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Regional Peer-to-Peer Exchange on Non-Revenue Water management / SOP: Selecting relevant KPIs and Target Setting

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v.1	*Regional Peer-to-Peer Exchange on Non-Revenue Water management / SOP: Selecting relevant KPIs and Target Setting*	*Cor Merks*	*Suzan Taha*

WATER AND ENVIRONMENT SUPPORT IN THE ENI SOUTHERN NEIGHBOURHOOD REGION

The "Water and Environment Support (WES) in the ENI Neighborhood South Region" project is a regional technical support project funded by the European Neighbourhood Instrument (ENI South). WES aims to protect the natural ressources in the Mediterranean context and to improve the management of scarce water resources in the region. WES mainly aims to solve the problems linked to the pollution prevention and the rational use of water.

WES builds on previous similar regional projects funded by the European Union (Horizon 2020 CB/MEP, SWIM SM, SWIM-H2020 SM) and strives to create a supportive environment and increase capacity all stakeholders in the partner countries (PCs).

The WES Project Countries are Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Libya, Palestine, Syria and Tunisia. However, in order to ensure the coherence and effectiveness of EU funding or to promote regional cooperation, the eligibility of specific actions can be extended to neighboring countries in the Southern Neighborhood region.

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ABBREVIATIONS

AWWA	American Water Works Association
CARL	Current Annual Real Losses
DMA	District Metered Area
ENI	European Neighbourhood Instrument
EU	European Union
ILI	Infrastructure Leakage Index
IWA	International Water Association
KPI	Key Performance Indicator
MARP	Minimum Standard of Service Pressure
NRW	Non-Revenue Water
PMI	Pressure Management Index
Op	Operational
PI	Performance Indicator
SCF	System Correction Factor
SOP	Standard Operating Procedure
UARL	Unavoidable Annual Real Losses
WES	Water and Environment Support

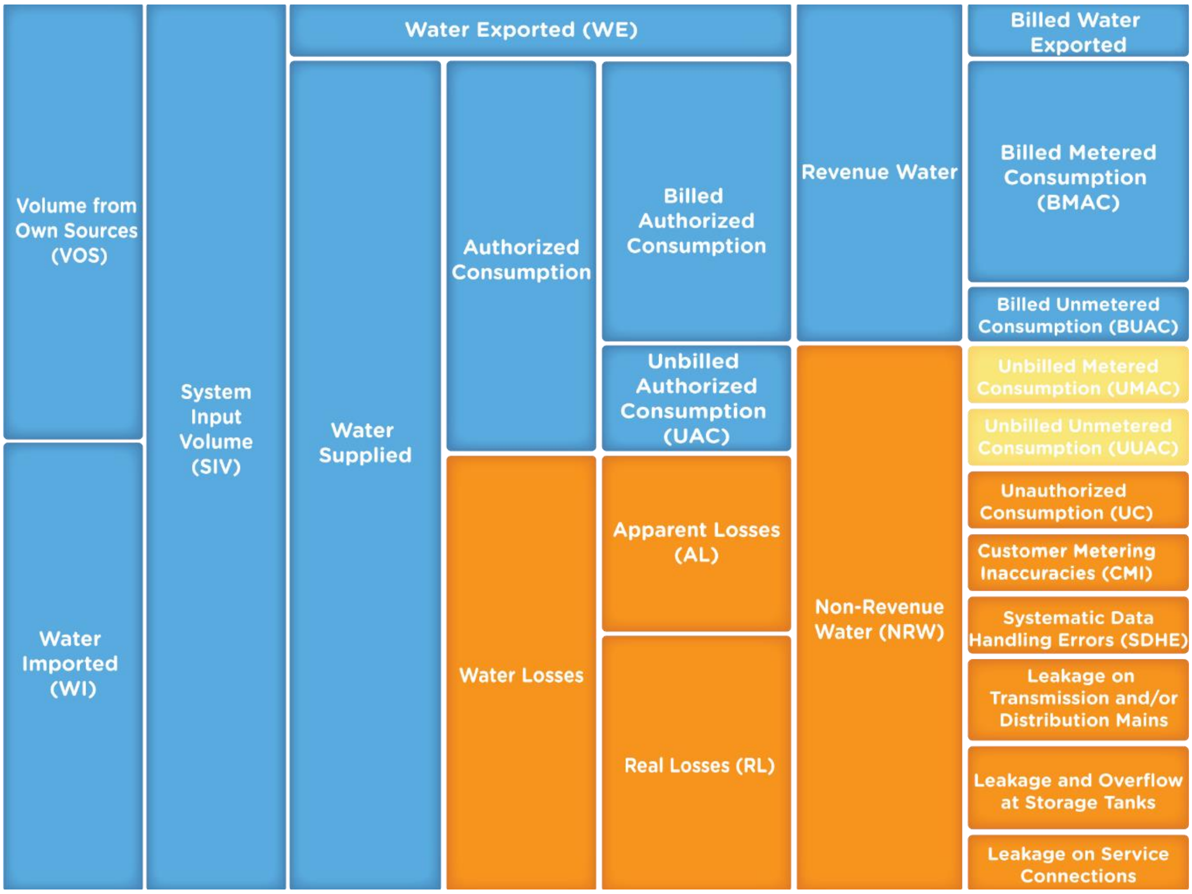
1 INTRODUCTION

This Standard Operating Procedure (SOP) outlines the Key Performance Indicators (KPIs) for Non-Revenue Water (NRW) reduction and how these KPIs should be used for target setting and monitoring of the results of the chosen interventions. This SOP is related to the SOP on *Calculating a Water Balance* as most data required to determine the most appropriate KPIs must be collected for the Standard Annual Water Balance.

1.1 STANDARD ANNUAL WATER BALANCE

Figure 1 presents the Standard IWA/AWWA Annual Water Balance. The process of calculating a Standard Annual Water Balance is an effort of data collection. Appendix 1 presents the required data input in tabular form. Refer to the SOP on *Calculating a Water Balance*.

FIGURE 1 – STANDARD IWA/AWWA ANNUAL WATER BALANCE.



