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WENEXUS

DELIVERING THE WATER-ENERGY NEXUS FOR ENERGY EFFICIENCY

D5.2 – Market Barriers´ Report

Final Version (1.0)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

CCP	Code of Public Contracts
ERSAR	Water and Waste Services Regulatory Authority
GA	Grant Agreement number 101120628 - LIFE22-CET-WENexus - LIFE-2022-CET-PDA - LIFE-PJG CINEA/D/01
Partners	For the purposes defined in this DMP, the following utilities shall be considered as the Consortium Partners: S317 Consulting, Lda. (hereinafter referred to as S317); ENGIDRO Engineering Solutions, Lda. (hereinafter referred to as Engidro); Sérvulo e Associados, Sociedade de Advogados, SP, RL (hereinafter referred to as Sérvulo).
PPP	Public-Private Partnerships
RASARP	Annual Report on Water and Waste Services

1. Introduction

1.1. WENexus Overview

Under the Grant Agreement[1] (GA), WENexus – *Delivering the Water-Energy nexus for energy efficiency* (hereafter referred to as "WENexus"), is a European project, financed under the LIFE - Clean Energy Transition 2022 Programme, and led by S317 Consulting in a consortium with Engidro Engineering Solutions and Goméz -Acebo & Pombo (GA_P). The project started in September 2023, and it is intended to last 3 years (pilot phase).

The WENexus project aligns seamlessly with the objectives and prerequisites outlined in key documents, including the *Plano Estratégico para o Abastecimento de Água e Gestão de Águas Residuais* (PENSAARP2030), *Plano Nacional de Energía e Clima 2030* (PNEC), the Portuguese Roadmap for Carbon Neutrality 2050, and the United Nations 2030 Agenda for Sustainable Development Goals (SDGs). At its core, the project looks for the adaptation of the water sector by directing the development, implementation, and standardization of innovative tools designed to enhance energy efficiency within the water sector. This handover is complemented by the provision of comprehensive technical, financial, and legal support to the organizations responsible for water and wastewater service management and operations, guaranteeing a high degree of replicability and transferability potential within the sector.

WENexus primarily focuses on mobilizing private investment for water infrastructure renovation by creating innovative financial models specifically tailored for energy efficiency investments in water services infrastructures. Additionally, the project aims to contribute to the de-risking of energy efficiency projects in water infrastructures. All things considered, the project's goals are:

1. Contribute to the energy transition and sustainable energy use in the water sector.
2. Leverage investments that promote energy efficiency in water supply and wastewater systems in Portugal.
3. Ensure the replicability and transferability of the projects and good practices identified through the pilots developed.

Hence, WENexus' goals were designed to achieve energy and efficiency improvements specifically through four key vectors:

[1] Grant Agreement number 101120628 - LIFE22-CET-WENexus - LIFE-2022-CET-PDA - LIFE-PJG CINEA/D/01

- Vector 1 - acting on the system's electromechanical equipment efficiency, replacing them with more energy-efficient ones, where warranted, or eliminating hydraulic inefficiencies that may exist in the systems;
- Vector 2 - acting on sustainable energy production capacity by implementing energy production systems generated from photovoltaic panels;
- Vector 3 - acting on the power storage capacity, foreseeing the installation of storage batteries;
- Vector 4 - acting on energy production capacity the efficiency of the overall system, introducing systems to produce biomethane.

1.2. Scope of the Document

This Report was developed with the objective of encompasses a comprehensive examination of market barriers to energy efficiency projects within the water sector, focusing specifically on challenges encountered by managing utilities. The further document and respective approach look for identify and analyse financial, informational, organizational, supply, and policy-related barriers that hinder the successful implementation of such projects. By outlining these barriers, this report aims to provide valuable insights and recommendations to the entities involved in promoting sustainable and efficient practices within the water sector.

1.3. Document Structure

The current document is structured in five sections, aiming to provide a structured and comprehensive approach to the main subject identified as crucial to the Market Barriers’ Report.

The current section 1 corresponds to the Introduction.

In section 2 is presented a Market Perspective, where is briefly described the different types of management utilities that exist in Portugal Water Sector.

Section 3 outlines the importance of energy efficiency projects implementation in the water sector.

Then, section 4 presents the main contents of the report. In this section are listed and described the identified Market Barriers´ for energy efficiency projects.

Finally, section 5 summarizes the overview and recommendations of the developed Market Barriers analysis.

2. The Market Perspective

The WENexus project, as mentioned before, aims to support the energy transition and promote sustainable energy use in the Water sector through four key vectors: i) enhancing the efficiency of the system's electromechanical equipment; ii) increasing sustainable energy production capacity; iii) improving energy storage capacity; and iv) boosting the overall system efficiency, by introducing systems to produce biomethane.

To achieve its main goals, WENexus has maintained direct communication with water and wastewater utilities, relevant bodies, institutions, and other key market participants in the water sector in Portugal. Throughout the project, numerous contributions have been received through both formal and informal channels, stemming from the various interactions between WENexus market intervenients.

Additionally, it is crucial to recognize the variety of management models within this sector. Thus, **Table 2.1** contains the different types of Portuguese managing models of water and wastewater utilities.

Table 2.1 – Management models of Water Services in Portugal - State-owned Systems[2]

State-owned Systems		
Model	**Management entity**	**Cooperation Type**
Direct Management	State (no cases currently)	Not applicable
Delegated Management	Public Company (only one case currently, EPAL)	Not applicable
Concession Management	Multi-municipal concessionaires	Participation of the State and municipalities in the share capital of the management entity, with the possibility of minority participation of private capital in the case of water supply and wastewater / sanitation services

[2] RASARP 2023

Table 2.2 – Management models of Water Services in Portugal - Municipal or Intermunicipal Owned Systems[3]

Municipal or Intermunicipal Owned Systems		
Model	**Management entity**	**Cooperation Type**
Direct Management	Municipality Services	Not applicable
	Municipal or Intermunicipal Services	In case of “Intermunicipal Services”, Cooperation between two or more Municipalities
	Municipalities Association	Establishment of a legal person under public law consisting of several municipalities
Delegated Management	Company established in partnership with the State (part of the local or State economic sector)	Participation of the State and the municipalities in the share capital of the managing body of the partnership
	Local business sector company without State participation (incorporated under the terms of commercial law)	Possible participation of several municipalities in the capital management entity, in the case of an inter-municipal service, with the possibility of minority participation of private capital
Concession Management	Municipal concessionaires	Public-private partnership (municipalities and other private entities)

State-owned utilities are usually technologically advanced and have extensive experience, but they often face limitations in autonomy. On the other hand, privately held municipal concessionaires, though operating on a smaller scale, actively pursue strategic partnerships and show greater independence in implementing energy efficiency measures. Municipal utilities under direct management models, despite facing technological and managerial challenges, represent a significant portion of the sector in Portugal. These utilities typically have the greatest need for services like those offered by WENexus, yet they also encounter the most substantial obstacles in implementing energy efficiency projects.

Table 2.3 presents the number of water and wastewater management utilities in Portugal, categorized by different management models and by "bulk" or "retail" services.

[3] RASARP 2023

Table 2.3 – General overview of the Portuguese management models of water and wastewater services in Portugal[4]

Management Model	Management Sub-model	Water Supply			Wastewater / Sanitation		
		Bulk	Retail	Total (*)	Bulk	Retail	Total (*)
Direct Management	Municipality Services	2	144	144	0	141	141
	Municipal or Intermunicipal Services	3	19	19	0	18	18
	Municipalities Association	0	0	0	1	1	2
Delegated Management	State Delegations	1	1	1	0	0	0
	State / Municipalities Partnerships	1	3	4	1	3	4
	Municipal or Intermunicipal Companies	1	29	30	0	28	28
Concession Management	Multi-municipal concessionaires	6	1	6	8	0	8
	Municipal concessionaires	4	25	26	2	22	24
TOTAL		**18**	**222**	**230**	**12**	**213**	**225**

(*) It should be noted that in some municipalities there are management utilities that provide “bulk” services and in others “retail” services (e.g. EPAL). Thus, the "Total" column but instead it represents the total number of utilities that provide bulk and/or retail services, from each management sub-model.

[4] RASARP 2023

The following figures (2.1 to 2.4) illustrate the distribution of management models across the country for both water and wastewater systems.

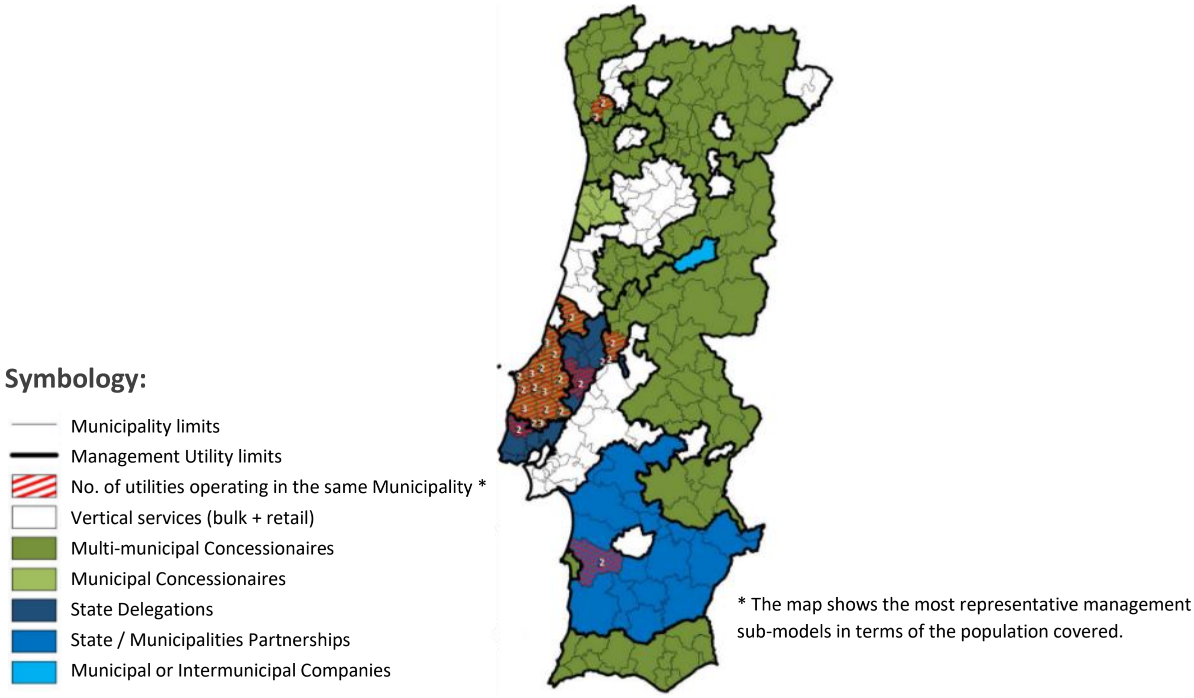

Figure 2.1 - Geographical distribution of water supply management utilities in Portugal - "Bulk" Systems (source: adapted from RASARP 2023)

