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**Environmental thecnology**

# Assessment of the economic sustainability of water capture from surface and underground water sources to supply urban areas

## Avaliação da sustentabilidade econômica da captação de água em manancial superficial e subterrâneo para abastecimento de áreas urbanas

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## ABSTRACT

Analyze the implications of the configuration of the Sectors that make up the Water Supply Systems (WSSs) in the municipality of Belém, capital of the state of Pará, on their economic sustainability. The research was developed in three stages. The first stage consisted of identifying and collecting information regarding the WSSs operated by Companhia de Saneamento do Pará – COSANPA. In the second stage, operational and commercial indicators were determined for both Sectors selected as the most suitable for comparison, in this case the 12th Sector and the 23rd Sector. In the last stage, an analysis of the economic sustainability of selected Sectors was performed. It was verified that 04 of the 39 WSSs collect raw water from a surface water source, while the other 35 WSSs use deep wells (about 270 meters deep) to collect water from Pirabas artesian aquifer. In addition, operational efficiency indicators were calculated, such as the “Distribution Losses Index” – 69,08% (12th Sector) and 72,67% (23rd Sector), and economic sustainability indicators, such as the “Total Expense with the Services per Billed Cubic Meter” – R$1,92/m³ (12th Sector) and R$1,29/m³ (23rd Sector). In conclusion, due to the classification of both studied Sectors, regarding operational efficiency and economic sustainability, as inefficient and partially sustainable respectively, it is recommended to improve the operational and comercial management of the regional concessionaire, in compliance with the premises of Law No. 14.026/2020 and to ensure the economic and financial balance of the service provider.

**Keywords**: Water supply; Conception; Type of water source; Indicators; Economic sustainability; Performance

## RESUMO

Analisar as implicações da configuração de Setores integrantes de Sistemas de Abastecimento de Água (SAAs) do município de Belém, capital do estado do Pará, na sustentabilidade econômica. A pesquisa foi desenvolvida em três etapas. A primeira etapa consistiu na identificação e no levantamento de informações referentes aos SAAs gerenciados pela Companhia de Saneamento do Pará – COSANPA. Na segunda etapa foram determinados indicadores operacionais e comerciais dos dois Setores selecionados como mais indicados para comparação, no caso o 12º Setor e o 23º Setor. Na última etapa foi realizada a análise da sustentabilidade econômica dos Setores selecionados. Foi verificado que 04 dos 39 SAAs realizam captação de água bruta em manancial superficial, enquanto nos outros 35 SAAs são utilizados poços profundos (cerca 270 metros de profundidade) para captação de água no aquífero artesiano Pirabas. Complementarmente, foram calculados indicadores de eficiência operacional, como o “Índice de Perdas na Distribuição” – 69,08% (12º Setor) e 72,67% (23º Setor), e indicadores de sustentabilidade econômica, como a “Despesa Total com os Serviços por Metro Cúbico Faturado” – R$1,92/m³ (12º Setor) e R$1,29/m³ (23º Setor). Por fim, em função da classificação de ambos os Setores estudados, quanto à eficiência operacional e à sustentabilidade econômica, como ineficientes e parcialmente sustentáveis, respectivamente, é recomendado o aperfeiçoamento da gestão operacional e comercial da concessionária regional, em atendimento às premissas da Lei n.º 14.026/2020 e na garantia do equilíbrio econômico-financeiro do prestador de serviços.


**Palavras-chave**: Abastecimento de água; Concepção; Tipo de manancial; Indicadores; Sustentabilidade econômica; Desempenho

# 1 INTRODUCTION

Over the last decades, the accelerated growth of the Brazilian population in large urban centers has increased the demand for potable water, although in many areas there has not been a proportional expansion of coverage and service of public water supply. This process resulted in a deficit of population service, setting a great challenge for current public managers, service providers and other social actors involved in the process (BARROS *et al.*, 2017).

This situation is represented by the indicators made available at the National Sanitation Information System (SNIS, 2020a), with the water supply serving 70,30% of the country’s population, 39,8% of water loss in distribution systems and just 46,22% of water metering in branches, which makes it necessary to expand the structures and improve the efficiency of public water supply systems in Brazil.

At the same time, it is essential for the water supply systems (WSS) to be properly managed and continuously improved, in which it is directly related to the sustainability of service provisions. This necessity is highlighted on the recent changes in the basic sanitation regulatory legislation in Brazil, with the enactment of Law No. 14.026/2020

(BRASIL, 2020), which sets bold goals and enables the increase of competition between private companies and state water utilities for service provisions.

Bezerra (2012) comments that the sustainability in service provisions of water supply services must ensure the maintenance of the existent infrastructure, the assurance of customers service and the renovation and/or expansion of structures; in order to have the conditions to increase future costumers, ensuring the quantity and quality of potable water served to the population.

Additionally, it is imperative the improvement of operational and commercial management of water supply service providers through the control and reduction of water losses and efficient management of water demand at the WSS; considering that these actions have a direct impact on the system exploitation expenses and, consequently, on the provider's economic sustainability.

At this conjuncture, it is necessary that these expenses are measured during the project elaboration phrased, considering that different design alternatives of each WSS directly impact on each system expenses.

After the technical-economic feasibility study of the design alternatives, where the implementation costs and exploitation expenses predicted by each WSS alternative are measured, the service provider will have conditions to designate, by the analysis of economic-financial, technical, institutional, environmental, and social criteria, which system configuration will be better detailed in the project phase, including the spring for raw water abstraction.

The water source must be determined during the design alternative study, in view of the direct impact of this definition on several elements to be projected and/or defined; such as the extension of adduction lines, the water treatment technology, the units that integrate the system and the implementation and operation costs of the WSS (FERREIRA, 2019).

Despite doing the economic feasibility study of the design alternatives to provide resources for decision-making over the WSS configuration, as well as the subsequent follow-up on the efficiency and economic sustainability, it is still little known and little used by the actors who develop activities in city halls, regulation agencies, sanitation companies, as well as the organized civil society.

