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

LoSENS

WP4c:
Efficient Pump Management

WP4: Project Technicalities & Method

IfaS Institut für angewandtes Stoffstrommanagement

COMMUNE DE SAINT-LOUIS

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SUBJECT:	***WP4c: Efficient Pump Management***
LOCATION:	City of Saint-Louis, Senegal
CATEGORY:	Knowledge Transfer and Feasibility Assessment
SYNOPSIS:	This report presents the findings of ***city Saint-Louis*** model region as part of ***"Local Sustainable Energy networks in Senegal"*** project with the objective of developing ***an Efficient Pump Management*** system. This report provides a holistic, comprehensive methodology of planning for Saint-Louis current and future energy efficiency pumping stations as a showcase for further regions in Senegal to duplicate. WP4c identifies and evaluates the city's pumping stations current energy uses, efficiency and gaps. 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 project. 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 Saint-Louis in wastewater pumping systems relevant efficiency.
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CONSULTANT:	Institute for Applied Material Flow Management (IfaS) Environmental Campus Birkenfeld University of Applied Sciences Trier P.O. Box 1380, 55761, Birkenfeld
PROJECT LEAD:	Prof. Dr. Peter Heck Managing Director/Chief Executive Officer E-Mail: p.heck@umwelt-campus.de Tel.: +49 6782 17 – 12 21 | Fax: +49 6782 17 – 12 64 Econ. Marco Angilella Head of the International Department E-Mail: m.angilella@umwelt-campus.de Tel.: +49 6782 17 – 26 34| Fax: +49 6782 17 – 12 64
AUTHORS:	Sarah Hakim Semlali, Eng. Project Manager, International Department E-Mail: s.semlali@umwelt-campus.de Tel.: +49 6782 17 – 26 40 | Fax: +49 6782 17 – 12 64 Bhushan Suresh Chaudhary, HiWi

Trier University of Applied Sciences - Environmental Campus Birkenfeld

Institute for Applied Material Flow Management – IfaS

P.O. Box 1380

55761 Birkenfeld

Phone: +49 6782 17 - 12 21

E-Mail: ifas@umwelt-campus.de

www.stoffstrom.org

Table of Content

List of Figures

List of Tables

List of Abbreviations

CDM	Clean Development Mechanism
GHG	Greenhouse Gas
LoSENS	Local Sustainable Energy Networks in Senegal
ONAS	National office for Wastewater Treatment in Senegal
SP	Pumping Station
WW	Wastewater

1 Executive Summary

One of the key actors of LoSENS project was 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.

Analyzing the efficiency of wastewater pumps in Saint-Louis city required a comprehensive assessment of various factors. Here is an outline of the key steps involved in conducting this efficiency analysis:

1. Data collection
2. Measurement analysis
3. Performance evaluation
4. Energy consumption and Pump efficiency analysis
5. Methodology extrapolation for unmeasured pumps
6. Economic Analysis
7. Recommendations and implementation

The project had two active partners who helped to conduct the analysis of pumping stations in Saint-Louis. 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.

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.

The evaluation was made on six priority pumping stations and taking same methodology to be extrapolated for the available list of pumps. 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. This range accounts for potential improvements in the new pump's design and engineering, resulting in higher efficiency compared to the existing pumps.

As results from following the above constructions, 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_{2eq}/a. From these results, Saint-Louis will benefit in the future from reduced energy consumption, decreased CO_2 emissions, and positive environmental impact. By implementing energy-saving measures, improving efficiency, and adopting sustainable practices, the pumping stations can contribute to a greener and more sustainable future.

2 Status Quo of Pumping Stations in Saint-Louis

LoSENS project team planned two trips to Senegal and precisely Saint-Louis to preview and analyze the pump stations. There exists almost 12 wastewater stations and 17 rainwater stations which are named as follow:

Table 1 | Pump Stations for Wastewater and Rainwater

WASTEWATER STATIONS			*RAINWATER STATIONS*		
	NAME	*NUMBER OF PUMPS*		*NAME*	*NUMBER OF PUMPS*
N°1	SP 14	2	N°1	Leona	3
N°2	SP AB	2	N°2	Stade Mawade WADE	2
N°3	SP 5	2	N°3	Cite niax	2
N°4	SP 6	2	N°4	Bas senegal	2
N°5	SP 2	2	N°5	Tableau walo	2
N°6	SP 3	2	N°6	Talbakhle	2
N°7	SP 4	2	N°7	Pikine 15 m	2
N°8	PR 1	2	N°8	Pikine 700	3
N°9	PR 2	2	N°9	Ile nord	2
N°10	PR 3	2	N°10	Goxu mbacc	2
N°11	PR 4	2	N°11	Diaminar	2
N°12	EPURATION	2	N°12	Diawling	2
			N°13	Ndioloffene	2
			N°14	Guinaw Rail	2
			N°15	Escale 01	3
			N°16	Khouma 1	3
			N°17	Khouma 2	2

According to ONAS, the current situation for the pumping stations at Saint-Louis 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 (APD, 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 1 and the pipeline leading to the lagooning station.

Figure 1 | 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 2.

Figure 2 | 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 3 demonstrate a nonfunctional exemplary pump.

Figure 3 | Low Efficient and Nonoperating Pump, (© IfaS)

From the 29 pumping stations, LoSENS project focused more on six 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 4):

Table 2 | Main Six Pumping Stations and Their Average Volumes 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

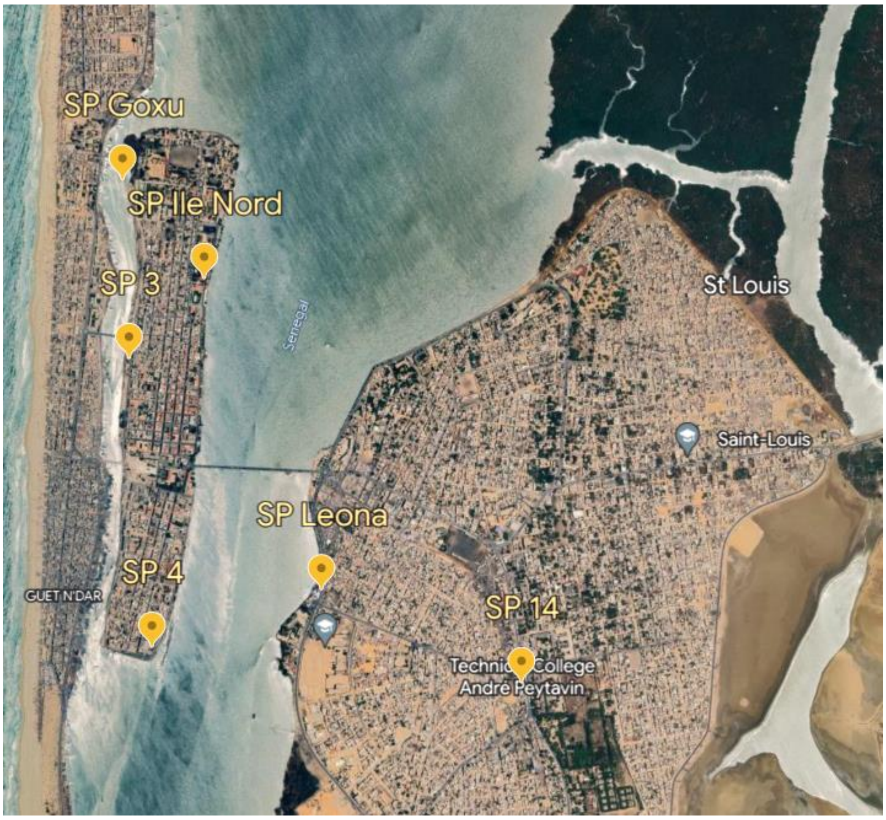

Figure 4 | Priority Pumping Stations Location in Saint-Louis, (Google Earth Satellite Image edited by IfaS)

From the summary map in Figure 5, 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.