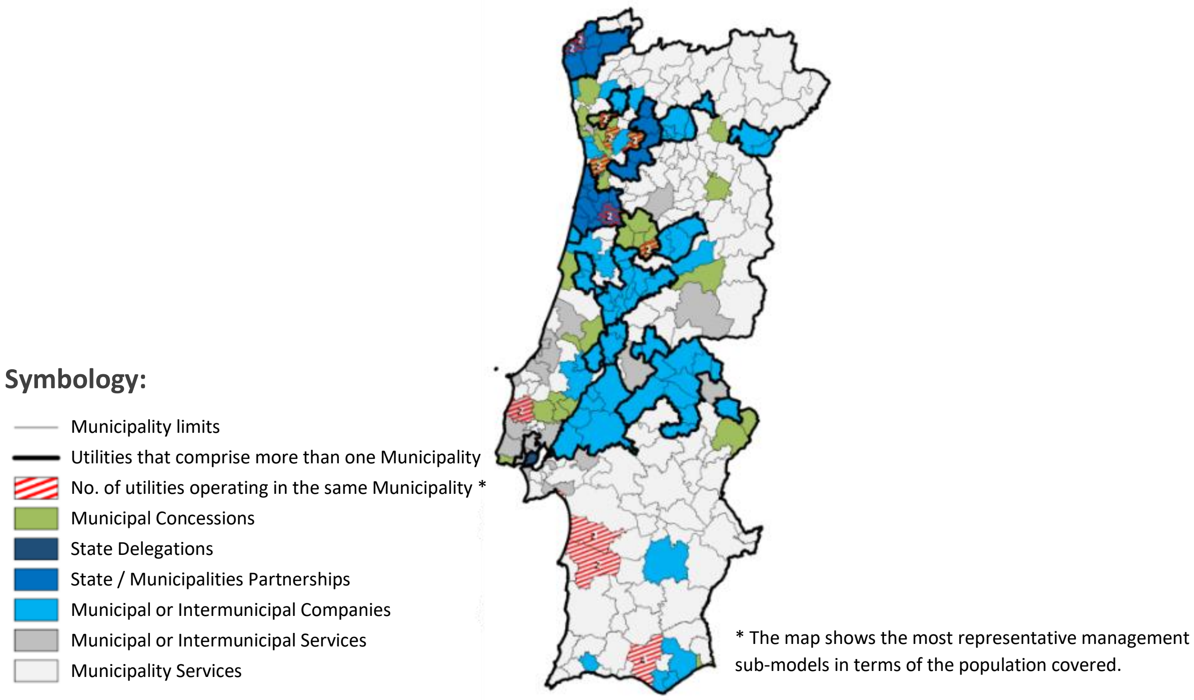

Figure 2.2 - Geographical distribution of water supply management utilities in Portugal – "Retail" Systems (source: adapted from RASARP 2023)

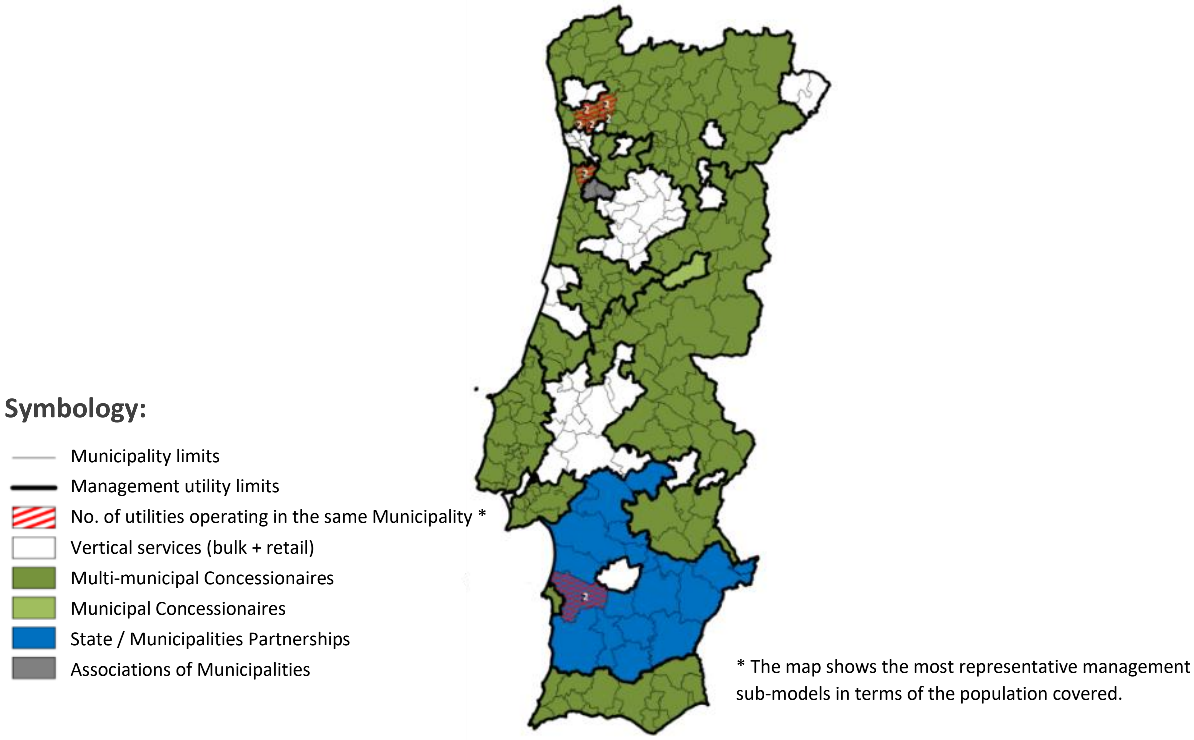

Figure 2.3 - Geographical distribution of wastewater management utilities in Portugal - “Bulk” Systems (source: adapted from RASARP 2023)

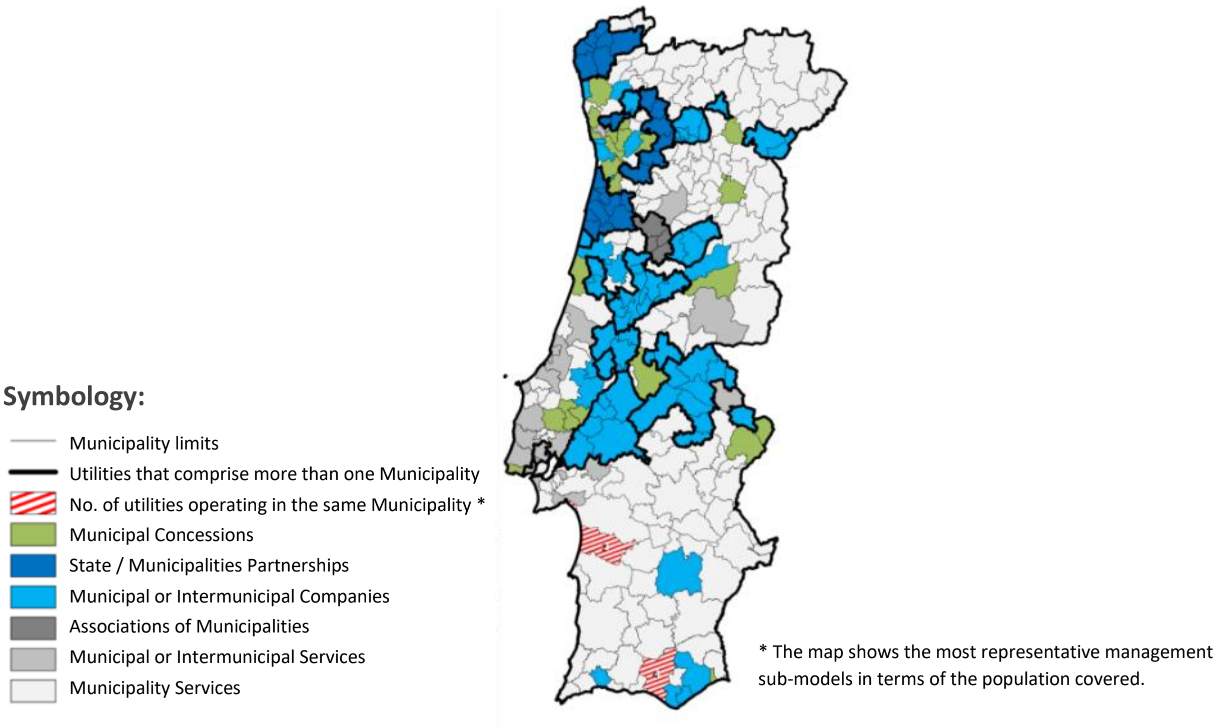

Figure 2.4 - Geographical distribution of wastewater management utilities in Portugal – “Retail” Systems (source: adapted from RASARP 2023)

3. Energy Efficiency Measures relevancy in the Water Sector

Effective management of resources in the water sector is vital for safeguarding public health, supporting economic activities, and fostering sustainable development. Considering urgent issues like resource scarcity, climate change, and rising demand, it becomes imperative to embrace strategies that reduce energy use and environmental footprint. Energy efficiency measures play a crucial role in achieving this goal.