This lack of knowledge weakens the decision making and the improvement of management processes, as well as the participation and social control on the water supply service providing; perpetuating inefficient operational practices. Therefore, it is imminent that the configuration impact of WSSs distinct from each other to be measured, specially regards to raw water abstraction, in monitoring indicators of water supply service providers in national territory.

Therefore, in this present study will evaluate the efficiency and economic sustainability of WSS integrating sectors with different water sources regards its raw water abstraction unit, located in the municipality of Belém and operated by the regional utility responsible for water supply service in the state of Pará. This activity is necessary, considering the limited availability of studies that investigate the implications of the water source used by the abstraction unit (surface and/or groundwater) on its sectors efficiency and economic sustainability.

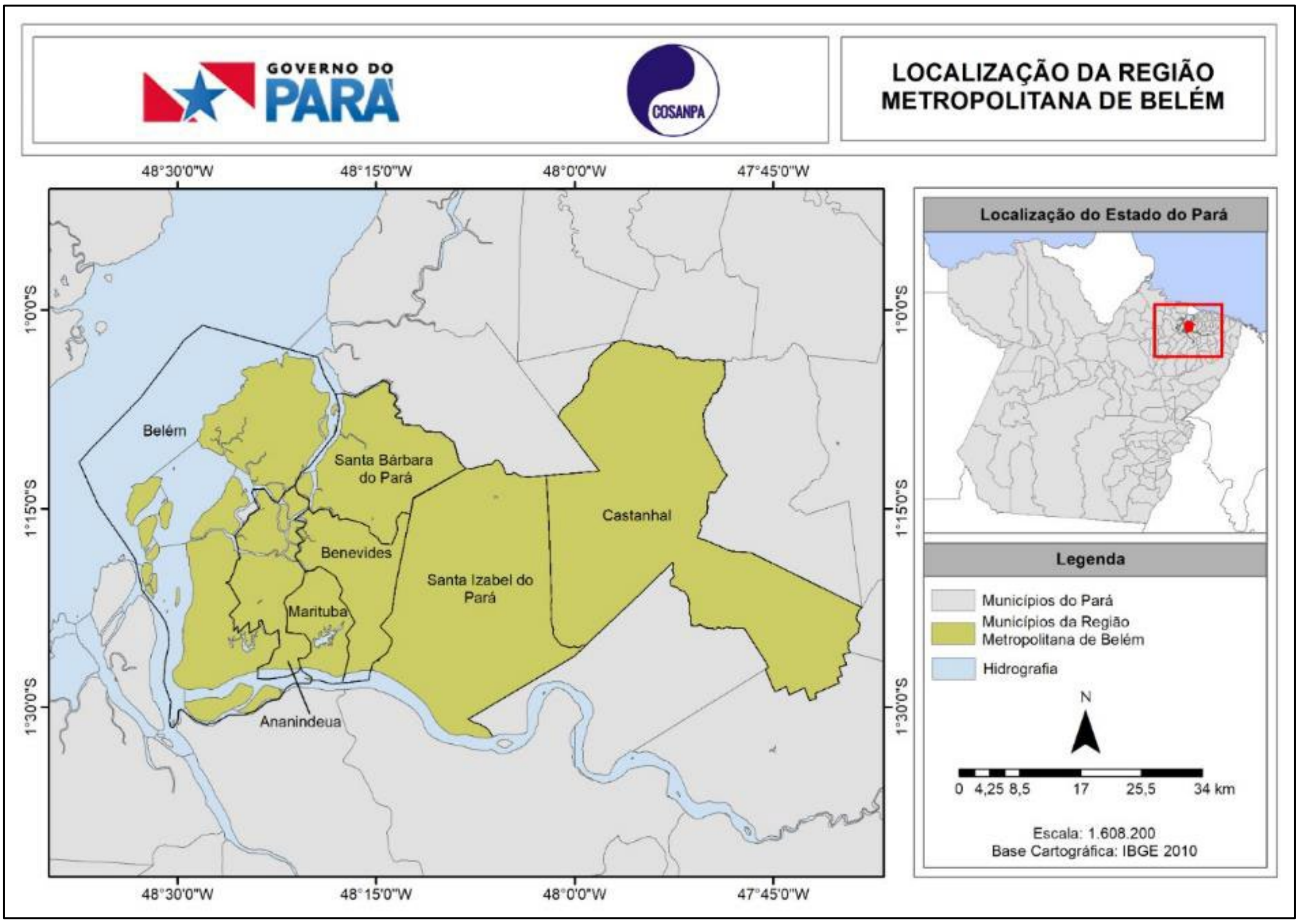
## 2 METHODOLOGY

The developed research might be categorized as quantitative – it considers the compression of reality from raw mathematic data analysis (SILVEIRA & GERHARDT, 2009) - and bibliographic – which implies in an ordered group of procedures in search of solutions, attentive to the study object, which can not be random (LIMA & MIOTO, 2007).

The main information sources consisted of the Master Plan for Water Supply System of the Metropolitan Region of Belém, operational reports, and technical and commercial registrations; and, in addition, the collection of information in field, to study the impact of the abstraction type in the WSS integrating Sectors in the efficiency and economic sustainability of the water supply service providers in the municipality of Belém.

The research has as study object two Water Supply System integrating Sectors with different raw water sources, located in the municipality of Belém; whose geographic location is illustrated below, in Map 1.

**Map 1** – Location of the municipality of Belém in its homonymous Metropolitan Region




Source: Authors (2021)

The municipality of Belém, besides integrating the MRB (Metropolitan Region of Belém), belongs to the homonymous Microregion. The municipal seat has the geographic coordinates 1º27'20"S and 48º30'15"W. The territorial extension of the municipality is 1.059,46 km² (IBGE, 2019), whereas the estimated resident population is 1.499.641 inhabitants (IBGE, 2020).

The research object are the WSS managed by COSANPA, a mixed capital company with public administration, responsible for the operation of WSS and water treatment system (WTS) in 55 of the 144 municipalities in the state of Pará.

The main indicators related to water supply service provision in the municipality of Belém are reunited at Table 1.