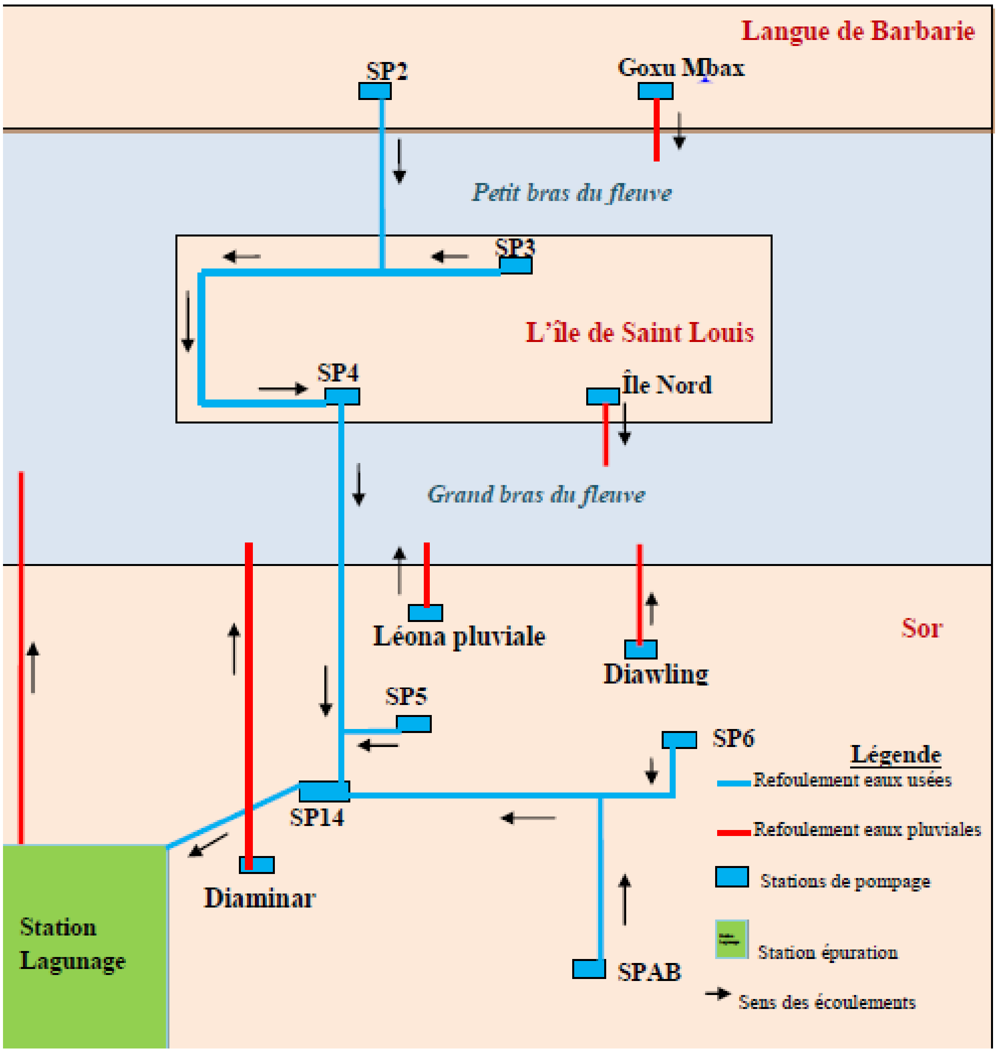

Figure 5 | Summary Map of Main Pumping Stations in Saint-Louis, (© ONAS)

Additionally, the sewer network consists of:

- 34 km of gravity pipelines,
- 10 km of discharge pipelines, including 7 km between the SP 14 pumping station and the lagooning station.

NOTE: The sewage treatment plant, as shown in Figure 5 is planned to be re-established in next few 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 the highest amounts of collected wastewater.

Further data are provided by ONAS to demonstrate the actual situation of the stations chosen and can be found in Appendix I. In order to have an accurate feasibility study, the need of measurements and recalculation of several parameters are needed to compare the efficiency of the old pumps with new and developed ones.

NOTE: Because of old infrastructure, the stations do not include a digital system to collect data automatically.

ONAS plans to install new pumps and even build new pipes to serve other areas. They have the desire to install an automatic pump operation data collection system, as well as a remote management system to replace unnecessary travels and avoid wasting time.

3 Project Outline and Planning

The objective of analyzing the pumping stations is to develop a vision of an efficient system for the future. In general, the energy efficiency method refers to the case 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:

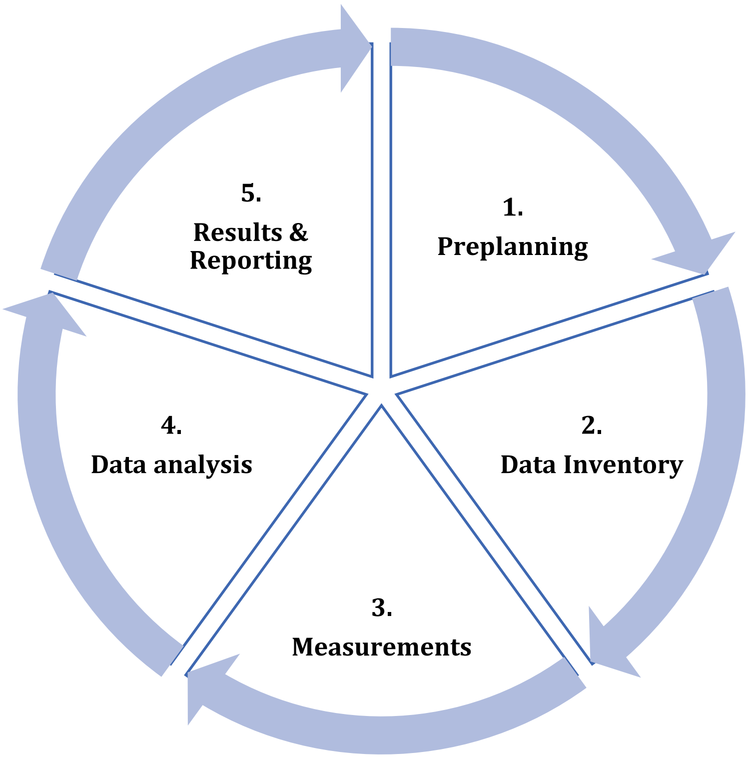

Figure 6 | Efficient Pump Management Work Package Stages, (© IfaS)