Traditionally, water and wastewater treatment, water and wastewater transportation, and water distribution require significant amounts of energy. To better illustrate this affirmation, some of the most relevant procedures or specific components with highest energy consumption in Portuguese water supply systems are mentioned:

- Water treatment: Portugal relies heavily on conventional treatment processes like coagulation, flocculation, sedimentation, and filtration. These processes utilize pumps to move large volumes of water, and some require aeration for tasks like removing iron and manganese. These pumps and aeration systems are significant consumers of electricity.
- Water transportation: the topography of Portugal, with its hills and valleys, requires pumping water over long distances and significant heads. This reliance on pumps results to high energy use for transporting treated water to consumers.
- Distribution networks: leaks in aging pipes are a common issue in many water distribution systems, including those in Portugal. These leaks not only waste precious water but also require additional energy to treat and pump more water to compensate for these physical losses.

Wastewater systems also present challenges in terms of energy consumption:

- Biological treatment: a widely used method for wastewater treatment in Portugal is the activated sludge process. This process relies on aeration to provide oxygen for microorganisms that break down organic matter. The aeration blowers can be significant energy consumers, especially in larger facilities.
- Sludge treatment: the process of thickening and dewatering the separated sludge after treatment also requires energy. Traditional methods like centrifuges and belt presses consume a considerable amount of electricity.

Pumping: similarly to water transportation, wastewater also needs to be pumped throughout the collection and treatment system. This can be particularly energy-intensive in areas with hilly terrain or where wastewater needs to be lifted for gravity-fed treatment processes

According to ERSAR, the Portuguese Water Sector Regulator, data on key performance indicators (KPIs) collected annually indicates that many utilities still need improvement in energy efficiency and energy production.

- Energy efficiency of pumping facilities

This indicator aims to assess the service's environmental sustainability level in terms of efficiency in the use of environmental resources, regarding the acceptable use of energy resources as a scarce asset that requires rational management.

This is defined as the standard average energy consumption of pumping facilities (a concept applicable to bulk and retail system operators), and it is measured in [$kWh/(m^3 \cdot 100\ m)$]. This KPI is considered both for water and wastewater "bulk" systems and "retail" systems. The calculating method of this KPI and the reference values are shown in the following figures, and it should be noted that the code used by ERSAR corresponds to AA16 (in the case of water supply systems) and AR16 (in the case of wastewater systems).

AA16ab – Energy efficiency of pumping facilities [kWh/(m³ · 100 m)]	
Goal: Environmental sustainability Criterion: Efficiency in use of environmental resources	
Standard average energy consumption of pumping facilities. AA16ab = dAA72ab / dAA73ab dAA72ab – Energy consumption for pumping (kWh/year) dAA73ab – Standardisation factor [m^3/(year · 100 m)]	
Reference values for systems that are	*bulk and retail*
Good service quality	[0.27; 0.43] (average efficiency between 63% and 100%)
Average service quality	[0.43; 0.60] (average efficiency between 45% and 63%)
Unsatisfactory service quality	[0.60; 5.0] (average efficiency below 45%)
This indicator consists of the average quantity of energy consumed per m^3 elevated to a manometric head of 100 m and corresponds to the inverse of the pump set's average pumping efficiency. 0.43 kWh / (m^3 · 100 m) corresponds to an average pumping efficiency of: 9810 N x 100 m / (3600 J/Wh) / 430 Wh x 100 = 63%. The theoretical minimum value, corresponding to engine and pump efficiency of 100%, is 0.27 kWh/(m^3 · 100 m). The maximum permitted value of 5.0 kWh/(m^3 · 100 m), corresponding to engine and pump efficiency of around 5%. All pumping facilities should be considered for this indicator.	
IWA Code: Ph5	Previous ERSAR Code: AA13ab

dAA72ab – Energy consumption for pumping (kWh/year)
Total energy consumed at the water pumping facilities (excluding private pumping facilities). Data derived from: Operator Relative to the year under review
This data is the sum of the actual energy consumption of all the water pumping equipment of the system, and should be determined using the energy consumption meters. Pumping related to abstraction should be considered in this data. Only the pumping energy of the facilities for which the standardisation factor is calculated (dAA73ab) is counted in this data. This data is only calculated when the sum of the energy for pumping of the pumping facilities for which the standardisation factor is calculated corresponds to at least 50% of the total value of pumping energy. For situations in which a meter is associated with more than one facility, the operator should demonstrate the method used to divide the costs for validation purposes, with the maximum reliability being considered.

dAA73ab – Standardisation factor [m^3/(year · 100 m)]
Sum of the standardisation factor of all the pumping facilities. $$\text{dAA73ab} = \sum_{i=1}^{n} V_i \times h_i / 100$$ where: V_i - volume (m^3) pumped by pumping facility i; h_i - manometric head (m) of pumping facility i. Data derived from: Operator Relative to the year under review
A pumping facility is defined as an electric pump set or a series of sets installed alongside one another, with the same manometric head. Pumping related to abstraction should be considered in this data. For pumps with significant variation of manometric head throughout the reference period, it may be necessary to subdivide this period into a limited number of time intervals. For example, if during 1/3 of the time a pump lifts a flow of 10 m^3/h at a manometric head of 50 m, and during 2/3 of the time it lifts 12 m^3/h at a manometric head of 42 m, dAA73 (i) shall be: dAA73 (i) = [(10 x 24 x 365/3) x 50 + (12 x 24 x 365 x 2/3) x 42] / 100 The pump's nominal flow multiplied by the number of hours of pumping counted by an hour-meter is considered to be a reliable estimate of the pumped volume. Manometric head calculations based on the pump's characteristic curve or based on the difference in height (geometric height) plus the theoretically calculated load losses along the pumping pipes are considered reliable estimates of manometric head.

Figure 3.1 - KPI – AA16ab - Energy efficiency of pumping facilities - Water Supply Calculating method and reference values (source: adapted from RASARP 2023)

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Project 101120628 — LIFE22-CET-WENexus

AR16ab – Energy efficiency of pumping facilities [kWh/(m³ · 100m)]	
Goal: Environmental sustainability Criterion: Efficiency in use of environmental resources	
Standard average energy consumption of pumping facilities. AR16ab = dAR72ab / dAR74ab dAR72ab – Energy consumption for pumping (kWh/year) dAR74ab – Standardisation factor [m³/(year · 100 m)]	
Reference values for systems that are	*bulk and retail*
Good service quality	[0.27; 0.54] (average efficiency between 50% and 100%)
Average service quality	[0.54; 0.90] (average efficiency between 30% and 50%)
Unsatisfactory service quality	[0.90; 5.0] (average efficiency below 30%)
This indicator consists of the average quantity of energy consumed per m³ elevated to a manometric head of 100 m and corresponds to the inverse of the pump set's average pumping efficiency. 0.54 kWh / (m³ · 100 m) corresponds to an average pumping efficiency of: 9810 N x 100 m / (3600 J/Wh) / 540 Wh x 100 = 50%. The theoretical minimum value, corresponding to engine and pump efficiency of 100%, is 0.27 kWh/m³ · 100. The maximum permitted value of 5.0 kWh/m³ · 100 corresponds to engine and pump efficiency of around 5%. All pumping facilities should be considered for this indicator. IWA Code: wOp20 (adapted) Previous ERSAR Code: AR10ab	

dAR74ab – Standardisation factor [m³/(year · 100 m)]
Sum of the standardisation factor of all the pumping facilities. $$\text{dAR74ab} = \sum_{i=1}^{n} V_i \times h_i / 100$$ where: V_i is the volume (m³) pumped by pumping facility i; h_i is the manometric head (m) of pumping facility i. Data derived from: Operator Relative to the period under review
A pumping facility is defined as an electric pump set or a series of sets installed alongside one another, with the same manometric head. This data should consider the pumping at the entrance of treatment plants, provided that it is possible to individualise the energy consumption of the pumping station. For pumps with significant variation of manometric head throughout the reference period, it may be necessary to subdivide this period into a limited number of time intervals. For example, if during 1/3 of the time a pump lifts a flow of 10 m³/h at a manometric head of 50 m, and during 2/3 of the time it lifts 12 m³/h at a manometric head of 42 m, $dAR74_i$ shall be: $dAR74_i = ((10 \times 24 \times 365/3) \times 50 + (12 \times 24 \times 365 \times 2/3) \times 42) / 100$ The pump's nominal flow multiplied by the number of hours of pumping counted by an hour-meter is considered to be a reliable estimate of the pumped volume. Manometric head calculations based on the pump's characteristic curve or based on the difference in height (geometric height) plus the theoretically calculated load losses along the pumping pipes are considered reliable estimates of manometric head.

dAR72ab – Energy consumption for pumping (kWh/year)
Total energy consumed at the wastewater pumping facilities (excluding private pumping facilities). Data derived from: Operator Relative to the period under review
This data is the sum of the actual energy consumption of all the wastewater pumping equipment of the system, and should be assessed using the energy consumption meters. This data should consider the pumping at the entrance of treatment plants, provided that it is possible to individualise the energy consumption of the pumping station. Only the pumping energy of the stations for which the standardisation factor is calculated (dAR74ab) is counted in this data. This data is only calculated when the sum of the energy for pumping of the pumping stations for which the standardisation factor is calculated corresponds to at least 50% of the total value of energy for pumping. For situations in which a meter is associated with more than one facility, the operator should demonstrate the method used to divide the costs for validation purposes.