1.2 THE FOUR BASIC REAL LOSSES AND APPARENT LOSSES CONTROL STRATEGIES

Figure 2 on page 8 presents the four basic control strategies for Real Losses and for Apparent Losses. The four basic Real Losses control strategies are:

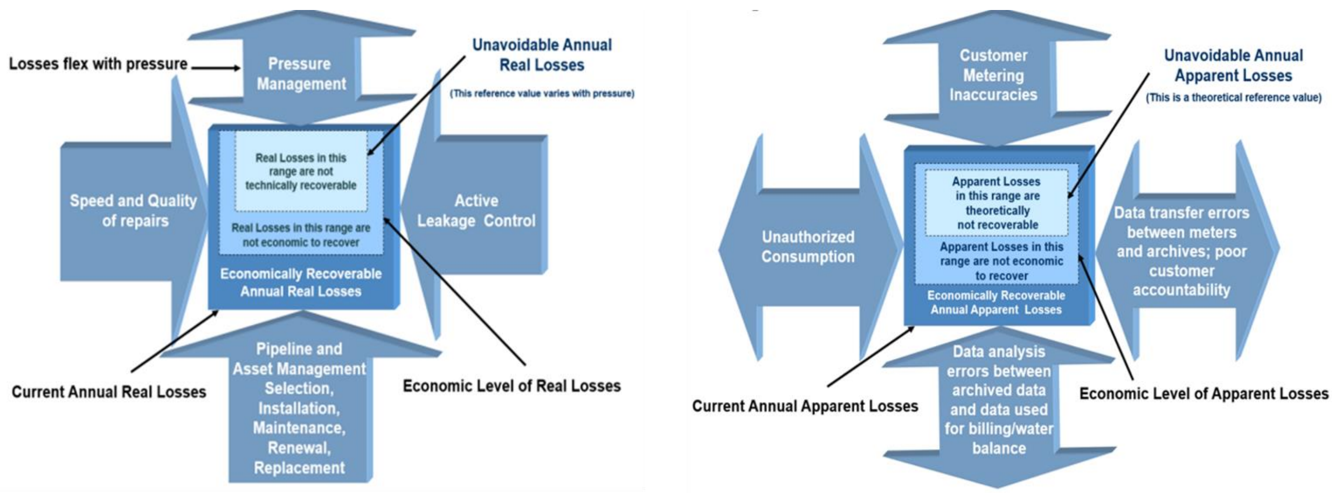
Pressure management.
Active leakage control.
Speed and quality of repairs.

Asset management.

The four basic Apparent Losses control strategies are:

Meter management of both large-volume system flow meters and customer meters.
Minimise systematic data handling errors.
Improve customer accountability and database.
Improve customer billing system.

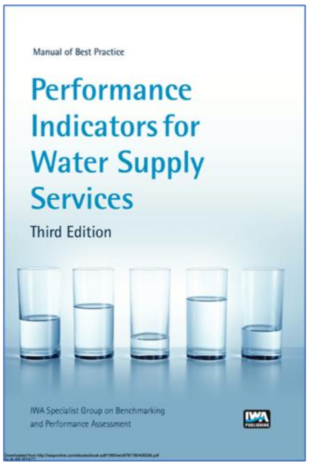
FIGURE 2 – BASIC REAL LOSSES CONTROL STRATEGIES (LEFT) AND BASIC APPARENT LOSSES CONTROL STRATEGIES (RIGHT).



As each control strategy receives less or more attention, the Real Losses and/or Apparent Losses will increase or decrease.

1.3 IWA SYSTEM OF PERFORMANCE INDICATORS

The International Water Association (IWA) started a performance indicators journey in 1997. The first edition of the Manual of Best Practice *Performance Indicators for Water Supply Services* was published in 2000. This first edition showed that it is possible and desirable to adopt standard performance indicators (PIs).



The third edition was published in 2017. This third edition reflects the accumulated experience and recent learning, bringing a fresh set of inspiring cases that show how the IWA PI system has been successfully applied as a management tool, as a regulatory and public policies instrument and as the support for benchmarking initiatives. This Manual of Best Practice has been published in English (see cover page on the left) and French languages.

This IWA PI system clearly links:

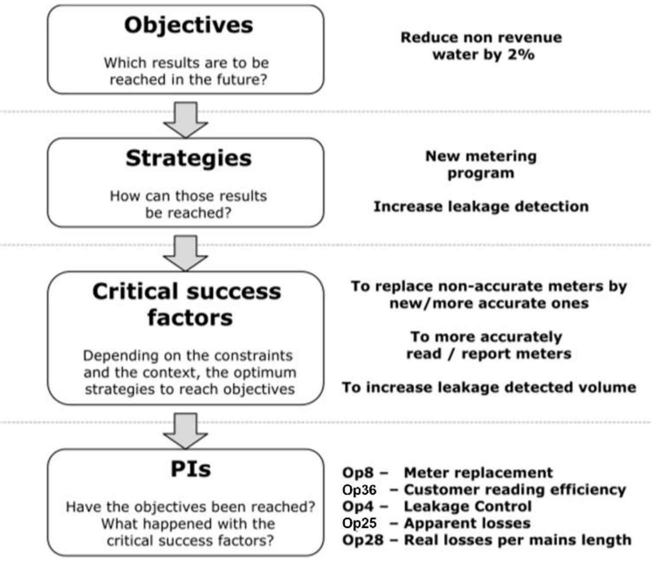
1. Objectives – Which are the results to be reached in the future?
2. Strategies – How can those results be reached?

3. Critical success factors – Depending on the constraints and the context, the optimum strategies to reach objectives.
4. Performance Indicators – Have the objectives been reached? What happened with the critical success factors?

The performance indicators are not randomly selected. Furthermore, there's no reason to start with a longlist of performance indicators. It is important to understand that the performance indicator(s) must be selected as a measure of the efficiency and effectiveness of the delivery of the optimum strategy to reach objectives.

Figure 3 presents an example of the IWA PI system for the reduction of both Real Losses and Apparent Losses.

FIGURE 3 – EXAMPLE OF THE IWA PI SYSTEM FOR NRW REDUCTION.



Step 1:

The objective is specified by Reduce NRW by 2%.