**Table 1** – General data of water supply in the municipality of Belém

| Indicators | Values | Units |
|---|---|---|
| Average Per Capita Water Consumption | 126,91 | $L/inhab.day$ |
| Total Water Service Index | 70,30 | % |
| Urban Water Service Index | 70,90 | |
| Water Metering Index | 46,22 | |
| Macro metering Index | 15,41 | |
| Consumption-Related Micro metering | 49,02 | |
| Distribution Losses Index | 39,87 | |
| Losses Per Service Connection Index | 390,58 | $L/connection.day$ |
| Average Water Tax | 3,36 | $R\$/m^3$ |

Source: SNIS (2020a)

## 4.1 Research steps

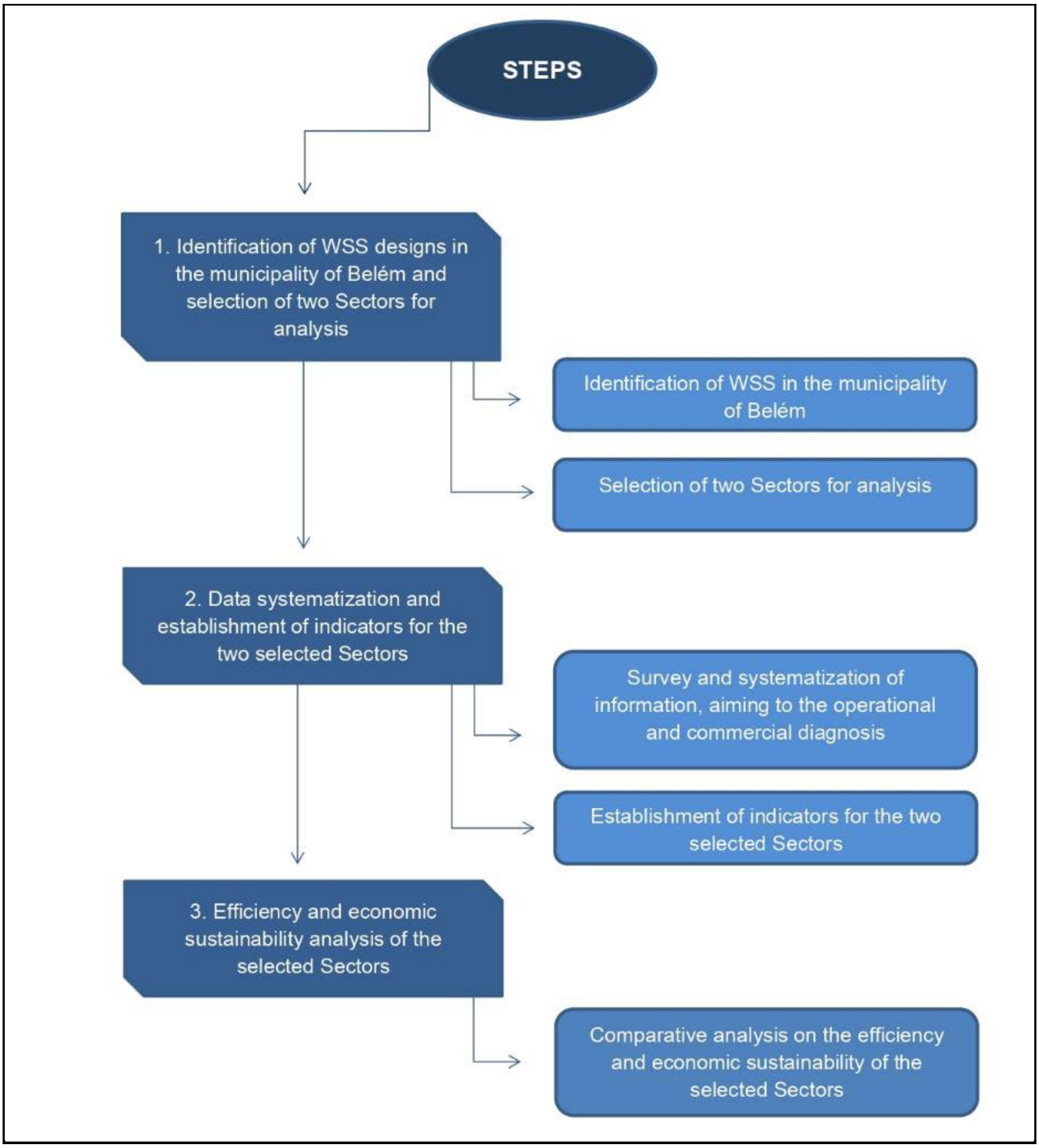
The proposed study development was performed in three steps: a) identification of the WSS design in the municipality of Belém and selection of two Sectors for analysis, being distinct about the spring for water abstraction; b) survey and systematization of operational and expenditure informations, and setting the indicators for both previously selected Sectors and c) comparative analysis on efficiency and economic sustainability of the selected Sectors. These steps are illustrated in Diagram 1:

The first step consisted of the identification of Water Supply Systems in the municipality of Belém and the selection of the two Sectors that will be the scope of the present study.

In the second step, data were surveyed and systematized for the two selected Sectors, through management and control information collection along COSANPA

(Sanitation Company of the State of Pará); resulting on the setting of indicators related to the operational efficiency and the economic sustainability.

**Diagram 1** – Methodology Integrating Steps




Source: Authors (2021)

Finally, in the last step, it was performed a comparative analysis on the efficiency and economic sustainability for each studied Sector; the details of the developed activities in each one of these steps are shown below.