Figure 3.2 - KPI – AR16ab - Energy efficiency of pumping facilities - Wastewater Calculating method and reference values (source: adapted from RASARP 2023)

According to the RASARP 2023 conclusions, the energy efficiency of pumping installations in water supply systems was good in the bulk systems and average in the retail systems. In wastewater systems, the panorama is quite different, and many “bulk” and “retail” management utilities have average and unsatisfactory service quality. With the management utilities presenting the same value as the previous year. therefore, there is potential for improvement with the adoption of equipment, operational and/or monitoring methodologies that allow for more rational energy management.

Figure 3.3, Figure 3.4Figure 3.5Figure 3.6illustrate the distribution of the Energy efficiency of pumping facilities KPI, for water and wastewater “bulk” systems and “retail” systems.

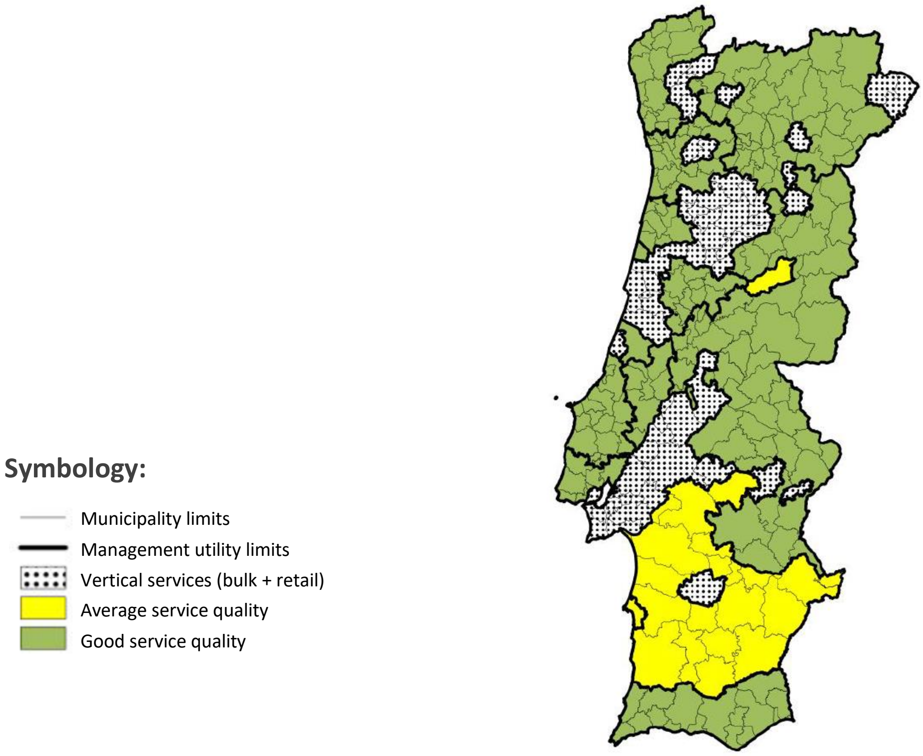

Figure 3.3 - KPI – AA16a - Energy efficiency of pumping facilities - Water Supply “Bulk” Systems (source: adapted from RASARP 2023)

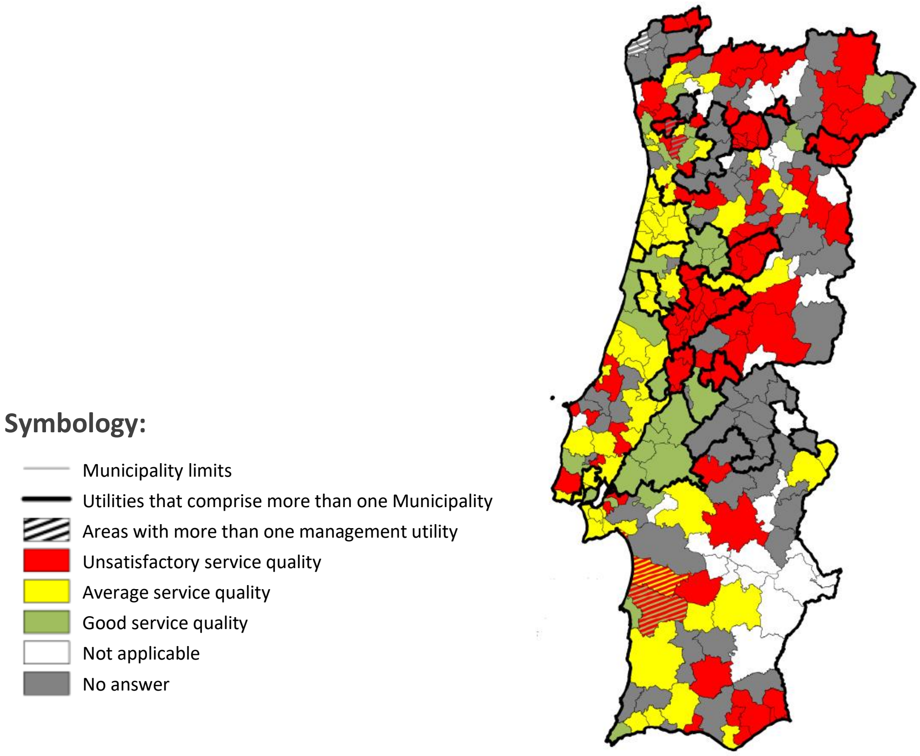

Figure 3.4 - KPI – AA16b - Energy efficiency of pumping facilities - Water Supply "Retail" Systems (source: adapted from RASARP 2023)

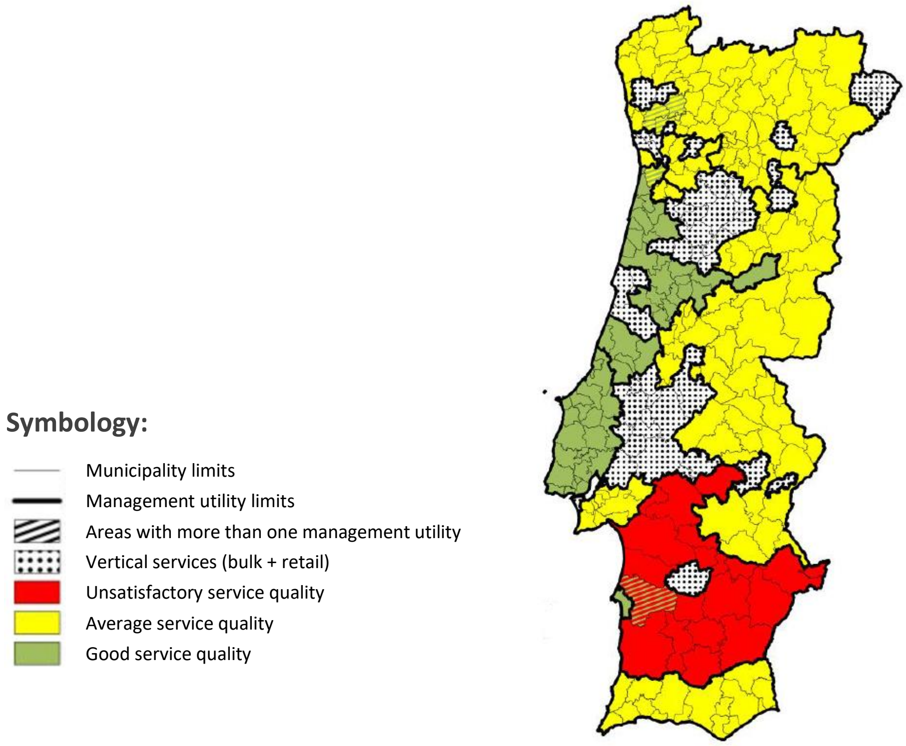

Figure 3.5 - KPI – AR16a - Energy efficiency of pumping facilities - Wastewater "Bulk" Systems (source: adapted from RASARP 2023)

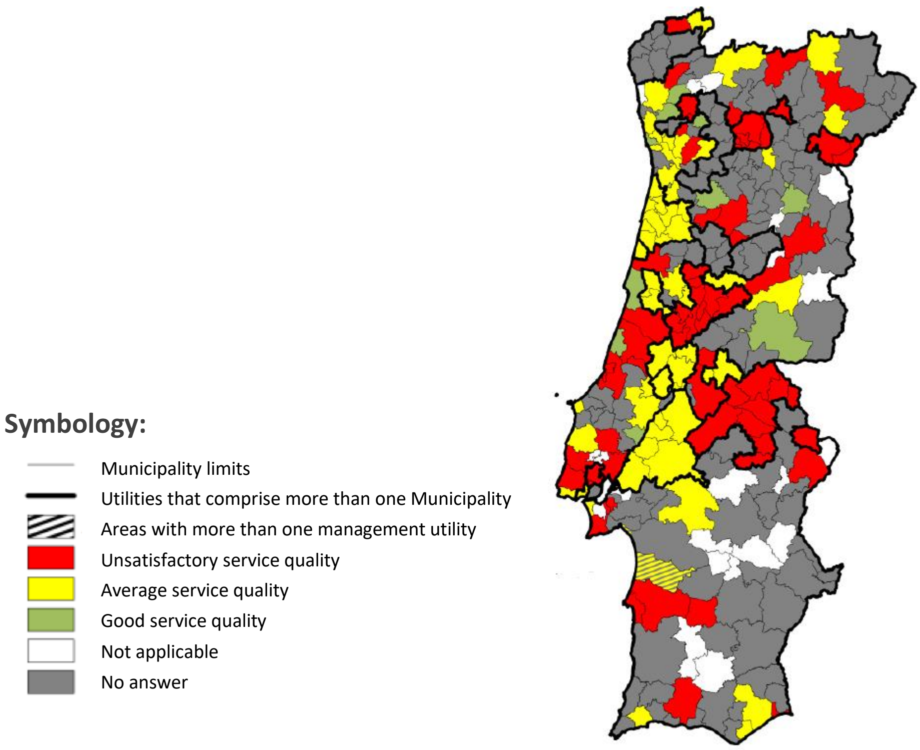

Figure 3.6 - KPI – AR 16b - Energy efficiency of pumping facilities - Wastewater “Retail” Systems (source: adapted from RASARP 2023)

- Self-produced energy

This indicator aims to assess the service's environmental sustainability level in terms of circulation and resource enhancement regarding energy production by the operator.

