power need	Pumps and mixers	Low
Fuel need	None, except if dualfuel engine	None, except if dualfuel engine
Digestate	Pumpable	Removed with loader
Manpower need	Possible automation	Important for loading/unloading
Biogas production	Linear production	Sequenced production over time
Security	Plant commissioning = high risk period	Loading/unloading = high risk period

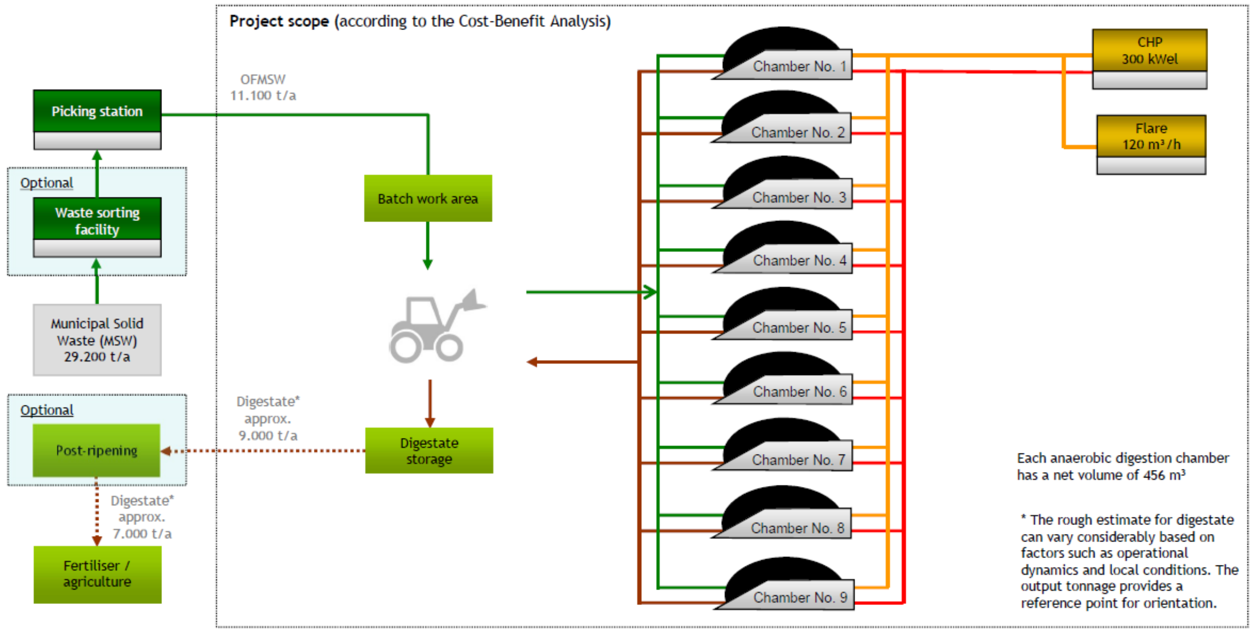
Figure 33 | Comparison between Dry and Wet Anaerobic Digestion, (© Biogas World)

8.4.3 Feasible Potential

The selected scenario for this feasibility study focuses on processing the Organic Fraction of Municipal Solid Waste (OFMSW) at Gandon's Landfill using the innovative drive-in silo digester chambers using dry anaerobic digestion technology. The proposed location for installing the plant is Gandon landfill which belongs to municipality of Saint-Louis (Figure 35). Dry AD was chosen in this case for the several advantages mentioned below:

- It is more cost-effective, energy efficient, does not require water, and emits fewer greenhouse gases compared to the traditional garage-like systems.

- The system is designed to maximize the use of local resources, thus decreasing reliance on imported equipment, which is not the case in wet AD systems.
- The design is simple, with no moving parts, reducing the need for highly skilled personnel.
- The system is resistant to sand and contaminants and offers more stability than wet AD.
- If a failure occurs, it only affects a single chamber, ensuring system resilience.
- It offers flexibility in design, expansion potential, and can be replicated in other areas.



Total sorted OFMSW	11.100 t/a
Potential gas yield	approx. 989.843 m³/a
Potential CH_4 content	60,0 %
η_{el} CHP	41,6 %
η_{th} CHP	42,7 %
Potential full load hours	8.235 h/a

Batch AD parameter	
Theoretical Retention Time (per chamber)	91,25 d
Time between changeover (per chamber)	30,42 d
Time between changeovers (entire plant)	3,38 d
Tonnage per batch changeover	102,78 t
Temperature	40 - 42 °C

Legend			
Biogas	→ (orange)	Solid	→ (green)
Liquid	→ (blue)	Digestate	····→
Heat	→ (red)	Substrate	→ (brown)

Figure 34 | Dry Anaerobic Digestion Technology Process, (© ÖKOBIT GmbH)

Figure 35 | Location of Dry AD Plant in Gandon Landfill, (© ÖKOBIT GmbH)

For effective waste management, technical sorting concepts are proposed, emphasizing the need for collective strategies to enhance waste management services' quality and value. The organic output of this technology proves to be of excellent quality and can serve as a high-quality organic fertilizer.

For biogas utilization, the most fitting application is seen in electricity and heat generation. With a Combined Heat and Power (CHP) unit, the potential electricity output is approximately 300 kW_{el}, leading to an annual production of 2,396,700 kWh_{el}, without considering the plant's energy consumption. To efficiently integrate the generated electricity into the grid, government involvement in the landfill project is desired. The proposed investment for such a facility stands at around €2.58 million, exclusive of the MSW recycling costs. The economic viability of the Gandon Landfill facility looks promising, with a payback time of 7.9 years and a possible yearly profit averaging €96,000.

Table 21 | Summary of Main KPIs of the Two Scenarios

KPI	*SCENARIO A: WET ANAEROBIC DIGESTION*	*SCENARIO B: DRY ANAEROBIC DIGESTION*	*UNITS*
CAPEX	6,225,000	2,585,000	€
Input OFMSW + Sewage sludge	11,100	11,100	t/a
	16,000		m^3/a
Electricity	3,131,100	2,470,700	kWh/a
Heat	3,355,300	2,536,000	kWh/a
OPEX	N/A	308,750	€/a
LCOE	N/A	0.18	€/kWh

Table 22 | CO_2 Emission Savings

CO_2 EMISSION SAVINGS	SCENARIO A: WET ANAEROBIC DIGESTION	SCENARIO B: DRY ANAEROBIC DIGESTION	UNITS
By replacing LPG	1,019	770	t/a
By replacing oil/diesel	1,163	879	t/a
By replacing wood pellets	61	46	t/a
By replacing conventionally generated electricity	1,946	1,536	t/a

The interviews done during the fact-finding mission to Saint-Louis in 2022 showed that the use of fertilizers in the agricultural sector is very common. Therefore, it is considered as a good market, creating a source of profitability. In the feasibility assessment of the planned biogas plant, fertilizer production was examined for each technological scenario. The wet anaerobic digestion (AD) option, anticipates yielding 25,526 m^3 annually of digestate, comprising 5,605 tonnes of solid matter and 19,922 m^3 of liquid by-product. As for the dry AD scenario, recommended for Saint-Louis, is forecasted to produce around 9,000 tonnes of fertilizer annually from all the nine chambers. This could generate a yearly revenue of €61,800 through fertilizer sales, calculated at a unit price of €6.86 per tonne.

9 Global Greenhouse Gas Emission Pathway

In the transition from exploring the status quo of the Senegalese national context, Saint-Louis city energy systems, and key actions analyzed for LoSENS project in the preceding chapters to delving into the diagnosis of the energy situation for greenhouse gas emissions (GHG) in the upcoming chapter, a critical bridge emerges. The foundation laid in the previous chapters serves as a backdrop, unravelling the intricacies of the project technicalities presented in the project and their interplay within the broader national landscape. As the step into the next chapter, the focus narrows to a challenging diagnosis of the energy dynamics, with a specific lens on identifying and understanding the factors contributing to greenhouse gas emissions.

NOTE: The groundwork laid earlier provides a context for examining the detailed challenges and opportunities in energy efficiency for different sectors. This connection ensures a comprehensive exploration, bridging the gap between the big picture and the specific diagnosis, providing a holistic view of the changing energy landscape.

9.1 Saint-Louis GHG Scenarios

The investigation conducted in Saint-Louis spanning the period from 2021 to 2023 utilized Material Flow Analysis (MFA) as the foundational method, complemented by project-specific methodologies detailed within each Work Package. The resultant Greenhouse Gas (GHG) balance serves as a comprehensive representation, illustrating the cumulative impact arising from the integration of these methodological approaches.

To provide a holistic perspective on the system boundary and the consequential GHG savings, the study extended its analysis to encompass the extrapolation of LED street lighting and Photovoltaic (PV) potential. Simultaneously, the assessment of efficiency improvements in pumps and the analysis of Biogas potential were integral components addressing the predefined system boundary, which corresponds to a population of 201,300 inhabitants. The outcomes derived from the pilot projects pertaining to streetlights and PV potential were used in the extrapolation process.

Moreover, the formulated GHG balance restricts its focus to emissions related to Electricity, Liquified Petroleum Gas (LPG), and Organic waste fraction in the municipal solid waste. This selective consideration is because the pilot projects exclusively contribute to GHG savings within these specified sectors. Consequently, the developed GHG balance provides the analysis specific to the chosen sectors, The baseline scenario graphically represented below, offering a comparative insight into emissions within the indicated timeframe (

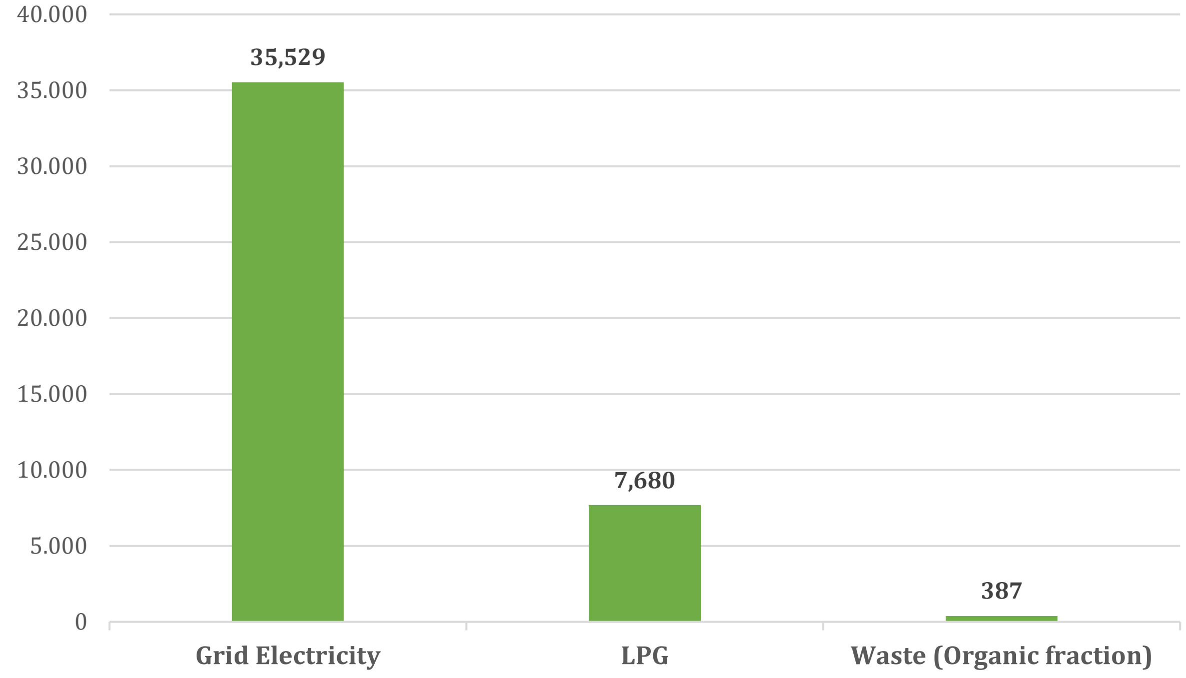


Figure 36).

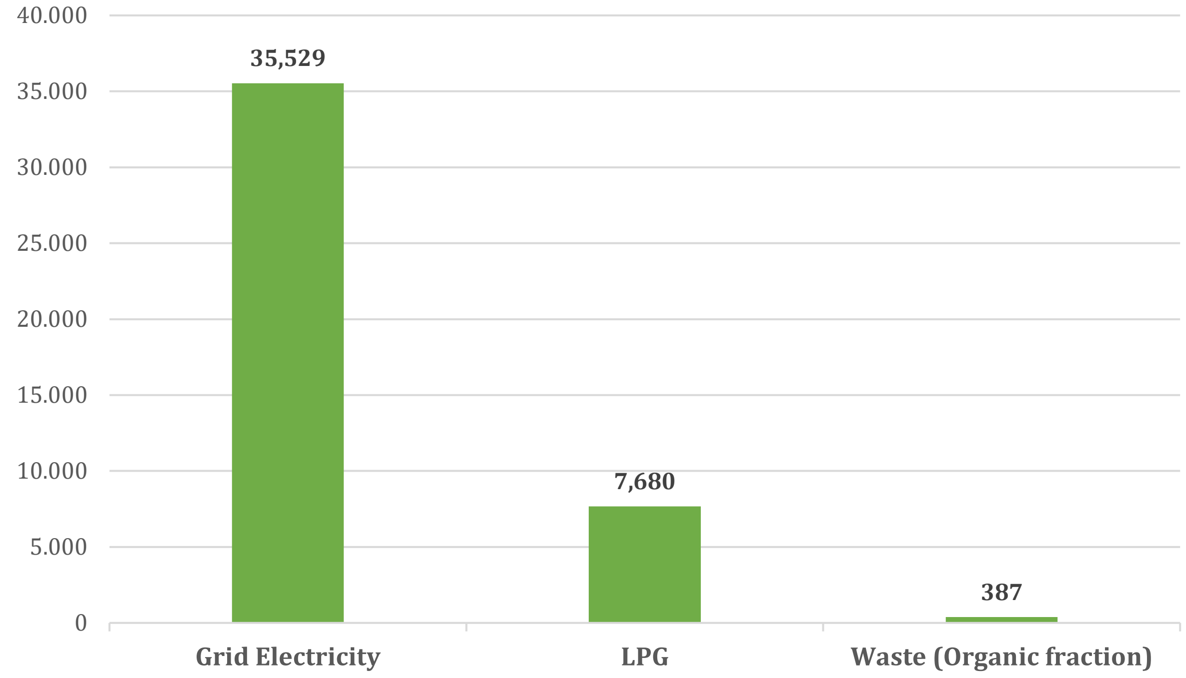


Figure 36 | Total CO_{2e} Emissions (t CO_{2e}/a) Based on 2021-2022 Data, (© IfaS)

Electricity consumption of the Saint-Louis is calculated based on the population of the chosen city limits. According to the World bank data of year 2000 to 2014, the electricity consumption per capita has an 6% average growth per year (IEA, 2014). Therefore, the calculated values, the electricity consumption for the year 2021 in the city limit is 40,837,479 kWh/a.

