TECHNICAL ASSISTANCE ON SUPPORT TO REDUCE WATER LOSS WITHIN THE REFORM OF THE WATER SECTOR IN CROATIA

Trust Fund No. TF073805

EC Contract No. REFORM/IM2022/004

OUTPUT 2

Draft National loss reduction action plan

December 2022

Project carried out with funding by the European Union in cooperation with the European Commission's DG REFORM

European Commission

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22HR06 CROATIA: SUPPORT TO REDUCE WATER LOSS WITHIN THE REFORM OF THE WATER SECTOR

OBJECTIVE

Support the economy and efficiency of operations of Croatia's water utility sector by improving capacity of the Public Water Service Providers (PWSP) to reduce excessive losses from water supply systems. This is expected to contribute to sustainability and affordability of water service provision, and to water security and resilience more broadly.

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ACTIVITY 2:

DRAFT NATIONAL LOSS REDUCTION ACTION PLAN

i. Background analysis and collection of relevant and available date on water resources, water supply systems and operators that enabled the preparation of a draft NLRAP. This includes a stakeholder analysis, collection of data and information including data derived from installed measuring devices and real-time measurements of the quantity of abstracted water, water balance sheets and an assessment of water losses utilizing an Infrastructure Leakage Index according to IWA methodology.

ii. Review of existing water losses reduction plans/documents/reports in Croatia, and international best practice examples in the preparation of water losses reduction plans (with focus on EU countries).

iii. Support to the Croatian authorities in the preparation of a first draft NLRAP, which includes: Introduction and purpose; Implementation objectives; Development of the methodology for water losses reduction and balance sheet of waters; Descriptions of measures and priority setting for the reduction of water losses; Risk assessment; Timeline for implementation; Assessment of the planned water usage fee method/calculation its effect on water prices and affordability of the measures and activities; Implementation mechanisms at national level and PWSPs level; Total estimated implementation costs; Potential sources of funding and co-financing ratios; Establishment of monitoring and measurement criteria for implementation performance; Development of guarantee mechanism for the implementation of the action plan and protection of invested public funds.

NLRAP – DRAFT

December, 2022.

ABBREVIATIONS

CW	Croatian Waters
DG	Directorate-General for Structural Reform Support
DMA	District metered area
DWD	Drinking Water Directive (Directive 98/83/EC)
DWD Recast	Drinking Water Directive (Directive 2020/2184)
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
ESIF	European Structural and Investment Funds
EU	European Union
HGVIK	Croatian Association of Water and Wastewater Companies
IBRD	International Bank for Reconstruction and Development
ILI	Infrastructural leakage index
IWA	International Water Association
KPI	Key performance indicator
LSGU	Local self-government unit
MESD	Ministry of Economy and Sustainable Development
MIS	Management Information System
MS	Member States
NLRAP	National Loss Reduction Action Plan
NRW	Non-revenue water
NWLRP	National Water Loss Reduction Programme
OG	Official Gazette
OPCC	Operational Programme Competitiveness and Cohesion
PE	Population equivalent
PI	Performance indicator
PMA	Pressure management area
PWSP	Public water service provider
RBMP	River Basin Management Plan
SIV	System input volume
ULRAP	Utility Loss Reduction Action Plan
UWWTD	Urban Wastewater Treatment Directive
VAT	Value added tax
WAREG	European Water Regulators
WFD	Water Framework Directive
WLSG	Water Loss Strategic Group
WSC	Water Service Council
WWTP	Wastewater treatment plant

CONTENT:

LIST OF TABLES

LIST OF FIGURES

PREAMBLE

The Project 22HR06 **Croatia: Support to reduce water loss within the reform of the water sector** is implemented through a number of activities over a period of 19 months (May 2022 - December 2023).

The first Project activity (**Activity 1**) was completed in September 2022, and it concerned the preparation of a **Stocktaking Report** about the status of water supply services in Croatia, including an estimation of losses and technical capacities of PWSPs (Final version, October 2022).

The **Activity 1** elements were the following:

- Assessment of the current status of water supply services provision in Croatia, including legal responsibilities, service regulation, coverage, operational efficiency and financing of services, PWSP organization and sector reform changes. The objective of this activity was to provide an overview of the sector organization and operational efficiency in light of ongoing sector reforms.
- Collection and analysis of available technical data for the estimation of water losses in public supply systems and assessment of technical capacities of PWSPs to identify and reduce water losses. This analysis included:
    - Collection of available technical data on characteristics and status of water supply systems required for the assessment of present water losses, potential and risk for future water losses;
    - Collection and preliminary analysis of existing project documentation related to optimization of water supply systems and water losses reduction
- Analysis of provisions, required assessments and expected reporting obligations for Croatia deriving from Article 4 (3) of Council Directive (EU) 2020/2184 of 16 December 2020 on the quality of water intended for human consumption (recast) connected to water leakage levels

In terms of content, the **Stocktaking Report** gives a comprehensive overview of the status of the water sector and the water services sector, as well as an overview of a number of completed analyses related to the status of water losses, capacities of PWSPs and water supply systems. The analyses and assessment of the status were done using data from the national water management planning documents, PWSPs' studies and designs, as well as data from Croatian Waters' SOV database (from the application for input of data on wastewater collection and treatment, and water supply of all PWSPs in Croatia), and data received from the questionaries designed and completed through this Project activity (the questionaries were sent to all 129 PWSPs dealing with public water supply services, and data was submitted by PWSPs that on the annual level deliver more than 90% of totally delivered water volumes). The collected data was assessed as relevant and reliable for analyzing the status of the water sector and characteristics of water supply systems, technical capacities of PWSPs, the current level of water losses and potential for their reduction, presented in detail in the **Stocktaking Report**.

An approach selected within this **Activity 2** is for the Draft National Loss Reduction Action Plan (**Draft NLRAP**) to present a summary overview of the results of the completed analyses of the status of the water and water services sectors, thus defining the **Stocktaking Report** as a background document of the **Draft NLRAP**.

SUMMARY

Measures within this Project directly contribute to the implementation of the reform of the water utility sector and investments under the National Recovery and Resilience Plan 2021-2026 as well as the Operational Program Competitiveness and Cohesion 2021-2027. The Project is financed by the European Union through the Technical Support Instrument and is implemented by the World Bank in cooperation with the Directorate-General for Structural Reform Support (DG REFORM).

The assessment of the current status of public water supply service in Croatia indicates that an integrated water loss management system hasn't been established yet. There are no clearly specified national and specific objectives and indicators of water losses which will in a clear and standardized way indicate the efficiency of the implementation of water loss reduction measures which are to a certain extent implemented even today. That is why the NLRAP is prepared, which identifies the status of water supply systems and technical capacities of PWSPs to identify and reduce water losses on the national level, defines the measures that need to be taken, defines priorities taking account of risks, estimates the costs of implementing the measures and expected effects. An important element of the NLRAP is the standardization of the calculation of loss reduction indicators and a proposal of organizing a system to control and monitor the efficiency of implementation of the loss reduction plan.

The institutional framework, i.e., the competences and responsibilities of stakeholders in the water and water services sectors on the national level are defined through the organization of state bodies and local self-government units. The roles in the water sector are clearly defined by the laws supporting the water sector, without any functional deficiencies identified. In terms of implementation, the Croatian Government, through the MESD and CW, implements a comprehensive reform of the water services sector focused on merging currently more than 160 water service providers into 41 more efficient water service providers in order to strengthen the implementation and investment capacities of PWSPs as well as their financial and technical self-sustainability, raise the service level, and comply with the rising standards (closely related with the water loss issues).

The level of completion of water supply systems is favorable. The water supply network is developed, with around 95% of the users able to connect and with a generally sufficient storage tank volume. Water supply is continuous, with water treatment plants built where water quality doesn't comply with the statutory parameters, thus making water from the public water supply system potable throughout the area. However, a third of PWSPs have limitations in the availability of water resources in relation to the current consumption and they expect such limitations in the future as well, which clearly points to the need to preserve water resources through the reduction of losses.

Even though the level of development of water supply systems is favorable, there is a significant lack of knowledge about own water supply systems (system maps, updated consumer databases and registers of system age are missing). A significant share of water supply networks is very old, particularly in urban areas, and practically all PWSPs replace significantly less than 2% of the network per year. Many PWSPs continuously operate in unfavorable pressure conditions, with an average pressure on the national level of around 5 bar. Only a few DMAs have been established. A lack of leakage metering and detection equipment has also been identified.

The analysis of water losses in Croatia has so far been largely associated with the basic (simplest) form of the water balance that implies three basic components: Water Supplied, Billed Authorized Consumption, and Non-Revenue Water. In 2021, the total volume of water supplied in Croatia amounted to 479 million m3, the total volume of water delivered through the system to the final users in Croatia in 2021 amounted to 244 million m3, and the total NRW volume in Croatia in 2021 amounted to 235 million m3. The share of Non-Revenue Water in Croatia in 2021 amounts to around 49%. Analyzing the NRW volumes on the level of individual PWSPs, it can be concluded that the distribution of the NRW volumes is highly uneven. A few PWSPs in Croatia account for the majority of NRW volumes on the national level (5 PWSPs with the biggest NRW volume account for around 51% of the total NRW volume on the national level).

The management of water losses started developing only recently, once the basic objectives of ensuring the water supply service coverage have been achieved. The first planning documents dealing with the water loss issue were prepared, after which first activities were launched more intensively. Significant problem in water loss reduction refers to human resources and a lack of theoretical and practical knowledge. There are no training programs for efficient training of technical staff for water loss management/reduction on the national level. Even in the PWSPs that have technical teams for water losses established, these teams are not sufficient with regard to the length of the water supply network. The majority of PWSPs have no special departments (teams) for active leakage control, or they do have such a team, but these people also do other work within the company. Also, the majority of PWSPs don't even adopt active leakage control plans or they adopt them, but don't report on the implemented loss reduction activities.

All water supply systems are faced with water losses. Attempts to address the water loss issue partially by applying different measures don't contribute to its long-term resolution. For that reason, this NLRAP establishes a water loss reduction methodology. It is based on improving knowledge about one's own water supply systems, users, operating conditions, and on improving knowledge about the water loss issue, starting from the management board of providers of water services, to technical teams that will take action on the field. The methodology defines measures and foresees the effects of such measures. The dynamics of implementation of certain groups of measures can be adapted to the specifics of a particular water supply system and realistic needs, and some groups of measures can be implemented simultaneously. It is of utmost importance to understand the overall issue of water losses through the definition and analysis of all the measures that affect water losses, as well as to understand the interdependence of the proposed measures, and define priority measures and appropriately assess the effects of the proposed measures.

The NLRAP proposes the following groups of measures: (i) System data improvement measures; (ii) Water supply system optimization measures; (iii) Measures to divide the system into DMAs; (iv) System pressure control and management measures; (v) Active leakage control measures; (vi) Measures to address apparent losses; (vii) Planning and mains replacement measures; (viii) Institutional strengthening measures; (ix) Analysis and reporting measures; (x) Technical assistance to PWSPs to implement the measures; and (xi) Establishment of a system of PWSP benchmarking and performance indicators, covering the costs of the national control body for the reduction of losses. These measures try to cover all the areas that affect the reduction of water losses, also aiming to raise awareness about the importance of long-term implementation of all the measures. Due to relatively high costs of mains replacement measures, in order to identify their scope (also used later when defining the time framework for implementation) the relevance of losses was estimated using the criteria of the size of losses, age of mains, and risks associated with resource limitations and climate change. It is estimated that with the proposed measures the NRW will be reduced from the current 235 million m3/year to 113 million m3/year, representing a reduction of around 50% of the 2021 NRW.

The time framework for the implementation of measures was proposed based on analyses of levels of water losses, PWSPs' capacities, time needed to prepare plans and designs and to form teams, the complexity of public procurement procedures in terms of time, the capacities of available consulting and construction sectors, the financial weight of investments, and requirements of the EU directives which have also put focus on water leakages since 2020. It is estimated that the implementation of the comprehensive plan of measures in the amount of EUR 1.6 billion would require 15 years. It can be assumed that the implementation of the measures will start already in 2024, i.e., the measures to a certain extent build on the already initiated measures/activities from the National Water Loss Reduction Program (NWLRP) or other programs (NRRP or OPCCs) which have already stopped a multi-annual trend of increasing water losses, noting that for efficient implementation of measures from the NLRAP it is essential to improve approach and organization of implementing the measures.

The achievement of the national water loss reduction objectives will be monitored based on the annual volume of NRW reduction. According to the NLRAP, the targeted NRW volume reduction over a 15-year period is 122 million m3. As the result of loss management improvement measures in the first 15-year period (NLRAP), which also includes significant strengthening of PWSPs to cope with water losses, and with continued implementation of active leakage control measures and continued rehabilitation/replacement of mains (with a proposed investment in replacement of at least 2% per year), further significant advances in the reduction of losses are also expected after the first 15-year period, which it will only be possible to estimate in a certain phase of implementing the NLRAP measures and analyzing the actual effects of measures (and the required modifications of the approach/measures). The progress in water loss management by each PWSP or service area will be monitored using the ILI and other unit indicators of the Real Losses. After the establishment of the benchmarking system for performance efficiency and the adequate monitoring period (estimated at 5 years), the target or reference performance values will be defined for the same indicators, which is under the authority of the Council for Water Services, except for the indicators the definition of which is under the authority of the MESD for the purpose of the Regulation on special conditions to perform water service activities.

The analysis of financing sources is focused on ensuring the maximum possible amount of available international and national grants and on defining a financial gap, i.e., a preliminary calculation of the missing funds to close the financing scheme for the proposed measures and activities. According to the preliminary analysis of availability, the total projected available funds amount to EUR 676 million (projected available funds of active projects including available EU financial instruments, State

Budget funds, and budgetary funds of Croatian Waters and PWSPs), while the total financial gap amounts to – EUR 906 million or 57% of the total projected investment value of the measures. Due to a high percentage of the financial gap, two financing models were considered: Model 1. Emergency government funds (the State Budget on its own or with the help of new EU financial instruments for the reduction of leakages) in the amount of 85% of the gap, with the PWSP covering on the average 15% of the gap charged through the future water price or through increasing the PWSP's development fee; and Model 2. Loan financing 100% of the gap charged through the future water price or through increasing the PWSP's development fee.

The implementation of the Model 1 measures doesn't significantly affect the affordability of water services, but it is important to note that besides the identified measures, numerous projects are in implementation across Croatia, particularly in the sector of wastewater collection and treatment, which will significantly affect the overall affordability of the service, which still remains within the affordability threshold (higher burden in relation to affordability is present in areas with a lower level of development). If Model 2 is selected as a means to close the financing scheme, the impact on the price of the water service is more considerable, i.e., the share that is not covered by the grants is fully co-financed through the price of the water supply service or through the development fee, which has implications on the affordability of the water service, but which still remains within the 2.5% threshold. However, smaller service areas with additional burden from other water and wastewater projects (primarily wastewater collection and treatment which place the highest burden on affordability) are faced with critical affordability levels (around 3.5%).

According to the Guide used for the preparation of water and wastewater projects on the EU level, using risk and sensitivity analyses acceptable risks of impact on the price of water have been identified (maximum cumulative impact up to EUR 0.5 per m3 of water), with the NLRAP acceptable in terms of criteria of impact on the price of water. However, the risks of not achieving the national loss reduction objectives are significant (due to PWSPs' technical capacities or failure to provide funds for the implementation of the NLRAP), which can lead to the operational inefficiency of PWSPs being retained or increased, but potentially also to the European Commission imposing measures on the country due to the failure to achieve objectives at the EU level, the consequences of which cannot be foreseen at this moment with an acceptable level of certainty, and further failure to achieve the loss reduction objectives can even lead to denying the instruments of EU's financial assistance by reducing the funds available from the NRRP 2021-2026 and MFF 2021-2027. In case the implementation of measures is delayed (the initial years with a slightly slower rate in the initial activities, preparation of plans, organization of teams and active leakage control, and in later years more considerable delay in the renewal of mains), the effects would significantly fail to occur, particularly in the first 10 years of the NLRAP implementation. Such unfavorable results definitely have to be prevented with the application of safety mechanisms for the NLRAP implementation, particularly since the reduction of losses is closely related with the basic national objectives in the water sector, and these are the reduction of water losses and increased operational efficiency of PWSPs.

Since it is not expected that a single national financial fund or a project unit/organization will be established to implement exclusively loss reduction projects, the loss reduction measures or projects deriving from the NLRAP will be implemented through several national financial/operational programs and/or through individual measures/activities of individual PWSPs. At the same time, the NLRAP points to the need for a comprehensive analysis of water losses, monitoring the implementation of measures, and evaluation of results, including monitoring the achievement of the national objectives. In such form of implementation, it is extremely important to establish mechanisms for monitoring, control, and expert evaluation of, including approval, activities on the reduction of losses deriving from the NLRAP. The NLRAP proposes the establishment of a National Body for Water Losses which would report to the MESD, composed of the representatives of the MESD, Croatian Waters, the Croatian Association of Water and Wastewater Companies, and independent experts experienced in loss management. The National Body for Water Losses will as an expert and operating body verify the PWSPs' loss reduction action plans and give opinions/decisions about priorities in implementing individual activities (investment plans), which will through the MESD become binding in terms of the eligibility of measures for the financing of loss reduction measures which are aimed at achieving the effects foreseen by the NLRAP. This will also ensure that the invested public funds are protected.

The preparation of the NLRAP completes the whole in the water sector which has in the last ten years or so been characterized by significant strategic breakthroughs, which are the result of the adoption of a set of legislation, but also of national planning and intensive investment in the construction of water and wastewater structures. This has nationally improved the starting points and visions/goals in the provision of water services, with a significant financial assistance provided on the local level for the development of water and wastewater infrastructure. At the same time, more significant planning on the local level or the level of service area has so far been missing, which is understandable since the sector has been significantly transformed, with a clear direction and assistance from the government expected. It can be concluded that the direction of the water policy is today clear and that it needs to be consistently integrated into PWSPs' action and business plans. Such an approach will strengthen the established institutional framework (line ministry, Croatian Waters, Council for Water Services, PWSPs) and will fully round up the planning/cycle, which will bring improved sustainability of the provision of water services. The principles and objectives, in regulatory and planning terms lowered from the national to the regional/local level, i.e., the business level of PWSPs, are monitored by means of PWSP performance indicators. Such a system enables insight into the legality of setting the price of water services, but also the application of incentive pricing policy of water services that affects the performance of providers, users, and the aquatic environment.

1 BACKGROUND, PURPOSE AND OBJECTIVE OF PREPARING THE NLRAP

The MESD is implementing a reform of the water utility sector. The sector is currently fragmented, faced with a lack of human capacity and efficiency issues, and without restructuring it is not able to respond to the requirements set by the relevant EU Directives[1]. The need to support PWSPs is particularly urgent in terms of improving their capacity to reduce excessive water losses from water supply systems, which are on average 50%, and represent a problem that hasn't been addressed for many years.

The MESD and Croatian Waters support PWSPs by preparing the NLRAP that identifies the guidelines and strengthens their capacity to prepare their own loss reduction action plans and implement the process of PWSPs integration. The NLRAP sets requirements for water infrastructure and establishes a joint methodology for the development of PWSPs' loss reduction action plans.

Although there are no significant water shortages in Croatia at present, the country is carefully monitoring worrying trends of growing and widening water shortage and stress which could affect a significant number of catchment areas, and thus resource management as well.

The NLRAP indicates three types of initiatives/incentives to reduce losses:

- Unjustified excessive resource use;
- Wasteful water consumption (high specific water consumption per capita per day);
- Adjustment to climate change.

Therefore, in addition to the obligatory implementation of measures to reduce losses as "unjustified excessive" resource use, it would be necessary to consider the possibility to implement different water-saving measures, and to encourage rational water use. Together with that, the implementation of measures to improve system management and introduction of climate change adaptation measures and their synergy allow for reduction of the volume of abstracted water and thus preservation of good status and the ecological function of water without significantly lowering the standards underpinning the supply of water intended for human consumption. It also needs to be noted that water loss reduction measures contribute to more rational management of public water supply systems, including a reduction in the consumption of electric energy.

PWSPs will have to implement the measures specified in their action plans, in accordance with the methodology defined in the NLRAP, if they will find their implementation acceptable and feasible, based on the assessment of the affordability of measures and activities that every action plan will have to contain. By implementing the reform/integration, bigger PWSPs will be financially stronger, they will have more human capacities/more qualified staff, they will have better capacities to implement investments and manage losses more successfully.

The objective is to reduce the level of losses, i.e., bring it to a sustainable level.

2 INITIAL ASSESSMENT OF THE CURRENT STATUS

2.1 Institutional framework

The institutional framework, i.e., the competences and responsibilities of stakeholders in the water and water services sectors are defined through the organization of state bodies and local self-government units. The overall water policy on the national level is defined by several bodies headed by the Ministry of Economy and Sustainable Development responsible for water policies and control over water management. Croatian Waters have a status of a legal entity for water management, while the Water Service Council as an independent and supervisory state body, acting as a regulator, ensures the legality of setting the price of water services and water fee of a public water service provider.

[1] 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, Water Framework Directive 2000/60/EC of 23 October 2000, Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment

Water services are activities of general interest which are performed as a public service. Local self-government units are obliged to ensure adequate provision of water services through public providers of water services by exercising their shareholder rights for the benefit of the people and legal entities that use their water services. Water and wastewater structures are public goods in public use, owned by the public provider of water services in the service area. These structures are managed by public water service providers by carrying out operation and maintenance activities and activities of the employer of construction of water and wastewater structures.

So, in the water sector and the water services sector an extended functional scheme of competences and responsibilities is in place, with these including regulations, control, national planning, national water management (including financing investment in the development of water supply and wastewater systems), the system of compulsory (national) water fees, planning in the area of water service provision, provision of water services in the service area of public providers, and regulating the price of water for the provided water service.

It is concluded that the institutional framework in the water sector is clearly defined, without any functional deficiencies identified.

However, in terms of implementation, regarding water services, it is necessary to adopt a final set of regulations (obligations from the act regulating water services of water supply and wastewater management) with the aim of achieving all the preconditions to complete the reform of the water services sector. Namely, the Croatian Government, through the MESD and CW, implements a comprehensive reform of the water services sector focused on merging currently more than 160 water service providers into 41 more efficient water service providers in order to strengthen the implementation and investment capacities of PWSPs as well as their financial and technical self-sustainability, raise the service level, and comply with the rising standards (closely related with the water loss issues).

2.2 Water resources[2]

Nearly a half of the water volume abstracted in Croatia goes for public water supply needs. In 2021, a total of 479 million m3 of water was abstracted, on average around 115 m3 of water per capita. Groundwater accounts for 49%, springs for additional 35% (84% in total), and surface water for 16% of the average abstracted water volumes.

There are around 500 registered water abstraction sites, of which around 60% are active. 90% of total water volumes for public water supply are abstracted at around 80 water abstraction sites (15% of the registered total or 20% of active water abstraction sites). Those water abstraction sites are of great importance for water supply systems in Croatia, providing the majority of the required water volume. Other water abstraction sites provide water for smaller water supply systems or fill up bigger systems with water when needed, frequently with lower operating costs since such sources are mostly closer to the supply zones.

In terms of the total volume of annual renewable reserves, the volume abstracted for water supply is currently relatively low. Data shows that only 0.5% of renewable water reserves per year is used for water supply (or 10% in case of water abstracted from renewable groundwater reserves). However, the situation differs significantly by regions and sub-regions in terms of hydro-geological diversity and availability of water. While the abstracted volume is significantly lower than the average annual yields of water abstraction sites, in the summer and dry months the yields of some water abstraction sites become equal to total abstraction volumes (particularly in the Adriatic region). There are some geographically specific areas with significant pressures to water abstraction sites due to a significant seasonal increase in water consumption (the Zadar coastal region, the Split region, the islands).

This indicates complexity and the importance of good management of water supply systems, which requires comprehensive monitoring of water quality and quantity parameters.

Groundwater bodies on which water abstraction sites are established currently can mostly achieve their aquatic environment objectives, i.e., good quantitative and qualitative status of water bodies which is needed to ensure safe and sustainable water supply. Surface water bodies on which abstraction points are found achieve aquatic environment objectives in terms of the

[2] (Source: River Basin Management Plan 2016-2021, http://www.voda.hr/sites/default/files/2022-05/plan_upravljanja_vodnim_podrucjima_2016._-_2021_0.pdf)

quality of water for human consumption. Abstractions of water for water supply don't lead to modifications in the hydro-morphological status of surface water.

It is necessary to point out the link between the reduction of water losses and pressures to water bodies from which water is abstracted for human consumption. A water rights permit for water usage (Water Act, Article 157) is issued for the abstraction of water intended for human consumption, to provide a public water supply service, for a specified period, with a possibility to modify/limit the approved conditions if that is in the public interest due to modifications in the water regime. The volumes of water abstracted for public water supply, generally speaking, aren't significant in relation to the total available resource, but problems occur locally where the awarded rights to water exceed the locally available resource capacities either in terms of volume or in terms of the period of abstraction. In such areas it is necessary to intensify activities of monitoring the abstracted volumes and of the implementation of measures to rationalize water consumption. Water supply has priority over other forms of resource usage. The River Basin Management Plan establishes a Program of Measures to control water abstraction that shall: (i) reduce the impact of water abstraction to a moderate level, i.e., to the maximum allowed water usage index (WUI) ≤ 0.4[3], and (ii) increase the water usage efficiency. For that reason, when defining the financial efficiency of water usage, it is definitely necessary to define the volume of non-revenue water, or its components that can be rationalized/reduced.

2.3 Water supply systems and water service providers

2.3.1 Water services

The Water Services act defines water services as the services of public water supply and public sanitation, which PWSPs perform as their only activities[4]. These are activities of general interest which are performed as a public service. The rate of population connection to public water supply systems is 89.4 %, while the coverage rate is 96% (source: Multi-Annual Program for Construction of Water and Wastewater Structures for the Period until 2030). There are differences in coverage rates among counties, and particularly among municipalities and towns, with the connection rates lower in areas with lower population density.

[3] The impact of water abstraction and rerouting on the volume of water flow is expressed with a "usage index" that measures the share of abstracted/rerouted water in relation to a multi-annual average flow as a reference value. The usage index of up to max. 0.4 indicates status assessment – moderate status according to the quantity of water flow, meaning – water abstraction has a moderate impact).

[4] This also includes additional activities of sampling and testing, building connections, special water deliveries (public water supply for other PWSPs, by a water tanker truck and a water tanker vessel, acceptance of urban wastewater and sewage sludge from another PWSP, acceptance of urban wastewater and sewage sludge of other PWSPs), production of energy in the process of performing water services, including sale of energy, management of sewage sludge generated in the process of wastewater treatment, management of a construction project when the PWSP is its employer.

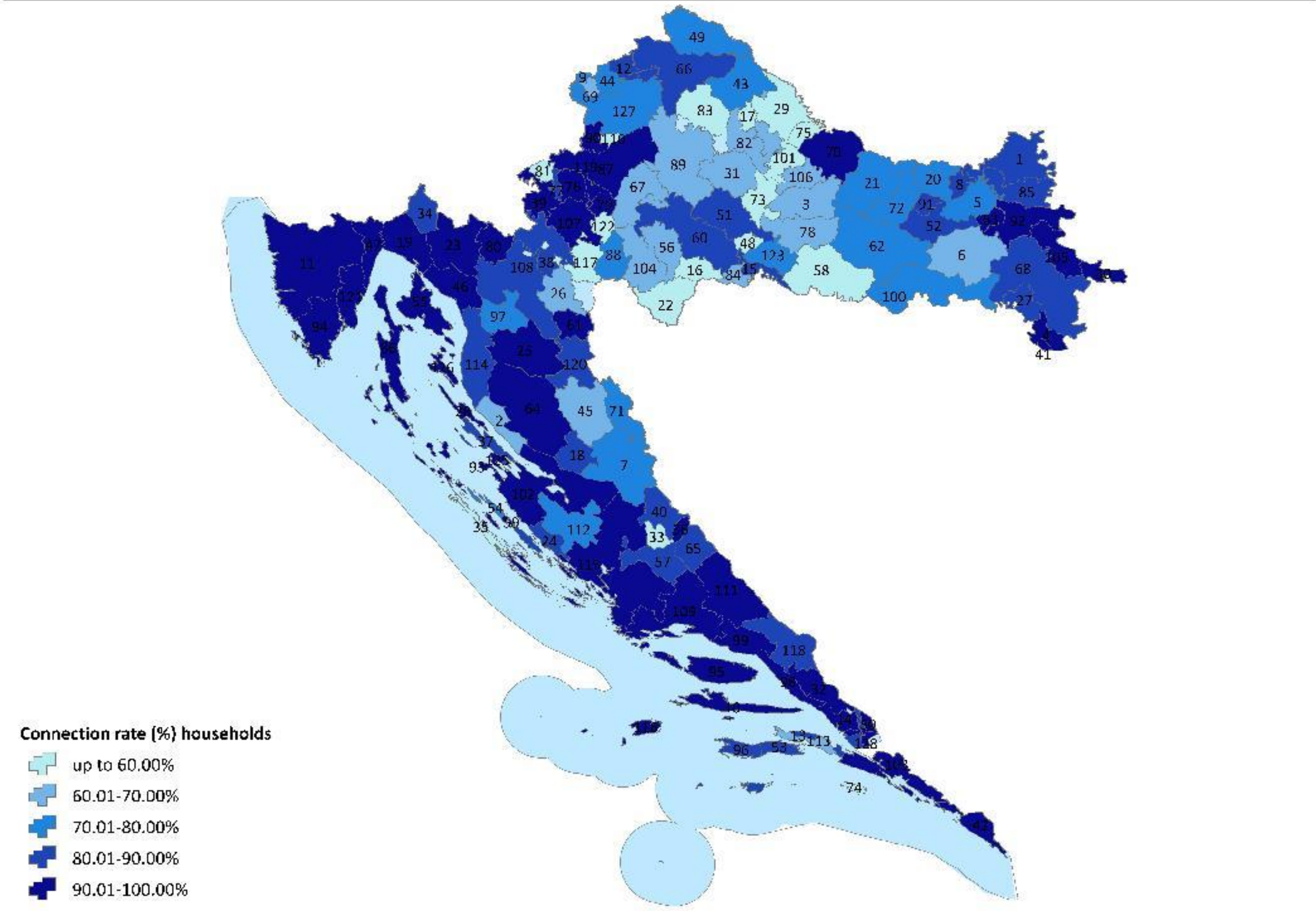

Figure 2.1. Rate of connection to the public water supply system in 2021 (PWSP level with IDs)

The average rate of connection to the public sanitation systems in the agglomerations of more than 2,000 PE (260 agglomerations in total) is 68%, and 9% in the agglomerations of less than 2,000 PE (487 agglomerations in total). A total of 105 urban wastewater treatment plants have been built in the agglomerations with loads bigger than 2,000 PE (45 plants with the established treatment comply with the requirements of the Urban Wastewater Treatment Directive, i.e., have the required or higher treatment; this refers to 9% of the overall load of those agglomerations). 75 wastewater treatment plants have been built in the agglomerations of less than 2,000 PE (source: Multi-Annual Program for Construction of Water and Wastewater Structures for the Period until 2030).

In 2020, the sector of water services had total revenues of EUR 538 million and expenses of EUR 523 million. The whole sector in the aggregate recorded a positive result for the year 2020. Pre-tax profit amounted to 2.72% of the total sector revenues, whereas profit after tax amounted to 1.46%, which indicates that the whole sector in the aggregate doesn't exceed 5% of the permitted margin. Trends in the sector's revenues and expenses in the 2017-2020 period show a trend of higher increase of expenses in relation to revenues, resulting in a decreased profit in that period.

The majority of operating expenses has to with material costs, staff costs, and depreciation. The structure of PWSPs' operating expenses indicates potential future problems, i.e., financial stability problems can be expected as the result of the impact of growing prices of energy sources on the global and national markets and of the impact of inflation on the increased cost of work.

Operating revenues from the performance of water services (revenues based on the price of water services and the development fee) were estimated based on the data about PWSPs' average prices, delivered volumes of water, and overall financial data. Total operating revenues from water services in 2020 amounted to around EUR 500 million. Looking at the operating revenues generated from the water sold and development fee in the water supply sector, the total operating revenues are estimated at around EUR 253 million, of which around 70% come from the water sold to households, and 30% from the water sold to industry. The remaining operating revenues were generated from the sanitation and treatment service.

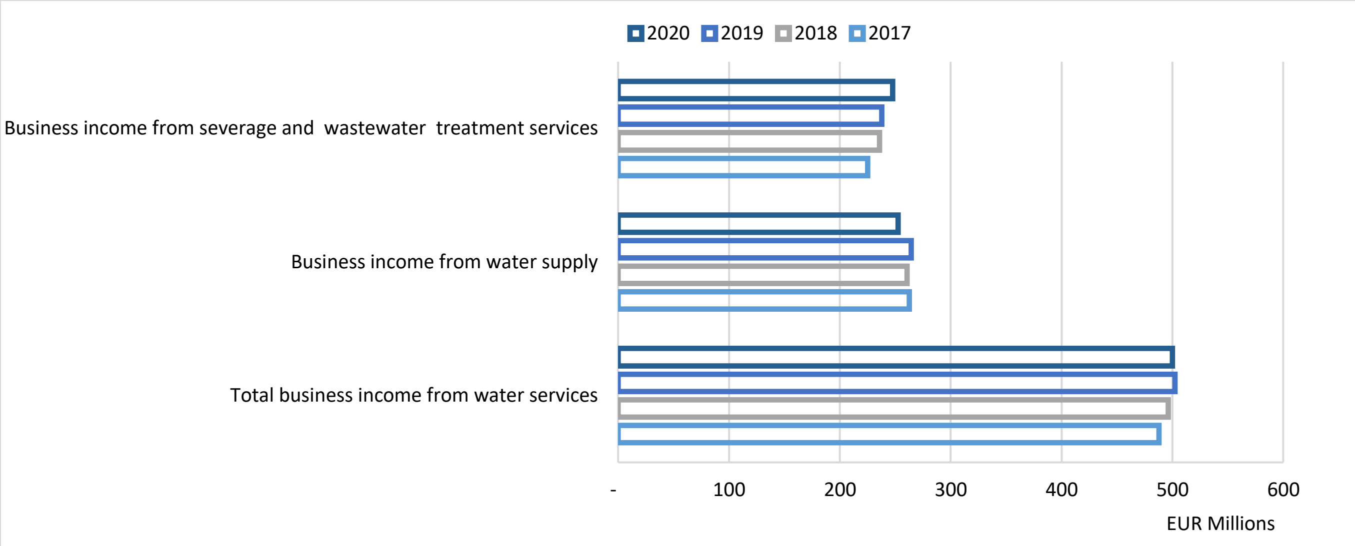

Figure 2.2. Estimated shares of revenues from individual water services (water supply, sanitation, and treatment) in total revenues from water services

The average total water price paid by the household category in 2020[5] was EUR 2.14 per m3. The prices ranged from EUR 1.26 per m3 to EUR 4.41 per m3. The specified total water price in the household category represents the total price of water paid by the citizens through the bills (a fixed part reduced to m3, a variable part, VAT, compulsory water fees, development fees).

The differences in the price have to do with the quantity (type) of the services provided, only water supply, water supply and sanitation, or water supply and sanitation with wastewater treatment, but also with the adequacy of the water price level related to the needs for successful system operation, maintenance, and development, i.e., whether the water price reflects the cost generated from the provision of the services.

At the level of PWSPs, the average share of the total price of water paid by citizens in the net disposable income of the population is 1.34%.

[5] Last available year.

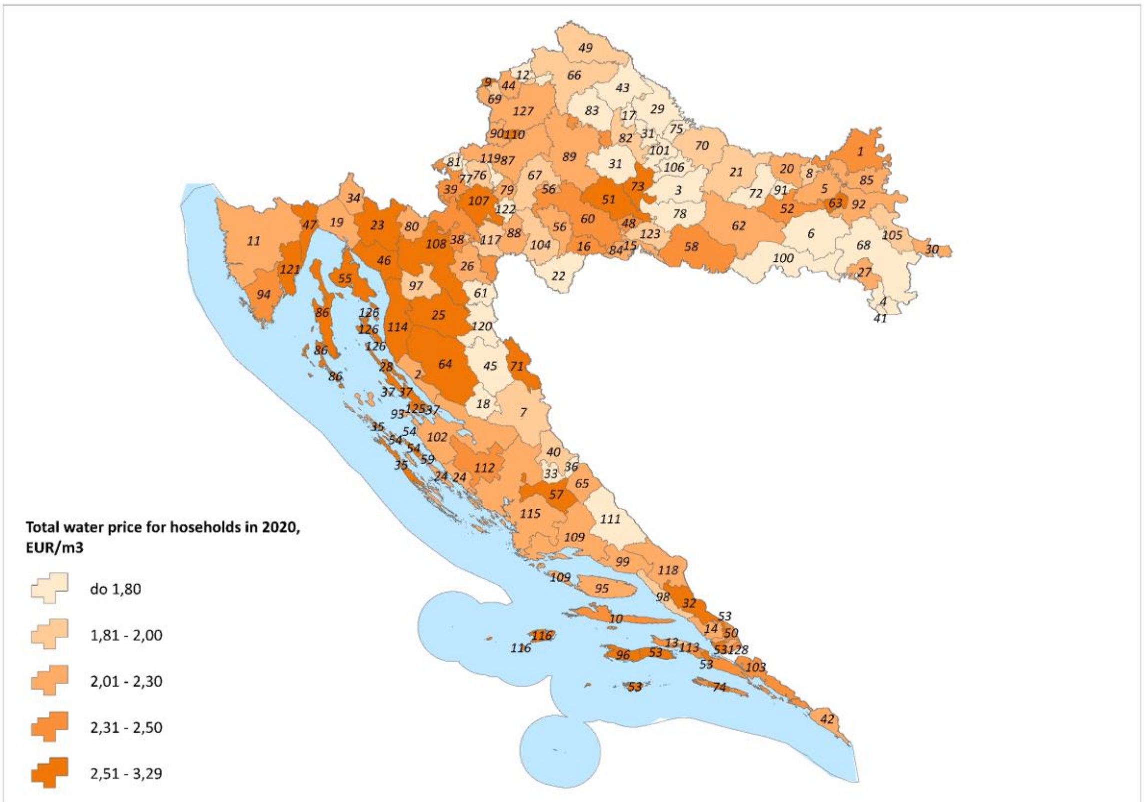

Figure 2.3. Average water price in 2020 for the household category, PWSP level (with IDs)

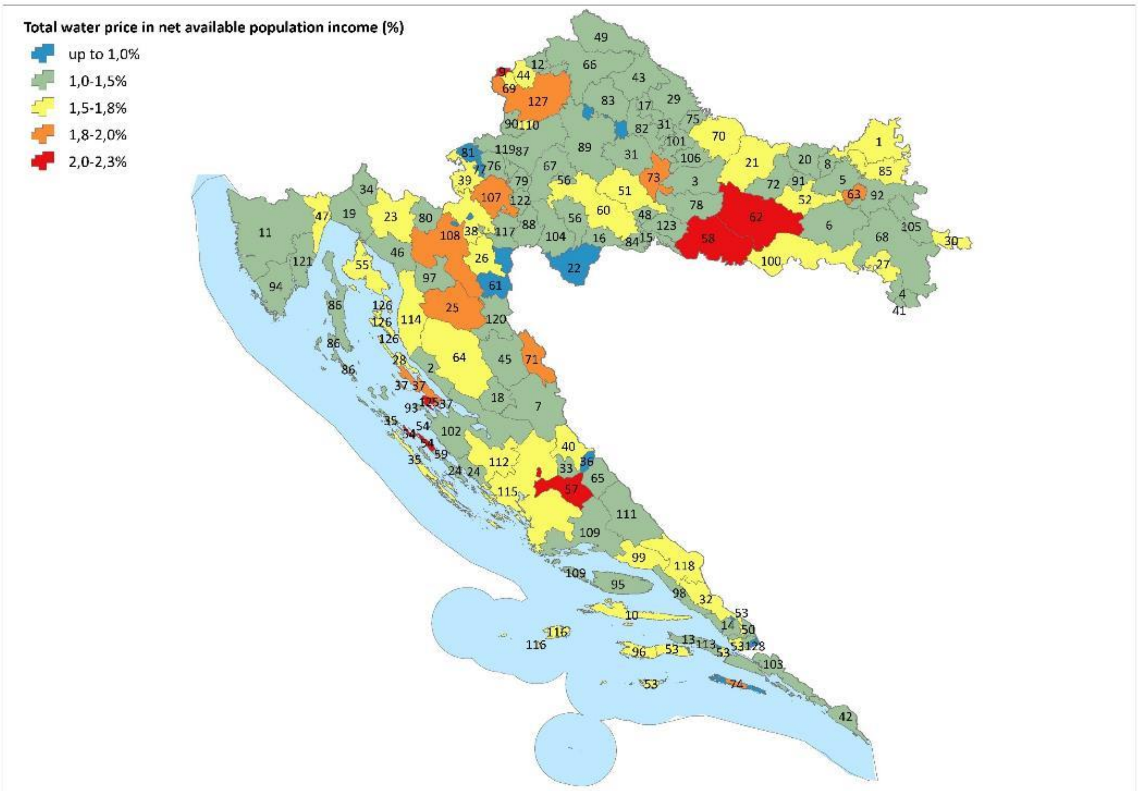

Figure 2.4. Share in net disposable household income of the average total water price in 2020 paid by citizens, PWSP level (with IDs)

The structure of the water price is defined by the provisions of the Water Services Act, the Regulation on the minimum basic price of water services and type of costs covered by the price of water services (2010), the Water Management Financing Act and the Value Added Tax Act. The Regulation on the minimum basic price of water services and type of costs covered by the price of water services is the basic instrument to achieve the cost recovery principle for water services, i.e., the costs of operation and management of hydraulic structures. The Regulation, among other things, lays down the components of a water service bill, making the structure of the water service price and the water fees charged alongside the water service price transparent. The structure of the price of water services needs to be adjusted to the reform requirements, which is why a Regulation on the methodology to define the prices of water services is being drafted and is planned to be adopted by the end of 2022. The Regulation will specify the types of costs recovered from the price of water services, the procedure of public consultation, the application of the rule about the same price of the water service in the service area and exceptions from that rule, the minimum volume of delivered water needed for basic household needs, permitted forms of cross-subsidies from the price of water service between different categories of water service users, the method of calculating the provision and price of the water service.

So, the prices of water services are defined based on the principle of the recovery of costs for water services as regulated by the law regulating the financing of water management within the limits of economic efficiency, and on the principles of equity, protection against monopoly and socially affordable price of water. The recovery of costs for water services is ensured on the one side by paying the price of water services and the development fee in the area where the water services are provided, and on the other side by paying the compulsory water usage fee and the compulsory water protection fee on the territory of the Republic of Croatia (principle of the recovery of costs for water services).

The responsibility for the provision of water services to users in Croatia is shared by about 160 public providers[6]. 15% of them provide only the services of public water supply, 68% provide the services of public water supply and sanitation (with or without the wastewater treatment service), and 17% provide exclusively the services of public sanitation (with or without the wastewater treatment service). The total volumes of water delivered by all the 128 public providers that deliver the water directly to their users amounted to 243.9 million m3 in 2021, which is by app. 4% more than in 2020 or close to 2019, when approximately 245.0 million m3 were delivered. The volumes of water delivered in 2018 are within -1.4% of the volumes delivered in 2019.

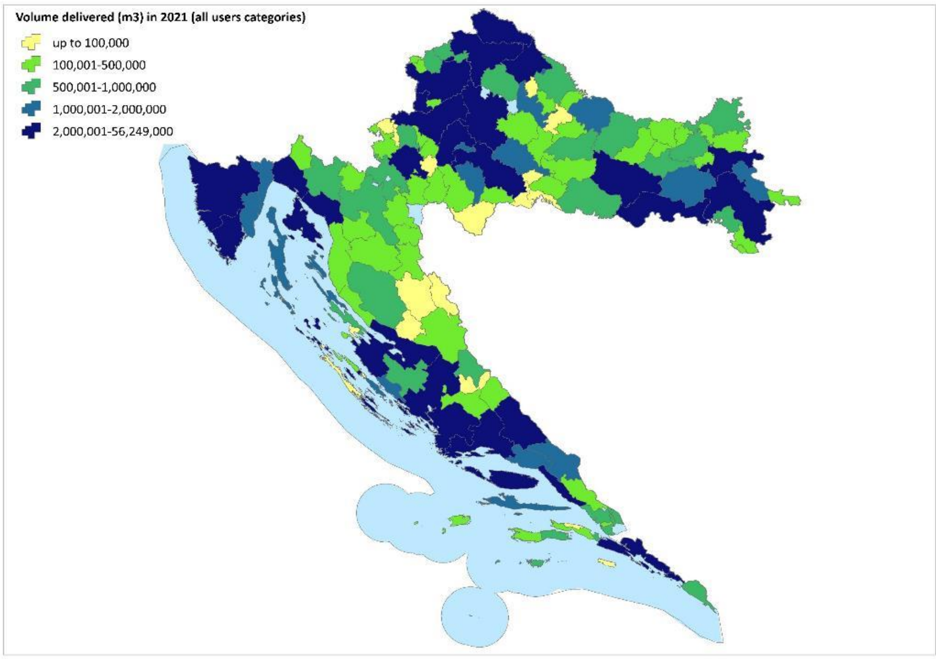

Figure 2.5. Spatial distribution of water volumes delivered (billed authorized consumption) to users in 2021 (PWSP level today)

[6] The water service sector has two more providers that don't directly provide (don't charge) the service to the users: the regional company Vodovod Hrvatsko primorje - Južni ogranak d.o.o. Senj that performs the service of intermediary delivery of water through 6 public water service providers, and the company Zagrebačke otpadne vode d.o.o. Zagreb that performs the service of urban wastewater treatment for the area of the PWSP Vodoopskrba i odvodnja d.o.o., Zagreb.

About 70% of the water providers deliver less than 1.0 million m3 per year (and as much as 50% of the providers, i.e., 64 of them, deliver less than 0.5 million m3 per year). The remaining 30% deliver on average 4.0 million m3 per year (the Zagreb PWSP is excluded from the average as the biggest provider with annual delivery of app. 56.3 million m3).

2.3.2 Service areas

One of the most significant strategic objectives of water management is the implementation of the reform in the sector of water services through institutional and technical integration of the existing PWSPs in a service area. The reform is ongoing, and its implementation had started in July 2019 with the adoption of the Water Services Act. The integration of PWSPs will ensure full implementation of the principle of recovery of costs for water services, meaning that the operation and maintenance of water and wastewater structures and the provision of water service of public water supply and sanitation is financed exclusively from the price of water service. Furthermore, water services have to be provided under socially affordable conditions, meaning that the price of water even after the implementation of EU-dictated investments is socially affordable within the limits of PWSP’ economic efficiency.

The adoption of the Water Services Act has established the legal basis for integration in the sector of water services, and the adoption of the Regulation on service areas (2021) has established the territorial basis for its operational implementation. The Regulation on service areas establishes new service areas, defines their borders, and the takeover company (PWSP). It is part of a series of regulations reforming/consolidating the water services sector. Although the establishment of the new service areas is taking place at a slightly slower rate than planned (related to procedures on the national level), it is estimated that the process of actual consolidation of the PWSPs will start in 2023.

Figure 2.6. New service areas (41 service areas planned, OG 147/21)

Table 2.1. Size of the planned service areas in relation to water volumes delivered to users (Billed authorized consumption

Annual volume of delivered water (m³/year)	Number of service areas
Up to 1,000,000	3
1,000,000-3,000,000	16
3,000,000-10,000,000	17
10,000,000-20,000,000	4
More than 20,000,000	1
Total number of planned service areas	**41**

2.4 New model of calculating the water usage fee

With the aim of reducing the environmental impacts of water abstraction, but also with the aim of reducing the costs of operating and managing water supply systems and reducing water losses, the Regulation on amendments to the Regulation on the amount of the water usage fee was adopted (OG 82/10, 83/12, 10/14, 32/20). It specifies the models of calculating the water usage fee (fee to cover resource and environmental costs[7]), which is one of the original revenues of Croatian Waters. Since the specified models of calculating the water usage fee also include the level of losses from public water supply systems, it is to be expected that with the start of application of this Regulation (1 January 2023) PWSPs will start taking measures to reduce the losses.

So, starting from 1 January 2023, the models for the calculation of the water usage fee will take losses into account, enabling the reduction of the fee if the losses are below 25%. On the other hand, the fee will be higher for those PWSPs that won't be efficient in reducing losses (which implies a potential increase of the price of water for end users). The new method of calculating the water usage fee can affect the majority of end users because the problem of water losses is widespread and affects the majority of PWSPs but is particularly marked for the 20 biggest PWSPs that cover the largest part of the population in Croatia. However, what is important, after the application of the new methodology of calculation from 1 January 2023, an increase of the price of water for end users cannot be higher than EUR 0.4 per m3. In other words, the volume of water losses affects the amount of the water usage fee which affects the price of water for end users. If PWSPs won't reduce their water losses, the consequence will be an increase of the price of water for end users (population and industrial activities).

In order to make an impact on the problems of the fragmented and inefficient sector with lacking capacities, the MESD promotes the integration of PWSPs that are responsible for the management of water supply systems in their (bigger) service area.

Activities for the reduction of losses will be monitored with the installation of meters at water abstraction points for public water supply and of a system to record, collect, analyze, and control data about abstracted water volumes, which is all organized by CW (the activity is in implementation).

Forecast has been made of the calculation of the water usage fee based on the current model and based on one of the models presented in the Regulation (the model more favorable for the PWSP was used, with a certain correction of the formula in agreement with the MESD, for which the MESD will issue the Calculation Application Guidelines[8]). The table below presents an incremental analysis of introducing the new calculation model for the water usage fee at the level of 41 service areas.

[7] The revenue from the water usage fee is used for collecting and keeping data about water reserves and their usage, monitoring the status of water reserves and taking measures for their economical usage, water research works, financing the construction of major public water supply structures: water intakes, pumping stations of drinking water treatment plants, pumping stations, storage tanks, mains and associated structures of the water supply network, and financing the reconstruction or rehabilitation of public water supply structures for the purpose of water loss reduction. The revenue from the water usage fee is used according to the principles of solidarity and priority in needs on the national territory. The current amount of the water usage fee for public water supply is EUR 0.39 per m3, with the basis for calculation billed authorized consumption. An average of around EUR 98.7 million per year was calculated over the last three years.

[8] This refers to the calculation which was in this forecast made in relation to the water supplied, which doesn't include the volumes of water exported to another PWSP.

Table 2.2. Analysis of introducing the new calculation model for the water usage fee

Service area	Water usage fee until January 2023 (EUR/year)	Water usage fee from January 2023 (EUR/year)	Increase/decrease of annual fee (EUR/year)
1	1.759.000	1.029.000	-731.000
2	2.714.000	2.382.000	-333.000
3	1.222.000	680.000	-542.000
4	1.231.000	929.000	-302.000
5	1.104.000	695.000	-410.000
6	982.000	881.000	-101.000
7	311.000	216.000	-95.000
8	3.320.000	3.028.000	-292.000
9	1.823.000	1.214.000	-609.000
10	1.059.000	1.165.000	107.000
11	21.751.000	24.697.000	2.946.000
12	1.124.000	1.108.000	-17.000
13	1.628.000	963.000	-666.000
14	2.229.000	3.117.000	888.000
15	779.000	1.314.000	535.000
16	902.000	1.271.000	369.000
17	676.000	412.000	-264.000
18	1.029.000	837.000	-193.000
19	355.000	274.000	-81.000
20	1.512.000	1.987.000	475.000
21	1.739.000	2.345.000	607.000
22	776.000	485.000	-291.000
23	4.715.000	3.087.000	-1.628.000
24	3.248.000	1.940.000	-1.309.000
25	5.932.000	5.641.000	-292.000
26	1.581.000	1.202.000	-379.000
27	763.000	675.000	-88.000
28	1.266.000	1.053.000	-213.000
29	751.000	1.654.000	903.000
30	4.143.000	6.410.000	2.267.000
31	922.000	1.110.000	189.000
32	3.388.000	3.918.000	531.000
33	7.106.000	10.000.000	2.895.000
34	1.090.000	1.412.000	322.000
35	717.000	673.000	-45.000
36	1.412.000	1.108.000	-304.000
37	1.591.000	2.314.000	723.000
38	752.000	1.135.000	384.000
39	755.000	916.000	162.000
40	1.843.000	1.738.000	-106.000
41	265.000	155.000	-110.000
Ukupno	**92.245.000**	**97.154.000**	**4.910.000**

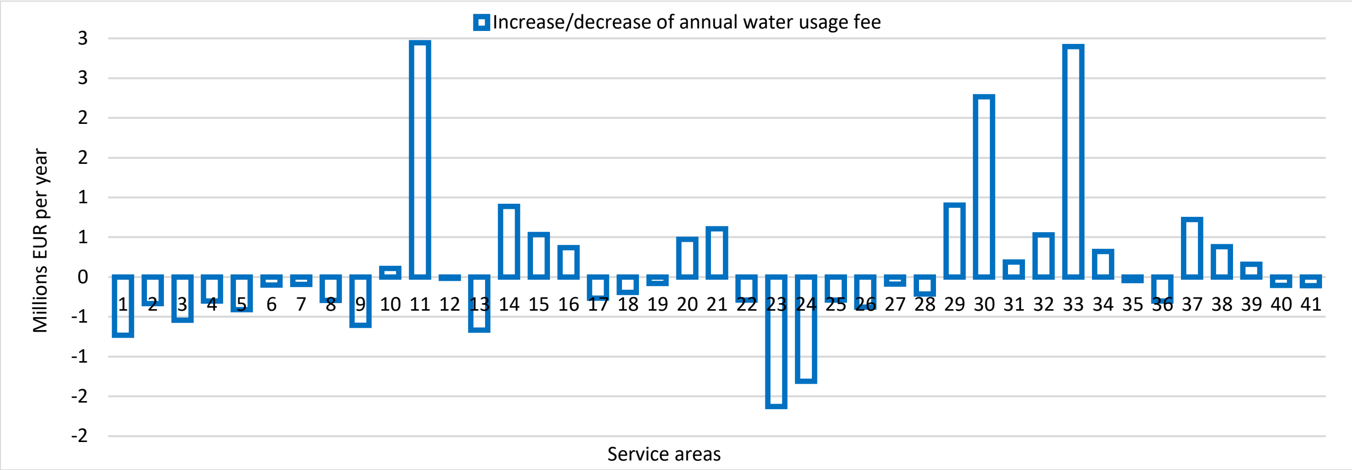

Figure 2.7. Changes in the calculation of the water usage fee after the introduction of the new model by service areas

With the presented changes to the existing system of calculation and collection of the water usage fee, the basis for the calculation becomes the abstracted (alternatively supplied to the system) water volume. It is expected that such system will encourage PWSPs to more economical consumption, but also to improving the efficiency of the water supply system they manage. Figure 2.8. shows an analysis of the total amount of the water usage fee after the introduction of the new model and comparison of the old and new fee payment models by PWSPs.

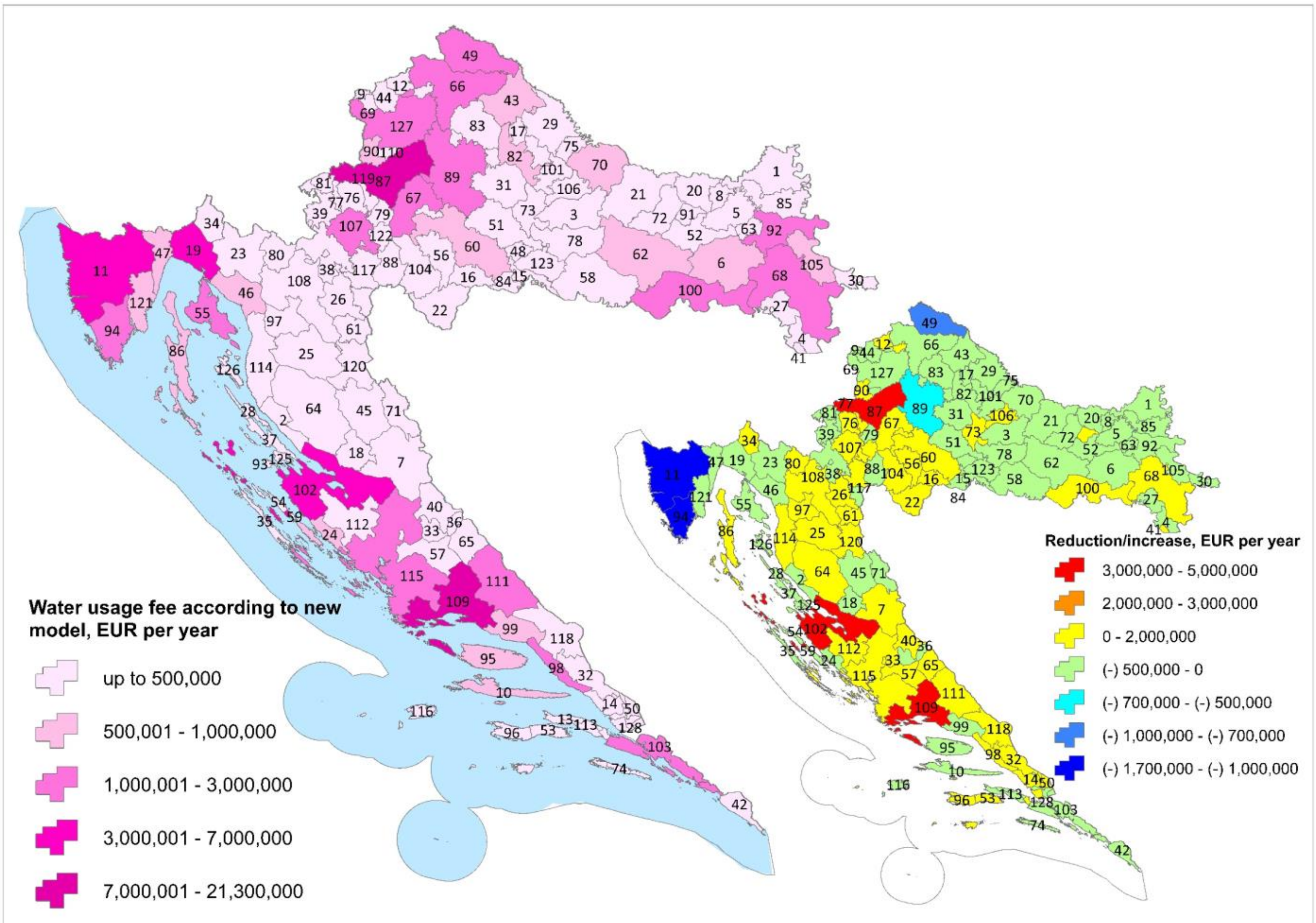

Figure 2.8. Revenues from the compulsory water usage fee according to the new model (left) and difference in revenues from the compulsory water usage fee according to the old and new models (right), PWSP level (with IDs)

2.5 Water Balance

The basis for the development of water loss management plans is gaining better understanding not only of the reasons behind the occurrence of water losses and the factors affecting them, but also of theoretical assumptions that define the term “water losses” and their components within the overall water balance.