Step 2:

The strategy for reaching the results is twofold:

New metering program (to address Apparent Losses).
Increase leak detection (to address Real Losses).

Step 3:

The optimum strategy for reaching the results is defined. For the new metering program, the optimum strategy is:

To replace non-accurate meters by new/more accurate meters.
To more accurately read/report meters.

For increasing leak detection, the optimum strategy is to increase the leakage detected volume.

Step 4:

The appropriate performance indicators are selected as a measure of the efficiency and effectiveness of the delivery of the optimum strategy. The appropriate PIs are included in the group Operational (Op) PIs.

The PIs for the new metering program are:

Op8 – Customer meter replacement (-/year); the rate of flow meter replacement per year.
Op36 – Customer reading efficiency (-); the ratio between effective meter readings and the total number of readings if all the customers meters were read according to the pre-established frequency.
Op25 – Apparent losses (%); the percentage of the water supplied to the system (system input volume minus water exported; refer to Figure 1) that corresponds to apparent losses. This indicator is adequate for urban distribution systems.

The PIs for increasing leak detection are:

Op4 – Leakage control (%/year); the percentage of mains length subject to active leakage control.
Op28 – Real losses per mains length (l/km/day when system is pressurised); real losses expressed in terms of the average daily volume lost per mains length. This indicator is adequate for bulk supply and low service connection density distribution systems.

This example demonstrates how selection of a control strategy (Section 1.2) ultimately drives the selection of the performance indicator(s).

2 KPIS FOR NRW REDUCTION

2.1 IWA PIS FOR WATER SUPPLY SERVICES

Much of the efficiency of a *water department/operator/utility* can be lost or improved in the operation and maintenance activities. Managers need to monitor the planned activities for inspection, preventative maintenance and rehabilitation, and the unplanned activities caused by the failure of system elements. The third edition of the Manual of Best Practice *Performance Indicators for Water Supply Services* (2017) includes a total of 44 performance indicators regarding the inspection and maintenance of physical assets of a water utility.

Table 1 presents an overview of the Operational PIs in the IWA PI system that are related to NRW reduction or that provide interesting information in the context of water losses.

TABLE 1 – OPERATIONAL PIS IN THE IWA PI SYSTEM RELATED TO NRW MANAGEMENT.

Indicator	Indicator name and description
Op4	Leakage control (%/year)
	Percentage of mains length subject to active leakage control.
Op5	Active leakage control repairs (No./100 km/year)
	Number of leaks detected and repaired due to active leakage control per unit of mains length.
Op7	System flow meters calibration (-/year)
	Rate of system flow meter calibrations per year.
Op8	Customer meter replacement (-/year)
	Rate of flow meter replacement per year.
Op9	Pressure meters calibration (-/year)
	Rate of pressure meter calibrations per year.
Op10	Water level meters calibration (-/year)
	Rate of water level meter calibrations per year.
Op16	Mains rehabilitation (%/year)
	Percentage of mains length rehabilitated per year.

Indicator	Indicator name and description
Op17	Mains renovation (%/year)
	Percentage of mains length renovated per year.
Op18	Mains replacement (%/year)
	Percentage of mains length replaced per year.
Op19	Replaced valves (%/year)
	Percentage of mains valves replaced per year.
Op20	Service connection rehabilitation (%/year)
	Percentage of service connections replaced or renovated per year.
Op23	Water losses per connection (m^3/connection/year)
	Total (apparent and real) losses expressed in terms of annual volume lost per service connection. This indicator is adequate for urban distribution systems.
	A more detailed description of urban distribution systems can be found below this table.
Op24	Water losses per mains length (m^3/km/year)
	Total (apparent and real) losses expressed in terms of annual volume lost per mains length. This indicator is adequate for bulk supply and low service connection density distribution systems.
Op25	Apparent losses (%)
	Percentage of the water supplied to the system that corresponds to apparent losses. This indicator is adequate for urban distribution systems.
Op26	Apparent losses per system input volume (%)
	Percentage of the water entering the system that corresponds to apparent losses. This indicator is adequate for bulk supply and low service connection density distribution systems.
Op27	Real losses per connection (l/connection/day when system is pressurised)
	Real losses expressed in terms of the average daily volume lost per connection. This indicator is adequate for urban distribution systems.
Op28	Real losses per mains length (l/km/day when system is pressurised)
	Real losses expressed in terms of the average daily volume lost per mains length. This indicator is adequate for bulk supply and low service connection density distribution systems.
Op29	Infrastructure Leakage Index (-)

Indicator	Indicator name and description
	Ratio between the actual real losses and an estimate of the minimum real losses that could be technically achieved for the system operating pressure, average service connection length and service connection density.
	A more detailed description of the ILI can be found below this table.
Op31	Mains failures (No./100 km/year)
	Average number of mains failures per 100 km of mains and per year.
Op32	Service connection failures (No./1000 connections/year)
	Average number of service connection failures per 1000 connections and per year.
Op36	Customer reading efficiency (-)
	Ratio between effective meter readings and the total number of readings if all the customers meters were read according to the pre-established frequency.
Op37	Residential customer reading efficiency (-)
	Ratio between effective residential meter readings and the total number of readings if all the residential customers meters were read according to the pre-established frequency.
Op38	Operational meters (%)
	Percentage of the customer meters that are installed that are not out-of-service.
Op39	Unmetered water (%)
	Percentage of the system input value that is not accounted for as metered consumption.

Service connection density

Service connection density is a critical parameter in selecting the appropriate performance indicator. The service connection density is calculated by: “total number of connections / total length of all transmission and distribution pipelines in the distribution system”.

An urban distribution system is considered to have more than 20 service connections per km of mains length. A low service connection density (rural) distribution system has 20 or less service connections per km of mains length.

Unavoidable Annual Real Losses

The volume of Unavoidable Annual Real Losses (UARL) represents the best estimate of the technically achievable lowest actual leakage from a pressurised distribution system. It serves as a reference value for the "lowest possible actual leakage" of a distribution system, with relevant system-specific parameters being determining factors. The reference value assumes a wellmaintained and well-operated distribution system, in good technical condition at the current average operating pressure.