Based on the current situation, the investigated area, encompassing 201,300 inhabitants, exhibits an annual emission of 43,596 t CO_{2e}. The calculation of waste-related emissions focuses exclusively on the organic fraction, assuming the disposal of all waste in a landfill.

In the conclusive Greenhouse Gas (GHG) balance, the extrapolation of PV energy and street lighting data to a larger system scale is undertaken. Leveraging insights from the pilot Photovoltaic (PV) project, a larger 5 MWp system is projected to generate approximately 8 GWh annually. The estimated system, occupying available space in the area, is anticipated to fulfil 20% of the annual electricity consumption in Saint-Louis, thereby preventing 7,105 t CO_{2e} emissions associated with grid electricity consumption per year.

In the street lighting simulation pilot project, an evaluation of 100 units serves as the basis for extrapolating the system to 1,000 units in the area. This extrapolation suggests a potential annual energy savings of 349,072 kWh, avoiding 303 t CO_{2e} emissions annually from the grid electricity.

The Biogas generation project is estimated to yield 5.93 GWh of energy annually, with 41.6% converted to electricity and 42.7% to thermal energy. In the final GHG balance, the thermal energy is considered a substitute for Liquefied Petroleum Gas (LPG) consumption. This substitution results in an annual avoidance of 2,147 tons of CO_{2e} emissions from grid electricity and 583 tons from LPG consumption. All in all, the biogas production can fulfil 6% of electrical energy consumption for one year.

Summing up all project outcomes and extrapolated estimations, the final GHG emissions projection for the Saint-Louis area stands at 31,735 t CO_{2e} annually. The baseline scenario and the projected scenario are graphically represented in the graph below (

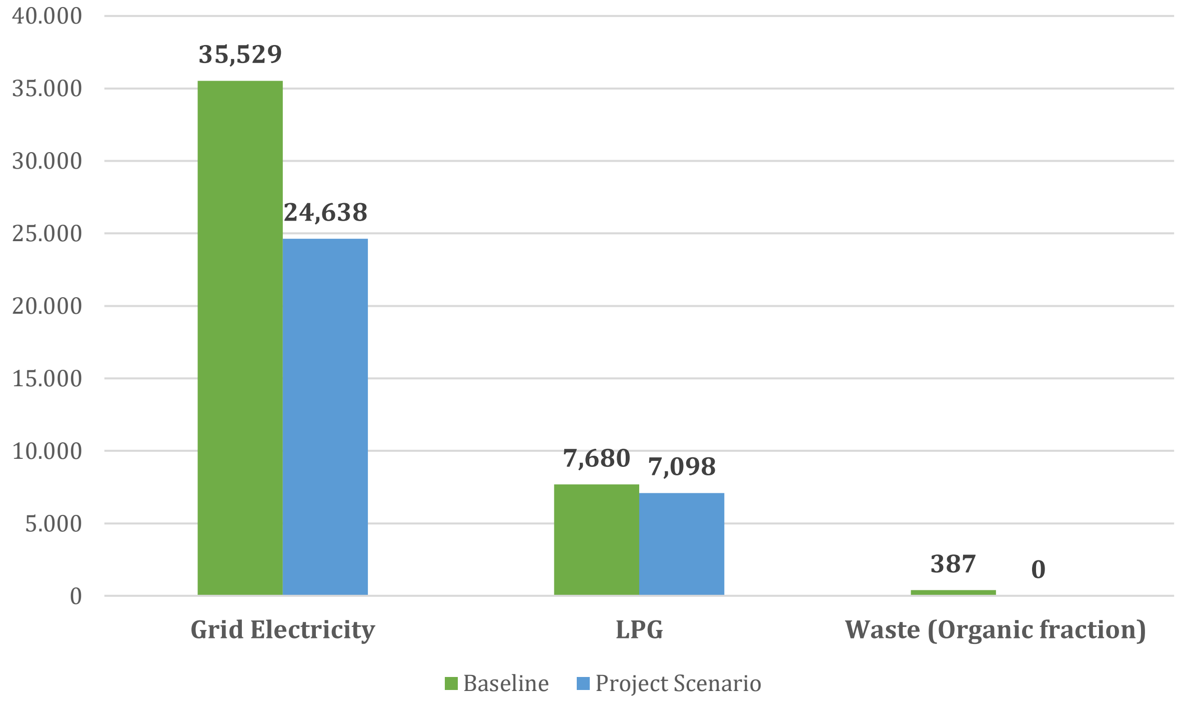


Figure 37).

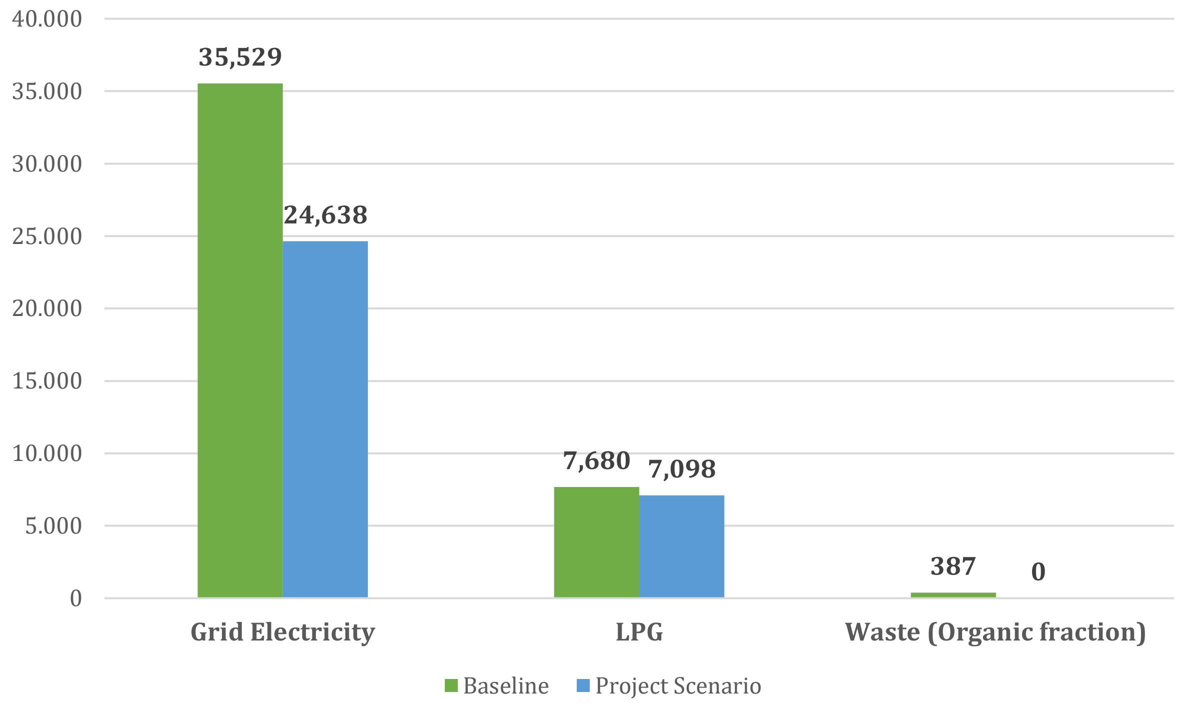


Figure 37 | GHG Balance Baseline vs Project scenario (t CO_{2e}/a), (© IfaS)

Biogas produced from organic waste is considered renewable because it is derived from the breakdown of organic materials through anaerobic digestion. Anaerobic digestion is a natural process where microorganisms break down organic matter in the absence of oxygen, producing biogas as a byproduct. The primary component of biogas is methane, which can be captured and used as a clean energy source mainly for electricity generation and heating.

The key distinction lies in how organic waste is managed. When organic waste decomposes in a landfill without proper controls, it undergoes anaerobic decomposition, releasing methane into the atmosphere. This uncontrolled release of methane is a potent greenhouse gas (GHG) that contributes to global warming[23].

On the other hand, when organic waste undergoes anaerobic digestion in a controlled environment, such as a biogas plant, the methane produced can be captured and used for energy, preventing its release into the atmosphere. By utilizing the methane as a renewable energy source, not only generate clean energy but also mitigate the emissions of a potent greenhouse gas that would have otherwise contributed to climate change.

Therefore, biogas from organic waste is considered renewable when it is captured and utilized through controlled processes like anaerobic digestion, while emissions from organic waste in landfills are considered greenhouse gas emissions due to the uncontrolled release of methane during decomposition.

Based on the findings and the estimated results, If the projects are realized as extrapolated, the total GHG emission savings will be 11,860 t CO_{2e}/a. It is a 27% reduction compared to the status-quo emissions.

[23] Methane is over 25 times more effective at trapping heat in the atmosphere than carbon dioxide over a 100-year period.

9.2 Greenhouse Gas Mitigation Pathway

To articulate the trajectory of Greenhouse Gas (GHG) mitigation aligned with the Paris Agreement and project goals, the strategic evolution of energy efficiency measures and the transition from fossil-fuel reliance to green electricity-powered modalities has been systematically organized. Short-term targets, outlined until the year 2030, have been established for these initiatives, considering their anticipated economic development and feasibility. This framework aims to provide a visual representation of the planned course toward GHG mitigation, demonstrating a commitment to sustainable practices and acknowledging the imperative of mitigating climate change within the specified timeframe (Table 23).

Table 23 | GHG Mitigation Pathway and Implementation Targets

APPLIED YEAR	*PROJECTS/ IMPROVEMENTS*	*CATEGORY*	*SAVINGS % (FROM BASELINE VALUE)*
2024	Pumps Efficiency	Electricity	3.65%
2024	LED Street Lights	Electricity	0.85%
2026	Biogas	Electricity	6.04%
2026	Biogas	Thermal (LPG)	7.59%
2027	PV 5 MWp	Electricity	20.00%

It is important to note that renewable energy alternatives, such as large-scale Biogas and Photovoltaic (PV) systems, which have the most substantial impact on Greenhouse Gas (GHG) mitigation, present complexities due to the scale of implementation and the associated planning challenges. The intricate nature of deploying these technologies demands exacting consideration and strategic planning. However, it is crucial to emphasize that despite these challenges, these renewable energy technologies are economically viable. Their long-term benefits and positive environmental impacts demonstrate the commitment to overcoming logistical difficulties, reinforcing the importance of sustained efforts in fostering the transition toward cleaner, more sustainable energy sources.

In the event that the identified technology replacement options are implemented within the specified time frames, and the associated Greenhouse Gas (GHG) abatement measures are actualized, a prospective mitigation pathway emerges. This pathway is designed to affect a reduction in the overall emissions, specifically pertaining to electricity, the organic waste fraction, and Liquefied Petroleum Gas (LPG), considering a business-as-usual scenario with a 1% annual

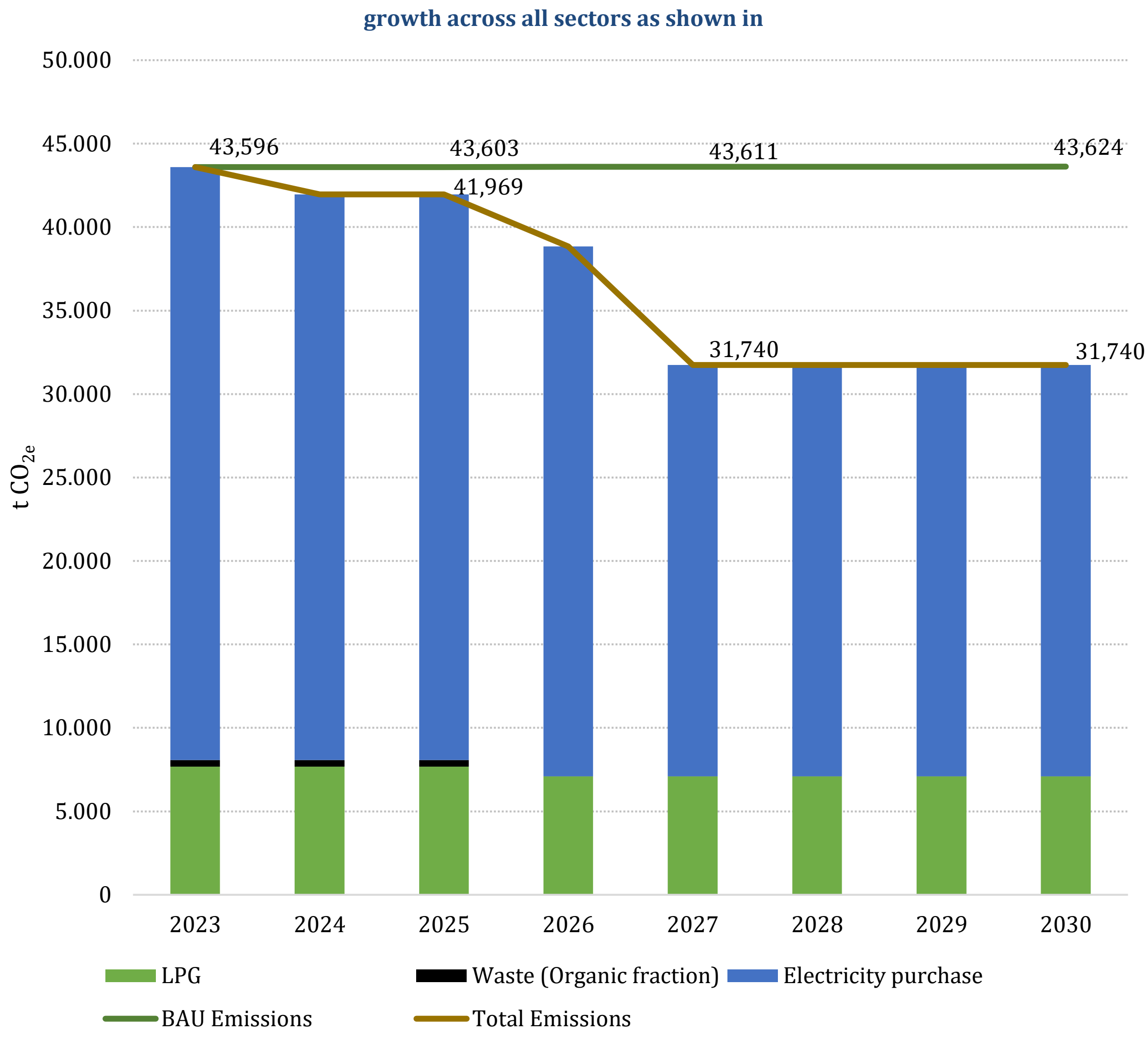


Figure 38.