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 saving 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. The steps taken for this feasibility study are:

- **Step 1.** A research aspect revolving around the documentary and informative collection.
- **Step 2.** The visit of the main sites and probable points of impact of the project.
- **Step 3.** Status quo analysis.
- **Step 4.** Communication with all parties:
    - a. Contacts with institutional actors in Senegal (ONAS)
    - b. Meetings with the technical services involved in the project (Kocks Consult GmbH)
- **Step 5.** Pump stations measurement:
    - a. Methods and the plan to measure the pump stations with instruments needed

b. Find company to offer the service onsite: the pump data compilation and monitoring was organized in cooperation with Water Technologie[1]
c. Start measuring in the rainy season which corresponds to the month of August

Step 6. Evaluation and reporting

[1] Water Technologie is a Tunisian specialist in the study, construction, and operation of urban and industrial wastewater treatment plants as well as pumping stations.

4 Measurements & Status Quo Analysis

As part of the project to optimize energy consumption in pumping stations, *Water Technology Company* visited the six priority pumping stations with the aim of collecting the data necessary to analyze the operating status of the various equipment such as amperage, power consumption, pressure and flow. The summary of measured data can be found in Appendix IV. The following step is to prepare an action plan to achieve optimal energy efficiency while ensuring the proper functioning of the stations.

The general outcome from the measurement shows that:

Table 3 | Six Pumping Stations Operating Situation

PUMPING STATION (SP)	NUMBER OF PUMPS	REMARK
SP 14	2	P2[2] is in abnormal operation
SP 3 (Replacing SP 2)	2	Both pumps work
SP 4	2	Both pumps work
SP Leona	3	Cannot be measured
SP GOXU M'BACC	2	P2 pump is broken
SP Ile Nord	2	P2 pump is down

The presented report from *Water Technologie* makes indications that the curves of the supposed pumps installed in these stations do not correspond to the measured data. This difference between the values measured on sites and the theoretical characteristics of the pumps are explained by the following observations:

A.) SP 14

Large amount of sludge below P1 and as a result, it is not properly placed on the foot of the seat, which explains the low pressure and flow rate at the level of the discharge pipe of this pump.

B.) SP 2

The valve chamber was submerged because of a leak in the pipe and consequently, it was impossible to take the measurements, and directly replaced by SP 3 station.

C.) SP 3

The presence of a leak on the discharge pipe which explains the low pressure and flow.

D.) SP Leona

The emptying was not done and as a result, the flow and pressure were not measured (as shown in Figure 7).

[2] P1 is pump 1 and P2 is pump 2.

E.) Other stations

It was recorded a low pressure at the level of the discharge pipes of the pumps compared to their technical sheets. Several parameters can be presented as:

- Worn wear rings of the pumps and is not replaced by the operation.
- Worn pump turbines, especially given the presence of sand in the tarpaulins (abrasion phenomenon).
- Blocked valves that can be partially closed.
- Non-functional and non-return valve which can lead to loss of flow.

NOTE: it was hard to check the condition of the parts of the pumps since even the handling accessories are not functional. On the other hand, Leona station could not be replaced by Diaminar station because of encountering the same problem. Indeed, there is a leak in the pump discharge lines.

Figure 7 | Leona Pump Station Full of Wastewater, (© IfaS)

To sum up the result from the measurements, it is concluded that SP Leona and SP 2 were not well positioned to have the data needed. On the other hand, the inventory was carried out at SP Ile Nord, SP Goxu M'bacc, SP 3, SP 4 and SP 14. Furthermore, the pressure results are very low compared to the expected values. It is valuated that these results are neither realistic nor plausible. Thus, a verification of the as built data / presumed design data was not possible. From Kocks Consult, the data determined are not suitable to be used as a basis for a reliable identification of a potential for energy saving.

5 Kocks Consult GmbH Analysis Results

In order to analyze the wastewater pumping efficiency as the main source of gaps in the city of Saint-Louis, Kocks Consult GmbH prepared a checklist in order to collect information of the existing water supply and wastewater disposal systems, as well as individual pumping stations. A checklist was prepared and forwarded to ONAS for data provision. The outputs were as follows:

- There has been no information received regarding the water supply.
- Neither design nor as-built drawings have been furnished.
- Following an examination of the given data, the decision was made to concentrate on the wastewater and rainwater pumping stations of Saint-Louis.

The objective of LoSENS project is to improve the lacks and find how can the situation of pumps be sustainable with less negative impacts. To do so, an efficiency as well as economic analysis was conducted by Kocks Consult GmbH.

NOTE: Kocks Consult GmbH had delivered a report regarding their evaluation. This latter will be joined to this master plan for more details.