2.5.1 Basic Water Balance

The analysis of water losses in Croatia has so far been largely associated with the basic (simplest) form of the water balance that implies three basic components: Water Supplied (the difference between the System Input Volume and the Water Exported), Billed Authorized Consumption (Revenue Water), and Non-Revenue Water. In practice, there is sometimes still misunderstanding between the terms “water supplied” and “system input volume”, with the term “water supplied” implying the overall volume of water input into the system, without subtracting the volumes exported to another PWSP.

In 2021, the total volume of water supplied in Croatia amounted to 479 million m3. The spatial distribution of the water supplied by PWSPs is presented in Figure 2.9.

The total volume of water delivered through the system to the final users in Croatia in 2021 amounted to 244 million m3. The spatial distribution of the annual water volumes delivered to final users (billed authorized consumption) by PWSPs is presented in Figure 2.10.

The total NRW volume in Croatia in 2021 amounted to 235 million m3. The spatial distribution of the annual NRW volumes by PWSPs is presented in Figure 2.11, while Figure 2.12. presents the spatial distribution of the annual NRW volumes by service areas.

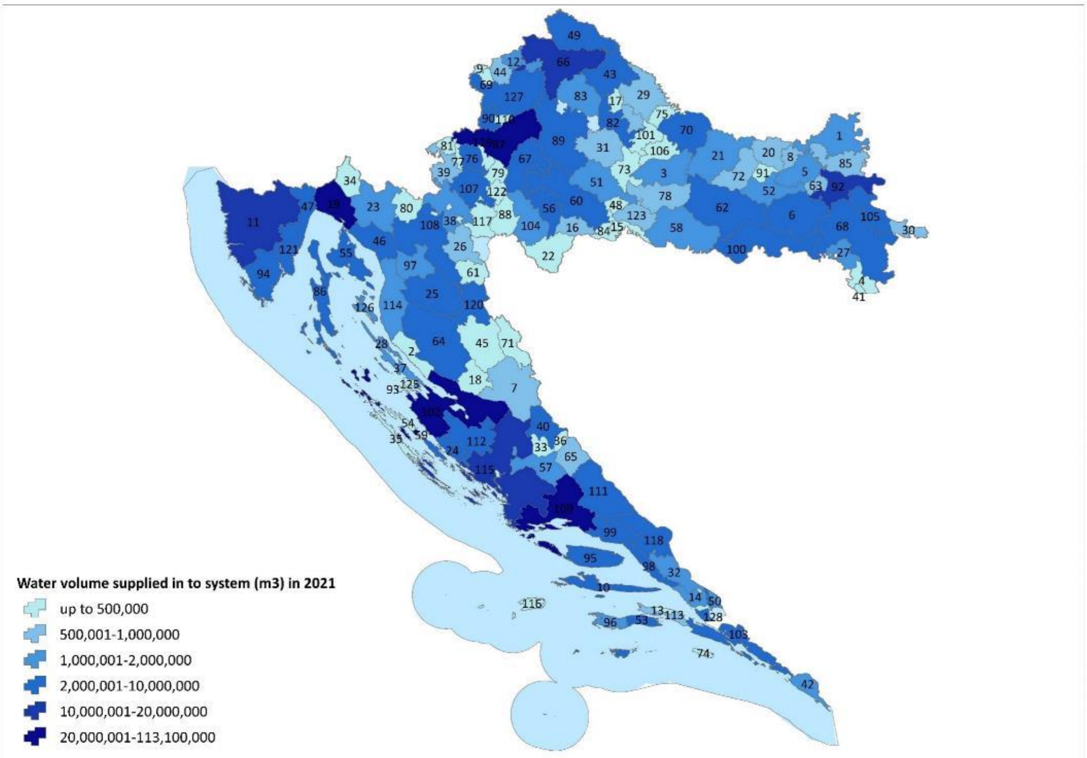

Figure 2.9. Spatial distribution of water supplied to water supply systems in Croatia, PWSP level (with IDs)

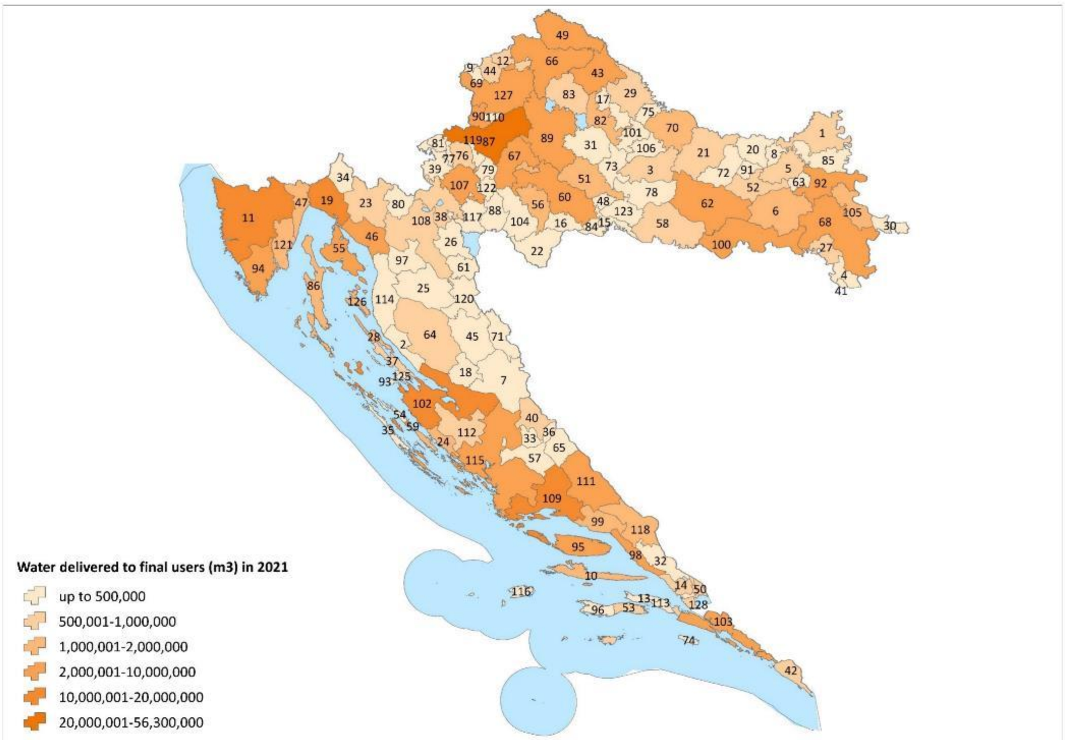

Figure 2.10. Spatial distribution of annual water volumes delivered to final users in Croatia (Billed Authorized Consumption), PWSP level (with IDs)

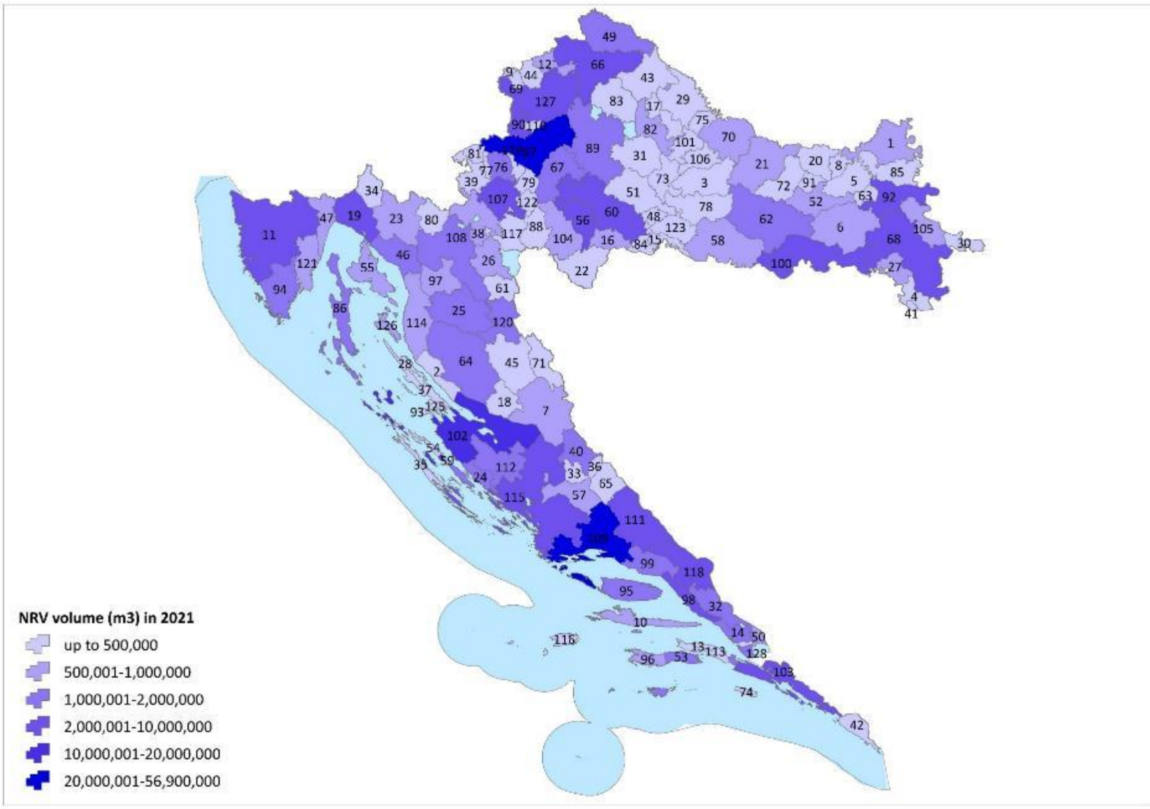

Figure 2.11. Spatial distribution of NRW in Croatia, PWSP level (with IDs)

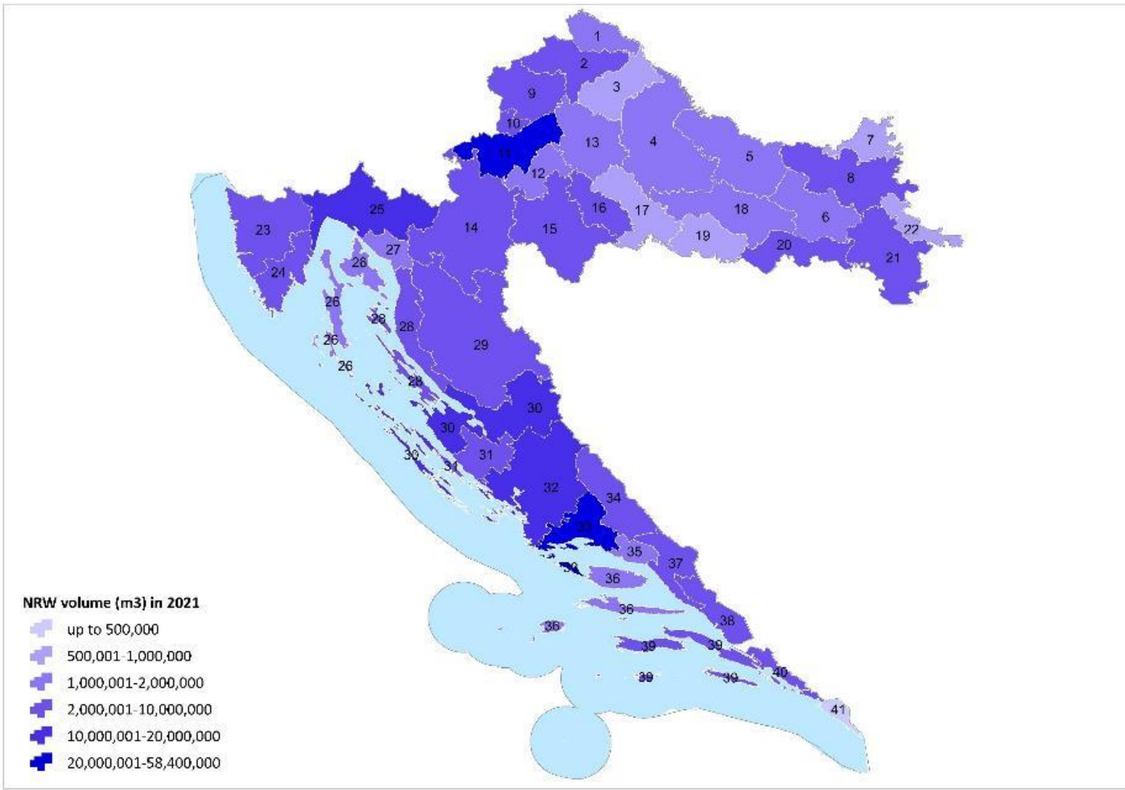

Figure 2.12. Spatial distribution of NRW in Croatia, level of 41 service areas (with IDs)

Figure 2.13. presents the basic water balance on the national level for the last 5 years, 2017-2021.

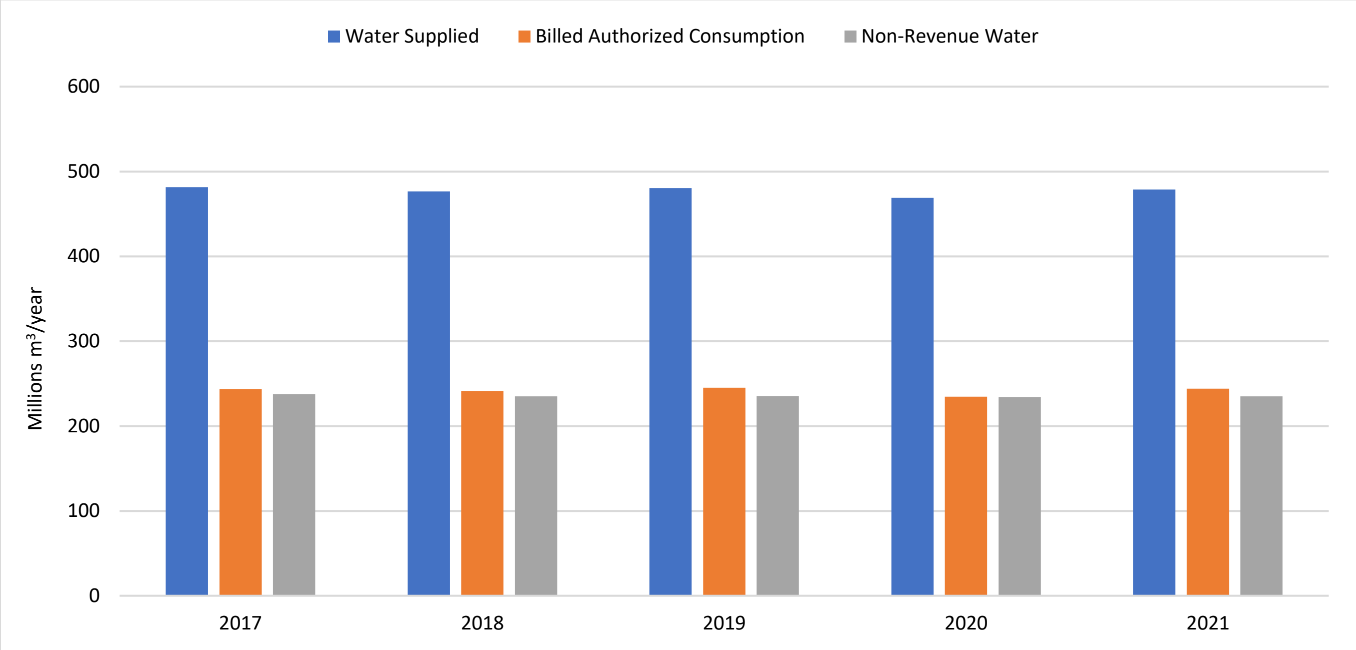

Figure 2.13. Basic water balance on the national level for the last 5 years (2017-2021)

One can notice that in terms of all the three basic components of the basic water balance the state has remained nearly unchanged over the last 5 years, with neither the NRW volume nor the NRW share changing significantly (around 49%). However, in the period until 2017 the NRW volumes had continuously increased (Figure 2.14), as the result of not implementing adequate water loss management on the national level, as well as in the majority of PWSPs. In early 2018, the line Ministry together with Croatian Waters initiated the National Water Loss Reduction Program (NWLRP) which is still in implementation. Its results are visible through stopping the negative trend of increasing water losses and achieving a certain reduction in 2018 and further stagnation until the end of 2021. In that period, some PWSPs have managed to rationally use the financial resources available from the NWLRP and reduce the NRW volumes from year to year, some have stagnating NRW volumes, while some have increasing NRW volumes from year to year (Figure 2.15. and Figure 2.16).

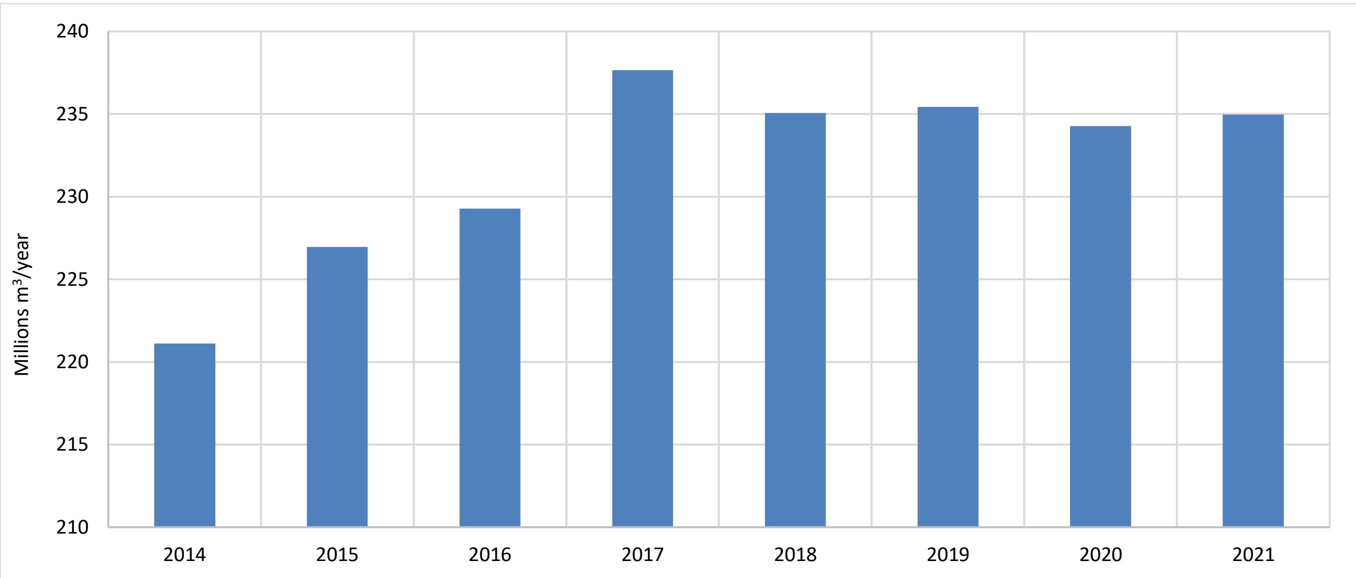

Figure 2.14. Trends in NRW volumes (m3/year), 2014-2021

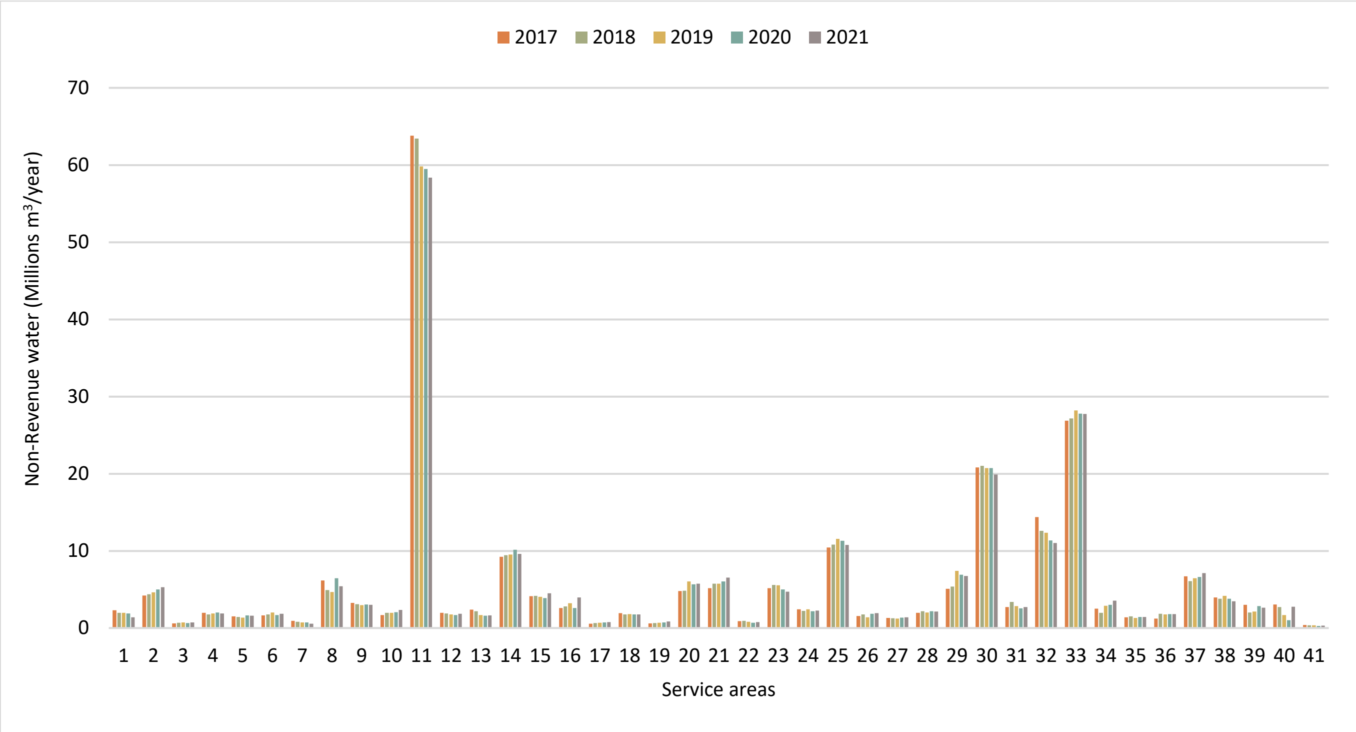

Figure 2.15. Basic water balance on the level of 41 service areas over the last 5 years (2017-2021)

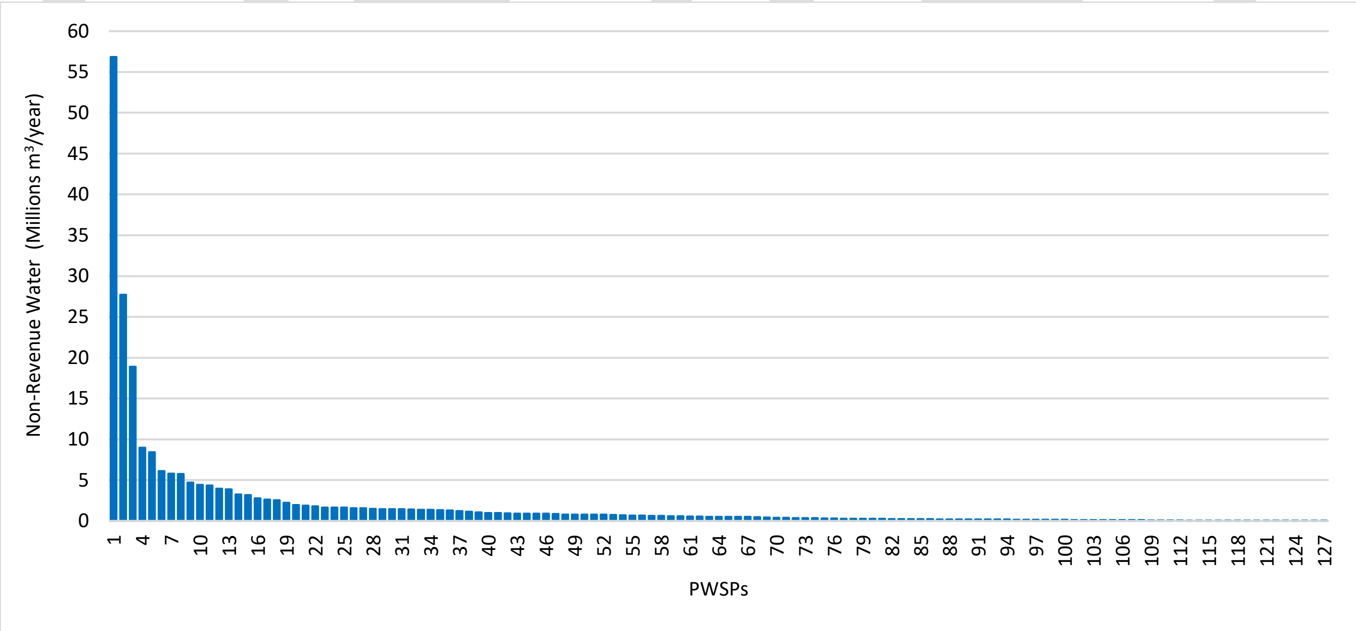

Figure 2.16. Change in NRW volumes by individual PWSPs in the 2017-2021 period (the positive and negative values refer to decreasing and increasing NRW, respectively)

Under the simplest form of the water balance described above, the term "water loss" in Croatian practice has so far been primarily associated with the NRW share.

The NRW share on the level of Croatia in 2021 was around 49%. The spatial distribution of the NRW share by PWSPs is presented in Figure 2.17, while Figure 2.18. presents the spatial distribution of annual NRW volumes by service areas.

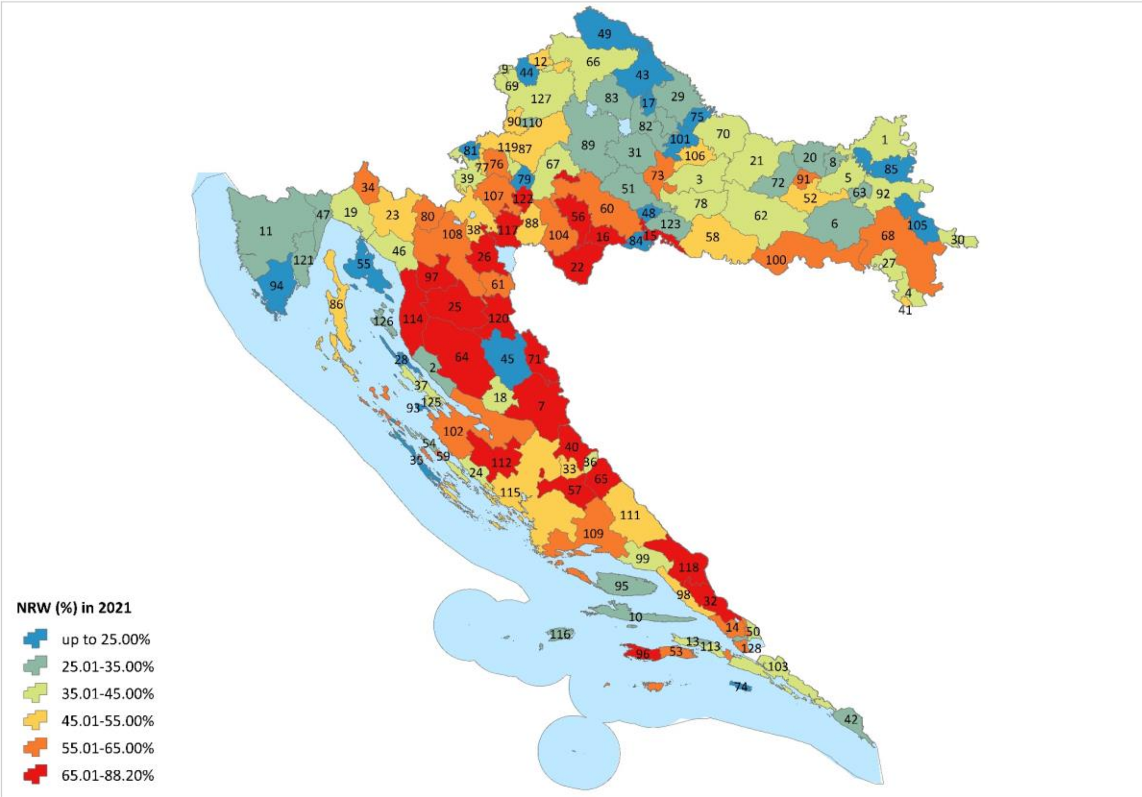

Figure 2.17. Spatial distribution of the NRW share in Croatia, PWSP level (with IDs)

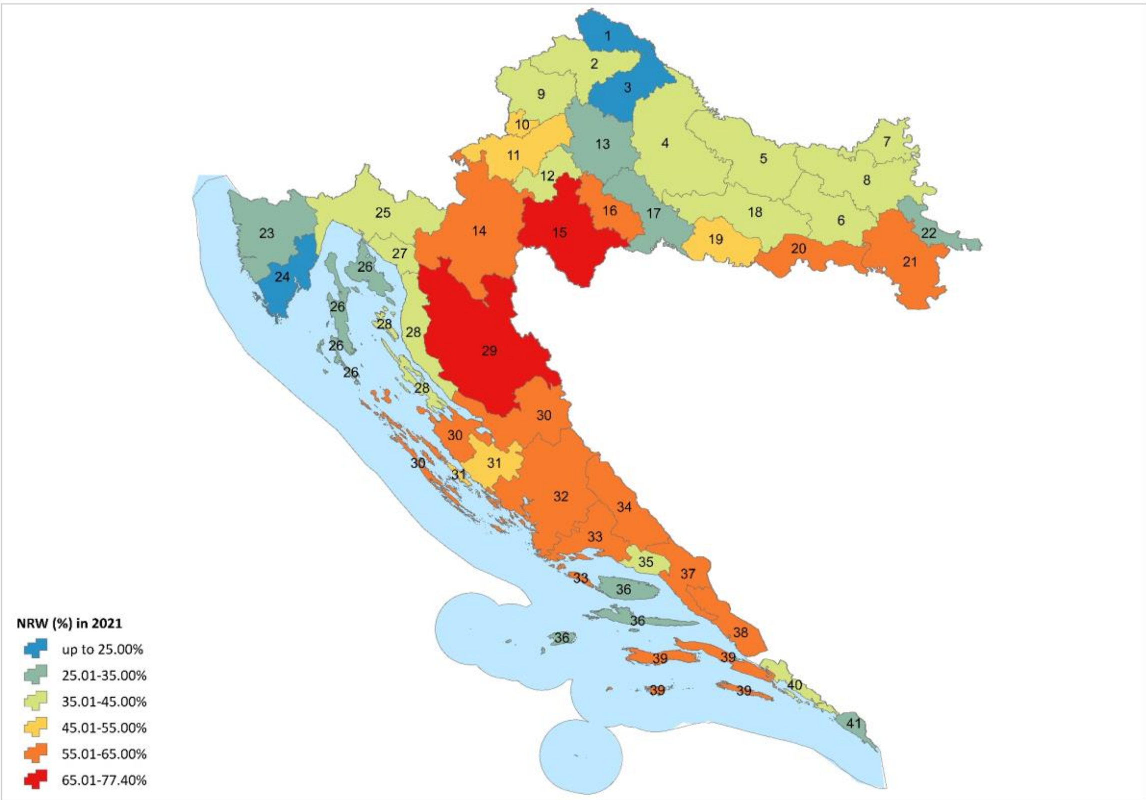

Figure 2.18. Spatial distribution of the NRW share in Croatia, level of 41 service areas (with IDs)

Although the terms "water loss" and "non-revenue water" are internationally accepted terms, it is necessary to make a distinction between the two. Non-Revenue Water (NRW) is defined as the difference between the water supplied and the revenue water:

Non-revenue water (m^3/year) = Water supplied (m^3/year) – Revenue water (m^3/year)

Water supplied = System input volume (m^3/year) – Water exported (m^3/year)

Water supplied = Revenue water (m^3/year) + Non-revenue water (m^3/year)

System input volume (m^3/year) = Volume from own sources (m^3/year) + Water imported (m^3/year)

In the same context, NRW is most often defined as the percentage of the Water Supplied:

$$NRW\ (\%) = \frac{Non-revenue\ water\ (m^3/year)}{Water\ supplied\ (m^3/year)} \cdot 100$$

$$NRW\ (\%) = \frac{Non-revenue\ water\ (m^3/year)}{Revenue\ water\ \left(\frac{m3}{year}\right) + Non-revenue\ water\ (m3/year)} \cdot 100$$

However, it needs to be stressed that such method of presenting the percentage share of NRW doesn't give an insight into the real state in terms of water losses. It also doesn't provide an insight into the real efficiency of the management of a particular water supply system in terms of water losses. Namely, based on the above calculation, the NRW share includes not only the NRW volumes, but also the volumes of revenue water on which the volume of water supplied depends. Analyzing two PWSPs with identical characteristics (the same network length, the same number of population) and with the same NRW volume, but different volumes of revenue water, the NRW share apparently decreases for the PWSP with a higher volume of revenue water (e.g., as the result of increased water consumption by the existing or new industrial or tourist facility).

On the other hand, for the PWSP that through the implementation of certain activities and financial investment has achieved a certain reduction of water losses, but had a decrease in water consumption at the same time (e.g., decreasing population, decreased specific water consumption by the population, decreased water consumption by industry), there is an apparent impression that the water losses have remained on the same level because the calculated value of the NRW share has remained the same. For that reason, evaluating the efficiency of the water loss reduction program based on the NRW share is assessed as inappropriate, since it can lead to wrong conclusions that water loss reduction hasn't been achieved, whereas it has clearly been achieved in terms of volume..

Figure 2.19. presents the sensitivity of the change in the NRW share to changes in the Revenue Water on the national level, with a realistic range of change in Revenue Water from 0 to 15%. In other words, it is presented that, assuming that the NRW volumes don't change on the national level, there is a change in the NRW share as the result of reduction in the Revenue Water (pointing out the fact about a population decrease according to the 2021 Census, or specifically a population drop by around 9.5% or around 400,000 people). This additionally clarifies that water losses expressed as the NRW share cannot be a transparent indicator of the assessment of the state of a PWSP, and even of a country, in relation to efficiency in water loss management, of which account was taken when proposing the indicators of water losses today and after the implementation of the water loss reduction measures (Chapters 2.6. and 3.2.4.).

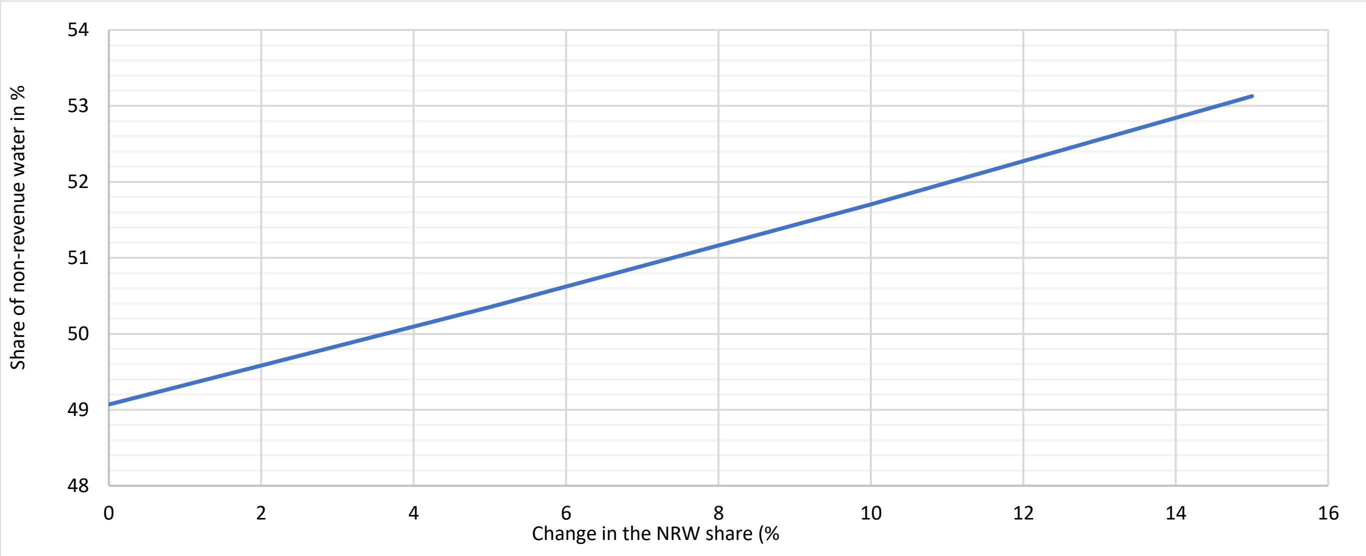

Figure 2.19. Sensitivity of the change in the NRW share to changes in the Revenue Water on the national level in Croatia

Analyzing the state in PWSPs in Croatia, it can be concluded that there is no correlation between the NRW volume and the NRW share, which is visible in Figure 2.20. For example, some PWSPs that have relatively low NRW volumes have a high NRW share and vice versa. Consequently, it cannot be concluded that the NRW shares increase with increasing NRW volumes.

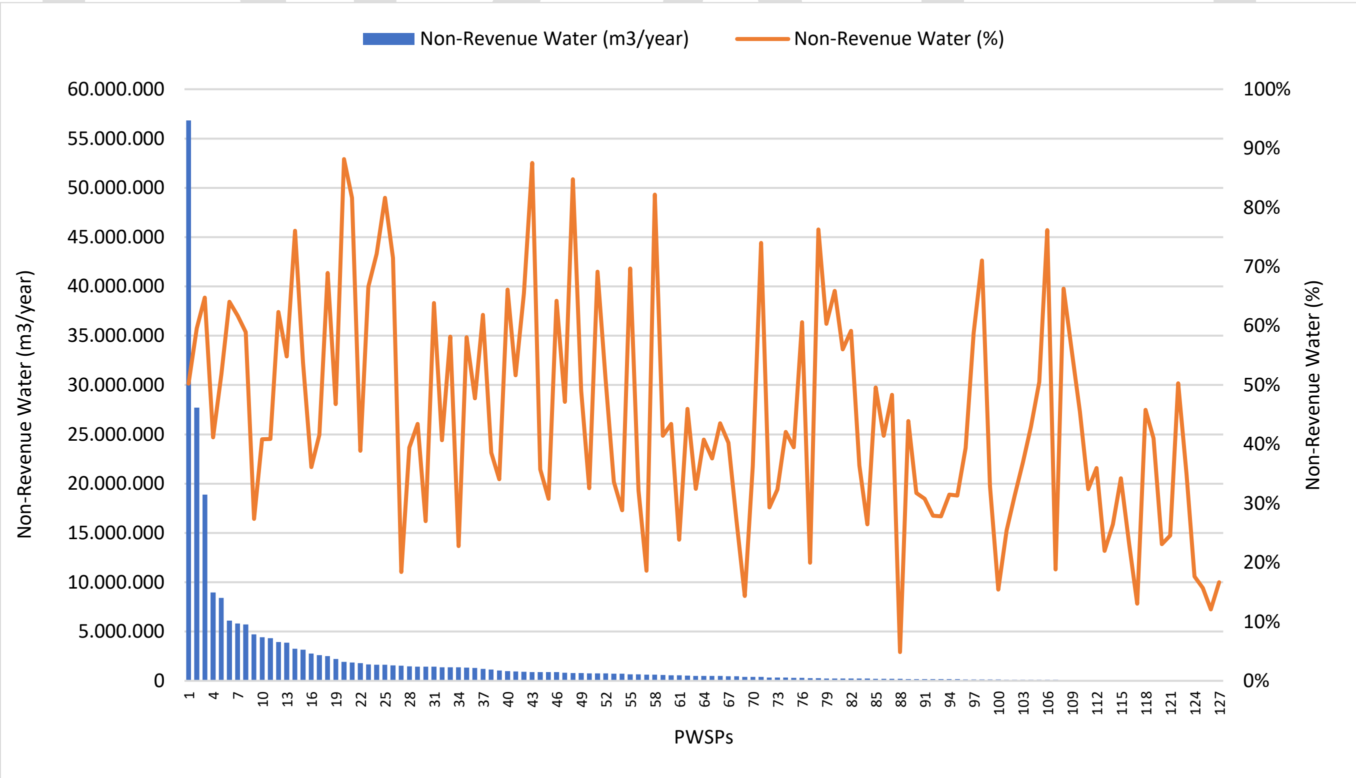

Figure 2.20. Comparison of NRW volumes and NRW shares by PWSPs in Croatia (2021)

Analyzing the NRW volumes on the level of individual PWSPs, it can be concluded that the distribution of the NRW volumes is highly uneven (part of the chart marked in blue in Figure 2.20. A few PWSPs in Croatia account for the majority of NRW volumes on the national level.

For example, 5 PWSPs with the biggest NRW volume account for around 51% (120,797,503 m3/year) of the total NRW volume on the national level (234,957,677 m3/year).

10 PWSPs with the biggest NRW volume account for 63% (147,574,685 m3/year) of the total NRW volume on the national level (234,957,677 m3/year).

15 PWSPs with the biggest NRW volume account for 71% (166,132,107 m3/year) of the total NRW volume on the national level (234,957,677 m3/year).

20 PWSPs with the biggest NRW volume account for 76% (178,177,231 m3/year) of the total NRW volume on the national level (234,957,677 m3/year).

On the other hand, 60 PWSPs with the smallest NRW volume account for 4% (9,398,599 m3/year) of the total NRW volume on the national level (234,957,677 m3/year).

80 PWSPs with the smallest NRW volume account for around 9% (21,934,324 m3/year) of the total NRW volume on the national level (234,957,677 m3/year).

90 PWSPs with the smallest NRW volume account for around 13% (31,343,181 m3/year) of the total NRW volume on the national level (233,706,601 m3/year).

The analyses made confirm that a bigger impact on the national level is achieved at a 10% reduction of the NRW volume among the 20 largest PWSPs than at a 50% reduction of the NRW volume among the 90 smallest PWSPs. From the above it can be concluded that in order to reduce the NRW on the national level the priority is to implement improvement measures and reduce the NRW among the PWSPs with the currently biggest NRW volumes, which are at the same time the PWSPs with the biggest volumes of water supplied to the system and the biggest volumes of billed authorized consumption, even though it is clear that the required financial investment for the largest PWSPs will also be higher. Such statement does not mean that at the same time it is not necessary to implement the water loss reduction program among the smaller PWSPs, i.e., among the PWSPs which now have smaller NRW volumes, but rather that the reduction of water losses among such PWSPs will contribute to the reduction of water losses on the national level to a smaller extent.

2.5.2 'Standard' and 'Extended' water balance

As a response to the deficiencies in expressing water losses as a % of NRW, as part of the practice of developed countries new standards were defined that provide a more detailed insight into the real state and enable making conclusions of better quality. In order for the issue of water losses to be understood better, the International Water Association (IWA) defined a new water balance standard, i.e., the preparation of a 'Standard' Water Balance and an ' Extended' Water Balance, adopted on the global level under the name of “IWA methodology”.

Developing the standard and extended water balance comes down to calculating all the components of the NRW and standardizing (unifying) the individual components and terminology, with a special focus on distinguishing between the terms “water losses” and “leakages” by defining real and apparent losses, because by knowing the exact volumes of this part of the water balance it is later possible to properly plan measures and activities for their reduction.

Even though water losses are most often associated with poor condition of the infrastructure (old age of the mains network, inadequate maintenance and repair, high pressures, frequent and intensive water hammers), it is important to note that not all water losses are the result of poor condition of the infrastructure and leakages from the mains network. Apparent losses in the network which are associated with unauthorized water use (unauthorized consumption) and water consumption metering inaccuracies can represent a significant share in the overall water balance, also belonging to the category of water losses and NRW. For that reason, the IWA methodology defines water losses as follows:

$$\textit{Water Losses } (m^3/year) = \textit{Water Supplied } (m^3/year) - \textit{Authorized Consumption } (m^3/year)$$

$$\textit{Water Losses } (m^3/year) = \textit{Real Losses } (m^3/year) + \textit{Apparent Losses } (m^3/year)$$

Real losses include leaks from pipes, joints and fittings, leaks through the bottom and walls of storage tanks, as well as through overflows on storage tanks. Real losses can be very high and can remain undetected over a number of months or even years. The volume of water lost will largely depend on the characteristics of the mains network and the leak detection and repair policy implemented by the water service provider, i.e., on:

- Network pressure;
- Frequency and intensity of new leaks and bursts;
- The share of new leaks that are 'notified';
- 'Perception' time (how fast a leakage is perceived);
- 'Location' time (how fast is every new leakage located);
- Repair times (how fast are leakages repaired or eliminated from the system);
- 'Background leakage' level (small undetectable leakages).

Leakage is usually the main component of water losses in many water supply systems. However, that is not always the case, because on the other hand many water supply systems have a high share of illegal connections and unauthorized consumption of water, as well as metering inaccuracies or accounting errors, all of which makes the component of apparent losses significant.

Table 2.3. presents the standard water balance on the Croatian level based on the 2021 data. Some components of the standard water balance (Water Supplied and Billed Authorized Consumption) were taken over from the registers (basic water balance according to the SOV database) filled in by the PWSPs themselves. The standard water balance doesn't make the term 'Water Supplied' or its calculation fully understandable, with the component of volumes of water exported to other PWSPs also missing, which is also important from the aspect of correct calculation of the non-revenue water for those PWSPs that export water to another PWSP. Namely, in the practice so far, the non-revenue water for some PWSPs has been calculated incorrectly as the difference between the 'System Input Volume' and the 'Revenue Water', with the NRW thus incorrectly including the water exported to another PWSP. A full understanding of the water balance is provided by the 'Extended' water balance. U Table 2.4. presents the extended water balance on the Croatian level based on the 2021 data. Some water balance components (Volume from Own Sources, Water Imported from other PWSPs, Water Exported to other PWSPs, and Billed Authorized Consumption) were taken over from the registers (basic water balance according to the SOV database) filled in by the PWSPs themselves. The 'Extended' water balance clearly shows all the components, without the possibility of their wrongful interpretation, and with risks of errors in the calculation reduced to the minimum. Analyzing the 'Extended' water balance it is clear that the 'System Input Volume' is calculated as the sum of the metered 'Volume from Own Sources' and the 'Water Imported from another PWSP'. It is also clear that the 'Water Supplied' for the system for which the extended water balance is prepared is calculated as the difference between the 'System Input Volume' and the 'Water Exported to another PWSP'. It is also clear that the non-revenue water is calculated as the difference between the already calculated 'Water Supplied' and the 'Revenue Water' ('Billed Authorized Consumption'). The main terms from the standard and extended water balance are described in Table 2.5.

Table 2.3. Standard water balance on the Croatian level based on the 2021 data (values in m3/year)

<table>
<tr><td rowspan="9">Water Supplied
478,823,423</td><td rowspan="4">Authorized Consumption
250,499,832</td><td rowspan="2">Billed Authorized Consumption
243,865,747</td><td rowspan="2">Revenue Water
243,865,747</td><td>Billed Metered Consumption</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
6,634,086</td><td rowspan="7">Non-Revenue Water
234,957,677</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
228,323,591</td><td rowspan="2">Apparent Losses
13,577,145</td><td>Unauthorized Consumption
7,051,613</td></tr>
<tr><td>Customer Metering Inaccuracies (and data handling errors)
6,525,532</td></tr>
<tr><td rowspan="3">Real Losses
214,746,446</td><td>Leakage on Mains</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of customer metering</td></tr>
</table>

Table 2.4. Extended water balance on the Croatian level based on the 2021 data (values in m3/year)

Volume from Own Sources 479,123,913	System Input Volume (corrected for known errors) 521,977,620	Water Exported to another PWSP 43,154,197				Billed Water Exported to another PWSP
Water Imported from another PWSP 42,853,707		Water Supplied 478,823,423	Authorized Consumption 250,499,832	Billed Authorized Consumption 243,865,747	Revenue Water 243,865,747	Billed Metered Consumption
						Billed Unmetered Consumption
				Unbilled Authorized Consumption 6,634,086	Non-Revenue Water 234,957,677	Unbilled Metered Consumption
						Unbilled Unmetered Consumption
			Water Losses 228,323,591	Apparent Losses 13,577,145		Unauthorized Consumption 7,051,613
						Customer Metering Inaccuracies (and data handling errors) 6,525,532
				Real Losses 214,746,446		Leakage on Mains
						Leakage and Overflows at Storage Tanks
						Leakage on Service Connections up to point of customer metering

Table 2.5. Description of the main terms in the extended water balance

Term	Description
Volume from Own Sources	Volume of water entering the system from own sources of the water service provider
Water Imported from another PWSP	Volume of water taken over from other water service providers
Water Exported to another PWSP	Volumes of water delivered to another water service provider
System Input Volume	Volume of water input into that part of the water supply system to which the water balance relates, with metering errors corrected. It equals the sum of Volume from Own Sources and Water Imported
Water Supplied	System Input Volume minus the Water Exported to another PWSP
Authorized Consumption	Volume of water (metered and unmetered) consumed by registered consumers, the water service provider, and other authorized consumers (firefighting, watering of municipal gardens, street cleaning, etc.)
Billed Authorized Consumption	Volume of water consumed by registered consumers. It comprises metered (read water meters of registered consumers) and unmetered (lump estimates) volumes
Unbilled Authorized Consumption	Volume of water consumed (metered and unmetered) by the provider of water services (water treatment, flushing of pipeline network, frost protection, filling and cleaning of water tanks, etc.) and other authorized unregistered consumers (firefighting activities and drills, flushing of sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc.)
Water Losses	The difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses and Real Losses
Real Losses	Water physically lost from the water supply system during its transport from the water intake to the consumer (mains, storage tanks, service connections up to the point of customer metering)
Apparent Losses	Water lost due to unauthorized consumption (illegal connections and water theft, for example from hydrants), customer metering inaccuracies, and errors in data handling (calculations)

The Unbilled Authorized Consumption was estimated based on the results of the studies and conceptual solutions prepared before, and certain indicators and experience of each individual PWSP. For the PWSPs where the PWSP itself uses significant volumes of water for the needs of water treatment or provision of sanitary quality of drinking water through occasional flushing of mains, and with increased water use by public institutions (e.g., firefighters, etc.), higher values of the share of Unbilled Authorized Consumption have been adopted. The minimum share of the Unbilled Authorized Consumption amounts to 0.5%, whereas the maximum value ranges up to 20% in relation to the Billed Authorized Consumption, and the averaged value weighted against the Billed Authorized Consumption amounts to 2.7% (Figure 2.9).

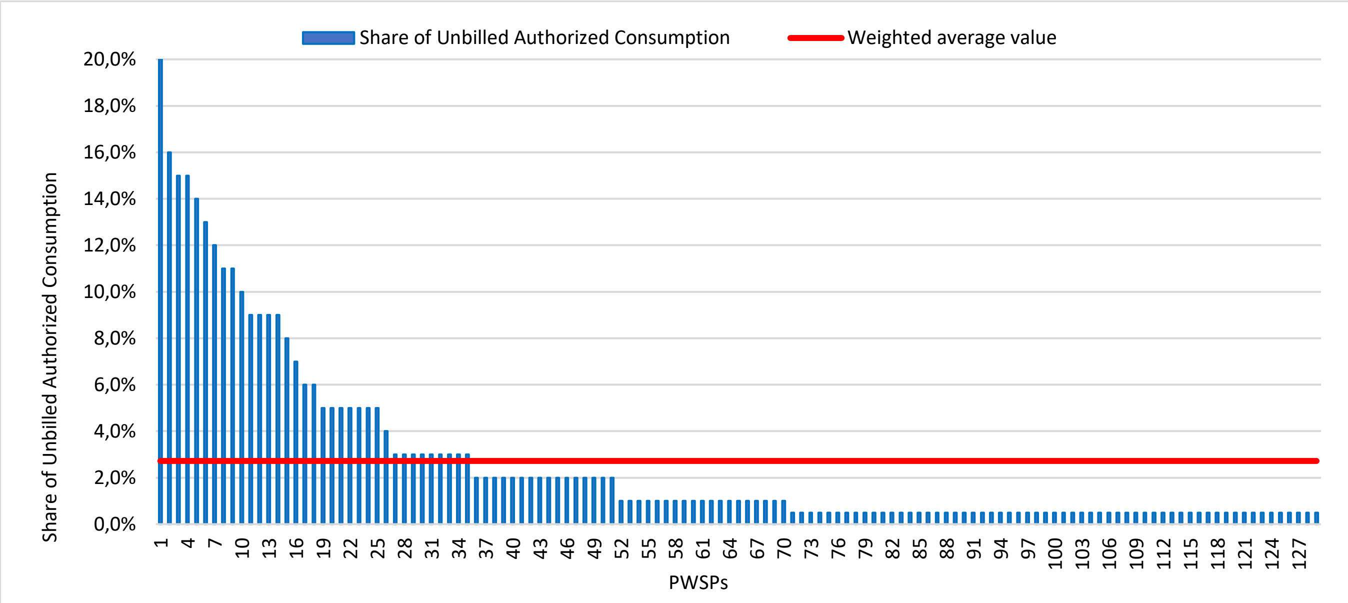

Figure 2.21. Share of 'Unbilled Authorized Consumption' in relation to 'Billed Authorized Consumption' by PWSPs

The Unauthorized Consumption was estimated based on the results of the questionaries that were filled in by the PWSPs for the purpose of preparing the relevant analyses of current status, that were based on certain indicators and experience of individual PWSPs, in combination with the results of the studies and conceptual solutions prepared before. The minimum share of the Unauthorized Consumption amounts to 0.2%, whereas the maximum value ranges up to 17% in relation to the Billed Authorized Consumption, and the averaged value weighted against the Billed Authorized Consumption amounts to 2.9% (Figure 2.22). When defining the share of Unauthorized Consumption by PWSPs, account was taken of flow measurements by DMAs established either permanently or for the purpose of developing conceptual solutions and of the assessment of the intensity of water theft in the system and method of controlling illegal connections by PWSPs.

When assessing Customer Metering Inaccuracies (and data handling errors), the reference value of Customer Metering Inaccuracies was initially defined as 5% in relation to the Billed Authorized Consumption, and was later on corrected in relation to the earlier analyses of the questionary results that relate to the frequency of water meter readings, the way in which water meter readings are controlled, the water meter replacement practice and the age of water meters, the state related to the water meter precision class, and the way in which consumer databases are managed by PWSPs. Na Figure 2.23. presents the distribution of the adopted Customer Metering Inaccuracies by PWSPs, based on the results of the analyses made earlier.