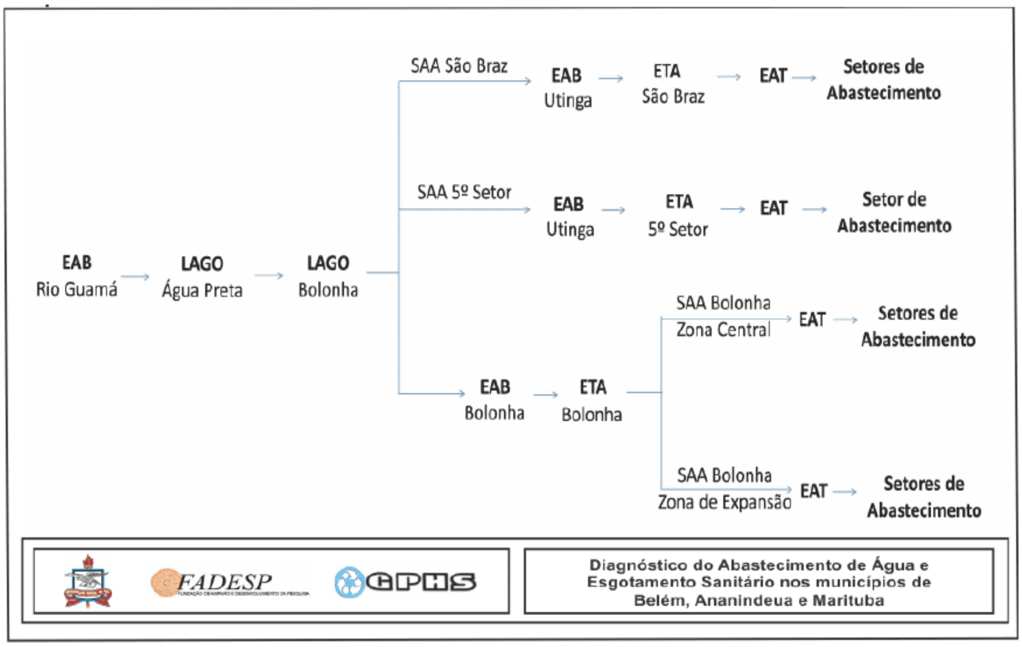
# 3 RESULTS

## 3.1 Identification of the Water Supply Systems in the municipality of Belém

According to the Water National Agency (2013), a water supply system can be classified as integrated when it supplies more than one municipality. These systems are constituted to meet, mainly, the demands of metropolitan regions and low water availability regions.

The metropolitan region of Belém is constituted of 04 (four) WSSs classified as integrated, namely: WSS Bolonha – Downtown, WSS Bolonha – Expansion Zone, WSS Utinga – São Brás and WSS Utinga – $5^{th}$ Sector, as illustrated in Figure 1:

**Figure 1** – Configuration of WSS Bolonha – Downtown, WSS Utinga – São Bras, WSS Utinga – $5^{th}$ Sector and WSS Bolonha – Expansion Zone




Source: UFPA (2013)

In parallel, according to the National Water Agency (2013) a water supply system can be classified as isolated when it supplies urban areas of one single municipality. These systems can count with a groundwater abstraction type. The municipalities which use groundwater sources for water supply are located, in its majority, in places where there are aquifer systems with good water availability.

In this sense, the municipality of Belém is constituted of thirteen WSSs classified as isolated, namely: WSS 10th Sector, WSS Águas Lindas/Verdejante, WSS Pratinha, WSS Panorama XXI, WSS Catalina, WSS Benguí, WSS Cordeiro de Farias, WSS IPASEP, WSS Benjamin Sodré/Sideral, WSS Coqueiro, WSS Ariri/Bolonha, WSS Canarinho, WSS Tenoné.

Therefore, in this universe of existent WSS in the municipality of Belém, in function of the proximity related to the Population Served and Coverage Area, for the evaluation in the present research, were selected the Systems named “Bolonha – Expansion Zone – 12th Sector” (Population Served: 28304 inhabitants; Coverage Area: 1,84 km²) and “23rd Sector – Benjamin Sodré/Sideral” (Population Served: 24.966 inhabitants; Coverage Area: 1, 48 km²).

The constituent units characterization of the 12th and 23rd Sector are reunited below, in Tables 2 and 3:

**Table 2** – Characterization of constituent units of 12th Sector

| Data | 12th Sector – C1 | |
|---|---|---|
| Water Source | Surface Water | |
| Production System | Water Treatment Station of Bolonha | |
| Pump Station - CMB | Pumping from the Treated Water Pumping Station directly to the 12th Sector Elevated Storage Tanks, with arrival flow of 313 m³/h. | |
| Arrival Adductor | Length (m) | 3.945,4 |
| | Material | CI |
| Arrival Pipeline | Diameter (mm) | – |
| | Material | |
| Elevated Storage Tanks | Useful volume (m³) | 350 e 700 |
| | Useful area (m²) | 112,90 e 162,86 |
| Pump Pipeline | Diameter (mm) | 200 e 200 |
| | Material | CI and steel |
| Distribution Pipeline | Diameter (mm) | 200 e 250 |
| | Material | CI and steel |
| Water Distribution Network | Length (m) | 30.005,20 |
| | Material | Asbestos cement, PVC/PBA, PVC/MPVC and CI |

Source: COSANPA (2021a)

**Table 3** – Characterization of the constituent units from the 23rd Sector – Benjamin Sodré/Sideral

| Data | | | WSS Benjamin Sodré/Sideral |
|---|---|---|---|
| Water Source | | | Groundwater |
| 3 Wells | Well P-5 | Depth (m)<br>Flow (m³/h)<br>Manometric height (m) | 200<br>73<br>19,70 |
| | Well P-7 | Depth (m)<br>Flow (m³/h)<br>Manometric height (m) | 272<br>187<br>36,4 |
| | Well P-8 | Depth (m)<br>Flow (m³/h)<br>Manometric height (m) | 268<br>141<br>37,4 |
| Raw Water Main | Material<br>Length (m)<br>Diameter (mm) | | - |
| Water Treatment Station | WTS of water deferrization composed of tray aerator and fast filters, with treatment capacity of 460 m³/h | | |
| Ground-level Tanks | Useful Volume (m³) | | 300 |
| Treated Water Pumping Station | Setting<br>Flow (m³/h)<br>Manometric Height (m) | | 1+1<br>460<br>35 |
| Elevated Tank | Useful Volume (m³) | | 200 + 300 |
| Arrival Pipeline | Diameter (mm)<br>Material | | 150<br>CI |
| Pump Pipeline | Diameter (mm)<br>Material | | 200; 250; 300<br>CI; Steel; CI |
| Distribution Pipeline | Diameter (mm)<br>Material | | 150; 300<br>CI; Steel |
| Water Distribution Network | Length (m) | | 34.845,00 |

Source: COSANPA (2021a)

### 3.2 Information gathering and establishment of indicators for the two selected Sectors

#### 3.2.1 Information gathering

In the following sequence, on Table 4, the operational and commercial informations about the 12th Sector – C1 and the 23rd Sector – Benjamin Sodré/Sideral are detailed.