5.1 Development of 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 8:

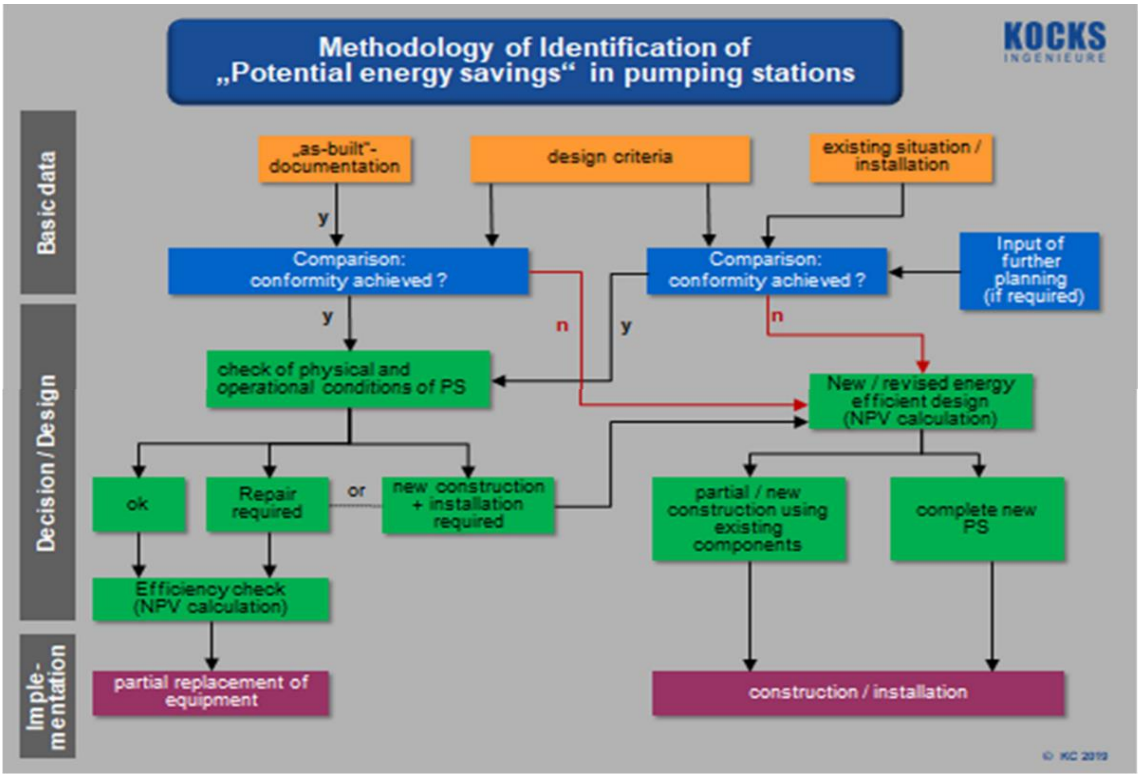

Figure 8 | Methodology for Technical and Economical Assessment of Pumping Stations, (© Kocks Consult GmbH)

5.2 Identification of Potentials for Energy Savings

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 in the previous chapter, 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 (Appendix V).

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 P1 in SP 14, concerning flow and power (see Table 4), 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 4 | 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[3]	2,770[4]
Electrical consumption	kWh/a	63,648	120,495
Calculated flow rate (As auxiliary value only)	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%.

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

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

Table 5 | SP 14 Energy Savings Results

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

The fictious potential of energy saving for SP 14 (under the assumptions as given above) is estimated to app. 56,847 kWh/a respectively a reduction of 47% com- pared to the assumed electrical consumption.

NOTE: The total electrical consumption as indicated by the operator is approx. 158,000 kWh/a.

5.3 Economic Analysis

Economic assessments serve the purpose of comparing and evaluating the following aspects:

- Various technical solutions (options) - applicable to either constructing new facilities or renovating existing ones.
- Determining whether to proceed with the renovation or replacement of equipment or maintain the current status quo by continuing the operation with the existing facility and equipment.

Typically, a distinction must be made between two scenarios: new construction and the renovation or replacement of pumping station equipment. For new construction, it is essential to assess the investment costs for the structure, mechanical and electrical equipment.

On the other hand, when considering pump replacement, one needs to investigate the investment costs for the new pumps, including installation expenses, and if necessary, the reconstruction of the pipe installation. Additionally, costs related to the replacement or renovation of electrical installations should be examined.

5.3.1 Estimation of Investment Costs and Operating Costs

To assess the investment costs for the analyzed options, separate evaluations are required for construction technology and mechanical equipment. Unit prices are established for the construction technology, encompassing the enclosed space of basins, channels, and buildings.

For the mechanical equipment, it is necessary to obtain prices for the main components from relevant manufacturers, factoring in delivery and installation costs. Similarly, for the electrical and control technology components, investment costs are estimated using unit rates based on comparable projects.

The following are the parameters that are crucial to determine the operating costs:

- Electrical power consumption (high influence)
- Manpower (low influence)
- Maintenance and servicing (low influence)
- Consumption of operating materials (low influence)

5.3.2 Investment and Net Present Value Calculation for SP 14

To make a sound economic investment decision, it is crucial to calculate the present value of project costs for the analyzed options using dynamic cost comparison methods. Apart from the initial investment costs, it is equally important to determine the anticipated operating costs for each of the investigated variants.

The electrical energy consumption of the main units is calculated based on their required power consumption and daily operating hours. To perform the cost estimation, it is necessary to determine the actual electrical energy price per kWh.

The personnel requirements have only low influence on the result of net present value calculation because the required input of manpower at different variants will most probably be nearly similar.

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 work package.

As a result, only the replacement of existing pumps is analyzed and compared to a continuation of the operation using the existing equipment for a period of 12.5 years. After 12.5 years the existing equipment will be replaced by new equipment.

Two variant data assumptions are as follows:

A.) Variant 1

- Continuing operation with the existing equipment (no changes)
- Annual electrical consumption = 120,495 kWh/a
- Replacement of pumps by new, effective pumps after 12.5 years
- Annual electrical consumption = 63,468 kWh/a

B.) Variant 2

- Replacement of pumps (only) by new, effective pumps meeting the duty point
- Annual electrical consumption = 63,468 kWh/a

Regarding the NPV general assumptions are made as follows:

- Costs for electrical power is 0.30 €/kWh[5].

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

- No price increase for the replacement of the pumps as foreseen in variant 1.
- Total term (lifetime) considered to be 25 years.

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

Table 6 | 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[6]	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.

6 Extrapolation of Pump Efficiency Analysis

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 with the installation of new pump, and CO_2 abatement potential based on the provided data.

6.1 General Methodology

A.) Gathering required data and assumptions

a. Head of the pump:
   - **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 considers a consistent relationship between head and pump performance across the pumps being analyzed.
   - **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.

b. For the flow rate, the measured value on-site is assumed to be representative of the actual flow rate.

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

c. The absorbed power of the pump is assumed to be same as that measured value on site.

NOTE: This assumption is made under the consideration that the measured power accurately reflects the actual power consumption of the pump during operation.

d. As the working fluid is water, density of water is considered for the sake of calculations.

B.) Calculate hydraulic power

The hydraulic power (E_h) of a pump is determined by the density (ρ) of the fluid being pumped, the gravitational constant (g), the total dynamic head (H), and the flow rate (Q) of the fluid. This relationship can be mathematically expressed as follows (Pump Power Calculator, 2003):

$$\mathrm{Eh\ (W)} = \mathrm{Q}\left(\frac{\mathrm{m}^3}{\mathrm{s}}\right) \times \mathrm{H(m)} \times \rho\left(\frac{\mathrm{kg}}{\mathrm{m}^3}\right) \times 9.81\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right)$$

This value represents the power output of the pump in terms of hydraulic energy transfer, taking into account the fluid properties and the operational characteristics of the pump.

C.) Calculate pump efficiency (η)

The pump efficiency is defined as the ratio of hydraulic power (E_h) to the power input (E_p) of the pump[7].

$$\eta = \frac{\mathrm{Eh\ (W)}}{\mathrm{Ep(W)}}$$

D.) Selection of new pump from KSB

Pumps are presently not operating at their designated capacities; therefore, pump selection is now based on rated operating conditions rather than just their nominal ratings. Upon careful evaluation of the process parameters, it has been concluded that the most suitable pump for the application will be chosen from the range of pumps offered by KSB. This pump model is known for its high efficiency under the given operating conditions.