The anticipated emission reduction potential of approximately 11,860 t CO_{2e}, representing a 27% reduction from the baseline scenario, emphasizes the viability of these initiatives. This assessment is based on the feasibility demonstrated by the pilot projects and underscores the potential for successful implementation.

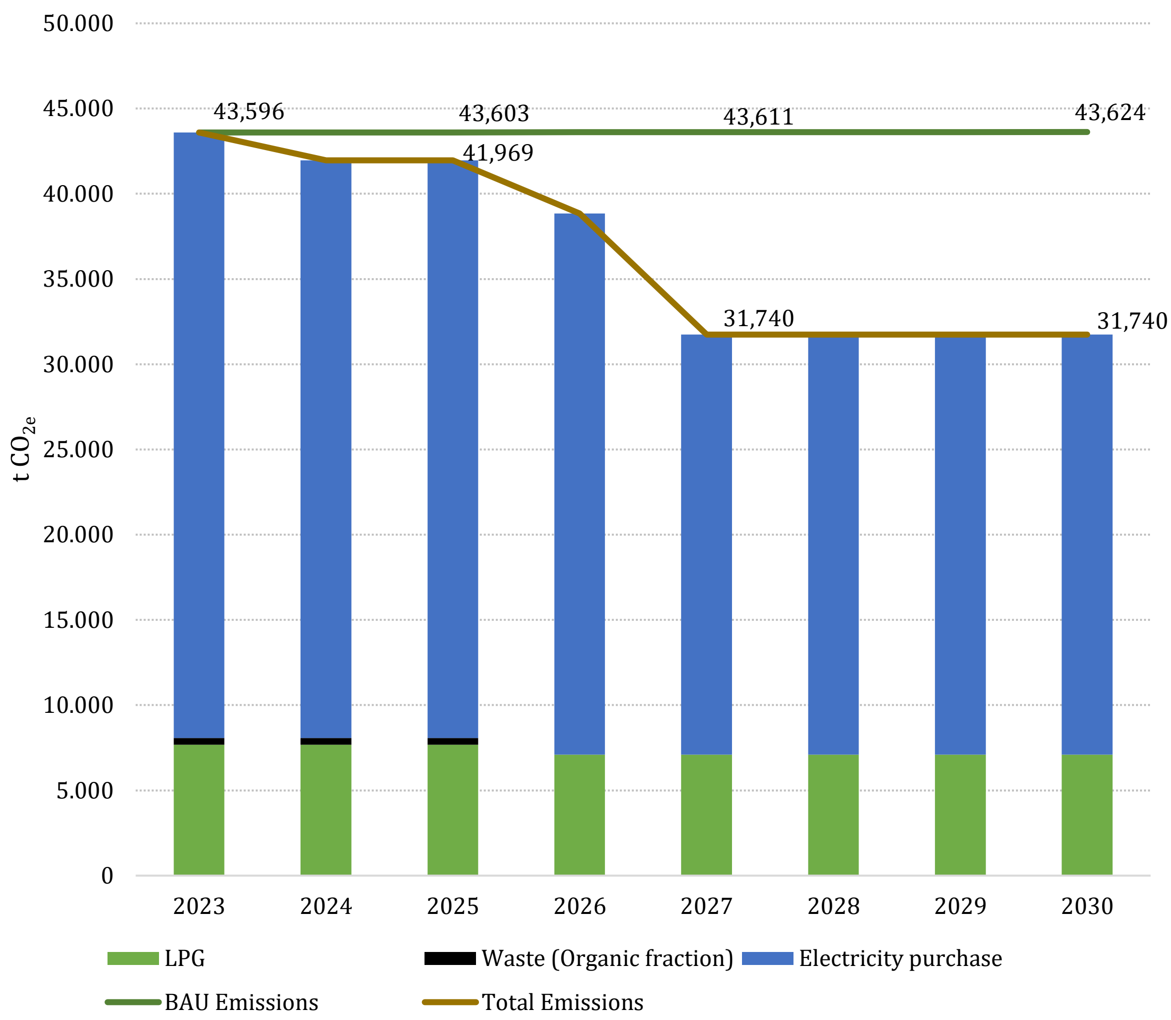


Figure 38 | GHG BAU vs Mitigation Pathway, (© IfaS)

Additionally, it is also important to consider technology options such as Green-hydrogen and electric transportation, known for their substantial impact on achieving net-zero transformation. While acknowledging that certain technologies may currently face economic viability challenges, ongoing global research, and development efforts in areas like green hydrogen and e-mobility, along with the corresponding infrastructure, are expected to expedite their commercialization and applicability.

Therefore, a continuous evaluation of existing technological advancements is crucial, allowing for the identification of economic windows of opportunity. This strategic approach ensures that advancements in technologies, particularly those with transformative potential for GHG mitigation, can be effectively integrated into the overall mitigation strategy once they reach a commercially viable stage.

9.3 Monetary relation to the GHG reduction potentials

The relative GHG reduction potential of 27% contrasted to the Business-as-usual (BAU) scenario without GHG mitigation a total of emission level of 11,860 t CO_{2e}. would correspond to an annual GHG removal cost saving potential of nearly €2.965 million if a removal price of 250 €/t CO_{2e} in 2030 (and €6.2 million in 2040 with 525 €/t CO_{2e}) as predicted by the European Investment Bank would occur (Eib, 2020).

This pathway strategy developed for communities/municipalities to leverage their greenhouse gas (GHG) reduction efforts for tangible economic gains. Commencing with a challenging baseline GHG inventory, the process involves setting ambitious reduction targets and prioritizing measures across sectors like energy, waste, and transportation. By conducting a thorough cost-benefit analysis, communities can quantify the direct costs and ancillary benefits of each implemented measure, considering improved air quality, public health, and potential job creation.

A pivotal aspect of this strategy is the quantification of GHG emissions reductions and their subsequent monetization. Using the existing values from voluntary carbon markets as they are open to anyone, or more accurate customized values such as adding social cost of carbon as a reference point, communities can attach a monetary value to their environmental contributions. This valuation extends to the exploration of carbon markets, cap-and-trade systems, and incentive programs, providing opportunities to sell carbon credits and participate in regional environmental initiatives. These strategies also emphasize the importance of securing public and private funding, utilizing financial instruments like green bonds, and establishing a robust monitoring and reporting system to track progress and communicate the economic value of GHG reduction initiatives.

In conclusion, the transformative potential of GHG reduction initiatives not only in mitigating climate change but also in generating economic prosperity for communities and municipalities. By embracing sustainable practices, local entities can contribute to a healthier environment while simultaneously unlocking new financial opportunities, thereby paving the way for a resilient and prosperous future.

10 Business Plan and Financing Concept

10.1 Operating Models

10.1.1 Tasks of the Municipal Water and Energy Industry in Saint-Louis

The previous chapters have already described possible measures for optimizing the wastewater and energy sectors. The expansion of renewable energies for decentralized power/heat and the planned efficiency increases of the systems lead to new fields of action and actors, such as the question of the plant operator, the landowner or the maintenance, which have to be linked organizationally and institutionally in addition to the existing tasks. The city of Saint-Louis has a municipal service provider, the directorate of municipal technical services, which currently handles waste collection and landfill operations.

Water management can be subdivided into wastewater management and drinking water management. According to the current status, the tasks of wastewater management include, in particular, the basic activities of wastewater treatment and sewer operation, which, together with the necessary management, are performed centrally by the public institution Office National de l'Assainissement (ONAS). A comparable situation can be seen in the drinking water management. In urban areas, water management and the production and distribution of drinking water are handled by the Société Nationale des Eaux du Senegal (SONES) and the private operating company Sénégalaise des Eaux (SDE). Similar to an operating management model, SONES owns the assets, is responsible for infrastructure investment management, and regulates SDE. SDE handles operations, regular maintenance, some investments for system expansion, and billing end users. For both systems, there is a particular opportunity to introduce new more efficient pumping systems. This means that a decision has to be made regarding which actors will take over the investment and subsequent maintenance for the new technology in this context.

The energy concept is composed of a combination of energy saving, increased efficiency and the expansion of decentralized renewable energies as well as storage technologies, so that a large part of the heat and electricity demand can be covered locally. Depending on the regionally available potentials, different energy sources such as wind, sun or biomass can be used. Due to the already described potentials on site, the installation of PV systems, a biogas plant and the replacement of the street lighting are currently suggested as first measures. In addition to the technical planning and implementation of individual system components, this requires the development of operating concepts for the individual systems. Depending on the system component, different tasks from different sectors may arise, in which different players could be involved in each case.

Since the development of an energy concept should also include the expansion of the system components in a structured and coordinated manner, it makes sense to define a coordinating unit that at least coordinates the planning of the system components and the quality control or monitoring in order to control demand and production. Involving external consulting (e.g., by IfaS), this could be done, for example, by the City of Saint-Louis or an installed utility.

For the construction of the PV systems and the biogas plant, it is necessary as a first step to develop possible areas for the installation. Since private land could possibly be included for project implementation, this results in different landowners who will be involved in the implementation. This can lead to a higher planning and negotiation effort. In addition to the financing and providing of construction services, the operation, maintenance, and sale of the resulting "products" will also arise as new areas of responsibility, which will have to be assigned to municipal and private actors.

PV systems are primarily intended to generate electricity with subsequent self-use by public or private entities or storage.

In the case of the biogas plant, the input sources must also be accessed and coordinated, which has clear crossing points with the work area of the public waste management authority. Municipal green and organic waste or waste from farmers or foresters can serve as input. Currently, the total accumulated waste from domestic collection is disposed of centrally and unsorted at a landfill, which would also require the implementation of a separation system for biogenic domestic waste. The possible product spectrum is also broader, depending on the path chosen. On the one hand, there is the possibility of marketing the generated gas to private individuals or a central customer. Alternatively, this could also be transferred into electricity and heat on site and marketed as well. For this purpose, it is necessary to obtain a connection to an electricity and a heat network. Furthermore, a fermentation residue is produced as an additional by-product, which can be utilized materially as fertilizer or thermally.

10.1.2 Principle Options for Institutional Implementation at the Actor Level

In principle, the implementation of municipal tasks or projects can be carried out either exclusively by the public sector, private individuals or through some form of public-private cooperation. Depending on the existing structures and preferences, different operator concepts are possible. First, a general description is given of possible institutional and organizational design variants involving municipal and private actors. Then, based on the existing structures and conditions on site, various approaches for the concrete implementation of the projects studied are presented in the form of a blueprint.

10.1.2.1 Implementation by Public Authorities

In principle, the legal framework and local resources must be taken into account when opening up new fields of activity. The options for organizational implementation by the public sector can be divided into several different variants.

First, the new areas of responsibility can be taken over by individual municipal actors (if necessary, by adapting the statutes), or they can be handled jointly by several municipal actors by means of contractually agreed cooperation. Building on this idea, it would also be possible for two or more municipal actors to join forces in a cooperative.

Alternatively, a "modification of the existing corporate structure" can be undertaken. In concrete terms, this means that for certain tasks in connection with energy projects, daughter companies organized under private law can be established. This would also reduce the entrepreneurial risk for the core business and lead to a clear accounting separation between parent company and daughter company. Ultimately, building on this possibility, cross-sectoral "hybrid" affiliates can again be established between several players from different sectors to fulfill the newly emerging areas of responsibility in the context of energy supply. This can lead to synergies, such as the development of mutual specialist know-how, and prevent conflicts of interest between the municipal companies regarding their general public services.

The investments can initially be financed from the municipal utility's own funds as well as from current revenues from fees and contributions. In addition, grants or loans, for example, can be included in private financing.