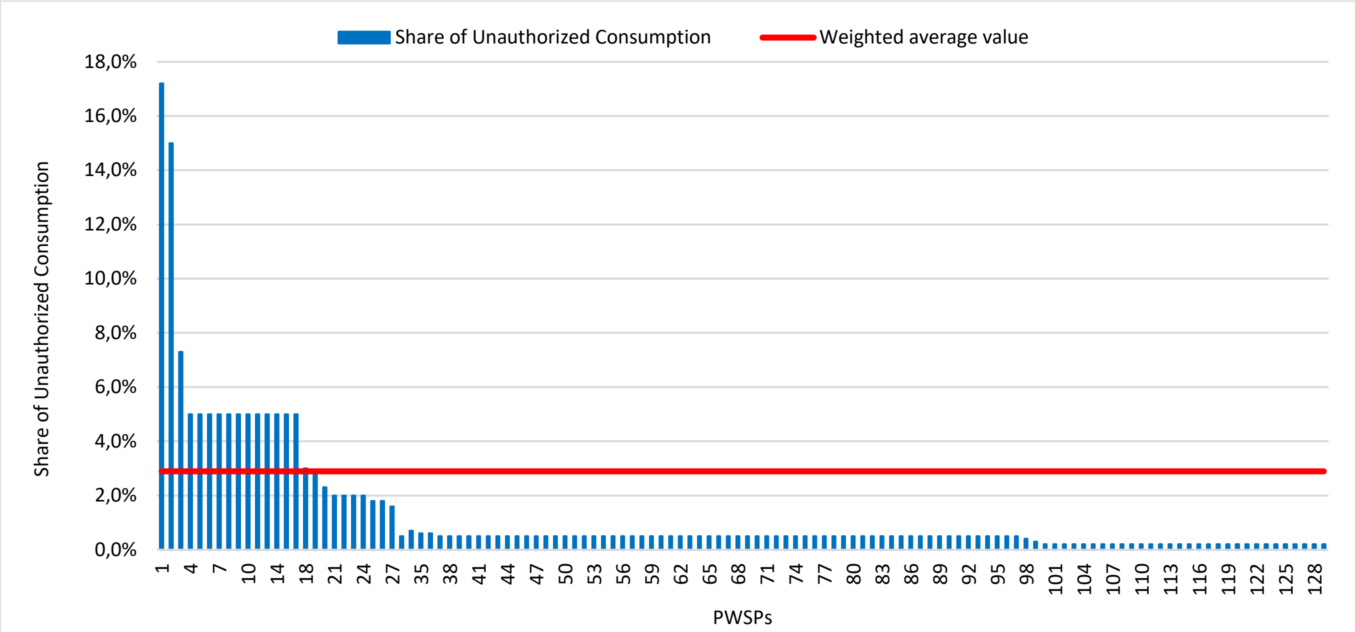

Figure 2.22. Share of 'Unauthorized Consumption' in relation to 'Billed Authorized Consumption' by PWSPs

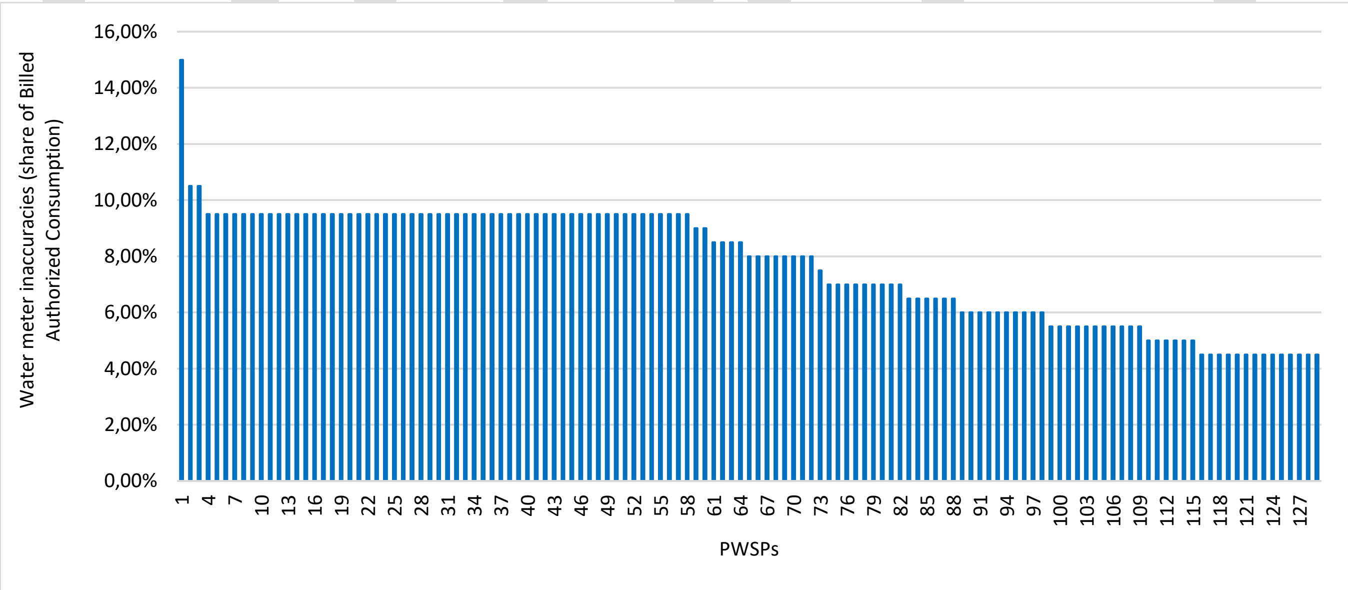

Figure 2.23. Customer Metering Inaccuracies as a share of Billed Authorized Consumption

All the components of the water balance are prone to errors in inputs. Therefore, the NRW and its components calculated from the water balance aren't exact figures, even in fully metered systems. In other words, all the metered or estimated inputs in the water balance may have an error or be more or less uncertain, with such errors accumulating in the eventually calculated real losses, resulting in the uncertainty of the calculated value of real losses.

In line with that, more recent examples of the application of the IWA methodology are associated with an analysis of 95% confidence of the calculation of the water balance components, the purpose of which among other things is to identify priorities in the implementation of activities to improve metering accuracies or estimates of water volumes, in order for the estimate (calculation) of the volume of real losses, and thus also of the monitoring of the real state in the system, to eventually be as accurate as possible.

The analysis implies applying a method of calculating confidence with 95% certainty of accuracy, with initial definition of the value of the 95% confidence limit for Water Supplied, Unbilled Authorized Consumption, and Apparent Losses, and with automatic calculation of the values of the 95% confidence limit for the NRW, Water Losses, and Real Losses.

Table 2.6. contains an analysis of 95% confidence of the calculation of the water balance components on the level of Croatia. The obtained results are also graphically analyzed and presented in Figure 2.24. The adopted 95% confidence limit for the Water Supplied is 5% and was estimated based on the results of the questionaries filled in by the PWSPs for the purpose of making the analyses of the current status, which are based on certain indicators and experience of individual PWSPs. The adopted 95% confidence limit for the Unbilled Authorized Consumption is 50% and was estimated based on the analyses made earlier, which are based on certain indicators and experience of individual PWSPs. The adopted 95% confidence limit for the Apparent Losses is 30% and was estimated based on the analyses made earlier, which are based on certain indicators and experience of individual PWSPs.

Table 2.6. Analysis of 95% confidence of the calculation of Water Balance components on the national level

IWA Water Balance components	**Volume (V) in m³/year**	**95% confidence limit (CL)**		**+/- m3**	**Standard deviation (SD) [=V x Pt / 1.96]**		**Variance (Va) [=SD²]**
Water Supplied	478,823,423	+/- *	5%	23,941,171	12,214,883	→	149,203,372,705,185
-							+
Billed Authorized Consumption	243,865,747	+/- *	0%	0	0	→	0
NRW	**234,957,677**	**+/-**	**10%**	23,941,171	**12,214,883**	←	**149,203,372,705,185**
		[=SD/Vx1.96]					
-							+
Unbilled Authorized Consumption	6,634,086	+/- *	50%	3,317,043	1,692,369	→	2,864,112,365,810
Water Losses	**228,323,591**	**+/-**	**11%**	24,169,867	**12,331,565**	←	**152,067,485,070,995**
-		[=SD/V/0.5]					+
Apparent Losses	13,577,145	+/- *	30%	4,073,143	2,078,134	→	4,318,642,552,918
Real Losses	**214,746,446**	**+/-**	**11%**	24,510,670	**12,505,444**	←	**156,386,127,623,913**

* Inputs of uncertainty estimates in the calculation of 95% confidence limit

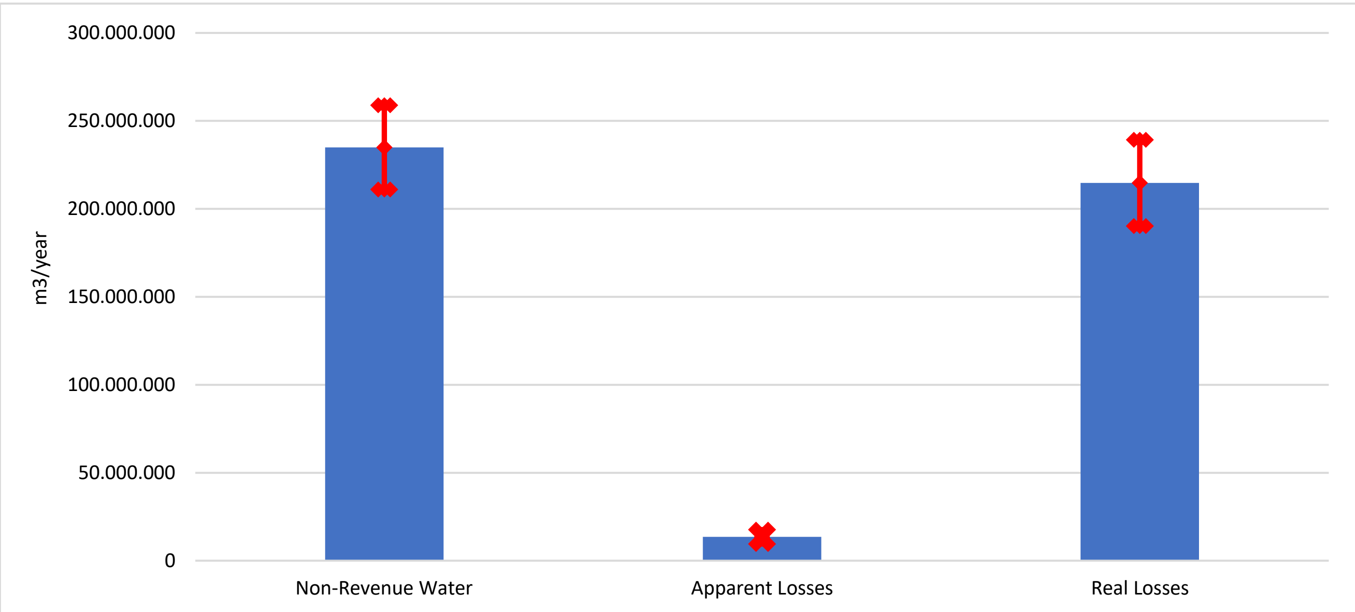

Figure 2.24. Result of analysis of 95% confidence of the calculation of Water Balance components on the national level in Croatia

2.6 Estimating water losses using water loss indicators

2.6.1 ILI according to IWA methodology

The application of appropriate water loss indicators is an unavoidable segment aimed at properly understanding the issue and improving efficiency in water loss management. A large number of different water loss indicators is used in global practice, primarily the Infrastructure Leakage Index (ILI) and other indicators (Current Annual Real Losses and Unavoidable Annual Real Losses) that define the ILI value as the basis for applying the IWA methodology.

The Infrastructure Leakage Index is actually the first indicator defined so as to give a better insight into the efficiency of managing a water supply system, i.e., to show how successful a PWSP is in addressing and managing water losses and is defined within the generally accepted IWA methodology. The ILI represents the ratio of the CARL (Current Annual Real Losses) to the UARL (Unavoidable Annual Real Losses). A higher ILI value indicates a poorer condition and reduced efficiency in addressing water losses within the analyzed system.

$$ILI = \frac{CARL}{UARL}$$

Both these components of real losses (CARL and UARL) are, for easier presentation and possibility to compare with other systems or own sub-system, expressed in unit terms as m^3/km/d (used mostly in cases when the number of service connections is < 20 per km of mains) or as l/service connection/d (used mostly in cases when the number of service connections is > 20 per km of mains).

Current Annual Real Losses (CARL)

The CARL represents real losses that encompass all leakages in the mains network (transmission and distribution), overflows and leakages from storage tanks, and leakages in service connections up to the customer water meters. The CARL is most frequently identified using one of the two methods specified below or a combination thereof:

- “Top-Down” method – according to which the CARL is defined within the preparation of the extended water balance (Table 2.4) under component 'Real Losses' as the volume remaining once the Authorized Consumption and Apparent Losses are deducted from the Water Supplied.
- “Bottom-Up” method – according to which the CARL is defined from the results of flow measurements in small, discrete areas of a water distribution system – District Metered Areas (DMA). The basis for the calculation of the CARL is the identification of the Minimum Night Flow (MNF) and a share of authorized consumption by consumers in the MNF. Deducting the estimated authorized consumption in the night period from the identified MNF value gives the volume of real losses in that night period. Since a change in pressure in the water supply network is inversely proportional to a change in water consumption, the highest pressures are present precisely in the night period with minimum water consumption (minimum flows within the system). For that reason, the identified value of real losses in the night period with maximum pressures is averaged on a daily level (over a 24-hour period), using in the calculation the average daily pressure value. A FAVAD method is used in this process.

Unavoidable Annual Real Losses (UARL)

The UARL represents the losses of very low intensity due to the formation of small cracks and leaks at joints and valves (background leakage), which it is very difficult or impossible to detect using the most frequently used acoustic methods. They are defined by empirical equations that include the following relevant parameters: the length of transmission and distribution mains (without service connection pipes), the number of service connections, the length of service pipes (after the property line up to the customer meter), and the average operating pressure. The UARL is according to the original IWA methodology calculated using the following expressions:

$$UARL = \frac{18 \cdot L_m + 0.8 \cdot N_c + 25 \cdot L_p) \, x \, P_{av}}{L_m} \; (l/km \; mains/d)$$

$$UARL = \frac{18 \cdot L_m + 0.8 \cdot N_c + 25 \cdot L_p) \, x \, P_{av}}{N_c} \; (l/service \; connection \; /d)$$

Where:

- L_m – Mains length, transmission and distribution mains (km)
- N_c – Number of service connections (1)
- L_p – Total length of service pipes – from property line (most often a fence) to meter, i.e., part of the service pipe lying on private property (km)
- P_{av} – Average operating pressure (m of water column)

In Croatian practice mistakes have often been made in calculating the UARL using the above equations when defining the L_p parameter, applying the service connection pipe length from connection to the street main to the water meter (most often 6-10 m length), instead from the property line to the water meter (most often 0-3 m length).

Some countries and PWSPs around the world have introduced modifications in the calculation of the UARL, the correctness of which cannot be checked in practice and the appropriateness of which cannot be confirmed in use in all other circumstances because just like the original (above-mentioned) equations it is based on defining individual factors that are defined based on relatively small databases, associated primarily with the area (PWSP, region, and country) in which the modification was developed. Even in Croatia, the Regulation on the amount of the water usage fee (OG 82/10, 83/12, 10/14, 32/20), Annex VI, defines the calculation of the UARL in a modified form:

$$UARL = (6.57 \cdot L_m + 0.256 \cdot N_c + 9.13 \cdot L_p) \, x \, P_{av} \; (l/d)$$

where, unlike the earlier equation defined based on the original IWA methodology, the parameter L_p is defined as the length of all service connection pipes as pipes in the ownership of the provider of water services, which connect the main of the water supply network with the connection for the water service user. In other words, the service pipe is defined from the connection to the street main to the water meter, which is different from the same parameter in the equation according to the original IWA methodology, where the service pipe is defined from the user's property line (most often a fence) to the water meter.

The spatial distribution of the ILI by PWSPs in Croatia is presented in Figure 2.25. Figure 2.26. shows the distribution of the ILI by PWSPs in Croatia presented in a descending order. The distribution of the ILI by the proposed service areas in Croatia is presented in Figure 2.27.

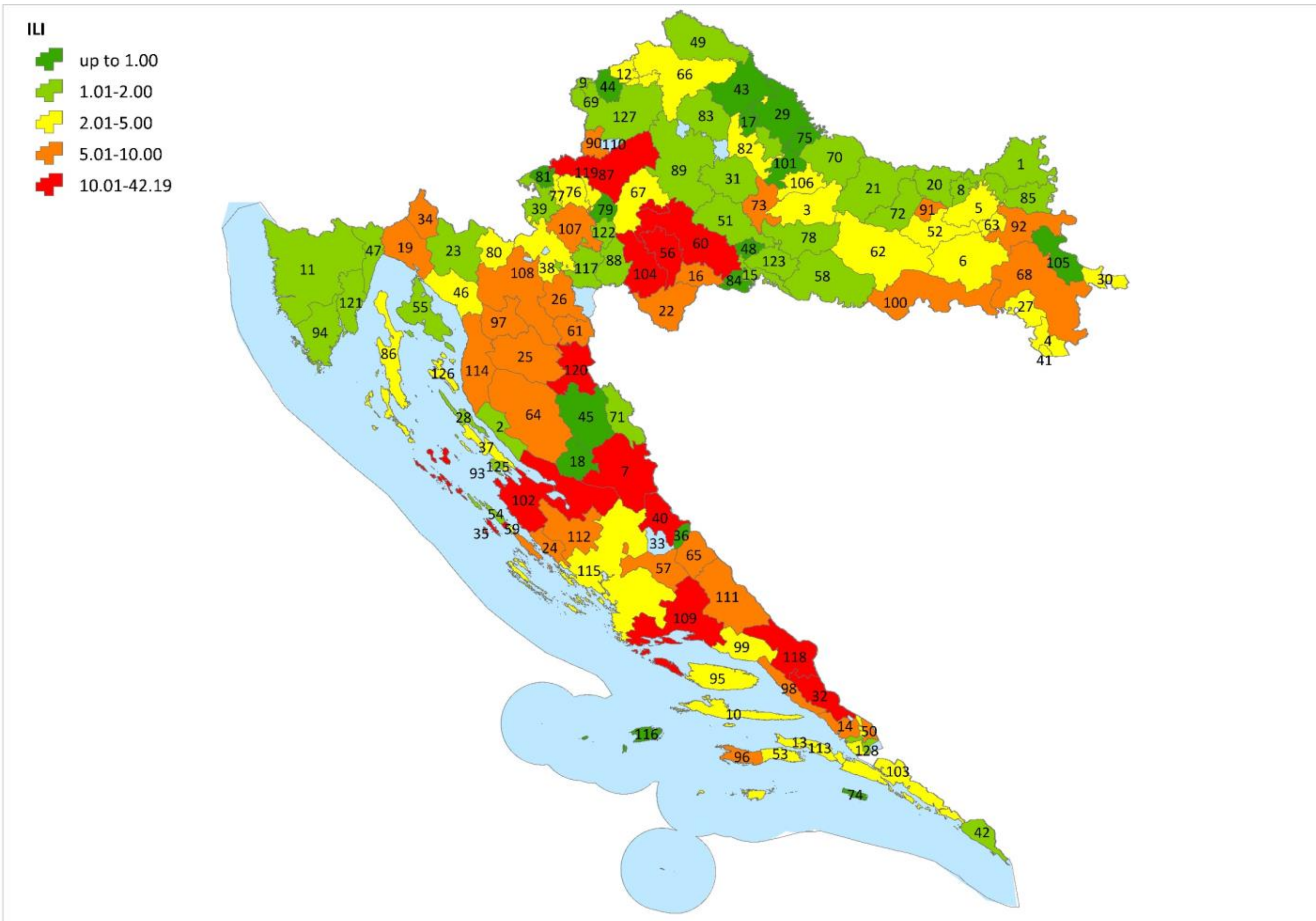

Figure 2.25. Calculated ILI, PWSP level (with IDs)

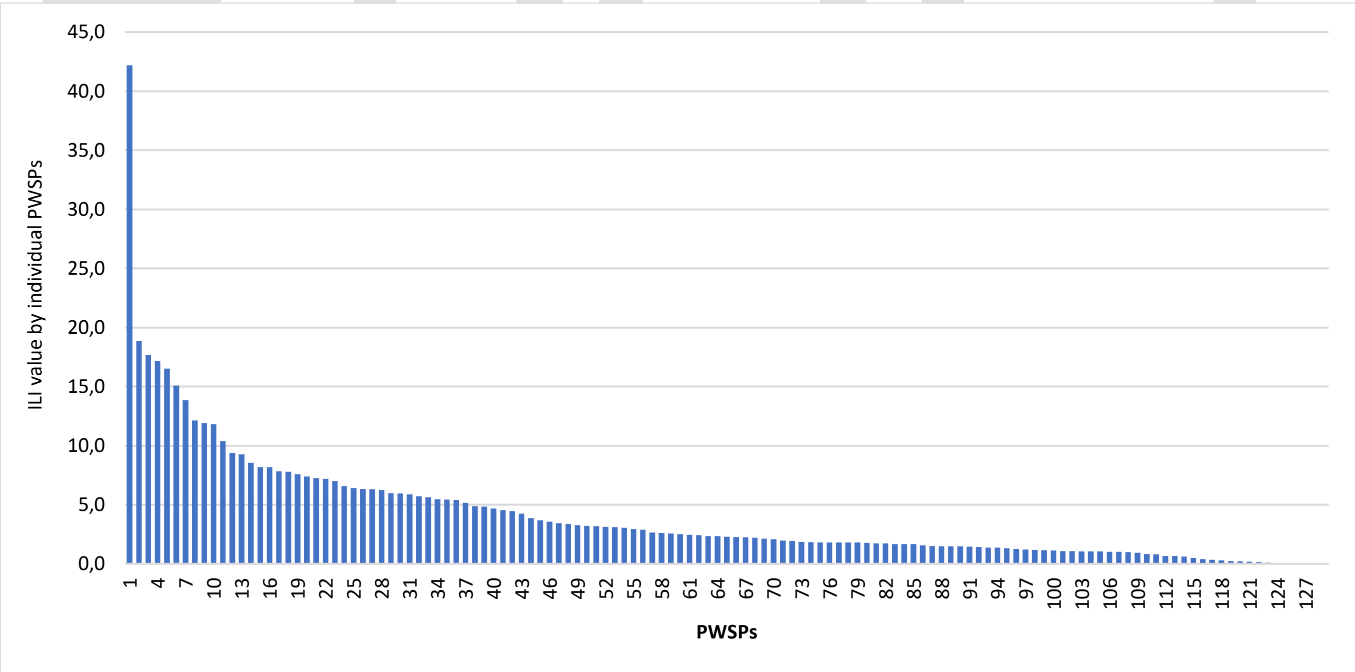

Figure 2.26. Distribution of the ILI value by PWSPs in Croatia

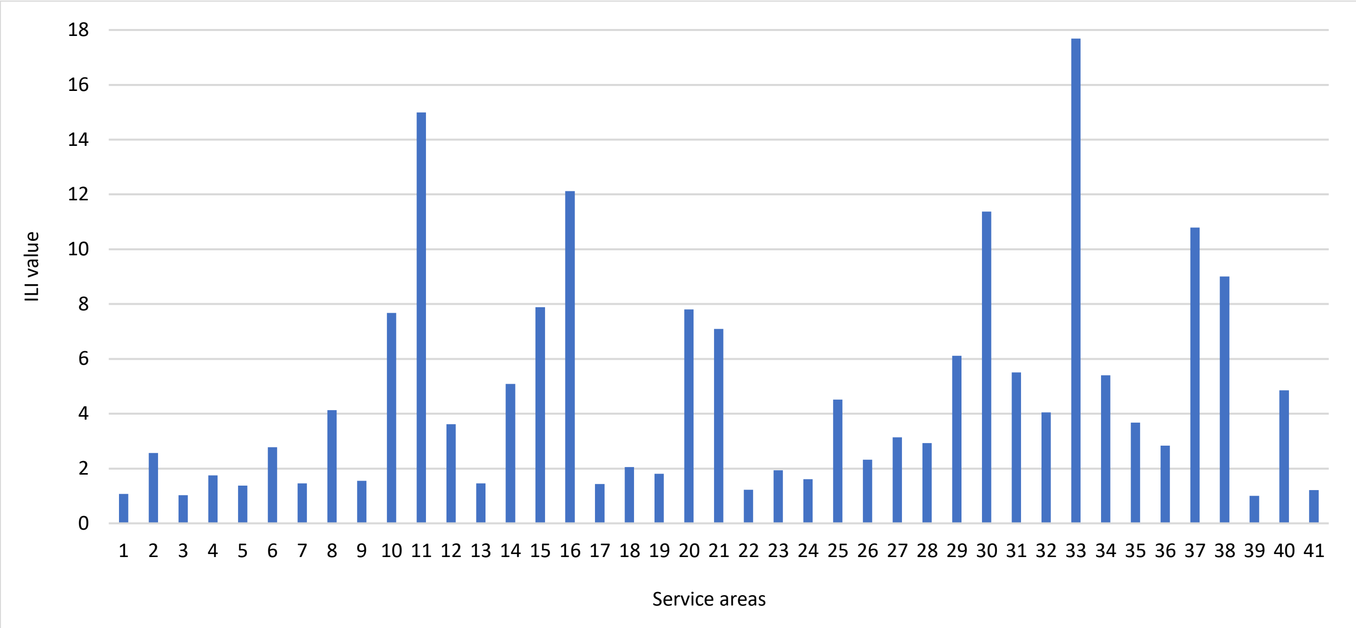

Figure 2.27. Distribution of the ILI value by the proposed service areas (41) in Croatia

Even though the ILI illustrates the efficiency of managing a water supply system, the national ILI averages using several methodologies of expressing the average values are also presented.

The average ILI value on the national level expressed as an arithmetic mean of all the ILI values by PWSPs is 4.18.

The value of 50% percentile of the ILI on the level of all PWSPs in Croatia is 2.34.

The calculated ILI value on the national level taking into consideration the weighted value of the average pressure in relation to the network length of individual PWSPs is 2.9.

The ILI value on the national level calculated by PWSPs and weighted against the number of service connections is 5.75.

Table 2.7. presents the distribution of the PWSPs in Croatia with regard to the ILI, in accordance with the general categories of real losses management for the developed countries based on the guidelines of the World Bank Institute.

Table 2.7. Water supply systems in Croatia grouped according to the ILI value

Developed countries ILI range	Number of PWSPs in Croatia based on the ILI	Band	Guideline description of the real loss management performance categories for developed and developing countries
< 2	56	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective leakage management
2 – 4	28	B	Possibilities for further improvement; consider pressure management, better active leakage control, better maintenance
4 – 8	27	C	Poor leakage management, tolerable only if plentiful cheap resources; even then, analyze level and nature of leakage, intensify reduction efforts
8 or more	16	D	Very inefficient use of resources, leakage reduction programs imperative and high priority

Water losses are often in practice associated with the pressure in the system, with the same parameter used in the calculation of the UARL, which is in turn used to calculate the ILI. It is therefore in practice often wrongly believed that increased ILI values are present in systems with higher pressures. However, analyzing all the PWSPs in Croatia, one can notice that high ILI values are present even in systems with average pressures of below 5 bar.

The ILI is also often in practice associated with the NRW volume, with a shared opinion that the increased ILI values are present in systems with bigger NRW volumes. Figure 2.28. which presents the relationship between the ILI and the NRW among the PWSPs in Croatia, contradicts such conclusions. One can notice that big NRW volumes are present even in systems with low ILI values. However, a certain correlation does exist between the ILI and the NRW expressed in % of the Water Supplied, even though that correlation is not complete. Figure 2.29. illustrates that some systems, although having a high share of the NRW, are characterized by low ILI values.

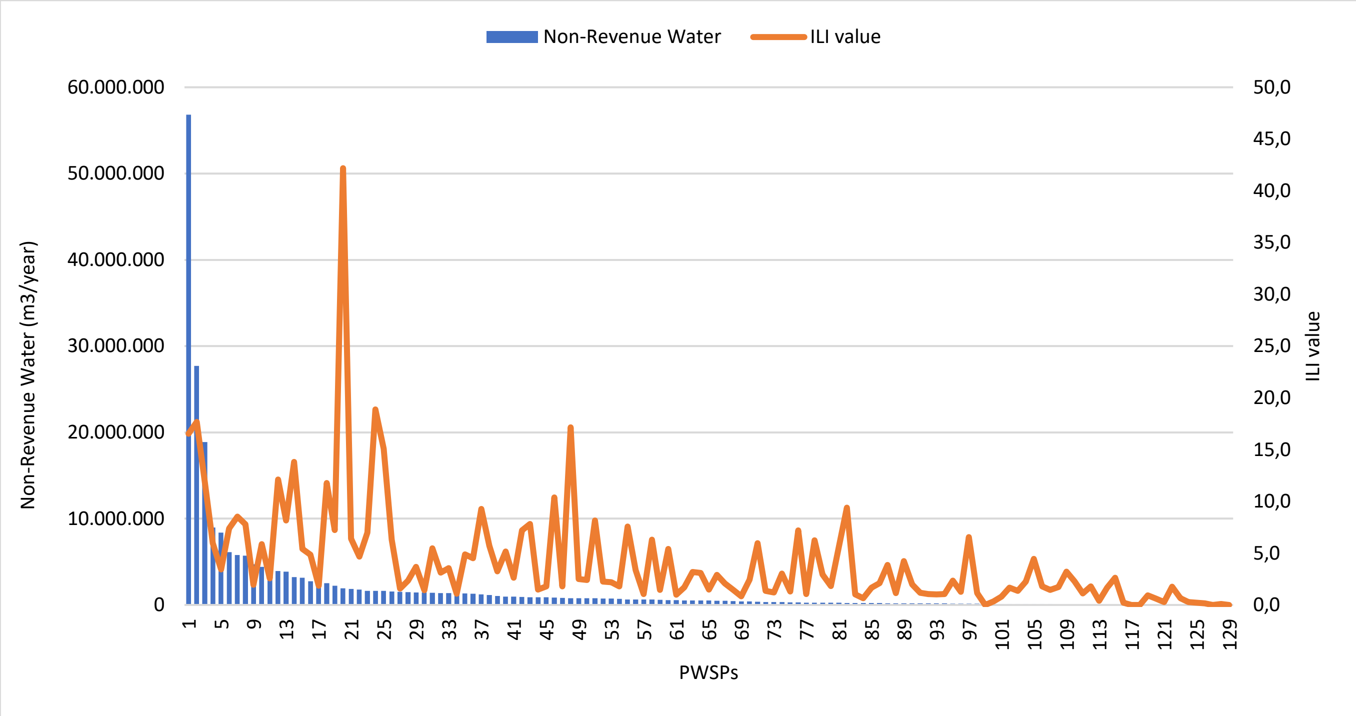

Figure 2.28. Relationship between the ILI and NRW in m3/year by individual PWSPs

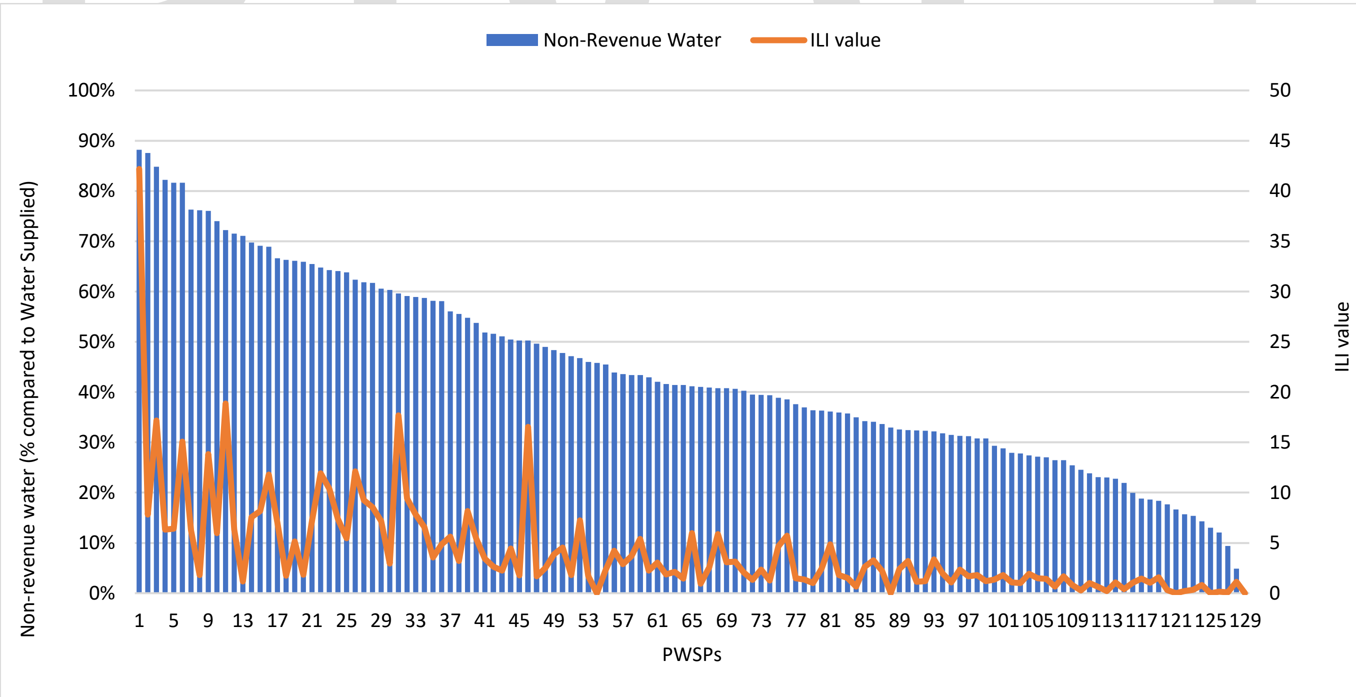

Figure 2.29. Relationship between the ILI and NRW in % by individual PWSPs

Many guidelines throughout the world, including in Croatia, adopt the ILI value as a benchmark of successful implementation of certain water supply system improvement measures. For example, in Croatia even the legislation encourages analyzing the efficiency in the reduction of water losses using the ILI. More specifically, according to the Regulation on the amount of the water usage fee (OG 82/10, 83/12, 10/14, 32/20), based on one of the two models of calculation the fee will be calculated based on the calculation that includes the ILI value, in an effort to encourage the PWSPs to take certain improvement measures to reduce the ILI value, and thus of the water usage fee amount, and achieve certain economical savings. However, taking certain system improvement and water loss reduction measures will not necessarily result in the reduction of the ILI value; in certain circumstances it can even result in it increasing or remaining at the earlier level. This happens in systems where the regulation (reduction) of pressures with the establishment of PMAs was taken as an improvement measure, and the system is characterized by a higher share of rigid pipes with the value of the N1 exponent lower than or equal to 1.0. So, the practice so far indicates that the ILI is not a reliable indicator in every case, stressing the need to make additional analyses of water losses (technical and economic) not only on the level of the system, but also separately on the level of each DMA.

The practice so far in Croatia, since more intensive application of the IWA methodology started, confirms that the ILI has no major importance in practice in terms that, once its value for a system is expressed, the implementation of specific activities would start which would result in its reduction, i.e., in increased PWSP efficiency in water loss management.

The above can lead to the conclusion that the ILI as a practical indicator of the efficient management of a water supply system is not an argument (motive) enough to more actively address the water loss issue.

2.6.2 Other indicators of water losses

In addition to the NRW, the real losses and the ILI, in Croatian practice the use of other performance indicators is becoming more frequent, such as unit real losses (liters/service connection/d; liters/service connection/d/m of pressure; m3/km/h).

Figure 2.31. presents the distribution of unit values of the Real Losses in liters/service connection/day by individual PWSPs in Croatia, while Figure 2.32. presents their distribution by the service areas.

Figure 2.35. presents the distribution of unit values of the Real Losses in m3/km of mains/hour by individual PWSPs in Croatia, while Figure 2.36. presents their distribution by the service areas.

Figure 2.39. presents the distribution of unit values of the Real Losses in liters/service connection/dan/m of pressure by individual PWSPs in Croatia, while Figure 2.40. presents their distribution by the service areas.

In Figure 2.33. the water supply systems in Croatia are grouped by the unit values of Real Losses in liters/service connection/day.

In Figure 2.37. the water supply systems in Croatia are grouped by the unit values of Real Losses in m3/km of mains/hour.

In Figure 2.41. the water supply systems in Croatia are grouped by the unit values of Real Losses in liters/service connection/day/m of pressure.

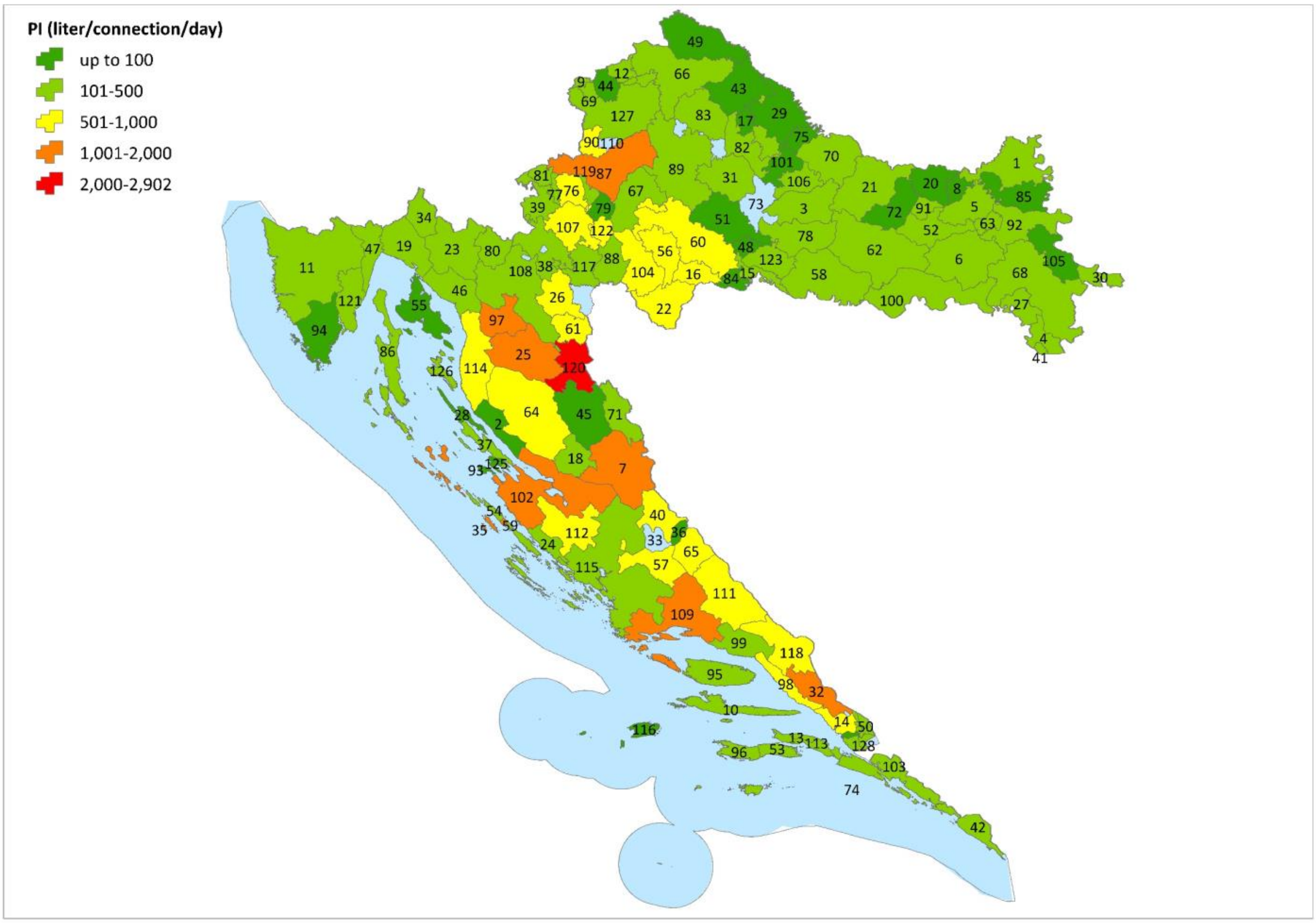

Figure 2.30. Calculated unit value of Real Losses in liters/service connection/day, by individual PWSPs (with IDs)

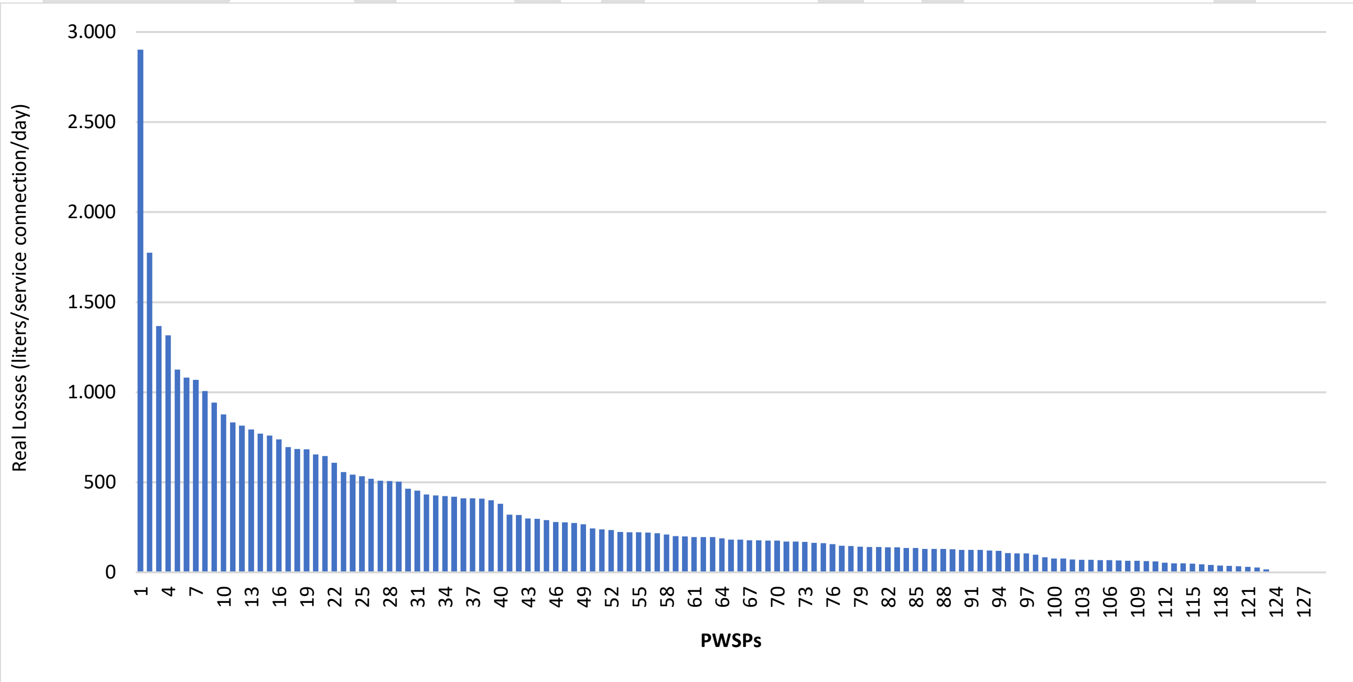

Figure 2.31. Distribution of unit values of Real Losses in liters/service connection/day/m of pressure, by individual PWSPs

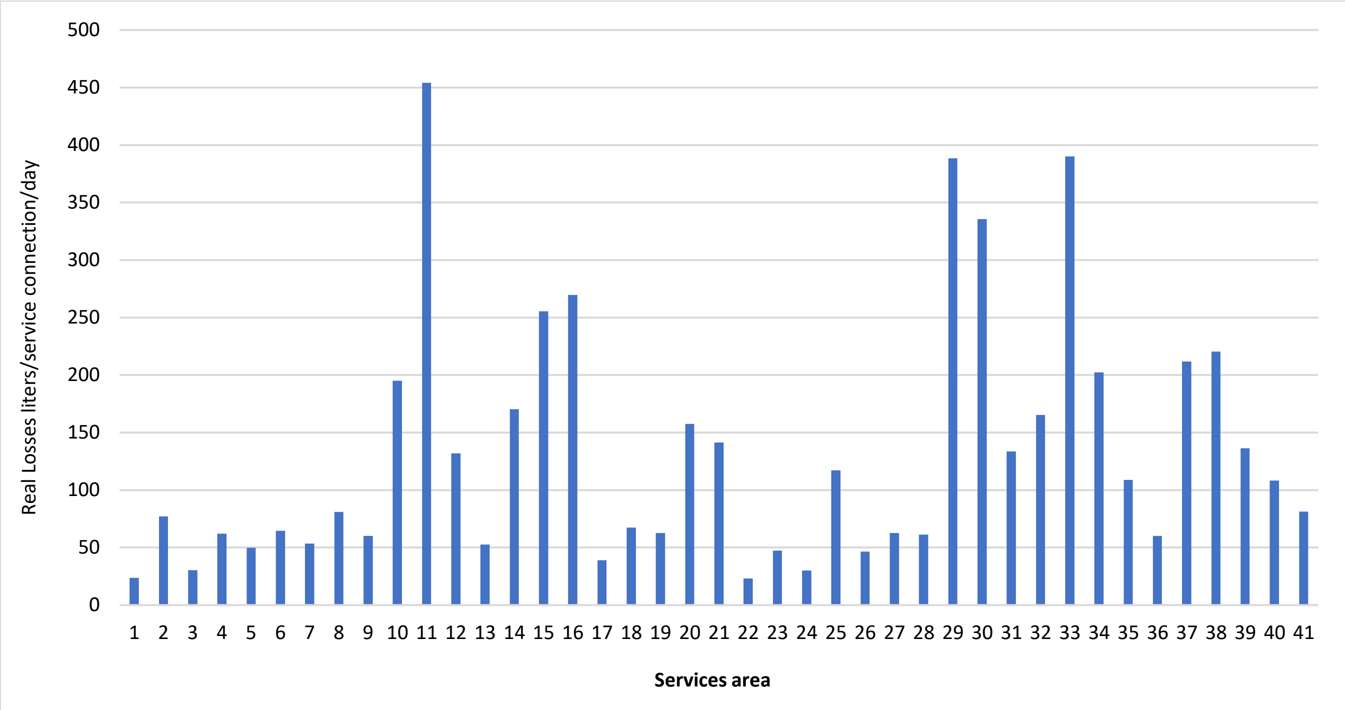

Figure 2.32. Distribution of unit values of Real Losses in liters/service connection/day/m of pressure, by service areas

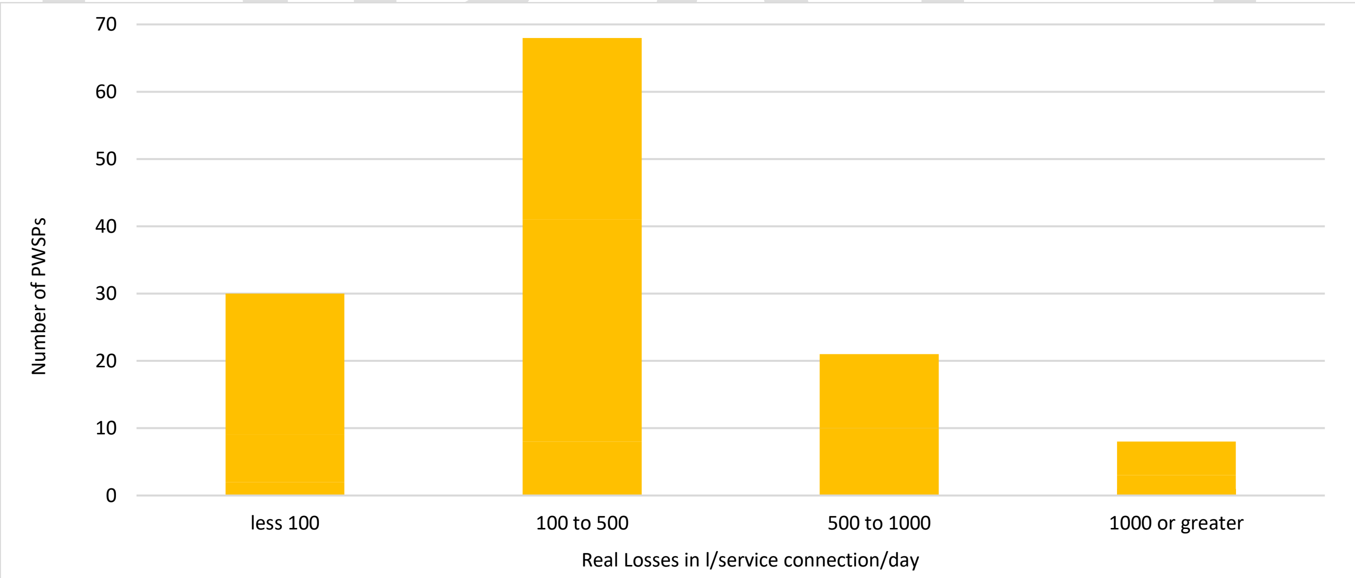

Figure 2.33. Water supply systems in Croatia grouped by the unit values of Real Losses in l/service connection/day

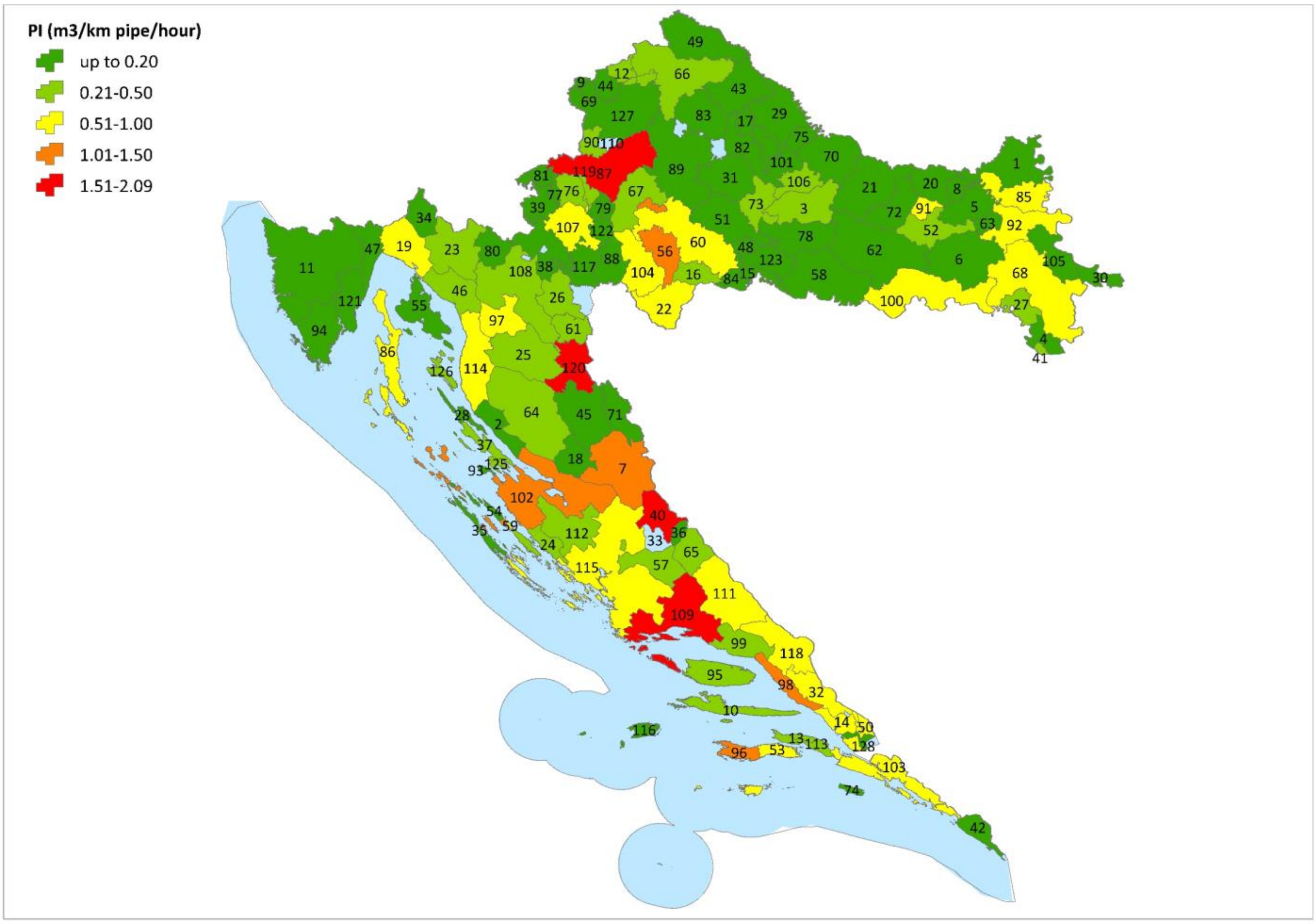

Figure 2.34. Calculated value of Real Losses in m3/km of mains/hour, by individual PWSPs (with IDs)

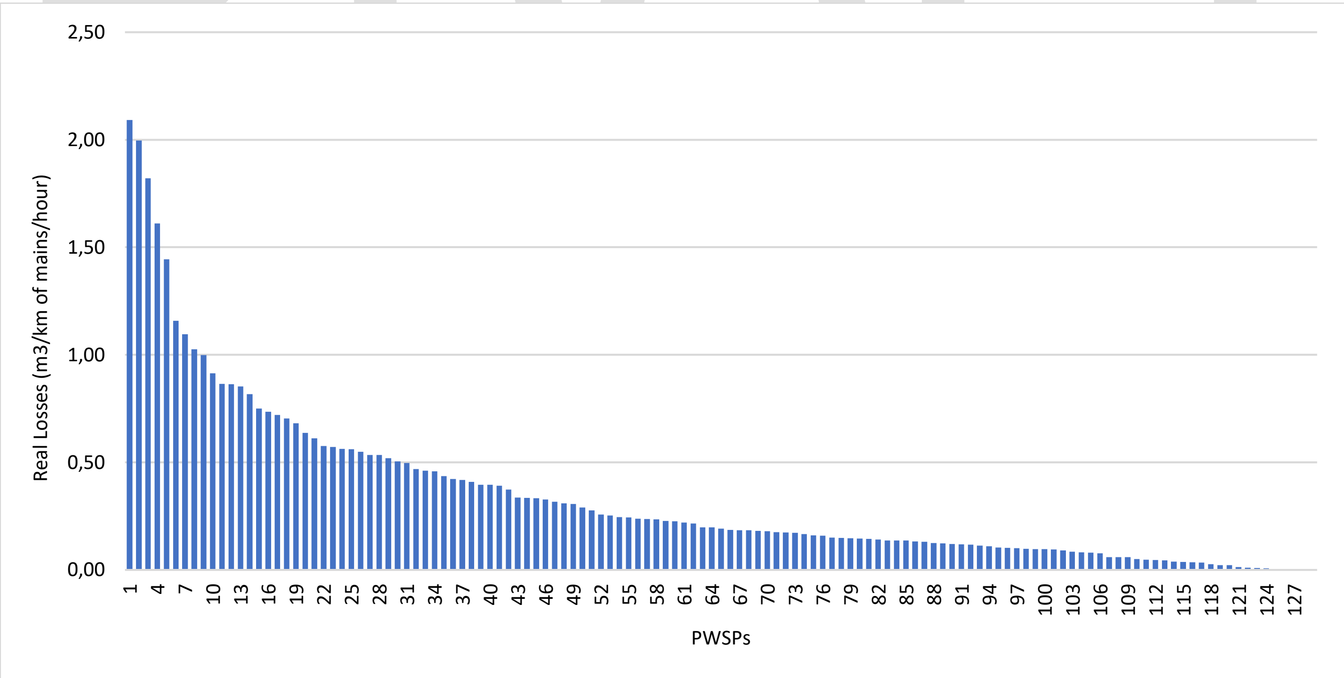

Figure 2.35. Distribution of unit values of Real Losses in m3/km of mains/hour, by individual PWSPs

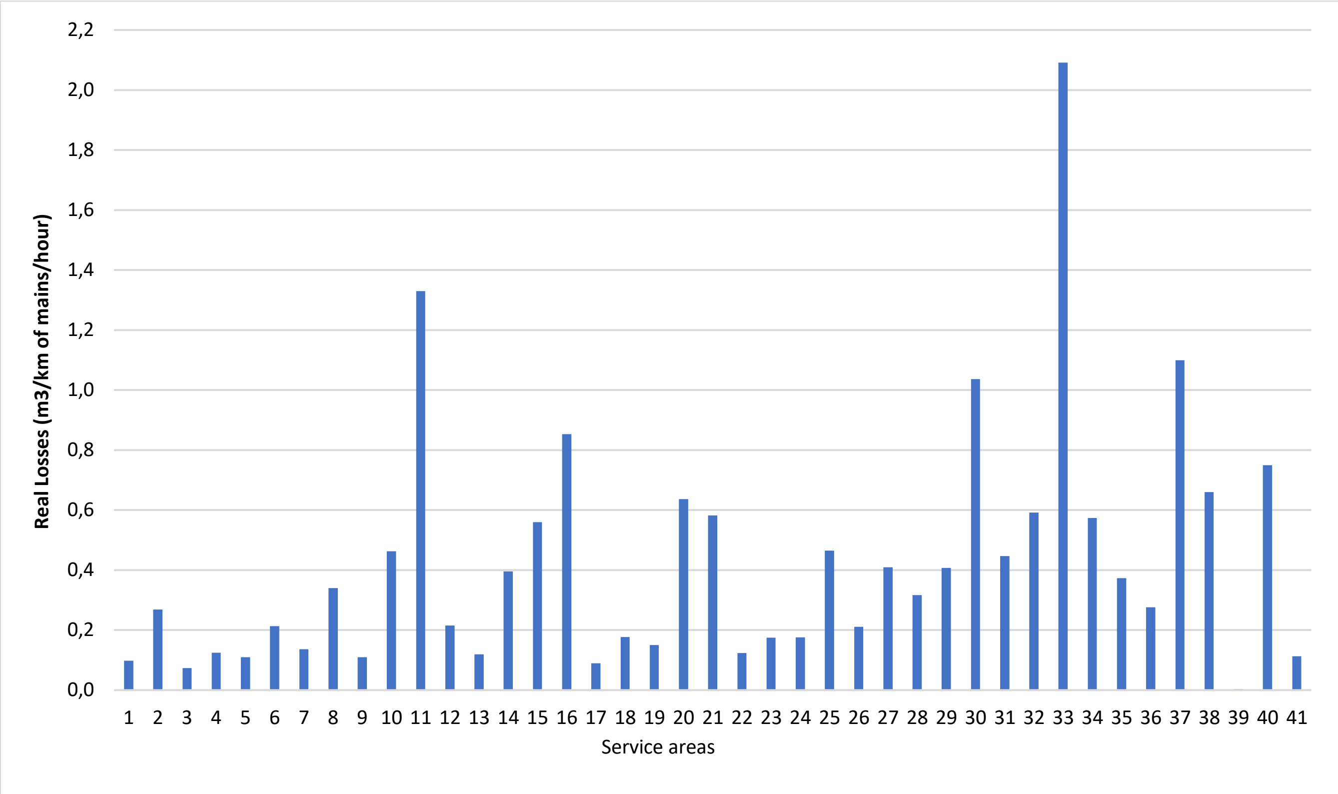

Figure 2.36. Distribution of unit value of Real Losses in m3/km of mains/hour, by service areas