This is defined as the percentage of energy produced by the operator in relation to the total energy consumed at the facilities allocated to the water supply or to the wastewater service (a concept applicable to bulk and retail system operators).

This KPI is considered both for water and wastewater "bulk" systems and "retail" systems. The calculating method of this KPI and the reference values are shown in the following figures, and it should be noted that the code used by ERSAR corresponds to AA18 (in the case of water supply systems) and AR19 (in the case of wastewater systems).

AA18ab – Self-produced energy (%)	
Goal: Environmental sustainability Criterion: Circularity and recovery	
Percentage of energy produced by the operator in relation to the total energy consumed at the facilities allocated to the water supply service. AA18ab = dAA74ab / dAA75ab x 100 dAA74ab – Self-produced energy (kWh/year) dAA75ab – Energy consumption (kWh/year)	
Reference values for systems that are	*bulk and retail*
Good service quality	[10; +∞]
Average service quality	[5; 10]
Unsatisfactory service quality	[0; 5]
IWA Code: -	Previous ERSAR Code: System profile - Self-produced energy

dAA74ab – Self-produced energy (kWh/year)
Energy produced internally by the operator at the facilities allocated to the water supply service. Data derived from: Operator Relative to the year under review
The energy produced internally by the operator should be considered, including energy recovery processes, for example, by using solar energy panels or other processes.

dAA75ab – Energy consumption (kWh/year)
Energy consumed by the operator for the operation of the water supply system. Data derived from: Operator Relative to the year under review
The energy related to pumping stations that use fossil fuels should be converted into kWh. The data includes the energy consumed arising from own production. Energy consumption associated with administrative buildings (for example, head office) should not be considered in this data.

Figure 3.7 - KPI – AA18ab – Self-produced energy – Water Supply
Calculating method and reference values (source: adapted from RASARP 2023)

AR19ab – Self-produced energy (%)		
Goal: Environmental sustainability Criterion: Circularity and Recovery		
Percentage of energy produced by the operator in relation to the total energy consumed at the facilities allocated to the urban wastewater management service. AR19ab = dAR70ab / dAR71ab x 100 dAR70ab – Self-produced energy (kWh/year) dAR71ab – Energy consumption (kWh/year)		
Reference values for systems that are	*bulk*	*retail*
Good service quality	[20, +∞]	[10, +∞]
Average service quality	[10, 20]	[5, 10]
Unsatisfactory service quality	[0, 10]	[0, 5]
The reference values for bulk entities are also applicable to retail system operators that operate wastewater treatment plants with installed capacity of more than 20,000 m³/day.		
IWA Code: -	Previous ERSAR Code: System profile	

dAR70ab – Self-produced energy (kWh/year)
Energy produced internally by the operator at the facilities allocated to the wastewater management service. Data derived from: Operator Relative to the period under review
The energy produced internally by the operator should be considered, including energy recovery processes, for example, by co-generation, using solar energy panels or other processes.

dAR71ab – Energy consumption (kWh/year)
Energy consumed by the operator for the operation of the wastewater system. Data derived from: Operator Relative to the period under review
The energy related to pumping stations that use fossil fuels should be converted into kWh. The data includes the energy consumed arising from own production. Energy consumption associated with administrative buildings (for example, head office) should not be considered in this data.

Figure 3.8 - KPI – AR19ab – Self-produced energy – Wastewater
Calculating method and reference values (source: adapted from RASARP 2023)

According to the conclusions of RASARP 2023, self-produced energy was generally unsatisfactory in Portuguese management utilities, both in "bulk" and "retail" systems. This indicates a significant dependence on external energy sources and higher operational costs. Therefore, there is high potential for the implementation of equipment and measures to enhance self-produced energy in sector infrastructures, overcoming this barrier and enhancing sustainability and energy efficiency. Figure 3.9Figure 3.10Figure 3.11Figure 3.12 illustrate the distribution of the self-produced energy KPI, for water and wastewater “bulk” systems and “retail” systems.

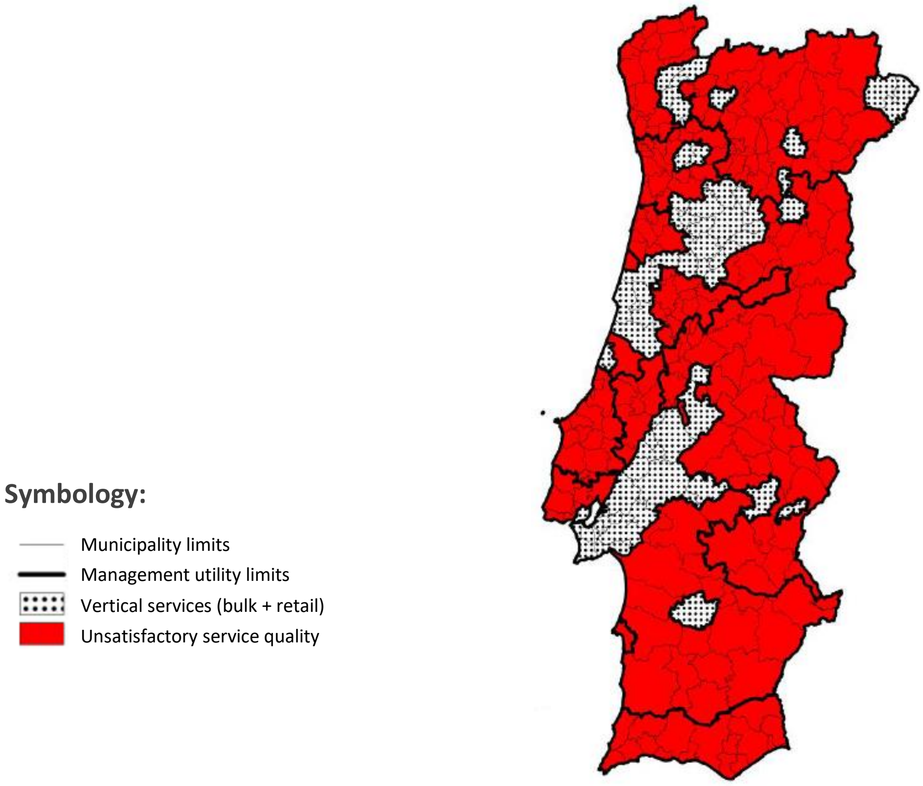

Figure 3.9 - KPI – AA18a - Self-produced energy -
Water Supply “Bulk” Systems (source: adapted from RASARP 2023)

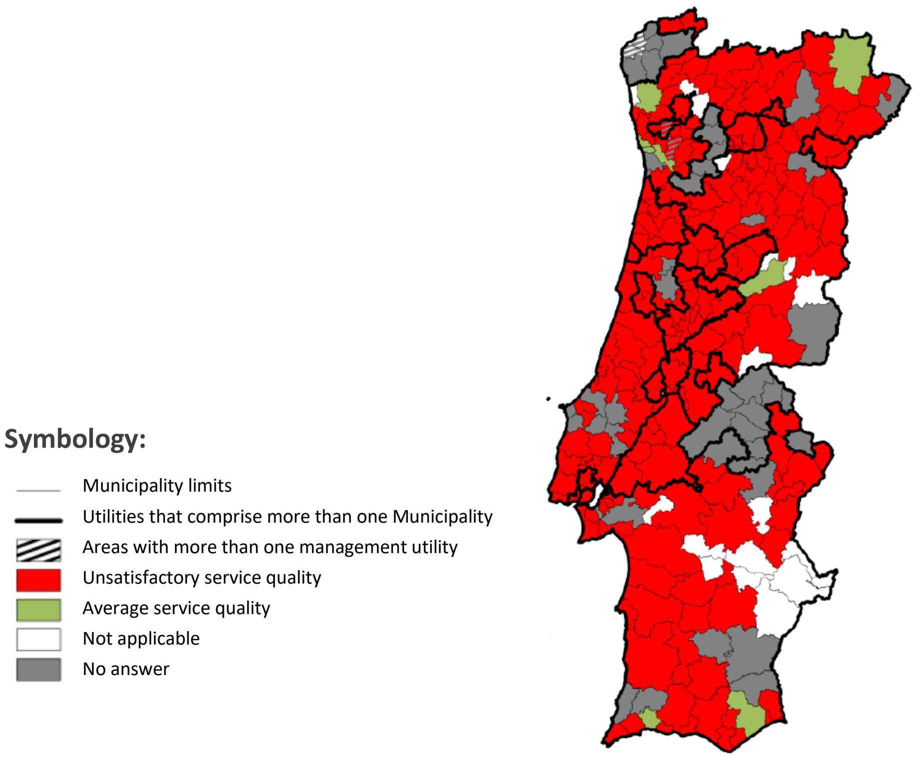

Figure 3.10 - KPI – AA18b - Self-produced energy -
Water Supply “Retail” Systems (source: adapted from RASARP 2023)

