The impact of differences in defining leakage indicators on the comparability of data required by the Drinking Water Directive

Wpływ różnic w definicjach wskaźników wycieków na porównywalność danych wymaganych Dyrektywą w sprawie jakości wody do spożycia

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DOI 10.36119/15.2025.12.16

Recent changes in European Union legislation impose new obligations on water utilities to gather, analyse, and report impartial Key Performance Indicators (KPIs). These include data on water leakage, entity condition, energy consumption, and its sources. Benchmarking has emerged as a valuable tool for collecting standardized and reliable data, facilitating improvements. Utilities in Poland participate in both national benchmarking, led by the Chamber of Commerce's "Polish Waterworks" (IGWP), and international benchmarking through the European Benchmarking Cooperation (EBC). However, differences in data definitions affect the comparability of indicators and the accuracy of ranking results. A crucial issue is to select the most appropriate and objective KPI for water loss. The DWD mandates the use of the Infrastructure Leakage Index (ILI), but this indicator is difficult to calculate and verify, prompting a search for simpler, standardized alternatives, such as Non-Revenue Water (NRW). The authors compare selected KPIs from the two benchmarking projects, EBC and IGWP, showing that minor definitional differences may make the comparison non-objective or impossible.
Keywords: benchmarking, DWD, leakage

Ostatnie zmiany w prawodawstwie Unii Europejskiej nakładają na przedsiębiorstwa wodociągowe nowe obowiązki w zakresie gromadzenia, analizowania i raportowania obiektywnych Kluczowych Wskaźników Efektywności (KPI). Obejmują one dane dotyczące wycieków wody, stanu przedsiębiorstwa, zużycia energii i jego źródeł. Benchmarking stał się cennym narzędziem gromadzenia znormalizowanych, rzetelnych danych i ułatwiania wprowadzania usprawnień. Przedsiębiorstwa wodociągowe w Polsce uczestniczą zarówno w benchmarkingu krajowym, prowadzonym przez Izbę Gospodarczą „Wodociągi Polskie" (IGWP), jak i międzynarodowym, prowadzonym przez European Benchmarking Co-operation (EBC). Różnice w definicjach danych wpływają jednak na porównywalność wskaźników i wyniki rankingowe. Kluczową kwestią jest wybór obiektywnego i bezstronnego KPI dla strat wody. Dyrektywa 2020/2184 (DWD), nakazuje stosowanie Infrastrukturalnego Wskaźnika Wycieków (ILI), ale wskaźnik ten jest trudny do obliczenia i weryfikacji, co skłania do poszukiwania prostszych, znormalizowanych alternatyw, takich jak woda nieprzynosząca dochodu (NRW). Autorzy porównują wybrane kluczowe wskaźniki efektywności (KPI) z dwóch projektów benchmarkingowych, EBC i IGWP, pokazując, że drobne różnice definicyjne mogą sprawić, że porównanie będzie nieobiektywne lub niemożliwe.
Słowa kluczowe: benchmarking, Dyrektywa wodna DWD, wycieki,

Introduction

Changes in EU legislation require the acquisition of more and more data, and it is necessary to calculate KPI s, which should be impartial. The Drinking Water Directive (European Union, 2020) requires reporting not only on leaks but also on the general condition of the entity. Moreover, the Taxonomy Regulation (European Union, 2020a) and its delegated and implementing acts impose, among other obligations, the requirement to monitor energy consumption and its origin (fossil fuels or renewable). The essence of strengthening water supply systems is also monitoring reliability (Rak et al. 2022).

A helpful tool for obtaining reliable and valuable data is benchmarking (EurEau, 2015; Suchacek et al., 2018; Goh and See, 2021; Marques et al. 2021). The overarching goal is to objectively compare participants to indicate areas for structural and management changes and corrections. To improve their operations and compare efficiency at the national and international level, the Polish frontrunner utilities participate in two types of benchmarking: international, carried out by the European Benchmarking Cooperation (EBC), and Polish, implemented by the Chamber of Commerce "Polish Waterworks." Both projects were established in the early 2000s and are dedicated to companies involved in the drinking water supply and wastewater collection and treatment (water services).

Nearly 200 Polish water companies, members of the organization, are participating in the IGWP benchmarking project. The Chamber has about 500 members, which include both water and sewage companies. There are a few very small entities among them. The benchmarking participants are split into three groups, based on the number of inhabitants served:

- Small, serving of less than 20 thousand inhabitants,
- Medium-sized, serving from 20 thousand to 100 thousand inhabitants,
- Big, serving more than 100 thousand inhabitants.