The UARL can be calculated with the following equation from the IWA PI system:

UARL (litres/service connection/day) = (18 × Lm/Nc + 0.025 × Lp) × (P/10)

Variables used in this equation, on empirical results of international investigations, are length of mains (Lm in km), number of service connections (Nc), average length of service connections (Lp in m) and average operating pressure (P in kPa).

The $UARL_{1999}$ in m^3/year can be calculated with the following equation:

UARL (m^3/year) = (6,57 × Lm + 0.265 × Nc + 9,13 × Lp) × AZP

The $UARL_{1999}$ in m^3/day can be calculated with the following equation:

UARL (m^3/day) = (18 × Lm + 0.8 × Nc + 25 × Lp) × AZP/1000

Variables used in these two equations are:

Length of mains Lm in km.
Number of service connections (from main to property line) Nc.
Total length of underground service connections (from property line to meter) Lp in km.
Current average zone pressure AZP in metres.

Infrastructure Leakage Index (ILI)

The ILI is the ratio of the Current Annual Real Losses (CARL) to the Unavoidable Annual Real Losses (UARL). The ILI is the sole performance indicator for comparing the technical performance of water utilities in the operational management of real losses.

It is recommended that the ILI is not assessed for periods shorter than one year, since it may lead to misleading conclusions. If a shorter assessment period cannot be avoided, special care is required in result interpretation. External comparisons on such time bases must be avoided.

2.2 EU GOOD PRACTICES ON LEAKAGE MANAGEMENT

The European Union published the *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM* in 2015 (© European Union, 2015). The development of this good practices document was project managed by the author of this SOP. This good practices document on leakage management is developed through a drafting group under the Water Framework Directive (WFD) Common Implementation Strategy (CIS) Working Group (WG) Programme of Measures (PoM). Allan Lambert and Stuart Trow were principal advisers (voluntary) for this project, and they were also members of the drafting group.

The *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM* includes the following recommendations on performance indicators:

> *"Performance indicators are of importance to enable the public, NGOs, and regulators to have a clear picture about water utility performance regarding leakage reduction, including the impacts on environment, resource efficiency, and cost-efficiency. Inappropriate traditional performance indicators are still widely used for setting leakage targets, tracking progress, and comparing performance within and between utilities and countries."*

The following three recommendations on PIs were included:

Leakage expressed as a % of System Input Volume (SIV) is simple and easy to calculate. However, it has several limitations in interpretation which have led some Member States to stop or to reduce the use of % of SIV as a leakage PI. For example, it can result in substantial under- or over-estimates of true achievements in reduction of leakage volume. This is because % of SIV is a 'Zero-sum' calculation, which is unable to identify actual decreases in both consumption and leakage volume in the same period. Therefore, use a volumetric parameter for tracking progress.

Use m^3/km mains/day, or litres/service connection/day or (for UK) litres/billed property/day for tracking progress in individual systems and sub-systems, but not for comparing performance between systems and sub-systems.

For making technical comparisons of leakage levels between systems and sub-systems under their current pressure management regimes, calculate 'how low could you go' in Mm^3/year by calculating the UARL. Then calculate the ILI as the multiple obtained when the system's CARL in Mm^3/year is divided by the system's UARL in Mm^3/year. As the current pressure regime may not be optimal, ILI should always be interpreted with some measure of pressure, and only used for tracking progress if all justifiable pressure management has already been completed.

Table 2 presents the 'fit for purpose' water loss performance indicators. This Table 2 provides a summary of the recommendations in the *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM* (© European Union, 2015). Table 3 presents the context of the PIs for Real Losses by questions and answer to what extent a performance indicator makes allowance for relevant system infrastructure characteristics and pressure.

TABLE 2 – 'FIT FOR PURPOSE' WATER LOSS PERFORMANCE INDICATORS.

OBJECTIVE	GOOD PRACTICE PERFORMANCE INDICATOR FOR LEAKAGE, FIT FOR PURPOSE						
	Volume per year	litres/ service connection	m^3/km mains	litres/ billed property	% of System Input Volume	% of Water Supplied	Infrastructure Leakage Index, with Pressure
SET TARGETS AND TRACK PERFORMANCE, FOR AN INDIVIDUAL SYSTEM	YES, for large systems	YES*	YES*	YES (UK)	NO	NO	Only if all justifiable pressure management completed
TECHNICAL PERFORMANCE COMPARISONS OF DIFFERENT SYSTEMS	NO	NO	NO	NO	NO	NO	YES
DRAW GENERAL CONCLUSIONS FROM SINGLE OR MULTIPLE SYSTEMS	NO	NO	NO	NO	NO	NO	YES, together with other context factors

* Choose services connection density > 20/km; if not, choose mains; or base choice on country custom and practice

TABLE 3 – CONTEXT MATTERS FOR THE REAL LOSSES PERFORMANCE INDICATORS (PIS).

Does the Performance Indicator make allowance for:	Performance Indicator for Real (Physical) Losses				
	% of System Input Volume	m3/km mains/day wsp*	Litres/service connection/ day wsp*	Litres/conn/day /metre of pressure wsp*	Infrastructure Leakage Index ILI (incl. UARL)
% of time pressurised?	No	Yes	Yes	Yes	Yes
water exported?	No	Yes	Yes	Yes	Yes
length of mains?	No	Yes	No	No	Yes
number of connections?	No	No	Yes	Yes	Yes
average pressure?	No	No	No	Yes	Yes
connections/km mains ?	No	No	No	No	Yes
length of services ?	No	No	No	No	Yes
how low could you go?	No	No	No	No	Yes**
* when system pressurised ** Unavoidable Annual Real Losses UARL					

The development of these recommendations is a joint effort by Member States, stakeholders and the drafting group with policy makers, economists, environmental experts, renowned non-revenue water (NRW) experts including members of the IWA Water Loss Specialist Group.