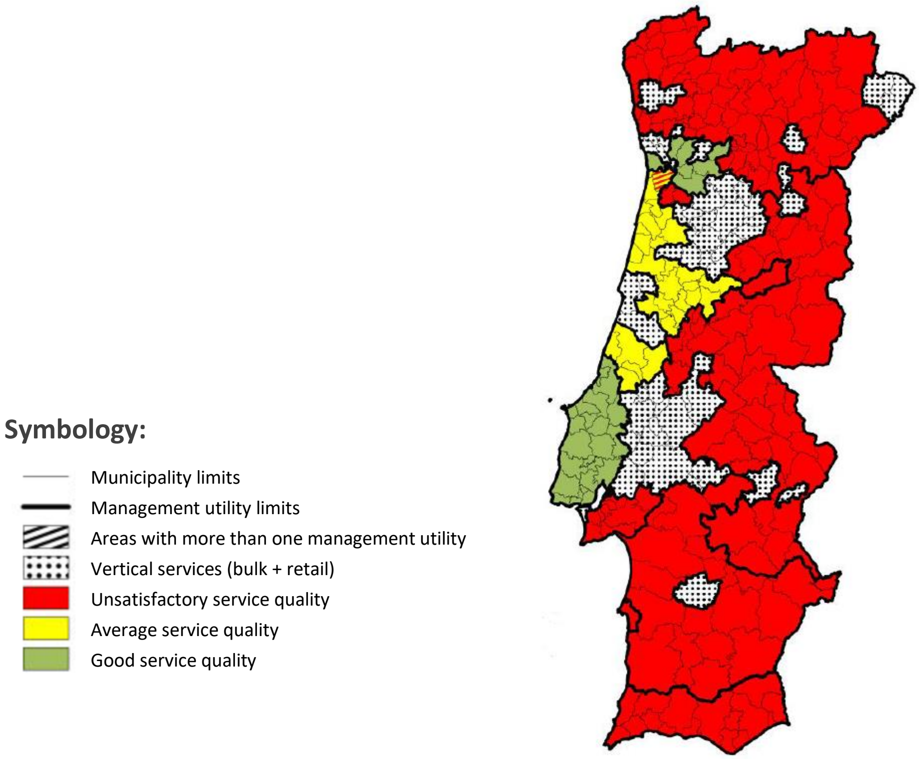

Figure 3.11 - KPI – AR19a - Self-produced energy --
Wastewater "Bulk" Systems (source: adapted from RASARP 2023)

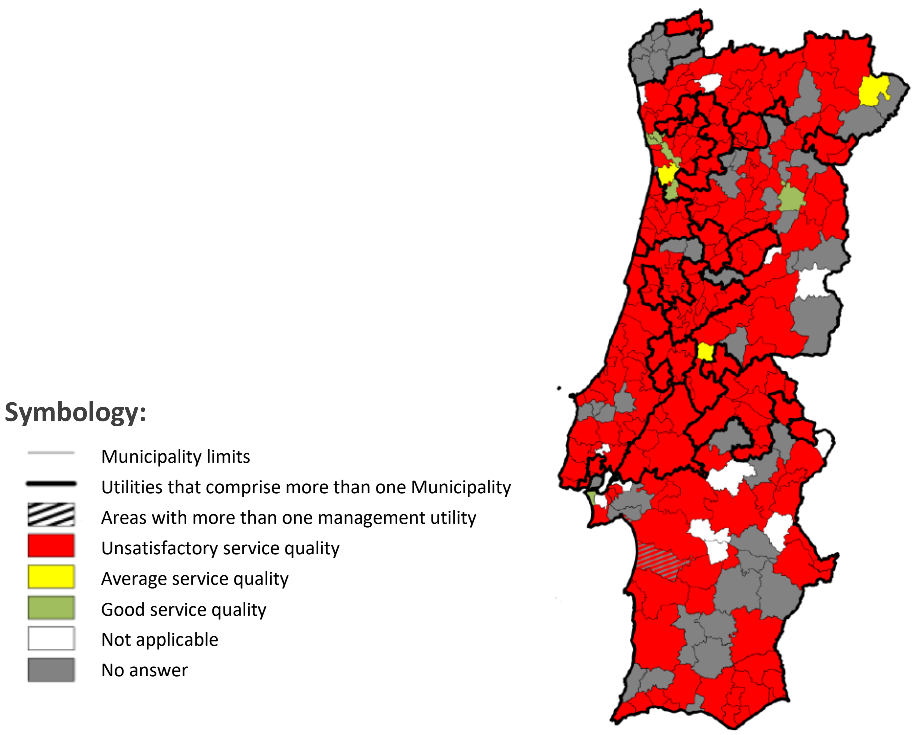

Figure 3.12 - KPI – AR19b - Self-produced energy -
Wastewater "Retail" Systems (source: adapted from RASARP 2023)

As previously mentioned, there is a potential to increase the systems efficiency and the self-production energy. It's important to acknowledge that the government and management utilities are exploring measures to improve this energy aspects. Several initiatives are underway, including the use of more energy-efficient pumps and motors, optimizing treatment processes, and exploring renewable energy sources like solar power, biogas production and hydro turbines. These efforts can lead to lower operating costs for utilities, and a smaller carbon footprint for the entire water sector in Portugal, making significant progress towards environmental and economic sustainability.

In this context, the WENexus project stands out by proposing a holistic strategy to improve and strengthen energy efficiency across water supply and wastewater systems.

4. Market Barriers'

4.1. General Considerations

Several market barriers' hinder the implementation of energy efficiency projects in the water sector. Overcoming these barriers involves tackling a range of challenges that constraint their effective implementation and widespread adoption. These obstacles include financial limitations, uncertainties around technology, complex regulatory environments, and resistance within institutional frameworks. To successfully surmount these challenges, it's crucial to implement innovative financial models, adopt reliable technologies, simplify regulatory processes, and proactively adjust institutional strategies. Addressing these barriers comprehensively is essential for unleashing the full potential of energy efficiency initiatives within the water sector, thereby fostering sustainability and resilience in response to ongoing global challenges. In this report, are highlighted 5 main themes in which market barriers fall under:

- **Financial**: issues such as initial capital constraints, high operational costs, and difficulties in securing adequate financing are common challenges faced by utilities. Moreover, uncertainty regarding return on investment and the need to demonstrate financial feasibility are critical concerns influencing the decision to implement such projects and alternative and innovative technical-financial models;
- **Informational / Behavioral**: lack of awareness about efficient technologies, inadequate energy management practices, and resistance to change are significant informational and behavioural barriers. Many utilities may not be fully informed about available options or the benefits of energy efficiency measures, while lack of training and capacity-building can limit the adoption of more efficient practices;
- **Organizational**: complex bureaucratic structures, lack of alignment between departments, and heavy decision-making processes can hinder efficient implementation of energy efficiency projects. The complexity and limitations established by the CCP (Public Contracts Code) is also a barrier for the municipalities and public companies which are bound by these rules, both in terms of the content to be entered into and the choice of the entity that will carry out the chosen energy efficiency measures. Other aspect corresponds to some organizational cultures that does not prioritize sustainability and energy efficiency can also pose challenges for managing utilities;

- **Supply and Provision**: barriers related to the supply and provision of necessary technologies and services for energy efficiency projects—such as limited availability of specialized suppliers, inconsistent product and service quality, and logistical challenges—can negatively impact implementation and effectiveness of projects;
- **Policies and External Factors**: external factors including ambiguous or restrictive regulations, unfavourable public policies, or lack of specific financial incentives for energy efficiency projects represent significant barriers. Insufficient government support and political instability can also adversely affect the development and sustainability of these projects. The global political environment also impacts project implementation, as events like wars and economic inflation can affect equipment acquisition costs.

The mentioned aspects create significant barriers to the widespread adoption of energy-efficient projects in the water sector, hindering progress towards more sustainable and cost-effective water and energy management practices.

4.2. Financial

In the water sector in Portugal, utilities plan energy efficiency projects, that in most cases are not prioritised in termos of implementation, due to lack of funds. This represents the financial issue that is considered on of the main market barriers identified.

The barriers in this component correspond, for example, to the following aspects:**Implementation Costs**

The implementation of energy-efficient technologies in the water sector faces a substantial barrier related to the high initial investment costs. Introducing specialized equipment and upgrading existing infrastructure requires significant financial outlays. For many management utilities, particularly those operating with very limited financial resources, these initial costs can be prohibitive. The expenses related to procuring advanced technologies, installing them, and integrating them into current systems often require a level of capital that is beyond the financial availability of many management utilities. This financial strain can discourage even the most committed entities from pursuing energy-efficient upgrades.

Operational costs also present a challenge. Beyond the initial investment, maintaining and operating energy-efficient systems can incur additional expenses. These costs include regular maintenance, potential repairs, and the need for skilled personnel to manage the advanced technologies. For many utilities, especially those already working within tight budget plans, the operational costs can add another layer of financial burden. This can lead to reluctance in adopting energy-efficient solutions, as the perceived financial risks outweigh the short-term benefits.

In this sense, the high initial and operational costs create a significant barrier to the widespread adoption of energy-efficient projects in the water sector, hindering progress towards more sustainable and cost-effective water and energy management practices.

Lack of Adequate and Accessible Financing

One of the significant barriers to the adoption of energy efficiency projects in the water sector is the lack of adequate and accessible financing. Many funding opportunities or direct financial mechanisms are not tailored specifically to the needs of the water sector, making it difficult for management utilities to secure necessary funds. So, market players, namely the management utilities, often highlight the absence of targeted funding programs, which exacerbates the challenge of financing energy efficiency initiatives. Without specific financial support, entities in the water sector struggle to cover the substantial initial costs associated to this type of projects.