The entities participating in the benchmarking operate more than 16% of the total length of the water network and serve approximately 56% of households in Poland. This benchmarking project has been conducted

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through a survey method, with the support of a dedicated web platform. The application was created based on the team's expert experience and has been modified during operation. The interface is friendly for participants and enhances the accuracy of data. The attendants must fill in the basic data, which is verified automatically upon gathering. The Polish benchmarking project focuses on four groups of factors: operational, investment and renovation, environmental, and financial.

ECB has several benchmarking proposals but focuses on large water utilities. This is due to the complexity of the survey to be completed. In 2023, 46 entities participated in the exercise, primarily from Europe, as well as from Asia and South America. These are mainly large entities, supplying over 5 million inhabitants of Singapore, Oman, or Ankara. However, there are also smaller ones, such as those in Nicosia (Cyprus), which serve 50,000 inhabitants. Additionally, this company is affected by the extremely high seasonality of water demand. In total, EBC benchmarking participants serve 78 million people. EBC indicators are grouped into four categories: resources, utility management, performance, and societal effects.

Kraków City Waterworks (WMK) participates in both exercises. Experience shows that differences in approach to data collection and definitions are a crucial factor influencing an entity's position in the ranking and providing valuable insights. A key difference between the two benchmarks lies in their definitions. In both cases, they were developed by expert groups and accepted by the participants.

Benchmarking can help implement Article 4 of the DWD; it imposes the obligation to monitor leaks related to water losses in the water supply network. There is a lively discussion in the EU regarding the implementation of this practice.

The Infrastructure Leakage Index (ILI) is the only one directly specified in the Drinking Water Directive. In the text of the Directive, we can find: "In accordance with Directive 2000/60/EC, Member States shall ensure that an assessment of water leakage levels within their territory and of the potential for improvements in water leakage reduction is performed using the infrastructural leakage index (ILI) rating method or another appropriate method."

The equation for the ILI is:

$$ILI = \frac{Vl}{UARL} \qquad (1)$$

Where:
Vl – volume of real losses,
UARL – Unavoidable Annual Real Losses.

The most difficult part is calculating the denominator of the equation above.

The equation for the UARL is:

$$UARL = (18 \cdot D + 0,8 \cdot Nc + 25 \cdot Lc) \cdot P \cdot \frac{365}{1000} \qquad (2)$$

Where:
D – total length of the water network,
Nc – number of pipe connections,
Lc – total length of pipe connections,
P – pressure of water in the network.

Considering the unsold water volume, ECB relies on the International Water Association (IWA) guidelines covering non-revenue water (NRW) and real losses (AbuEltayef et al, 2023). NRW is the difference between water injected into the network and water sold in a specific unit of time. Therefore, it is an easy indicator to calculate (Rizzo et al., 2007; LeaksSuite Library, 2025).

EBC proposes several indicators linked to water losses. Still, according to the EBC, the best indicators for the DWD Article 4 report are the NRW per number of connected properties and the NRW as a percentage of water pumped into the network. Water loss indicators are described in the "Drinking Water" area. In turn, IGWP includes water losses in the group of environmental indicators. It is not based on NRW, but on the amount of water injected into the network, excluding the water used for the entity's own technological purposes (e.g., flushing the network) after being pumped into the network (volume in m^3). IGWP benchmarking includes a percentage indicator and a linear leakage index (LLI), which represents the leakage volume per kilometer of the network.

DWD indicates the obligation to collect values for the infrastructure leakage index (ILI) or "another appropriate method". However, IGWP and ECB emphasize that it is dedicated to entities that conduct intensive leakage management and have a network that is in good condition. ILI is an indicator that depends on the technical features of the network, such as the length of distribution pipes or connecting pipes (Winarni, 2009). For many water operators, it is very difficult to calculate, sometimes even impossible (Palachova and Tuhovcak, 2024; Ociepa-Kubicka et al, 2024). On the other hand, the way of defining and calculating this KPI can be influenced by different assumptions (Iwanek M., Suchorab P. 2019), which may be subjective and unclear. It is also not possible to verify the value of the ILI factor through external or regulatory agendas. It is necessary to identify the fundamental and clear factors that will be widely used to evaluate the efficiency of the water supply system and compare the systems in terms of leakage level. More so, because the results are to be reported to the Commission by January 2026.