E.) Check for net savings in energy and CO_2 abatement potential based on theoretical consumptions:

The net saving in energy is defined as the difference between absorbed power (E_n) of new pump into no. of operating hours per annum (T_n) of new pump and absorbed power (E_o) of old pump into no. of operating hours per annum of (T_o) pump. This relationship can be mathematically expressed as follows:

$$\text{Net Energy saved (kWh)} = (\mathrm{Eo\ (W)\ x\ To\ (h)}) - (\mathrm{En\ (W)\ x\ Tn\ (h)})$$

It is worth noting that the annual operating hours will decrease due to the increased flow rate of the new pump, which enables faster filling of the desired volume. The no. of operating hours per annum (T_n) in the previous equation are calculated based on below equation:

[7] Pump Efficiency: https://www.engineeringtoolbox.com/pumps-power-d_505.html

$$\text{Tn (h)} = \frac{\text{Qo}\left(\left(\frac{m^3}{s}\right)\right) \text{x To (h)}}{\text{Qn}\left(\left(\frac{m^3}{s}\right)\right)}$$

Where, Q_o is the flowrate of old pump, T_o is number of operating hours per annum of old pump and Q_n is the flowrate of new pump.

In order to determine the GHG abatement potential associated with pumping activities in Saint-Louis, the baseline CDM methodology AM0020[8]; Water pumping efficiency improvements was employed (see Box below for the methodological outline). Oil was considered for specific CO_2 emission factor because most of the energy generated and supplied to grid comes from the power plant which are oil based.

BOX | AM0020: Baseline Methodology for Water Pumping Efficiency Improvements

SCOPE: The methodology applies to project activities that aim to reduce emissions to the existing capacity of the system. It does not consider to project activities cases where entirely new schemes are built to augment existing capacity.

APPLICABILITY:

The methodology applies to project activities that:

- Aim to reduce GHG emissions by explicitly reducing the amount of energy required to deliver a unit of water to end-users.
- Improve energy efficiency in the overall water pumping systems, which consume electricity from the electricity grid, either by improving the efficiency of existing schemes or by developing a new scheme to completely replace the old scheme.

METHODOLOGY: Calculation of GHG emissions of project activity according to methodology AM0020 is the difference between PE_y *and* BE_y.

$$PE_y \text{ or } BE_y = kWh_y \times EF_y$$

Where:

PE_y	=	Total project emissions in year y (kg CO_2)
BE_y	=	Total baseline emissions in year y (kg CO_2)
kWh_y	=	Total post-project amount of electricity required to move water (kWh) to its destination in year y
EF_y	=	Carbon emission factor for the electricity grid in year y (kg CO_2/kWh)

[8] CDM methodology: https://cdm.unfccc.int/methodologies/DB/TH0MTJC0KYJYYMQLL9B71Q9QJHOPZ9

6.2 Example of Methodology for SP 4

SP 4 is chosen for sample calculations due to its ability to replicate the operating conditions of the pump accurately, aligning with the specific process parameters provided by KSB. This deliberate selection enables a direct and meaningful comparison of the actual efficiency between the old and new pump.

Table 7 | SP 4 Inventory Data for Scenario 1 and 2

PARAMETERS	UNIT	SCENARIO 1	SCENARIO 2
Head	m	14.72	2
Measured flowrate	l/s	19.71	19.71
Absorbed power[9]	kW	8.35	8.35
Density	kg/m^3	998	998
Hydraulic power	kW	2.8	0.4

Regarding the operating hours in both scenarios, the SP 4 pump station consists of two pumps, with one pump operating for 866.21 hours per year and the other pump operating for 905.2 hours per year.

NOTE: It is important to note that all the aforementioned data, including head, flow rate, and absorbed power, pertains to each individual pump within the pumping station. On the other hand, the assumption of observed drop in head of 22.5% is also extrapolated to other pumps.

For checking the net save in energy and CO_2 abatement potential, several data as shown in

Table 8 are needed:

[9] The absorbed power of the pump is assumed to be same as that measured value on site.

Table 8 | Given Parameters for New Pump in SP 4

PARAMETERS	UNIT	VALUE
Flowrate	m^3/h	130
Absorbed power[10]	kW	10.69
Total dynamic head	m	19
Hydraulic power	kW	6.73
Efficiency	%	63
Annual energy consumption for P1	kWh/a	5,051.1
Annual energy consumption for P2	kWh/a	5,278.5
Annually operating hours for P1	h/a	473
Annually operating hours for P2	h/a	494.2

NOTE: For both scenarios, considering the operating conditions, the KSB AMAREX KRT series pump emerges as a suitable option for this operation. With a pump efficiency of 63%, it ensures effective utilization of hydraulic power.

A.) Scenario 1

By utilizing the methodology and parameters specified, the resultant pump efficiency for both the pumps in SP 4 is determined to be 34%. This indicates that the current pump set does not exhibit satisfactory operating efficiency, as it falls below the desired efficiency standards.

[10] Extracted from pump datasheet.

Upon installing the new pump, the energy-saving potential is estimated to be approximately 2,181.7 kWh per year for P1 in SP 4 pump station.

Utilizing the formula specified in the methodology, the estimated annual total CO_2 abatement potential of the P1 in SP 4 pump sets is approximately 0.545 t CO_{2eq}. This calculation takes into account the specific CO_2 emission factor of 0.25 kg CO_2/kWh, considering that the electricity supplied to the pump sets is generated using oil. Furthermore, according to the International Financial Institutions Technical Working Group on Greenhouse Gas Accounting (IFI TWG)[11], the total emission factor in Senegal for the grid energy is 0.87 kg CO_2/kWh which gives an avoided emission value of 1.89 t CO_{2eq} per year.

Regarding P2 in same station, same methodology was followed. The energy-saving potential will be 2,279.9 kWh per year with a total CO_2 abatement potential of 1.98 t CO_{2eq} from total Senegalese grid energy sources.

B.) Scenario 2

By utilizing the methodology and parameters specified, the resultant hydraulic power in SP 4 pump station for both the pumps is determined to be 0.4 kW.

From the above data, the resultant pump efficiency for SP 4 two pumps is determined to be 4.6%. This indicates that the current pump set does not exhibit satisfactory operating efficiency, as it falls below the desired efficiency standards.

Upon installing the new pump, the energy-saving potential is estimated to be approximately 2,181.7 kWh per year for P1 in SP 4 pump station.

Utilizing the formula specified in the methodology, the estimated annual total CO_2 abatement potential of the P1 in SP 4 pump sets is approximately 1.89 t CO_{2eq}.

The same methodology was followed for P2 in SP 4 pumping station. The calculations showed that the energy-saving potential is 2,279.9 kWh per year with a total CO_2 abatement potential of 1.98 t CO_{2eq}.

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

Table 9 | 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**					

[11] Emission factor in Senegal: https://unfccc.int/documents/437880

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 the 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 (Appendix II). The summary of performance parameters is shown as follows:

Table 10 | 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[12]	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.

The discrepancy between the intended and current absorbed power stems from reduced hydraulic efficiency, impeding the optimal conversion of power into pumping action. Consequently, this inefficiency leads to heightened energy consumption and amplified operating costs.

[12] 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.