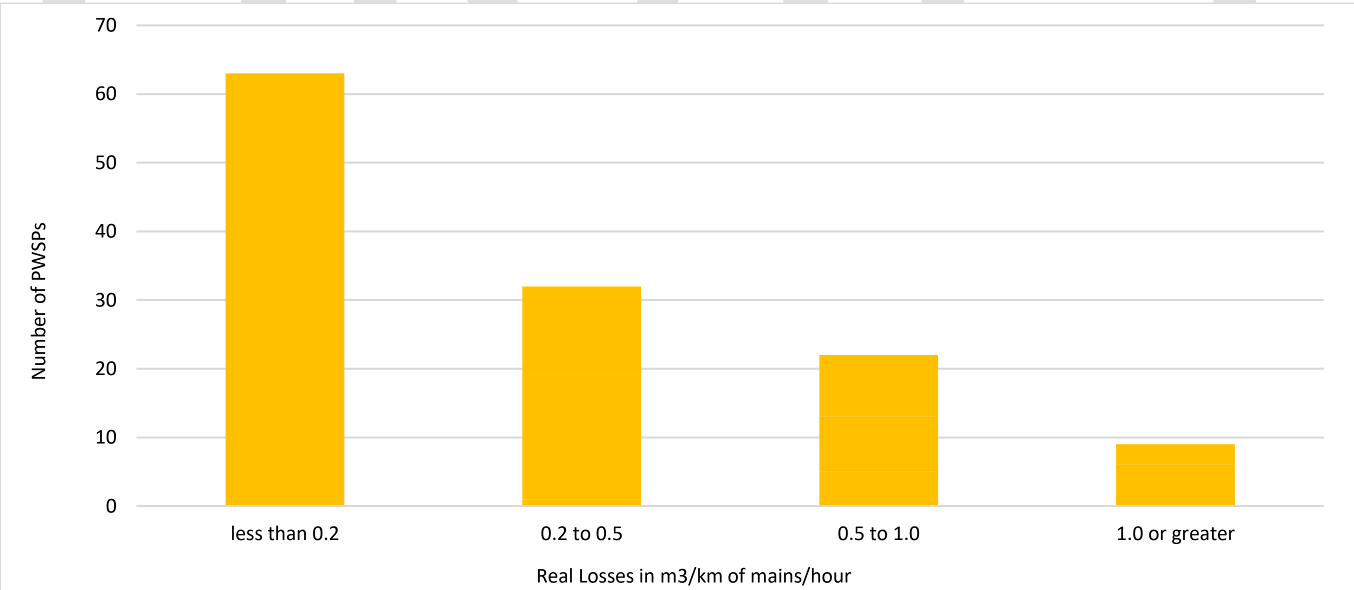

Figure 2.37. Water supply systems in Croatia grouped by the unit values of Real Losses in m3/km of mains/hour

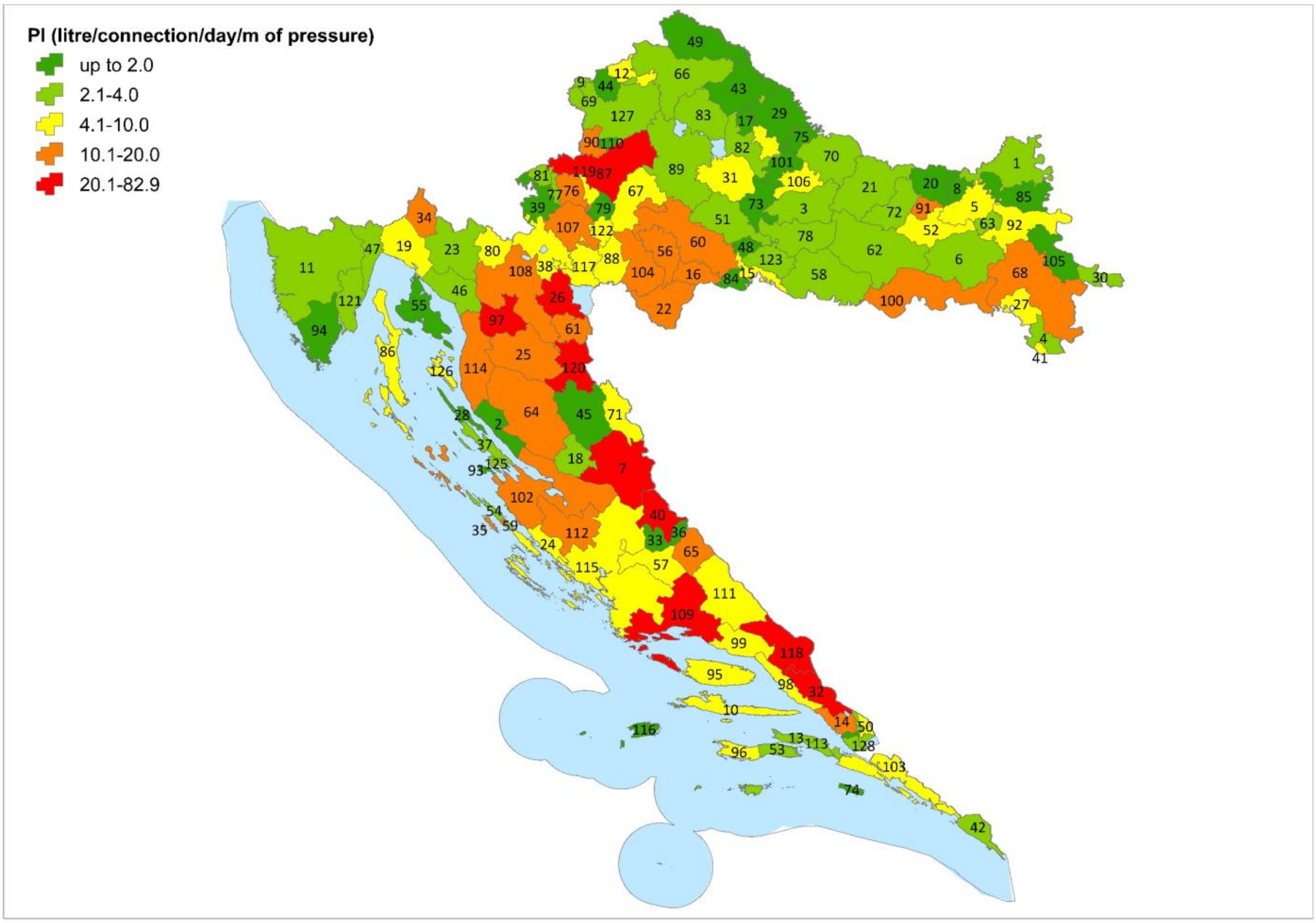

Figure 2.38. Calculated unit value of Real Losses in l/service connection/day/m of pressure, PWSP level (with IDs)

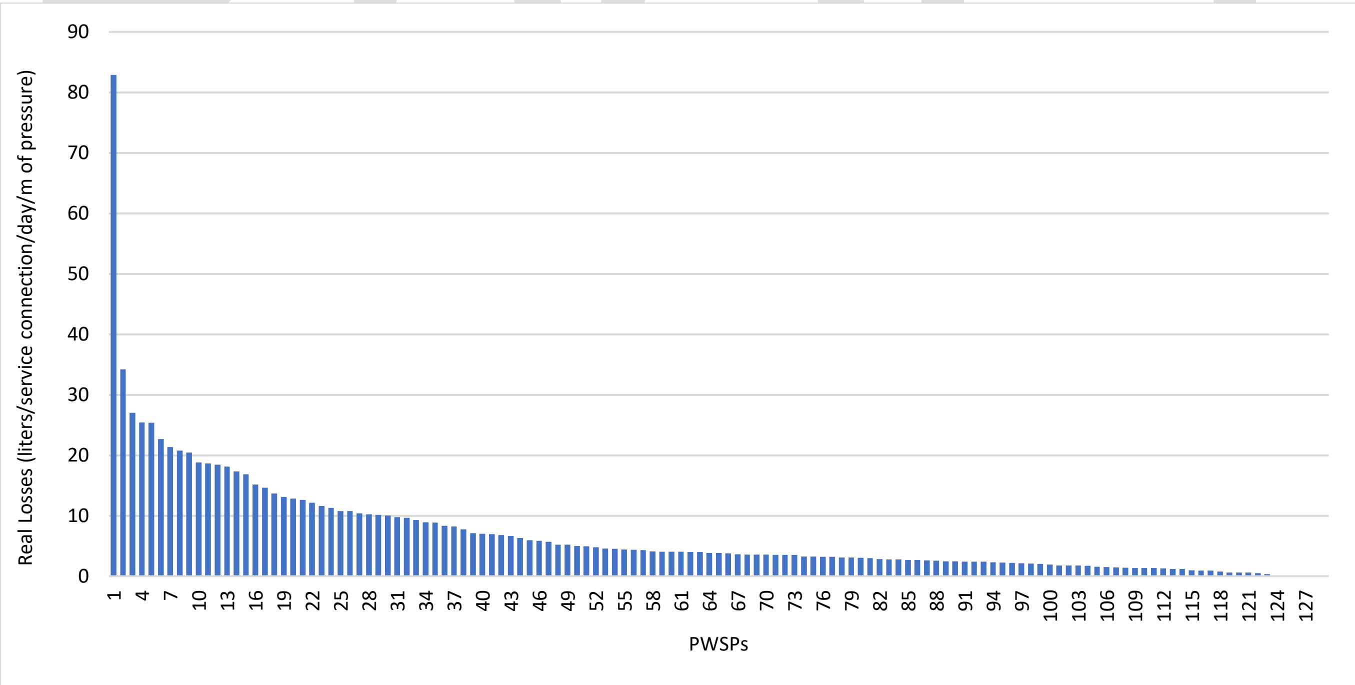

Figure 2.39. Distribution of unit values of Real Losses in liters/service connection/day/m of pressure, by individual PWSPs

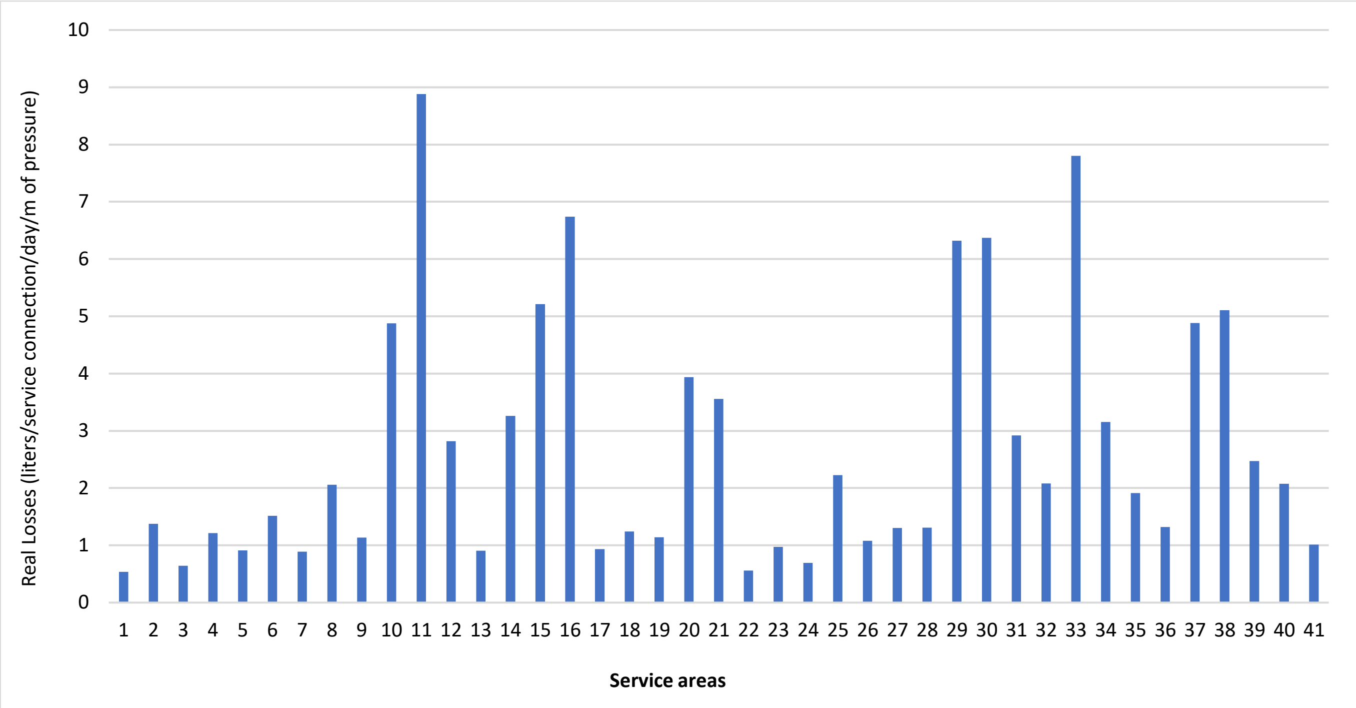

Figure 2.40. Distribution of unit values of Real Losses in liters/service connection/day/m of pressure, by service areas

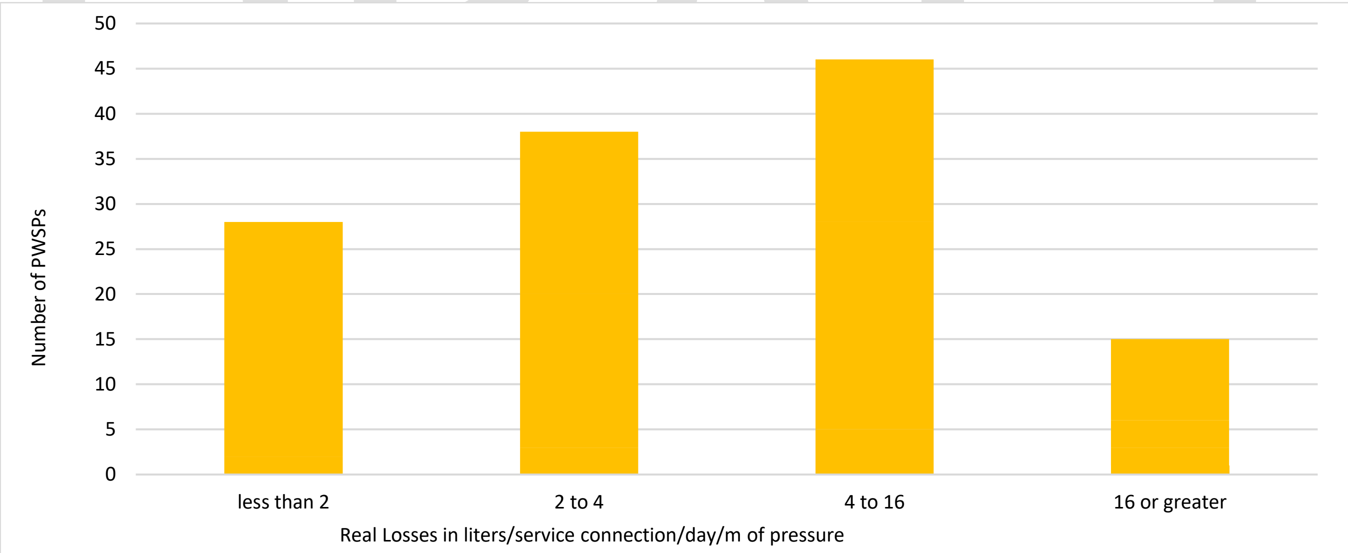

Figure 2.41. Water supply systems in Croatia grouped by the unit values of Real Losses in l/service connection/day/m of pressure

2.7 Existing water losses reduction plans/documents/reports

The development of water supply systems in Croatia intensified after it became an independent country, particularly after the 1990s war ended. The greatest effort was invested in the renewal of damaged and old infrastructure and in the extension of water supply systems, the primary purpose of which was to increase the coverage with public water supply systems, i.e., possibility to supply drinking water. Available limited financial resources, effective lack of adequate knowledge about the water loss issue, and the lack of resources were the reason why the technical solutions related to water loss reduction weren't present too much in water supply plans and development documents.

That is why it is only recently, once the basic objectives have been achieved, that the first planning documents were prepared dealing with the water loss issue, after which first activities were launched more intensively. Such activities can be divided into three (groups of) documents relevant for the purpose of analyzing water supply systems and the water loss issue in Croatia:

1. ***"Study – Analysis of Performance by Water Service Providers in Croatia: Technical and Technological Aspects of Performance"***, IMGD d.o.o. Samobor, September 2017;

2. **National Water Loss Reduction Program (NWLRP)**, Ministry of Economy and Sustainable Development and Croatian Waters, launched in 2018;

3. **Conceptual Solutions for water supply**.

2.7.1 Analysis of PWSP Performance (2017)

The document ***"Study – Analysis of Performance by Water Service Providers in Croatia: Technical and Technological Aspects of Performance"*** (2017) analyzes the public water service providers in Croatia, including among other things data about water supply systems and suppliers (pipeline lengths, service connections, volumes of water supplied and delivered, etc.), as well as water balance calculations using the IWA methodology. A proposal for improvement was also prepared which will enable efficient and economically justified system management. Special attention was given to the issue of water losses and their management, particularly measures for their prevention and considerable reduction.

The document/study served as the basis for several further activities. One of them was giving recommendations about decision-making about the method and criteria of charging the water usage fee based on abstracted water volumes. It also served as the basis to facilitate the procedure of functional integration of service areas, and finally as the basis to initiate and prepare the National Water Loss Reduction Program (NWRLP).

2.7.2 National Water Loss Reduction Program (NWLRP)

The **National Water Loss Reduction Program (NWLRP)** was launched with the aim to significantly reduce the NRW on the national level, reduce the unit value of real losses, reduce the ILI indicator on the level of Croatia and by individual PWSPs, bring all the PWSPs (in particular those performing poorly) to an appropriate technological level, and achieve the return of financial investment over maximum 10 years. The NWLRP is implemented through four basic groups of activities or measures (Measure M, Measure A, Measure B, and Measure C).

The NWLRP Measure M implies the installation of flow meters at all the water abstraction (intake) sites in Croatia with a system of technical protection in individual water abstraction (intake) sites. The importance of establishing realiable metering of abstracted water volumes is a priority, only after which it is possible to establish a reliable, high-quality system of water loss management.

The NWLRP Measure A implies the preparation of conceptual solutions which include a detailed analysis of the current state (including the preparation the calibrated mathematical model of the current state) of a water supply system and the development of conceptual solutions for further development and improvement of water supply systems (based on the mathematical models of the planned state), with a primary focus on the reduction of water losses. Measure A is implemented by individual PWSPs, with a separate conceptual solution prepared for each PWSP. So far, conceptual solutions with identical content (level of detail of particular analyses) haven't been prepared on the level of the planned service areas, regions, or counties, which is assessed as necessary in order to ensure the achievement of the expected effects of the water service sector reform in Croatia, with the integrated planning of water loss management on the level of service areas bringing significantly more favorable results/effects.

The NWLRP Measure B represents the first group of measures with specific implementation of certain activities on the field, and includes the following: *hydraulic balancing of the water supply system with regulation (reduction) of pressures, implementation of a remote SCADA system with designing* and construction of control and measurement and regulation shafts for flow measurement with metering equipment in several locations, i.e., the establishment of DMAs, and one of the most important and most efficient activities – active leakage control including staff training to operate the leakage detection equipment, procurement of leakage testing and detection instruments (correlators, geophones, noise loggers, portable flow meters, portable pressure meters, metal detectors, etc.), organizational measures of monitoring and control of losses and identification of locations of leaks in the system (formation of technical teams or outsourcing), detection (micro-locating), and repair of leaks, and replacement of pipes in critical sections confirmed to be in a particularly poor state of repair (a large number of leaks, thinning pipe wall, increased encrustation within the pipe, etc.).

The NWLRP Measure C implies the repair/replacement/reconstruction of entire sections of the mains network and major structures within the system with frequent bursts. It also implies the preparation of design documentation.

The launch of the NWLRP has prevented further negative trend of increasing NRW volumes on the national level in Croatia. Since 2018, with relatively small investment and implementation of the NWLRP measures an approximately the same volume of NRW has been retained, which is assessed as relatively successful. Namely, the results so far have confirmed the initial expectations that the implementation of some measures will result in certain efficiency in water loss reduction, while some measures resulted in the acquisition of certain experience and identification of certain limitations and deficiencies. All of that served as the basis to define an Action Plan of the highest possible quality.

2.7.3 Conceptual Solutions for Water Supply

Conceptual solutions for water supply represent detailed studies or analyses of the current and planned (including system extension and improvement measures) states of water supply systems, in which the issue of water losses is analyzed in detail for the first time, including the definition of short- and long-term measures for their reduction. Conceptual solutions enabled detailed familiarization with the water supply system, increased the level of knowledge among all the actors (the Ministry, Croatian Waters, the PWSPs, the design engineering sector, contractors, etc.), and set good standards for the planning and implementation of further measures. That makes the preparation of conceptual solutions one of the priority activities within the NWLRP (Measure A). More intensive preparation of conceptual solutions started in 2018. However, a certain number of conceptual solutions had been prepared before the launch of the NWLRP, and it is important to note that those conceptual solutions are content-wise not identical to the conceptual solutions prepared as part of the NWLRP. Some analyses in those conceptual solutions are not at the same level of detail (a simpler analysis of the current state, mathematical models at a lower level of detail, a lower level of calibration of the model of the current state as the result of a significantly smaller number of flow and pressure measurements, lack of analysis of the current state according to the IWA methodology or making such an analysis without expressing a larger number of performance indicators, less modest analysis of potential improvement measures, etc.). For that reason, there is already a need felt to revise certain conceptual solutions prepared in the 2004-2017 period.

In addition to detailed analysis of the current state of an individual water supply system through the calibration of the model of the current state and analysis of the system according to the IWA methodology, including an economic analysis of water losses, conceptual solutions also define the measures for system extension and improvement, justifying them hydraulically using the mathematical model of the planned state. The analysis covers a design period of 30 years during which the water demand analysis is supplemented. As part of the analysis of the future state and required measures, the required future effective volumes of storage tanks are additionally defined, as well as the optimum operation of the water supply system in terms of network pressures, the altitude of the planned elements of the water supply systems, the future water supply structures are modelled (pressure booster stations, storage tanks, distribution mains), and the required number of preliminary simulations and corrections of the planned inputs by development priorities and by water supply sub-systems is made. Furthermore, pressure regulation is foreseen, the operating algorithms of the existing structures are corrected if needed, simulations of characteristic operating conditions are made, together with analyzing different configurations of the water supply system and foreseeable operating variants, the real water age and the residual chlorine status are defined simulating a number of days with average annual consumption. The results of the simulations made are analyzed, based on which potential corrections of the current assumptions of the development concept are confirmed or suggested, the mains and associated water supply structures in the model are dimensioned or their already defined (designed and built) dimensions are corrected if needed, additional system zoning is done in terms of balancing the pressures in the network and supplying water to individual DMAs and/or PMAs. A calculation is also made of the reduction of water losses as the result of pressure reduction by individual distribution area and/or DMA, a proposal is given for priority measures and projects of construction, rehabilitation, and optimization of the current and future state of the water supply system, and a conclusion of the analyses made is presented, systematizing the foreseen construction, reconstruction and rehabilitation measures. For all the proposed improvement measures a cost estimate is prepared that includes the costs of construction, operation, maintenance, and depreciation. As part of conceptual solutions, a conceptual solution for the establishment of permanent DMAs is also prepared, as well as a conceptual solution for the establishment of a SCADA system for the entire water supply system.

In terms of the content and all the benefits of conceptual solutions, their preparation is a precondition for the implementation of further measures for sustainable system management (operational optimization and upgrade in terms of improvements), because it is only on the basis of a comprehensive analysis of the current state of a system, including water losses, that it is possible to reach quality conclusions which will within the definition of measures result in economical spending of available financial resources. However, justified deviations in the dynamics of implementation of certain measures are possible if a certain measure turned out to be justified during the preparation of conceptual solutions, such as ALC in the critical zones or certain sections of the system, and implementation of emergency repair and replacement of certain shorter sections of the mains network.

The preparation of conceptual solutions didn't enable a significant reduction of water losses for the majority of PWSPs in the initial years. It enabled only partial reduction of water losses in certain parts of the systems based on direct comprehension on the field through flow and pressure measurements and mathematical model calibrations, and detailed familiarization with the hydraulic and operating conditions of flow in the system, enabling insight into all the deficiencies (or chances for improvement) of the current hydraulic state in the integrated water supply network.

2.7.4 Conclusion about the current status of water loss reduction in Croatia

The National Water Loss Reduction Program (NWLRP) has properly addressed the water loss issue, stopping the negative trend of increasing NRW volumes on the national level. The importance of establishing reliable measurement of abstracted water volumes (Measure M) is a priority, only after which it is possible to establish a water loss management system. The preparation of detailed conceptual solutions as a precondition for further measures (with possible deviations in dynamics if a certain measure would turn out as justified during the preparation of conceptual solutions) didn't enable a significant reduction of water losses for the majority of PWSPs in the initial years, only a certain reduction resulting from direct comprehension through measurements and mathematical model calibrations. However, it enabled detailed familiarization with the water supply system, increased the level of knowledge among all the actors (the Ministry, Croatian Waters, the PWSPs, the design engineering sector, contractors, etc.), and set good standards for the planning and implementation of further measures.

The problems that occur then refer first of all to the integrated loss management system which hasn't been defined so far. Further measures are implemented by individual PWSPs or partially within available financial resources or according to PWSPs' own considerations. Such considerations have their justifications, but don't necessarily contribute to optimum resolution of the water loss issue.

There are examples of investing in the establishment of DMAs/PMAs or the GIS, the SCADA system, in locating and repairing leaks, procurement of equipment, or even in the reconstruction of individual sections which don't necessarily have to have priority, but preconditions exist (e.g., permits issued), and in the repair of storage tanks and shafts. The measures themselves are not problematic, but they're not standardized and comprehensive, so it happens that only certain measures from those mentioned above are implemented and will not be able to give appropriate results on their own.

A system that isn't established has no defined indicators which would in the form of straightforward guidelines in a standardized way indicate the success of implementing certain water loss reduction measures.

It is precisely that reason that calls for the preparation of this National Loss Reduction Action Plan, which will make an inventory of all the data on the national level, define measures that have to be foreseen, define priorities through risks, estimate of costs and expected impacts, standardize the methods to calculate performance indicators, propose organizing a control and monitoring system, and define reporting methods.

3 WATER LOSS MANAGEMENT PLAN

3.1 Methodology for water loss reduction and water balance

All water supply systems are faced with water losses. The reasons are numerous – culturological, economic, environmental, and the availability of water resources leads to different treatment of this issue in different countries and water supply systems. If adequate measures are not taken, there is an unavoidable continuous increase in water losses, at least due to an increasing system age, both of water mains and of all the fittings, valves, concrete, and coatings in water chambers, etc. Attempts to address the water loss issue partially by applying different measures don't contribute to its long-term resolution. An additional problem comes from the fact that addressing this issue requires a coordinated action of several professions, with a combination of works, procurement of equipment and services.

The water balance is the basis for understanding water losses. The water balance can be calculated in a number of ways, from simpler forms which imply the quantification of only the most basic components to more complex forms such as the extended and simplified water balance according to the IWA methodology, quantifying other components important for much better understanding and calculation of not only the most basic components of the water balance, but of water losses as well.

Many guidelines throughout the world adopt the ILI value as a benchmark of successful implementation of certain water supply system improvement measures. in Croatia even the legislation encourages analyzing the efficiency in the reduction of water losses using the ILI in an effort to encourage the PWSPs to take certain improvement measures to reduce the ILI value, and thus of the water usage fee amount, and achieve certain economical savings.

Water loss management requires a methodological approach. Therefore, a water loss reduction methodology is being established together with methodology for the preparation of the water balance, as well as methodology to calculate the ILI.

3.1.1 Establishment of a loss reduction methodology

Water loss reduction methodology is based on improving knowledge about one's own water supply systems, users, operating conditions, and on improving knowledge about the water loss issue, starting with the management board of providers of water services, to technical teams that will take action on the field. After that, it is necessary to define measures and foresee the impacts of such measures, and then start with the management of system pressures, active leakage control, and systematic rehabilitation of the water supply network with repairs and replacement of pipelines. The dynamics of implementation of certain groups of measures can be adapted to the specifics of a particular water supply system and realistic needs, while some groups of measures can be implemented simultaneously. For example, part of the ACL measures such as micro-locating (correlators, geophones, noise loggers, etc.) can be implemented even before the regulation of pressure in the system or individual parts of the system, since the detection of leaks using acoustic methods is more efficient at higher network pressures.

Water loss reduction methodology includes approach to digitization of data on water supply systems, determination of hydraulic characteristics in water supply systems, approach to active leakage control and optimal rehabilitation of the water supply network, and determination of PWSPs capacity to assess and reduce water losses.

3.1.1.1 Digitizing of data on water supply systems

On the national level there is still a significant lack of basic knowledge about own water supply systems. This refers to not knowing the real status within the water supply network (level of completion, register of consumers, operating characteristics, hydraulic patterns, etc.), and thus also not knowing the quantitative and spatial distribution of water losses and the causes behind water losses. Few PWSPs have a quality GIS of the entire water supply system. In other words, few PWSPs have a properly digitized current status of the completion of the entire water supply network, as well as of real-time monitoring of system operation, not only by particular key structures within the system, but also segmented into smaller sub-systems/zones through the establishment of DMAs and active real-time monitoring of the operation of each part of the system.

Nowadays, system digitization is assessed as a mandatory factor of sustainable and efficient management of water supply systems. From the aspect of water loss management, having at one's disposal quality GIS tools and SCADA significantly speeds up the identification of leakage and timely micro-location and eventually the removal of a leak, resulting in the reduction of total NRW volumes on the annual level.

Looking at the current status of the PWSPs, one can notice that the use of the GIS correlates with the PWSP size. On the national level, only 38% of the PWSPs have updated maps and use or don't use the GIS, and only 29% use the GIS. As much as 24% of the PWSPs don't have system maps yet. If during consolidation on the level of 41 PWSPs one would analyze the practice of the most up-to-date PWSPs which would with their software tools and experience update the remaining PWSPs, the indicators would be much more favorable Figure 3.1.

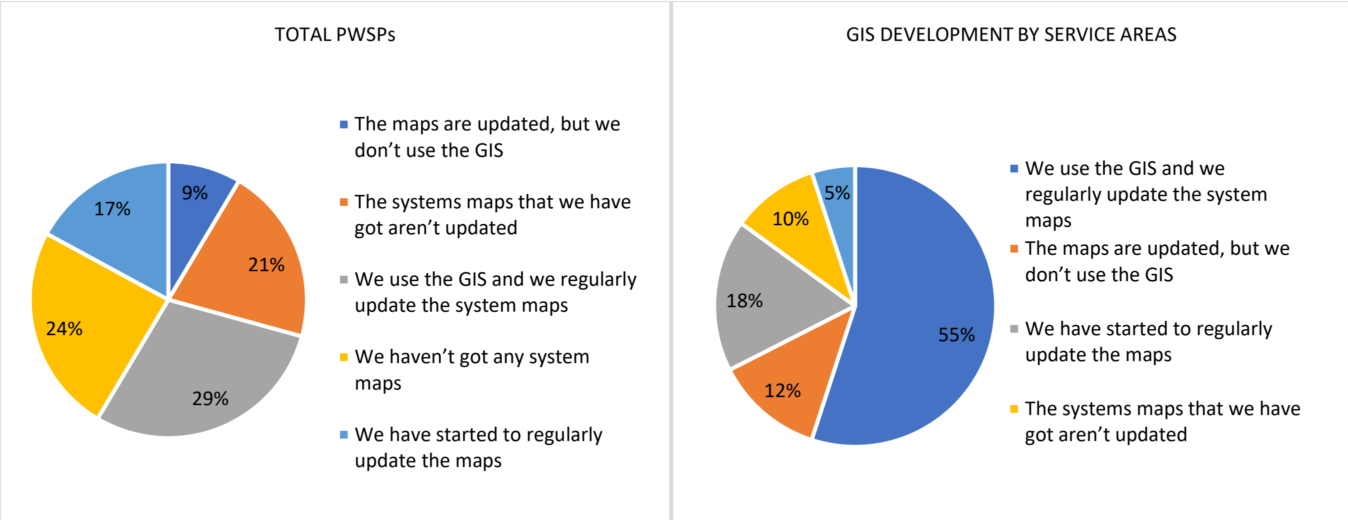

Figure 3.1. Status of GIS development by individual PWSPs on the national level and projected by service areas

The lack of digitization is reflected for example in the poor record-keeping of leakages, which has a negative effect on the planning of optimum pipeline rehabilitation/replacement (Figure 3.2).

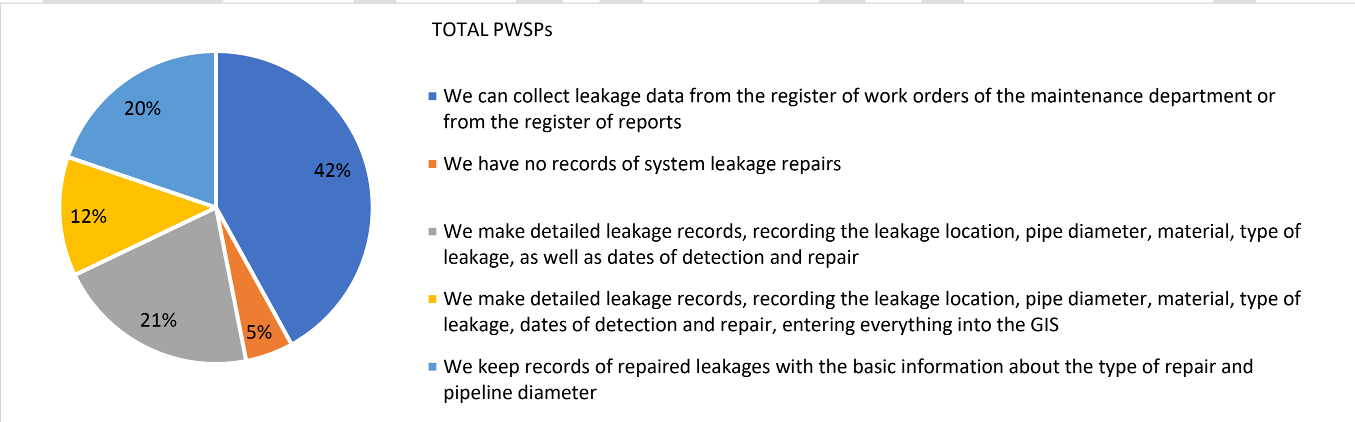

Figure 3.2. How leak record is kept by individual PWSPs on the national level

3.1.1.2 Identification of hydraulic characteristics in water supply systems

Water loss management needs to start with hydraulic analyses and optimization of water supply systems. Optimum pressures, minimum variations of flow in the main transport routes, optimum positioning of storage tanks, and protection from water hammers are essential to be able to properly evaluate the success of further loss reduction measures. Regretfully, due to the current level of completion and high financial investment, that often cannot be achieved in short term, but needs to be taken into account depending on possibilities.

When the system layout modification measures are not feasible or cost-effective or are depending on financial capacities planned as long-term measures (in later phases), the optimization of water supply systems has to proceed with the establishment of District Metered Areas (DMA) and/or Pressure Management Areas (PMA). The measure of establishing DMAs and/or PMAs doesn't limit the implementation of any other measure for system extension and improvement, and it is possible, even preferable, to plan it simultaneously with the modification of the system layout.

The lack of hydraulic optimization of systems is primarily reflected in the presence of uneconomically high pressures in the water supply network, as well as the presence of marked nonstationary phenomena within the water supply network with frequent water hammers. Analyzing the operating characteristics of water supply systems in Croatia it can be concluded that the majority function in unfavorable operating conditions, which is the result of uneconomically high pressures in the water supply network. The average pressure is around 5.0 bar (Figure 3.3).

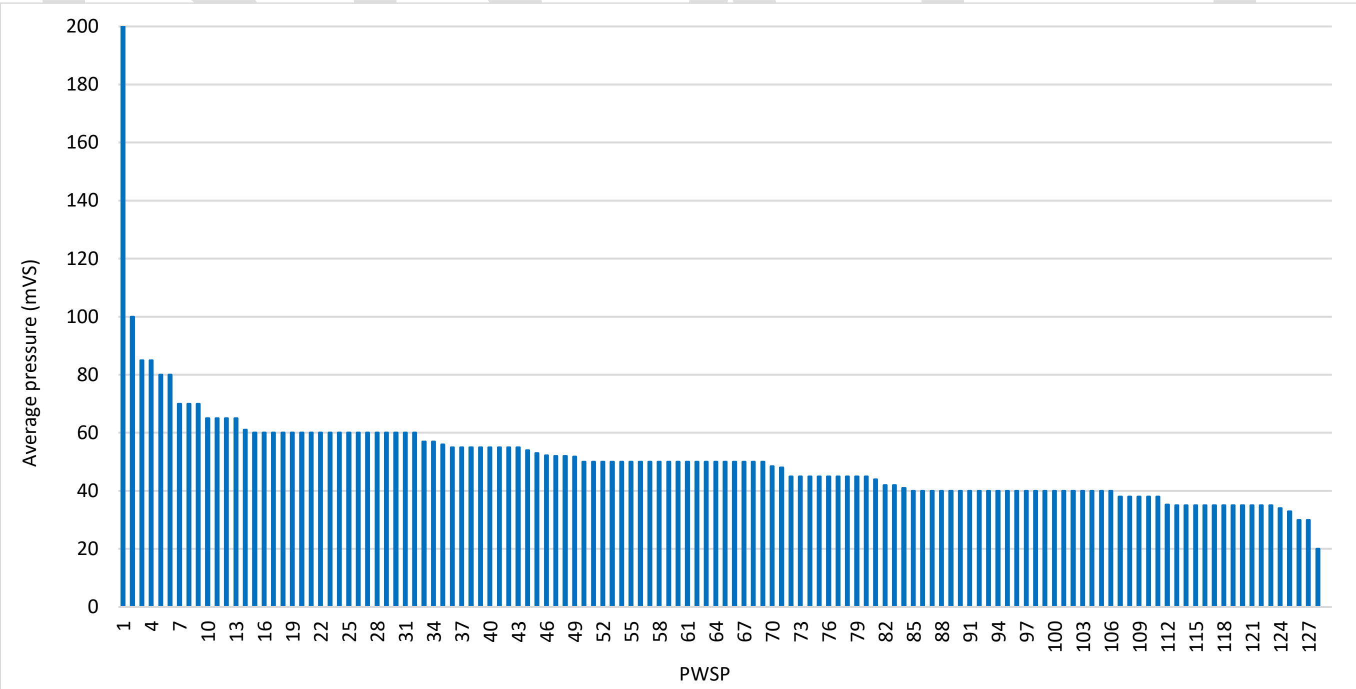

Figure 3.3. Average pressure in water supply systems on the national level

What is of essential importance for the methodological approach to the reduction of water losses is the preparation of Conceptual Solutions for water supply, particularly those that include updating of databases, system maps, and are based on the calibrated mathematical models with performed flow and pressure measurements. Such Conceptual Solutions for water supply have been prepared for 44% of the PWSPs (almost all the biggest PWSPs covered), including the extended water balance prepared according to the IWA methodology. The largest number of Conceptual Solutions has been prepared in the 2017-2022 period. Figure 3.4, i.e., it corresponds with the launch of the National Water Loss Reduction Program (NWLRP) in 2018.

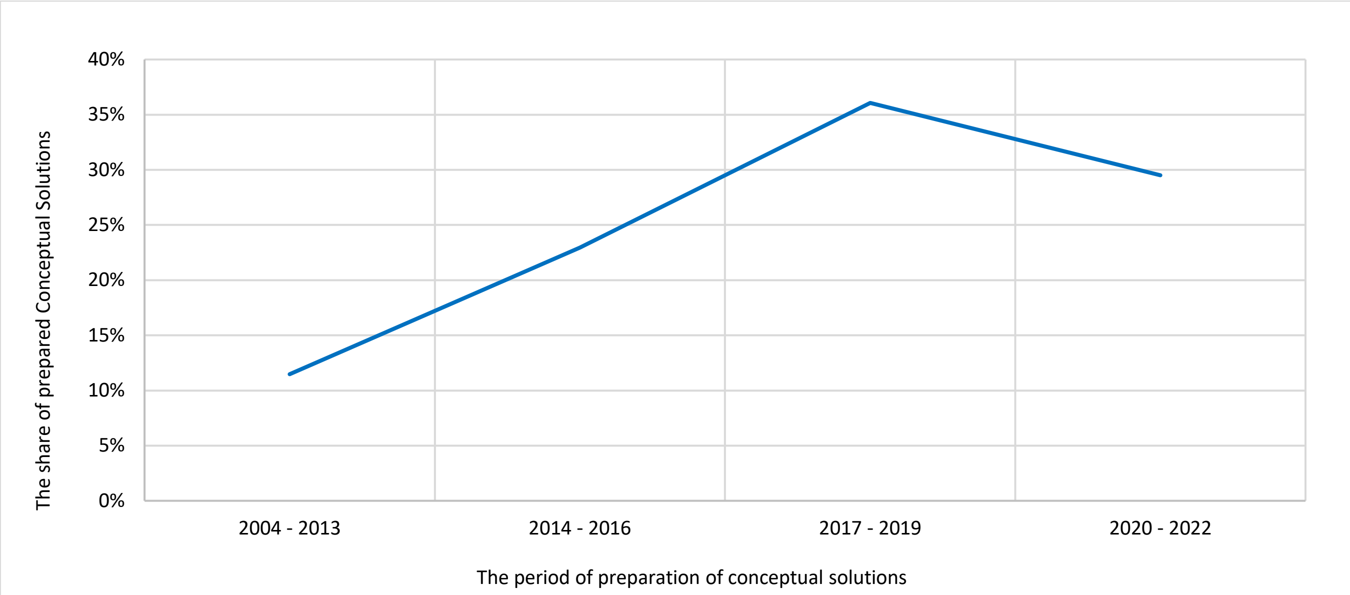

Figure 3.4. Analysis of PWSPs by periods of preparation of Conceptual Solutions for water supply

3.1.1.3 Active leakage control and optimum rehabilitation of water supply network

The global and European practice, as well as plenty of experience in Croatia, show that pressure reduction is the most efficient and most economical measure of water loss reduction, which is why it should have priority in implementing measures for system improvement and water loss reduction. In order to be able to efficiently reduce pressures in a water supply system, detailed knowledge about the hydraulic characteristics of the system is required. This in turn is possible exclusively from having at one's disposal a calibrated mathematical model, for the calibration of which it is necessary to implement systematic measurement of flow and pressure by DMAs (the majority of recommendations aim at a minimum of 7 days of continuous measurement for each DMA, including both the workdays and the weekend). Developing a calibrated mathematical model of the current status implies having at one's disposal a quality database with inputs, i.e., a detailed survey of the current status of system completion, together with being familiar with the basic technical characteristics of the installed electro-mechanical equipment. The reduction of pressures in the water supply system implies dividing the system into Pressure Management Areas (PMA) which may overlap with the DMAs, and installing pressure regulation valves, which often also requires the installation of new valve control shafts. When installing pressure regulation valves, the only proper solution is the installation of hydraulic valves instead of spring valves. Namely, the current practice in Croatia confirms very frequent use of spring valves, which is assessed as inadequate and is the cause of many problems, particularly in systems or parts of systems with lower water consumption, which eventually manifest themselves through water losses.

As for system pressure management, the results cannot be assessed as satisfactory. According to the way in which analyses of potential for system pressure management are made, on the level of all the PWSPs a (Figure 3.5) as much as 80% of them don't make analyses of system pressures or only occasionally measure the pressure and try to make analyses.

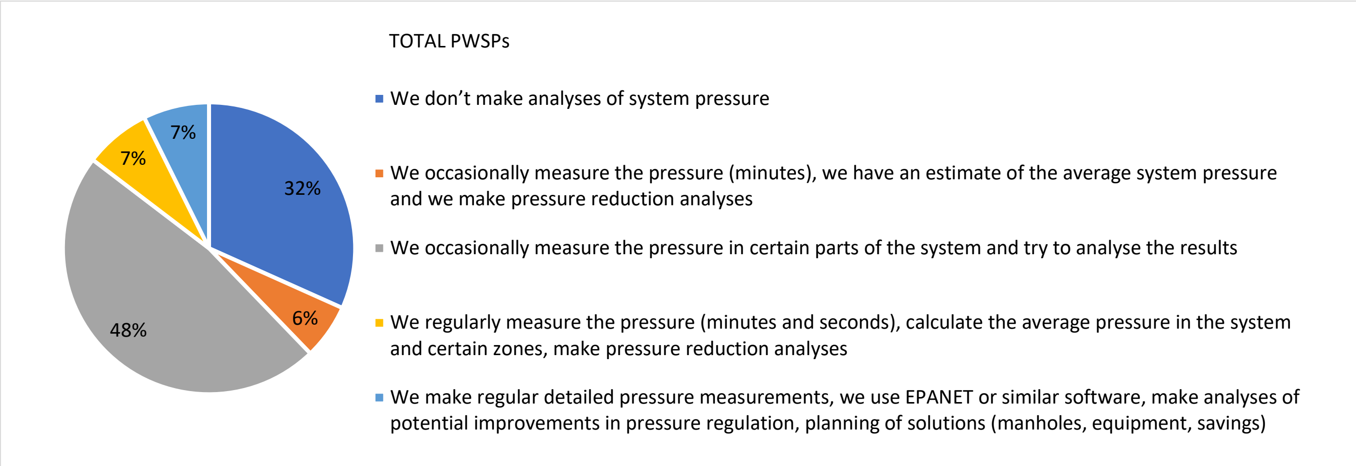

Figure 3.5. How potential for system pressure management is analyzed on the national level

The inefficient practice in Croatia so far shows that it is the visible leaks which result in the water flooding the surface of the ground, collapsing of ground, roads, and pavements, etc. that are primarily, and in many cases even exclusively, eliminated. After the reduction of pressures in the water supply network, it is necessary to implement active leakage control by establishing DMAs which will enable an insight into the spatial and quantitative distribution of water losses, and timely noticing new leaks. Once a leak within a DMA is noticed, a technical team goes out to the field in order to find the micro-location of the leakage (invisible leak), after which the necessary works on its removal and registration are carried out.

On the national level, 58% of the PWSPs use the equipment to detect reported and sometimes unreported leaks and for regular detection of unreported leaks. Na Figure 3.6. presents the results of the active leakage control methods on the national level.

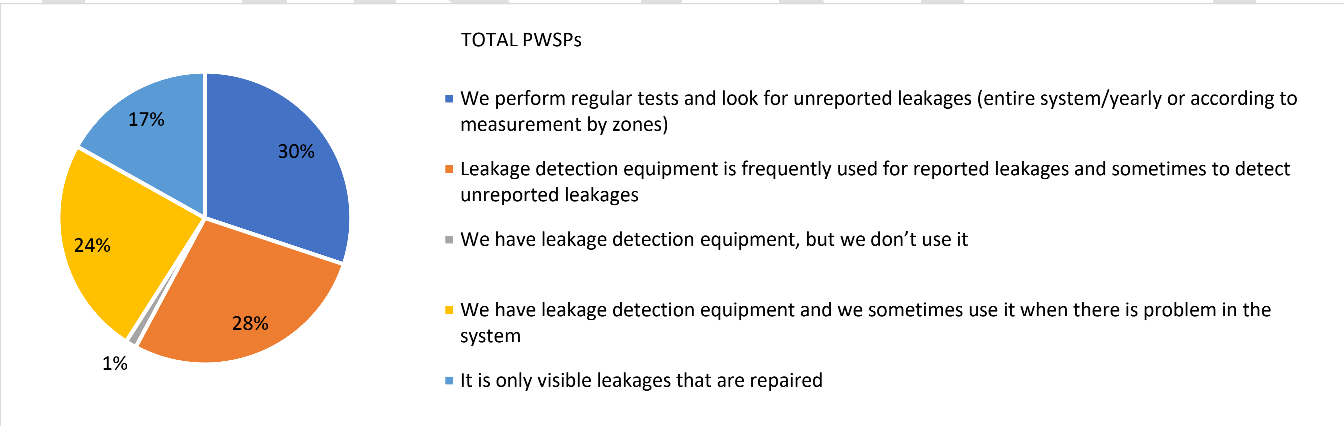

Figure 3.6. Active leakage control methods on the national level

As for the planning and implementation of the program of annual rehabilitation of the water supply network and structures, a high share of the PWSPs does the planning, but not in a way to perform optimum rehabilitation (replacement) in order for the system to be restored efficiently and functionally over a long term (it would be optimum to replace 2% of the mains network per year, with the assumption that the mains network doesn't initially have a high average age), but only within the limits of available financial resources, primarily of the line Ministry and Croatian Waters. This results in a small average annual quantity of the mains restored, and a low average annual rate of restoration of service connections (a pipe from connection to the main to the water meter). It is therefore necessary to systematically start with optimum mains replacement, with the priorities based on the knowledge of the system and users (GIS – data on the network, consumers, leaks, pressures, etc.).

3.1.1.4 Identifying capacities of PWSPs to identify and reduce water losses

The capacities of PWSPs are the key prerequisite for efficient water loss management. These capacities can be divided into **technical equipment** and **human resources**, with both components requiring continuous financial investment. The fragmented water sector in Croatia in terms of too many public providers (129 PWSPs) directly affects the inability to ensure adequate components of technical equipment and appropriate staff. Namely, the costs of procuring and implementing the GIS modules for registering structures and network, recording leaks, monitoring losses, then costs of procuring and implementing the SCADA system, as well as the costs of procuring leakage detection equipment (flow and pressure meters, geophones, correlators, noise loggers, etc.) can be too high for many PWSPs in relation to the pricing policy and the affordability of water services.

The problem is made even much bigger when technical equipment needs to be joined with appropriate technical staff, who with their education, expert knowledge and experience have to continuously, in the long run, and efficiently manage an integrated and highly complex water loss management program, the cost of which even exceeds the investment costs for equipment. The planned consolidation of the public sector will definitely help in the reduction of costs and improved capacities of PWSPs to identify and reduce water losses.

For that reason, the first thing that needs to be done is identify the condition of the existing equipment, identify the organizational structure of water loss management within a PWSP, analyze the availability of teams for water loss management, and give guidelines for future development. Parallel with the planning and implementation of measures, it is necessary to carry out additional measurements, analyze, and report on the results. In doing so, based on the experience so far, there is an imminent need to establish a central national body to manage the overall water loss management program (by implementing the NLRAP), with an obligation to establish benchmarking, and with additional establishment of a technical assistance mechanism for each PWSP.

Numerous PWSPs don’t have at their disposal the required equipment for efficient management of water losses. The equipment implies portable metering equipment (flow and pressure meters) and other water loss detection devices (correlator, geophone, noise loggers, etc.) used by technical teams. Each technical team (at least 2 low-skilled workers and 1 engineer who can lead several teams) should as a minimum have at its disposal three portable flow meters and two portable pressure meters, and a correlator, a geophone, a locator of pipes and fittings, and a set of noise loggers. The global and EU guidelines vary among countries and even regions in terms of defining the required number of technical teams, but all of them range from 200 to 500 km of the water supply network per technical team.

The most significant problem in water loss management in Croatia today has to do with human resources. A problem that is so specific requires different know-how and capacities for team management, HR management, water loss management, field work, etc. Investing in knowledge, technical teams, implementation of active leakage control, rational planning and implementation of the pipe replacement program, and an organizational structure that respects these issues are the basic preconditions to adequately manage water losses. However, it can already based on the analysis of the current status in Croatia, and taking account of the knowledge and experience gained so far (available databases, results of the questionaries filled in by the PWSPs that deliver 90-95% of the total volume of water delivered on the national level), be concluded that a certain number of PWSPs, particularly the smaller ones, have no interest in this matter or have no adequate staff and background to address the challenges of water loss management.

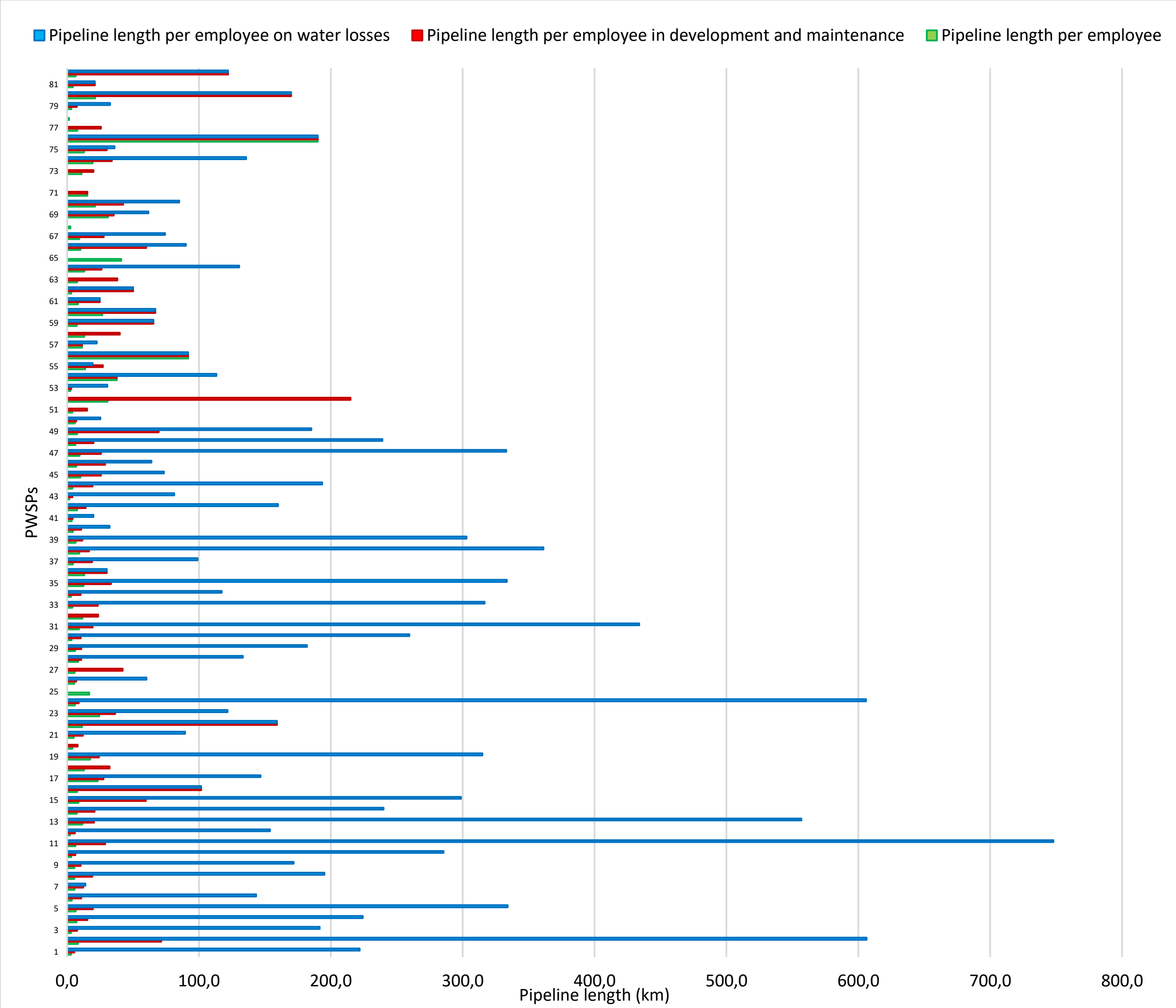

Figure 3.7. Mains length by employee categories, divided by PWSPs

All the mentioned components which the PWSPs have to identify for efficient water loss management without an organizational structure within the PWSPs will not be able to ensure successful water loss reduction. On a project level, they can be successful for a short time, but examples show that due to inaction already in the periods that follow water losses return to their previous levels, and even increase over time. It can be said that in the PWSPs there are no organized programs or strategies for medium- or long-term action aimed at efficient water loss control, the result of which is a lack of continuous action. Constantly analyzing the systems, regular planning of maintenance, servicing and replacement of the key elements, and planning of annual replacement of the sections at highest risk are not characteristic for the PWSPs in Croatia. As this problem is also related to insufficient financial means for own investment in improvements (people and equipment), it's clear that water losses are not managed at a satisfactory level, resulting in high volumes of water losses.

Analyzing the collected data about the way in which work in a company is organized, it is evident that as much as 70% of the PWSPs either have no special department (team) for NRW control activities or there is a team (person) to locate leakages, but these people when needed, or more often full time, do other work as well (Figure 3.8).

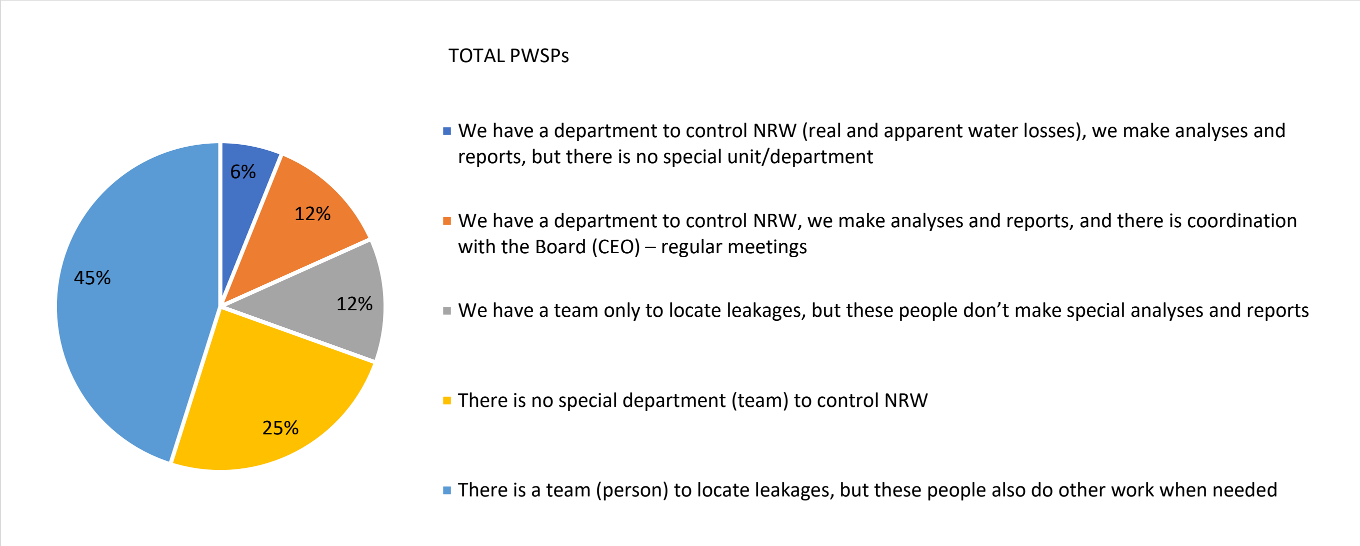

Figure 3.8. How work in a company is organized on the national level

When it comes to the way in which the water loss control program is planned and implemented, the situation is at a very low level (Figure 3.9). As much as 67% of the PWSPs either don't make any plans or reports on the implementation of water loss control activities or make implementation plans for annual water loss control activities but make no special reports on results.