The authors conducted a comparative analysis of indicators related to water losses to determine the optimal approach. They used KPIs from EBC and IGWP and analysed the results of these two benchmarkings. Neither institutions publish reports with full results. These are available only to project participants. However, much data is published in a shortened, anonymized version and presented at conferences and workshops.

It is also worth emphasizing that ILI only concerns losses in the water supply network; hence, an equivalent method should also focus on losses in the network and not in the entire supply system (from source to tap).

Materials and methods

the Drinking Water Directive requires a leakage monitor for entities supplying at least 10,000 m^3 per day or serving at least 50,000 people. According to the Chief Sanitary Inspectorate (2024), in Poland in 2023, there were 69 waterworks that took in more than 10,000 m^3/day, supplying 12 million people.

The European Federation of Water Services (EurEau) emphasizes that managing water losses from the distribution system is a crucial aspect of the water supplier's role (EurEau, 2021). The reporting of the leakage estimate across Europe is based on several indicators. These indicators are calculated using different formulas that incorporate components of the water balance, which are also calculated in various ways. Based on the study, EurEau members use 16 different indicators, mostly based on volume, e.g., m^3 or m^3/km of water pipe. Some indicators are given in percentages. The Infrastructure Leakage Index is only used by a very small number of large water providers due to the difficulty in data collection and its sensitivity to average pressure in the network.

Figure 1 presents the distribution of answers to the question among the members of the Chamber regarding which water loss indicator the entity bases its monitoring on. The survey was part of a bigger investigation conducted in 2022.

In IGWP benchmarking (IGWP, 2024), the water loss factors are part of three environmental KPIs:

The first one is a percentage of water loss:

$$\frac{A - B - C}{A} \cdot 100 \qquad (3)$$

Where:
A – water pumped into the network [thousands m^3],

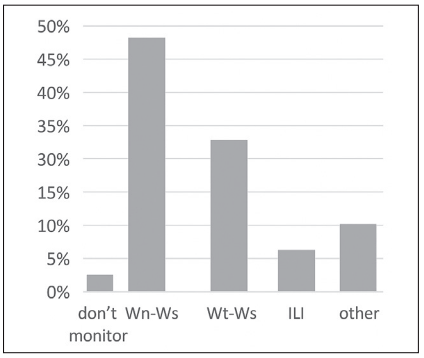
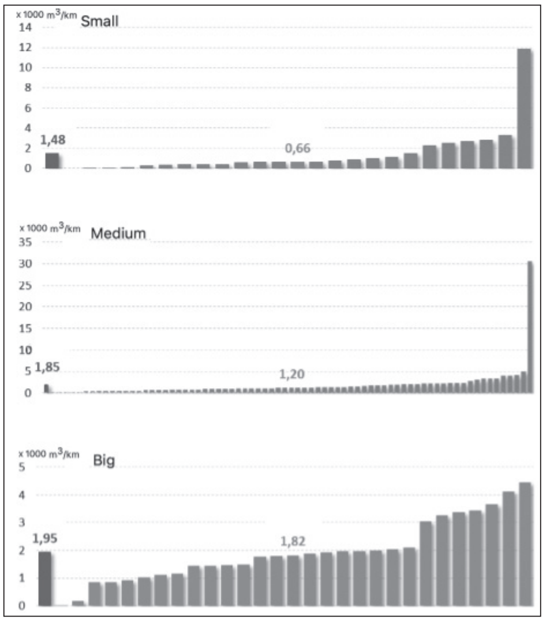


Figure 1.
Distribution of responses to the question about the most frequently monitored water loss indicator, where: Wn – water pumped into the network, Wt – water taken from the environment, Ws – water sold (invoiced)
Figure 1. Odpowiedzi na pytania o najczęściej używany wskaźnik strat wody, gdzie: Wn – woda wpompowana do sieci dystrybucyjnej, Wt – woda pobrana ze środowiska, Ws – woda sprzedana(zafakturowana)

Figure 3.
Annual water loss in m^3/km of water mains in three categories of water suppliers (small, medium, big). The number on the left indicates the average value, and the number in the middle indicates the median. Each bar represents an entity participating in the benchmarking
Figure 3. Roczna wielkość strat wody w m^3/km sieci w trzech kategoriach dostawców (małych, średnich i dużych). Liczba po lewej stronie oznacza wartość średnią, a liczba w środku medianę. Każdy słupek reprezentuje jednostkę biorącą udział w benchmarkingu