NOTE: As the emptying process was not carried out, it was not possible to conduct flowrate and pressure measurements. Consequently, the calculations and analysis for the LEONA station cannot be performed due to insufficient data.

6.3 Realistic and Theoretical Energy Consumption Comparison

The aforementioned results for all pumping stations were calculated from theoretical data with addition to measured ones. During the site visit, it was observed that the pump station had to handle not only wastewater or rainwater but also a variety of objects, including traces of sand and other foreign particles. This deviates from the theoretical assumption that the sludge being pumped does not contain such particles. As a result, the power consumption of the pump was found to be significantly higher in practical operation than what was initially calculated based on theoretical assumptions. ONAS provided the necessary data, including the power consumption of the pumping station and the annual operating hours, which were taken into account during the site visit.

Based on data provided by ONAS regarding power consumption of each pump station (Ec) and pump power rating (Ep), cumulative operating hours (Tc) was calculated based on the below formula:

$$Tc\ (h) = (Ec\ (kWh)\ )/(Ep\ (kW))$$

This equation gives cumulative operating hours of each pumping station. Thus, the realistic net save in energy and CO_2 abatement potential were calculated based on same methodology described in subchapter 6.1 General Methodology.

Referring to ONAS data inventory for the six priority pumping stations, the following table presents the realistic net saving in energy and CO_2 abatement potential for priority pumping stations.

Table 11 | Realistic Performance of Priority Pumping Stations

PUMPING STATION	***REALISTIC TOTAL ENERGY CONSUMPTION* (kWh/a)**	***TOTAL ENERGY SAVINGS POTENTIAL* (kWh/a)**	***PERCENTAGE OF ENERGY SAVINGS POTENTIAL (%)***	***TOTAL CO_2 ABATEMENT POTENTIAL* (t CO_{2eq}/a)**
SP 14	158,081	97,720	61.8	85.02
Ile Nord	101,732	97,005	95.4	84.39
Goxu Mbacc	3,562	3,487	97.9	3.03
SP 3	3,972	-35,420	-8.92	-30.82
SP 4	158,081	153,619	97.2	133.65

NOTE: The provided data for SP 3 pumping station on the operating hours for the pumping station and total electrical consumption appears to be inconsistent. For instance, if the total electrical consumption is accurate, the calculated annual operating hours based on the pump motor rating and electrical consumption suggest a significantly lower value of 633 hours per annum. This is nearly 18 times less than the overall operating hours of 11,104 hours per annum reported by ONAS.

6.4 General Pump Stations Savings in Saint-Louis

Due to insufficient data regarding the rated head and annual operating hours of the other pumping stations in Saint-Louis, it was not possible to accurately determine their current efficiency and electrical consumption. However, the pump models for these stations were provided, either from Flygt or KSB.

To estimate the new efficiency of the pumps, the same pump models were searched in the pump catalogue. The efficiency values from the pump curves and the rated flowrates were used to assume the rated heads. Consequently, the hydraulic power and absorbed power were calculated accordingly.

To calculate the energy-saving potential and CO_2 abatement potential, the average number of operating hours for the other pumps was considered, based on the values observed in the priority pumping station. The current efficiency of the pumps was determined based on their realistic power consumption. It was noted that, on average, the priority pump operated at an overall efficiency of 5%, which was assumed to be the same for all the other pumping stations.

For instance, Table 12 below presents the energy-saving potential for P1 in PR3 pumping station.

Table 12 | Performance Data for P1 in PR3 Pumping Station

PARAMETERS	*UNIT*	*VALUE*
Flowrate	m^3/h	32.5
Rated power	kW	3.1
Pump model [13]	-	Flygt 3102
Head based on pump curve	m	12
New Efficiency	%	52
Calculated hydraulic power	kW	1.1
Calculated absorbed power	kW	2
Estimated old efficiency of pump	%	5
Estimated annual operating hours	h/a	2,000
Net saved in energy	kWh/a	3,589.8
CO_2 abatement potential	t CO_{2eq}/a	3.12

[13] Pump model: https://www.xylem.com/en-us/products--services/pumps-packaged-pump-systems/pumps/submersible-pumps/wastewater-pumps/n-technology-pumps/n-3102/curves/

Similar methodology was followed for all the other pump, Appendix III, shows in detail about all the performance indicators for the other pumps.

As result of the efficient pump management work package, Table 13 below shows total energy saving potential and CO_2 abatement potential for all pumps in Saint-Louis:

Table 13 | 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**
Total CO_2 abatement potential (IFI)	t CO_{2eq}/a	**1,334**

To sum up, 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.

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.

7 Limitations and Challenges

Wastewater pump efficiency checks in the city of Saint-Louis had an essential role to ensure proper functioning and cost-effective operation of the sewage system in the coming future. However, there are several limitations and challenges associated with these efficiency checks:

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

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

C.) *Data collection*
Gathering accurate data for pump efficiency checks was difficult, especially the pump stations lack modern monitoring and data logging systems.

D.) *Aging infrastructure*
Older pump stations have outdated equipment and are not performing optimally, making it harder to achieve high efficiency levels.

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

F.) *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.

G.) *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.

H.) *Environmental Pollution*
The absence of sewage treatment system, the discharging untreated or inadequately treated wastewater into a river is a significant environmental concern.

In general, the first main complication for analyzing the situation was the absence of automatic screens and isolation valves in front of the pumping stations. Thus, a measurement step was crucial in order to have accurate data for the pumping stations during the rainy season (August-September) by Water Technology.

Accordingly, the saturation of the production capacity of the departments of Saint-Louis and the difficulties of available generation in correctly covering demand are the main constraints facing the hydraulics technical services.

Technically, the operation of the pumps is adapted to a range of specific flow rates. When pumps are operated below their optimum operating flow rate, they wear out more quickly and consume more energy per cubic meter pumped. This problem is encountered because of stormwater. The pumping stations operate year-round due to wastewater that is frequently discharged into drainage channels and illegal connections to the existing stormwater network.

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.

8 Adaptability to Needs and Future Scope

Adaptability to needs and standards for efficiency and energy savings in pumping wastewater stations is crucial for sustainable and cost-effective wastewater management. These stations are responsible for transporting wastewater from different sources to treatment plants, and optimizing their operation can lead to significant energy savings and reduced environmental impact.

The pumping stations in Saint-Louis and the use of wastewater are not adapted to standards and laws. There is still a need of integrating management of wastewater pumping stations. According to Law n° 2009-24[14] on the sanitation code, it is mandatory to treat wastewater and a daily volume is fixed to be 34,000 m3/d. As mentioned in Art. L 39, any urbanized public or private place must have a rainwater collection and drainage system capable of preventing water stagnation.

From the analysis conducted for the pumping stations in Saint-Louis, several limitations and technical problems were faced. Thus, in future applications, it is advisable to consider shifting to a horizontal centrifugal pump over a submersible pump, particularly when the tank size is less than 7 meters. This recommendation is based on the following technical reasons:

A.) Handling fluid with solids and abrasive

In general, the wastewater or rainwater contains sand and abrasive particles. Horizontal centrifugal pumps are often better equipped to handle fluids containing solids or abrasive materials. The horizontal design allows for the incorporation of features like vortex impellers or agitators, which can help prevent clogging or damage to the pump when pumping fluids with high solid content.