**Table 4** – Summary of operational and commercial informations gathered for 12th Sector - C1 and 23rd Sector – Benjamin Sodré/Sideral

| Informations | WSS | | Units |
|---|---|---|---|
| | 12th Sector – C1 | 23rd Sector – Benjamin Sodré/Sideral | |
| Water Network Length | 30,005 | 34,845 | $km$ |
| Macromeasured Water Volume | 3.330,024<br>0,11765 | 3.313,22<br>0,13271 | $x10^3 m^3$/year<br>$x10^3 m^3$/inhab.year |
| Revenued Water Volume | 1.029,672<br>0,03638 | 905,363<br>0,03626 | $x10^3 m^3$/year<br>$x10^3 m^3$/ inhab.year |
| Micromeasured Water Volume | 591,551<br>0,02090 | 141,221<br>0,00566 | $x10^3 m^3$/ year<br>$x10^3 m^3$/ inhab.year |
| Total Collection | 4.473.912,60<br>158,07 | 1.152.159,52<br>46,15 | $R$$/ year<br>$R$$/ inhab.year |
| Total Electric Energy Consumption in WSS | 4.066,72<br>0,14368 | 2.030,25<br>0,08132 | $x10^3$ $kWh$/ year<br>$x10^3$ $kWh$/ inhab.year |
| Electricity Exploration Expenses | 1.561.248,64<br>55,16 | 1.042.236,71<br>41,75 | $R$$/ year<br>$R$$/ inhab.year |
| Chemical Products Exploration Expenses | 261.528,96<br>9,24 | 63.423,00<br>2,54 | $R$$/year<br>$R$$/ inhab.year |
| Exploration Expenses with Own Personnel | 45.003,36<br>1,59 | 35.169,29<br>1,41 | $R$$/ year<br>$R$$/ inhab.year |
| Exploration Expenses with Third-Party Services | 112.190,23<br>3,96 | 23.431,77<br>0,93 | $R$$/ year<br>$R$$/ inhab.year |

Source: COSANPA (2021a); (2021b)

The comparision between the gathered informations about the 12th Sector – C1 and the 23rd Sector – Benjamin Sodré/Sideral, as well as the establishment of preliminar indicators for Macromeasured, Revenued, and Micromeasured Volumes (in $x10^{3}m^{3}$/inhab.year, in $x10^{3}m^{3}$/economy.year and in $x10^{3}m^{3}$/km.year) and for the constituent portions of Exploration Expenses (in R$/inhab.year and in R$/economy.year), enable to conclude that, despite the differences between each other regards the water source and setting, the Sectors referred are close to each other regards their "Total Electric Energy Consumption in WSS" (0,14368 $x10^{3}$ $kWh$/inhab.year and 0,17966 $x10^{3}$ kWh/econ.year on the $12^{th}$ Sector, so as 0,08132 $x10^{3}$ $kWh$/inhab.year and 0,30659 $x10^{3}$ kWh/econ.year on the $23^{rd}$ Sector), the "Electricity Exploration Expenses" (R$55,16/inhab.year and R$ 68,96/econ.year on the $12^{th}$ Sector, so as R$41,75/inhab.year and R$157,39/econ.year on the $23^{rd}$ Sector) and the "Exploration Expenses with Own Personnel" (R$1,59/inhab.year and R$6,00/econ.year on the $12^{th}$ Sector, bem como R$1,41/inhab.year and R$5,31/econ.year on the $23^{rd}$ Sector).

In the other hand, as for the "Chemical Products Exploration Expenses" (R$9,24/inhab.year and R$34,84/econ.year on the $12^{th}$ Sector, so as R$2,54/inhab.year and R$9,58/econ.year on the $23^{rd}$ Sector) and the "Exploration Expenses with Third-Party Services" (R$3,96/inhab.year and R$16,94/econ.year on the $12^{th}$ Sector, so as R$0,93/inhab.year and R$3,54/econ.year on the $23^{rd}$ Sector), it was observed that integrating Sector served by an surface water source has shown superior expenses than the Sector served by groundwater source.

This phenomenon can be attributed to the amount of chemical products used for raw water potabilization by the Bolonha Production System, as well as the older age of the $12^{th}$ Sector's Distribution Network over the $23^{rd}$ Sector, and its asbestos cement pipelines; directly increasing the probability of leakage occurrences (physical losses).