2.3 DIRECTIVE (EU) 2020/2184 ON QUALITY OF DRINKING WATER

Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 december 2020 on the quality of water intended for human consumption includes under Article 4 General obligations obligation 3 relating to water leakage levels. This general obligation 3 reads:

> "*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. That assessment shall consider relevant public health, environmental, technical, and economic aspects and cover at least water suppliers supplying at least 10 000 m³ per day or serving at least 50 000 people.*
>
> *The results of the assessment shall be communicated to the Commission by 12 January 2026.*
>
> *By 12 January 2028, the Commission shall adopt a delegated act in accordance with Article 21 in order to supplement this Directive, by setting out a threshold, based on ILI or another appropriate method, above which Member States shall present an action plan. That delegated act shall be drafted using the Member States' assessments and the Union average leakage rate determined on the basis of those assessments.*
>
> *Within two years of the adoption of the delegated act referred to in the third subparagraph, Member States having a leakage rate exceeding the threshold set out in the delegated act shall present an action plan to the Commission laying down a set of measures to be taken in order to reduce their leakage rate.*"

The ILI is the only rating method mentioned by name in Directive (EU) 2020/2184.

2.4 AWWA PIS FOR NRW TARGET SETTING AND PROGRESS TRACKING

AWWA provides the drinking water industry guidance and tools that help utilities measure, track, and reduce water losses in a verifiable manner. To advance water loss control efforts, AWWA's Water Loss Control Committee formed a Performance Indicator Task Force to evaluate the applicability and effectiveness of performance indicators (PIs) used to assess Non-Revenue Water

(NRW). The report *Assessment of Performance Indicators for Non-Revenue Water Target Setting and Progress Tracking* (© American Water Works Association, 2019) was published in September 2019. This report presents the findings of the study.

Table 4 presents summary findings on suitable purposes (assessment, benchmarking, target setting, planning, and tracking) of candidate volume-related indicators, and the suggested users.

TABLE 4 – SUITABLE PURPOSES AND USERS OF CANDIDATE VOLUME-RELATED INDICATORS (AWWA, 2019).

Candidate Indicator	Assess-ment	Bench-marking	Target Setting	Planning	Tracking	Users [1)]
Unit total water loss volume (gal/connection/day)	Yes	Yes	Yes	Yes	Yes	U, R, C
Unit apparent loss volume (gal/connection/day)	Yes	Yes	Yes	Yes	Yes	U, R
Unit real loss volume (gal/connection/day)	Yes	Yes	Yes	Yes	Yes	U, R
Unit real loss volume (gal/mile/day)	Yes	Yes	Yes	Yes	Yes	U, R
Unit real loss volume (gal/connection/day/psi)	Yes	Yes	Yes	Yes	Yes	U, R
Apparent loss volume / billed authorised consumption (volume)	Yes		Yes	Yes	Yes	U, R
Infrastructure Leakage Index (ILI)	Yes			Yes	Yes	U
Pressure Management Index (PMI)	Yes			Yes	Yes	U
Infrastructure Leakage Index × Pressure Management Index (ILI × PMI)	Yes		Yes	Yes	Yes	U

[1)] Users code: U = Utilities, R = Regulators, C = Customers and consumer interest groups.

Please note that the United States uses the imperial system. Consequently:
"gal/connection/day" is the equivalent of "litres/connection/day".
"gal/mile/day" is the equivalent of "litres/km/day".
"gal/connection/day/psi" is the equivalent of "litres/connection/day/metre of pressure".

The findings of the study resulted in three performance indicators that are not included in the IWA PI system currently:

Apparent loss volume / billed authorised consumption (volume). Both volumes are included in the Standard Annual Water Balance (refer to Figure 1). This PI is simple and easy to calculate and should be used as a PI for apparent losses.
Pressure Management Index (PMI).
ILI × PMI.

Pressure Management Index (PMI)

The PMI is the ratio of the existing average system operating pressure to a lower "reference" pressure that maintains desired service levels. Trow (2009) proposed the PMI where:

PMI = Average System Operating Pressure / Minimum Annual Reference Pressure (MARP); and
MARP = Minimum Standard of Service Pressure + 3 metres.

This PMI is also included in the *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM*.

Infrastructure Leakage Index × Pressure Management Index (ILI × PMI)

The correspondence between real loss volume and ILI appears to be empirically influenced by pressure and, to a lesser extent, by connection density. If ILI is to be used for assessment, target setting, planning, or tracking, the pressure should be accounted for. *Refer to Table 2 where this remark also has been made*. By using the ILI × PMI, the ILI is indeed accounted for pressure.

The proper use of the ILI depends on consideration of the situational (i.e., average operating) pressure. Thus, the combined use of ILI and PMI is gaining considerable interest. In addition, the use of the product of ILI multiplied with the PMI has been analysed by international research efforts, revealing that this combined indicator is more highly correlated with overall real losses and unit real losses than ILI alone.

Plotting the PMI versus the ILI on a quadrant plot (refer to Figure 4 on page 17) identifies intervention methods associated with three of the four basic Real Losses control strategies (refer to Figure 2): proactive pressure management, active leakage control, and improved speed of leak detection and repair. This can assist a *water utility/department/operator* in taking appropriate action te reduce real losses.

FIGURE 4 – PEARSON AND TROW QUADRANT ANALYSIS.

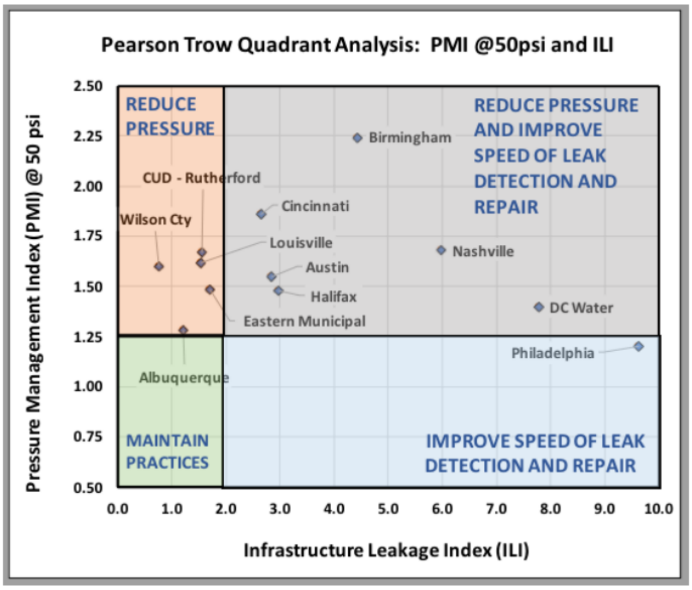


Figure 4 has been developed by Trachtman *et al*., 2019. It uses the PMI at 50 psi (about 34.5 metre). Utilities with a high PMI and relatively low ILI should consider operating at a lower system pressure to reduce real losses. Utilities with a high PMI and high ILI would be candidate for proactive pressure management, with consideration for implementing the other two basic Real Losses control strategies. Utilities with a low PMI and high ILI may improve performance by focussing on improving the speed of leak detection and repairs by performing additional active leak detection.