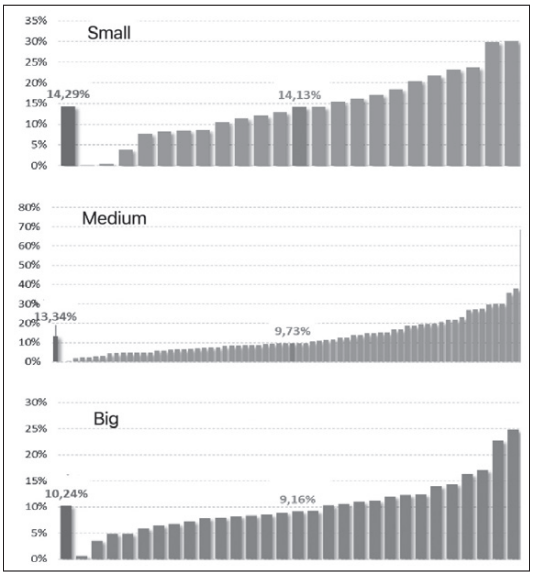


Figure 2.
Water loss percentage value in three categories of water suppliers (small, medium, and big). The number on the left indicates the average value, and the number in the middle indicates the median. Each bar represents an entity participating in the benchmarking
Figure 2. Procentowy wskaźnik strat wody w trzech kategoriach dostawców (małych, średnich i dużych). Liczba z lewej strony oznacza wartość średnią, a liczba w środku medianę. Każdy słupek reprezentuje jednostkę biorącą udział w benchmarkingu

B – water sold (wholesale included) [thousands m^3],
C – water used in technological purposes of the operator [thousands m^3].

Figure 2 presents results from 2023. In every chart, we can see the red median value and the green average value in the group.

The second indicator is a linear water loss index defined by the equation:

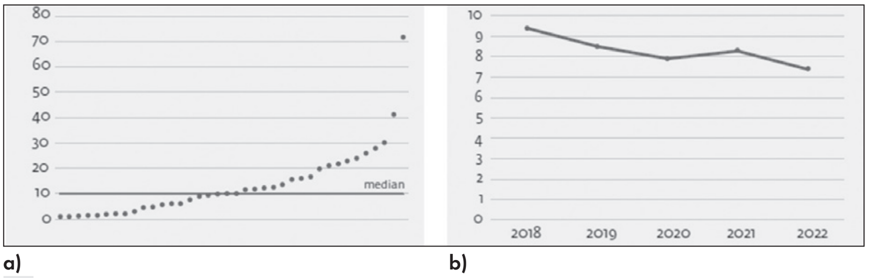
$$\frac{A-B-C}{D}\cdot 1000 \qquad (4)$$

Where:
A – water pumped into the network [thousands m^3],
B – water sold (wholesale included) [thousands m^3],
C – water used in technological purposes of the operator [thousands m^3],
D – the total length of the operated water network (without pipe connections) [km].

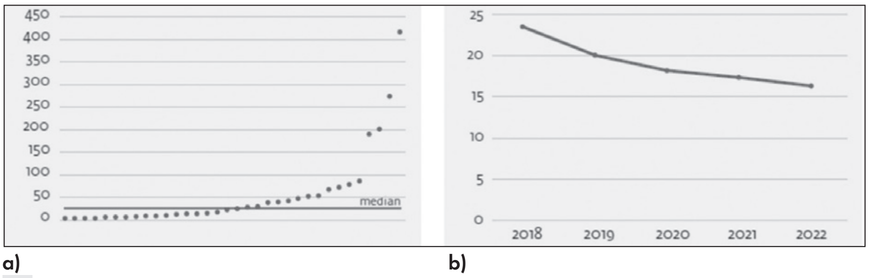
The third indicator, named the drinking water network efficiency, is a ratio of water sold to water pumped into the network. It is defined as a percentage. For small entities, the median is 78,64%, for medium 84,69% and for big 85.75% [9].

European Benchmarking Co-operation also measures distribution losses through several indicators. Because the IWA Specialist Group on Water Losses recommends not relying on the water loss indicator expressed as a percentage, the 2024 EBC does not use this indicator. It focuses on non-revenue water per mains length for less urbanized areas and on non-revenue water per property for more urbanized areas. Figure 4 presents the results presented by EBC for 2023 in a public report (European Benchmarking Co-operation, 2024).