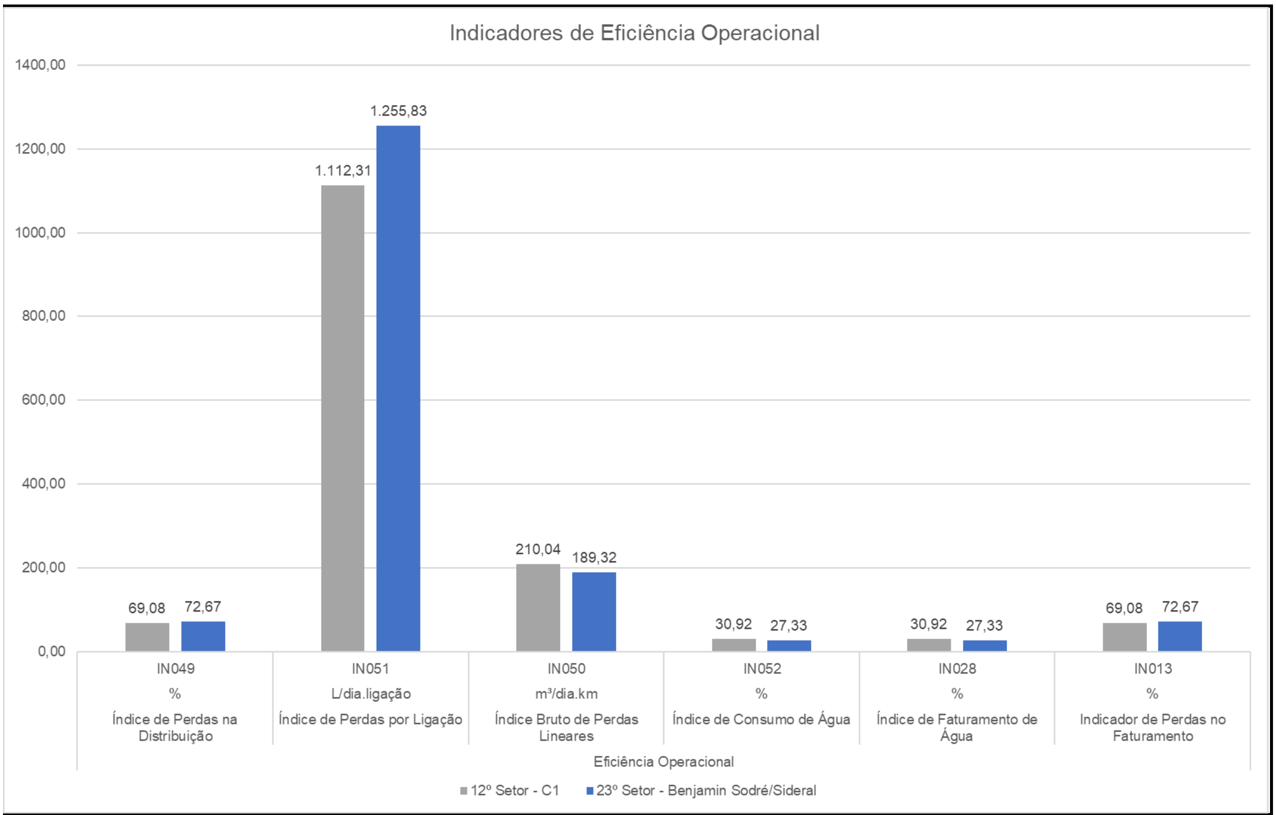
### 3.2.2 Establishment of indicators for the two selected Sectors

In the operational efficiency indicators analysis, for $12^{th}$ Sector – C1 and the $23^{rd}$ Sector - Benjamin Sodré/Sideral, according to the proposed equations from SNIS (2020b), the indicators referring to physical losses can be highlighted in the $12^{th}$ Sector – C1 and in the $23^{rd}$ Sector - Benjamin Sodré/Sideral, as shown in Graphic 1.

Conceptually, the physical losses constitute an intrinsically bonded part to Water Supply Systems, and must be considered in the water balance. The water loss volume is resultant from the subtraction of the consumed volume (revenued) and the total exploited volume (produced/macro measured) and it applies to all WSS units.

In this case, as for the "Distribution Losses Index", it was observed percentages in a range of 69,08% (12$^{th}$ Sector) and 72,67% (23$^{rd}$ Sector). For both Sectors, this indicator was higher than the State of Pará average (29,83%) and the National average (27,21%); illustrating the necessity of investment prioritization, by the service provider, in institutional programs for control and reduction of water losses.

**Graphic 1** – Operational efficiency indicators related to physical losses in the WSSs



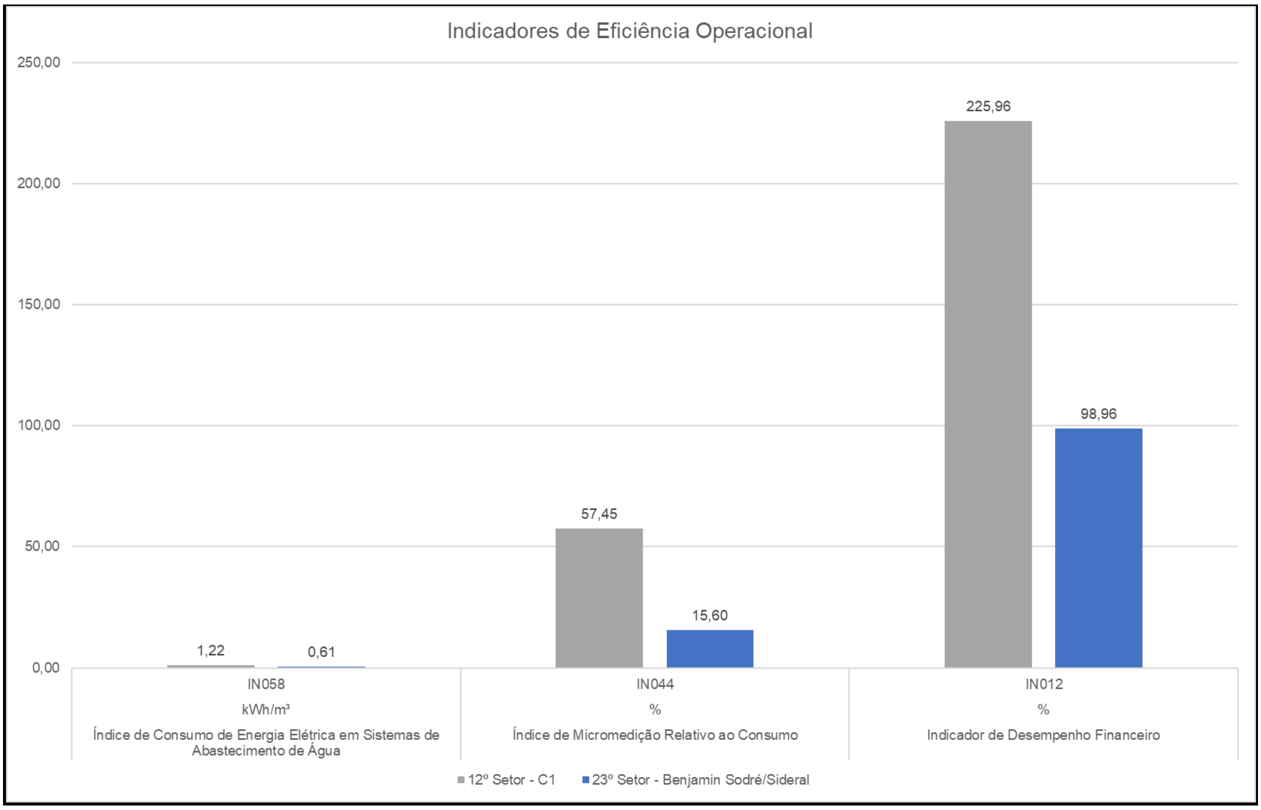

Source: Authors (2021)

This pattern of high physical losses in both researched Sectors, is confirmed by the indicators of "Losses Per Service Connection Index" (L/day.connection) and the "Raw index of linear losses" (m³/day.km); considering that, both for the 12$^{th}$ Sector – C1 and the 23$^{rd}$ Sector - Benjamin Sodré/Sideral, the calculated indicators were higher than the state and national averages present in the SNIS (2020a).