Moreover, the complexity of financing processes further complicates access to necessary funds. The management utilities find it challenging to navigate the complex procedures required to obtain loans or grants. This characteristic, coupled with limited access to financial and human resources, hampers their ability to invest in energy efficiency projects. The bureaucratic hurdles and stringent requirements for securing financing can be daunting, particularly for smaller management utilities.

Financial Feasibility Demonstration

In the current water sector state, demonstrating the financial viability of energy efficiency projects is crucial for their implementation in the water sector. The management utilities currently operate with a "managing" rather than "construction" mindset, focusing more on rehabilitating and managing existing infrastructure instead of investing in new projects. So, this shift in focus is clearly a barrier, and necessitates that any new initiative, especially those requiring significant investment like energy efficiency projects, must be clearly shown to be financially viable.

The emphasis on financial viability is driven by the need to maximize limited resources and ensure sustainable operations. Management utilities need to be prudent in their investments, often facing budget constraints and the pressure to justify expenditures. By presenting a compelling financial case through rigorous analysis, entities can make a strong argument for the adoption of this type of projects.

Financial metrics such as Net Present Value (NPV), Return on Investment (ROI), and Internal Rate of Return (IRR) have become essential tools in evaluating the potential benefits of these projects. These metrics provide a quantitative basis for decision-making, helping to illustrate that the long-term savings and efficiencies gained can outweigh the initial costs. NPV analysis is particularly important in this context, as it assesses the value of an investment by calculating the difference between the present value of cash inflows and outflows over time. A positive NPV indicates that a project is expected to generate more value than it costs, making it an attractive option for water management utilities. Similarly, ROI and IRR are critical for understanding the profitability and efficiency of an investment. ROI measures the gain or loss generated relative to the investment's cost, while IRR provides the expected rate of return, helping entities compare the potential profitability of different projects. Demonstrating favorable NPV, ROI, and IRR figures can therefore be instrumental in gaining approval and securing financing for energy efficiency initiatives.

4.3. Informational / Behavioural

A lack of awareness and resistance to change are key informational and behavioural barriers. Many management utilities technicians and managers may not be fully aware of available options or the benefits of energy efficiency, and insufficient training and capacity-building can hinder the adoption of better practices. The barriers in this component correspond, for example, to the following aspects:

Lack of Awareness and Limited Technical Knowledge

Raising awareness about the importance and benefits of energy efficiency among technicians, water managers, and decision-makers is crucial. Many management utilities are not fully informed about the potential savings and operational improvements that energy-efficient technologies can bring. This lack of awareness can result in a lower prioritization of energy efficiency initiatives, as decision-makers may not see the immediate value or understand the long-term benefits. Educating all levels of staff about energy efficiency and providing clear information on successful case studies can help shift this perspective and foster a more proactive approach towards adopting energy-efficient solutions.

In addition to awareness, the successful implementation of energy efficiency projects requires specialized technical knowledge. Many management utilities face challenges due to the limited access to qualified professionals and inadequate training to design, implement, and maintain these technologies. The disparity in technical expertise and experience among different entities further complicates this issue, as some organizations may be more advanced in their knowledge and capabilities than others. This uneven maturity level means that some entities struggle to keep pace with the latest advancements in energy-efficient technologies and practices.

Lack of Knowledge of Energy Consumption Patterns

A significant barrier to the implementation of energy efficiency projects in the water sector can be the lack of knowledge regarding energy consumption patterns. Many management utilities do not have the necessary operational data to analyse energy use effectively, particularly concerning the operation modes of water supply and wastewater systems. Without consistent and comprehensive data, it becomes challenging to identify inefficiencies and develop targeted energy-saving strategies. This lack of information impedes the ability to assess consumption patterns and devise strategies to promote more efficient behaviours.

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Other data, which is often not available either, as for example water consumptions requirements, required operating conditions of pumping systems and existing equipment's characteristics (as efficiency), are crucial for the projects development.

So, the absence of data makes it difficult to design and implement effective energy efficiency projects, hindering efforts to reduce energy usage and improve overall system performance.

Resistance to Change

In some cases, resistance to change can be a barrier to the adoption of energy efficiency projects in the water sector. Many management utilities perceive the introduction of new technologies as risky, often due to a lack of previous successful examples and concerns about having to operate systems different from those they are accustomed to. This perceived risk can lead to a preference for maintaining traditional practices and a reluctance to invest in innovative solutions. The fear of unknown outcomes and the disruption of established workflows contribute to this resistance, making it challenging to gain buy-in for energy-efficient initiatives. Overcoming this barrier requires demonstrating the reliability and long-term benefits of new technologies, as well as providing robust technical support during the transition.

4.4. Organizational

Complex bureaucracy, departmental misalignment, and slow decision-making hinder the projects implementation. The CCP (Public Contracts Code) also creates additional barriers for municipalities and public companies in contract management. Furthermore, organizational cultures that don't prioritize sustainability and energy efficiency also pose challenges. The barriers in this component correspond, for example, to the following aspects:

Management Utilities Structure and Decision-Making Processes

The lack of strong leadership and management commitment leads to poor implementation and follow-up. In addition, effective implementation often requires coordination between different departments and stakeholders. Poor communication and coordination can lead to misunderstandings, delays, and inefficiencies. A lack of clear energy management policies and procedures can lead to confusion and inconsistency in implementation efforts, making clear guidelines and standardized procedures essential for effective project implementation. In addition, organizations that prioritize short-term results over long-term benefits may overlook energy efficiency projects that often require an initial investment for future savings, hindering sustainable energy strategies. Finally, complying with energy regulations and standards can be complex and resource-intensive, and organizations struggle to understand and meet regulatory requirements, which can delay or derail projects.

Lack of Human Resources

The multi-tasking of technicians and specialists leads to an overburdened staff, which can lead to time constraints and insufficient attention to energy efficiency initiatives, with an impact on the quality of the project and its deadlines. This is especially true for those working in the energy sector. Often, a single technician handles both hydraulics and energy issues and does not have the time or knowledge to adequately respond to all requests.

Another aspect that overlaps with the previous one is recruitment and the difficulty in hiring qualified staff with expertise in energy efficiency. This can delay project implementation and reduce organizational capacity to meet project requirements.

Contract Management Challenges

The complexity and time required to comply with contract laws is a significant obstacle. The need to follow strict and detailed procedures can delay project implementation, increase costs and extend timelines. These bureaucratic and legal requirements can discourage utilities from investing in energy efficiency projects, as they also significantly increase project implementation durations and may lead to missed opportunities.

In particular, the complexity and limitations established by the CCP (Public Contracts Code) is also a barrier for the municipalities and public entities which are bound by these rules, both in terms of the content to be entered into and the choice of the entity that will carry out the chosen energy efficiency measures

The Portuguese legal framework, in the provision and management of water services, has been increasing more open to private investment, be it in the form of minority participation in the capital of multi-municipal concessionaires; minority participation in the capital of local companies; and/or concession of the municipality to a private entity, which is made evident by the growing influx of operators and foreign capital in recent years.

Furthermore, current legislation also reveals an increasing concern in the objectives ensued by WENexus project, through the establishment of more flexible regimes.

Management Utilities Culture

The organizational culture within the public sector can be a barrier if it does not prioritize innovation, sustainability, and continuous improvement. Without a supportive culture, implementing energy efficiency initiatives becomes challenging.

A lack of strong leadership commitment can impede progress, as leaders who do not champion sustainability initiatives or provide the necessary resources fail to motivate staff and drive project success. Employee disengagement is another obstacle; without employee involvement at all levels, there is a lack of ownership and commitment that limits innovation and efficiency in project implementation.

In addition, the lack of clear performance metrics related to energy efficiency can hinder accountability and make it difficult to measure progress toward sustainability goals. Metrics such as energy savings, carbon emission reductions, and cost effectiveness are essential for tracking results and optimizing resource allocation.

Poor communication and a lack of transparency within the organization further hinder energy efficiency efforts. Without open channels of communication and transparent reporting, it is difficult to build trust with stakeholders, including customers and regulators. Lack of clear and transparent communication about goals, progress, and challenges can lead to a lack of trust with stakeholders, including customers and regulators. This can limit support and cooperation, making the successful implementation of energy efficiency projects even more difficult.

4.5. Supply and Provision

Barriers like limited specialized suppliers, inconsistent quality of products and services, and logistical challenges can hinder the implementation and effectiveness of energy efficiency projects. The barriers in this component correspond, for example, to the following aspects:

Equipment's Availability and Provision

A scarcity of suppliers specializing in energy efficiency equipment's can limit the ability of project promoters to obtain reliable, high-quality equipment, materials and expertise tailored to the specific needs of the project. A lack of competition between suppliers can also result in higher costs and longer lead times for purchasing the necessary components.

Limited availability of equipment, as interruptions in production or shortages of key components can require longer delivery times or dependence on distant suppliers, adding complexity to the procurement process and resulting in project delays and increased costs. In Portugal, however, this aspect doesn't seem to be very relevant. Although it is a factor to be considered, it is not, at the moment,a significant problem in our market.

Geographic constraints relating to transporting materials and equipment to remote or isolated project sites can be costly due to long distances and limited access. These logistical obstacles can lead to delays, increased operational complexity, and higher project costs.

Inefficient equipment inventory management leads to problems such as inaccurate inventories, out-of-stocks and overstocks, which can cause costly delays and disruptions to project schedules. This inefficiency not only disrupts project workflow, but also drains financial resources with rush orders or unnecessary storage costs.

Also, inconsistent quality of equipment can lead to differences in the performance and reliability of technologies, resulting in varying levels of energy savings and operational efficiency. This inconsistency can compromise the expected financial and environmental benefits of projects. For example, if equipment does not meet standards, it may not deliver the promised energy savings, resulting in longer payback periods and a lower return on investment.