10.1.2.2 Implementation with the Involvement of Private Parties

The previous chapter described the implementation of tasks largely by the public sector, although this can sometimes be accompanied by formal privatization or financing via private players (e.g. credit institutions). Alternatively, there are also different ways of creating a public-private cooperation through collaboration with private third parties, so-called Public Private Partnerships (PPP). The German Federal Ministry of Finance defines a PPP as "cooperation between the public sector and private industry in the design, planning, creation, financing, management, operation and utilization of public services that were previously the sole responsibility of the state. Public-private partnerships thus represent a procurement alternative for the state to conventional in-house implementation." (Bundesministerium für wirtschaftliche Zusammenarbeit, 2023)

Overall, there are numerous PPP models that differ in terms of the structure of capital participation and task transfer as crucial criteria.

To simplify matters, these can be divided into three categories:

- Service contracts
- Private-public operating companies or joint ventures
- Leasing/contracting/rental models

In the case of **service contracts**, certain tasks can be carried out with the involvement of private third parties without any capital commitment on the part of the private sector company. This means that there is no budgetary relief for the investment. This category includes various contractual models such as **management, operations management, service and maintenance or consulting contracts**. In these cases, the private party can assume responsibility for managing the operating organization, individual plants or system components, or for machines. It is also possible to provide only consulting services. This variant appears to make sense if the municipality has sufficient funds available for independent financing (e.g., own funds and loans), but at the same time there are deficits in specific know-how or capacity bottlenecks.

In the second category, "private-public operating companies," the municipality and one or more private parties jointly establish a company (joint venture) that fulfills defined tasks. This results in co-financing or participation in the investment responsibility by the private partner(s). This category can be further subdivided into many different models, which differ, for example, in terms of the degree of participation of the actors or the company's ownership rights to the infrastructure. It should be noted that the responsibility of municipal self-government for the municipality remains in place in the case of mandatory municipal tasks and is not transferred. In this case, the municipal budget can be relieved and private know-how can be acquired. If the municipality retains a majority of the voting rights (e.g., in the case of the cooperation model), it can continue to have a decisive influence on the company's business activities.

Ultimately, in different leasing/contracting/rental models, the private partner takes over the planning, construction and financing, and then provides the object contractually regulated for a fee. The models can differ in terms of the assessment basis for the fee and the final (optional) transfer of ownership of the object to the municipality. In this context, the private sector can also take over various services (e.g., monitoring, maintenance). The terms used in this context, such as contracting, can be interpreted differently overall regarding the agreed payment of a fee, associated services and subsequent acquisition of the facility. Final it is individually crucial that the contractual design of the agreed fee for refinancing and further services are designed according to the preferences of both partners and that all possible tender-relevant aspects are considered. The advantage of this variant is that the municipal investment budget is not burdened, and less specific know-how is required. The end user, e.g., the municipality, ideally receives a service, e.g., power supply, at more favorable conditions as well as the option to purchase the plant. However, regional value creation is reduced in a partnership with non-resident partners, as cash flows continue to flow out of the region.

Overall, there are many other options for regulating cooperation between the private and public sectors. The models mentioned above provide a rough overview of the topic and can serve as an impulse for further concept development. It is also possible to combine different models. For example, a joint venture or special purpose vehicle (SPV) founded by private and public actors can also provide services to the municipality by means of a contracting-like agreement. The municipality would thus be part owner and customer at the same time. The specific model options on site are addressed in more detail below. It is assumed that the public institutions are financially weak actors with limited technical know-how for the implementation and operation of the planned facilities.

10.1.3 Possible Institutional Implementation on Site: Municipal Utility

As described, PPP models can offer themselves as a solution for the implementation of projects for municipalities with a small budget and a lack of know-how. In order to tap existing potential on a large scale, a medium-sized consortium consisting of financing and technical experts, for example, could approach the public actors and offer a possibility for at least budget-neutral implementation of climate protection or energy efficiency measures. It is also possible to sell services to private individuals (e.g., electricity sales).

For structural implementation, a company could be created at the first level which, if possible, bundles the capital of the equity and debt capital providers. In principle, the establishment of a special purpose vehicle (SPV) is a suitable option, which in this model could be initiated by an active investor (e.g., by an operating construction company). The choice of legal form should be made by an appropriate expert, taking into account aspects of tax law and liability law. Active investors and passive investors can act as shareholders.

In this context, active investors are equity donors that also have management competencies and support the development or project implementation with operational contributions (e.g. management tasks or construction of facilities). Examples of possible actors are the companies listed in the report. In addition to active investors, passive investors can also act as equity investors who do not take on any operational tasks in the development of the financing concept. Public stakeholders can also participate in the company, provided that there are no legal or statutory regulations to the contrary.

The SPV then has plants (e.g., PV plants, street lighting, pumps) built by various plant suppliers and acquires them or is provided with them via a leasing agreement. After completion of the plants, the products, i.e., energy generation or energy savings, are to be marketed to the customers by means of a long-term contract (here the so-called "project contract"). In this context, purchasers could be public actors as well as actors organized under private law or individuals. The project contract must be designed in such a way that there is an incentive for both the service buyers and the investors to implement the project: The purchasers want more favorable conditions than their existing status quo, and the investors seek a satisfactory return. A free transfer of the equipment after a defined period of time could also create incentives for the purchaser for the model.

After a certain period, a purchase option for further company shares could be agreed with the public actors in a separate contract. In line with the envisaged local capacity building, structures for a public facility for the generation or saving of energy can thus be created locally in the long term. The associated maintenance of the plants can be transferred to local companies by means of a service contract. In the context of the construction of the plants, contracts must also be concluded with private parties regarding land rights. With regard to a possible biogas plant, purchase and supply contracts must be agreed with possible input suppliers.

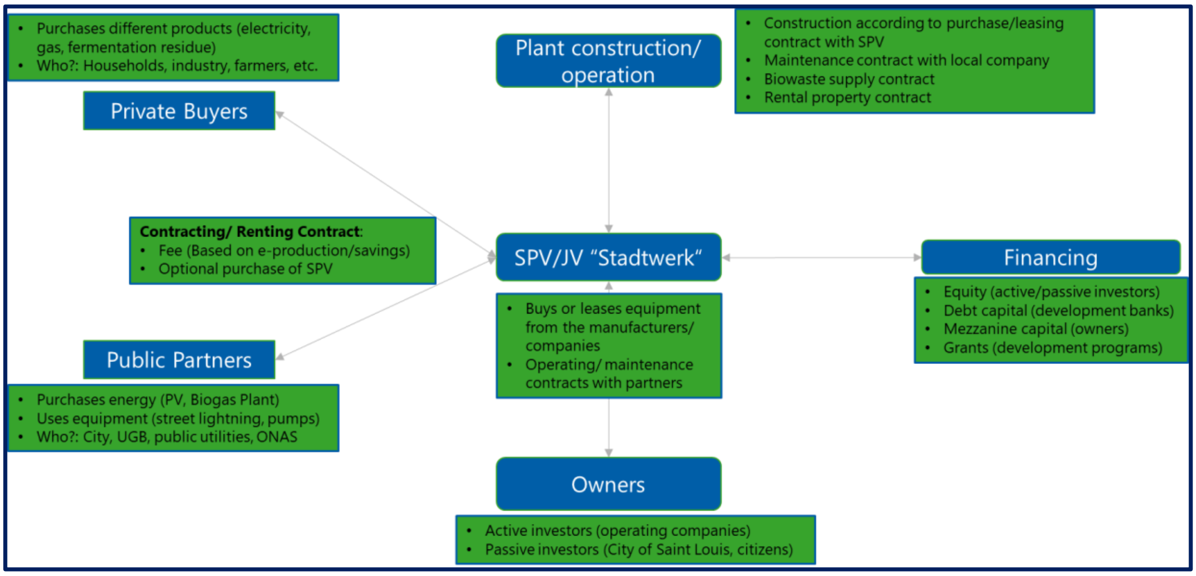


Figure 39 | Scheme of Possible Operating Model for the Implementation of New Projects, (© IfaS)

10.2 Financial Instruments

The central element of the model will be the issue of financing and the associated capital costs. Overall, the following options for financing the SPV emerge:

- Equity (through active and passive investors)
- Debt capital (through development banks)
- Mezzanine capital (through subordinated shareholder loans)
- Financing subsidies (through funding programs)

Due to the very high initial investment and the long payback character of the measures described, financing instruments with a long term are generally conducive to the project. This is confirmed by Yescombe, a consultant for public-private partnerships and project financing. For example, he sees long loan terms of more than 15 to 20 years as common practice for PPP projects (Yescombe, 2007).

In practice, PPP projects are usually characterized by a high proportion of debt capital. Due to the comparatively low interest rates on debt capital, this has the advantage from the equity investor's point of view that the return generated can be increased by the leverage effect of the debt capital. This is offset by the interest of the debt lenders, who expect a certain amount of equity capital to hedge credit risks. According to the European PPP Competence Center, 70% to 80% of the financing for most PPP projects is provided by debt capital (Europäisches PPP-

Kompetenzzentrum, 2013). This is also in line with information from the European Investment Bank (EIB), which envisages a debt ratio of 75% to 90% in its PPP projects (Goodwin, 2005).

Overall, the capital providers must be convinced that the project cash flow can cover the interest and redemption payments and at the same time meet the minimum return expectations of the equity. In the final analysis, this means that in addition to the capital requirement, the ability to service the debt is also a decisive criterion in determining the financing mix. The level of interest will depend on the one hand on the project risks (e.g. creditworthiness of the company, technologies used, electricity price and acceptance risk or country risks) and on the other hand on the collateralization. In addition to the debt interest rate, covenants can also have an influence on the financing. For example, the debt service coverage ratio (DSCR) is the most important determinant for determining the maximum loan volume that can be taken out for the project. It indicates the factor by which the expected Free Cash Flow (CF) covers the debt service for the respective year and must be agreed with the financing partner (Yescombe, Principles of Project Finance, 2018).

10.3 Potential Analysis "Municipal utility”

As described in the previous WPs, the project investigated potentials for PV systems, LED street lighting, water efficiency measures (pumps) and biogas systems. These are now examined individually as part of a profitability analysis and finally combined in a fictitious company (hereinafter referred to as "SPV"). As already described above, the SPV will act similar to a contracting provider. It will install various plants and sell the resulting products (electricity and efficiency) to private and public actors by means of a long-term purchase agreement. The initiation of the business model, such as contract negotiations with the purchasers, is not examined in the model.

Since this is a theoretical analysis of potential, various assumptions must be made here, which in practice must be determined with the partners on a project-by-project basis:

- Based on the above literature sources, a financing structure with 80% debt and 20% equity is assumed. The interest rate on debt capital is varied between 7% and 12% by means of a sensitivity analysis for the overall model and its effects on the return and the DSCR are described. In addition, the electricity price is also shown as part of a sensitivity analysis with a reduction of up to 20% and the effects on corresponding KPI.
- A credit period of 15 years is assumed for the projects, with the first year being repayment-free. No commitment interest is assumed.
- To calculate the weighted average cost of capital (WACC), the minimum return on equity in the present concept is estimated at 15% (Yescombe, Principles of Project Finance, 2018).
- The minimum available liquidity of the company (reserve account) must be able to cover the current operating and financing costs for 3 months at the end of the year.
- Based on historical data, a uniform inflation rate of 3.57% per year is assumed (Urmersbach, 2023).
- The entrepreneurial tax burden on profit is calculated at 30%.

As KPIs, the net present value (NPV) using the discounted cash flow (DCF) method, the internal rate of return (IRR), the payback period of the plant and the multiple on invested capital ("MOIC") are determined via the free CF. The WACC at the beginning of the project on the one hand and the hurdle rate of 10% set in the application are used as the discount rate. For the presentation of the return on equity in the final company it is assumed that the profit of the previous year can be fully distributed, provided that sufficient CF is available. It is explicitly noted that the return on equity could be increased through the use of mezzanine capital (avoiding a "dividend-trap" through legal limitations on distributions (Yescombe, Public-Private Partnerships, 2007)).

Table 24 | Assumptions and Financing Conditions

PARAMETER	VALUE	UNIT	SOURCE
Equity	20	%	
Dividend	15	%/a	Yescombe
Loan	80	%	
Loan Period	15	a	Assumption
Redemption Period	14	a	Assumption
Interest	7%	%/a	Assumption
Annuity Factor	0.1143		
Tax	30	%	Germany Trade and Invest (2022)
Value Added Tax	18	%	Germany Trade and Invest (2022)
Inflation	3.57	%	IMF (2023)

10.3.1 Wastewater Pumps Efficiency

Based on the technical and economic data determined in the report of the company Kocks for the pump station SP 14 of the public wastewater service provider ONAS, an economic evaluation is carried out. The basis of the evaluation is the idea that the established SPV finances the replacement of the existing pump and bears the maintenance costs. In return, by means of a contractual assurance over 12.5 years, ONAS commits to pass on the realized operating cost savings to the SPV. The maintenance of the pump could either continue to be carried out by ONAS or by a third party. It is assumed that the plant will be operational from the fourth quarter, other assumptions remain analogous.

Table 25 | Key Figures for Pumps[24]

[24] Data taken from ONAS and Kocks.

PARAMETER	VALUE	UNIT
Energy Savings	56,847	kWh/a
Electricity Price	0.30	€
Energy Savings	17,054	€
Investment	96,000	€
Operating Cost	19,094	€
Op. Life	12.5	a

The table below shows the corresponding KPIs for 80/20 financing at 7% interest on debt.

Table 26 | KPIs for Pumps

PARAMETER	VALUE	UNIT
Average DSCR	1.71	-
Hurdle Rate	10.00	%
NPV	24,057	€
WACC	6.92	%
NPV	24,057	€
IRR (Free CF)	14.29	%
MOIC Total Capital (OCF/ICF)	2.41	-
Amortization Time	6.53	a

10.3.2 Solar Energy Potential

The assumptions of the business model are based on the WP4b report. In this case, the SPV has PV plants planned and constructed on roof or open spaces. The main target group are industrial companies, as they have a significantly higher electricity consumption and a higher electricity purchase price. The SPV assumes the maintenance costs and guarantees the industrial companies a transfer of ownership of the plant after a term of 20 years. In return, the contracting parties undertake to use the electricity produced by the PV system. The basis of the agreement is again a long-term purchase contract whose price assumptions in the calculations are based on the current electricity purchase price.