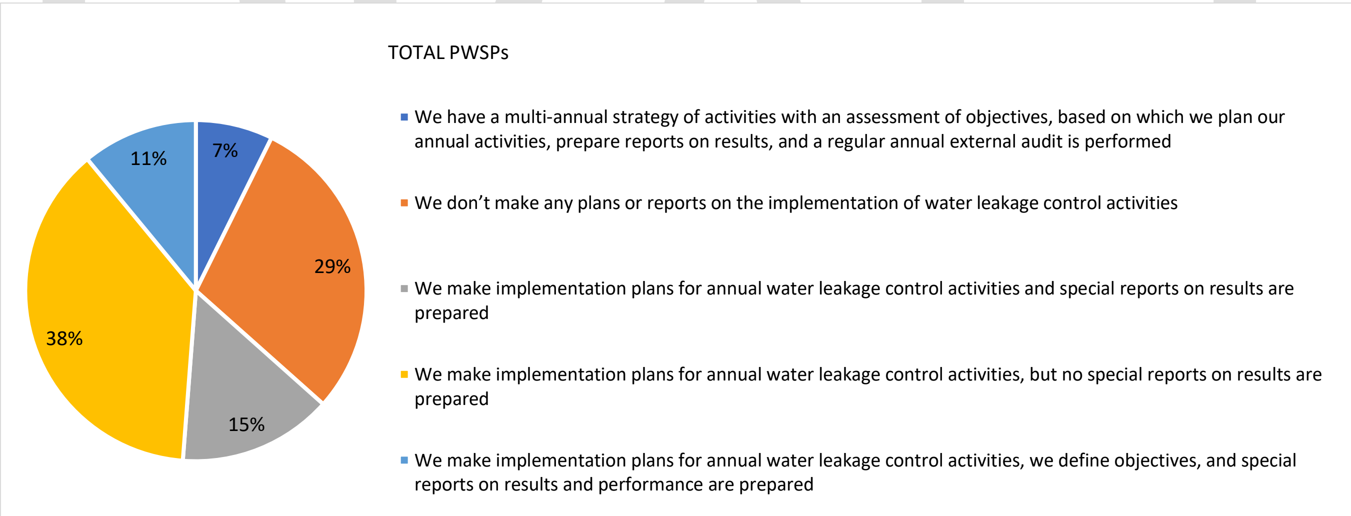

Figure 3.9. How water loss control programs are planned and implemented on the national level

3.1.2 Methodology for the preparation of the water balance

Understanding all the components of the water balance is the main precondition to recognize the size of the issue, the potential for water loss reduction, and further efficient resolution of the water loss reduction issue. The water balance can be prepared in three levels of complexity:

- Basic water balance
- Standard water balance according to the IWA methodology
- Extended water balance according to the IWA methodology

The basic water balance is explained in detail (methodology of preparation, problems in practice, etc.), including all disadvantages, in Chapter2.5.1.

The Standard and Extended water balance are explained in detail (methodology of preparation, advantages and disadvantages, the description of main terms, etc.) in Chapter 2.5.2.

Of the above-mentioned three levels of water balance complexity, it is only the extended water balance that is assessed as relevant to fully understand the overall water loss issue. For that reason, it is recommended to use exclusively the 'Extended' water balance in further practice.

Table 3.1. 'Extended' water balance

<table>
<tr><td rowspan="2">Volume from Own Sources</td><td rowspan="10">System Input Volume (corrected for known errors)</td><td>Water Exported</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td rowspan="2">Revenue Water</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="8">Water Imported</td><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td rowspan="7">Non-Revenue Water</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies (and data handling errors)</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Mains</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of customer metering</td></tr>
</table>

The preparation of the 'Extended' water balance starts with the definition of the 'Volume from Own Sources' and 'Water Imported'. Both components are measured water volumes. The 'Volume from Own Sources' will be measured using new, fixed flow meters permanently installed at all water abstraction sites, which will on the national level be implemented within the NWLRP through the implementation of 'Measure M'. The establishment of a unique system to measure the abstracted volumes, through which the measured data will at the same time be submitted to the relevant PWSP and the Ministry with Croatian Waters, will bring maximum transparency and control of one of the key pieces of data in the water balance.

'Water Imported' is also at the point of delivery/takeover obligatorily measured using fixed and permanently installed flow meters which are under the responsibility of the PWSP delivering water. In that way, the 'Water Exported' is also measured. The PWSP that takes over the water is not obliged to install its own flow meters. However, based on its own interest to control the water volumes that it takes over, it can construct its own valve and meter shafts with fixed and permanently installed flow meters.

In the next step, the 'System Input Volume' is calculated as the sum of the 'Volume from Own Sources' and the 'Water Imported'.

Then, the 'Water Supplied' is calculated as the difference between the 'System Input Volume' and the 'Water Exported'.

In the next step, the 'Billed Metered Consumption' is defined as the metered volume of water consumed by the registered consumers (water meter readings). In the same step, the 'Billed Unmetered Consumption' is defined as a lump estimate of the water volumes consumed by the registered consumers. The lump estimate has to be given based on the specifics of each registered consumer (e.g., the average number of people per household, specifics of consumers not categorized for residence like the number of employees, size of a construction site, etc.). The sum of the 'Billed Metered Consumption' and the 'Billed Unmetered Consumption' defines the 'Revenue Water', i.e., the 'Billed Authorized Consumption'. In Croatia, there is a relatively low share of registered consumers without metered water consumption, and the short-term goals are aimed at achieving the 100% metered water consumption by all the registered consumers.

Then, the 'Unbilled Metered Consumption' and the 'Unbilled Unmetered Consumption' are defined, with their sum giving the 'Unbilled Authorized Consumption'. The 'Unbilled Metered Consumption' is defined by metering (fixed or portable flow meters) water consumption by the PWSP itself for the needs of water treatment (water volumes can differ significantly from one PWSP to next depending on the applied technological process of treatment), flushing of the water supply network in order to ensure sanitary quality of drinking water or to prevent water from freezing in the mains (water volumes can differ significantly from one PWSP to next, depending on the characteristics of abstracted water and hydrological cycles in the relevant catchment area, and the characteristics of the water supply network itself, requiring bigger or smaller flushing volumes and frequent or less frequent flushing needs), flushing of storage tanks, filling of tanks that provide water to the population and industry not connected to the public water supply system, and other authorized unregistered consumers such as firefighters (firefighting activities and drills), sewerage maintenance services (flushing of sewers), town services maintaining pavements and sidewalks (street cleaning), taking care of parks and gardens (watering), squares (public fountains), registered construction sites, etc. The 'Unbilled Unmetered Consumption' has to be estimated in the lump, depending on the characteristics of the area supplied with water (e.g., number of fires, number and size of construction sites, number and size of fountains, length of the sewer network and frequency of flushing, etc.). The lump estimate of the unbilled unmetered consumption comes down to defining the percentage share in relation to the 'Billed Authorized Consumption'. Based on the analysis of the current state in Croatia, it is estimated that the 'Unbilled Unmetered Consumption', without the consumption needed for water treatment, ranges from 0.5% to 5.0% in relation to the 'Billed Authorized Consumption'. The 'Unbilled Unmetered Consumption' needs to be reduced to the minimum, i.e., already within short-term objectives and activities it is necessary to establish a metering system for water consumption by all the unregistered consumers, including the consumption of water by the PWSP itself (flushing of the water supply network, etc.). On the national level it is also necessary in short term to design a program and implement measures which will enable as accurate as possible quantification of the volumes of unbilled unmetered consumption, which have to be based on metering.

In the next step it is necessary to calculate the 'Authorized Consumption' as the sum of the 'Billed Authorized Consumption' and the 'Unbilled Authorized Consumption'.

It is then necessary to calculate the 'Non-Revenue Water' as the difference between the 'Water Supplied' and the 'Revenue Water' ('Billed Authorized Consumption').

In the next step, the 'Water Losses' have to be calculated as the difference between the 'Water Supplied' and the 'Authorized Consumption'.

Then, the 'Unauthorized Consumption' and 'Customer Metering Inaccuracies' (and data handling errors) are identified. Both components are identified as a lump estimate, as a percentage share of the 'Billed Authorized Consumption'. The 'Unauthorized Consumption' implies water theft mostly through illegal connections or unauthorized opening of hydrants. Based on the analysis of the current state in Croatia, it is estimated that the 'Unauthorized Consumption' ranges from 0.2% to 17.0% in relation to the 'Billed Authorized Consumption' (Figure 2.22) The 'Unauthorized Consumption' needs to be reduced to the minimum, i.e., already within short-term objectives and activities it is necessary in short term to design a program and implement measures which will enable as accurate as possible quantification of the volumes of unauthorized consumption, which have to be based on metering, primarily metering per DMAs, but also implement measures to prevent thefts of significant water volumes (Chapter 0). If the PWSP doesn't have at its disposal data based on which it could better analyze and define the percentage share of the unauthorized consumption, it is recommended to adopt the value 2.0% of the 'Billed Authorized Consumption'.

'Customer Metering Inaccuracies' (and data handling errors) are also estimated as a percentage share of the 'Billed Authorized Consumption'. Based on the results of the analysis of the current state in Croatia, the share of customer metering inaccuracies is defined in the range from 4.0 to 15% in relation to the 'Billed Authorized Consumption' (Figure 2.23). PWSPs can occasionally perform targeted field investigations (with metering at house connections) in order to better analyze and define metering inaccuracies. If the PWSP doesn't have at its disposal data based on which it could better analyze and define the percentage share of the metering inaccuracies, it is recommended to adopt the value 5.0% of the 'Billed Authorized Consumption'.

In the next step, the 'Apparent Losses' are calculated as the sum of the 'Unauthorized Consumption' and the 'Customer Metering Inaccuracies'.

In the last step of the preparation of the 'Extended water balance' it is necessary to calculate the 'Real Losses' as the difference between the 'Water Losses' and the 'Apparent Losses'.

As noted in the individual components, in the short-term period it is essential to define better and more reliable methods of their calculation in order to define the water balance of the best possible quality and as reliable as possible values of the individual components of water losses (real losses, apparent losses – unauthorized consumption, customer metering inaccuracies).

There is also a definite need for high-quality and reliable metering of all the components of the water balance which are subject to metering.

The calculation of the 'Real Losses' through the 'Extended' water balance is called the 'Top-Down' method.

All the components of the water balance are prone to errors in inputs. Therefore, the 'Non-Revenue Water' and its components calculated from the water balance aren't exact figures, even in systems with a high level of metering, as the result of errors in metering or estimates, which together with the accumulation of errors in individual components results in the uncertainty of the calculated value of real losses. For that reason, it is essential to apply an analysis of 95% confidence of the calculation of the water balance components. The bases of the 95% confidence analysis are presented in Chapter 2.5.2.

In the absence of more detailed information and check of accuracy of flow meters at water abstraction sites and points of water import (or water export), it is recommended that the adopted 95% confidence limit for the 'Water Supplied' is adopted within the range between 2% and 5%. Likewise, in the absence of more detailed information about the 'Unbilled Unmetered Consumption', it is recommended that the adopted 95% confidence limit for the 'Unbilled Authorized Consumption' is adopted within the range between 30% and 50%. In terms of defining the 95% confidence limit for the 'Apparent Losses', in the absence of more detailed information about water thefts and customer metering inaccuracies, it is recommended that the value of 20% to 30% is adopted. The result of the 95% confidence analysis will among other things be the range of values of real losses the confidence of which is within the 95% limit.

Due to certain uncertainties when defining individual components of the 'Extended' water balance, it is necessary to define the 'Real Losses' according to the 'Bottom-Up' method as well, thus actually checking the definition of the 'Real Losses' using the 'Top-Down' method.

The application of the “Bottom-Up” method to identify the 'Real Losses' is based on their calculation from the results of flow measurements in DMAs which may already exist in the water supply system and may be formed temporarily for the purpose of implementing a metering campaign. The analysis of flow measurement results is key to properly define the 'Real Losses'. The basis for the calculation of the 'Real Losses' is the identification of the Minimum Night Flow (MNF) and a share of authorized consumption by consumers in the MNF. The MNF is usually present in the night hours, usually between 1:00 a.m. and 4:00 a.m., although the exact definition of the MNF interval varies from system to system or from DMA to DMA, depending on numerous system/DMA specifics. During the MNF period, authorized consumption is usually minimum (except in case of an industry with intensive night consumption of water), and the share of real losses in the total MNF is maximum. Authorized consumption during the MNF period needs to be estimated, using one or more recognized methods that have proven justified in local and global practice. It is recommended to use a simpler method which in rural areas assumes authorized night consumption in the night period with a value of up to 5% in relation to the predefined difference between the maximum hourly consumption and the MNF, and in urban areas it assumes authorized night consumption in the night period with a value of up to 10% in relation to the predefined difference between the maximum hourly consumption and the MNF. It is deemed wrong to calculate the authorized night consumption as a percentage share of the MNF because the value calculated in that way is also affected (in some DMAs even to a significant extent) by the amount of water losses, which in reality has no impact on the consumption of water by the population and industry. Deducting the calculated authorized consumption in the night period from the identified MNF value gives the volume of real losses in that night period. Since a change in pressure in the water supply network is inversely proportional to a change in water consumption, the highest pressures are present precisely in the night period with minimum water consumption (minimum flows within the system). For that reason, the predefined value of real losses in the night period with maximum pressures needs to be averaged on a daily level (over a 24-hour period), using in the calculation the average daily pressure value. It is recommended to use the FAVAD method. The averaged value of real losses over a 24-hour period multiplied with the number of days in a year gives the annual volume of 'Real Losses'.

The 'Bottom-Up' method of calculating the 'Real Losses' has additional benefits in that it ensures independent definition of the 'Real Losses'. If this analysis is carried out in the entire water supply system, it is easy to identify areas with high real losses and obtain priorities in addressing the water leakage issues, which can make the overall water loss reduction program more successful. This method of analysis should be avoided in the summer months when in smaller areas due to considerable seasonal water demand (watering of gardens, filling of pools,...), particularly in drier coastal regions, a distorted image of night flows can be obtained.

The results of calculating the 'Real Losses' using the 'Top-Down' and 'Bottom-Up' methods should be approximately the same, but they are often not so due to cumulative errors in the calculation of each method, as well as due to the fact that the real losses calculated using the 'Bottom-Up' method refer to the current condition identified during a metering campaign in a certain period within the year, while the real losses identified using the 'Top-Down' method refer to a full-year period. It is therefore recommended that the calculation of the 'Real Losses' using the 'Bottom-Up' method in case of pre-established DMAs is done a monthly basis. The precision of the calculating the 'Real Losses' using the 'Bottom-Up' method can be improved by collecting additional more detailed field data which is needed to define the pressure/losses ratio (N1) and the Infrastructure Condition Factor (ICF). It is essential to in short term establish a methodology applicable on the national level for the collection of field data, definition of the N1 exponent, and the ICF.

3.1.3 Methodology to calculate the ILI

The basis for the calculation of the ILI is presented in Chapter 2.6.1, and is based on the following expression:

$$ILI = \frac{Current\ Annual\ Real\ Losses}{Unavoidable\ Annual\ Real\ Losses} = \frac{CARL}{UARL}$$

The CARL is defined according to the 'Top-Down' or 'Bottom-Up' method of the water balance preparation. It is recommended to use both methods, which additionally confirms the correctness of defining the CARL.

The UARL can be calculated using different expressions, from the original equation according to the IWA methodology to different equations developed by different scientists and used in different countries of the world. In the absence of research based on which to define the equation applicable to water supply systems in Croatia, it is recommended to use the original equation according to the IWA methodology:

$$UARL = \frac{18 \cdot L_m + 0.8 \cdot N_c + 25 \cdot L_p)\ x\ P_{av}}{L_m}\ (l/km\ of\ mains/d)$$

$$UARL = \frac{18 \cdot L_m + 0.8 \cdot N_c + 25 \cdot L_p)\ x\ P_{av}}{N_c}\ (l/service\ connection/d)$$

Where:

- L_m – Mains length, transmission and distribution mains (km)
- N_c – Number of service connections (1)
- L_p – Total length of service pipes – from property line (most often a fence) to meter, i.e., part of the service pipe lying on private property (km)
- P_{av} – Average operating pressure (m of water column)

Account needs to be taken about the method of defining the L_p parameter, respecting the service connection pipe length from the property line to the water meter (one service connection pipe most often has a 0-3 m length).

It is definitely recommended to in the short-term conduct more detailed research on the national level and define the UARL calculation methodology which would be more realistic and more correct for use in Croatia.

3.2 Measures and definition of priorities for water loss reduction

For efficient management of water losses, it is necessary to define measures which will have an impact on the reduction of water losses. In accordance with the described methodology of how to approach water loss reduction, and having in mind the state of water losses, technical characteristics and capacities of PWSPs to manage water losses, on the PWSP level it will be necessary to prepare their own action plans which will depending on available financial resources define and prioritize those measures which will give the best results.

It is of utmost importance to understand the overall issue of water losses through the definition and analysis of all the measures that affect water losses, as well as to understand the interdependence of the proposed measures, and define priority measures and appropriately assess the effects of the proposed measures.

In order to define the scope, i.e., quantities and, consequently, the planned investments, for each measure the state was checked in each PWSP, after which a specific measure was foreseen in its entirety or in part with regard to the required standards. Namely, if a PWSP already has at its disposal certain elements of measures (availability of the GIS, the SCADA system, the conceptual solution prepared, establishment of DMAs, availability of equipment, etc.), such measure won't be foreseen or will be foreseen in part. The price itself was formed using the data from the recently conducted tender procedures, prices foreseen in the conceptual solutions, or feasibility studies.

3.2.1 Water loss reduction measures

Water loss reduction measures can be divided into those that will be implemented by PWSPs and those that refer to strengthening the capacities of the line Ministry and Croatian Waters with the establishment of the PWSP benchmarking system and performance indicators (establishment of the national database, training PWSPs to report to the Ministry). Table 3.2. presents the basic groups of measures.

Table 3.2. Groups of water loss reduction measures

Responsibility	Number	Group
PWSP measures	I	System data improvement measures
	II	Water supply system optimization measures
	III	Measures to divide the system into DMAs
	IV	System pressure control and management measures
	V	Active leakage control measures
	VI	Measures to address apparent losses
	VII	Planning and mains replacement measures
	VIII	Institutional strengthening measures
	IX	Analysis and reporting measures
	X	Technical (external) assistance to PWSPs to implement the measures
MESD measures	XI	Establishment of the PWSP benchmarking system and performance indicators (establishment of the national database, training PWSPs to report to the Ministry)
		Costs of the national control body for the reduction of losses (expert assistance for the verification and implementation of PWSPs' action and investment plans during NLRAP implementation)

The presented groups of measures try to cover all the areas that affect the reduction of water losses, also aiming to raise awareness about the importance of long-term implementation of all the measures. Certain groups of measures or measures within each group can successfully be implemented on their own, but optimum results and sustainability of the water loss management system will be achieved exclusively with the application of all the measures. The dynamics and scope of application of individual measures will depend on available funds. For that reason, both priorities and plan of implementation will be defined so that – depending on available funds –activities of priority importance are launched.

The measures that a PWSP has to implement are based on it knowing its own system, which is contained in the Group I measures – Improvement of data about the system. It includes improving technical data about the system, all asset information, data about bursts (differentiated between mains and connections), data about consumers, data about operating characteristics, integrating all the collected and updated data with the joint GIS platform. Any further measure will depend on or be more appropriate once the issue of knowing one's own system is addressed.

Before starting with the implementation of measures with the biggest effects in the reduction of water losses (pressure control and management, active leakage control, and replacement of mains), it would be ideal to check the possibility to modify the basic water supply layout with the aim of potentially modifying areas with significant pressures, which is foreseen by the Group II measures. In order to check whether such thing is possible, it is necessary to prepare appropriate conceptual solutions based on the calibrated mathematical model that gives a clear picture of the current status and of the possibilities to significantly modify the water supply system layout. Analyzing the planned solutions, one can see that these are still mostly smaller parts of the systems, while a more serious modification of the hydraulic layout is planned in the biggest PWSP (VIO Zagreb), which by establishing the so called "Zone 0", i.e., by interpolating a new storage tank and some other modifications to the layout, reduces the pressures by around 2 bar in the area that covers around 50% of the system consumption, and where the average pressures currently amount to around 7.0 bar (Figure 3.10). The effects of thus modified water supply system layout are a direct reduction of water losses due to lower pressures in "Zone 0", energy savings due to the need to invest less energy for around 50% of the consumers, and a significant impact on a smaller number of future leaks, in particular because this zone covers the most densely populated parts of the city with the oldest network.

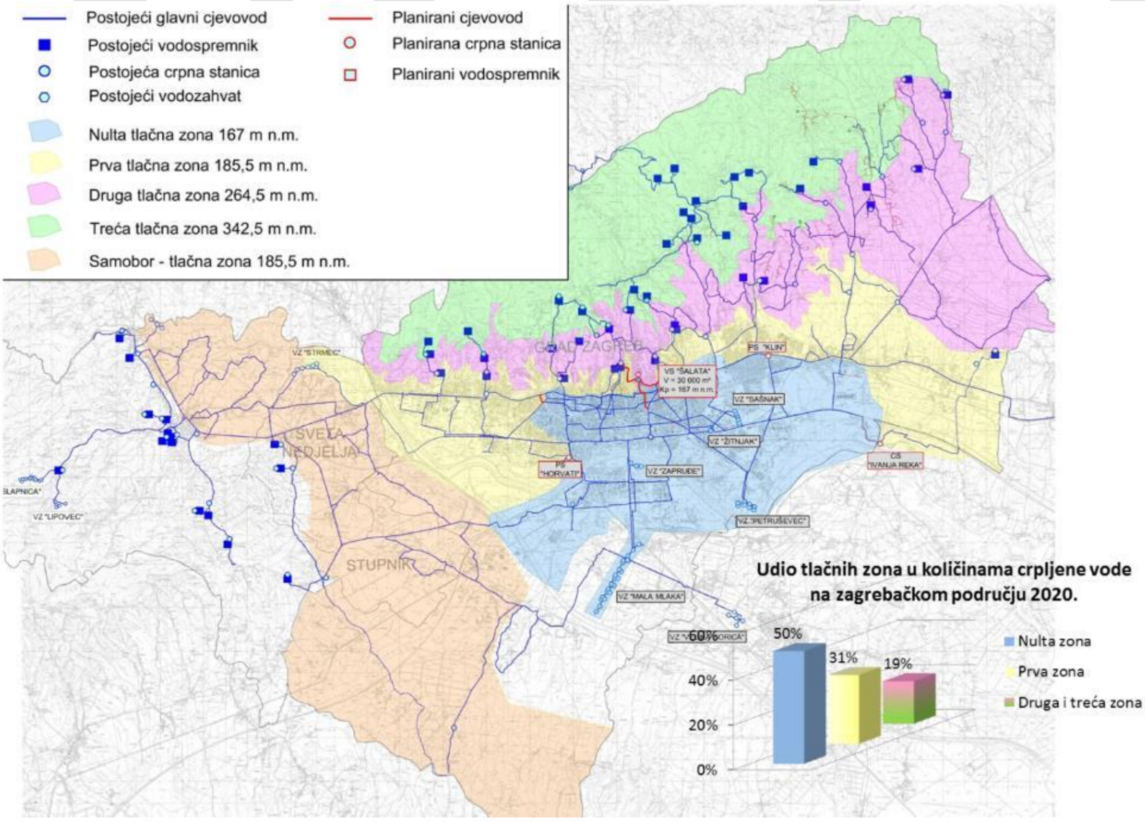

Figure 3.10. Establishment of the so called "Zone 0" (ViO Zagreb) in the area marked in blue

Once the possibilities for hydraulic system optimization by modifying the hydraulic layout have generally been exhausted (in practice, it will be possible to implement further measures parallel with this measure or even before), it is necessary to proceed with further measures, primarily measures **V** (implementation of active leakage control) and **III** in terms of establishing DMAs in order to more easily monitor operating conditions, analyze flows, raise alarms, shorten the time need to identify leakage locations, prioritize further measures of active pressure control, locate leakages (micro-locating), and replace mains.

All the already implemented measures will enable better quality implementation of further measures. The Group **IV** measures of pressure control and management have to start with a hydraulic analysis for protection from water hammer (hydraulic shock) and by applying appropriate measures to address the issue of instances with exceeded pressures which have a direct impact on the increased number of bursts. These include protection from increased pressures and the formation of negative pressure, the use of appropriate valves and frequency converters for pumps. With this measure, it is necessary to check the possibility to additionally reduce pressures by turning DMAs into PMAs and in other places within the system using regulation valves which can change parameters depending on the consumption in the system, i.e., flows.

Group **V** – active leakage control – is a measure that gives the biggest results in the total NRW volume. It consists of the procurement of equipment to micro-locate the leakages, implementation of additional metering or using data from the established DMAs about zones with increased losses, micro-locating in 50% of the priority water supply network, and the repair of failures, assuming that on average 4 failures per kilometer will be repaired. Here it is very important to understand that the efficiency of this measure will be questionable in the long run if the preceding measures are not implemented, since new bursts can continue occurring at the same rate as before if the causes of the bursts are not addressed, i.e., if hydraulic optimization is not done by reducing pressures and water hammer risks and if optimum rehabilitation (replacement) of mains of priority importance is not performed. Certain activities with Group V, such as locating leaks (micro-locating), are proposed to be implemented as a priority, continuously and simultaneously with all the preceding measures. Locating leaks using acoustic methods is more efficient at higher pressures in the networks and more intensive leakages. This does not mean that it is at the same time necessary to do repairs, except for bigger bursts, without previously implementing other priority measures, such as the Group IV measure.

The Group **VI** measure refers to the reduction of apparent losses (metering inaccuracies and unauthorized consumption – water theft). In that context a measure is foreseen to carry out a plan to test the accuracy of water meters and to replace 10% of water meters in the worst condition. In this group of measures, it is additionally planned to analyze and enable remote limitation of water theft through automatic reduction of pressure or closure of valves in the zones with unusually increased consumption not only during the night, but also during the day. This group of measures also foresees continuously informing the public about this issue through tv and radio shows, newspaper articles, leaflets, education, etc.

The next group (**VII**) of measures is financially the most demanding. Through the preparation of a plan for optimum rehabilitation of the water supply network (replacement of priority mains) it is planned to replace between 5 and 15% of the mains depending on the prioritization made which depends on a number of parameters and is described in more detail in 3.4.2. It is clear that there can be no optimum rehabilitation without the preceding measures of knowing the system and consumers and recording of failures.

The mere implementation of these measures without the organizational structure and the staff who are motivated and possess appropriate knowledge won’t be satisfactory. That is why the Group **VIII** measures (institutional strengthening) foresee investing in the development of processes, assistance in the formation of teams, investing in education and preparation of action plans of PWSPs that will be obliged to prepare adapted plans for their own areas.

The planned investments will have to be systematic, just like monitoring and reporting about the implemented activities. It will be necessary to regularly update databases and hydraulic models. For the implemented measures a financial and economic analysis of the project will have to be made. All of that is foreseen by the Group **IX** measures – analyses and reporting.

The Group **X** measures – technical assistance, just like for all major investments, will enable successful project implementation, i.e., the reduction of water losses. The analysis of the state of water supply systems and the current level of loss management suggest that all PWSPs need certain types of technical assistance for successful implementation of loss reduction measures. External expert teams can provide assistance in approach and organization of implementation of certain measures (from consulting services to active leakage control with specialized teams), thus transferring the required knowledge and building the PWSP’s capacity to manage losses.

The last group of measures, **XI**, is a measure under the responsibility of the line Ministry, and refers to the essential establishment of the PWSP benchmarking system and performance indicators (establishment of the national database, training PWSPs to report to the MESD), and includes the foreseen costs of the national body for water losses for the reduction of water losses (expert assistance in the verification and implementation of PWSPs’ action and investment plans during the NLRAP implementation, Chapter 3.7).

The table below will by groups of measures show the planned measures which will be implemented by PWSPs and describe objectives for each of the measures. It will also show the planned costs of all the measures both in the total amount and in percentages by measure groups.

The table will be followed by an overview or recapitulation of the planned investments in all the measures, both those under the responsibility of PWSPs and those under the responsibility of the line Ministry.

The financial estimate of measures was made using the results of analyses of the construction market, as well as the results of analyses of prices/values for services, goods and works achieved in other water and wastewater projects in the past period, until (including) 2022.

Table 3.3. Description of water loss reduction measures

No.	Group	% of the cost of measure	Measure	Objectives	Amount (EUR)
I	System data improvement measures	2.1%	GIS - General module (with entry/update of system data)	Knowing one's own system (pipelines, structures, connections, materials, age, profiles, etc.)	2,870,000
			GIS - Link to the business IT system (with development of the customer database)	Knowing the water supply service users, their exact positioning on a GIS map which also needs to have an updated overview of all the user structures built (address centroids)	1,940,000
			GIS - Register of failures (with entry of data for the last 5 years)	For the planned optimum rehabilitation (replacement of mains) it is necessary to have at one's disposal records of the place (pipeline, service connection pipes, structures) and description of failure	2,390,000
			GIS - Link between the technical and SCADA IT systems	Enable overview and analysis of data from the SCADA system on a joint platform	250,000
			GIS - Control of losses	Implement on the joint platform a module that automatically analyzes the flows, night flows, pressures in individual DMAs and raises alarms in case of deviations from the expected values	980,000
			SCADA (with enabled links to all the structures and data storage)	Upgrade the existing systems, enable multi-year analysis and raising alarms, and establish the SCADA system where there is still none	20,700,000
			Recording and digitizing field data (procurement of software and equipment, education)	Make it possible for the field staff to store data directly on their mobile phones, with software support to systematize and analyze the stored data and prepare appropriate reports, as well as make it possible to monitor the completed works. This also includes a link with individual GIS modules.	2,920,000
			Total price of system data improvement measures		**32,050,000**
II	Water supply system optimization measures	4.2%	Development/revision of the conceptual solution with the calibrated mathematical model	Revise solutions with regard to the updated states based on Measure I, according to standardized Terms of Reference, and prepare them if they haven't been prepared	10,610,000
			Extension of storage tanks, pumping stations, mains, and other structures to achieve pressure and energy optimization of water supply systems	Significantly modify the water supply system layout (adding storage tanks and pumping stations) in the systems where pressure conditions can be changed in the bigger part of the system, in order to reduce initial pressures, and consequently water losses as well (ViO Zagreb)	53,090,000
			Total price of water supply system optimization measures		**63,700,000**
III	Measures to divide the system into DMAs	14.6%	Design and construction of DMA shafts with installation of appropriate equipment (incl. SCADA system extension)	Form permanent or temporary DMAs for the purpose of faster and more efficient identification of leakage, more efficient active leakage control, control of higher quality, and facilitated analyses	223,120,000
			Total price of measures to divide the system into DMAs		**223,120,000**

No.	Group	% of the cost of measure	Measure	Objectives	Amount (EUR)
IV	System pressure control and management measures	3.7%	Hydraulic analysis and development of concept to protect the system from water hammers (hydraulic shocks)	Hydraulic check of exceeded pressures - water hammers, and preparation of conceptual solutions and design documents to implement optimum measures for protection from water hammers	3,080,000
			Installation of structures and equipment to protect from water hammers (incl. designing)	Installation/Extension of structures and equipment to protect from water hammers, reduction of exceeded pressures, reduction of the frequency of bursts	40,980,000
			Formation of PMAs - Installation of new hydraulic valves for pressure regulation with additional replacement of the existing spring valves	Additional pressure regulation where proven feasible and justified, and replacement of the existing inadequate spring valves in order to reduce unnecessarily high pressures and increased leakage	9,650,000
			Control and management of air in the pipes (application and control of air release and air release/intake valves)	Check the condition/service air release and air release/intake valves and apply them where so foreseen by the hydraulic analysis with the aim of releasing the air and enabling air intake when negative pressure forms	3,450,000
			Total price of system pressure control and management measures		**57,160,000**
V	Active leakage control measures	10.5%	Procurement of equipment for active leakage control (pressure and flow meters, geophones, correlators, noise loggers, smart balls, etc.)	Supplement the existing equipment and procure equipment where there is none for the needs of active field leakage control	9,190,000
			Conducting additional pressure and flow measurements by zones and sub-zones (with identification of priority zones/sub-zones), conducting STEP tests, etc.	Implement an additional metering campaign in order to identify the zones/sub-zones with the biggest leakages in which micro-locating the leakages will be done as a priority	9,080,000
			Identification of leakage micro-locations	Tour 50% of the route in order to identify leakage micro-locations (geophones, correlators, noise loggers, smart balls, etc.)	12,970,000
			Repairing detected failures (leakages, pipe bursts, damage to water supply fittings)	Repair detected failures assuming an average of 4 failures per kilometer	129,670,000
			Total price of active leakage control measures		**160,910,000**
VI	Measures to address apparent losses	2.2%	Water meter accuracy analysis and preparation of a replacement plan	Analyze the condition of water meters and identify 10% of water meters in the worst condition	940,000
			Replacement of water meters	Replace 10% of water meters	27,940,000
			Hydraulic analysis of possibilities for remote reduction of pressure at valves and possibilities to shut off zones in case of unauthorized water consumption	With the help of remote control and management at entries into zones or in other locations of special interest for protection from water theft foresee the possibility to shut off the valves or reduce the pressure at automatic alarm about unusually increased consumption	1,730,000
			Informing the public about the problem and cost of unauthorized water consumption (printing leaflets, daily press, billboards, newspaper articles, radio and tv broadcasts)	Inform the public about the water loss issue, raise the public awareness, particularly about the issue of unauthorized consumption and about all the measures taken to reduce water losses	3,730,000
			Total price of measures to address apparent losses		**34,340,000**
VII	Planning and mains replacement measures	61.1%	Preparation of mains replacement plans - optimum rehabilitation (based on the GIS, register of failures, additional measurements and micro-locating, and additional testing of built-in pipe materials such as the wall thickness, etc.)	Prepare plans for optimum rehabilitation – replacement of mains based on the updated data from the Group I measures, all according to expected needs (prioritization of measures) and capacities	1,730,000

No.	Group	% of the cost of measure	Measure	Objectives	Amount (EUR)
			Preparation of design documents	Prepare design documents and obtain permits, if needed	16,210,000
			Replacement of mains	Replace mains in the length of 5-15%, depending on a number of priority parameters	918,910,000
			Total price of planning and replacement measures		**936,850,000**
VIII	Institutional strengthening measures	1.2%	Preparation of an organization scheme, processes, tasks, human resources, control, communication	Strengthen PWSPs' capacities for water loss management	1,410,000
			Preparation of PWSPs' Loss Reduction Action Plans, preparation of PWSPs' business plans	Prepare for the implementation of the water loss management program	14,010,000
			Staff training	Invest in the training of staff - management, engineering, and field staff	3,230,000
			Total price of institutional strengthening measures		**18,650,000**
IX	Analysis and reporting measures	0.4%	Preparation of analyses of losses, updating the hydraulic model, GIS	Continuously update databases and models, prepare analyses	3,450,000
			Project economic and financial analysis	Financial and economic analysis of the project to monitor whether the investment is justified	1,410,000
			Preparation of monthly and annual reports incl. preparations for entry into the future central database	Continuously report to the competent bodies of the Ministry, Croatian Waters, and the National Body for the management of water losses	1,690,000
			Total price of analysis and reporting measures		**6,550,000**

Table 3.4. Recapitulation of the water loss reduction measures

Responsibility	Number	Group	Amount (EUR)
PWSP measures	I-IX	Measures total	1,533,330,000
	X	Technical assistance to PWSPs to implement the measures (3% of the value of Measures I-IX)	45,950,000
MESD measures	XI	Establishment of the PWSP benchmarking system and performance indicators (establishment of the national database, training PWSPs to report to the MESD)	670,000
		Costs of the national control body for the reduction of losses (expert assistance for expert verification of PWSPs' action and investment plans during NLRAP implementation)	2,000,000
Measures total			**1,581,950,000**

The initial assumption is that it is necessary to implement all the foreseen measures in the scope/amounts adjusted to the priority of reducing water losses on the national level, as well as to the needs of individual PWSPs or future service areas.

The most demanding measure in terms of financing and implementation has to do with the rehabilitation or replacement of the existing mains. For that reason, in order to identify its initial scope, impact elements were additionally analyzed. This refers to the level of losses in the specific area, the age of mains, as well as risks related to water availability and sensitivity to climate change.

3.2.2 Prioritization of measures

In order to prepare the scope of mains rehabilitation measures, 4 criteria (Criterion 1 - Unit Real Losses, Criterion 2 - Volume of PWSP's Real Losses, Criterion 3 - Water supply system age, Criterion 4 - Risks associated with limitations in available water volumes and climate change) with assigned weights were used. Each criterion contains sub-criteria graded from 1 to 4. In general, grade 1 describes the highest system (PWSP) sensitivity/risk according to that sub-criterion, while grade 4 classifies the system (PWSP) into the categories of lower sensitivity/risk according to that sub-criterion.

3.2.2.1 Unit Real Losses

The unit real loss, as a loss management peformance indicator, expressed in liters per service connection per day (liters / service connection / day) was selected for the assessment of the relevance of losses.

According to this Criterion 1, the PWSPs are classified into 4 categories:

- Unit Real Losses > 1,000, Grade awarded: 1 (very poor indicator of status);
- Unit Real Losses 500 - 1,000, Grade awarded: 2 (poor indicator of status);
- Unit Real Losses 100 - 500, Grade awarded: 3 (moderately poor indicator of status);
- Unit Real Losses < 100, Grade awarded: 4 (good indicator of status);

Figure 3.11. presents the distribution of the unit values of Real Losses in liters/service connection/day per PWSPs in Croatia, as well as the spatial distribution of unit values of Criterion 1 classified into four categories.

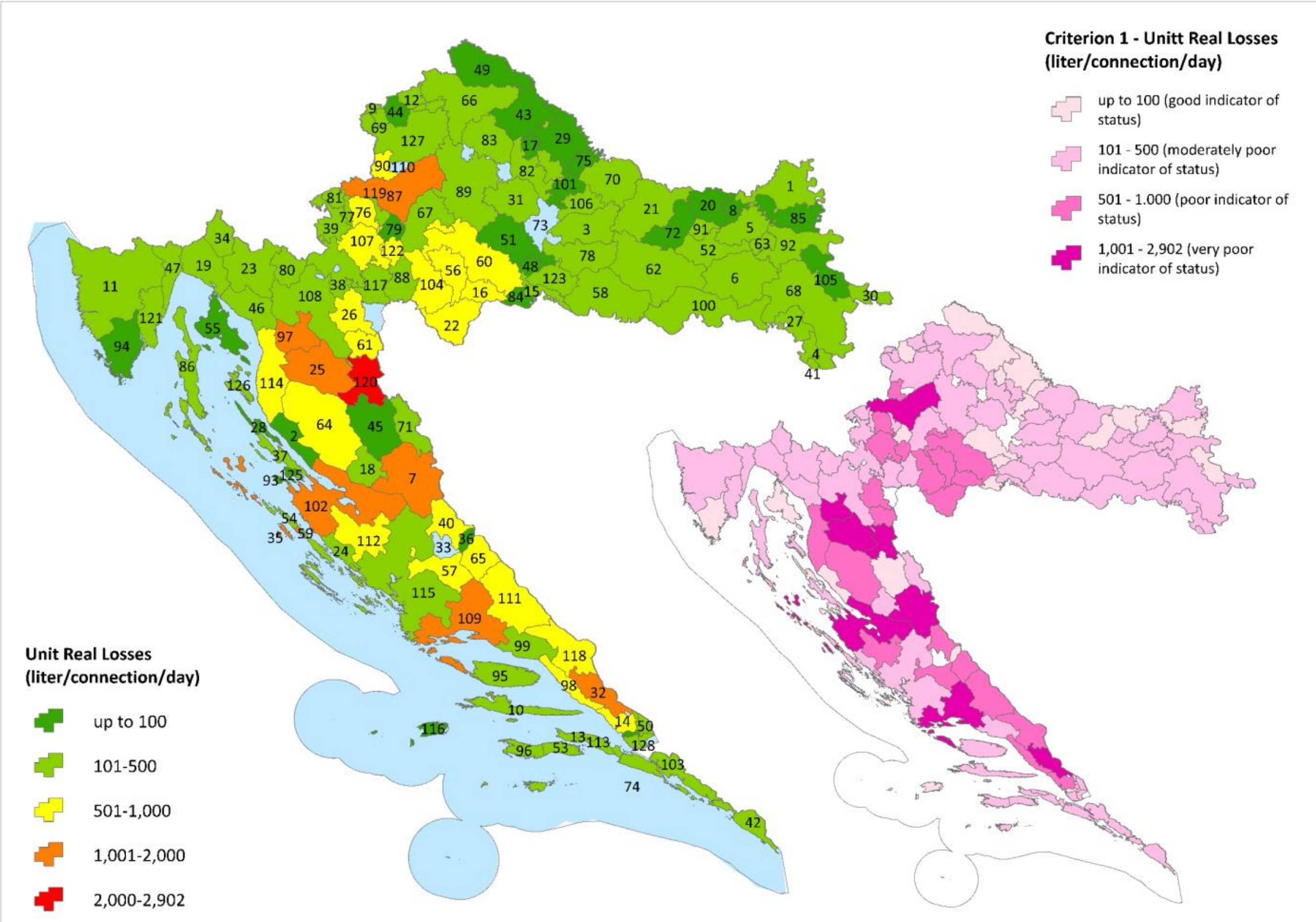

Figure 3.11. Spatial distribution of unit values of Real Losses (with the indicator values specified, left) and Criterion 1 (right)

3.2.2.2 Volume of PWSP's Real Losses

The share of Real Losses of a PWSP in the total Real Losses (%) was selected for the assessment of the relevance of losses as a measure of a PWSP's significant volume lost in relation to the total water losses at the national level.

According to this Criterion 2, the PWSPs are classified into 4 categories:

- PWSP CARL / CRO CARL > 20% – Grade awarded: 1 (a highly significant share);
- PWSP CARL / CRO CARL 3% – 20% – Grade awarded: 2 (a significant share);
- PWSP CARL / CRO CARL 1% – 3% – Grade awarded: 3 (a moderately significant share);
- PWSP CARL / CRO CARL < 1% – Grade awarded: 4 (a less significant share);

Figure 3.12. presents the distribution of the volume of Real Losses per PWSPs in Croatia, as well as the spatial distribution of the share of Real Losses in the total Real Losses by Criterion 2 classified into four categories.

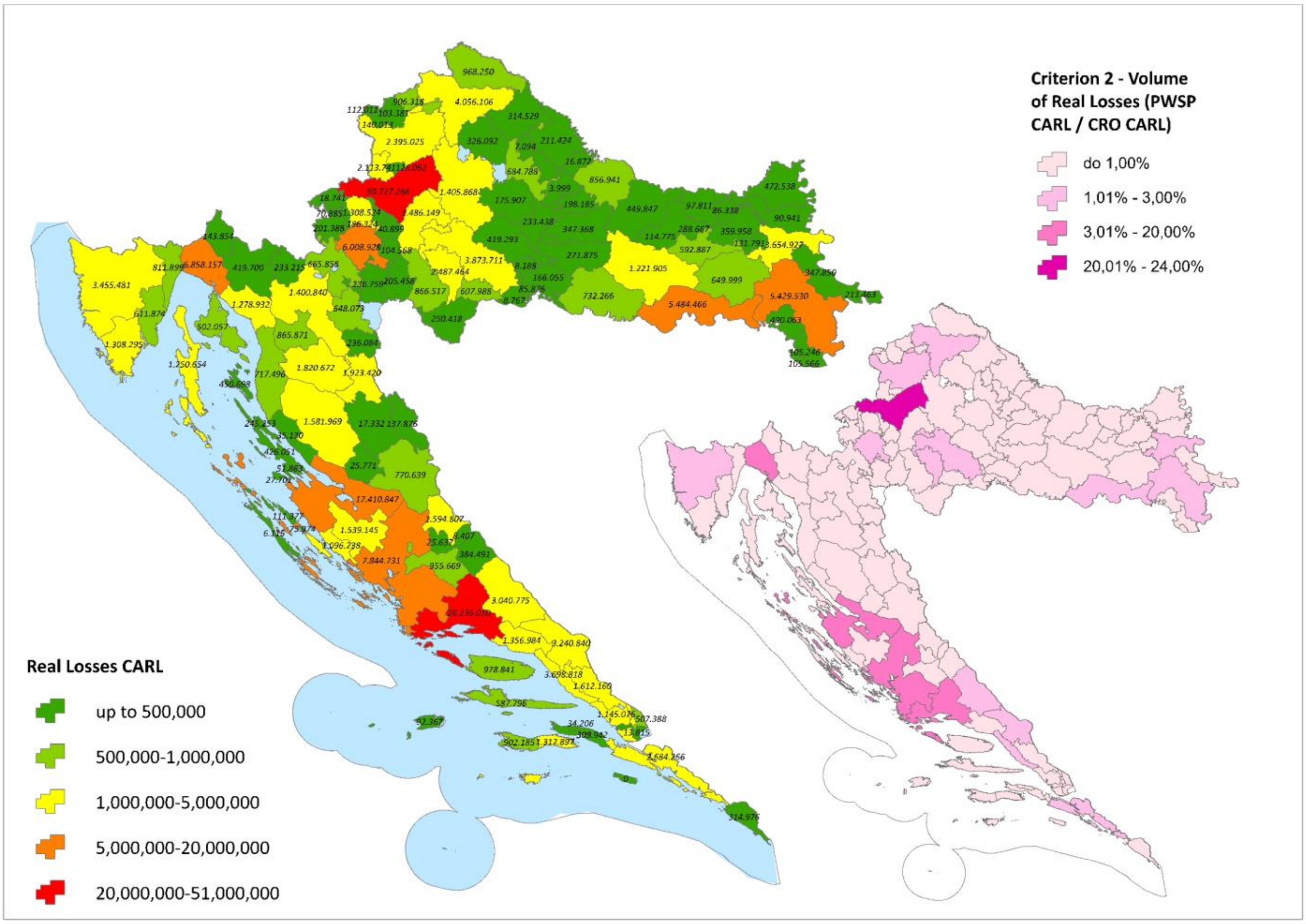

Figure 3.12. Spatial distribution of the volume of Real Losses (with the values in m3 specified, left) and Criterion 2 (right)

3.2.2.3 Water supply system age

The age of the water supply system has a significant impact on the status of water losses. This Criterion 3 analyzed the identified priority replacement of mains, which is associated with the system age.

When estimating the share of mains to be replaced:

- Data was used about the total purchase value of the assets of the water supply system defined as a priority for replacement (the book value of purchase was transformed into the current purchase value using an appropriate factor);
- The share of mains for priority replacement in the total assets for priority replacement was estimated.

Data about the total purchase value, the book value, written-off value, and the age of water supply systems is presented in detail within the Detailed Implementation Plan[9] of the Multi-Annual Programme for Construction of Water and Wastewater Structures for the Period until 2030. The same document identifies priorities for the renewal of the water supply infrastructure, based on a detailed analysis of the value of the assets and age of the systems.

The above-mentioned Detailed Implementation Plan lays down priority groups for system rehabilitation. Priority Group 1 includes the renewal of water supply asset infrastructure more than 30 years old (includes system age categories 31-40 years, 41-50 years, and more than 50 years old), while Priority Group 2 includes the renewal of water supply asset infrastructure 20-30 years old.

Criterion 3 took account of both Priority Groups.

According to this Criterion 3, the PWSPs are classified into 4 categories:

- Priority replacement of more than 15% of mains in a PWSP area – Grade awarded: 1 (a highly significant share);
- Priority replacement of 10% - 15% of mains in a PWSP area – Grade awarded: 2 (a significant share);
- Priority replacement of 5% - 10% of mains in a PWSP area – Grade awarded: 3 (a moderately significant share);
- Priority replacement of less than 5% of mains in a PWSP area – Grade awarded: 4 (a less significant share);

Figure 3.13. presents the distribution of the share of priority investment in mains replacement by PWSPs in Croatia used for the categorization of the significance of priority needs in mains replacement, as well as the spatial distribution of the categories by Criterion 3.

[9] https://www.voda.hr/sites/default/files/2022-07/DETALJNI%20PROVEDBENI%20PLAN%20VPGKVG%20-%2027.%20SRPANJ%202022.pdf

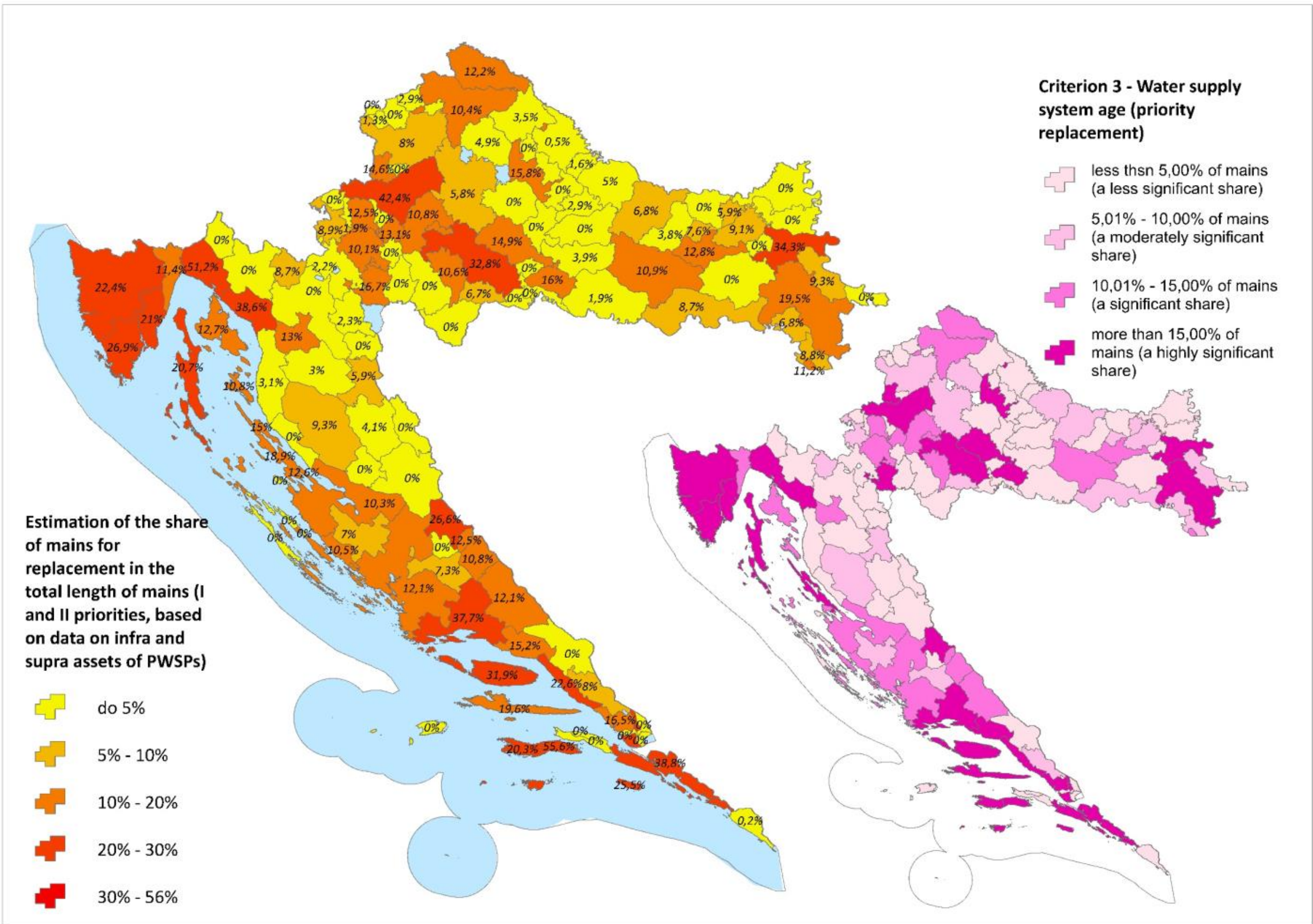

Figure 3.13. Spatial distribution of the scope of the required mains renewal in Priority Groups I and II (specifying the % of replacement, left) and Criterion 3 (right)

3.2.2.4 Risks associated with limitations in available water volumes and climate change

The availability of water sources or abstraction sites with appropriate quantity and quality of water is a significant factor in the context of importance to reduce losses.

Small basins in the Danube river basin district as well as basins in the Adriatic river basin district are particularly sensitive to the climate change impact. Trends indicate possible negative impacts on water supply (reduced availability of water for the current-level demand or for increased demand in certain areas). The reduction of NRW ensures, to a certain extent, a spare capacity for adjustment when coping with climate change impacts (retaining or reducing the current level of abstracted water volumes). Water loss reduction measures are therefore key measures with a strong positive impact on system reliability or increasing system resilience to climate change.

For that reason, the availability of sufficient water volumes needs to be considered in the context of climate change as well. A risk matrix has been developed associated with limitations in available volumes and climate change severity, constituting Criterion 4.

3.2.2.4.1 Available water volumes

Available water volumes are considered in the context of the following parameters and their combinations (cumulative impacts):

- Existing limitations at water abstraction sites;
- Possibility to expand the capacities of existing abstraction sites or to open new identified abstraction sites;
- Increased water demand by new consumers (planned expansion of systems and/or users);

With regard to available water volumes (in conditions of current and planned water demand) by PWSPs, the following groups of limitations have been identified:

- Grade awarded: 1 (very significant limitations);
- Grade awarded: 2 (significant limitations);
- Grade awarded: 3 (limitations of medium significance);
- Grade awarded: 4 (minor limitations);
- Grade awarded: 5 (no identified limitations);

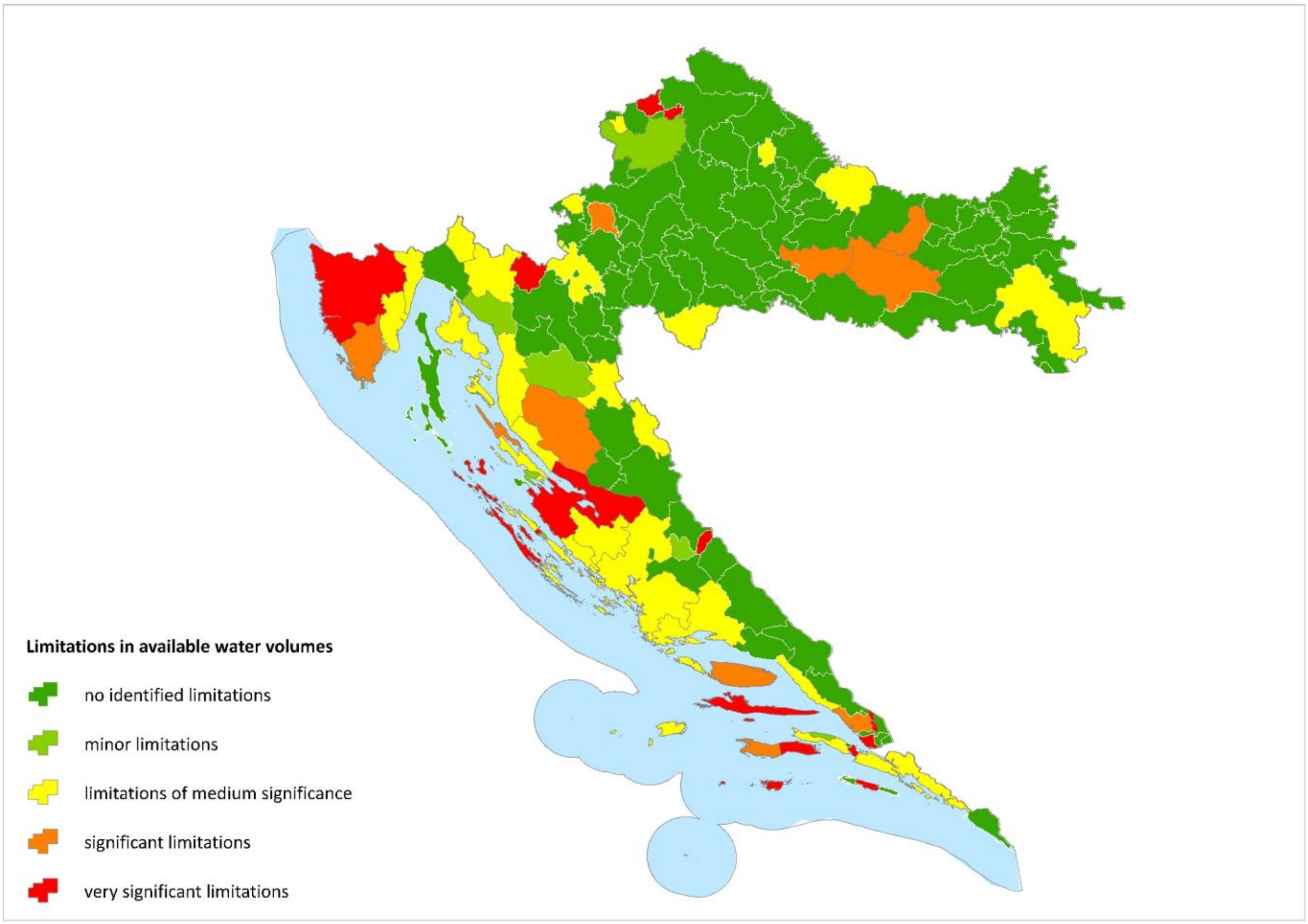

Figure 3.14. Limitations in available water volumes

3.2.2.4.2 Climate change severity

The assessment of climate change severity as an element of risk assessment for PWSPs is a pretty complex task due to the fact that multiple impacts are intertwined in a rather complex way:

- There are several climate change scenarios[10], without it being clear which of them – if any – will be fulfilled in the future;

[10] Climate change is modelled using representative scenarios, (i) RCP stabilization scenario 4.5 and (ii) RCP global warming scenario 8.5. The scenarios were adopted by the UN's Intergovernmental Panel on Climate Change (IPCC).