Technical Assistance

Lack of or limited technical assistance from equipment suppliers can affect project implementation. The limited availability of these services and delays in response times affect the reliability and performance of the equipment and undermine the confidence of promoters and stakeholders in achieving the desired results.

4.6. Policies and External Factors

Political and external factors, which are difficult to assess and control, also pose significant challenges in addressing market barriers. The barriers in this component correspond, for example, to the following aspects:

Policies and Regulations

In the regulatory environment, rigorous and frequently changing energy efficiency regulations can create uncertainty and increase compliance costs for projects. Extensive and complex permitting processes can cause significant delays and increase project costs. Inconsistent or outdated building codes and standards can prevent the implementation of modern energy efficiency technologies, limiting the potential for projects to achieve their sustainability goals.

Regarding political stability, changes in government or policy direction can disrupt ongoing projects and discourage long-term investment in these areas, as investors and project planners face uncertainty about future regulations and support. In addition, shifts in government funding priorities away from energy efficiency can significantly reduce the resources and support available for these projects, making it difficult to secure the necessary funding and maintain momentum toward achieving efficiency goals.

The economic and trade policies include aspects as the absence or inconsistency of incentives and subsidies for these projects, which can significantly reduce their attractiveness to investors and stakeholders, making it more difficult to establish and maintain such initiatives. Unfavourable tax policies, such as high taxes on renewable energy technologies, can increase project costs and reduce returns on investment. These financial charges can discourage investment and limit the development and implementation of effective energy solutions. Also, high tariffs on imported energy efficiency technologies can increase project costs, making these initiatives less economically viable and limiting access to advanced solutions. In addition, the lack of supportive trade agreements can limit the availability of key materials and technologies needed for efficiency projects.

Global political environment

International relations and geopolitical tensions can affect trade policies, access to technology, and the stability of supply chains. The generation of conflict between countries can prevent cooperation on climate goals and limit the shared use of resources and knowledge. These challenges can increase costs, limit access to needed technologies, and reduce the effectiveness of international funding for these projects, making it harder to achieve their goals.

External Factors

Climate change poses many challenges for planning and investing in energy efficiency. Uncertainty about climate policies and regulations can complicate decision-making and discourage long-term investment in energy projects. In addition, physical risks such as extreme weather events (e.g., hurricanes, floods, droughts) can damage energy infrastructure and disrupt project schedules, increasing financial uncertainty. As a result, it becomes more difficult to secure financing and insurance at favourable rates. In addition, responding to climate change often requires the adoption of new technologies and innovative solutions. However, developing and implementing these technologies can be costly and time-consuming. If technological advances fall behind regulatory changes or climate impacts, this can hinder the effective implementation of energy efficiency projects.

Another external factor aspect is the community expectations. The lack of or inadequate information and consultation with local communities about proposed projects can lead to resistance or opposition due to concerns about environmental impact, noise, visual aesthetics, or perceived threats to property values. This opposition can lead to delays in project approvals or even legal action, increasing project costs and timelines. In addition, a lack of communication between the expectations of project promoters and the community regarding the scale, scope, or benefits of energy efficiency projects can weaken support and hinder project implementation. Communities may expect tangible benefits, such as improved air quality, reduced energy costs or job creation, and if these expectations are not met or communicated effectively, this can undermine trust and support. From a market perspective, failure to respond effectively to community expectations can damage the reputation of project promoters, affecting their ability to attract investors and secure financing. It can also create regulatory and permitting obstacles, further delaying project implementation and increasing overall costs.

5. Market Barriers´ Overview and Recommendations

Table 5.1summarizes the previously identified market barriers, presenting in a quantitative and general manner the impacts each one has on the implementation of energy efficiency projects in the water sector. The table also describe recommendations and suggestions to minimize the impacts of these identified barriers.

Table 5.1 – Market Barriers' Overview

Marke Barriers' Categories	Market Barriers Identification	Importance / Impact	Recommendations
Financial	Implementation Costs	High	• Develop optimized and phased solutions that allow for reduced initial costs. • Simplify the establishment of Renewable Energy Communities (CER) to optimize the energy produced by management utilities, such as streamlining licensing, providing financial incentives, and promoting public-private partnerships. • Examination of different financing models such as public funding, private investments, public-private partnerships (PPP), and the impact of interest rates and loan conditions.
	Lack of Adequate and Accessible Financing	Medium	• Development of specific financing programs, creating financing programs that are accessible and suitable for water and wastewater management utilities of different sizes and financial capacities. • Implement fiscal incentives, subsidies, and other financial mechanisms to stimulate investments in energy efficiency in the water sector.
	Financial Feasibility Demonstration	Medium	• Analysis of long-term economic benefits, including operational savings, reduced energy costs, and potential financial incentives or subsidies available. • Use financial metrics tolls such as Net Present Value (NPV), Return on Investment (ROI), and Internal Rate of Return (IRR). • Request support from suppliers who typically have information and are experienced in developing analyses that estimate the financial potential resulting from the implementation of their equipment. • Consultancy support projects such as WENexus help to overcome this barrier. • Take profit of Renewable Energy Communities (CER) to optimize the energy produced by management utilities.
Informational / Behavioural	Lack of Awareness and Limited Technical Knowledge	Medium	• Training programs, workshops, continuous education programs and access to expert consultants who can provide the necessary technical support. this training should be transversal to water sector managers, technicians, and operators. • Consultancy support projects such as WENexus help to overcome this barrier.

Marke Barriers' Categories	Market Barriers Identification	Importance / Impact	Recommendations
	Lack of Knowledge of Energy Consumption Patterns	High	• Implement data management methodologies, adopting technologies that monitor and analyse the operational information. • Designate specific teams to collect, manage, and interpret energy data, ensuring continuous and accurate analysis.
	Resistance to Change	Low	• Showcasing success stories, promoting and share successful case examples of energy efficiency projects in the water sector to help reduce perceived risks and resistance to change.
Organizational	Management Utilities Structure and Decision-Making Processes	High	• Delegate authority to mid-level managers and form autonomous, cross-functional teams to speed up operational decisions. • Making clear guidelines and standardized procedures essential for effective project implementation. • Adopt a flat hierarchy and flexible teams to facilitate direct and rapid communication among decision-makers.
	Lack of Human Resources	Medium	• Collaborate with universities and research institutes to attract interns and recent graduates in engineering and energy fields. • Create specific teams/departments in the Management Utilities organization, to manage energy efficiency of the water and wastewater systems. • Hire consultants and external specialists for specific projects to ensure necessary technical support without permanently increasing staff. • Consultancy support projects such as WENexus help to overcome this barrier.
	Contract Management Challenges	High	• Streamlining and standardizing contractual procedures to simplify and expedite the contract management in the public management utilities • Increase private participation in the water sector management. • Establishment of more flexible regimes.
	Management Utilities Culture	Low	• Publicise the energy efficiency measures promoted by the management utility, in order to promote these behaviours. • Define measurable energy efficiency goals and integrate them into the entity's strategic objectives. • Embed energy efficiency principles into decision-making processes and organizational policies. • Showcasing success stories, promoting and share successful case examples in the water sector to encourage a culture of energy efficiency.
Supply and provision	Equipment's Availability and Provision	Low	• Expand and diversify the supplier network to include companies not yet present in Portugal, promoting local and regional representation to stimulate market growth. • At the same time, prioritize local sourcing to reduce transportation costs and simplify logistics, establish partnerships with regional suppliers or create distribution centers in remote areas, and advocate policies to support local production to reduce dependence on distant suppliers.

Marke Barriers' Categories	Market Barriers Identification	Importance / Impact	Recommendations
			• Improve infrastructure such as roads for efficient delivery and/or use remote monitoring technology to reduce on-site visits. • Develop contingency plans and alternative sourcing strategies to manage delays.
	Technical Assistance	Low	• Expand accessibility and availability of technical support through enhanced training, streamlined communication, and proactive service initiatives.
Policies and External Factors	Policies and Regulation	High	• Review and improvement of Regulation, as develop and implement clear and effective regulations that promote the adoption of energy-efficient technologies and practices in the water sector. • Keep policies stable for long-term investments. Prioritize energy efficiency funding to keep projects moving and draw investors. • Continue to incentivize and subsidize to make projects attractive. Revise taxes to lower the cost of renewable energy and increase returns. • Secure trade agreements for materials needed to reduce tariffs on imported energy technology.
	Global Political Environment	Medium	• Use technologies less affected by international tensions. • Push for stability in trade rules that facilitate technology imports. • Strengthen partnerships and forums on technology and water management. Strengthen ties to share knowledge and technology and collaborate on research. • Mix suppliers and invest locally. • Work with groups that fund sustainable water projects. Push for funding that protects against global risks and keeps plans on track. • Support research that makes water systems around the world more resilient and better.
	Other External Factors	Medium	• Strive to strengthen infrastructure to withstand extreme weather events and adapt technologies to withstand climate impacts. • Engage the public through education and transparency. Raising awareness of the benefits of climate action and energy efficiency builds community support and leads the way to effective climate solutions. • Engage with local communities early and comprehensively. Clearly communicate the tangible benefits of energy efficiency projects and maintain a positive reputation by fulfilling commitments and demonstrating social responsibility.

In conclusion, overcoming the barriers to energy efficiency in Water Sector requires a multifaceted approach. It necessitates not only financial and regulatory support but also robust capacity building, knowledge dissemination, and the establishment of clear incentives. By addressing these challenges comprehensively, stakeholders can foster a conducive environment for the adoption of energy-efficient technologies and practices in the sector. This, in turn, will contribute to achieving sustainability goals, improving service delivery, and enhancing overall resilience in water and energy management.

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DELIVERING THE WATER-ENERGY NEXUS FOR ENERGY EFFICIENCY

CONTACT US

wenexus@wenexus.eu

VISIT US

www.wenexus.eu

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