To make this model more economically viable for the contracting parties, a rent for the built-up area could be agreed if necessary, or the electricity could be offered at more favorable conditions.

Due to the lack of information on the energy consumption of the industry in Saint-Louis, the profitability calculation is based on a scenario in which 2,000 kWp are installed at a price of 1,600 €/kWp.

Table 27 | Technical Key Figures of PV

PARAMETER	VALUE	UNIT	SOURCE
Installed Capacity	2,000	kWp	Assumption
Spec. Yield	1,608	kWh/kWp*a	Simulation PV*SOL
Energy Production	3,216,000	kWh/a	
Op. Life	20	a	Haselhuhn (2013)
Capacity Loss	0.5	%/a	solarenergie (2022)

Table 28 | CAPEX and OPEX of PV

PARAMETER	VALUE	UNIT	SOURCE
PV System	1,600	€/kWp	Interview Senegal
Investment	3,200,000	€	
Net Metering	0.252	€/kWh	SENELEC
Operation Expense	1.0	% of investment	Haselhuhn (2013)
Insurance	1.0	% of investment	Haselhuhn (2013)

The table below shows the corresponding KPIs for 80/20 financing at 7% interest on debt.

Table 29 | KPIs for PV

PARAMETER	VALUE	UNIT
Average DSCR	2.40	-

Hurdle Rate	10.00	%
NPV	2,971,237	€
WACC	6.92	%
NPV	4,702,032	€
IRR (Free CF)	21.15	%
MOIC Total Capital (OCF/ICF)	4.94	-
Amortization Time	5.33	a

10.3.3 Public Street Lighting

The basis for the calculations of the street lighting division is the WP4a. Here, 100 existing lamps in Saint-Louis are replaced with new efficient and long-lasting LED lamps and the maintenance costs are covered by the SPV. As a result, the city will save on regular replacement of the existing lamps. These costs are spread evenly over the years and passed on to the SPV.

Table 30 | Technical Key Figures Lighting (Dimensioning LED)

PARAMETER	VALUE	UNIT	SOURCE
Op. Life Status Quo	3	a	Interview Senegal
Op. Life LED	15	a	Interv. Municipal Idar-Oberstein

Table 31 | CAPEX and OPEX for Lighting (Pricing LED)

PARAMETER	VALUE	UNIT	SOURCE
Price / LED	226	€	AEC
Installed Lamps	100	x	
Investment	22,600	€	
Operation Expense/Lamp	32.00	€/a	Interview Senegal
Operation Expense/a	3,200.00	€/a	
Price / conv. Lamp	129	€	Interview Senegal
Potential Savings/ LED*a	43	€/a	
Potential Savings/ a	7,500	€/a	

The table below shows the corresponding KPIs for 80/20 financing at 7% interest on debt.

Table 32 | KPIs for Public Street Lighting (LED)

PARAMETER	VALUE	UNIT
Average DSCR	2.17	-
Hurdle Rate	10.00	%
NPV	10,572	€
WACC	6.92	%
NPV	18,040	€
IRR (Free CF)	16.95	%
MOIC Total Capital (OCF/ICF)	3.10	-
Amortization Time	6.10	a

10.3.4 Biogas Plant with Dry Fermentation

In the Biogas Feasibility Study report, a possible business model has already been presented and a profitability analysis for a biogas plant with dry fermentation has been performed. The assumptions and data from this scenario are adopted: The SPV has a biogas plant and an equivalent sorting plant built and recycles the biowaste from the surrounding area and finally sells the produced electricity by feeding it into the grid. Compared to the calculation in the study, the financing mix is adjusted in the same way as the inflation rate.

Table 33 | Technical Key Figures Biogas Plant[25]

PARAMETER	VALUE	UNIT
Excess Electricity for grid injection	2,397,000	kWh el/a
Solid Digestate from drive-in silo biogas plant	9,000	t/a
Depreciation and Amortization	16	a
Op. Life	20	a

Table 34 | CAPEX and OPEX for Biogas Plant[25]

PARAMETER	VALUE	UNIT
Investment	2,585,000	€
Operation Expenses	105,250	€
Feed in Tariff	0.15	€/kWh
Market Price Digestate	6.86	€/t
Sales El. Grid Feed	359,550	€/a
Sales Fertilizer	61,740	€/a

The table below shows the corresponding KPIs for 80/20 financing at 7% interest on debt.

[25] Biogas Feasibility Study

Table 35 | KPIs for Biogas

PARAMETER	VALUE	UNIT
Average DSCR	1.44	-
Hurdle Rate	10.00	%
NPV	403,476 €	€
WACC	6.92%	%
NPV	1,238,771	€
IRR (Free CF)	12.04%	%
MOIC Total Capital (OCF/ICF)	2.96	-
Amortization Time	8.40 a	a

10.3.5 Consolidation into One Organization

In the following, the individual potential business units are consolidated into the SPV. The general operating costs of the company are difficult to estimate and again assumptions have to be made. Due to a lack of information, operating cost assumptions based on German conditions are assumed.

Regarding personnel expenses, the calculated salaries for a managing director and a secretary, who also performs accounting tasks, are included. On top of the employee salaries, 32% is added for other non-wage expenses from the employer's point of view. The tasks of the managing director include communication and coordination with all parties (manufacturer, municipality, insurance company), planning of (re)investments or coordination of services.

For the operation it is assumed that an office space is rented. Other costs for vehicle, equipment, liability insurance and other expenses are given in the following table with corresponding source.

Table 36 | General Cost Assumptions (OPEX SPV)

PARAMETER	VALUE	UNIT	SOURCE
Liability insurance	0.5%	% of sales	Interview Insurance Provider (For Germany)
Salary Managing Director	113,000	€/a	StepStone Deutschland GmbH
Salary Secretary	35,000	€/a	StepStone Deutschland GmbH
Personnel Fringe Costs	32	%	Estimation
Vehicle	36,000	€	DAT (2023)
Office Equipment	15,000	€	Estimation
Op. Life Vehicle/ Equipment	5	a	Estimation
Other Operating Cost	20,000	€/a	Estimation

In summary, capital expenditures (CAPEX) for the various facilities and operating equipment are presented for the first fiscal year:

Table 37 | CAPEX of First Year

YEAR	0	Q1	Q2	Q3	Q4	UNIT
CAPEX PV		960,000	2,240,000	-	-	€
100%		30	70			%
CAPEX Pumps		28,800	28,800	38,400	-	€
100%		30	30	40		%
CAPEX LED		6,780	15,820	-	-	€
100%		30	70			%
CAPEX Biogas		775,500	775,500	1,034,000	-	€
100%		30	30	40		%
CAPEX Vehicle & Equipment		51,000	-	-	-	€
100%		100				%
Reserves		485,000				€
100%		100	0%			%

In total, there is a capital requirement of just under € 6,440,000 for financing and bridging purposes for the first financial year. Of this amount, € 1,288,000 will be provided via equity and € 5,152,000 via debt capital in three tranches or quarters. The resulting income statement and cash flow statement are presented below.

Table 38 | Profit and Loss Statement SPV

Year	0	Q1	Q2	Q3	Q4	2	3	4	5	6	7	8
Sales PV				202,534 €	202,534 €	834,864 €	860,345 €	886,604 €	913,665 €	941,551 €	970,289 €	999,903 €
Sales Pumps					9,037 €	37,439 €	38,775 €	40,159 €	41,593 €	43,078 €	44,616 €	46,209 €
Sales LED				1,875 €	1,875 €	7,768 €	8,045 €	8,332 €	8,630 €	8,938 €	9,257 €	9,587 €
Sales Biogas					105,323 €	436,330 €	451,907 €	468,040 €	484,749 €	502,055 €	519,978 €	538,541 €
Total Sales		- €	- €	204,409 €	318,769 €	1,316,400 €	1,359,073 €	1,403,136 €	1,448,637 €	1,495,622 €	1,544,140 €	1,594,241 €
Operating Cost PV				- 8,000 €	- 8,000 €	- 33,142 €	- 34,326 €	- 35,551 €	- 36,820 €	- 38,135 €	- 39,496 €	- 40,906 €
Insurance PV				- 8,000 €	- 8,000 €	- 33,142 €	- 34,326 €	- 35,551 €	- 36,820 €	- 38,135 €	- 39,496 €	- 40,906 €
Operating Cost Pumps					- 4,774 €	- 19,776 €	- 20,482 €	- 21,213 €	- 21,970 €	- 22,754 €	- 23,567 €	- 24,408 €
Operating Cost LED				- 800 €	- 800 €	- 3,314 €	- 3,433 €	- 3,555 €	- 3,682 €	- 3,813 €	- 3,950 €	- 4,091 €
Operating Cost Biogas					26,313 €	109,007 €	112,899 €	116,929 €	121,104 €	125,427 €	129,905 €	134,543 €
Personnel Cost		- 48,840 €	- 48,840 €	- 48,840 €	- 48,840 €	- 202,334 €	- 209,558 €	- 217,039 €	- 224,787 €	- 232,812 €	- 241,123 €	- 249,732 €
Liability Insaurance		- 506 €	- 506 €	- 506 €	- 506 €	- 4,174 €	- 4,302 €	- 4,433 €	- 4,568 €	- 4,708 €	- 4,851 €	- 5,000 €
Other Cost		- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 20,714 €	- 21,453 €	- 22,219 €	- 23,013 €	- 23,834 €	- 24,685 €	- 25,566 €
EBITDA		- 54,346 €	- 54,346 €	133,263 €	269,162 €	1,108,810 €	1,144,093 €	1,180,504 €	1,218,080 €	1,256,858 €	1,296,876 €	1,338,175 €
Depreciation and amortization PV				- 40,000 €	- 40,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €
Depreciation and amortization Pumps					- 1,920 €	- 7,680 €	- 7,680 €	- 7,680 €	- 7,680 €	- 7,680 €	- 7,680 €	- 7,680 €
Depreciation and amortization LED				- 377 €	- 377 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €
Depreciation and amortization Biogas					- 40,391 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €
Depreciation and amortization Vehicle & Equipment		- 2,550 €	- 2,550 €	- 2,550 €	- 2,550 €	- 10,200 €	- 10,200 €	- 10,200 €	- 10,200 €	- 12,155 €	- 12,155 €	- 12,155 €
EBIT		- 56,896 €	- 56,896 €	90,336 €	183,924 €	767,861 €	803,144 €	839,555 €	877,131 €	913,953 €	953,972 €	995,271 €
Interest loan		- 29,134 €	- 116,611 €	- 147,267 €	- 147,267 €	- 360,618 €	- 344,626 €	- 327,515 €	- 309,206 €	- 289,616 €	- 268,654 €	- 246,225 €
EBT		- 86,030 €	- 173,508 €	- 56,931 €	36,657 €	407,244 €	458,518 €	512,040 €	567,925 €	624,337 €	685,317 €	749,045 €
Tax		- €	- €	- €	- €	- 122,173 €	- 137,555 €	- 153,612 €	- 170,377 €	- 187,301 €	- 205,595 €	- 224,714 €
EAT		- 86,030 €	- 173,508 €	- 56,931 €	36,657 €	285,071 €	320,963 €	358,428 €	397,547 €	437,036 €	479,722 €	524,332 €