Plotting the PMI versus the ILI on a quadrant plot provides both a useful performance indicator and the recommendation for a strategy (refer to Figure 3).

2.5 UARL WITH SYSTEM CORRECTION FACTOR

UARL with System Correction Factor (SCF) extends the limits of application of the original Unavoidable Annual Real Losses equation, using a system-specific SCF which varies with pressure, system size and pipe materials. In many situations the original $UARL_{1999}$ equation will be confirmed to within ten per cent. Outside the original limits, UARL with SCF helps to explain why lower UARL volumes can be achieved in small systems at low pressures, or higher UARL can occur at higher pressures (https://www.leakssuitelibrary.com/low-ilis-and-small-systems/).

UARL with SCF is calculated using online software, purchased through WLR&A Ltd (https://www.wlranda.com/). There are a maximum of seven inputs required for each calculation:

Length of mains (km or miles).
Number of service connections.
Average length of service connections from property line to meter (m/connection or feet/connection).
Average Zone Pressure (m or psi).
Estimated % of rigid mains.
Estimated % of rigid service connections (main to property line).
Estimated % of rigid service connections (property line to meter).

The SCF is referenced in the ISO 24528:2021 standard *Service activities relating to drinking water supply, wastewater and stormwater systems* (https://www.iso.org/standard/59819.html) and in the American Water Works Association Free Water Audit Software v6.0 (https://www.awwa.org/Resources-Tools/Resource-Topics/Water-Loss-Control/Free-Water-Audit-Software).

SCF calculations are recommended for whole systems, zones, or DMAs with < 5.000 service connections, operating at average zone pressure (AZP) of < 45m or > 60m. There is now no practical lower or upper system size limits for a UARL calculation using UARL with SCF, with practical AZP ranging from 7 – 140m. This makes it ideal for small utilities as well as for large utilities or for province-wide surveys.

SCF can be used to map all zones and systems within a utility for a complete top-down/bottom-up view of a water distribution system. Such calculations would guide a *utility* to zones or DMAs within their network where current UARL volume targets could be reduced further, as well as where current UARL volume targets may not be achievable. Targeted decisions can then be made as to where further pressure management may be possible to reduce UARL volumes, with volume reductions quantified. The website https://www.wlranda.com/uarl-with-system-correction-factor/ provides further information on SCF calculations, including how to purchase calculations.

3 PIS FOR TARGET SETTING AND PERFORMANCE MONITORING

The *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM* includes the following recommendations on leakage targets:

> *"Leakage targets should be set considering Political, Economic, Social, Technological, Legal and Environmental (PESTLE) considerations. Good practice procedures for setting economic leakage targets for smaller systems (less than around 30.000 service*

connections) can usually be simplified to some extent, by identifying activities or combinations of activities which have the highest Payback Period, Net Present Value or Benefit Cost ratio, and continuing with such activities (whilst allowing for the other PESTLE considerations) until no further economic proposals can be identified."

The following four recommendations on leakage targets were included:

Financial costs are one part of leakage management, but environmental and resource costs of leakage must be explicitly considered as well (as a function of water scarcity including ecosystems needs), even though there is no conclusive methodology available at this moment. Including environmental externalities will require an increased level of leakage reduction than basing this level only on financial considerations.

Set targets in a **volumetric parameter**. The most appropriate volume measure for this purpose is an annual volume expressed as a total for the year e.g., in million metres cubed (Mm^3/year) or as an average in thousand m^3 per day (TCMD).

For smaller systems (less than around 30.000 service connections) use the 'squeezing the box' approach (*refer to Figure 2*) until no further economic actions can be identified. The target may be set using appropriate technical measures.

Leakage targets for larger systems should be set for an individual water supply or unconnected water resource zone in a holistic approach, taking account of the operating environment, the network condition, the supply demand balance, resource and abstraction limitations, funding issues for investments, and willingness to pay by customers. Strategic annual zonal targets can be aggregated to the utility as a whole and can be disaggregated to the component smaller systems (or DMAs) for operational management.

3.1 TARGET SETTING

The following performance indicators (PIs) are recommended for target setting for urban distribution systems:

Total water losses per connection (Op23), expressed as "m^3/connection/year" or "litres/connection/day".

Apparent losses per connection, expressed as "m^3/connection/year" or "litres/connection/day".

Real losses per connection (Op27), expressed as "m^3/connection/year when system is pressurised" or "litres/connection/day when system is pressurised".

UARL with SCF.

For large urban distribution systems: Total annual water losses, expressed as "Mm^3/year".

The following performance indicators (PIs) are recommended for target setting for bulk supply and low service connection density (rural) distribution systems:

Total water losses per mains length (Op24), expressed as "m^3/km/year" or "litres/km/day".

Real losses per mains length (Op28), expressed as "m^3/km/year when system is pressurised" or "litres/km/day when system is pressurised".

UARL with SCF.

For large rural distribution systems: Total annual water losses, expressed as "Mm^3/year".

3.2 PERFORMANCE MONITORING

The following performance indicators (PIs) are recommended for performance monitoring for urban distribution systems:

Total water losses per connection.

Apparent losses per connection.

Real losses per connection.

Total annual water losses (for large urban distribution systems).

Apparent losses (volume) / billed authorised consumption (volume) – a PI recommended from the AWWA, 2019, study.

ILI × PMI – a PI recommended from the AWWA, 2019, study.

UARL with SCF.

The following performance indicators (PIs) are recommended for performance monitoring for rural distribution systems:

Total water losses per mains length.

Real losses per mains length.

Total annual water losses (for large rural distribution systems).