B.) Ease for maintenance

Horizontal centrifugal pumps are generally easier to access and maintain compared to vertical pumps. In rainwater and wastewater applications, where debris and sediment accumulation can occur, easy access for cleaning and maintenance is crucial. In the case of a horizontal pump, maintenance and repair work can be performed at ground level or on a platform, eliminating the need for personnel to enter confined spaces or use specialized equipment for vertical pump extraction.

C.) Remote monitoring and control systems

It is strongly recommended to equip at least major pumping stations with permanent measurement devices for flow, pressure and electrical power in order to have reliable data for the assessment of the pumps.

D.) Efficiency

Horizontal centrifugal pumps may offer better efficiency due to their design and ability to handle higher flow rates. These pumps are typically designed to handle large volumes of fluid, making them suitable for applications where high-capacity pumping is required.

E.) Durability and lifespan

Horizontal pumps are often constructed with robust materials and designed for heavy-duty applications. In rainwater and wastewater environments that may contain abrasive or corrosive substances, the durability of horizontal pumps becomes an advantage. They can withstand challenging conditions and offer a longer lifespan compared to submersible pumps, which are fully submerged and exposed to the harsh environment continuously.

[14] Law n° 2009-24: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC175484/

By implementing these strategies, wastewater pumping stations can become more adaptable to changing needs, reduce energy consumption, and align with energy efficiency standards. This is not only results in cost savings but also contributes to environmental sustainability and improved wastewater management.

NOTE: On one hand, Saint-Louis is a model that could be adapted for other cities or villages by implementing a similar guideline and reasoning. On the other hand, this adaptation concerns also the national level with more developed planning.

9 Bibliography

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10 Appendix

Appendix I | Visit Report of The Six Main Pumping Stations

PUMP STATIONS (PS)	ENERGY		PRESSURE SENSOR		FLOWRATE	
	EXISTINT	PROJECT	EXISTINT	PROJECT	EXISTINT	PROJECT
SP 14	1TC 300/5A	PREDICT 3 TC DE 600/5A	CAST IRON PIPE DN 350	POSSIBLE	CAST IRON PIPE DN 350	Possibility of measurement outside by portable flow meter
LEONA	0 TC	PREDICT 3 TC DE 150/5A	CAST IRON PIPE DN 800	POSSIBLE	CAST IRON PIPE DN 800	Possibility of measurement outside by portable flow meter
ILE NORD	2 TC 100/5A / GEP	PREDICT 3 TC 200/5A	CAST IRON PIPE DN 250	POSSIBLE	CAST IRON PIPE DN 250	Possibility of measurement outside by portable flow meter
GOXU MBACC	0 TC	PREDICT 3 TC 63/5A	CAST IRON PIPE DN 250	POSSIBLE	CAST IRON PIPE DN 250	Possibility of measurement outside by portable flow meter
SP 2	to verify	PREDICT 3 TC 63/5A	CAST IRON PIPE DN 150	POSSIBLE	CAST IRON PIPE DN 150	Possibility of measurement inside (7m) by portable flowmeter
SP 4	0 TC	PREDICT 3 TC 63/5A	CAST IRON PIPE DN 200	POSSIBLE	CAST IRON PIPE DN 200	Possibility of measurement inside (4m) by portable flowmeter

Appendix II | Detailed Comparison of Six Priority Pumping Stations Scenarios

PARAMETERS	***UNIT***	***OLD PUMP – SCENARIO 1***		***OLD PUMP – SCENARIO 2***		***NEW PUMP***	
SP 14 pump station [15]							
Pump	-	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
Total dynamic head	m	30	30	13.5	13.5	38.7	38.7
Flowrate	m^3/h	159.79	159.79	159.79	159.79	324	324
Hydraulic power	kW	13	13	5.9	5.9	34	34
Absorbed power	kW	43.48	43.38	43.48	43.48	44.2	44.2
Pump efficiency	%	30	30	13.5	13.5	77	77
Change in pump efficiency	%	47.2	47.2	63.7	63.7	-	-
Annually operating hours	h/a	1,036.5	1,732.5	1,036.5	1,732.5	511.2	854.4
Annual energy consumption	kWh/a	45,067	75,329	45,067	75,329	22,594	37,765
Energy savings potential	kWh/a	-	-	-	-	22,473	37,563
CO_2 abatement potential	t CO_{2eq}/a	-	-	-	-	19.55	32.7
Total energy savings potential	kWh/a	**60,036**					
Total CO_2 abatement potential	t CO_{2eq}/a	**52.23**					
ILE NORD							
Pump	-	**P1**		**P1**		**P1**	
Total dynamic head	m	13.49		2		17.41	
Flowrate	m^3/h	322.8		322.8		382	
Hydraulic power	kW	11.8		1.8		18	
Absorbed power	kW	10.56		10.56		22	
Pump efficiency	%	112.2		16.6		82	
Change in pump efficiency	%	-30.1		65.5		-	
Annually operating hours	h/a	254		254		214.6	

[15] 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.

Annual energy consumption	kWh/a	2,682		2,682		4,726.3	
Total energy savings potential	kWh/a			**-2,044**			
Total CO_2 abatement potential	t CO_{2eq}/a			**-1.8**			
				GOXU MBACC			
Pump	-	**P1**		**P1**		**P1**	
Total dynamic head	m	9.3		10		12	
Flowrate	m^3/h	139.76		139.76		303	
Hydraulic power	kW	3.5		3.8		9.8	
Absorbed power	kW	10.61		10.61		13.51	
Pump efficiency	%	33		35.8		73	
Change in pump efficiency	%	40		37.4		-	
Annually operating hours	h/a	12		12		5.5	
Annual energy consumption	kWh/a	127.3		127.3		74.8	
Total energy savings potential	kWh/a			**52.5**			
Total CO_2 abatement potential	t CO_{2eq}/a			**0.045**			
				SP 3			
Pump	-	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
Total dynamic head	m	9.6	9.6	2	2	12.39	12.39
Flowrate	m^3/h	60.58	60.58	60.58	60.58	73.17	73.17
Hydraulic power	kW	1.6	1.6	0.3	0.3	2.4	2.4
Absorbed power	kW	2.9	2.9	2.9	2.9	4.28	4.28
Pump efficiency	%	54.6	54.6	11.4	44.4	57	57
Change in pump efficiency	%	3	3	46.2	46.2	-	-
Annually operating hours	h/a	5,144	5,960	5,144	5,960	4258	4934
Annual energy consumption	kWh/a	14,917	17,284	14,917	17,284	18,228	21,119