Year	9	10	11	12	13	14	15	16	17	18	19	20	21
Sales PV	1,030,422 €	1,061,872 €	1,094,282 €	1,127,681 €	1,162,100 €	1,197,569 €	1,234,120 €	1,271,787 €	1,310,604 €	1,350,606 €	1,391,828 €	1,434,309 €	739,043 €
Sales Pumps	47,858 €	49,567 €	51,336 €	53,169 €	55,067 €	14,258 €							
Sales LED	9,930 €	10,284 €	10,651 €	11,032 €	11,425 €	11,833 €	12,256 €	6,347 €					
Sales Biogas	557,767 €	577,679 €	598,303 €	619,662 €	641,784 €	664,696 €	688,425 €	713,002 €	738,456 €	764,819 €	792,123 €	820,402 €	637,268 €
Total Sales	1,645,977 €	1,699,403 €	1,754,572 €	1,811,544 €	1,870,376 €	1,888,356 €	1,934,801 €	1,991,136 €	2,049,061 €	2,115,425 €	2,183,952 €	2,254,711 €	1,376,311 €
Operating Cost PV	- 42,366 €	- 43,879 €	- 45,445 €	- 47,068 €	- 48,748 €	- 50,488 €	- 52,291 €	- 54,158 €	- 56,091 €	- 58,094 €	- 60,167 €	- 62,315 €	- 32,270 €
Insurance PV	- 42,366 €	- 43,879 €	- 45,445 €	- 47,068 €	- 48,748 €	- 50,488 €	- 52,291 €	- 54,158 €	- 56,091 €	- 58,094 €	- 60,167 €	- 62,315 €	- 32,270 €
Operating Cost Pumps	- 25,280 €	- 26,182 €	- 27,117 €	- 28,085 €	- 29,087 €	- 7,531 €							
Operating Cost LED	- 4,237 €	- 4,388 €	- 4,545 €	- 4,707 €	- 4,875 €	- 5,049 €	- 5,229 €	- 2,708 €					
Operating Cost Biogas	139,346 €	144,320 €	149,473 €	154,809 €	160,336 €	166,060 €	171,988 €	178,128 €	184,487 €	191,073 €	197,894 €	204,959 €	159,207 €
Personnel Cost	- 258,647 €	- 267,881 €	- 277,444 €	- 287,349 €	- 297,607 €	- 308,232 €	- 319,236 €	- 330,632 €	- 342,436 €	- 354,661 €	- 367,322 €	- 380,436 €	- 394,017 €
Liability Insaurance	- 5,152 €	- 5,309 €	- 5,471 €	- 5,638 €	- 5,810 €	- 5,988 €	- 6,171 €	- 6,359 €	- 6,553 €	- 6,753 €	- 6,959 €	- 7,172 €	- 3,695 €
Other Cost	- 26,479 €	- 27,424 €	- 28,403 €	- 29,417 €	- 30,468 €	- 31,555 €	- 32,682 €	- 33,849 €	- 35,057 €	- 36,308 €	- 37,605 €	- 38,947 €	- 40,338 €
EBITDA	1,380,796 €	1,424,781 €	1,470,174 €	1,517,021 €	1,565,368 €	1,595,083 €	1,638,890 €	1,687,401 €	1,737,320 €	1,792,589 €	1,849,625 €	1,908,485 €	1,032,928 €
Depreciation and amortization PV	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 160,000 €	- 80,000 €
Depreciation and amortization Pumps	- 7,680 €	- 7,680 €	- 7,680 €	- 7,680 €	- 7,680 €	- 1,920 €	- €	- €	- €	- €	- €	- €	- €
Depreciation and amortization LED	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 1,507 €	- 753 €					
Depreciation and amortization Biogas	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 161,563 €	- 121,172 €				
Depreciation and amortization Vehicle & Equip	- 12,155 €	- 12,155 €	- 14,486 €	- 14,486 €	- 14,486 €	- 14,486 €	- 14,486 €	- 17,263 €	- 17,263 €	- 17,263 €	- 17,263 €	- 17,263 €	
EBIT	1,037,891 €	1,081,876 €	1,124,939 €	1,171,786 €	1,220,133 €	1,255,609 €	1,301,335 €	1,347,822 €	1,438,885 €	1,615,326 €	1,672,362 €	1,731,223 €	952,928 €
Interest loan	- 222,226 €	- 196,547 €	- 169,071 €	- 139,671 €	- 108,213 €	- 74,553 €	- 38,537 €	0 €	0 €	0 €	0 €	0 €	0 €
EBT	815,665 €	885,329 €	955,868 €	1,032,115 €	1,111,920 €	1,181,055 €	1,262,798 €	1,347,822 €	1,438,885 €	1,615,326 €	1,672,362 €	1,731,223 €	952,928 €
Tax	- 244,699 €	- 265,599 €	- 286,761 €	- 309,635 €	- 333,576 €	- 354,317 €	- 378,839 €	- 404,347 €	- 431,666 €	- 484,598 €	- 501,709 €	- 519,367 €	- 285,878 €
EAT	570,965 €	619,730 €	669,108 €	722,481 €	778,344 €	826,739 €	883,959 €	943,476 €	1,007,220 €	1,130,728 €	1,170,654 €	1,211,856 €	667,050 €

Table 39 | Cash Flow Statement SPV

Year	0	Q1	Q2	Q3	Q4	2	3	4	5	6	7	8
EBITDA	- €	-54,346 €	-54,346 €	133,263 €	269,162 €	1,108,810 €	1,144,093 €	1,180,504 €	1,218,080 €	1,256,858 €	1,296,876 €	1,338,175 €
Tax	- €	- €	- €	- €	- €	-122,173 €	-137,555 €	-153,612 €	-170,377 €	-187,301 €	-205,595 €	-224,714 €
Δ Net Working Capital	- €	- €	- €	-68,136 €	-38,120 €	-3,444 €	-3,556 €	-3,672 €	-3,792 €	-3,915 €	-4,043 €	-4,175 €
CF f. Operations	- €	-54,346 €	-54,346 €	65,127 €	231,042 €	983,194 €	1,002,982 €	1,023,220 €	1,043,911 €	1,065,641 €	1,087,238 €	1,109,286 €
CF f. Investment		-1,822,080 €	-3,060,120 €	-1,072,400 €	- €	- €	- €	- €	- €	-60,777 €	- €	- €
Free CF	- €	-1,876,426 €	-3,114,466 €	-1,007,273 €	231,042 €	983,194 €	1,002,982 €	1,023,220 €	1,043,911 €	1,004,864 €	1,087,238 €	1,109,286 €
Loan		1,019,160 €	3,060,120 €	1,072,400 €	- €							
Interest	- €	-29,134 €	-116,611 €	-147,267 €	-147,267 €	-360,618 €	-344,626 €	-327,515 €	-309,206 €	-289,616 €	-268,654 €	-246,225 €
Redemption	- €					-228,451 €	-244,442 €	-261,553 €	-279,862 €	-299,453 €	-320,414 €	-342,843 €
Equity measures		1,287,920 €				- €	-285,071 €	-320,963 €	-358,428 €	-397,547 €	-437,036 €	-479,722 €
CF f. Financing	- €	2,277,946 €	2,943,509 €	925,133 €	-147,267 €	-589,069 €	-874,139 €	-910,031 €	-947,497 €	-986,616 €	-1,026,105 €	-1,068,791 €
Total CF	- €	401,520 €	-170,958 €	-82,141 €	83,775 €	394,125 €	128,843 €	113,189 €	96,414 €	18,248 €	61,133 €	40,496 €

Year	9	10	11	12	13	14	15	16	17	18	19	20	21
EBITDA	1,380,796 €	1,424,781 €	1,470,174 €	1,517,021 €	1,565,368 €	1,595,083 €	1,638,890 €	1,687,401 €	1,737,320 €	1,792,589 €	1,849,625 €	1,908,485 €	1,032,928 €
Tax	-244,699 €	-265,599 €	-286,761 €	-309,635 €	-333,576 €	-354,317 €	-378,839 €	-404,347 €	-431,666 €	-484,598 €	-501,709 €	-519,367 €	-285,878 €
Δ Net Working Capital	-4,311 €	-4,452 €	-4,597 €	-4,748 €	-4,903 €	-1,498 €	-3,870 €	-4,695 €	-4,827 €	-5,530 €	-5,711 €	-5,897 €	187,893 €
CF f. Operations	1,131,785 €	1,154,730 €	1,178,816 €	1,202,639 €	1,226,889 €	1,239,269 €	1,256,180 €	1,278,360 €	1,300,827 €	1,302,461 €	1,342,206 €	1,383,222 €	934,942 €
CF f. Investment	- €	- €	-72,429 €	- €	- €	- €	- €	-86,314 €	- €	- €	- €	- €	- €
Free CF	1,131,785 €	1,154,730 €	1,106,388 €	1,202,639 €	1,226,889 €	1,239,269 €	1,256,180 €	1,192,046 €	1,300,827 €	1,302,461 €	1,342,206 €	1,383,222 €	934,942 €
Loan													
Interest	-222,226 €	-196,547 €	-169,071 €	-139,671 €	-108,213 €	-74,553 €	-38,537 €	0 €	0 €	0 €	0 €	0 €	0 €
Redemption	-366,842 €	-392,521 €	-419,998 €	-449,398 €	-480,855 €	-514,515 €	-550,531 €	- €	- €	- €	- €	- €	- €
Equity measures	-524,332 €	-570,965 €	-619,730 €	-669,108 €	-722,481 €	-778,344 €	-826,739 €	-883,959 €	-943,476 €	-1,007,220 €	-1,130,728 €	-1,170,654 €	-2,887,014 €
CF f. Financing	-1,113,400 €	-1,160,034 €	-1,208,799 €	-1,258,176 €	-1,311,549 €	-1,367,413 €	-1,415,807 €	-883,959 €	-943,476 €	-1,007,220 €	-1,130,728 €	-1,170,654 €	-2,887,014 €
Total CF	18,385 €	-5,304 €	-102,411 €	-55,538 €	-84,660 €	-128,144 €	-159,627 €	308,087 €	357,351 €	295,241 €	211,478 €	212,568 €	-1,952,072 €

The evaluation of the KPIs shows that, given the assumptions made, both the NPV at the calculated WACC and the hurdle rate set at the level of free CF are positive. The internal rate of return on equity is 23.80%, which is significantly higher than the set 15.00%. The average DSCR is 1.89; whether this is sufficient to secure the lenders must be checked in each specific case and, if necessary, the financing structure adapted.

Table 40 | KPIs for SPV

PARAMETER	VALUE	UNIT
Average DSCR	1.89	-
Hurdle Rate	10.00	%
NPV	3,073,210	€
WACC	6.92%	%
NPV	5,626,271	€
IRR (Free CF)	16.33	%
MOIC Total Capital (OCF/ICF)	3.80	-
Amortization Time of Free CF	6.65	a
IRR Flow to Equity (Dividends)	23.80	%
Miniumum Dividends	15.00	%
NPV (Dividends)	1,284,797	€
Amortization Time of Flow to Equity (Dividends)	6.17	a
MOIC Total Capital (Dividens/Initital Equity)	11.66	-

Sensitivity Analysis: Interest Rate and Electricity Price

In the following, a sensitivity analysis of the KPIs of DSCR and equity IRR (based on dividends), which are important for financing, is dissected for a varying borrowing rate (7% to 12%) and a changing electricity price (100%, 90%, 80% of the price assumed in the base scenario).

With an increased borrowing rate and unchanged electricity price, the sensitivity analysis shows that the return on equity would decrease, but still remain above the required 15%. At the same time, however, the DSCR would drop significantly, which could possibly lead to an exclusion criterion on the part of the lenders.

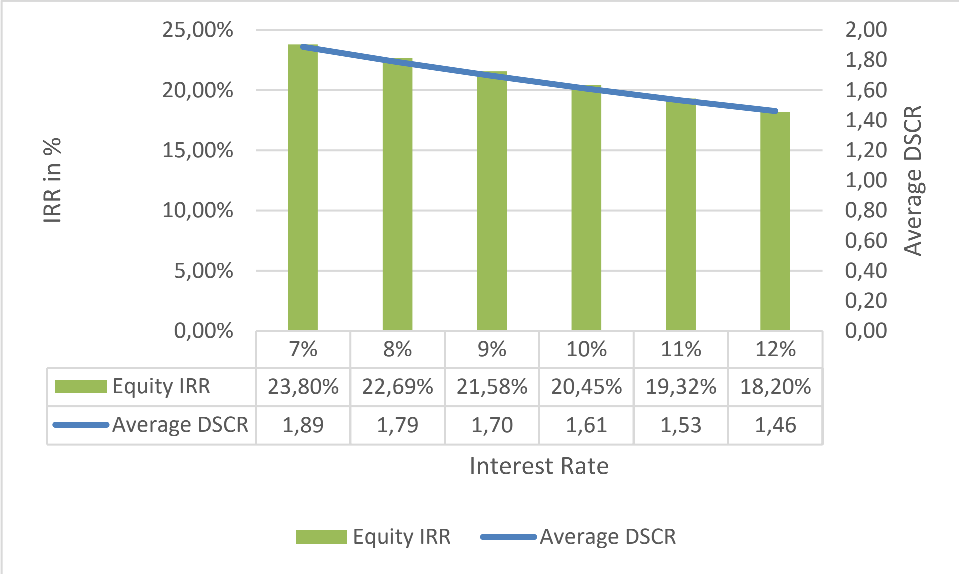


Figure 40 | Sensitivity Analysis of Interest Rate and Electricity Price on Selected KPIs (1), (© IfaS)

In order to create incentives for potential contracting customers to enter into the contractual relationship, it might be possible to undersell the current electricity market price. To do this, the electricity price is reduced by 10% compared to the baseline. It can be seen that the equity IRR drops below 15% when the borrowing rate is between 11% and 12%. In addition, the DSCR is significantly reduced.

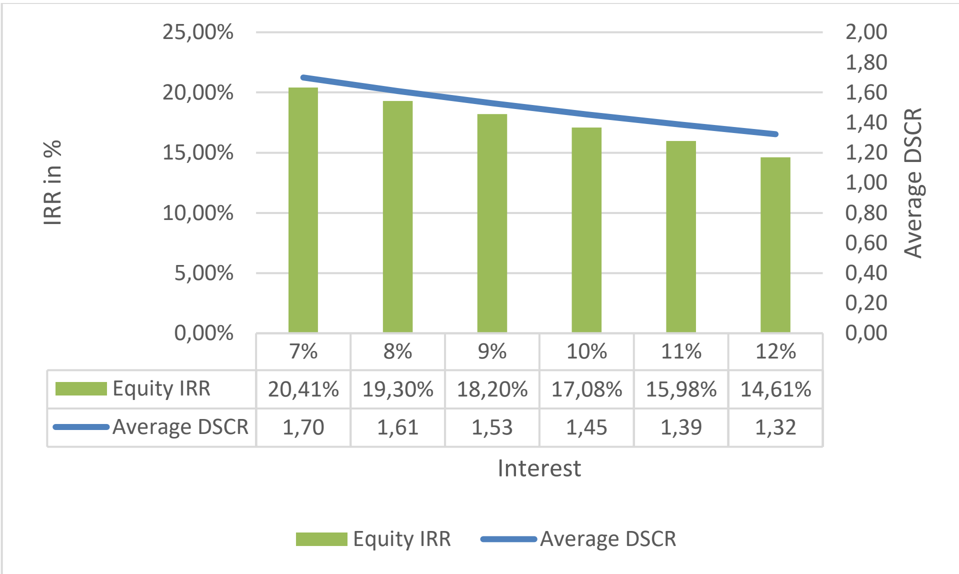


Figure 41 | Sensitivity Analysis of Interest Rate and Electricity Price on Selected KPIs (2), (© IfaS)

If an electricity price of 80% is used, the equity IRR is below 15% at a borrowing rate of between 8% and 9%.