Apparent losses (volume) / billed authorised consumption (volume) – a PI recommended from the AWWA, 2019, study.

ILI × PMI – a PI recommended from the AWWA, 2019, study.

UARL with SCF.

Tracking of ILI × PMI and the associated water loss control strategies employed by water utilities, together with real loss performance, will strengthen the body of knowledge when evaluating potential real loss intervention methods.

3.3 EXPERIENCE IN THE ENI NEIGHBOURHOOD SOUTH REGION

Two sets of KPIs have been provided by the WES Partner Countries:

The *KPI for NRW Directorate* from the Hashemite Kingdom of Jordan.

The *Palestinian KPI for Service Providers Regulation 2023*. This set of KPIs also includes a very good model for the Standard Annual Water Balance.

Both sets of KPIs demonstrate thorough knowledge of PIs for a *water utility/department/operator* in general and provide some specific technical PIs for NRW reduction. The Palestinian set of KPIs includes:

Non-Revenue Water by volume (m^3).

Non-Revenue Water per mains length per year (m^3/km/year).

Non-Revenue Water per connection per day (m^3/connection/day).

The Jordan set of KPIs includes the following PIs from the IWA PI system:

Op5 – Active leakage control repairs (No./100 km/year)

Op8 – Customer meter replacement (-/year)

Op20 – Service connection rehabilitation (%/year)

Op23 – Water losses per connection (m^3/connection/year)

Op24 – Water losses per mains length (m^3/km/year)

QS3 – Population coverage (%); % of the resident population that is served by the *utility.*

QS8 – Per capita water consumed in public taps and standpipes (litre/person/day).

QS25 – Connection repair time (days); average time spent repairing service connections.

These sets are a good basis for further development based in the recommendations in this SOP.

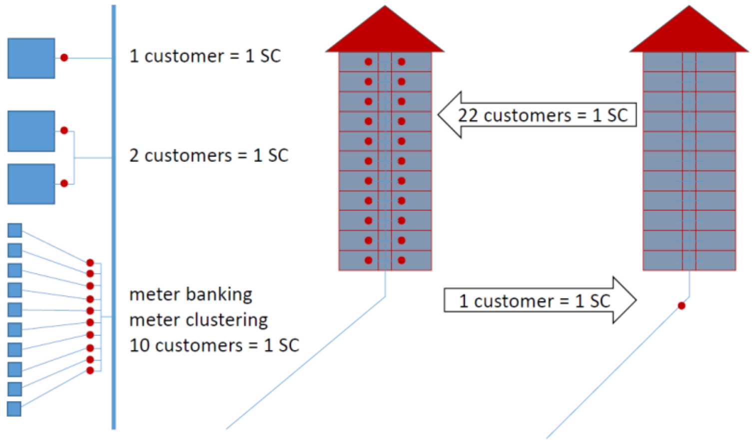
4 HOW TO START?

Get started and learn as you progress!

Stop or reduce the use of % of System Input Volume as a leakage performance indicator. Leakage expressed as % of SIV is easy and simple to calculate, but it has several limitations in interpretation. If the use of % of SIV is unavoidable, always also present the total volume of water loss or NRW in m^3 for the specified period (month, quarter, or year).

Understand the complexity of the performance indicator in terms of data availability and data quality. Examples:

"WATER LOSSES PER CONNECTION" REQUIRES A WELL-DEVELOPED STANDARD ANNUAL WATER BALANCE TO PROVIDE THE WATER LOSSES (VOLUME) AND THE CORRECT NUMBER OF SERVICE CONNECTIONS (REFER TO



in Appendix 1).

"ILI" requires precise data on length of mains, number of service connections, total length of underground service connections, and current average zone pressure. Where the first three data inputs may be included in the GIS, the current average zone pressure might require a measurement campaign.

"ILI × PMI" requires a discussion within the *water utility/department/operator* on the acceptable minimum standard of service pressure (MARP) as this is crucial for calculating the PMI.

"UARL with SCF" requires the same precise data as the ILI but in addition to this data also best estimates of % of rigid mains, % of rigid service connections (main to property line), and % of rigid service connections (property line to meter). These seven inputs are required for each calculation. Furthermore, these calculations must be purchased.

Although data availability has become a lesser concern during the last decade due to the implementation of i.e., SCADA systems, GIS and hydraulic modelling tools, there is still no need for a longlist of performance indicators. The IWA PI system explains how to select the relevant KPI (refer to Section 1.3 and Figure 3).

Example: Critical success factors for increasing leak detection

Let's presume that the *water utility* has 7.000 km of mains. Currently 10% of the length of mains is subject to active leakage control (700 km). The well-equipped, motivated, and trained team of leakage technicians can do 3.5 km per day, requiring 200 days (in practice one full year) to complete the target of 10% of mains length.

Increasing the target to 20% of mains length in a situation that mains length did also increase to 7.500 km of mains, results in 1.500 km of mains being subject to active leakage control. If performance continues to be 3.5 km per day, 430 days are required, with as consequences three times the amount of equipment (cars, noise loggers, correlators, hydrophones, ground microphones, etc.) and three trained teams of leakage technicians. This also means that each km of mains is subject to active leakage control every five years, both the mains in good and in poor condition.

What if innovative technology like satellite leak detection should cover 3.750 km per year and would provide guidance on i.e., the 350 km of mains in poor condition. Focusing on this 350 km of mains, the one trained team can do the job in 100 days. Consequently, the target changes from "% of mains length" to "leaks per km of mains inspected".

5 APPENDIX 1

Required data Standard Annual Water Balance

Table 5 presents the required data input for the Standard Annual Water Balance in tabular form.

TABLE 5 – REQUIRED DATA INPUT IN TABULAR FORM FOR A THREE-YEAR PERIOD (2020-2022).