- Direct impact of climate change on the availability of water is pretty challenging to assess at the level of a PWSP due to complex geology, relatively rough results of climate models, vague borders of groundwater bodies and basins in the karst;
- Other sectors also aspire to a share of available water resources;
- There are secondary climate change impacts that change water demand.

The assessment was made for two 30-year periods:

- Near future, 2011-2040;
- Distant future, 2041-2070.

The reference 30-year period for comparison is the 1971-2000 period.

At first, the analysis assessed available climate change indexes for the change of summer precipitation (hereinafter: “precipitation”) and summer air temperature (hereinafter: “temperature”) for 137 polygons (128 polygons of the existing PWSPs and 9 polygons not covered by public water supply services). The details of the assessment results are presented in Figure 3.15.

Based on the results, the following conclusions can be made:

- The foreseen evolution of deviation between the scenarios and an increase of negative impacts of both scenarios over time exists, with the impact of climate change more marked in the second period;
- There is a weak positive correlation correlation between decreasing precipitation and increasing temperatures for all the scenarios (Figure 3.15);
- Increasing temperatures in RCP 4.5 and RCP 8.5 highly correlate for the 2041-2070 period;
- Decreasing precipitation in RCP 4.5 and RCP 8.5 correlates slightly less for the same period;
- Differences in temperature between the scenarios are pretty clear and obvious, but differences in change in precipitation are much more vague, even though in the majority of cases the so called “optimistic” RCP 4.5 scenario results in a higher precipitation decrease over the summer, and can therefore be considered “more pessimistic” for the water supply sector.

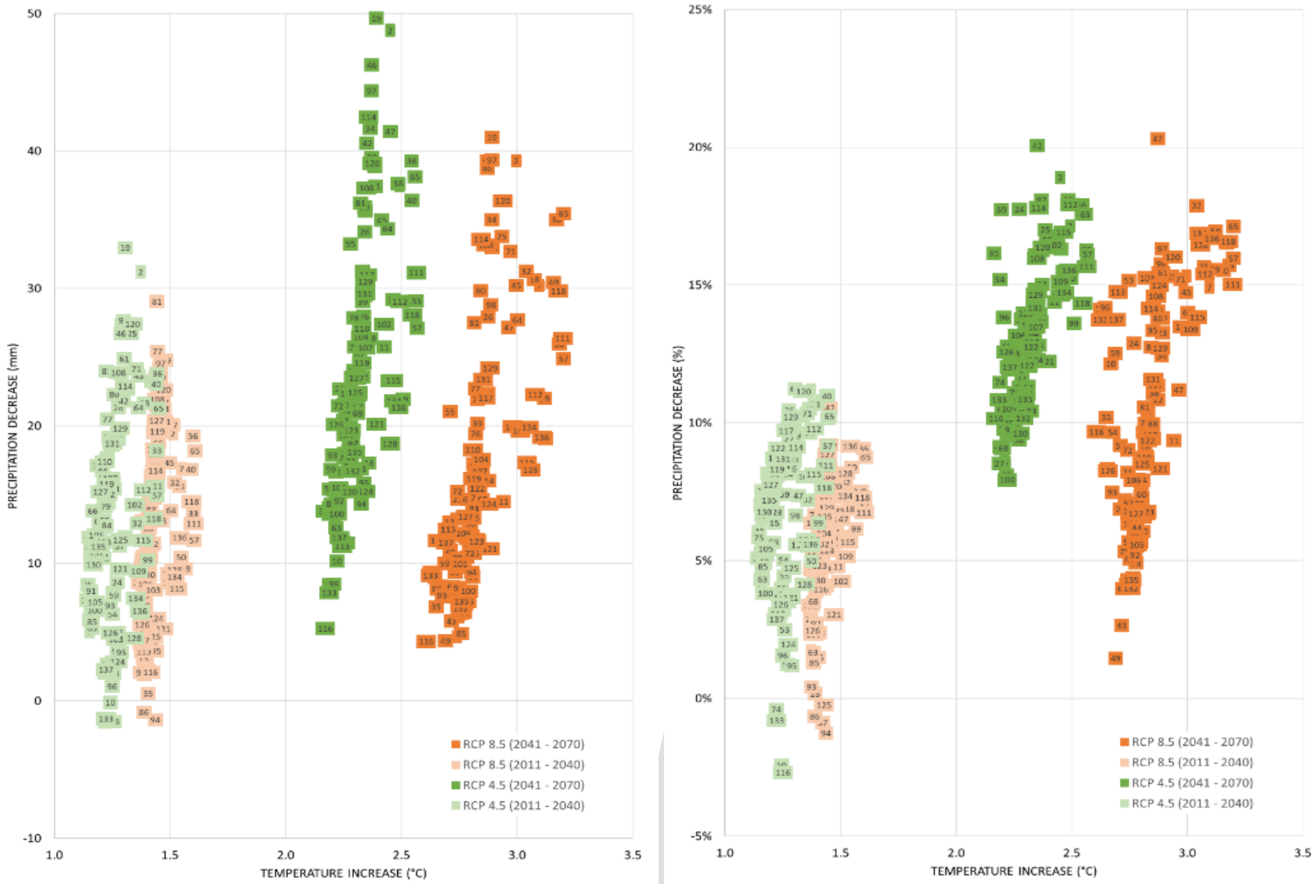

Figure 3.15. Climate change indexes (precipitation decrease in mm – left, precipitation decrease in % - right)

Since only one classification of severity is needed and since there are many combinations of periods, scenarios, parameters, etc., for pragmatic reasons the following approach was adopted:

- Since climate change data exists for two periods, 2011-2040 and 2041-2070, the results make it clear that nearly a half of the first period has already passed, and data from the second period more intensively illustrates the evolution and diversity of climate change. For that reason, it is only the 2041-2070 period that is considered in further analysis.
- For the 2041-2070 period there are two scenarios (RCP 4.5 and RCP 8.5) with pretty different fulfillment. While RCP 8.5 is characterized by significantly higher temperatures, RCP 4.5 has slightly less precipitation. Both events are unfavorable for water availability. **For that reason, the additional "average" scenario will be considered a combination of these two original scenarios.**
- Decreasing precipitation is expressed in absolute (mm) and relative (%) values. For severity assessment, relative values will be used because they more clearly describe the baseline (0% decrease) and the range of precipitation decrease (0 - 100%).
- Precipitation has a direct impact on the volume of water and temperature in a more complex and indirect way. The exact impact of temperature (change) on water volumes cannot be modelled on the level of the entire country within this project. For that reason, the impact of temperature on evapotranspiration will be considered in a robust way using a simple evapotranspiration model.
- Climate change severity for all the PWSPs will be classified in five identical class ranges, from "very low" (a low negative climate change impact on water availability) to "very high" (the highest possible negative climate change impact on water availability, maximum change recorded in the scenario). As a consequence, the comparability between the class values of different scenarios is somewhat limited since the class value expresses a relative deviation from the basic conditions to the maximum severity value within the scenario, and not some unique maximum severity value. In general, the scenarios are mutually exclusive because in reality only one fulfillment is possible and comparison between the scenario scales is questionable.

If the impact of temperature increase on water availability is taken into account and included in the severity assessment, the classification of RCP 4.5, RCP 8.5 and “average” scenarios is presented in Figure 3.16. and Figure 3.17.

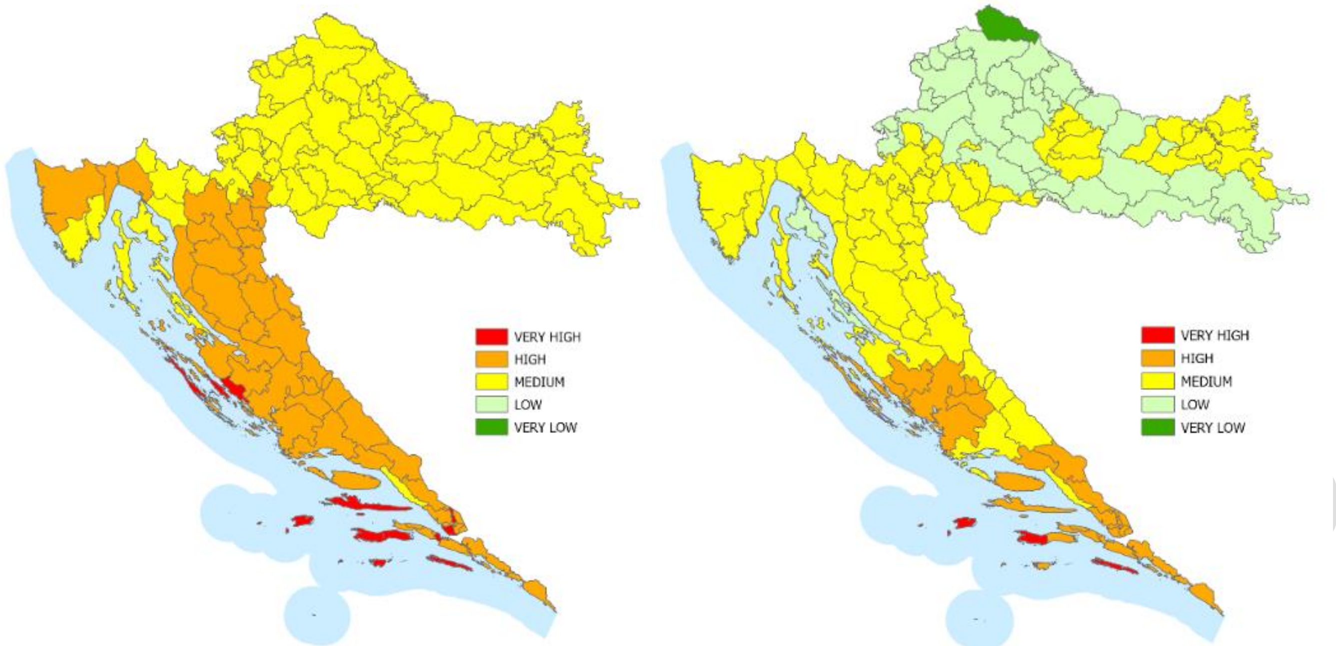

Figure 3.16. Climate change severity classes based on RCP 4.5 (left) and RCP 8.5 (right) scenarios (temperature impact taken into account)

Figure 3.17. Classification of climate change severity based on the “average” scenario (temperature impact taken into account)

3.2.2.4.3 Risk matrix

In addition to the classification of areas according to climate change severity, the risk assessment matrix has been used for:

- Identified limitations in available water volumes in combination with (if applicable) rising demand;
- Climate change severity

A more complex situation related to an increased strain on water supply systems requires a proper, permanent and adaptable assessment of the situation, decision-making based on results of analyses, planning and taking different sets of measures. The situation is particularly demanding on the Adriatic coast and islands due to spatial and temporal variations in demand and availability of resources, which is associated with geophysical (and hydrological) diversity.

At the same time, information important for making decisions, such as climate change projections and hydrological properties of karst aquifers on the one hand, as well as projections of future demand on the other hand, significantly vary in quantity, quality and reliability. For a rather inert water supply sector, such insecurities together with varying and limited financing capacities increase the exposure of a particularly vulnerable (health) and sensitive public sector.

Under such circumstances, in order to increase safety, resilience and adjustment to future challenges, the water supply sector as a whole should be focused on its elements which are at the highest risk of failure and inefficiency.

Due to limited data and information, which should be obtainable at the level of the national action plan, risk has been assessed using the adjusted risk assessment matrix for the most suitable available indicators: (i) Identified limitations in available water volumes in combination with (if applicable) rising demand, and (ii) Climate change severity, to assess the first indication of water supply risks.

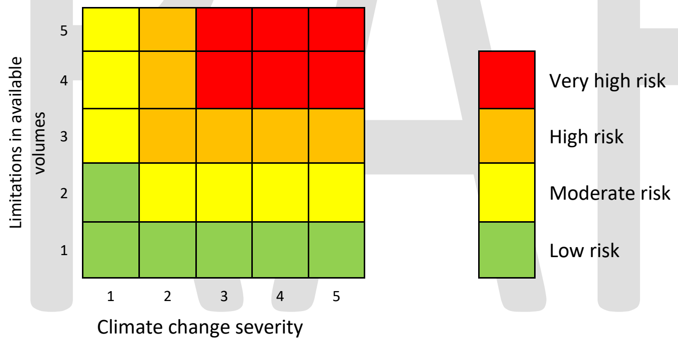

Figure 3.18. Adopted risk assessment matrix

According to this Criterion 4, PWSPs are classified into 4 categories:

- Grade awarded: 1 (Very high risk)
- Grade awarded: 2 (High risk)
- Grade awarded: 3 (Moderate risk)
- Grade awarded: 4 (Low risk)

Figure 3.19. presents the distribution of risk categories identified in combination with limitations in available water volumes and climate change severity.

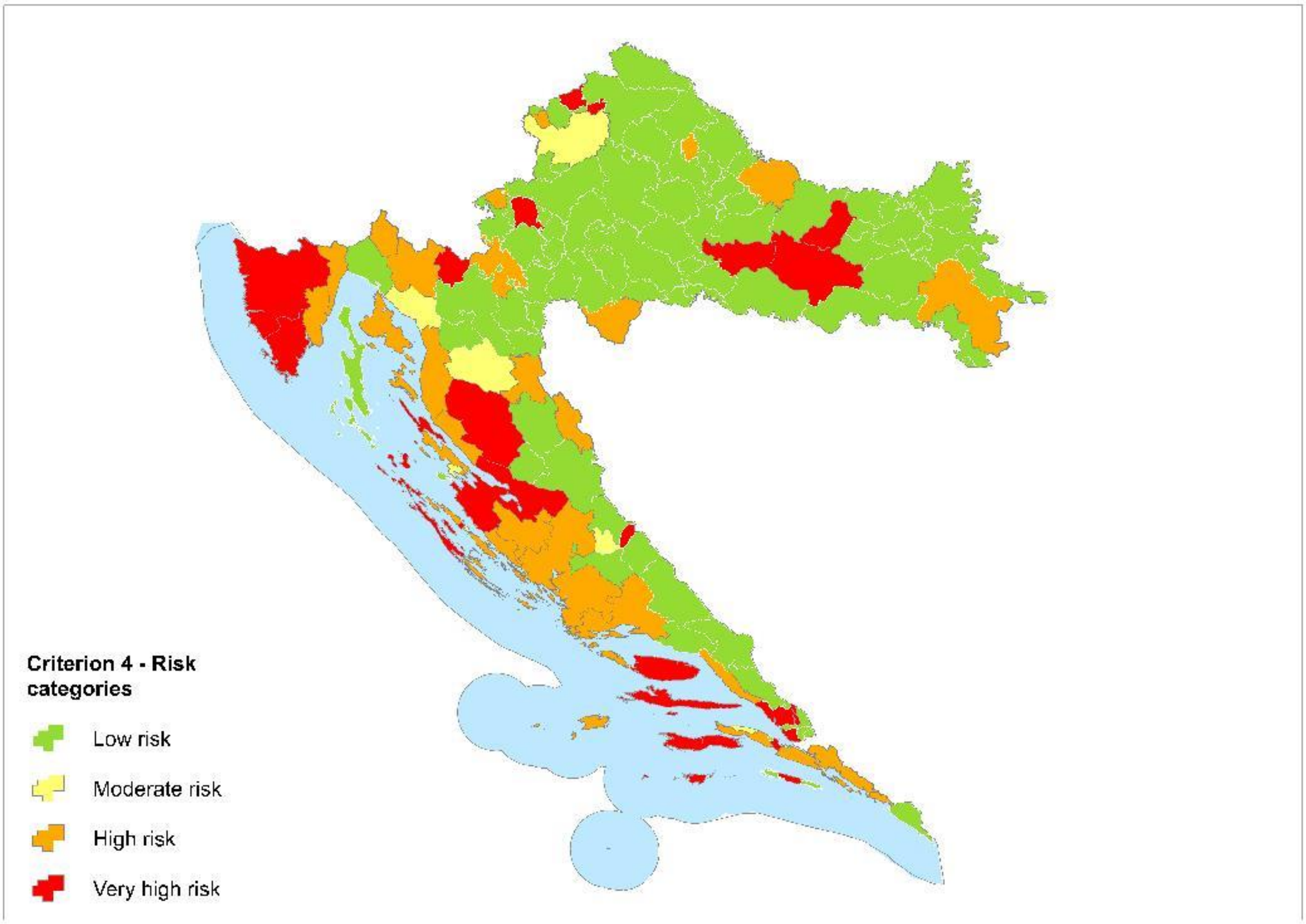

Figure 3.19. Spatial distribution of risks (Criterion 4) according to the risk matrix, limitations in available water volumes and climate change severity

3.2.2.5 Overall relevance of losses

The overall relevance of losses was obtained using the criteria in the following weighting ratios:

- Criterion 1 – PWSP's specific Real Losses, weight factor 35%
- Criterion 2 – Share of PWSP's annual Real Losses in total Real Losses, weight factor 25%
- Criterion 3 – System age, weight factor 20%
- Criterion 4 – Limitations in available water volumes and climate change, weight factor 20%

So, Criteria 1 through 4 were used for the calculation of the overall relevance, which is then used further for the initial proposal of the % of renewal of existing mains in the PWSP area, which is deemed a very important loss reduction measure.

Increased investment in mains renewal is proposed in relation to the relevance of losses:

- Very high relevance of water losses – renewal of 15% of mains proposed;
- High relevance of water losses – renewal of 10% of mains proposed;
- Medium relevance of water losses – renewal of 8% of mains proposed;
- Moderate relevance of water losses – renewal of 5% of mains proposed;

Figure 3.20. presents the distribution of the relevance of losses per PWSPs to assess the required replacement of mains and spatial distribution of the estimated investment amount through the mains replacement measure.

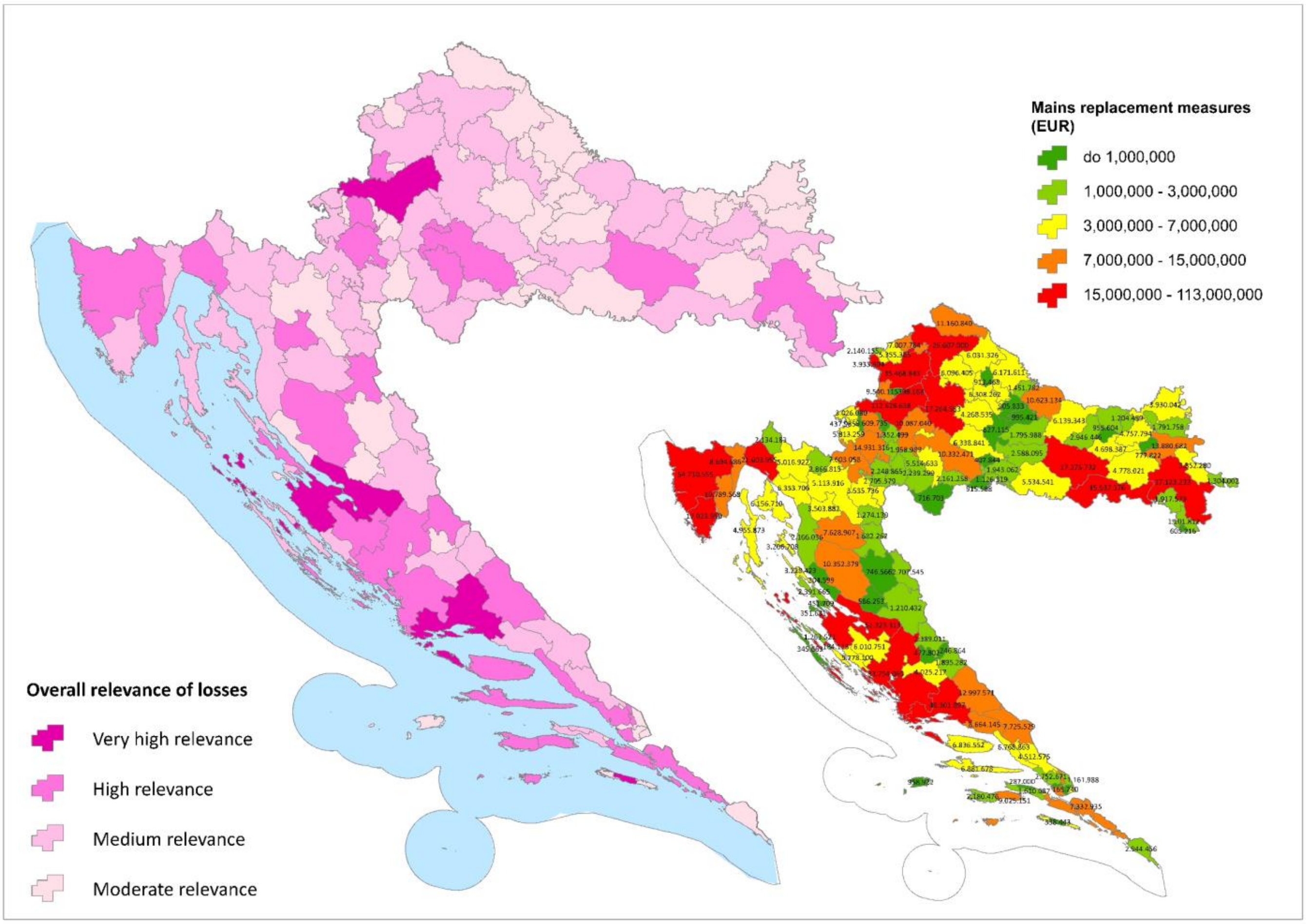

Figure 3.20. Overall relevance of losses to assess the required mains replacement (left) and the estimated amount of investment in mains replacement (right)

Investment in mains replacement by service areas (Figure 3.21), except Service Area 11 (Zagreb), amounts on average to EUR 20 million (with some investment reaching as high as EUR 50 million). Service Area 11 (Zagreb) has the highest investment (around EUR 125 million), which seems reasonable in relation to the system size and the assigned overall relevance of water losses.

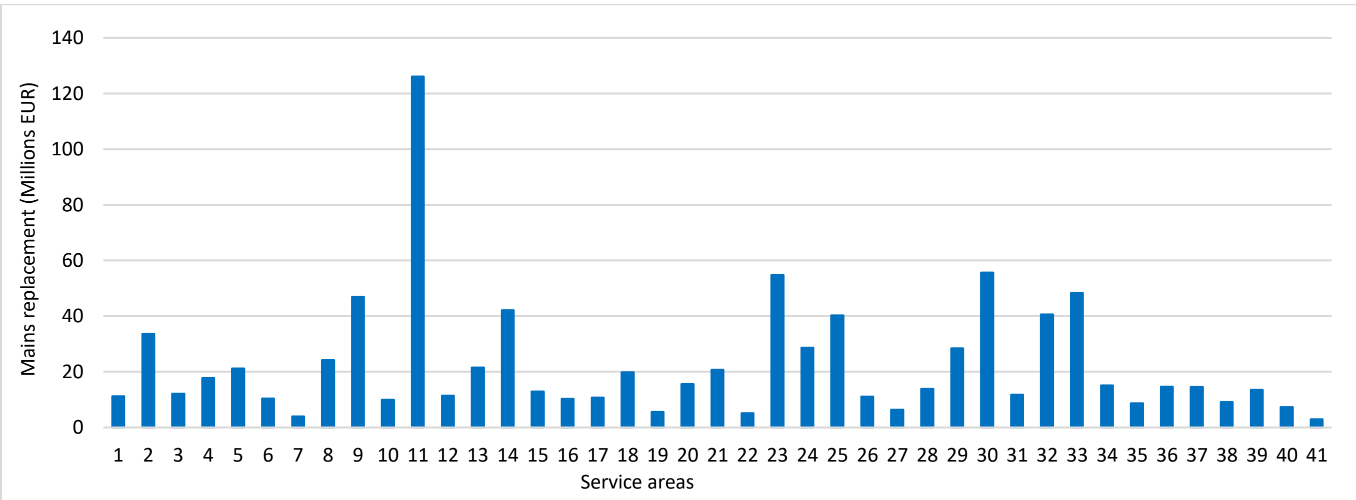

Figure 3.21. Investment in mains replacement by service areas

It is assumed that after a period of more intensive replacement of mains in the roughly proposed scope below (which is preceded by the exact identification of critical sections for replacement) PWSPs will continue working on the replacement of mains at an annual rate of around 2%.

3.2.3 Effects of recommended measures

3.2.3.1 System data improvement measures

Certain system data improvement measures will contribute to the speed of noticing increased leakages at the existing places of damage or occurrence of new failures (leakages), and thus to the reduction of losses (real losses). However, not all the system data improvement measures contribute to the direct reduction of losses, although they represent a quality basis for efficient implementation of other measures which will result in long-term sustainable and efficient reduction of water losses. For example, measures such as the creation and introduction of the GIS general module, GIS register of failures, GIS link between the technical and SCADA IT systems, and the SCADA (with enabled links to all the structures and data storage) are the bases for the full potential of developing GIS control of losses and recording and digitizing field data, the use of which will significantly speed up noticing the occurrence of failures and the detection of failures, which will both in short and long term result in the reduction of water losses.

The basic assumption adopted based on the practical experience in Croatia so far among the PWSPs that have implemented certain system data improvement measures is that the time needed to notice an increase in existing leakages or the occurrence of new failures (leakages) will be shortened by 50%. The total leakage removal time consists of three components – time to notice the leakage, time to identify the leakage micro-location, and time to repair/remove the leakage. In the practice in Croatia so far, the majority of time is needed to notice the leakage (around 60% of the total time) and to identify the micro-location of the leakage (around 30% of the total time). Therefore, by reducing the time to notice the leakage it is possible to achieve significant water loss reductions. With the above assumption of reducing the time to notice leakages by 50%, it is assumed that 20% higher loss reduction efficiency will be achieved due to active leakage control measures. In that process, the system data improvement measure is attributed a 50% efficiency in relation to the overall impact of reducing the time to notice the occurrence of leakage (the remaining 50% efficiency is attributed to the measure to divide the system into DMAs), resulting in a 10% higher loss reduction efficiency due to the system data improvement measures.

The share of the analyzed system data improvement measure in total investment costs of all the measures foreseen by this Action Plan is 2.1% (EUR 32,050,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of 4.0%.

3.2.3.2 Water supply system optimization measures

The development/revision of conceptual solutions with the calibrated mathematical model implies the implementation of certain measures which have proven efficient in direct reduction of water losses in Croatian practice so far, i.e., they have resulted in certain reduction of water losses among a significant number of PWSPs. The key measures are the implementation of zone flow and pressure measurements including the calibration of the mathematical model of present state and detailed analysis of the present hydraulic and operating characteristics of the entire system. This enables a quality insight into the spatial and quantitative distribution of water losses within the system, facilitating the timely detection of zones with bigger losses and timely initiation of active leakage control activities in such zones, which results in additional reduction of water losses. In light of the positive experience in Croatia so far, the expected reduction of real leakages during the preparation of conceptual solutions is 1%. It is short-term and related to a time period (one-year period) in which the conceptual solution is prepared.

For water supply systems for which conceptual solutions have been prepared, the spatial and quantitative distribution of water losses is known by preliminary DMAs which have been established for the purpose of implementing a measurement campaign for flows and pressures (as an integral part of conceptual solutions), with certain problems in the systems recognized. This enables the operating staff working on system management who were included through monitoring the implementation of measurements and preparation of individual phases of the conceptual solution to timely take certain active leakage control measures (the consequence of the initial growth of enthusiasm during and immediately after the preparation of the conceptual solution) and to more efficiently detect and repair the leakages, which is directly reflected on the efficiency of water loss reduction. In relation to the experience so far, an additional effect of real loss reduction by 0.5% is achieved for some PWSPs which have conceptual solutions prepared.

The extension of storage tanks, pumping stations, mains, and other structures to achieve pressure and energy optimization as a measure of water supply system optimization is considered exclusively for the Zagreb water supply system through the introduction of the so called “Zone 0”. The said measure will reduce the pressure in a significant part of the system (Zone 0) by around 2.0 bar (reduction of pressure by 25%), which will in relation to the system characteristics (pipe materials, etc.) result in the reduction of water losses by around 12%. The expected reduction of water losses is long-term and refers to annual savings throughout the project life.

The share of the analyzed water supply system optimization measure in total investment costs of all the measures foreseen by this Action Plan is 4.20% (EUR 63,700,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of 5.8%.

3.2.3.3 Measures to divide the system into DMAs

The measures to divide the system into DMAs will contribute to the speed of noticing increased leakages at the existing places of damage or occurrence of new failures (leakages), and thus to the reduction of losses (real losses). The establishment of DMAs with flow measurement at points of entry and exit from each DMA, linking the measurements with the SCADA and GIS modules, as well as the application to record and digitize field data, will significantly speed up noticing the occurrence of failures and thus the detection of failures, which will both in short and long run result in the reduction of water losses.

The basic assumption adopted based on the practical experience in Croatia so far among the PWSPs that have DMAs established is that the time needed to notice an increase in existing leakages, or the occurrence of new failures (leakages) will be shortened by 50%. The total leakage removal time consists of three components – time to notice the leakage, time to identify the leakage micro-location, and time to repair/remove the leakage. In the practice in Croatia so far, the majority of time is needed to notice the leakage (around 70% of the total time) and to identify the micro-location of the leakage (around 20% of the total time). Therefore, by reducing the time to notice the leakage it is possible to achieve significant water loss reductions. With the above assumption of reducing the time to notice leakages by 50%, it is assumed that 20% higher loss reduction efficiency will be achieved due to active leakage control measures. In that process, the measure to divide the system into DMAs is attributed a 50% efficiency in relation to the overall impact of reducing the time to notice the occurrence of leakage (the remaining 50% efficiency is attributed to the system data improvement measures described above), resulting in a 10% higher loss reduction efficiency due to active leakage control measures.

The share of the analyzed measure to divide the system into DMAs in total investment costs of all the measures foreseen by this Action Plan is 14.6% (EUR 223,120,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of 4.0%.

3.2.3.4 System pressure control and management measures

It is a well-known fact that system pressure control and management measures significantly contribute to long-term reduction of real losses. Pressure regulation (reduction) reduces discharges at the existing damage along the water supply network, as well as the number of new damages. The reduction of leakage volume depending on pressure reduction and characteristics of piping material is in mathematical terms described using the generally known FAVAD method. Therefore, the introduction of PMAs through the installation of new hydraulic valves for pressure regulation with additional replacement of the existing spring valves with the hydraulic valves reduces pressure in individual parts of the system and in the system as a whole, which is directly reflected on the reduction of real losses. A higher leakage reduction efficiency is achieved in systems (part of systems) where there is no pressure regulation in the current state, where higher pressures are present in the current state, and where bigger pressure reduction is achieved. In accordance with that, when assessing the effect of system pressure control and management measures on the reduction of water losses, account was taken of the fact whether a particular water supply system in the current state has pressure regulation and what is the range of the average pressure in a particular water supply system (< 5.0 bar; 4.0 – 5.0 bar; 3.0 – 4.0 bar; > 3.0 bar). This is also in line with the experience in Croatia so far, correlated with the current status of NRW in individual systems, and the fact whether the protection of the system from water (hydraulic) hammers and control and management of air in the pipes are implemented and if so, in what way. Namely, additional system pressure control and management is achieved both through protecting the system from water hammers and through controlling and managing air in the mains network (application and control of air release and air release/intake valves). In accordance with the practice in Croatia so far, the presence of air in the mains network can result in the local reduction of pressure by more than 3.0 bar, and it can locally increase the intensity of water hammers, which in long term results in the occurrence of new failures (leakages). In water supply networks where effective protection from and mitigation of water hammers has been established and where proper control and management of air in the pipes is conducted, the probability of new failures has been significantly reduced. In that way, real losses are reduced in the long run or are maintained at an acceptable level. The afore mentioned has also been taken into consideration when assessing the effect of system pressure control and management measures on the reduction of water losses.

The share of the analyzed system pressure control and management measure in total investment costs of all the measures foreseen by this Action Plan is 3.6% (EUR 57,160,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of 8.6%.

3.2.3.5 Active leakage control measures

Active leakage control (ALC) measures are one of the most efficient measures for the reduction of real losses. Active leakage control implies one of the two measures with which failures are physically removed and real losses are reduced. It is therefore assessed as one of the two most efficient measures for water loss reduction (the other one is pipe replacement).

The micro-locations of leakages cannot be identified without adequate equipment (portable pressure and flow meters, correlators, geophones, noise loggers, etc.). The procurement of equipment together with adequate education of technical teams is the main precondition for efficient implementation of ALC. ALC implies the implementation of several separate activities, including three main ones. Phase 1 implies the implementation of additional flow and pressure measurements (from zones and sub-zones to the level of individual sections). In that way, smaller areas are singled out in which Phase 2 of identifying the leakage micro-locations will be conducted using correlators, geophones, noise loggers, etc., which is more financially demanding and time-consuming. The identification of the micro-locations of leakages is followed by Phase 3, which implies the repair of leakages, pipe bursts, and damage to water supply fittings. The assessment of the impact of the said measure on the reduction of water losses (NRW) was done in relation to the system size (the cluster to which it belongs), the current NRW status, PWSPs' experience so far with the implementation of ALC, experience so far with the engagement of external companies to implement ALC, etc. It is logical to expect the achievement of higher efficiency in water loss reduction through ALC for larger systems with currently higher NRW volumes. In doing so, it is assumed that at least in the initial phases of implementation of this Action Plan external companies will be engaged to a greater extent to implement ALC, but primarily as a support to the existing and future technical teams of the PWSPs themselves, by implementing in parallel the same activities in other system locations. In that way, external specialized companies with many years of experience will at the same time conduct additional education of PWSPs' technical teams. Based on the experience from practice so far, the efficiency of ACL by external companies frequently presents an additional motivating factor for PWSPs' technical teams. All of the above has been included when assessing the effect of the said measure on the reduction of water losses.

The share of the analyzed active leakage control measure in total investment costs of all the measures foreseen by this Action Plan is 10.5% (EUR 160,910,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of 40.4%

3.2.3.6 Measures to reduce apparent losses

Although apparent losses as a rule aren't as significant and marked as real losses, the possibilities and needs for their reduction are unavoidable. Measures to reduce apparent losses imply more efficient control and prevention of unauthorized water consumption (water theft), increased accuracy of water consumption meters (water meters), and reduction of errors in data processing.

The implementation of all the measures to reduce apparent losses (regular analyses of water meter accuracy and preparation of water meter replacement plans, regular water meter replacement, implementation of hydraulic analyses of possibilities for remote reduction of pressure at valves and possibilities to shut off zones in case of unauthorized consumption, regularly informing the public about the problem and cost of unauthorized water consumption through the printing of leaflets, daily press, billboards, newspaper articles, radio and tv broadcasts) definitely achieves a certain reduction of water losses both in short and long term.

It is a fact that the shares of apparent losses in total water losses differ among PWSPs in Croatia, ranging between 0.3 and 29.4%, or in absolute terms between 58 and 5,815,756 m^3/year. It makes sense to expect more significant reduction of apparent losses among PWSPs that in the current state have higher volumes of apparent losses or higher shares of apparent losses in the total volumes of water losses. This has been included when assessing the effect of the said measure on the reduction of water losses.

The share of the analyzed measure to reduce apparent losses in total investment costs of all the measures foreseen by this Action Plan is 2.2% (EUR 34,340,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of 3.2%

3.2.3.7 Planning and mains replacement measures

Planning and mains replacement measures are together with ALC measures the most efficient measures for the reduction of real losses. Namely, by replacing damaged mains, water losses are directly reduced. Even in mains with significantly modified characteristics (e.g., by decreasing the thickness of walls of steel pipes without cathodic protection, etc.) water losses are reduced in the future.

It is unrealistic to expect and hence to analyze integrated implementation of this activity in the short term, since the replacement of pipes is highly demanding in technical and financial terms and in terms of time. A question is therefore raised about the dynamic at which the pipes should be replaced, i.e., which sections of the mains network should be given priority. In order to have maximum efficiency of pipe replacement in the reduction of water losses, it is necessary to prepare a high-quality mains replacement plan, giving priority to those sections identified through preliminary investigations as being in a poor state of repair, which is identified depending on a number of impact factors (number of failures, pipe material, pipe age, type of joints, is there cathodic protection, field characteristics, etc.).

The effect of the said measure on the reduction of water losses (NRW) was assessed per PWSPs in relation to the percentage of pipe renewal planned in short and medium term in relation to which the total investment is expressed, the current average age of the mains network, pipe material, etc. The NRW reduction rate as the result of pipe replacement per PWSPs ranges between 1% and 30%.

The share of the analyzed planning and mains replacement measure in total investment costs of all the measures foreseen by NLRAP is the highest compared to the other groups of measures, and amounts to 61.2% (EUR 936,850,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) as high as 33.1%. The said efficiency was assessed based on the assumption that the mains replacement is carried out according to the well-prepared replacement plan.

3.2.3.8 Institutional strengthening measures

The institutional strengthening measures imply the preparation of organization schemes, processes, and tasks, improving the quality of human resources management, and improved control and communication within PWSPs concerning water loss management. The measure also implies the preparation of PWSPs' loss reduction action plans with the preparation of short- and medium-term business plans, and mandatory and continuous education of the staff working on water loss management.

The implementation of this group of measures doesn't lead to direct water loss reduction; rather, their effect on water loss reduction is indirect. Regardless of that, it is rational to expect differences among the PWSPs that don't implement the measure and those that will implement it, with such expectation proven as justified by the practice so far. In other words, proper implementation of the institutional strengthening measures will contribute to increased efficiency of water loss reduction.

The effect of the said measure on the reduction of water losses (NRW) was assessed per PWSPs in relation to their estimated potential in its implementation, which results from the results of the filled in questionnaires related to the current status of HR management, the existing staff and organization schemes, PWSP size, etc. The NRW reduction rate as the result of the implementation of the institutional strengthening measures per PWSPs ranges between 0.2% and 1.0%.

The share of the analyzed institutional strengthening measure in total investment costs of all the measures foreseen by this Action Plan is relatively low compared to the other groups of measures, and amounts to 1.2% (EUR 18,650,000), with the expected efficiency in relation to the total impacts of NRW reduction foreseen by this NLRAP (in relation to the current state) of only 0.7%.

3.2.3.9 Analysis and reporting measures

Analysis and reporting measures imply the preparation of monthly and/or quarterly and/or annual analyses of water losses and entry of relevant indicators into the future central database and making economic and financial analyses of the water loss reduction project.

The implementation of this group of measures doesn't lead to direct water loss reduction; rather, their effect on water loss reduction is indirect and particularly small. The implementation of this group of measures is important from the aspect of support to all the other groups of measures, and thus also from the aspect of increasing their efficiency.

The share of the analyzed analysis and reporting measure in total investment costs of all the measures foreseen by this Action Plan is the lowest compared to the other groups of measures and amounts to only 0.4% (EUR 6,550,000). In relation to the expected insignificant impact on the NRW reduction (in relation to the current state), it is defined in the amount of 0.0%

3.2.3.10 Other measures

Support measures are also necessary for the successful implementation of NLRAP and the achievement of the expected effects:

- Technical assistance to PWSPs for successful implementation of loss reduction measures, which is estimated at 3% of the value of the measures (I to IX)
- MESD measures:
  - Establishment of a PWSPs benchmarking system of performance indicators, amounts to 0.05% of the NLRAP measures, and refers to the establishment of a national database, training of PWSPs for reporting to the MESD and Water Council
  - Professional assistance in the work of the National Supervisory Authority for Loss Reduction, which is estimated at a maximum of 0.2% of the NLRAP measures, and refers to expert assistance for the verification and implementation of PWSPs' action and investment plans during NLRAP implementation

3.2.3.11 Overview of measures and effects

The overview of measures is described in detail in Chapter 3.2.1, and their impacts on NRW reduction in Chapters 3.2.3.1. through 3.2.3.8.

Table 3.5. Estimated value of water loss management improvement measures and effects

Responsibility	Number	Group	% of the cost of measure	% NRW reduction	Measure	Amount
PWSP measures	**I.**	**System data improvement measures**	**2,1%**	**4,0%**	**GIS - General module (with entry/update of system data)**	**2.870.000**
					GIS - Link to the business IT system (with development of the customer database)	**1.940.000**
					GIS - Register of failures (with entry of data for the last 5 years)	**2.390.000**
					GIS - Link between the technical and SCADA IT systems	**250.000**
					GIS - Control of losses	**980.000**
					SCADA (with enabled links to all the structures and data storage)	**20.700.000**
					Recording and digitizing field data (procurement of software and equipment, education)	**2.920.000**
					Total price of system data improvement measures (EUR)	**32.050.000**
					Effect of system data improvement measures on % of water loss reduction (m3/year)	**4.950.000**
	II.	**Water supply system optimization measures**	**4,2%**	**5,8%**	**Development/revision of the conceptual solution with the calibrated mathematical model**	**10.610.000**
					Extension of storage tanks, pumping stations, mains, and other structures to achieve pressure and energy optimization of water supply systems	**53.090.000**
					Total price of water supply system optimization measures (EUR)	**63.700.000**
					Effect of water supply system optimization measures on % of water loss reduction (m3/year)	**7.080.000**
	III.	**Measures to divide the system into DMAs**	**14,6%**	**4,0%**	**Design and construction of DMA shafts with installation of appropriate equipment (incl. SCADA system extension)**	**223.120.000**
					Total price of measures to divide the system into DMAs (EUR)	**223.120.000**
					Effect of measures to divide the system into DMAs on % of water loss reduction (m3/year)	**4.950.000**
	IV.	**System pressure control and management measures**	**3,6%**	**8,6%**	**Hydraulic analysis and development of concept to protect the system from water hammers (hydraulic shocks)**	**3.080.000**
					Installation of structures and equipment to protect from water hammers (incl. designing)	**40.980.000**
					Formation of PMAs - Installation of new hydraulic valves for pressure regulation with additional replacement of the existing spring valves	**9.650.000**
					Control and management of air in the pipes (application and control of air release and air release/intake valves)	**3.450.000**
					Total price of system pressure control and management measures (EUR)	**57.160.000**
					Effect of system pressure control and management measures on % of water loss reduction (m3/year)	**10.570.000**
	V.	Active leakage control measures	10,5%	40,4%	Procurement of equipment for active leakage control (pressure and flow meters, geophones, correlators, noise loggers, smart balls, etc.)	9.190.000
					Conducting additional pressure and flow measurements by zones and sub-zones (with identification of priority zones/sub-zones), conducting STEP tests, etc.	9.080.000
					Identification of leakage micro-locations	12.970.000
					Repairing detected failures (leakages, pipe bursts, damage to water supply fittings)	129.670.000
					Total price of active leakage control measures (EUR)	160.910.000

Responsibility	Number	Group	% of the cost of measure	% NRW reduction	Measure	Amount
					Effect of active leakage control measures on % of water loss reduction (m3/year)	49.490.000
	VI.	Measures to address apparent losses	2,2%	3,2%	Water meter accuracy analysis and preparation of a replacement plan	940.000
					Replacement of water meters	27.940.000
					Hydraulic analysis of possibilities for remote reduction of pressure at valves and possibilities to shut off zones in case of unauthorized water consumption	1.730.000
					Informing the public about the problem and cost of unauthorized water consumption (printing leaflets, daily press, billboards, newspaper articles, radio and tv broadcasts)	3.730.000
					Total price of measures to address apparent losses (EUR)	34.340.000
					Effect of measures to address apparent losses on % of water loss reduction (m3/year)	3.930.000
	VII.	Planning and mains replacement measures	61,2%	33,1%	Preparation of mains replacement plans - optimum rehabilitation (based on the GIS, register of failures, additional measurements and micro-locating, and additional testing of built-in pipe materials such as the wall thickness, etc.)	1.730.000
					Preparation of design documents	16.210.000
					Replacement of mains	918.910.000
					Total price of planning and mains replacement measures (EUR)	936.850.000
					Effect of planning and mains replacement measures on % of water loss reduction (m3/year)	40.440.000
	VIII.	Institutional strengthening measures	1,2%	0,7%	Preparation of an organization scheme, processes, tasks, human resources, control, communication	1.410.000
					Preparation of PWSPs' Loss Reduction Action Plans, preparation of PWSPs' business plans	14.010.000
					Staff training	3.230.000
					Total price of institutional strengthening measures (EUR)	18.650.000
					Effect of institutional strengthening measures on % of water loss reduction (m3/year)	890.000
	IX.	Analysis and reporting measures	0,4%	0,0%	Preparation of analyses of losses, updating the hydraulic model, GIS	3.450.000
					Project economic and financial analysis	1.410.000
					Preparation of monthly and annual reports incl. preparations for entry into the future central database	1.690.000
					Total price of analysis and reporting measures (EUR)	6.550.000
					Effect of analysis and reporting measures on % of water loss reduction (m3/year)	0
	Total I.-IX.	Total measures	100,0%	100,0%	Total price of PWSP measures (EUR)	1.533.330.000
					Total effect of measures on water loss reduction (m3/year)	**122.300.000**
	X.	Technical assistance to PWSPs to implement the measures (3% of the value of Measures I-IX) (EUR)				45.950.000
MESD measures	XI.	Establishment of the PWSP benchmarking system and performance indicators (establishment of the national database, training PWSPs to report to the MESD) (EUR)				670.000
		Costs of the national control body for the reduction of losses (expert assistance for expert verification of PWSPs' action and investment plans during NLRAP implementation) (EUR)				2.000.000
		Total price of MESD measures (EUR)				2.660.000
Total measures		**Grand total (EUR)**				**1.581.950.000**

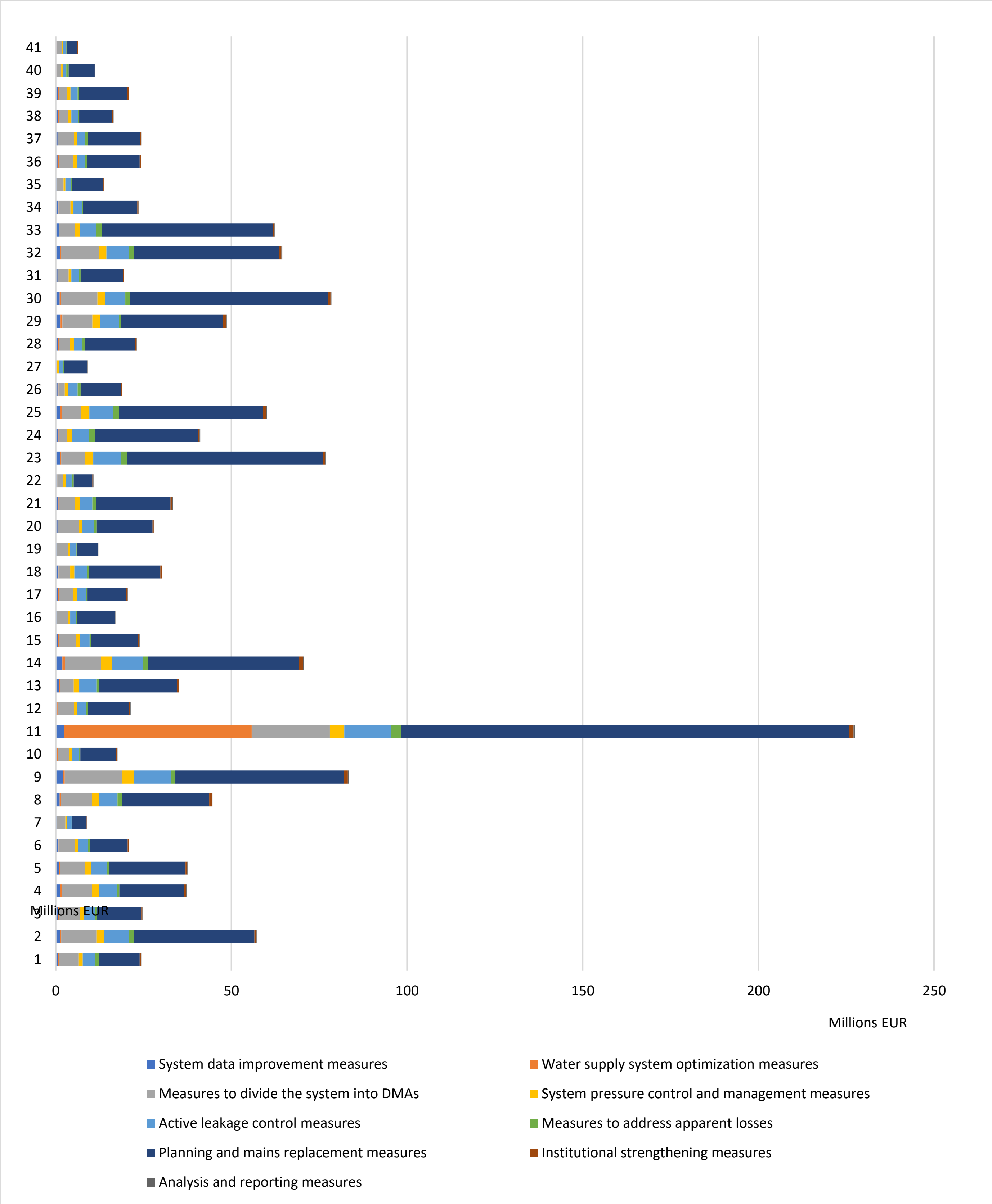

Figure 3.22. Water loss management improvement measures (I-IX), level of 41 service areas

3.2.4 Estimated indicators of water losses after implementation of loss reduction measures

3.2.4.1 Volumetric indicators of water losses

It is estimated that with the implementation of loss reduction measures foreseen by this Plan the NRW volume will reduce by around 122.3 million m^3/year.

The spatial distribution of the NRW by PWSPs in Croatia after the implementation of loss reduction measures is presented in Figure 3.23. Figure 3.24. compares the distribution of volumes today and after the implementation of measures by the proposed service areas in Croatia. The distribution of the NRW and the Real Losses (CARL) after the implementation of measures is presented in Figure 3.25.

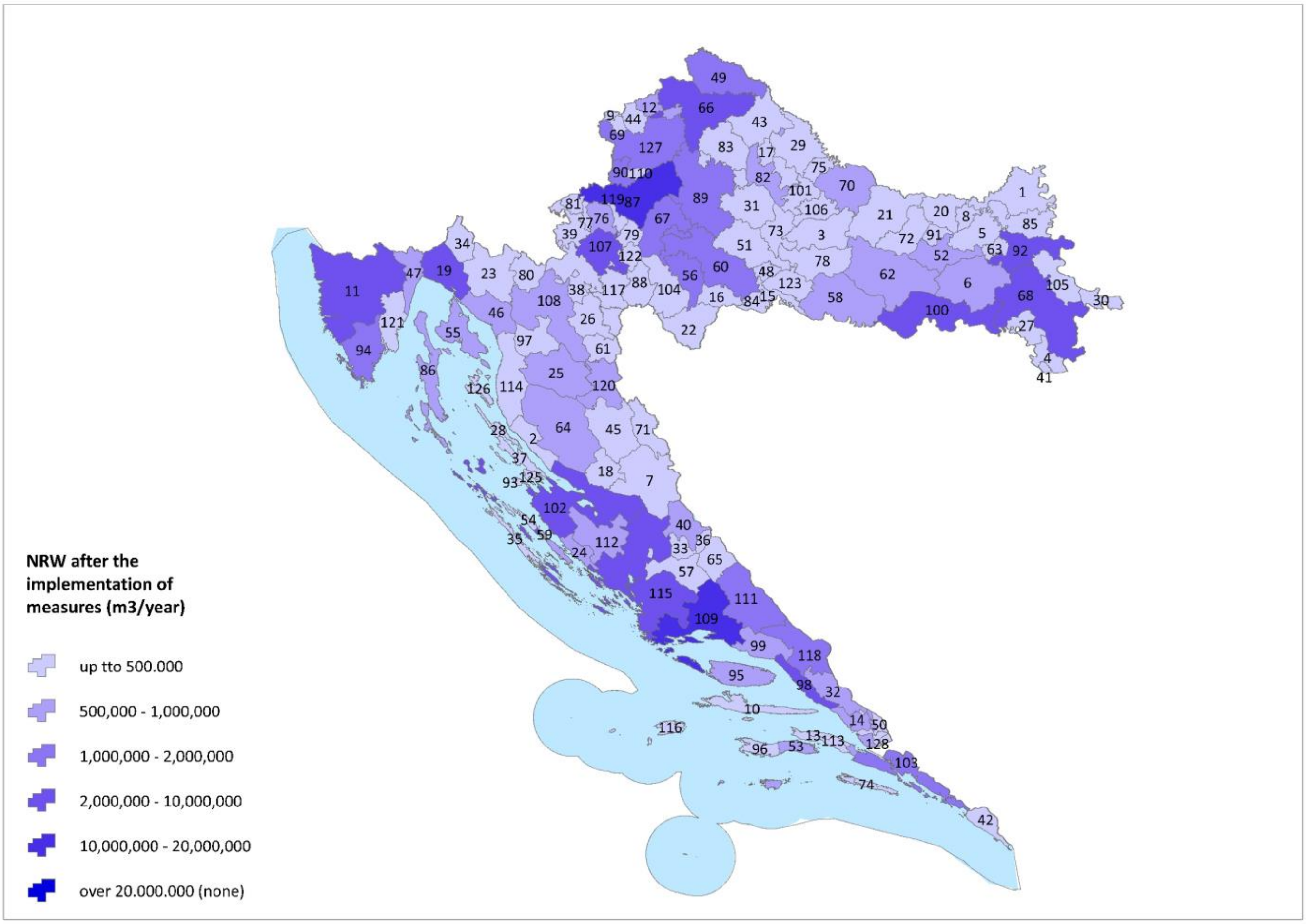

Figure 3.23. Spatial distribution of the NRW after the implementation of measures, PWSP level (with IDs)

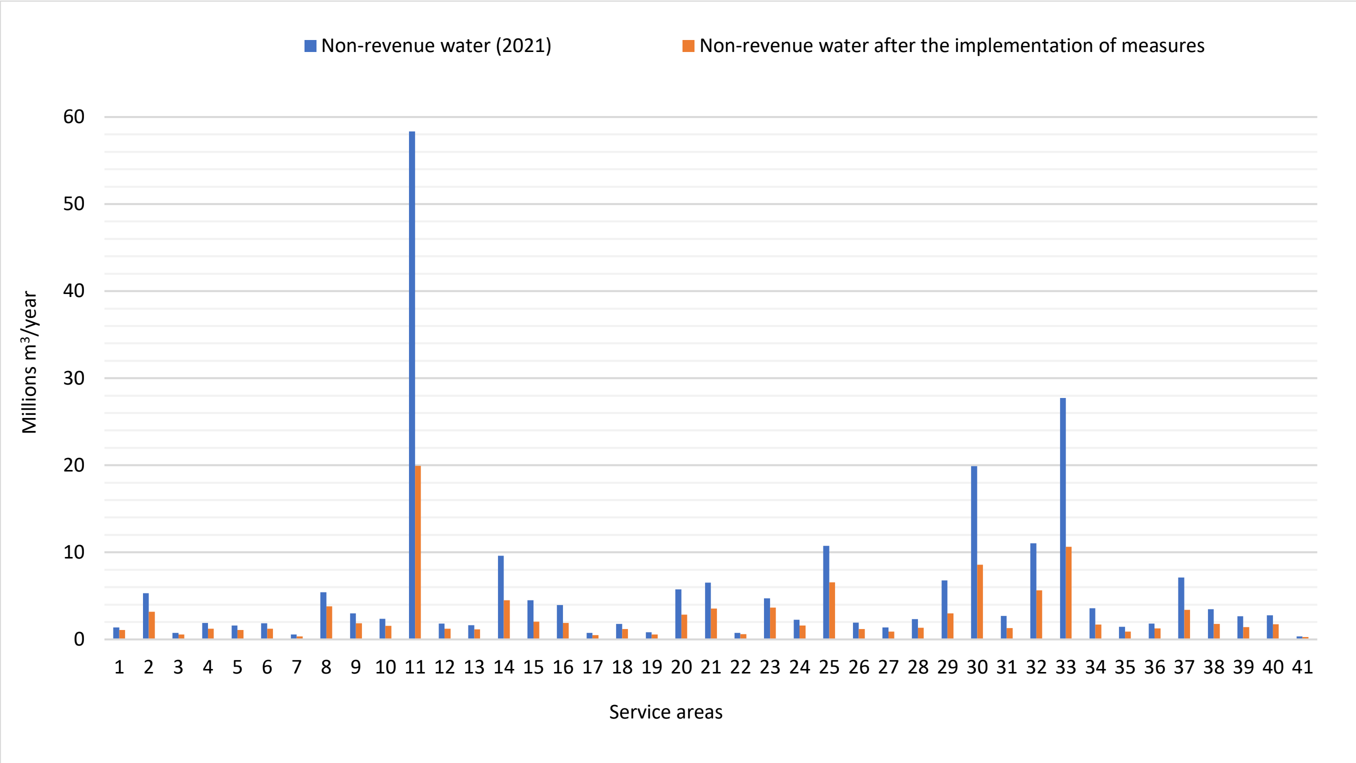

Figure 3.24. Comparison of NRW volumes before and after the implementation of measures by the future service areas

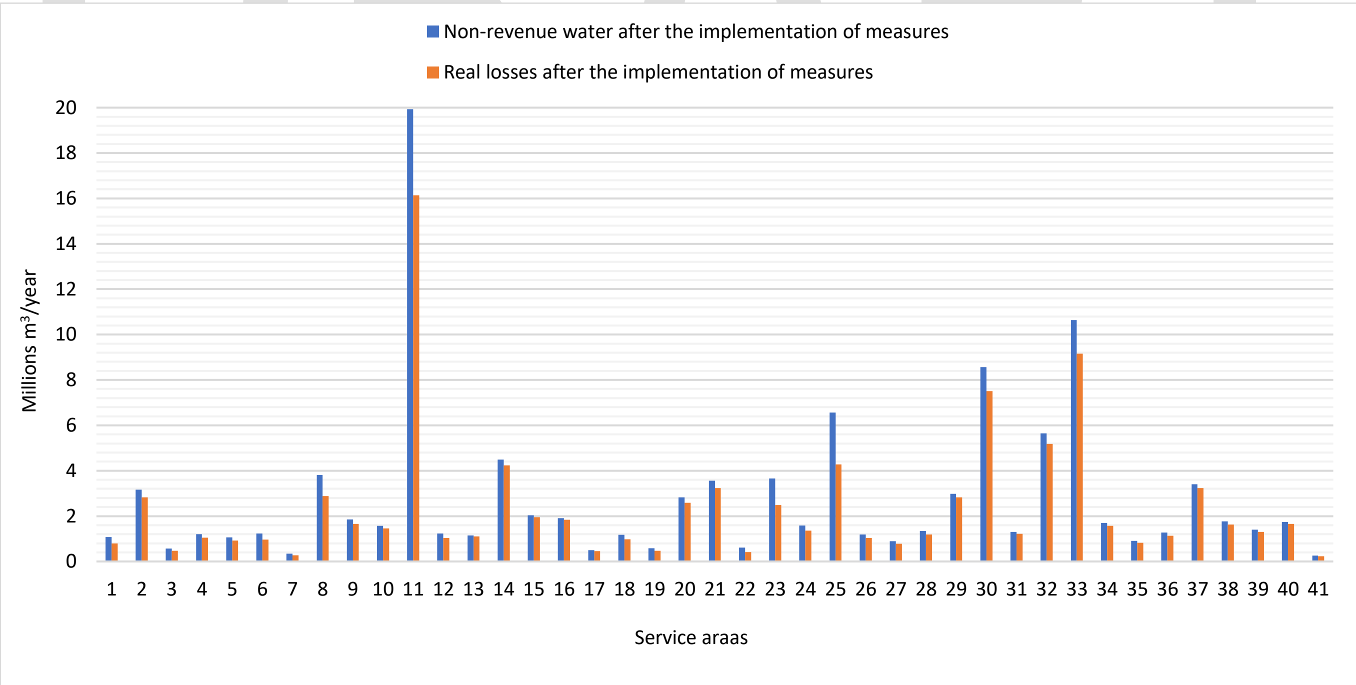

Figure 3.25. NRW and Real Losses after the implementation of measures by the future service areas

3.2.4.2 ILI according to IWA methodology

The spatial distribution of the ILI by PWSPs in Croatia after the implementation of loss reduction measures is presented in Figure 3.26. Figure 3.27. compares the distribution of the ILI after the implementation of measures by PWSPs.