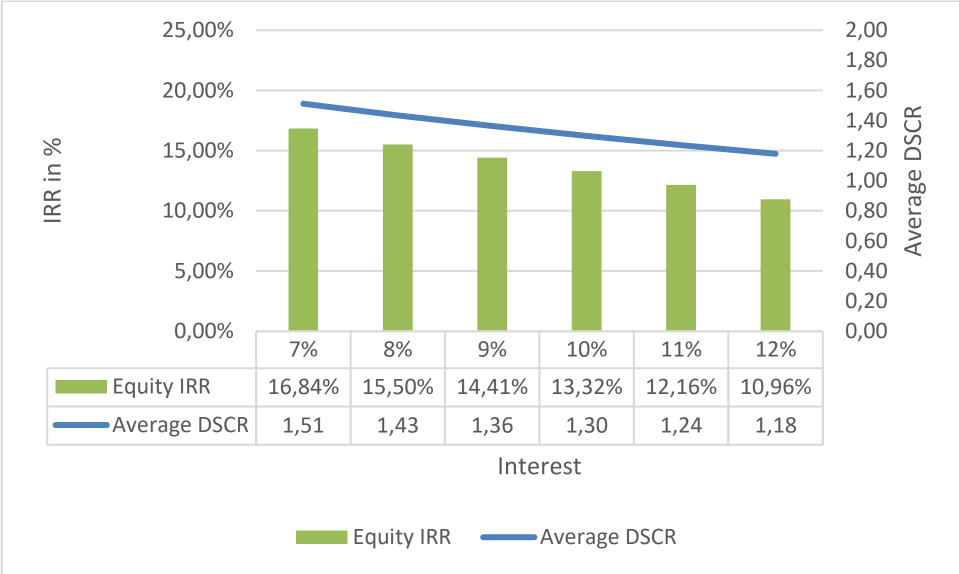


Figure 42 | Sensitivity Analysis of Interest Rate and Electricity Price on Selected KPIs (3), (© IfaS)

10.4 Investments and Funding Opportunities for Renewable Energy in Senegal

By 2025, the Senegalese government anticipate offering all of its population with; secure, cost-effective access to a sufficient supply of high-quality energy. Access to electricity is recognized as essential in the Senegalese setting to combat poverty and for country's overall development (Netherlands Enterprise Agency (RVO), 2022). To achieve above mission, Senegal is required to invest more in renewable energy sources that will add value to local industries, agriculture and community. Senegal's energy industry has drawn several financial partners and development partners in recent years locally, regionally and internationally.

10.4.1 Potential funding and assistance in national context

Despite the expectation of investing in renewable energies, public sector contribution for the energy industry in Senegal has been less than the required investment for new renewable energy projects and to modernize the already available infrastructure. The majority of investments and financial support for the energy sector come from multilateral and bilateral banks or donors. Due to a perceived risk, local banks and the private sector are still hesitant to participate in the energy sector. Senegal was one of the first nations in the region to open its energy industry to private investment, making it a pioneer in the reform of the sector. Although the national utility has a monopoly on grid transmission and distribution which is operated by Société National d'Électricité du Sénégal (SENELEC) (National Electricity Company of Senegal), the private sector generates around 40% of the nation's installed capacity, and its market share is constantly growing (GET. Invest, 2022). Regulation is in place to promote a competitive market for electricity, and energy policy is usually supportive of private involvement. While other applications, such as motor and thermal projects, are being implemented through donor-supported programs, electrification projects in the renewable energy sector are jointly funded by the private sector and the Rural Electrification Fund (REF).

As a result of government focusing more on supplying electricity to population in rural areas; REF has been established and operated by Rural Electrification Agency (ASER) under supervision of ministry of energy in Senegal. ASER is responsible for Rural electrification sub-sector financing proposals with clean development tools, Analysis of financial gaps and roundtable discussion on gap funding and development partners.

A private corporation, Promotion des Investissements et Grands Travaux (APIX) (Investment Promotion and Major Works Agency), which is mostly owned by the Senegalese government encourage both domestic and foreign businesses to invest in Senegal. In order to establish a business in Senegal and to apply for the many government incentives offered for new businesses in energy sector, APIX offers help for all administrative procedures. Additionally, APIX provides assistance for identification of local funding partners (GET. Invest, 2022).

The Conseil Patronal des Énergies Renouvelables du Sénégal (COPERES) (Senegal's Business Council for Renewable Energies) is actively participating in renewable energy advocacy (primarily on-grid). COPERES is responsible for increasing universal energy availability by depending on off-grid and mini-grid technologies, promoting large-scale energy storage options, assisting in the financing of solar household systems, launch of a national effort to promote solar home systems and productive energy, especially in rural regions and raising awareness and raising efforts for the general public to cooperate with SENELEC. COPERES has established partnerships with local private sector partners such as ENGIE (GDF Suez), Solar Africa company, Bonergie Solaire company as a solar equipment supplying company, LEKELA which is a Senegal based private company for utility scale projects for renewable energy and many other private companies (Business Council of Renewable energies of Senegal, 2022).

Senegalese government has signed a number of Investment Protection and Promotion Agreements (APPI) with many business partners worldwide. These agreements have strengthened the legal security of investments and has guaranteed expropriation, provided free repatriation of investment money and returned on investment. APPI provides loss compensation in a case of a war, armed conflict, or unstable political conditions. Senegal is completely dedicated to enhancing its business climate in order to encourage investment and private-sector-driven economic growth.

The government has established a Carbon Fund (CF) and levied a fee on the sale of hydrocarbons. This money is being utilized to build more capacity and to give consumers subsidies in the form of affordable electricity. Additionally, the government has established funding to promote biofuels and renewable energy sources and to increase public awareness of them (International Renewable Energy Agency, 2012).

In order to foster favorable investment circumstances, Senegal has also established a National Investment Code. The legislation offers protection from expropriation and nationalization as well as instructions for returning an investment's returns for the investor. The National Agency for the Promotion of Investment (APIX) has been created as a specific agency to supervise the code. Energy is not specifically mentioned in the investment code and is therefore not currently an eligible sector; however, if investments that create a new enterprise also create jobs and are located in underdeveloped areas of the country, the enterprise would receive all the benefits of the investment code (International Renewable Energy Agency, 2012).

10.4.2 Potential funding opportunities in the regional context

- **African Development Bank Group**

The African Development Bank manages the Sustainable Energy Fund for Africa (SEFA), a multi-donor Special Fund. It provides catalytic financing to stimulate private-sector investment in renewable energy and energy efficiency. SEFA provides technical support and concessional financing mechanisms to remove market obstacles, establish a more robust project pipeline, and optimize the risk-return profile of individual investments.

10.4.3 Potential funding partners in international context

Investment in clean energy has been fluctuating over years varying from €2.4 million in 2014 to €135 million in 2016, and then reducing the investments up to €11 million in 2018. Despite the lack of financial support for the procurement of renewable energy technologies, more than 80% of investment in this industry after 2017 comes ad foreign investments (GET. Invest, 2022).

- **Green Climate fund (GCF)**

GCF provides assistance to recipient nations through certified national and sub-national implementing entities (including non-governmental organizations (NGOs), government ministries, national development banks, and other domestic or regional organizations that satisfy the Fund's requirements). Under international access, countries can also obtain funds from accredited international and regional organizations (such as multilateral and regional development banks and UN agencies). African development bank is one of the accredited members of GCF and Senegal can request funds from GCF. Funds will be disbursed through Enhanced Direct Access (EDA), in which certified institutions in developing countries receive funds. Investors may seek financial aids for projects with the highest level of environmental and social impact risk (Category A/I-1) greater than USD 250 million.

- **The French Development Agency / Agence française de développement, AFD**

AFD is a public entity that finances and supports development initiatives in many disciplines, including energy, to help low- and middle-income nations achieve economic, social, and environmental growth(Agence française de développement, 2022). AFD has funded US $ 165,400,000 for a project on promotion of access to reliable, modern energy sources at reasonable cost in Senegal in 2017, a fund of € 11,000,000 for electricity production from a thermal power station in Senegal, a fund worth of € 52,900,000 with cooperation with European union for the network upgrading activities in Senegal and € 105,000,000 worth financial aid for the restructuring of SENELAC and the production of electricity from a hydroelectric dam in Manantali(Netherlands Enterprise Agency (RVO), 2022)

- **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)**

GIZ works in Senegal to achieve the goal of sustainable power supply by deploying renewable energy and promoting energy efficiency measures. Education and employment in the field of renewable energies are being fostered and GIZ provides access to power in rural regions through village grids or individual solar household systems (Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ, 2022). GIZ has provided US $ 19,370,000 for a Sustainable and Participatory Energy Management Project (PROGEDE II)(Netherlands Enterprise Agency (RVO), 2022).

- **KfW Bank**

KfW is a German state-owned investment and development bank. The German development cooperation in Senegal focuses on "renewable energy sources (RE), energy efficiency, and access to energy," including initiatives in the fields of renewable energy generation and energy efficiency through the modernization of power distribution networks in nine Senegalese cities and financial cooperation funds are provided by KfW bank (KfW Bank aus Verantwortung, 2021).

- **World Bank group**

With the aim of increasing access to electricity services for public and private sector electricity users of Senegal, World bank is providing financial aids. USD 150 million has already been granted for Senegal government for the period of 2022 – 2025 for energy transmission and distribution purposes, and public administration of energy and extractives (The world Bank Group, 2022).

11 Conclusions & Observations

In conclusion, the outcomes of this comprehensive ECPMP mark significant milestones in the pursuit of renewable energies and sustainability development in Senegal. This strategic roadmap has been accurately designed to achieve a zero-emission network in order to mitigate climate change and cultivate a greener future. In this last chapter, it is imperative to highlight the proposed recommendations to ensure the ECPMP success. These recommendations are not only serving as guidelines for immediate action but also it demonstrates a pilot project that makes Saint-Louis city to be an inspiration and model for the adoption of zero-emission networks in Senegal.

11.1 Future Measures for Saint-Louis City

A thorough set of analysis is carried out within this ECPMP to evaluate numerous aspects crucial to the success of the LoSENS project. This study analysis achieved results more or less compatible with the proposal' targets.

On one hand, the measures developed for the increase of RE share in the electricity mix is reaching 26% as shown in Figure 43:

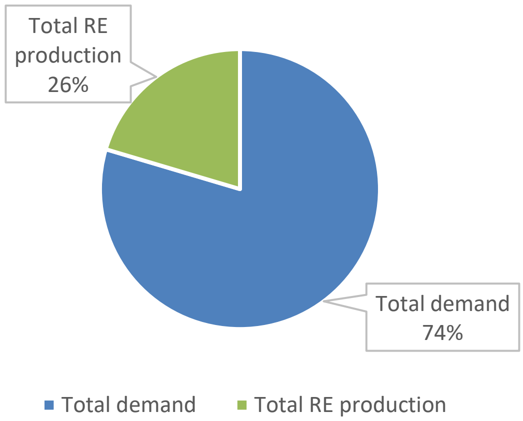


Figure 43 | Saint-Louis City RE Production by 2026-2027, (© IfaS)

On the other hand, the reduction of electricity demand is 5% by 2025 based on the extrapolated projects for wastewater pump efficiency and public street lighting as shown in Figure 44:

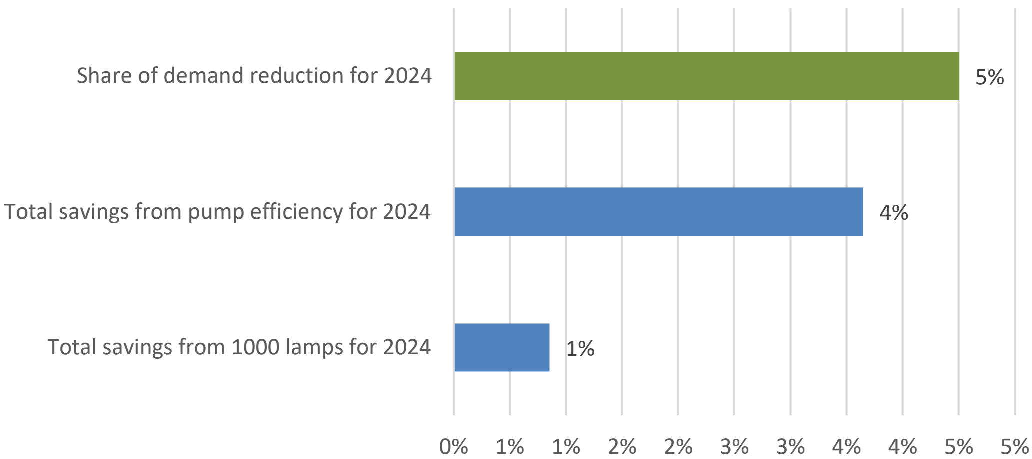


Figure 44 | Reduction of Electricity Demand by 2025 for Saint-Louis City, (© IfaS)

From the aforementioned achievements for the city of Saint-Louis, a concept for CO_2 abatement was developed and it is anticipated that the emission reduction potential will be 11,860 t CO_{2e}/a which represents a 27% reduction from the baseline scenario.

11.2 Recommendations

11.2.1 Public Lighting Efficiency

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

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

The data sheets of these products can be found WP4a:

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

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

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

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

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

11.2.2 Solar Energy

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

11.2.3 Wastewater Pumps Efficiency

The analysis of pumping stations in Saint-Louis revealed various limitations and technical issues. For future applications, it is recommended to shift to horizontal centrifugal pumps instead of submersible pumps, especially when the tank size is less than 7 meters. This recommendation is founded on several technical reasons. Firstly, horizontal centrifugal pumps are better suited for handling fluids with solids and abrasives, featuring vortex impellers or agitators to prevent clogging or damage. Additionally, they offer ease of maintenance, as they are more accessible and repairable at ground level or on platforms. Furthermore, it is advisable to equip major pumping stations with permanent measurement devices for flow, pressure, and electrical power for reliable data. The efficiency of horizontal centrifugal pumps, attributed to their design and ability to handle higher flow rates, makes them preferable, contributing to energy savings. Moreover, their durability and longer lifespan in heavy-duty applications align with the goal of improved wastewater management and environmental sustainability. Implementing these strategies enhances the adaptability of wastewater pumping stations, reduces energy consumption, and aligns with energy efficiency standards, resulting in both cost savings and environmental benefits.