Figure 5 presents the results of the EBC benchmarking on NRW per property.



a) b)
Figure 4.
Distribution of the NRW per mains length in EBC benchmarking [m^3/km/day] assessment results for 2022, b) 5-year trend
Figure 4. Wielkość wody nieprzynoszącej dochodu NRW na długość sieci w benchmarkingu EBC [m^3/km/day] wyniki za rok 2022, b) 5-letni trend



a) b)
Figure 5.
Annual NRW distribution in m^3 per property [m^3/property]; a) assessment results for 2022, b) 5-year trend.
Figure 5. Roczna NRW w m^3 na nieruchomość [m^3/property];

Discussion

Definitions

It is important that in papers, laws, regulations, and directives, the expressions used mean the same thing. Very often, different expressions have different meanings and show different phenomena. The DWD defines a leak, emphasizing the environmental aspect related to the protection of water resources as the most important. In turn, IWA focuses on losses, emphasizing the economic aspect, similarly to water utilities, for which the most important indicator is NRW.

As shown in the IWA water balance, these expressions do not mean the same KPI (Fig.6). The leakages are part of the real losses. The non-revenue water is a wider quantity than the water losses.

For last several years the water professionals have published many papers with conclusions that widely used percentage factor of water losses is inaccurate to compare the efficiency of the water supply systems, because it does not include crucial parts of the systems such as a size of the system, length of water network, number of connections, total length of connections, and pressure of water in the network, etc (Ociepa, 2021;Ong et al., 2023). IWA Water Loss Specialist Group recommends not using this indicator because it is a poor method of measuring progress or comparing similar utilities. However, this indicator is popular because of its simplicity and ease of calculation. In addition, it is understandable because it simply indicates to managers the value of water that has not been sold (Santos, 2024). It shows the value of lost revenue by multiplying the amount of unsold water by the tariff price. Even if this indicator is not good for benchmarking, it can fulfil its tasks in a company controlling (Yilmaz et al. 2023). According to Fig. 1, this indicator is still the most popular in Poland. Perhaps, instead of eliminating it from benchmarking, it should be counted for specific groups of water utilities.

The overview of the charts in Fig.2 suggests that the worst efficiency of the network is in the group of small utilities, where both the median and the average value exceed 14%. The best situation is in the group of the biggest operators; in this group, the median value equals 9.16% and the average value is slightly above 10%.

The analysis of the charts with linear water loss index (Fig.3), shows the opposite situation. The smallest amount of water is lost per mains length in the smallest networks, where the median value is less than 0.8 thousand m^3/km/year, and the average value is 1.57 thousand m^3/km/year. In the group of the biggest water operators, both the median value and the average value are about 1.7 thousand m^3/km/year. This example proves that the percentage indicator may not reflect reality correctly. Especially if it is given without a description of the technical conditions and size of the entity. It is incorrect to compare the efficiency of different water supply systems, especially systems of different scales.

Converting all data into annual losses, the median for Poland ranges from 660 to 1820 m^3/km, and for EBC equals 3650 m^3/km. This may be due to significant differences in the network layout and geographical location. Apart from one exceptionally high case for small and one for medium utilities, in Poland, LLI oscillates around 2000 m^3/km. In the EBC benchmark, LLI annual values range from below 1000 m^3/km to over 20,000 m^3/km.

EBC benchmarking, at the advanced level of participation, proposes a calculation of ILI for a professional analysis of network leakages.

To calculate the UARL, it is necessary to have accurate knowledge of the network parameters. Also, it is not obvious how to define the average pressure of water in the network. Especially in huge water supply systems supplied from more than one direction or source. It can happen that in one specific DMA, there are different pressures, one at the inlet and another at the customer point of supply. Showing the average water pressure could misrepresent the whole KPI and the method based on it. There are also different conditions in the systems operated on a flat territory and different ones in mountainous areas.

Maybe due to the shown issues in some surveys, utilities declare they have in their systems an ILI value below 1, which raises doubts about the reliable calculation of ILI and its credibility, for example, in the context of the UARL imposed several years ago. Another drawback of the ILI method is that it is not possible to calculate directly from the water balance. Every utility must calculate it on its own, in contrast to other KPIs, which are calculated from the basic data, like volume of water pumped into the network and water sold. Additionally, in different countries, there are different definitions of the specific parts of the network. In some countries, pipe connections are short, with many water meters and clients on every connection. In others, pipe connections are longer and with one water meter on each.