Complementarily, these indicators are coherent to the ones determined by Viegas (2009) for the Benjamin Sodré Residential Complex, served by the 23rd Sector, namely: “Distribution Losses Index” – 70,04%; “Losses Per Service Connection Index” – 1.446 L/connection.day and “Raw index of linear losses” – 157,96 m³/day.km or L/day.m.

In Graphic 2 below, the additional indicators of operational efficiency are reunited, for the 12th Sector – C1 and the 23rd Sector - Benjamin Sodré/Sideral:

**Graphic 2** – Additional indicators of operational efficiency referring the researched WSSs




Source: Authors (2021)

As for the “Consumption-Related Micro-metering Index” (%), percentages of 57,45% (12th Sector) and 15,60% (23rd Sector) were calculated, which illustrates a fraction of the micro measured volume (hydro metered) in relation to the macro measured volume (distributed). For the 12th Sector – C1, this indicator was higher than the State of Pará average (50,77%) and lower than the Brazilian average (68,01%), while in the 23rd Sector - Benjamin Sodré/Sideral, the indicator calculated was lower than reference values for state and national averages; enhancing the need for a stronger commercial performance in this referred Sector when it comes to micro measuring.

At the same time, when are compared the Exploration Expenses of both Sectors with revenues from the service charges, which is illustrated by the “Financial Performance Index” (%), it is observed that, in both cases, the amount collected exceeds or is too close to the registered expenses, specially for the $12^{th}$ Sector – C1 (225,96%); representing a favorable situation to the economic sustainability of the referred Systems.

Finally, as for the de “Electricity Consumption in Water Supply Systems Index” it was observed values of 1,22 kWh/m³ ($12^{th}$ Sector) and 0,61 kWn/m³ ($23^{rd}$ Sector).

This indicator is directly related to the information on “Total Electricity Consumption in Water Supply Systems” (x10³ kWh/inhab.year), which, in turn, is related to the units configurations and types, the number of equipment and the operational routine and maintenance of the WSS (PEREIRA & CONDURÚ, 2014).Therefore, the difference between the referred indicator, for both Sectors, is intrinsically associated, among other factors, with several required pumps for the availability of the water volume distributed in the $12^{th}$ Sector – C1 from the Bolonha Production System.

Below are listed the economic sustainability indicators calculated for the 12th Sector – C1 and the $23^{rd}$ Sector - Benjamin Sodré/Sideral.

### 3.3 Analysis of efficiency and economic sustainability of the selected Sectors

In this step, it was performed the efficient and economic sustainability analysis of the service provision in the municipality of Belém, specifically the researched Sectors, through the indicators calculated for each System and the reference values established; so as the predicted scores for attribution in function of the fitting of these indicators in the intervals constituted by their respective reference values, as shown in Tables 5 and 6 below:

**Table 5** – Operational Efficiency analysis of the 12th Sector – C1 and the 23rd – Benjamin Sodré/Sideral

| **Indicators** | **Units** | **12th Sector – C1** | | **23rd Sector – Benjamin Sodré/Sideral** | |
|---|---|---|---|---|---|
| | | **Calculated** | **Score/Quality Category** | **Calculated** | **Score/Quality Category** |
| Distribution Losses Index | % | 69,08 | 3,00 (Poor) | 72,67 | 3,00 (Poor) |
| Losses Per Service Connection Index | $L$/day.connection | 1.112,31 | 3,00 (Poor) | 1.255,83 | 3,00 (Poor) |
| Raw Index of Linear Losses | $m^3$/day.$km$ | 210,04 | 3,00 (Poor) | 189,32 | 3,00 (Poor) |
| Electricity Consumption in Water Service Systems Index | kWh/$m^3$ | 1,22 | 3,00 (Poor) | 0,61 | 9,00 (Excellent) |
| Water Consumption Index | % | 30,92 | 3,00 (Poor) | 27,33 | 3,00 (Poor) |
| Consumption-Related Micro-metering | | 57,45 | 7,00 (Good) | 15,60 | 3,00 (Poor) |
| Water Revenue Index | | 30,92 | 3,00 (Poor) | 27,33 | 3,00 (Poor) |
| Revenue Loss Index | | 69,08 | 3,00 (Poor) | 72,67 | 3,00 (Poor) |
| Financial Performance Index | | 225,96 | 9,00 (Excellent) | 98,96 | 9,00 (Excellent) |
| Final Score | | 41,11 (Inefficient) | | 43,33 (Inefficient) | |

Source: Authors (2021)

Note: The final score determination, regarding the operational conditions and economic sustainability of both selected Sectors, was performed using the recommended scale by Bezerra (2012)

**Table 6** – Economic sustainability analysis of the 12th Sector – C1 and the 23rd Sector - Benjamin Sodré/Sideral

| Indicators | Units | 12th Sector – C1 | | 23rd Sector – Benjamin Sodré/Sideral | |
|---|---|---|---|---|---|
| | | Calculated | Score/Quality Category | Calculated | Score/Quality Category |
| Total Service Expenses per Billed Cubic Meter | $R\$/m^3$ | 1,92 | 9,00 (Excellent) | 1,29 | 9,00 (Excellent) |
| Exploration Expenses per Economy | $R\$$/economy .year | 263,71 | 7,00 (Good) | 175,82 | 9,00 (Excellent) |
| Own Personnel Expenses Participation in Exploration Expenses | % | 2,27 | 9,00 (Excellent) | 1,78 | 9,00 (Excellent) |
| Electricity Expenses Participation in Exploration Expenses | % | 78,85 | 3,00 (Poor) | 52,64 | 3,00 (Poor) |
| Chemical Products Expenses Participation in Exploration Expenses | % | 13,21 | 3,00 (Poor) | 3,20 | 9,00 (Excellent) |
| Average Water Tax | $R\$/m^3$ | 4,34 | 9,00 (Excellent) | 1,27 | 3,00 (Poor) |
| Final Score | | 66,67 (Partially Sustainable) | | 70,00 (Partially Sustainable) | |

Source: Authors (2021)

Note: The final score determination, regarding the operational conditions and economic sustainability of both selected Sectors, was performed using the recommended scale by Bezerra (2012)

As it is observed in Table 5, most of operational efficiency indicators, both for the 12th Sector – C1 and the 23rd Sector – Benjamin Sodré/Sideral, were included in the category "Poor"; which contributes directly for the classification of both WSS as "Inefficient".