11.2.4 Waste-to-Energy

The proposed dry anaerobic digestion technology for Saint-Louis presents a range of advantages, such as cost-effectiveness, efficient utilization of local resources, minimal equipment requirements, water conservation, low energy consumption, resistance to contaminants, modular failure protection, and scalability. To advance this initiative, several key actions are recommended. These include introducing the concept to the government, engaging relevant government agencies for support, identifying potential investors and securing financing, finding buyers for the heat and fertilizer outputs, addressing infrastructure access points, analyzing waste characteristics with a focus on decomposable organics, establishing a process for sourcing clean organic fraction of municipal solid waste (OFMSW), securing a long-term power grid agreement, conducting soil and static evaluations, obtaining concrete construction estimates, and progressing with detailed engineering, planning, and eventual construction. These steps aim to ensure a comprehensive and well-supported implementation of the dry anaerobic digestion technology in Saint-Louis.

11.2.5 Business framework

WP3 first provides an overview of possible approaches to implement renewable energy and energy efficiency projects. Due to lack of existing municipal resources, low knowledge and insufficient information flow, PPPs could lead to the acquisition of financial resources and know-how.

The "SPV" examined in more details in this chapter could contribute to the social development and growth of the renewable energy sector and create basic structures for a future community-led municipal utility. Involving regional actors (companies, public institutions, farmers) would also create local jobs and utilize regional, unused material flows and potentials and consequently increase regional value creation.

Under the assumptions made, the combination of the various technologies into a fictitious enterprise shows an economically feasible potential. Possible next steps to concretize the project are listed below:

- Identification of possible industrial electricity consumers and collection of potential areas.
- Determination of actual electricity demand of industrial facilities on site (esp. for PV systems).
- Determine legal framework regarding access to the electricity grid (esp. feed-in of electricity from biogas plant).
- Identification and approach of potential project participants: planners, manufacturers and construction companies, service providers (plant operators, transport, biomass input providers, etc.), financing partners, energy consumers, licensing authorities.
- Contacting credit institutions/development banks to determine concrete financing conditions.
- Determination of legal framework conditions concerning the participation of public actors in a possible project company.
- Further development of the existing operating model (corporate form, contractual relationship of the parties, contract management, concretization of the exit / handover strategy to the public sector)

11.3 Stakeholders Management

Stakeholder management is a crucial aspect and core element of LoSENS project in the model region of Saint-Louis. Proceeding with the Energy and Climate Protection Master Plan (ECPMP), it needed first to involve, identify, understand, and effectively engage all individuals and groups who have a vested interest or influence in the project. By proactively managing stakeholders, LoSENS project mitigated risks, built relationships, and ensured the project's success. Here are some key steps and that was considered throughout the project:

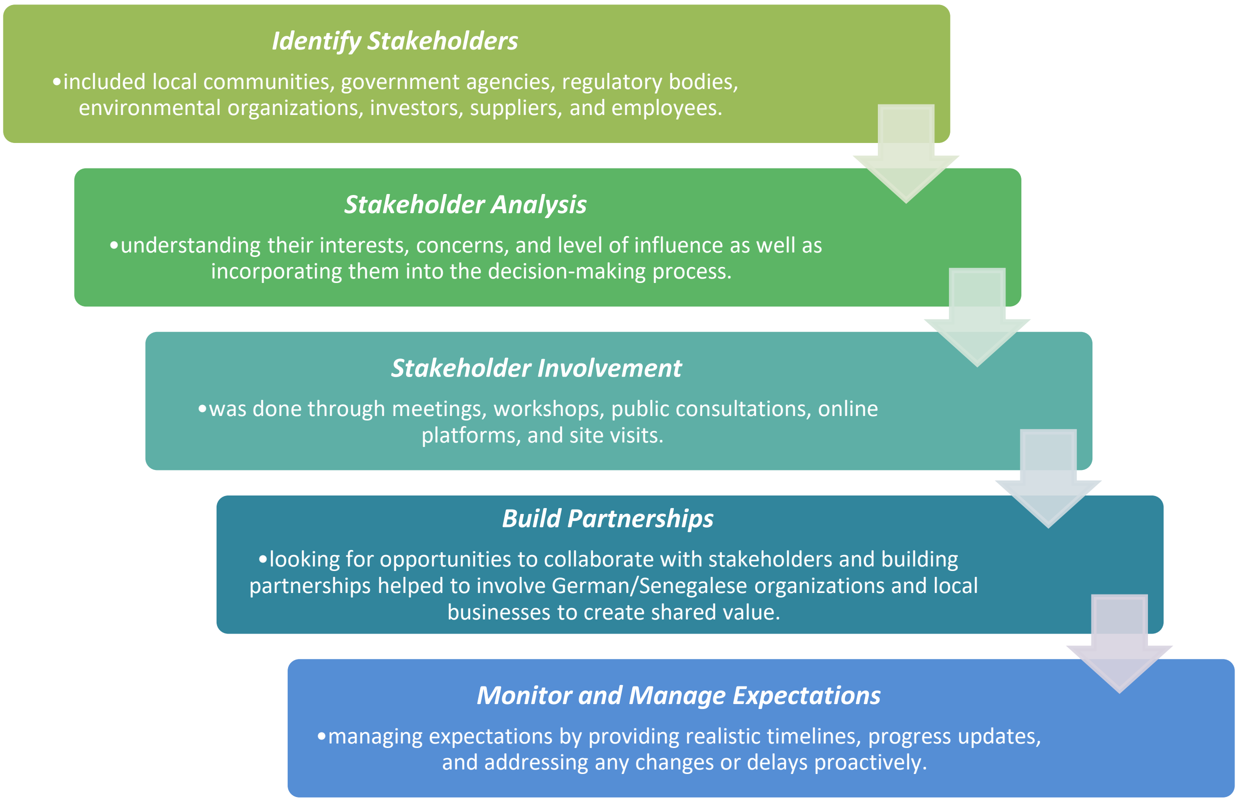


Figure 45 | Stakeholders Management Key Steps, (© IfaS)

LoSENS project model represented a German-Senegalese partnership in order to spread the implementation of project with varied international cooperations. To achieve this later, it is recommended to focus on an effective stakeholder management which requires flexibility, adaptability, and empathy. It is essential to balance the diverse interests and needs of stakeholders to achieve a successful and sustainable energy project.

The cooperation with local stakeholders such us UGB, ONAS, and the municipality was the major basis for the project success. Furthermore, the communication between all parties was thriving which leaded to good understanding of short- and long-term impacts. Additionally, the inventory of the real estate situation was also taken from scientific partners, implementation partners, public authorities, investors, etc. These steps served as a decision-making regarding the implementation of the demonstration project such as PV plant and LED for street lighting.

Work package 5 and 6 were dedicated to capacity building of stakeholders who are directly involved in the project. This gave an opportunity to new further education and training programs, which are implemented jointly with two universities. This part of the project had a great impact on students and follow up monitoring of key projects.

11.4 Capacity Building

Both work packages (WP5[26] and WP6[27]) were dedicated to preparing further education and trainings. This project segment deals with activities and initiatives undertaken to develop the skills, knowledge, and resources of the project team, as well as other stakeholders who are directly involved in the project, to effectively plan, implement, monitor, and evaluate the project. The

[26] Preparation for further education and training
[27] Implementation of further education and training + consolidation

smooth operation is ensured by the participating German and local Senegalese SMEs in close cooperation with the trained staff of the local authorities.

The project partner responsible of Capacity Building (CB) activities is the University of Nürtingen-Geislingen (HfWU) (Hochschule für Wirtschaft und Umwelt Nürtingen-Geislingen) in particular the Institute for International Research on Sustainable Management and Renewable Energy (ISR).

The CB tasks were developed by following these steps:

1. Actor analysis and identification of target groups
2. Assessing the barriers and identifying training needs
3. Determination of the target group among the students
4. Design of the training
5. Implementation of the training courses

NOTE: Due to the global COVID crisis, the training design had to be realigned. It was not possible for the HfWU team and the Senegalese experts to carry out all the planned trips to Senegal. Therefore, the e-learning had an advantage to replace face-to-face teaching.

The HfWU's online learning platform "ILIAS"[28] was used for the blended learning courses. The videos and external material were linked and available for download. Furthermore, the training videos have also been adapted and are published to the public for free use on the HfWU YouTube channel[29] .

NOTE: 100 places were allocated in the first training course. 50 places could be allocated for the second training course, adjusted to the lower implementation capacities of the on-site visits.

Regarding the conception of the integration of the training for the students in the UGB curriculum, it was not necessary to design a new master's program, as the MIER course is already established and is offered at five universities in Senegal. The project partner IfaS at the Trier University of Applied Sciences has also concluded a cooperation agreement with the UGB, in which cooperation in the IMAT (International Material Flow Management) course is intended.

Another duty of CB work packages is the publication of scientific papers. The articles are based on building the empirical results obtained from the interview studies from 2019, 2020 and 2022. The HfWU team wrote five scientific publications during the project period, most of which have already been published[30].

The results achieved in the project make a significant contribution to supporting SMEs and municipalities in Senegal in using EE and EnEff technologies. The extensive training program developed and implemented in the project was carefully tailored to the barriers and needs of actors in Senegal.

As an upcoming stage of the capacity building, the integration of the results of the master plan / pilot projects into the training courses for companies and municipalities is the responsibility of

[28] Plattform link: https://ilias.hfwu.de/goto.php?target=cat_37134&client_id=hfwu&lang=fr
[29] Training videos: https://www.youtube.com/@HfWUimFilm/playlists?view=50&sort=dd&shelf_id=10

[30] Published articles:
- https://doi.org/10.1016/j.rser.2021.111228
- https://doi.org/10.3390/su13169332
- https://doi.org/10.1016/j.erss.2022.102771
- https://doi.org/10.1016/j.geoforum.2022.09.018

the UGB. This latter needs to organize a training program with non-university institutions and actors such as regional network.

11.5 Sustainable Development Goals Implementation

Implementing a project in a urban area in line with the Agenda 2030 for Sustainable Development involves addressing specific challenges and opportunities unique to urban settings. In this regard, the sustainable urban energy project in city of Saint-Louis, Senegal, aims to address various Sustainable Development Goals (SDGs) including Goal 7 (Affordable and Clean Energy), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), and Goal 17 (Partnerships for the Goals). Figure 46 demonstrates the main contributions of LoSENS project in Saint-Louis to reach the SDGs:

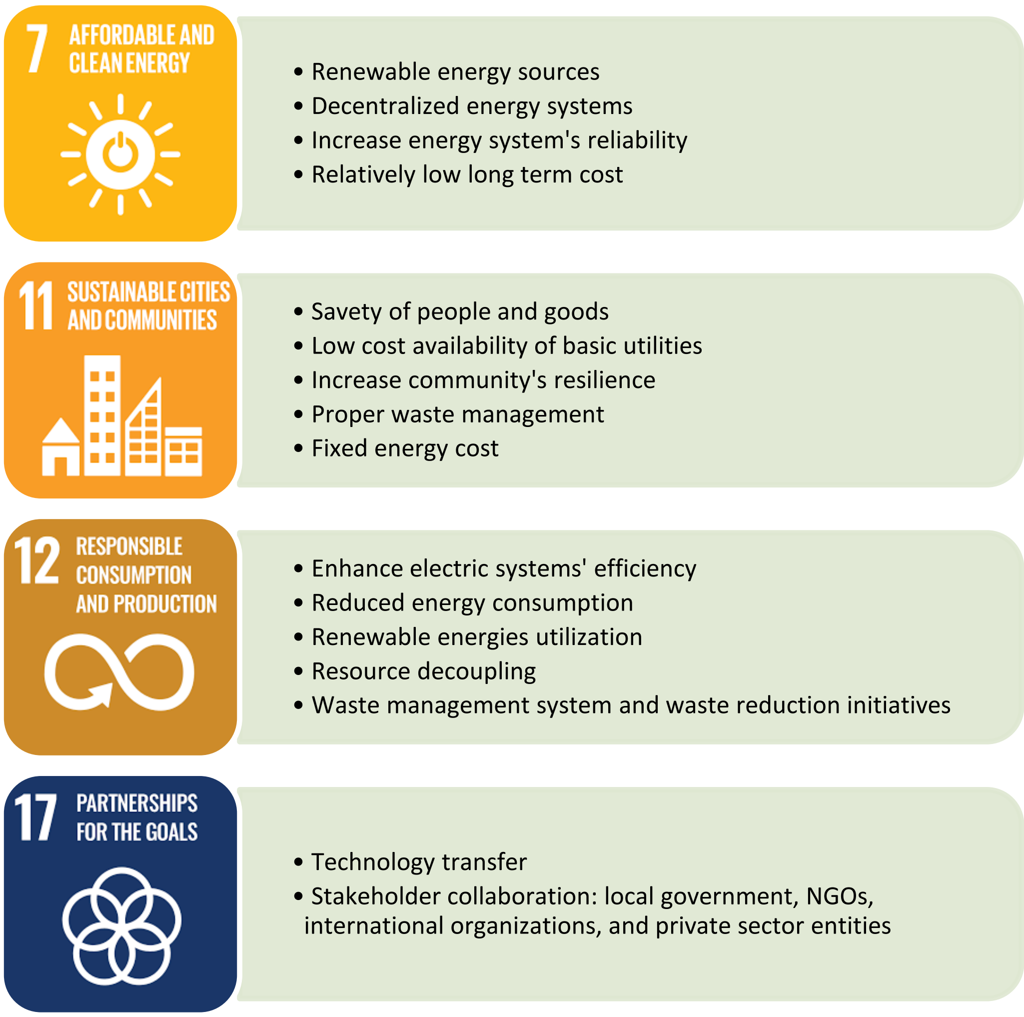


Figure 46 | Main SDGs Contributions, (© IfaS)

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

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