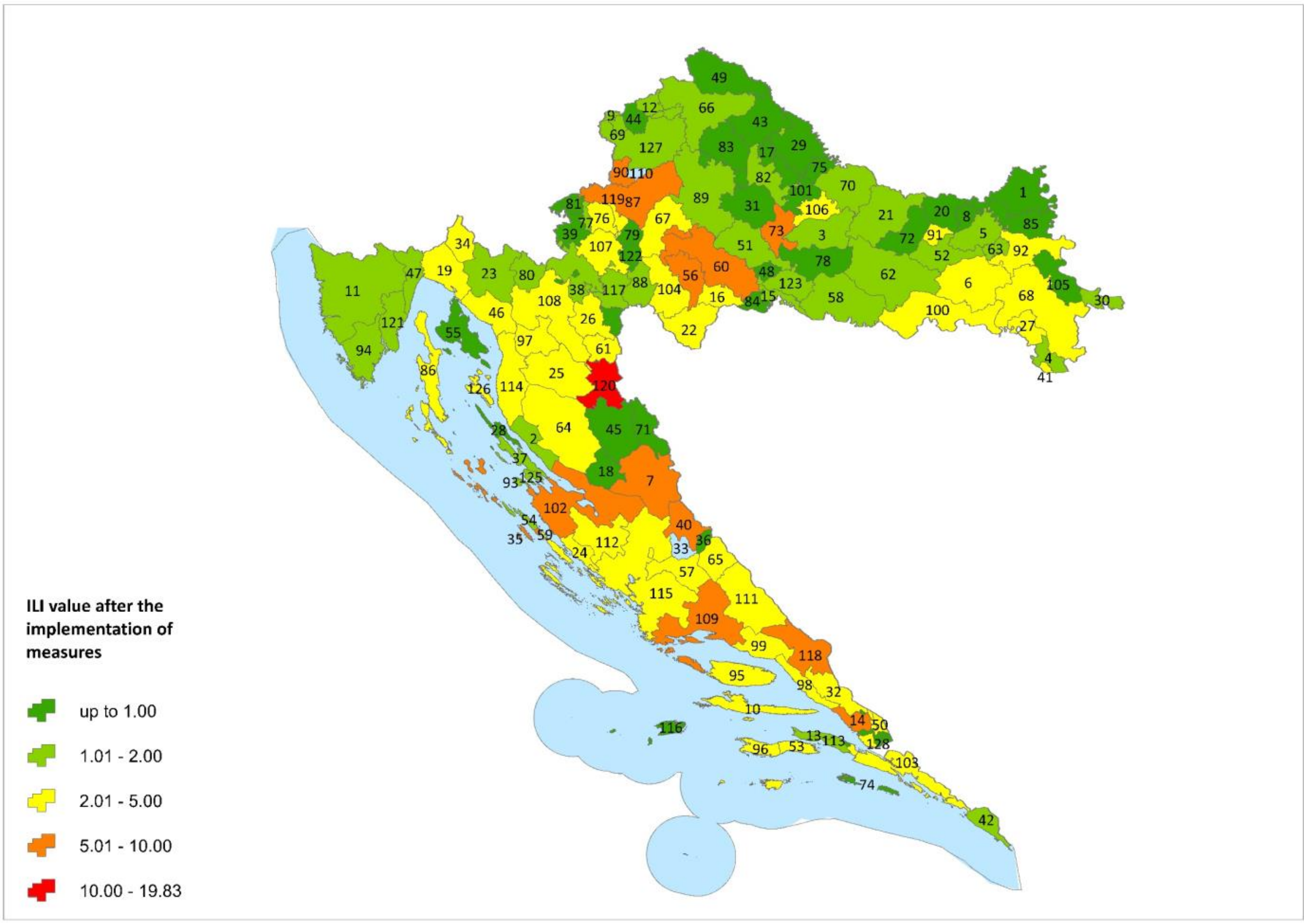

Figure 3.26. ILI after the implementation of measures, PWSP level (with IDs)

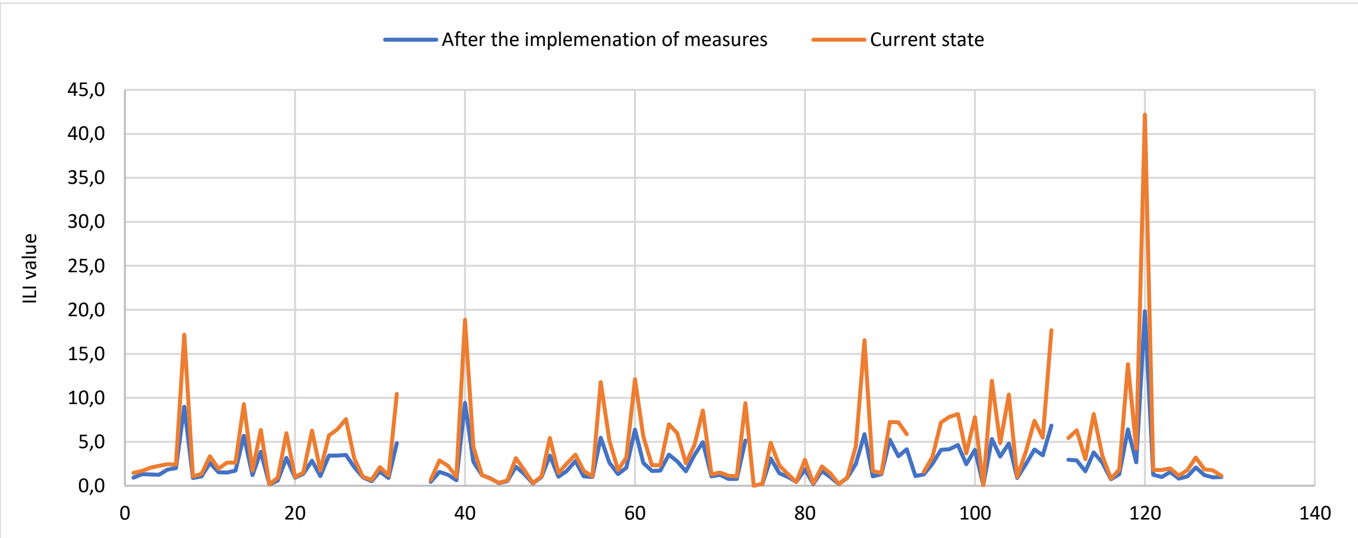

Figure 3.27. Comparison of the ILI before and after the implementation of measures by PWSPs in Croatia

Table 3.6. presents the distribution of the PWSPs in Croatia with regard to the ILI, in accordance with the general categories of real losses management for the developed countries based on the guidelines of the World Bank Institute.

Table 3.6. Water supply systems in Croatia grouped according to the ILI value after the implementation of measures

Developed countries ILI range	Number of PWSPs in Croatia based on the ILI	Band	Guideline description of the real loss management performance categories for developed and developing countries
< 2	74	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective leakage management
2 – 4	32	B	Possibilities for further improvement; consider pressure management, better active leakage control, better maintenance
4 – 8	18	C	Poor leakage management, tolerable only if plentiful cheap resources; even then, analyze level and nature of leakage, intensify reduction efforts
8 or more	3	D	Very inefficient use of resources, leakage reduction programs imperative and high priority

3.2.4.3 Other indicators of water losses

Figure 3.28. presents the spatial distribution of unit values of the Real Losses in liters/service connection/day by individual PWSPs in Croatia, while Figure 3.29. compares the indicators before and after the implementation of measures.

Figure 3.30. presents the spatial distribution of unit values of the Real Losses in m^3/km of mains/hour by individual PWSPs in Croatia, while Figure 3.31. compares the indicators before and after the implementation of measures.

Figure 3.32. presents the spatial distribution of unit values of the Real Losses in liters/service connection/dan/m of pressure by individual PWSPs in Croatia, while Figure 3.33. compares the indicators before and after the implementation of measures.

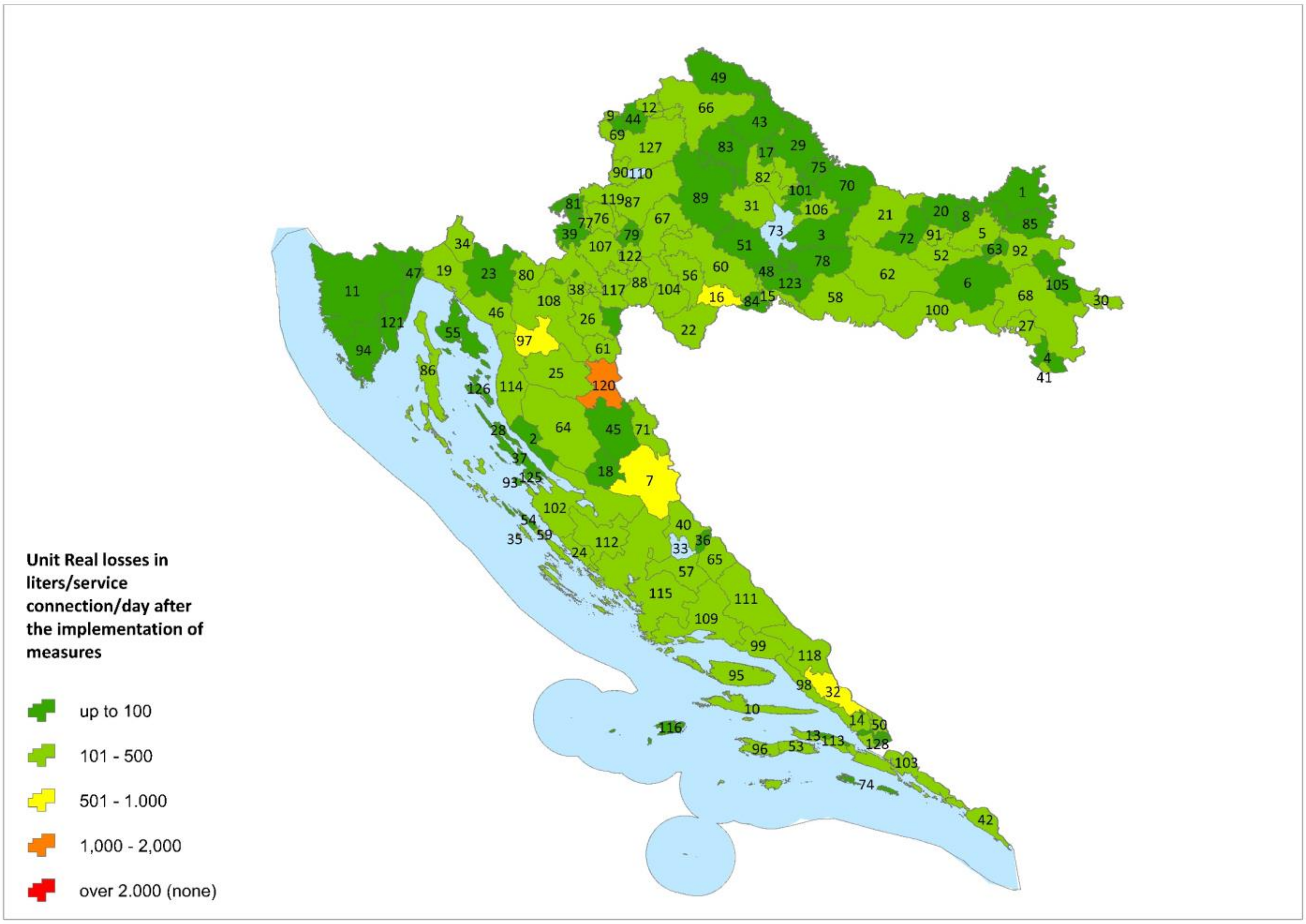

Figure 3.28. Unit value of Real Losses in liters/service connection/day after the implementation of measures, PWSP level (with IDs)

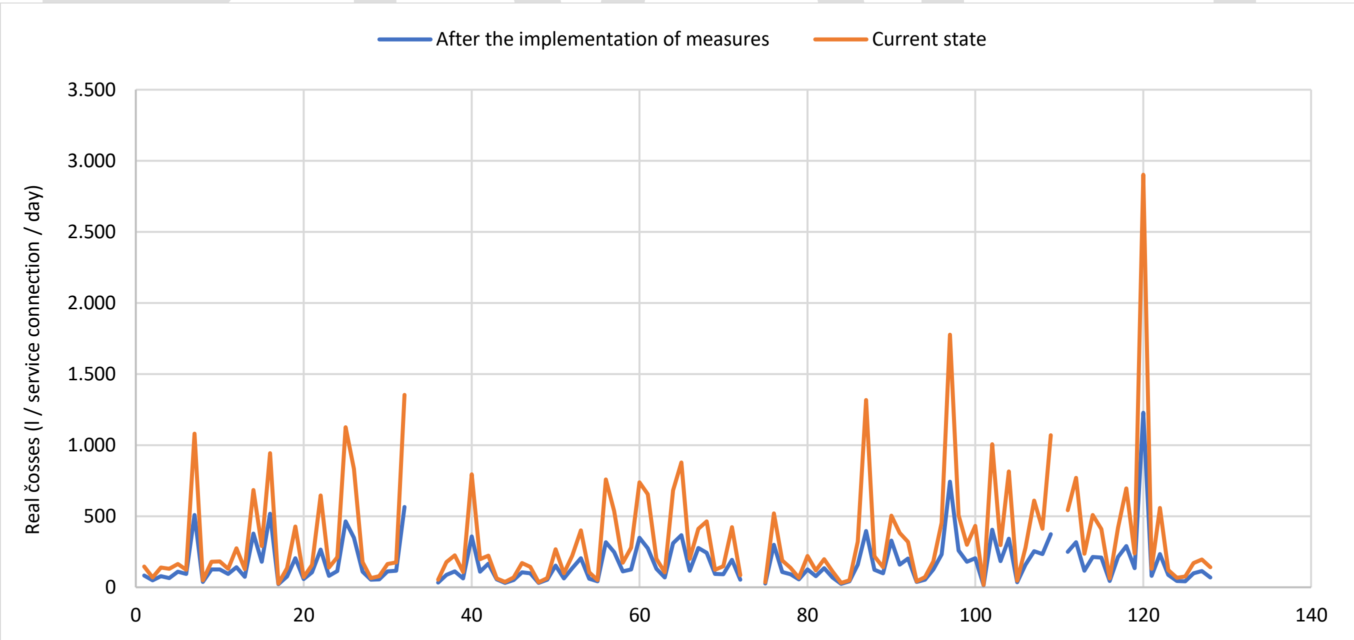

Figure 3.29. Comparison of unit values of Real Losses in liters/service connection/day, PWSP level before and after the implementation of measures

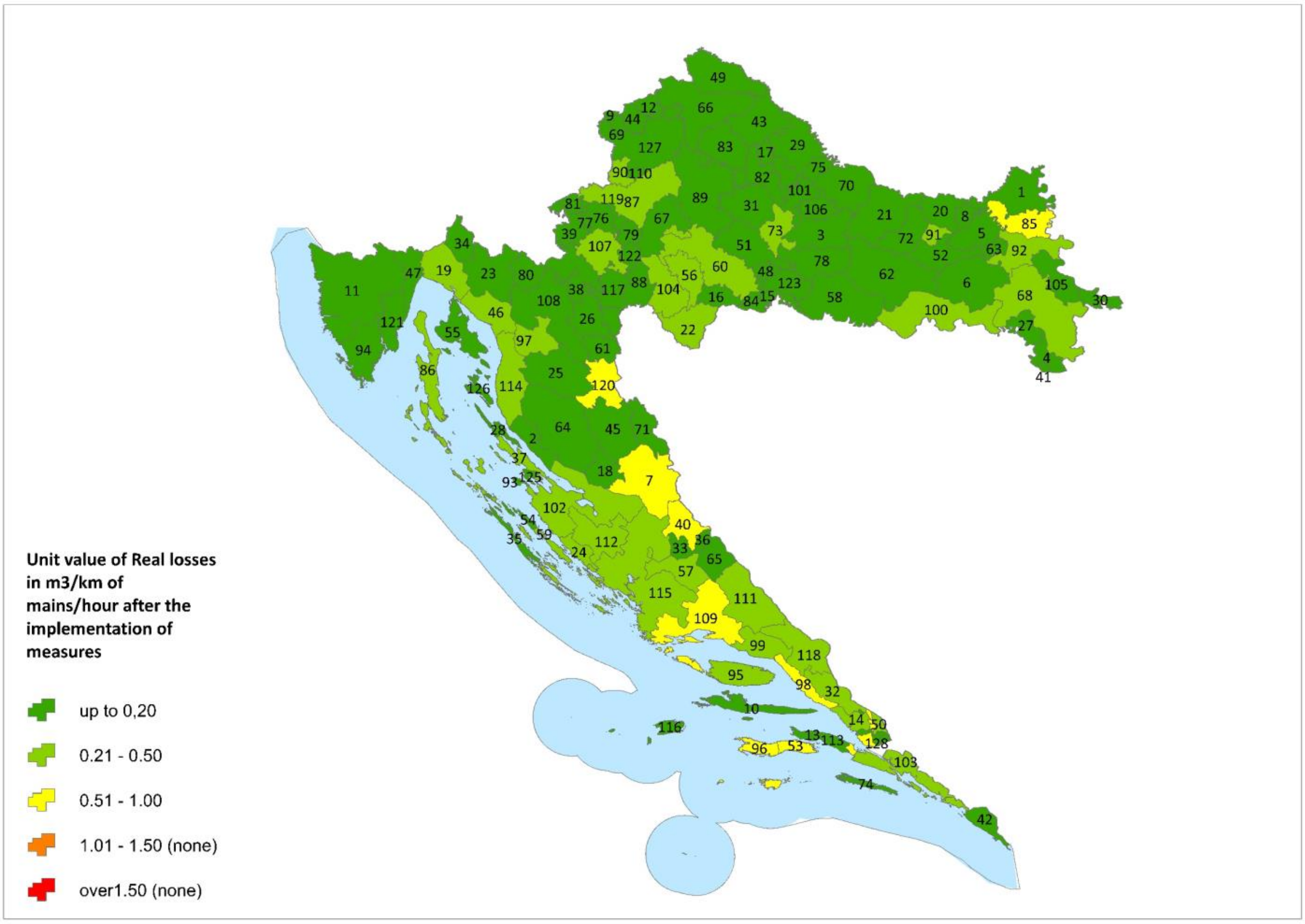

Figure 3.30. Unit value of Real Losses in m3/km of mains/hour after the implementation of measures, PWSP level (with IDs)

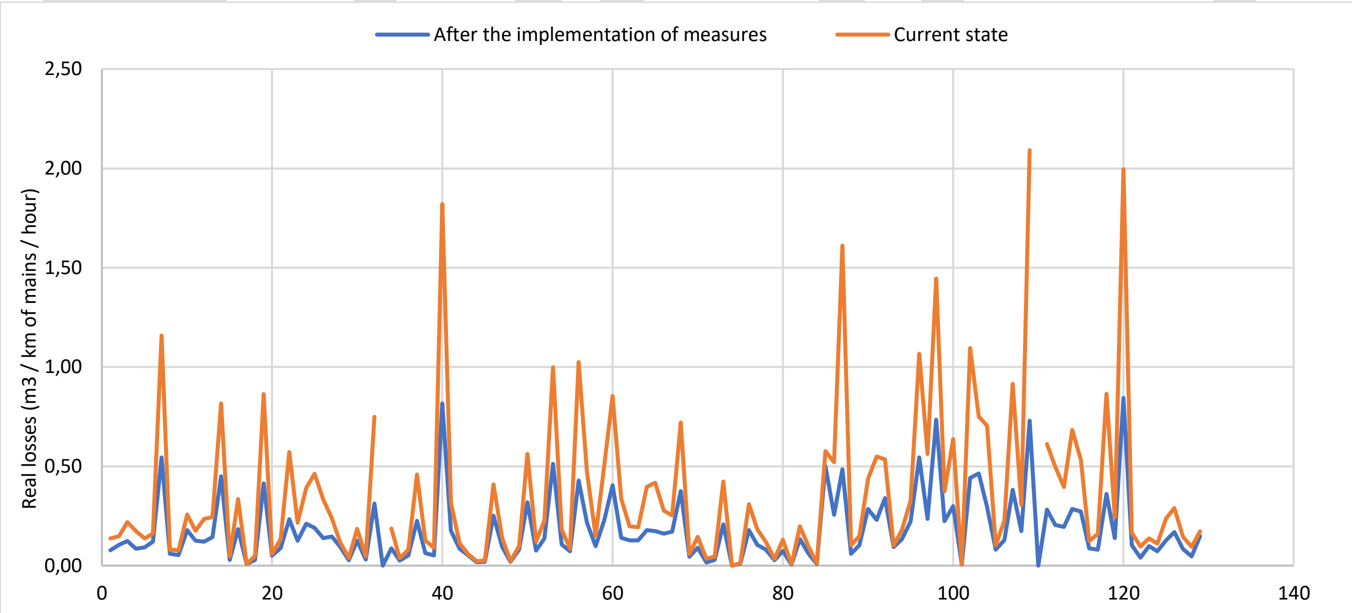

Figure 3.31. Comparison of unit values of Real Losses in m3/km of mains/hour, PWSP level before and after the implementation of measures

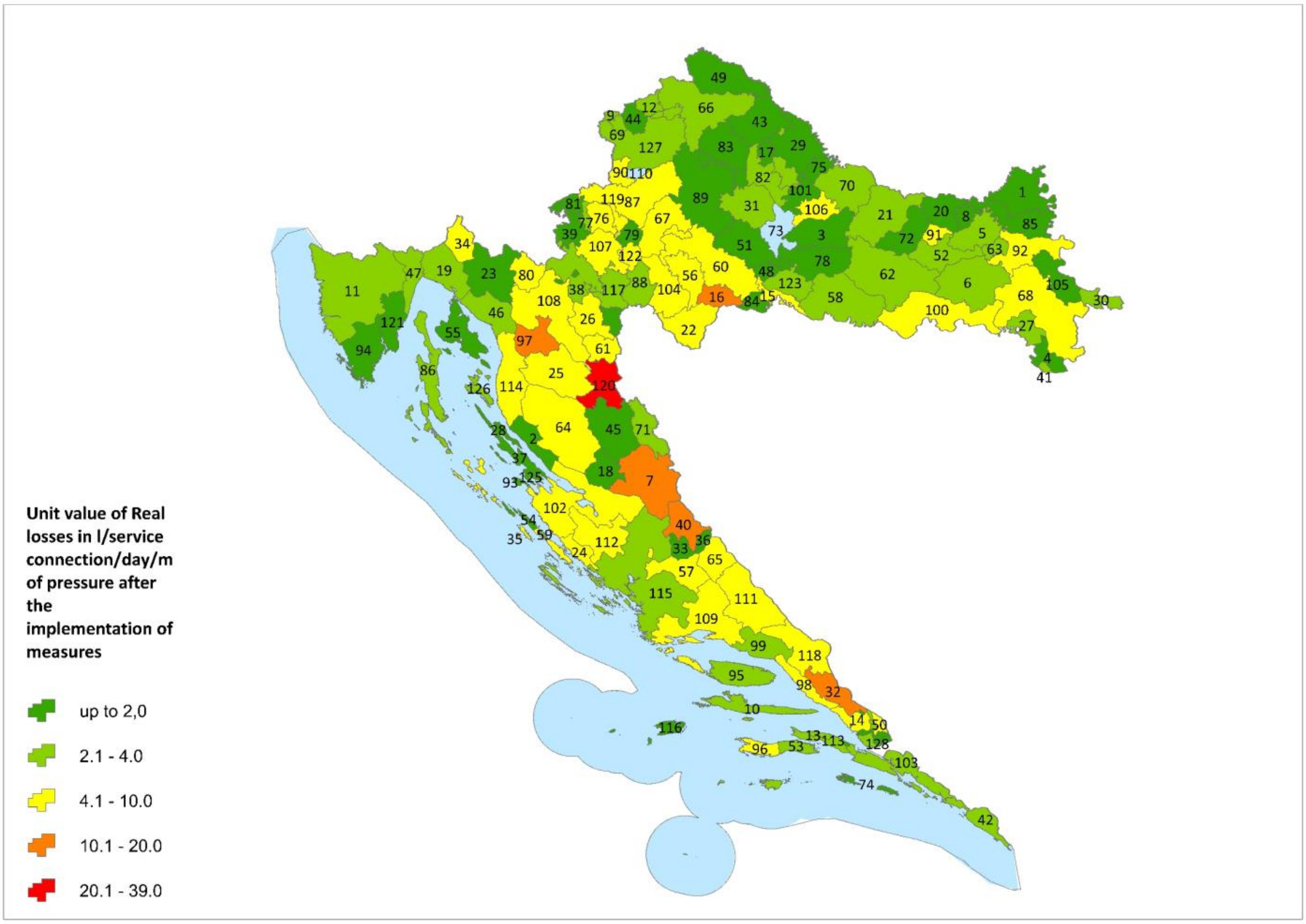

Figure 3.32. Unit value of Real Losses in l/service connection/day/m of pressure after the implementation of measures, PWSP level (with IDs)

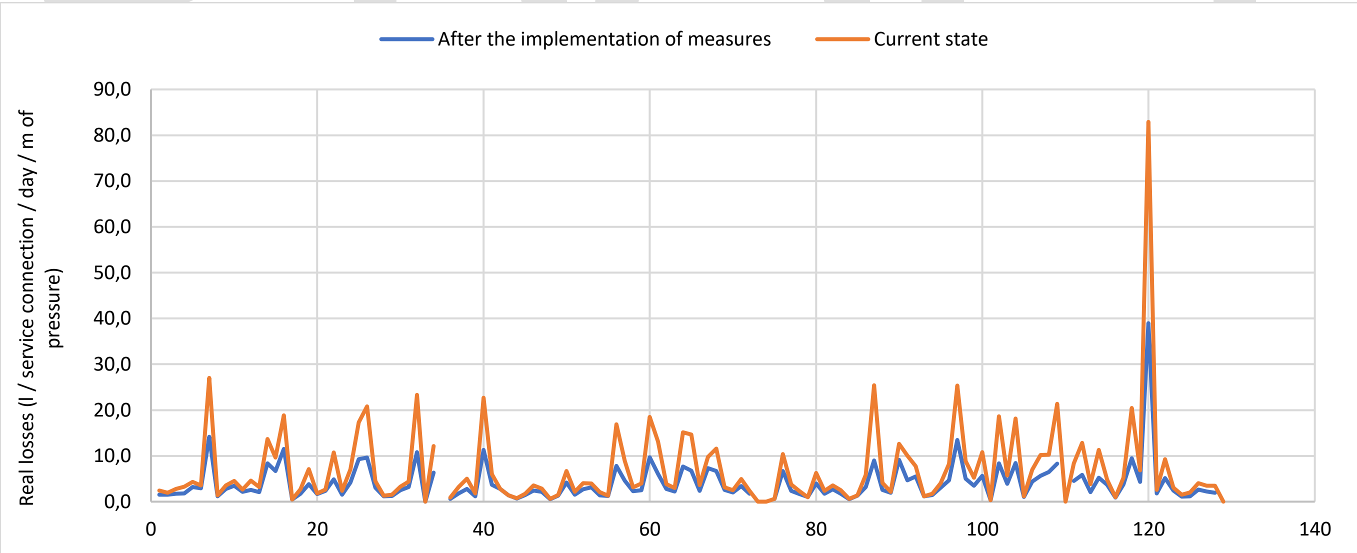

Figure 3.33. Comparison of unit values of Real Losses in l/service connection/day/m of pressure, PWSP level before and after the implementation of measures

3.3 Time frame to implement the Plan

The achievement of the objectives and impacts of the NLRAP (measured by NRW reduction, Chapter 3.2.3.11) requires the implementation of all the foreseen measures in the scope/amounts adjusted to the priority of reducing water losses on the national level (Chapter 3.2.1), or to the needs of individual PWSPs or future service areas (Figure 3.22).

The proposed measures cover all the areas that affect water loss reduction, thus stressing the importance of long-term implementation of all the measures. Some measures, for example Group V measures (Active leakage control), bring the biggest results in relation to the total NRW volume (not with the highest investment), but it is necessary that such measures are preceded by or implemented in parallel with or followed by other measures for the achievement of the targeted impacts, including those most demanding in terms of financing and implementation (Group VII measures – Planning and mains replacement measures) which also have significant effects on NRW reduction. All of that becomes clearer comparing investment by measures (Figure 3.38), cumulative investment (Figure 3.36), effects by measures (Figure 3.39) and cumulative effects (Figure 3.37), where one can see that significant effects of NRW reduction are achieved even with smaller investment (Group V measures), but the targeted values are approached only with financially heavy measures (Group VII measures) which also ensure the sustainability of loss reduction results.

The time frame for the implementation of measures to improve the management of water losses is proposed based on analyzing the following:

- The level of water losses on the national level;
- PWSPs' capacities to implement the measures and potential for improvements;
- The time needed to prepare plans and designs, obtain building permits, and to form teams in PWSPs (including if needed outsourcing technical assistance);
- The complexity of public procurement procedures in terms of time (for part of the activities that include public procurement of services/works/equipment);
- The capacities of available consulting and construction sectors (currently intensified implementation of infrastructural projects in the water sector);
- Financial weight of investments in the measures to improve water loss management;
- The requirements of the DWD Recast referring to the timetable related to water leakage reduction action plans, and in a later phase the expected specification of thresholds and/or target values of water loss reduction indicators.

It is estimated that the implementation of the comprehensive plan of measures in the amount of EUR 1.6 billion (Chapter 3.2.1) requires 15 years. It can be assumed that the implementation of the measures will start already in 2023, i.e., the measures to a certain extent build on the already initiated measures/activities (which have already stopped a multi-annual trend of increasing water losses) from the National Water Loss Reduction Program (NWLRP) or other programs (NRRP or OPCCs), noting that for efficient implementation of measures from the NLRAP it is essential to improve approach and organization of implementing the measures.

The proposed period of implementation of the measures from this NLRAP is 2024-2038, by which time it is expected that the NRW will be reduced from the current 235 million m^3/year to 113 million m^3/year, representing a reduction of around 50% of the 2021 NRW.

As the result of loss management improvement measures in the 2023-2037 period, which also includes significant strengthening of PWSPs to cope with water losses, and with continued implementation of active leakage control measures and continued rehabilitation/replacement of mains (with a proposed investment in replacement of at least 2% per year), further significant advances in the reduction of losses are also expected beyond 2037, which it will only be possible to estimate in a certain phase of implementing the measures from this NLRAP (e.g., after 10 years) and analyzing the actual effects of measures (and the required modifications of the approach/measures), noting that the estimates of the effects of measures by 2037 are rather conservative.

It is pointed out that one of the key measures of institutional strengthening of PWSPs deriving from this NLRAP is the preparation of action plans on the level of PWSPs and/or future (41) service areas. These plans will consider in greater detail the potential for water loss reduction and, what is also important, assess (update) the specific objectives (effects of measures for the analyzed area) with higher confidence, all based on the framework and methodology from this NLRAP. For that reason, the preparation of action plans on the level of PWSPs and/or service areas has to be among the initial activities the results of which will be used for the preparation of the future national loss reduction action plans, i.e., for the evaluation of objectives, and which will be presented to the E For successful improvement of water loss management on the national level it is necessary to implement all the measures foreseen by the NLRAP in the extent/scope/amounts which were (during the initial estimate) adjusted to the needs of the individual PWSP or service area.

Investment priorities in terms of time will be defined in relation to the relevance of water losses of the specific PWSP (presented in Chapter 3.2.2.5), since the relevance of losses considers the following:

- Size of losses;
- Specific indicators of water losses;
- Significance of loss reduction in relation to the sensitivity/risks of water supply systems (system condition and impact from the surroundings);

Table 3.7. Relevance of water losses and investment priorities

No./Relevance	Group of measures/Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I	**System data improvement measures**															
Relevance of water losses	Very high	20%	40%	40%												
	High		20%	40%	40%											
	Medium		10%	20%	40%	30%										
	Moderate		5%	10%	30%	30%	25%									
II	**Water supply system optimization measures**															
Relevance of water losses	Very high	5%	10%	15%	40%	30%										
	High		5%	10%	15%	30%	40%									
	Medium			5%	20%	30%	45%									
	Moderate			5%	15%	20%	30%	30%								
III	**Measures to divide the system into DMAs**															
Relevance of water losses	Very high	5%	10%	15%	40%	30%										
	High		5%	10%	10%	30%	30%	15%								
	Medium		5%	5%	10%	20%	20%	20%	20%							
	Moderate		5%	5%	5%	10%	20%	20%	20%	15%						
IV	**System pressure control and management measures**															
Relevance of water losses	Very high		5%	5%	20%	40%	30%									
	High			5%	5%	20%	20%	30%	20%							
	Medium			5%	5%	10%	10%	20%	30%	20%						
	Moderate			5%	5%	5%	10%	15%	20%	20%	20%					
V	**Active leakage control measures**															
Relevance of water losses	Very high	5%	10%	20%	20%	20%	10%	10%	5%							
	High	5%	10%	15%	15%	15%	15%	10%	10%	5%						
	Medium	3%	5%	10%	10%	10%	10%	10%	12%	10%	5%	5%	5%	5%		
	Moderate	2%	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%	8%	5%	5%	5%
VI	**Measures to address apparent losses**															
Relevance of water losses	Very high	5%	10%	20%	20%	20%	20%	5%								
	High	5%	10%	10%	10%	10%	15%	15%	15%	10%						
	Medium	3%	5%	5%	4%	10%	10%	10%	10%	10%	23%	10%				
	Moderate	2%	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%	8%	5%	5%	5%
VII	**Planning and mains replacement measures**															
Relevance of water losses	Very high	1%	2%	5%	10%	15%	15%	15%	15%	15%	7%					
	High		1%	2%	5%	10%	15%	15%	15%	15%	15%	7%				
	Medium		1%	1%	1%	5%	10%	10%	12%	10%	10%	10%	10%	10%	10%	
	Moderate		1%	1%	1%	2%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%
VIII	**Institutional strengthening measures (preparation of PWSPs' action plans, organization charts, processes, tasks, and staff training)**															
Relevance of water losses	Very high	20%	30%	30%	5%	5%	5%	5%								
	High	10%	20%	20%	20%	5%	5%	5%	5%	5%	5%					
	Medium	5%	10%	20%	30%	5%	5%	5%	5%	5%	5%	5%				
	Moderate	5%	10%	10%	35%	5%	5%	5%	5%	5%	5%	5%	5%			
IX	**Analysis and reporting measures**															
Relevance of water losses	Very high	10%	10%	20%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
	High	5%	5%	10%	10%	10%	10%	10%	5%	5%	5%	5%	5%	5%	5%	5%
	Medium	5%	5%	5%	10%	10%	10%	10%	10%	5%	5%	5%	5%	5%	5%	5%
	Moderate	5%	5%	5%	5%	10%	10%	10%	10%	5%	10%	5%	5%	5%	5%	5%
X	**Technical (external) assistance to PWSPs to implement the measures**															
Relevance of water losses	Very high	5%	15%	15%	10%	10%	10%	10%	5%	5%	5%	5%	5%			
	High	5%	10%	10%	10%	10%	10%	10%	10%	5%	5%	5%	5%	5%		
	Medium	3%	5%	5%	5%	10%	10%	10%	10%	10%	9%	8%	5%	5%	5%	
	Moderate	2%	5%	5%	5%	5%	5%	13%	10%	10%	10%	10%	5%	5%	5%	5%
XI	**MESD measures**															
	Establishment of a benchmarking system	20%	10%	10%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
	Activities of the national body for the reduction of losses	5%	10%	10%	10%	10%	10%	5%	5%	5%	5%	5%	5%	5%	5%	5%

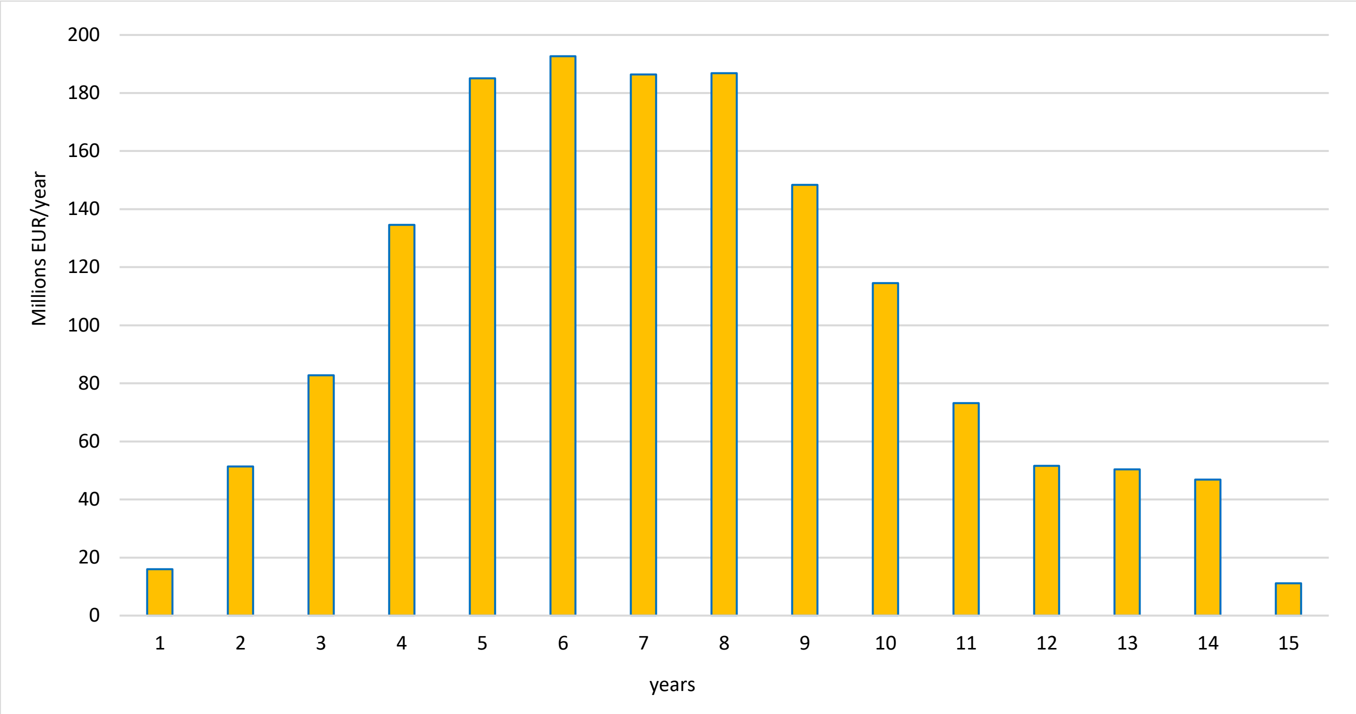

Figure 3.34. Investment by years

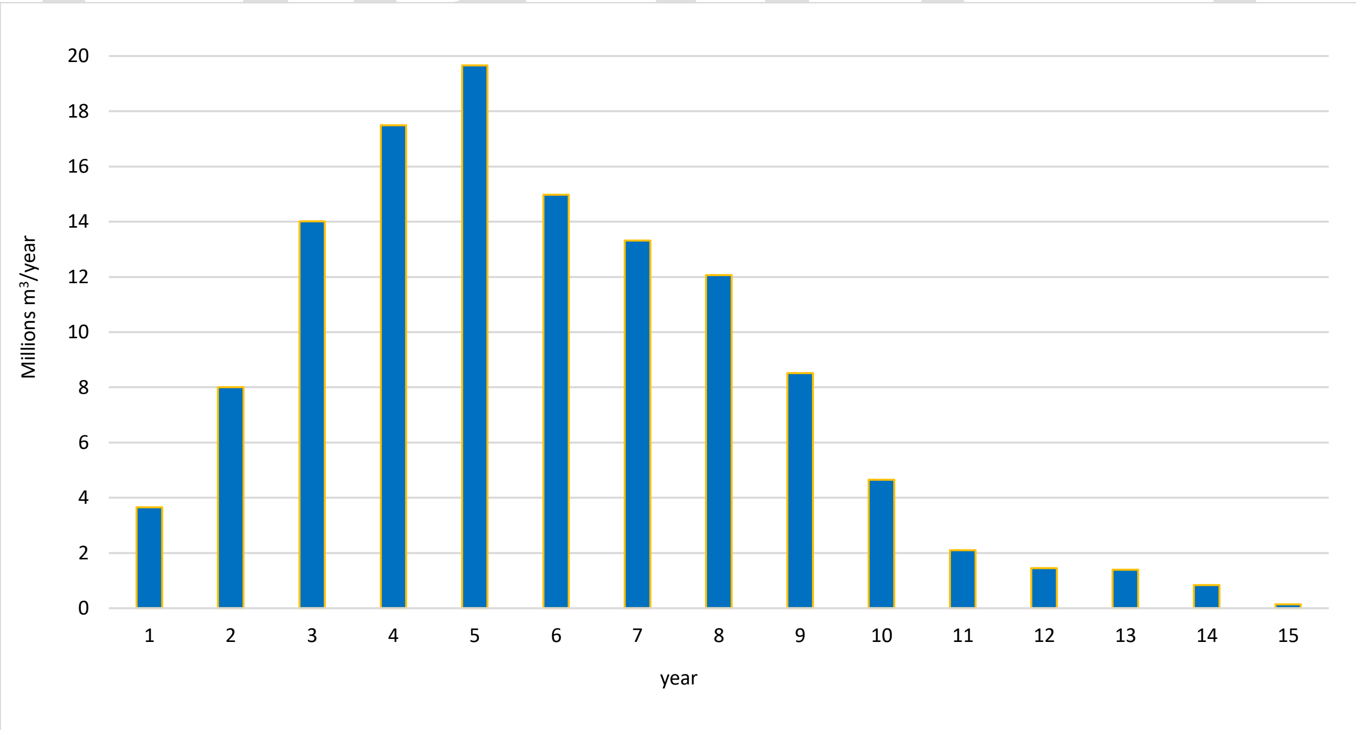

Figure 3.35. Effects of investment by years (NRW reduction, m3/year)

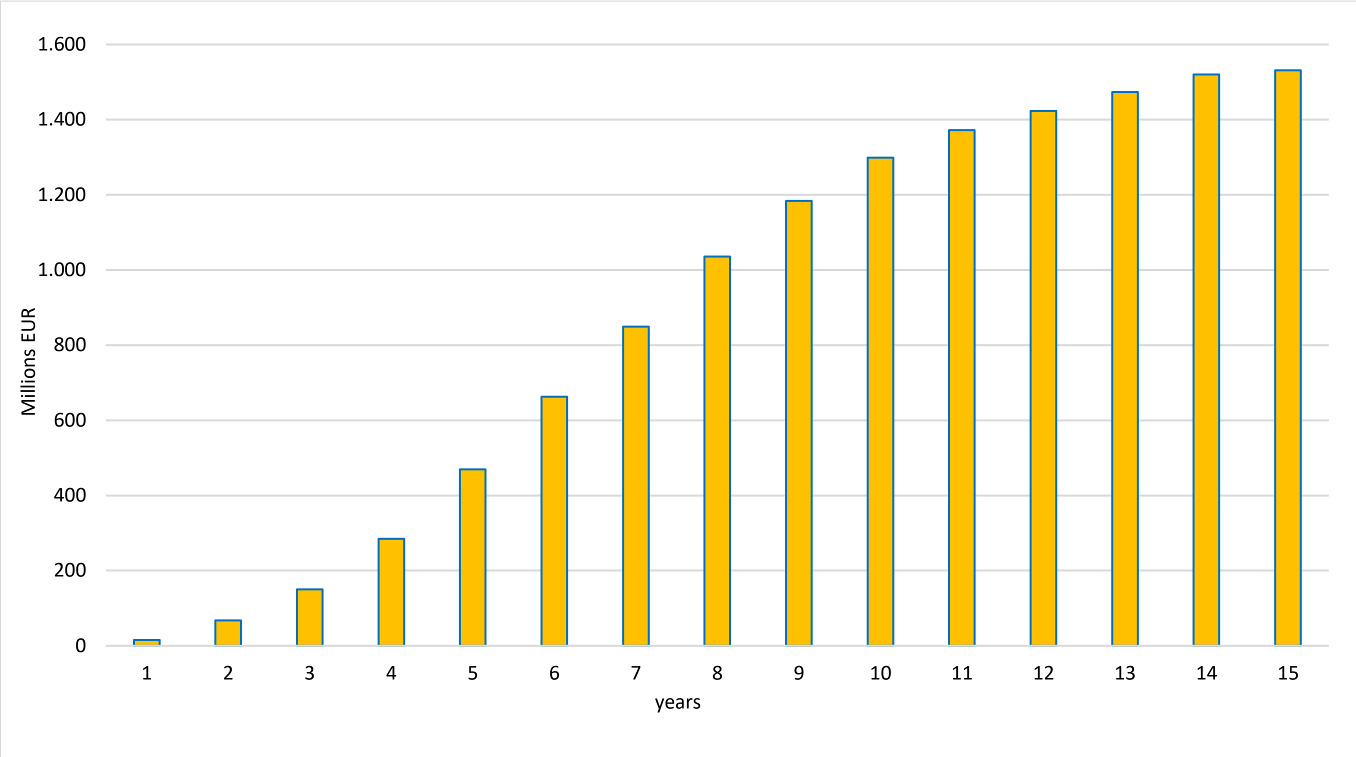

Figure 3.36. Cumulative investment

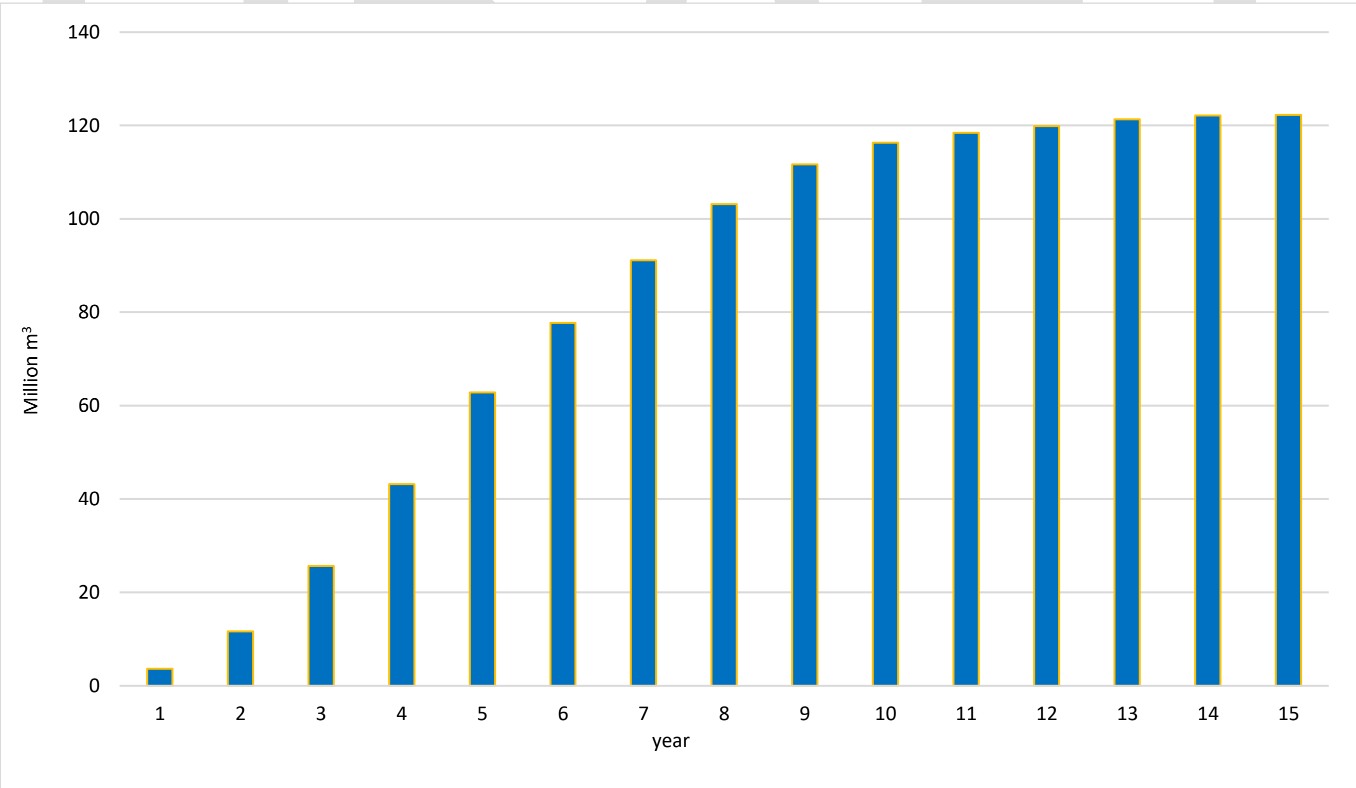

Figure 3.37. Cumulative effects (NRW reduction, m3)

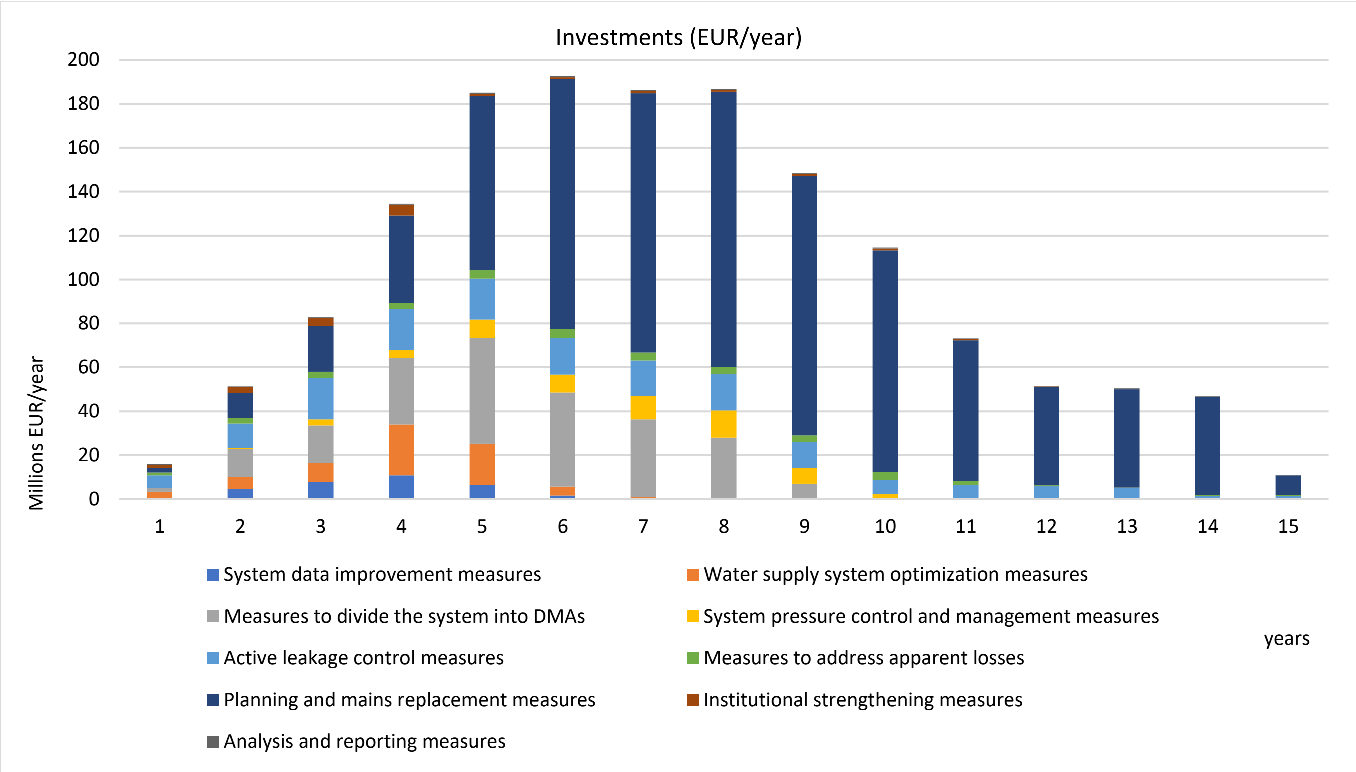

Figure 3.38. Costs of loss reduction measures by years

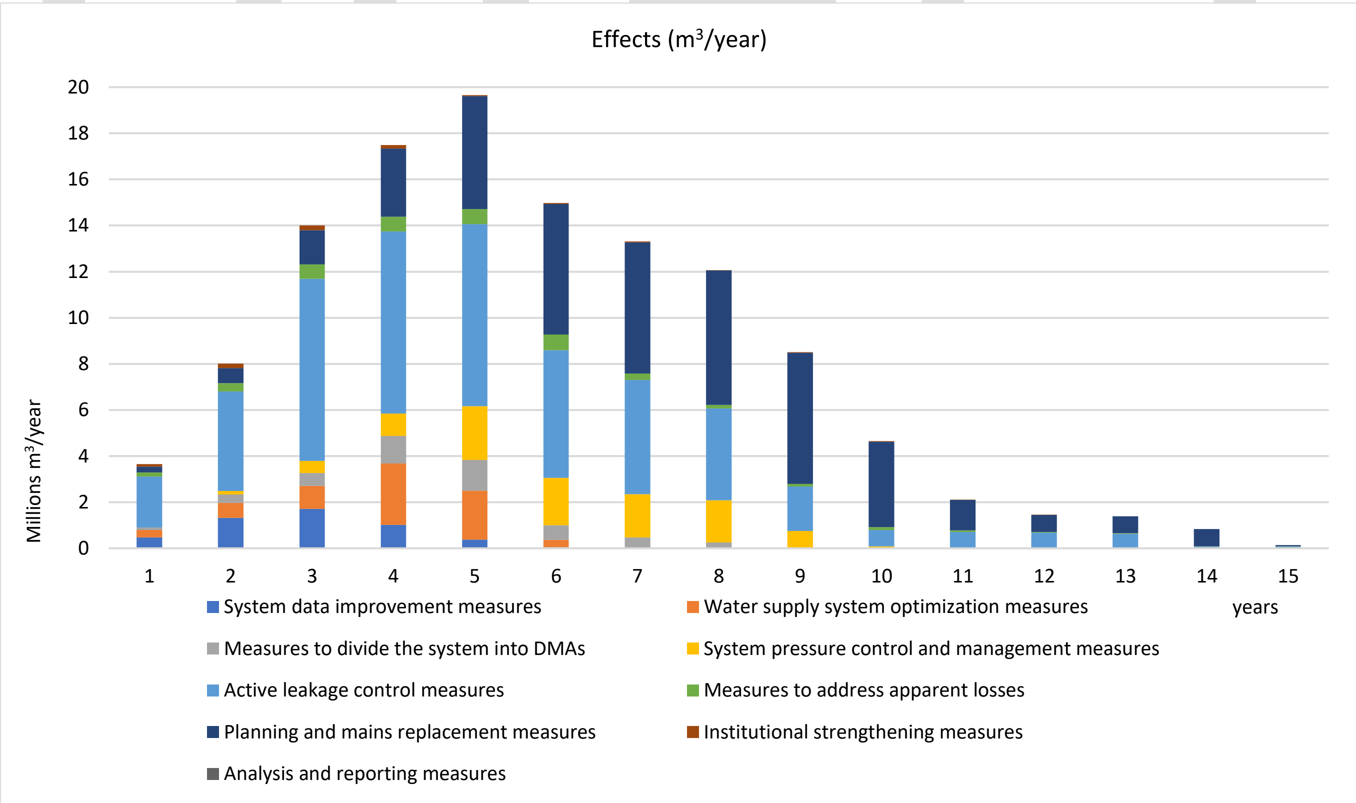

Figure 3.39. Effects of loss reduction measures by years (m3/year)

3.4 Risk assessment

The implementation of the NLRAP and all the defined measures implies numerous external and internal risks that may have an impact on expected results. Due to the complexity of measures and a large number of stakeholders in the entire NLRAP implementation process, the risk assessment is methodologically simplified and focused on the main risks that may affect the Plan's implementation.