This situation was resultant, mainly, from the indicators related to physical losses in the Systems, as the "Distribution Losses Index" (%), the "Losses Per Service Connection Index" (L/day.connecion), the "Raw index of linear losses" ($m^3$/day.km), the "Water Consumption Index" (%), the "Water Revenue Index" (%) and the "Revenue Loss Index" (%); in which those got too far from their respective reference values, as surveyed by SNIS (2019a), namely: from 27,21 to 41,91%; from 259,77 to 546,01 L/day.connection; from 17,85 ti 41,42 $m^3$/day.km; from 58,09 to 72,79%; from 58,08 to 69,61% and from 30,39 to 64,40%; respectively.

In contrast, the 23rd Sector - Benjamin Sodré/Sideral presented an excellent classification regards the "Electricity Consumption in Water Supply Systems" (kWh/$m^3$), so as the 12th Sector – C1 had shown a good commercial performance regards the water metering, which resulted in the classification of the "Consumption-Related Micro-metering Index" (%) as "Good". In addition, both Systems presented an "Excellent" assessment regards the "Financial Performance Index" (%); representing a favorable situation towards their economic sustainability.

At the same time, as seen in Table 6, in opposition to the mostly poor performance of the operational efficiency indicators, the economic sustainability indicators presented a categorized performance, on most parts, as "Excellent"; outstandingly in the "Total Service Expenses per Billed Cubic Meter" (R$/$m^3$), in the "Exploration Expenses per Economy" (R$/economy. Year) – for the 23rd Sector, in the "Own Personnel Expenses Participation in Exploration Expenses" (%), in the "Chemical Products Expenses Participation in Exploration Expenses" (%) – for the 23rd Sector, and in the "Average Water Tax" (R$/$m^3$) – for the 12th Sector.

On the other hand, the indicators "Electricity Expenses Participation in Exploration Expenses" (%), "Chemical Products Expenses Participation in Exploration Expenses" (%) – for the 12th Sector, and the "Average Water Tax" (R$/$m^3$) – for the 23rd

Sector, presented a “Poor” classification; contributing for both researched Sectors to express a final score as “Partially Sustainable”.

## 4 CONCLUSIONS

From the accomplishment of this present research, it was possible the diagnosis of the Water Supply Systems located in the municipality of Belém, capital of the State of Pará, operated by the Sanitation Company of the State of Pará.

As for the indicators of Operational Efficiency, it was verified that, despite the physical losses indicators being analogues for both studied Sectors (69,08% for the 12$^{th}$ Sector – C1 and 72,67% for the 23$^{rd}$ Sector – Benjamin Sodré/Sideral), from the commercial performance perspective, the Water Supply System Integrating Sector with surface water source (12$^{th}$ Sector) has a higher “Consumption-Related Micro metering” (57,45%) and revenue in relation to the billed amount, nominated “Financial Performance Index” (225,96%), in relation to the WSS Integrating Sector with groundwater source (23$^{rd}$ Sector).

Even though there is no direct relation between the type of water source and the Sectors commercial performance, regards the equalization of the Exploration Expenses in the Integrated WSS related to the System higher coverage, even with high expenses in Electricity (78,85%) and Chemical Products (13,21%), these expenses were more easily overcome compared to the referred Sector – Total Exploration Expense of R$1.980.037,18 and Revenue of R$4.473.912,60; illustrating the scale earns of the Integrated WSS with surface water source, as presented by the preliminary indicators related by x$10^3$$m^3$/inhab.year, R$/inhab.year and R$/economy.year.

Furthermore, in the Integrated System, regards the concentration of abstraction, adduction, treatment, reservation and pumping installations, the operational control is optimized; which is particularly useful in great urban conglomerates, with high demands for potable water.

In addition, according to a research by the National Water Agency (ANA, 2018), the Pirabas Aquifer, which is more explored due to its higher water production and lower iron content, with average flow of 250 m³/h, storages around 84% of all groundwater reservation of the Metropolitan Region of Belém, and, in this universe, only 3,2% constitutes the renewable reservation. Therefore, the exploitation of groundwater in the municipality of Belém, considering the non-renewable character of its main Aquifer System, must be carefully managed, in accordance with the regulations of the water resources management agency.

In its turn, as for the Economic Sustainability Indicators, it was observed a necessity for optimization on the Electricity Exploration Expenses from both Sectors, and on the Chemical Products Expenses in the WSS Integrating Sector with surface water source, due to the elevated percentage of these expenses in the Total Exploration Expense. In this sense, it is necessary the incorporation of premises for hydro energetic efficiency in the optimization of operational routines from the referred Systems, as well as the determination of chemical products - coagulants, flocculation auxiliary polymers and disinfecting agents – to be more suitable for local reality, specially regards to the seasonality of raw water quality from water source used for public supply, besides de verification of optimal dosages indicated through the performances of continuous treatability tests.

Finally, both researched Sectors were classified, regards the efficiency analysis and economic sustainability, as inefficient and partially sustainable, respectively, which presents the urgent necessity for the improvement of operational and commercial management of the local service provider; in order to follow the premises of Law n. 14.206/2020, so as the guarantee of the provider economic-financial capacity, as predicted in Decree n. 10.710/2021 (BRASIL, 2021), contributing for the continuous expansion of the system coverage, and, therefore, for the universalization of potable water supply in the municipality of Belém.

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