That is why, in the authors' opinion, ILI is more academic than practical and non-objective for comparing the efficiency of different systems.

Size of the water supply system

Article 4 of the DWD specifies the criterion of the size of utilities, which must provide data on leaks. The criterion is based on the number of people supplied and the volume of water supplied. The obligation applies to suppliers supplying at least 10,000 m^3 per day or serving at least 50,000 people. It therefore seems reasonable for leakage indicators to refer to at least one of these values. All indicators consider the volume of water injected into the network, or water sold (billed), and this is not a value equivalent to the water supplied to the consumer. No indicator refers to the number of people supplied. Most companies in Europe do not have such data. Based on billing data, they can determine the number of recipients, but not the number of people served. In addition, the DWD refers to the water supplier. Therefore, the data quoted by the Chief Sanitary Inspectorate (2024) in Poland may be questionable. It can be assumed that some suppliers operate on very small, rural waterworks, serving a total of over 10,000 people. The question remains whether they will be required to determine leaks for those small systems.

Water intended for human consumption

A controversial issue in the context of leaks is the scope of their monitoring. Both EurEau and IGWP emphasize that leaks should concern water losses in the water supply network. However, the definition of "water intended for human consumption" is not equivalent to

Figure 6. Water balance according to IWA (Liemberger and Malcolm, 2004)
Figure 6. Bilans wody według IWA (Liemberger and Malcolm, 2004)

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non-Revenue Water (NRW)
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorised Consumption	
			Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on service connections	

drinking water. "Water intended for human consumption" means water before and after treatment: "either in its original state or after treatment" as mentioned in Art.2 of DWD. Therefore, the limits of leak monitoring in the water supply system should be established. Moreover, Article 4 of the DWD advocates for maintaining monitoring only within the distribution network, which requires monitoring of ILI or the use of another, but equivalent, method. In this context, monitoring losses at the intake and treatment stages seems absurd.

Local conditions

Water loss indicators show a large variation due to the different operating environments of the participating utilities. The group trends show a clear decline over the past five years.

Raw leakage data alone are not sufficient to meet the requirements of Article 4 of the Drinking Water Directive. It is emphasized that "assessment shall take into account relevant public health, environmental, technical and economic aspects". Therefore, the loss report should include data on local conditions. Benchmarking can be useful here, as it includes certain indicators from these four groups. Therefore, there is a need for an objective assessment of local conditions of human health. Neither IGWP nor EBC focuses on data on the health condition of recipients, but EBC collects data on water quality. It would be necessary to define the relationship between public health and leaks. Perhaps the UWWTD requirements regarding monitoring diseases in sewage would help here. EBC collects more relevant indicators. This benchmarking focuses more on the consumer. KPIs are therefore related to access to drinking water services, water quality, and compliance, which can be considered directly related to public health.

Regarding environmental aspects in the benchmarking, these primarily include indicators related to energy consumption. In this context, it seems reasonable to assess the quality of the environment used by the water supplier. This data can be sourced from state environmental monitoring. Technical data useful for characterizing local conditions in the IGWP benchmarking include network failure rate (operation index), share of remote water meters (operation index), and the degree of network replacement (investment and renovation index). The EBC has similar indicators related to asset management.

The IGWP's economic indicators can also be used to assess water supply profitability and water prices. The ECB can leverage reliability and affordability.

Conclusions

The water sector possesses specific characteristics that require tailored benchmarking approaches to enable meaningful comparisons among utilities. The current condition of a water supply system can be effectively described using KPIs and factors calculated and balanced on the basis of reliable input data. It is essential that the calculation process be transparent, objective, and consistent across all water suppliers.

In the context of water losses, the LLI represents the most objective and comparable indicator. The reduction of leakages in the water sector is increasingly supported by new technologies and innovative solutions, which should be actively promoted. A particular emphasis should be placed on the accuracy and reliability of flow measurement data within water distribution networks, as this forms the foundation for credible performance assessment.

The process should begin with the development of clear and impartial definitions, ensuring that the terminology and methodology used are harmonized. Furthermore, leakage data should be synchronized with local contextual information to allow for accurate interpretation, while also ensuring that such data remains comparable across EU Member States.

It should also be emphasized that compliance with Article 4 of the Drinking Water Directive is inherently linked to the monitoring of water losses within distribution networks, in conjunction with other indicators describing the performance of water utilities. Therefore, the European Commission's proposal to monitor leakage across the entire water supply system appears unjustified.

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