Code	Description	Unit	2020	2021	2022
	Number of days	-	366	365	365
VOS	Volume from Own Sources	1 000 m^3			
VOSEA	Error Adjustments on VOS	%			
WI	Water Imported	1 000 m^3			
WIEA	Error Adjustments on WI	%			
WE	Water Exported	1 000 m^3			
WEEA	Error Adjustments on WE	%			
BMAC	Billed Metered Authorised Cons.	1 000 m^3			
BUAC	Billed Unmetered Authorised Cons.	1 000 m^3			
UMAC	Unbilled Metered Authorised Cons.	1 000 m^3			
UUAC	Unbilled Unmetered Auth. Cons.	1 000 m^3			
UC	Unauthorised Consumption	1 000 m^3			
CMI	Customer Metering Inaccuracies	%			
SDHE	Systematic Data Handling Errors	%			
Lm	Length of mains	km			
Nc	Number of service connections	-			
Lp	Length of customer service pipe	m			
AOP	Average Operating Pressure	mH_2O			
CRUC	Customer Retail Unit Charge	EGP/m^3			
VPC	Variable Production Cost	EGP/m^3			

We used the Egyptian Pound (EGP) as an example.

Volume from Own Sources (VOS)

The volume of water obtained from own sources for input to raw water mains leading to water treatment plants.

Error Adjustments

Large volume (large diameter) water meters wear out over time. This predominantly results in the under-registration of the volume of water passing through them. Large volume water meters are most times used for measuring the volume from own sources, water imported, and water exported. The error adjustments should be based on validated inaccuracies of water meters.

Authorized Consumption

The volume of metered and/or unmetered drinking water delivered to registered, connected customers, including the utility's own water usage (e.g., flushing) and water consumption by third parties for which the water utility has provided implicit or explicit permission (e.g., firefighting). This includes drinking water for residential, small business, and industrial use.

Customer Metering Inaccuracy (CMI)

All water meters wear out over time due to the volume of drinking water passing through them. Typically, the wear and tear of water meters result in the under-registration of the volume of drinking water passing through them.

In addition to under-registration due to worn-out water meters, there is also under-registration due to improperly sized water meters or the installation of the wrong type of water meter for the specific consumption pattern. If a commercial connection is made with an excessive delivery capacity, there is a risk that a low flow rate of drinking water will not be measured or will only be partially measured. The CMI should be based on validated inaccuracies of customer water meters.

Length of mains (Lm)

The total length of all transmission and distribution pipelines in the water distribution system, starting from the production meter(s) at the production location(s).

Number of service connections (Nc)

THE TOTAL COUNT OF ACTIVE AND INACTIVE CONNECTIONS INCLUDES CONNECTIONS TO THE DISTRIBUTION PIPELINE THROUGH WHICH DRINKING WATER CAN BE SUPPLIED TO CUSTOMERS. IT ENCOMPASSES ALL CONNECTIONS, INCLUDING THOSE FOR FIREFIGHTING SUPPLY. THE TOTAL NUMBER OF ACTIVE AND INACTIVE CONNECTIONS IS MOST

TIMES GREATER THAN THE NUMBER OF CUSTOMERS. REFER TO

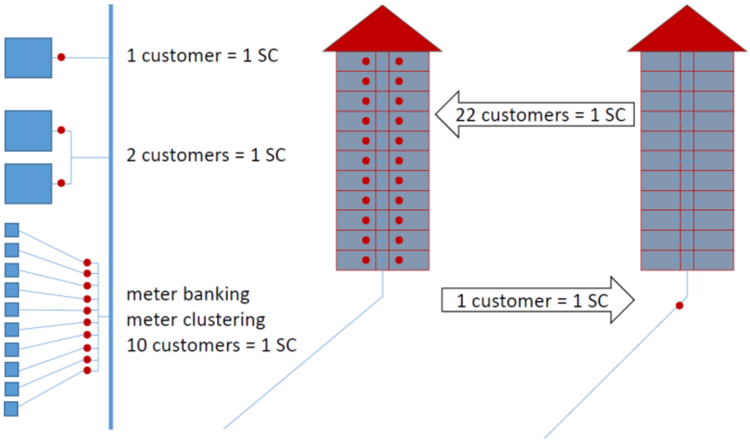


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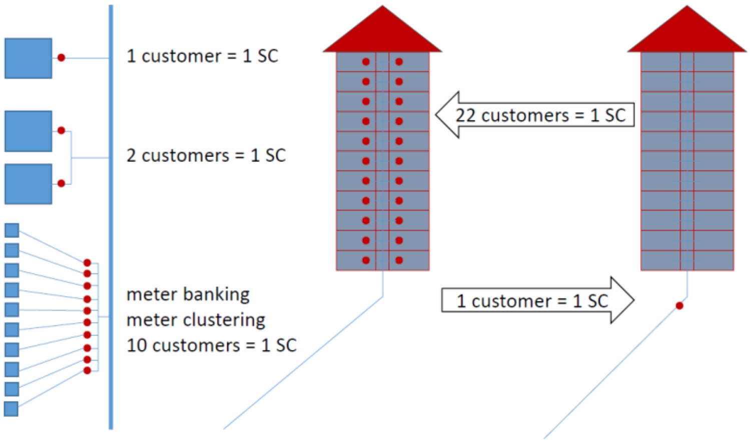
FIGURE 5 – CUSTOMERS VERSUS SERVICE CONNECTIONS.



Length of customer service pipe (Lp)

Often referred to as the house connection, from the distribution pipeline to the water meter. The total length of underground service pipes is one of the variables in the formula for calculating the Unavoidable Annual Real Losses (UARL).

Average Operating Pressure (AOP)

The average operating pressure in the water distribution system for which the Standard Annual Water Balance is being prepared and the UARL is being calculated.

Customer Retail Unit Cost (CRUC)

The drinking water rate charged to customers. This is a weighted average drinking water rate per m^3 that includes both the water price, fixed charges (capacity fee), taxes, and any billing costs. Any collection costs and the costs associated with making or modifying (new) connections should not be included in the drinking water rate. The drinking water rate varies by customer segment (residential, small business, and large business consumption) and delivery capacity.

Variable Production Cost (VPC)

The variable costs for the production and distribution of drinking water, in €/m^3 or EGP/m^3, for each additional m^3 of drinking water that can be produced without requiring an extra new investment. These are the drinking water operational costs per delivered m^3. These costs include taxes, depreciation, and operational costs (electricity and chemical usage, auxiliary and waste materials, checks, research, and analysis costs). Any wholesale purchases also fall under the drinking water operational costs per m^3.