Energy savings potential	kWh/a	-	-	-	-	-3310	-3935
CO_2 abatement potential	t CO_{2eq}/a	-	-	-	-	-0.82	-0.95
Total energy savings potential	kWh/a			**-7,145**			
Total CO_2 abatement potential	t CO_{2eq}/a			**-6.22**			

Appendix III | Detailed Extrapolation Results of Available Wastewater/Rainwater Pumping Stations in Saint-Louis

TYPE	STATION	TYPE OF PUMP	POWER (kW)	FLOWRATE (m^3/h)	NEW EFFICIENCY ESTIMATE (%)	TOTAL ENERGY SAVINGS POTENTIAL (kWh/a)	CO_2 ABATEMENT POTENTIAL ($t\ CO_{2eq}/a$)
WW	SP AB	3153-N	9.00	198	52.00	6035.02	5250.46
WW	SP AB	3153-N	9.00	198	50.00	12115.60	10540.57
WW	SP 5	3127-flygt	4.70	80	52.00	4719.47	4105.93
WW	SP 5	3127-flygt	4.70	80	52.00	4719.47	4105.93
WW	SP 6	3153-N	7.50	120	51.00	3532.22	3073.03
WW	SP 6	3153-N	7.50	120	50.00	7049.07	6132.69
WW	SP 2	cp flygt 3102	3.10	72	60.00	3589.81	3123.13
WW	SP 2	cp flygt 3102	3.10	72	60.00	3589.81	3123.13
WW	PR1	cp flygt 3102	4.20	31.2	70.00	1418.21	1233.84
WW	PR1	cp fllygt 3102	4.20	32.5	70.00	1477.30	1285.25
WW	PR2	cp flygt 3153	13.50	105	65.00	11597.83	10090.12
WW	PR2	cp flygt 3153	13.50	100	65.00	11045.56	9609.63
WW	PR3	cp flygt 3102	3.10	32.5	65.00	3589.81	3123.13
WW	PR3	cp flygt 3012	3.10	35.2	65.00	3888.04	3382.59
WW	PR4	cp flygt 3102	3.10	46.3	72.00	3280.79	2854.29
WW	PR4	cp flygt 3102	3.10	46.5	72.00	3294.96	2866.62
WW	EPURATION	cp flygt 3085	1.3	30	67.00	2717.93	2364.60
WW	EPURATION	cp flygt 3085	1.30	33	67.00	2989.72	2601.06
RW	Leona	KSB	78.00	1134	70.00	148911.68	129553.16
RW	Leona	KSB	78.00	1134	70.00	148911.68	129553.16
RW	Leona	KSB	78.00	1134	72.00	80354.54	69908.45
RW	Stade Mawade WADE	KSB	24.00	400	72.00	28343.75	24659.07

RW	Stade Mawade WADE	KSB	24.00	400	72.00	28343.75	24659.07
RW	Cite niax	3153-N	7.50	198	72.00	14030.16	12206.24
RW	Cite niax	3153-N	7.50	198	72.00	14030.16	12206.24
RW	Bas senegal	3153-N	7.50	130	72.00	9211.72	8014.20
RW	Bas senegal	3153-N	7.50	130	72.00	8224.75	7155.53
RW	Tableau walo	3153-N	7.50	72	72.00	4555.25	3963.06
RW	Tableau walo	3153-N	7.50	72	72.00	4555.25	3963.06
RW	Talbakhle	3153-N	7.50	72	75.00	7675.66	6677.82
RW	Talbakhle	3153-N	7.50	72	75.00	7675.66	6677.82
RW	Pikine 15 m	3153-N	7.50	130	75.00	13858.83	12057.18
RW	Pikine 15 m	3153-N	7.50	130	63.00	5207.72	4530.72
RW	Pikine 700	3153-N	7.50	150	63.00	6008.91	5227.75
RW	Pikine 700	3153-N	7.50	150	63.00	6008.91	5227.75
RW	Pikine 700	3153-N	7.50	150	63.00	6008.91	5227.75
RW	Diaminar	KSB	75.00	1000	72.00	111350.46	96874.90
RW	Diaminar	KSB	75.00	1000	72.00	111350.46	96874.90
RW	Diawling	KSB	24.00	640	75.00	25991.65	22612.73
RW	Diawling	KSB	24.00	640	75.00	25991.65	22612.73
RW	Ndioloffene	3153-N	7.50	500	65.00	15062.12	13104.05
RW	Ndioloffene	3153-N	7.50	500	65.00	15062.12	13104.05
RW	Guinaw Rail	KSB	18.00	500	57.00	7442.98	6475.39
RW	Guinaw Rail	KSB	18.00	500	57.00	7442.98	6475.39
RW	Escale 01	KRT 250-400	18	164	65.00	2470.19	2149.06
RW	Escale 01	KRT 250-400	18.00	160	65.00	2409.94	2096.65
RW	Escale 01	KRT 250-400	18.00	157	75.00	15940.19	13867.96
RW	Khouma 1	Flygt 3202	22.00	250	75.00	25382.47	22082.75

RW	Khouma 1	Flygt 3202	22.00	246	75.00	18732.26	16297.07
RW	Khouma 1	Flygt 3202	22.00	2058	75.00	156711.35	136338.87
RW	Khouma 2	Flygt 3153	7.50	85	75.00	6472.53	5631.10
RW	Khouma 2	Flygt 3153	7.50	87	70.00	1098.50	955.70

Appendix IV | Detailed Measurement Results from Water Technology Company

PARAMETER	***SP14***		***LEONA***		***ILE NORD***		***GOKHOU MBATH***		***SP3***		***SP4***		***UNIT***
Pumps	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	
Capacity Power	54	54			9	9	9	9	3.1	3.1	9	9	[kW]
Current	Ph1 = 72.2 Ph2 = 78.1 Ph3 = 79.3				Ph1 = 18.5 Ph2 = 19.2 Ph3 = 19.1		Ph1 = 18.4 Ph2 = 18.2 Ph3 = 19.3		Ph1 = 5.1 Ph2 = 5.3 Ph3 = 4.9	Ph1 = 5.9 Ph2 = 6.2 Ph3 = 5.3	Ph1 = 13.1 Ph2 = 14.2 Ph3 = 14.6	Ph1 = 13.5 Ph2 = 14.1 Ph3 = 15.2	[A]
Voltage	400				400		400		400	400	400	400	[V]
Ap. Power (S)	53.35				13.2		13.27		3.64	4.26	10.04	10.45	[KVA]
Cos Phi	0.8				0.8		0.8		0.8	0.8	0.8	0.8	-
Power	43.48				10.56		10.61		2.9	3.4	8.03	8.35	[kW]
Reactive Power Q	32.61				7.91		7.96		2.18	2.56	6.02	6.26	[KVar]
Pressure [bar]	1.35	0.2			0,2		1		0.2	0.1	0.2	0.1	[bar]
Flow Rate[m³/h]	159.79	34.56			322.8		139.76		60.58	55.08	70.98	50.7	[m³/h]

Appendix V | Performance Curve of SP 14 by Kocks Consult GmbH