The methodological steps in risk assessment are the following:

- Step 1: Risk identification;
- Step 2: Risk level assessment;
- Step 3: Sensitivity analysis;
- Step 4: Conclusion;

3.4.1 Risk identification

In relation to the defined measures, 4 main groups of risks (including both external and internal risks) have been established, identifying the main risks that may have a significant impact on the NLRAP implementation.

- Technical risks:
  - Inadequate level of collected data
  - Inadequate reduction of NRW volumes
  - Inadequate assessment of the system's technical issues

- Implementation risks:
  - Delay in the implementation of defined measures, primarily due to PWSP's insufficient capacities

- Financial risks:
  - Increase of the price of defined measures
  - Problems with financing sources

- Regulatory risks:
  - Unexpected political or regulatory factors affecting the NLRAP implementation
  - Public resistance at the introduction of the new system of calculation of the water usage fee

3.4.2 Risk level assessment

The next step is assessing the risk level for the identified risks. The methodological basis was taken over from the Guide used for the preparation of water and wastewater projects on the EU level. According to the Guide to Cost-Benefit Analysis of Investment Projects, Economic appraisal tool for Cohesion Policy 2014 – 2020; European Commission, December 2014), the risk level is defined as the combination of risk severity and risk probability.

The tables with the risk severity classification and risk probability, and the risk matrix are presented below

Table 3.8. Risk severity classification

	Meaning
I	No significant impact on the NLRAP implementation.
II	Minor loss of the effects generated by the NLRAP; minimally affecting the long-term implementation of the defined measures; corrective actions are needed
III	Moderate: Loss of effects of the measures defined by the NLRAP; mostly financial damage for the medium-long term plan of measures; corrective actions may correct the potential problem.
IV	Critical: High loss of effects generated by the NLRAP; the occurrence of the risk causes a loss of the primary functions of the NLRAP; corrective measures are not enough to prevent a significant delay in the implementation of the NLRAP measures.
V	Catastrophic: The failure of measures may result in serious or even total loss of the NLRAP purpose.

Table 3.9. Risk probability

	Probability
A	Very unlikely
B	Unlikely
C	About as likely as not
D	Likely
E	Very likely

Table 3.10. Risk level

Severity / Probability	I	II	III	IV	V
A	Low	Low	Low	Low	Moderate
B	Low	Low	Moderate	Moderate	High
C	Low	Moderate	Moderate	High	High
D	Low	Moderate	High	Unacceptable	Neprihvatljiva
E	Moderate	High	Unacceptable	Unacceptable	Unacceptable

Table 3.11. Identification of risks and risk prevention measures

Risk ID	Description of risk	Probability	Severity	Risk level	Explanation	Definition of prevention and mitigation measures	Responsibility for prevention and mitigation of main risks	Risk level after prevention measures
TECHNICAL RISKS								
TR01	**Inadequate level of collected data**	B	II		Data about the existing and future water demand and estimate of losses are based on estimates and calculations, in case when there is not enough relevant metering data.	With the implementation of defined measures (I, II, VIII and IX) the accuracy of the defined parameters is checked, and a system is established to minimize the risk.	**PWSPs, MESD and CW**	
TR02	**Inadequate reduction of NRW volumes**	B	IV		Inadequate reduction of NRW volumes due to a failure to implement certain measures or poor forecasts.	When analyzing the existing volumes use was made of the SOV database and data collected from PWSPs to obtain the correct number of consumers, i.e., of pressures to the water supply system. Also, when estimating reduction, a very conservative approach was used. Due to the significance of this risk, additional sensitivity analyses were made about how the risk affects end users.	**PWSPs, MESD and CW**	
TR03	**Inadequate assessment of the system's technical issues**	B	III		According to the defined measures, the financially most complex measure is Measure VII that includes the replacement of mains. Due to the importance of the measure – possible wrong prioritization of replacement will result in high amounts of funds with small effects on the overall reduction of NRW volumes.	Due to the defined measures and relevance and correlation of certain measures – importance of MEASURE IX that ensures coordination of all the proposed measures.	**PWSPs, MESD and CW**	

Risk ID	Description of risk	Probability	Severity	Risk level	Explanation	Definition of prevention and mitigation measures	Responsibility for prevention and mitigation of main risks	Risk level after prevention measures
IMPLEMENTATION RISKS								
IR01	**Delay in the implementation of defined measures**	**C**	**IV**		Delay in the implementation of defined measures and modified schedule of implementation may significantly affect the reduction of NRW volumes, primarily due to PWSPs' insufficient capacities	Implementation of Measure X (Technical assistance to PWSPs) and other measures are defined according to the relevance and level of losses; at the first sign of a problem in implementing certain measures, the national body responsible for monitoring the NLRAP implementation sends out warnings and an operational plan to reduce the risk.	**PWSPs, MESD and CW**	
FINANCIAL RISKS								
FR01	**Increase of the price of defined measures**	C	III		The prices are defined according to the current prices on the Croatian market respecting inflationary pressures and characteristics of the water utility sector.	Increase of the price of measures directly affects the implementation and price of the water service (through the full cost recovery principle). Due to the importance of this issue, an additional sensitivity analysis has been made to estimate the need for additional measures.	**PWSPs, MESD and CW**	
FR02	**Problems with financing sources**	B	III		Due to the financial amount of the defined measures and available financing sources, a problem may arise of not being able to find adequate sources for some measures.	The analysis of potential sources presents all currently available sources – the analysis presents the impact of financing certain measures by taking out a loan – and the impact on price affordability.	**PWSPs, Government, CW and MESD**	
REGULATORY RISKS								
RR01	**Unexpected political or regulatory factors affecting the NLRAP implementation**	A	I		Political disagreements; possible change in the direction of water policy	Croatia follows the EU directives in the field of defining its national water policy. The NLRAP implementation is one of the reform measures defined within the NRRP and Croatia's strategic objective.	**PWSPs, Government, CW and MESD**	
RR02	**Public resistance at the introduction of the new system of calculation of the water usage fee**	B	II		Due to inflationary pressures, a negative public attitude about the implementation of the new fee calculation system is expected.	The public has been informed about the new method of calculation from the start through e-consultations. Through the defined measures it will be clearly communicated that the overall implementation of the Measures will aim to reduce the total calculated fee.	**PWSPs, Government, CW and MESD**	

According to the defined methodology, the table below presents the results of the risk matrix. For three risks a moderate level of risk was identified after the implementation of risk prevention and mitigation measures, and an additional sensitivity analysis was made to estimate the impact on the implementation of the overall NLRAP. According to the table below, three risks are identified as moderate: Inadequate reduction of NRW volumes, Delay in the implementation of defined measures, and Increase of the price of defined measures.

Table 3.12. Results of risk analysis

Risk ID	Risk name	Risk level after prevention measures	Additional sensitivity analysis
TR01	Inadequate level of collected data		NO
TR02	Inadequate reduction of NRW volumes		YES
TR03	Inadequate assessment of the system's technical issues		NO
IR01	Delay in the implementation of defined measures		YES
FR01	Increase of the price of defined measures		YES
FR02	Problems with financing sources		NO
RR01	Unexpected political or regulatory factors affecting the NLRAP implementation		NO
RR02	Public resistance at the introduction of the new system of calculation of the water usage fee		NO

3.4.3 Sensitivity analysis

The purpose of the additional sensitivity analysis is to show the impact of change of certain factors on the main outputs of the NLRAP. There are three main identified risks that may significantly affect the implementation of the Plan, and for all three risks additional analyses have been made to identify the overall impact of these risks on the implementation of the Plan. The analysis is focused on the outputs, i.e., on the impact on the water usage fee and the total price of water services.

Table 3.13. Additional sensitivity analysis for the identified risks

Risk	TR02: Inadequate reduction of NRW volumes
Sensitivity level	
Probability	B
Severity	IV
Risk level	Moderate
Risk	Inadequate reduction of NRW volumes due to a failure to implement certain measures or poor forecasts
Direct impacts	Impact on the price of the water service
	Impact on the water usage fee
Sensitivity	Due to the defined risk, a sensitivity analysis was made – 20% lower reduction of the NRW volume than projected and impacts on the price of the water service and the water usage fee
Results	Price of the water service: insufficient reduction of the NRW negatively affects the price of water services, first of all through increasing costs of water abstraction, which results in increased system operation costs. This is reflected through cost increase of EUR 2.2 million per year, resulting in the impact on the price of the water service of EUR 0.009 per m3, which negatively affects the overall affordability of water services.
	Water usage fee: insufficient reduction of the NRW will negatively affect the total price of the water usage fee – according to the sensitivity analysis, inadequate reduction of the NRW by 20 % has an impact on EUR 6.8 million more of calculated water usage fee, which implies increasing the fee for end users by EUR 0.03 per m3, and a negative impact on the overall affordability of water services.
Based on the sensitivity analysis, the risk is assessed as acceptable with regard to the results defined above.	
Risk after sensitivity analysis:	Low
Risk	**IR01: Delay in the implementation of defined measures**
Sensitivity level	
Probability	C
Severity	IV
Risk level	High

Risk	Delay in the implementation of defined measures and modified schedule of implementation may significantly affect the reduction of NRW volumes
Direct impacts	Impact on the implementation of measures
	Impact on the water usage fee
Sensitivity	Due to the defined risk, a sensitivity analysis was made – pushing the implementation by three years and the related impact on effects by delaying NRW reduction.
Results	An analysis of the time schedule of the implementation of measures and effects shows the following: the financially most intensive implementation takes place in the 5^{th} to 10^{th} year of the NLRAP, and cumulative effects of the reduction of losses are at 90% in the 11^{th} year of the NLRAP implementation. If the implementation of measures is pushed by three years, the cumulative effects of measures are expected only in 2037, which is negatively reflected on the water usage fee (incremental impact of EUR 0.05 per m3) through increased water abstraction costs (EUR 0.08 per m3) and a negative impact on the overall affordability of water services.
Based on the sensitivity analysis, the risk is assessed as acceptable with regard to the results defined above.	
Risk after sensitivity analysis:	Low
Risk	**FR01: Increase of the price of defined measures**
Sensitivity level	
Probability	C
Severity	III
Risk level	Moderate
Risk	The prices are defined according to the current prices on the Croatian market respecting inflationary pressures and characteristics of the water utility sector.
Direct impacts	Impact on the price of the water service
	Impact on affordability
Sensitivity	Due to the defined risk, a sensitivity analysis was made – increasing the price of measures by 20% and an impact on the price of water services.
Results	Increasing the price of the identified measures by 20 % negatively affects the overall price of water services; according to the sensitivity analysis, increasing the price by 20% negatively affects the price of the water service through direct increase of EUR 0.08 per m3.
Based on the sensitivity analysis, the risk is assessed as acceptable with regard to the results defined above.	
Risk after sensitivity analysis:	Low

3.4.4 Conclusion

According to the Guide used for the preparation of water and wastewater projects on the EU level, using risk and sensitivity analyses acceptable risks of impact on the price of water have been identified (maximum cumulative impact up to EUR 0.16 per m^3 of water), with the **NLRAP acceptable in terms of criteria of impact on the price of water.**

However, **the risks of not achieving the national loss reduction objectives are significant** (due to PWSPs' technical capacities or failure to provide funds for the implementation of the NLRAP), which can lead to the operational inefficiency of PWSPs being retained or increased, but potentially also to the European Commission imposing measures on the country due to the failure to achieve objectives at the EU level, the consequences of which cannot be foreseen at this moment with an acceptable level of certainty, and further failure to achieve the loss reduction objectives can even lead to denying the instruments of EU's financial assistance by reducing the funds available from the NRRP 2021-2026 and MFF 2021-2027.

In case the implementation of measures is delayed (Figure 3.40) (the initial years with a slightly slower rate in the initial activities, preparation of plans, organization of teams and active leakage control, and in later years more considerable delay in the renewal of mains), the effects would significantly fail to occur, particularly in the first 10 years of the NLRAP implementation.

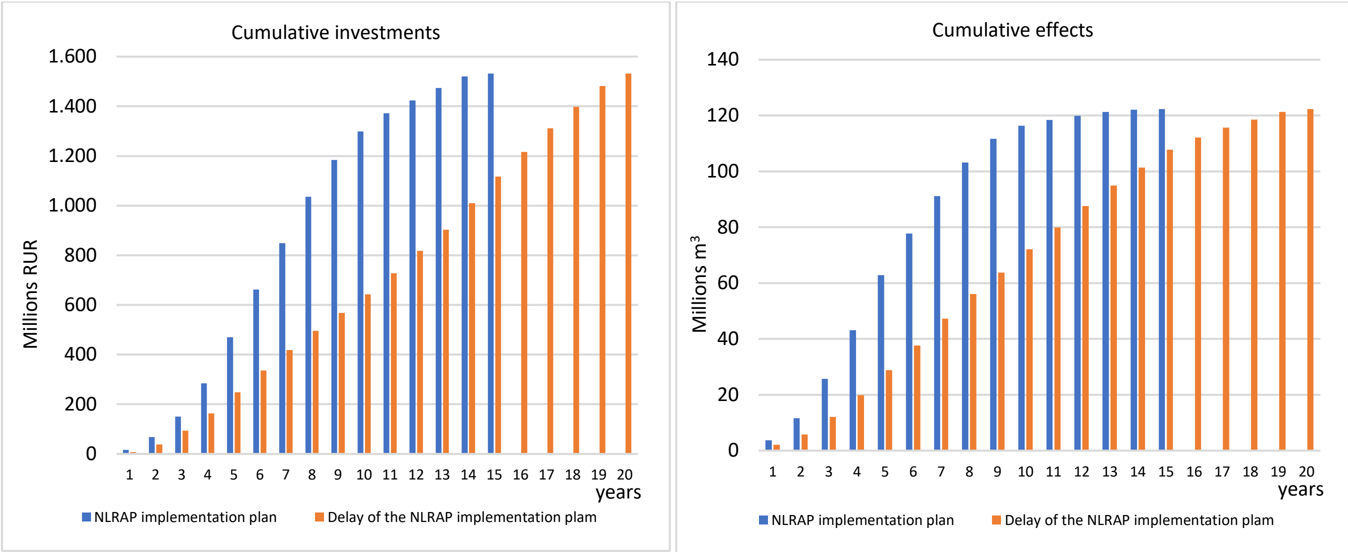

Figure 3.40. Effects of potential delay in the implementation plan

Such unfavorable results definitely have to be prevented with the application of safety mechanisms for the NLRAP implementation, particularly since the reduction of losses is closely related with the basic national objectives in the water sector, and these are the reduction of water losses and increased operational efficiency of PWSPs.

3.5 Analysis and proposal of potential financing sources and co-financing ratios

The reduction of water losses from public water supply systems to acceptable levels along the lines of developed European countries is a permanent mission of the water and wastewater sector in Croatia.

3.5.1 Framework

The potential financing sources will be considered through the framework offered by the European Union and the available and projected funds in Croatia which can be directed at loss reduction measures.

3.5.1.1 European Union

In a recently published report, the European Commission (OECD, 2020[11]) has assessed the capacity of the Member States to cover the investment needs they are now faced with in the water sector, and what will be needed until 2050 in order to achieve and maintain compliance with EU standards. The analysis shows that the average annual costs for water supply and sanitation are estimated at nearly EUR 100 billion in the Member States (EU-27), but with huge variations between the countries. Some countries spend less than EUR 100 per capita per year, while other spend more than EUR 250 per capita per year. According to the projections, all Member States (except Germany) will need to increase their annual expenditure for water supply and sanitation by more than 25%.

The ability to use funds from the European Union today plays an important role for some EU MSs (in particular EU-13[12]), covering up to 17% of the estimated total expenditures for water supply and sanitation. However, it is projected that the EU support through the cohesion funds will decrease in the future, thus additionally increasing the financial gap and intensifying the need to find alternative sources of finance. In that process, the possibility of commercial financing (credits/loans) will have an important role, since it is available in all Member States. So far it has only been marginally used for water-related investment,

[11] https://read.oecd-ilibrary.org/environment/financing-water-supply-sanitation-and-flood-protection_6893cdac-en#page1
[12] EU-13 (Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, and Slovenia).

accounting for approximately 6% of the total expenditures for water supply and sanitation (and only 1% in the latest EU Member States, EU-13), leaving additional room for an increase.

Increasing water tariffs might improve cost recovery and increase the source of income for water suppliers, which is a potential option for many Member States. The OECD analysis shows that in 24 EU Member States, more than 95% of the population could pay more for water supply and sanitation without facing an affordability issue. In accordance with research done by the EC, for the purpose of preparing water projects in Croatia for EU co-financing a little bit stricter (more conservative) approach is used, requiring that the annual price for water services including fees and the VAT shall range between 2.5% and 3% of the average annual household income.

All the aspects of the European water policy are interlinked through the Water Framework Directive, contributing to maintaining or achieving good water quality. It is precisely thanks to the EU policy and financing possibilities that the majority of the people living in Europe have good access to water services, but still not all the people. Through its cohesion policy the EU continuously invests in these objectives, allocating huge amounts for water management that are available to the Member States.

The Cohesion Fund is a primary source of EU investment in the water infrastructure to meet the specific needs of the Member States that benefit from such sources. It helps them meet their basic water needs and supports compliance with the EU acquis in the field of water. The EU's cohesion policy contributes to the availability and safety of drinking water through drinking water treatment plans and development of the water distribution network, particularly in areas where the population has no access to adequate water supply. Such measures should also be supported by measures for improvements in the distribution system by the water service providers, such as leakage reduction or water-saving measures. Water use efficiency helps preserve the available resources, and thus reduce the costs for water users as well. In addition, the cohesion policy supports investing in projects in those European regions that are faced with problems of water scarcity or drought brought about by climate change, projects dealing with wastewater reuse for urban irrigation or other uses, as well as investing in disaster protection projects, primarily flood protection projects. The European Regional Development Fund (ERDF) also provides financing for the infrastructure which provides citizens with the basic water supply services and supports the development of regional potential through small-scale infrastructure.

European funds are awarded within seven-year financial periods or perspectives (Multiannual Financial Framework, MFF). Strict rules are applied to make sure that the money is spent in a transparent and responsible way, with the use of funds constantly monitored. The amount of available funds as well as the definition of activities that can be financed with such funds in different areas of use are defined through Operational Programs.

In order to mitigate economic and social consequences of the new corona virus pandemic, a specific instrument supported by funds has been established at the EU level under the name of "Next Generation EU". Its purpose is to facilitate MSs' faster economic recovery and digital and green transformation for more sustainable development, and improved resilience of the society and economy to future crises. As part of that instrument, a Recovery and Resilience Facility (RRF) has been introduced from which the Member States have, through their own national recovery and resilience plans, been given the possibility to use grants and loans to finance reforms and related investment to speed up recovery and increase economic and social resilience

3.5.1.2 Republic of Croatia

Using water in a sparing and economical way is one of the basic principles of water management. Uneconomical water consumption is the result of very high losses and underestimated (low) price, and partly also the result of illegal connections to the public water supply network. The Stocktaking Report makes it clear that the average water losses in the public water supply network are very high and are estimated at 50%. Such losses are the result of the old age and inadequate maintenance/renewal of the public water supply system. In addition to institutional and administrative capacities (technical and organizational), the efficiency of PWSPs in managing water losses to the greatest extent depends on available financial capacities of each PWSP.

Even though the national water sector has so far for a number of years (through national funds) awarded considerable finances to PWSPs for the preparation and implementation of water and wastewater projects through which PWSPs invested in the improvement of their systems (network reconstruction, rehabilitation, extension, etc.), PWSPs still acted on a limited scale to increase their efficiency through improving the operation of their existing water supply systems in order to reduce losses.

A combined financing model for water services (water and wastewater sector) is in place in Croatia. According to the current financing model, the water and wastewater sector is financed from its own revenues (prices of water services) and to a smaller extent from the budgets of local/regional self-government units (only for special deliveries of water or subsidies to the population with decreased income). Such financing refers exclusively to operation and maintenance costs, while the construction of structures for public water supply and wastewater collection and treatment is to a significant share co-financed from the special-purpose funds at the disposal of Croatian Waters (water fees) and other forms of government subsidies, including EU funds and loans from domestic banks and international financing institutions.

The water fees, which are managed by Croatian Waters, and which can be directed at the implementation of water and wastewater projects are the following: the water usage fee and the water protection fee. The water fee managed by PWSPs is the development fee. These are all public levies paid by the users of water services or water polluters within the overall water price. The funds collected from the water usage and protection fees are the revenue of Croatian Waters and are used based on the principle of solidarity among all the users and on the principle of priority in needs throughout Croatia. The funds collected from development fee are the revenue of PWSPs and have to be used in such a way to ensure balanced development of public water supply and wastewater systems throughout the service area. This fee may be introduced with the same amount in the entire service area or in different amounts in different local self-government units in the service area.

The revenue collected from the water usage fee is used for: collecting and keeping data about water reserves and their usage, monitoring the water reserves and taking measures for their economical usage, water research works, financing the construction of major public water supply structures: water intakes, pumping stations of treatment plants for water intended for human consumption, pumping stations, storage tanks, mains and associated structures of the water supply network, and financing the reconstruction or rehabilitation of public water supply structures for the purpose of reducing water losses. The revenue collected from the water usage fee started increasing significantly in 2013, when the basis for the calculation of the fee was increased to ensure a sufficient amount to finance the national component in the implementation of projects co-financed by the EU funds. The new amendments to the existing system for the calculation and collection of the water usage fee, according to which the obligation to pay the fee is no longer on the end user (consumer), but is rather transferred primarily to the water service provider that will now pay the fee for the abstracted (alternatively supplied to the system) water volume, should encourage water service providers to more economical consumption, but also to improving their own efficiency of the water supply system they manage.

The primary sources of financing for system development (capital investment) are the following:

- EU Structural Funds
  - Cohesion Fund
  - European Regional Development Fund
  - Recovery and Resilience Facility through grants and loans
- Loans from international and national financing institutions
- National mechanisms:
  - Original funds of Croatian Waters
  - State Budget
  - Budgets of local self-government units, PWSPs, etc.

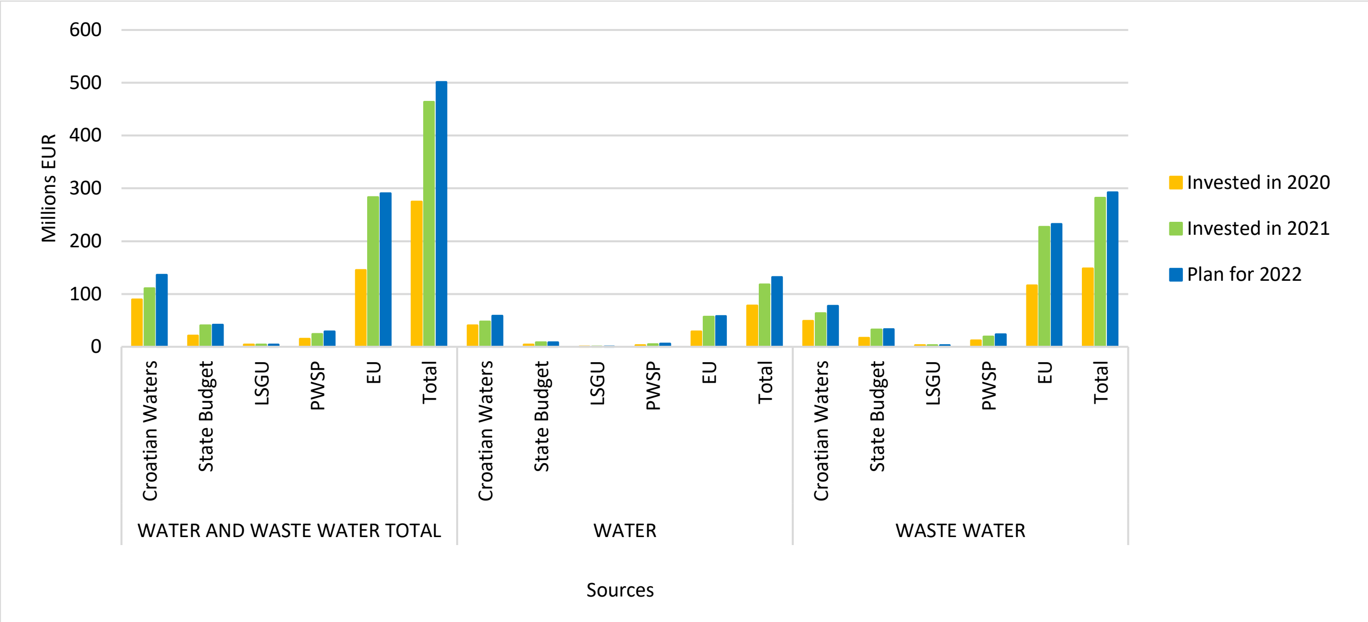

Figure 3.41. Capital investment in the water and wastewater sector over the last three years

Capital expenses in CW's Water Management Plan over the last three years show average investment of EUR 400 million, and they refer to investment in the renewal and development of water supply and wastewater systems. The analysis shows a significant relative increase in investment, with a comparison of the 2020 investments and the 2022 investment plan showing capital expenses increasing by 50 %. The majority of funds for the development of systems come from transfers. PWSPs are currently using funds from the EU's 2014-2020 financial envelope and the National Recovery and Resilience Plan 2021-2026. Investment in water supply systems accounts for a quarter of all investment, an average EUR 100 million per year.

Exceptionally high amounts of required investment to finance the costs of development of the water and wastewater infrastructure largely depend on available financing models which are or will be available over the next 10-15 years. According to estimates from the Multi-Annual Program for Construction of Water and Wastewater Structures for the Period until 2030 (November 2021[13]), the total value of planned investment in the water and wastewater infrastructure amounts to around EUR 6.9 billion, of which nearly a half needs to be channeled into further development of the public water supply infrastructure (EUR 3.4 billion). Around 25 % of such funds is planned to be directed at the reconstruction and rehabilitation of distribution systems and water supply networks, i.e., in the reduction of losses. Financing these costs largely depends on available sources and models of financing which will be available in the said period.

European Union funds

The following funds are currently available to Croatia to cover overall needs for further development of the public water supply infrastructure:

- Funds allocated through the Operational Program Competitiveness and Cohesion 2014-2020 (OPCC 2014-2021);
- Funds allocated through the National Recovery and Resilience Plan 2021-2026 (NRRP 2021-2026);
- Funds allocated through the new MFF 2021-2027

<u>OPCC 2014-2021</u>

In the current programming period MFF 2014-2020, the total financial envelope for Croatia from the Structural Instruments for the water sector projects amounts to EUR 1.27 billion. Of that amount, EUR 1.05 billion (with OPCC modification the amount was reduced to EUR 0.85 billion) is available for water and wastewater projects from the Cohesion Fund, of which around 10% of the funds refers to priority projects for improvement of public water supply systems (system rehabilitation and reconstruction, network extension, construction of pipelines, detecting and repairing leakages to improve system

[13] https://www.voda.hr/sites/default/files/2022-04/visegodisnji_program_gradnje_komunalnih_vodnih_gradevina_za_razdoblje_do_2030._godine.pdf

performance). Priority investment in terms of public water supply implies investment in water supply projects approved under the OPCC 2014-2020, not only as integrated water supply projects, but also as parts of the agglomeration projects. So far, around 220% of the allocation has been awarded for water and wastewater projects. The current rate of implementation is around 90% of the allocation, and it is expected that 100% of the allocated funds will be absorbed by the end of 2023, which is the final year in which the funds allocated from the OPCC 2014-2020 are available.

National Recovery and Resilience Plan 2021-2026

The NRRP 2021-2026 complies with the national strategic documents, as well as European priorities focused on digital and green transition. It includes reforms and investment to be implemented at the latest by 30 June 2026. Investment in water and wastewater infrastructure is covered through the implementation of the Water Management Program and contributes, among other things, to ensuring availability of safe water for human consumption to the population (in particular in rural and mountainous regions and regions at a demographic risk, through priority smaller investment in the construction/reconstruction of public water supply systems throughout Croatia) and to the reduction of losses in water supply systems. An integral part of the NRRP is the implementation of an overall reform in the sector of water services to strengthen implementation and investment capacities, and financial and technical self-sustainability of public water service providers. The objective is to establish a functional and permanently sustainable system following the completion of investment, and that the price of water services is affordable to the population. A EUR 0.7 billion grant is available within the NRRP for the implementation of the Water Management Program, of which EUR 0.54 billion is intended for investment in the water and wastewater sector. From the total allocation, a EUR 0.14 billion grant is provided for the Public Water Supply Development Program with the aim of providing access to safe and accessible drinking water.

Taking into account the above-mentioned currently available sources of financing for the public water supply projects (OPCC 2014-2020, NRRP 2021-2026, and national funds), it is estimated that for the overall investment in the water and wastewater sector there will be a significant gap in the funds to implement the planned projects in the total value of around EUR 6 billion until the year 2030.

MFF 2021-2027

Since we are now at the beginning of the EU's new financial period 2021-2027, the EU budget envelope is the biggest so far, amounting to EUR 1,824.3 billion, with more than EUR 25 billion in current prices available to Croatia. Financing is provided from the European Regional Development Fund and the Cohesion Fund. As a continuation of the current financial period 2014-2020, investment in the water sector projects will be implemented through the Operational Program Competitiveness and Cohesion 2021-2027 (PCC 2021-2027). PCC 2021-2027 is in the water sector part still directed at achieving the greener and more resilient Europe objectives which will contribute to quality and sustainable water management. Among other things, investment priorities have been defined for the reduction of losses in water supply networks and increasing the capacities of users for the purpose of long-term sector sustainability, which enables further investment from EU grants to finance the priority development of the water sector, particularly when it comes to public water supply and compliance with EU requirements. The MFF 2021-2027 allocation which is available for investment in projects concerning the improvement of the water and wastewater systems amounts to EUR 695 million, of which EUR 56.6 million is provided for investment in the reduction of water losses in public water supply systems, while EUR 160.4 million is provided for investment in the improvement of public water supply systems.

Availability of funds

In addition to the EU funds provided through the OPCC 2014-2020 and the NRRP 2021-2026 and the allocation awarded for the MFF 2021-2027, when calculating and defining the total available funds for the required investment in the water sector account needs to be taken of the relevant national co-financing component.

It needs to be pointed out that the implementation of projects through the OPCC 2014-2020 is particularly demanding in terms of financing and implementation. Trends have been observed of increasing amounts of tenders for construction works received in public procurement procedures compared to the estimated values for projects approved within the OPCC (which eventually exceeds the available grants). Considering the status of implementation of the contracted projects, it is expected that the funds allocated for the implementation of water and wastewater projects will be fully absorbed. Part of the projects end by the end of 2023, part of the initiated projects are planned to be completed using national funds during 2024, while part of the initiated projects which won't be completed in the current programming period are planned to continue being financed within the new programming period 2021-2027. Such an approach additionally burdens the allocation available for the new financial period 2021-2027, within which continued investment in the water sector (priority projects in terms of the objectives of the new PCC) should be ensured.

The projects approved within the NRRP have to be completed by the end of the eligibility period (June 2026).

However, despite everything mentioned above, large financial grants will not be sufficient to meet all investment needs in the water sector. This points to the conclusion that long-term financing conditions should be looked for on the market of investment development loans which offer a lower interest rate, a longer loan servicing period, a grace period adjusted to the planned construction period, and the maturity of instalments/annuities adjusted to the dynamic and method of collection of funds. In doing so, account needs to be taken of the fact that loan financing implies an increase in total expenditures due to additional financing costs.

3.5.2 Financial plan of the NLRAP

With regard to the dynamics and intensity of investment, the text below presents a preliminary analysis of potential sources of financing and closing of the financing scheme, as well as the impact of financing sources on the overall price of water services and on affordability (Chapter 3.6).

Figure 3.42. presents the structure and intensity of investment by years. The total projected investment value of the measures is EUR 1,581,950,000. According to the presented dynamics, the highest investment intensity is expected in the 2025-2030 period. According to the investment dynamics, a total of 90% of the identified measures by investment strength have to be implemented by the year 2033. It is precisely in that period that the most significant funds will have to be provided to close the overall financing scheme

Figure 3.42. Investment structure and intensity by investment years

Chapter 3.5.1. presents the grant funds currently available in the water and wastewater sector. In recent years Croatia has been a significant net beneficiary of funds from the joint EU budget, with the allocated funds setting in motion a strong investment cycle in the environmental sector. Projects in the water and wastewater sector are capital-wise highly intensive projects, and due to the financial capacities of PWSPs but also of local-self-government units as their owners it is not realistic to expect significant amounts of their own funds in financing the identified measures. The financial model has used the current approach, with PWSPs participating with around 8-10% in the total investment for major water and wastewater projects.

The analysis of financing sources is focused on ensuring the maximum possible amount of available international and national grants and on defining the financial gap, i.e., a preliminary calculation of the missing funds to close the financing scheme for the proposed measures and activities. This is presented inFigure 3.43.

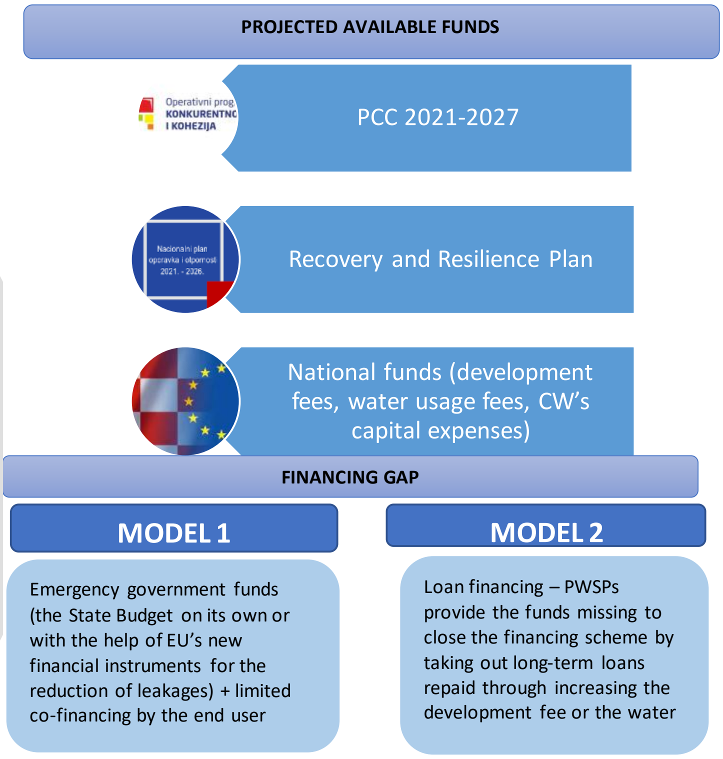

Figure 3.43. Projection of potential sources of financing of the NLRAP

The above defined projection of the potential sources of financing shows the structure of available sources of funds, based on which the financial gap is calculated, i.e., the amount which will have to be additionally provided in order to implement the identified measures. The first step is the identification of potential available sources of financing. According to analyses made, the highest grant amounts are expected from the currently allocated funds from the MFF and future financial envelopes.

According to the table below, the following results were obtained:

- PCC 2021-2027 – a projection has been made of the allocation of the whole MFF for the water loss projects;
- Recovery and Resilience Plan – with regard to the currently active projects and projects in the contracting phase, an estimate has been made of what part of the identified measures is financed through the Plan;
- National fees – with regard to the calculated fees, a projection of the fees in the 15-year period of the Plan's implementation has been made, estimating that 10% of the amount will be allocated to water losses;
- NEW MFFs – with regard to the period of the Plan's implementation and overlapping of EU's several multi-annual financial frameworks, a projection has been made that in the 2030-2038 period a total of EUR 200 million will be allocated for the water loss reduction measures.

<u>According to the preliminary analysis of availability, the total projected available funds amount to EUR 676,000,000, and the financial gap amounts to a total of EUR – 905,950,000 or -57% of the total projected investment value of the measures.</u>

Due to a high percentage of the financial gap, two models are proposed:

- MODEL 1: Emergency government funds and limited funds of the end users
MODEL 2: Loan financing (IFI loans as a more favorable option or loans from commercial banks) through charging the future water price or through increasing the development fee

The results of both models are presented in Table 3.14.

Table 3.14. Projection of available and missing funds to implement the identified measures

<table>
<tr><th colspan="2">Source of financing</th><th>Period of funds use</th><th>Amount (EUR)</th><th>Assumptions</th></tr>
<tr><td colspan="2">PCC 2021-2027</td><td>2024 - 2030</td><td>100,000,000</td><td>It is estimated that of the total allocated amount EUR 100 million will be allocated for the measures identified in the NLRAP</td></tr>
<tr><td colspan="2">Recovery and Resilience Plan</td><td>2022 - 2026</td><td>80,000,000</td><td>It is estimated that of the total allocated amount EUR 80 million will be allocated for the measures identified in the NLRAP</td></tr>
<tr><td colspan="2">Water usage fee</td><td>Throughout the Plan implementation period</td><td>200,000,000</td><td>It is estimated that 10 % of the calculated water usage fee will (in the NLRAP implementation period) be allocated for the measures from the NLRAP</td></tr>
<tr><td colspan="2">Development fees</td><td>Throughout the Plan implementation period</td><td>96,000,000</td><td>It is estimated that the existing development fee tariffs will be retained, and that 10 % of the calculated water supply development fee will (in the NLRAP implementation period) be allocated for the measures from the NLRAP</td></tr>
<tr><td colspan="2">FUTURE MFFs</td><td>2030 - 2038</td><td>200,000,000</td><td>It is estimated that through two future financial periods (future MFFs continuing on the current MFFs) EUR 200 million will be allocated for the measures from the NLRAP</td></tr>
<tr><td colspan="2">Total projected availability</td><td></td><td>676,000,000</td><td></td></tr>
<tr><td colspan="2">Financial gap (EUR)</td><td></td><td>905,950,000</td><td></td></tr>
<tr><td colspan="2">Financial gap (%)</td><td></td><td></td><td>57%</td></tr>
<tr><td colspan="5">Potential gap financing models</td></tr>
<tr><td rowspan="2">Model 1</td><td>Emergency government funds (the State Budget on its own or with the help of EU's new financial instruments for the reduction of leakages)</td><td>13 years</td><td>785,950,000</td><td>The model transfers part of the financing on the government through financial assistance or long-term credit arrangements with international institutions – no impact on the price of water</td></tr>
<tr><td>PWSPs taking part through the development fee</td><td>13 years</td><td>120,000,000</td><td>15.3% of the gap (or 8% of the total investment) – has an impact on the price of water, on average EUR 0.1 per m^3 in Croatia at the expense of introducing the new development fee</td></tr>
<tr><td>Model 2</td><td>The gap is financed exclusively through the price of the water service</td><td>13 years</td><td>905,000,000</td><td>The model foresees an impact of average EUR 0.26 per m^3 of water over a period of 15 years at the expense of the new development fee – has an impact on the affordability of the price of water service</td></tr>
</table>

The elements burdening the water price (increased development fees) presented in the table above refer to the increase calculated in relation to the missing investment amounts. However, the effects of implementing the measures have a positive impact on operating costs (average reduction of EUR 0.02 per m^3), which will be reflected on the incremental part of the total water price, to be presented in Chapter 3.6.

In light of the results of analysis of potential sources of financing, the simulation of projected use of specific sources of financing according to the dynamics of implementation of individual measures is presented below. The projection presents the time dynamics of the gap (regardless of whether Model 1 or 2 is applied). The projection shows that the biggest gap between the available projected sources of financing and the investment dynamics occurs in the 2027-2033 period, when according to the plan the most significant investment potential is expected, when emergency government funds will have to be provided through one of the proposed models.

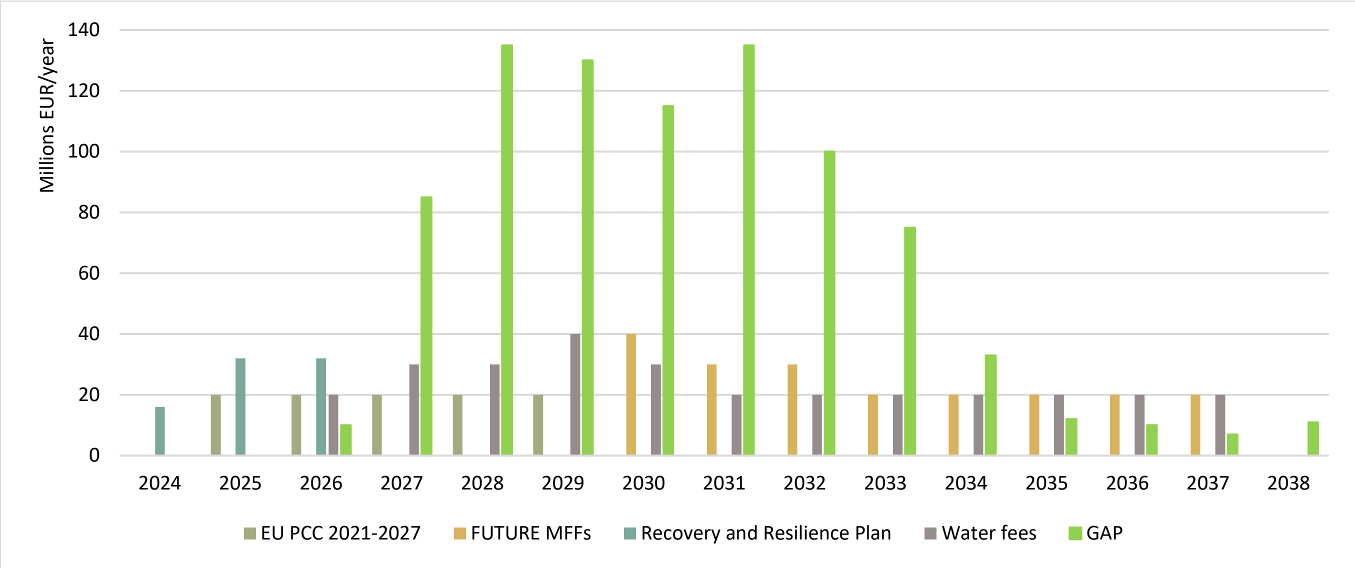

Figure 3.44. Projections of potential sources of financing by years

Also, from the analyses one can conclude that the initial years of the NLRAP have funds allocated in the existing Operational Programs, which is a positive thing from the aspect of initiating certain measures and providing sufficient time to define the final model of filling the financial gap in the financing scheme.

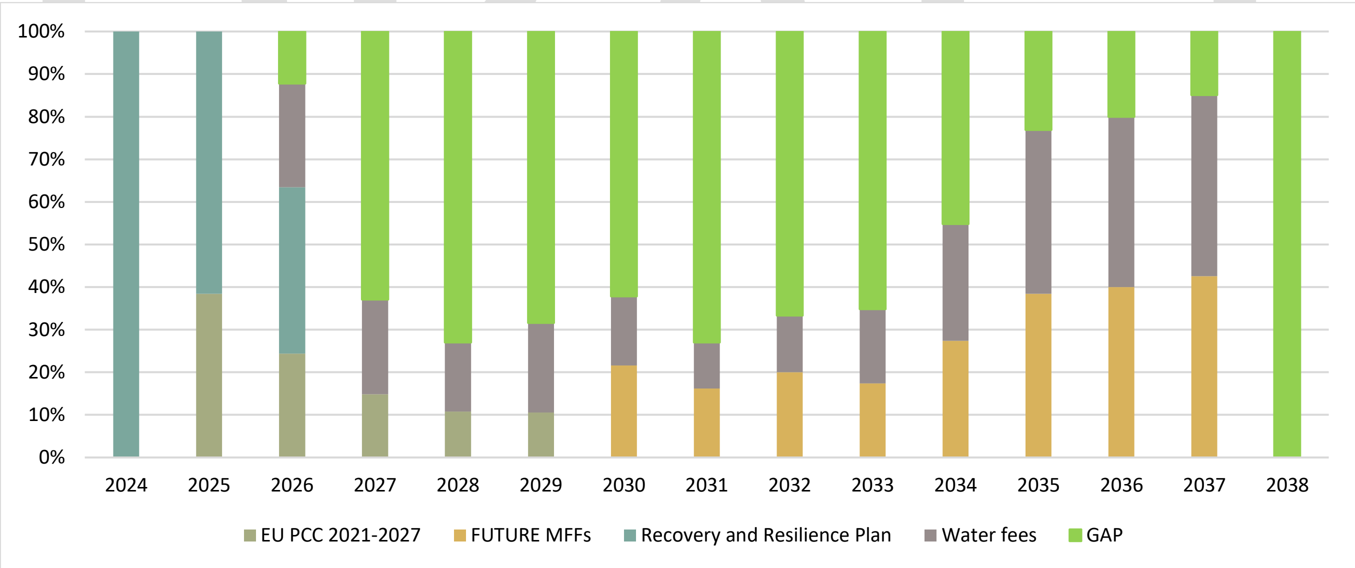

Figure 3.45. Projections of potential sources of financing by years in %

The final financing model will significantly depend on the effect on the total price of water service and the affordability of the water service for end users.

3.6 Effect on the price of water and affordability in the context of required measures and activities

The NLRAP foresees investment in the total amount of EUR 1,581,950,000 over a period of 15 years. Intervention measures will have an impact on the total NRW reduction of 122,277,538 m3 of NRW per year. The schedule of investment by service area with effects is presented in the chart below. The total amount of the measures (I-X) implemented within PWSPs is EUR 1,533,330,000, which also includes technical assistance in the amount of EUR 45,960,000, and MESD's measures in the amount of EUR 2,660,000. The lowest investment is foreseen in service area 41 (EUR 6,299,976), while the highest intensity is foreseen in service area 11 (EUR 228,094,105).

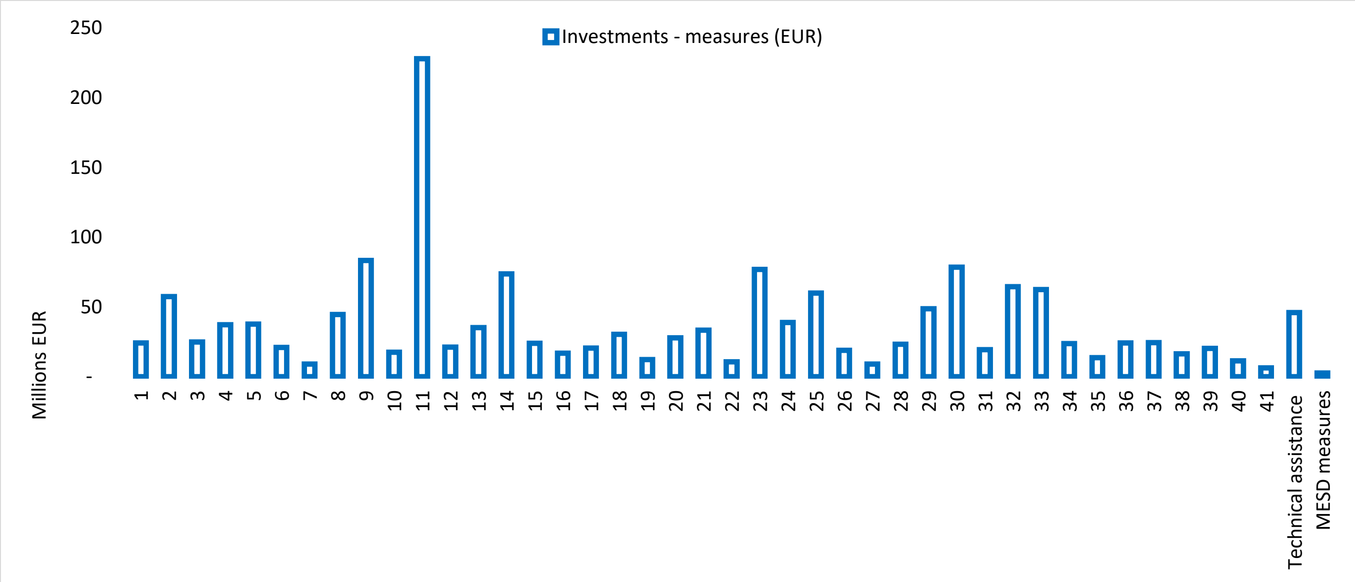

Figure 3.46. Investments and investment effects by service areas (EUR/year, m3/year)

The implementation of the defined measures and activities will result in the correction of the price of water supply and the correction of the total amount of the water usage fee. The intention of the NLRAP financial plan is to, based on the results of the analysis of current state that identified the issue of achieving full coverage of the water service price, check the level of correction of prices of water services and impact on overall affordability.

The implementation of the NLRAP measures and activities will directly affect the prices of water services:

- Price of the water service, and
- Amount of the water usage fee

The price of water services is analyzed in the Plan based on the current prices in PWSP's service areas and the current prices in 41 new service areas (SA) (see the figure below). In addition to the price of water services, the current analysis of affordability on the level of PWSPs and service areas is also shown.

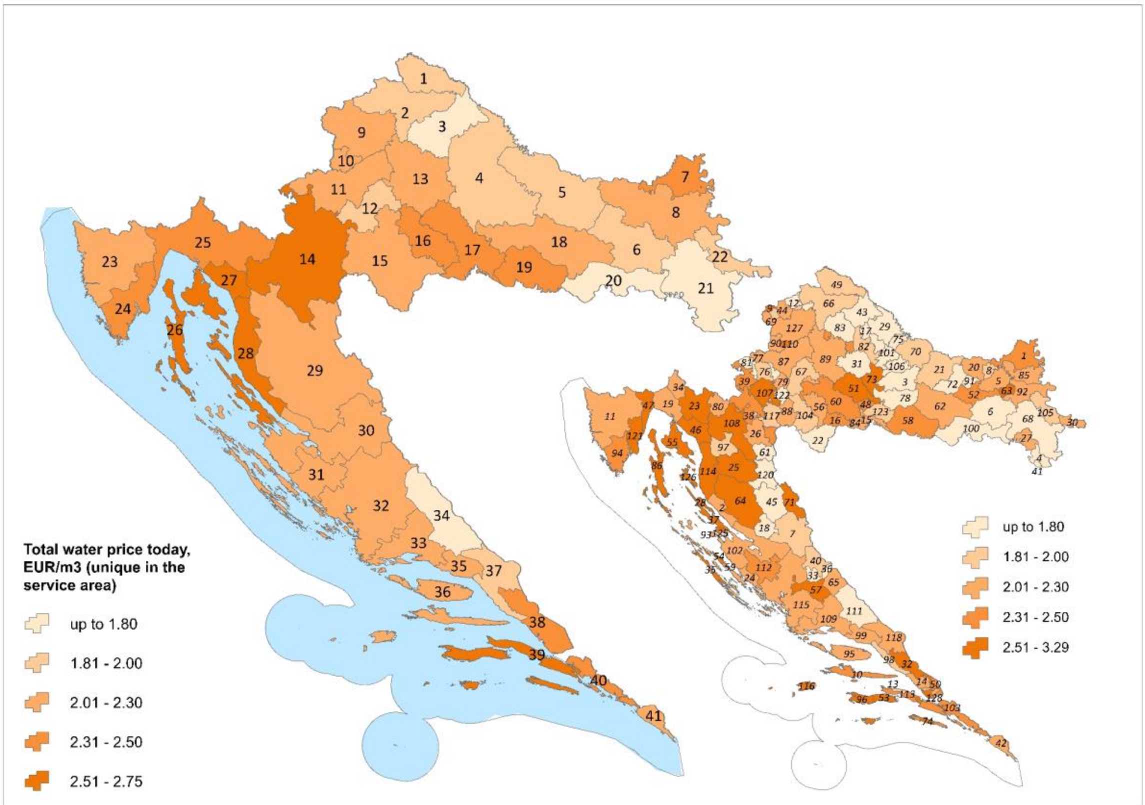

Figure 3.47. Current price of water services on the level of PWSPs and service areas (EUR/m3)

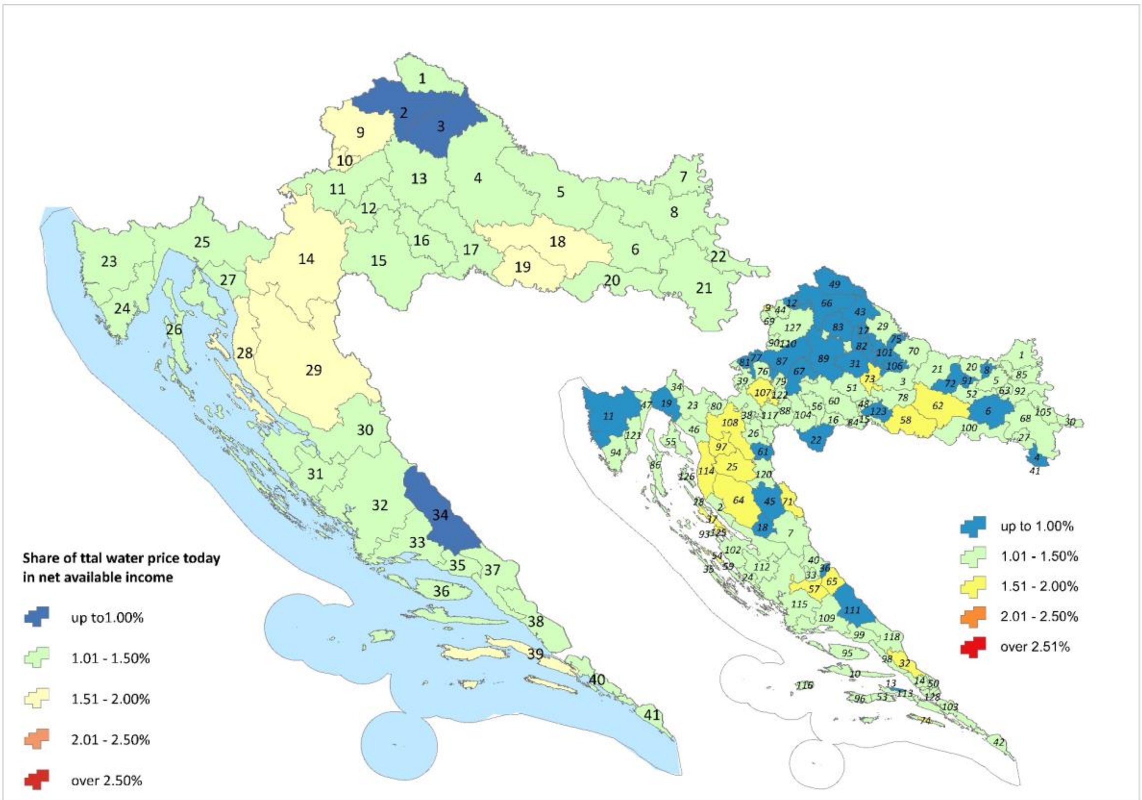

Figure 3.48. Current affordability on the level of PWSPs and SAs (%)

The investment dynamics will have a significant role in the formation of future prices and impacts on the prices of water services. According to the analysis made, it is clear that the highest investment is expected in the medium term of the Plan's implementation (from the 5th to the 10th year). Looking at cumulative investment, more than 85% of the investment is achieved until the 10th year of the implementation of measures (2033).

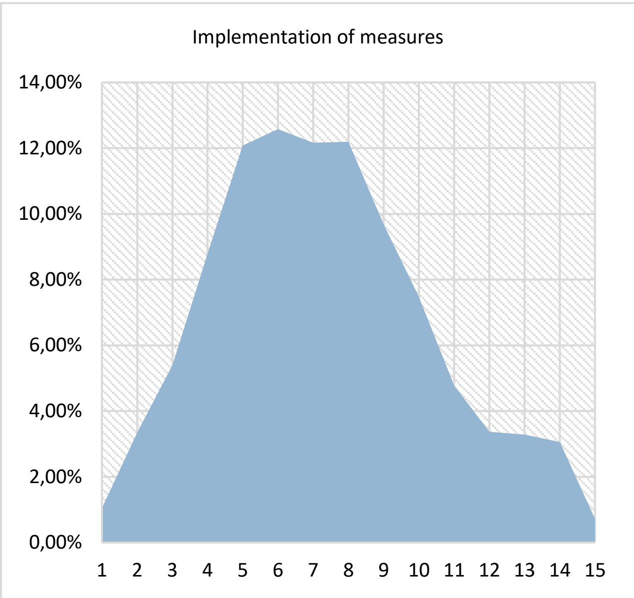

Figure 3.49. Implementation of measures by years %

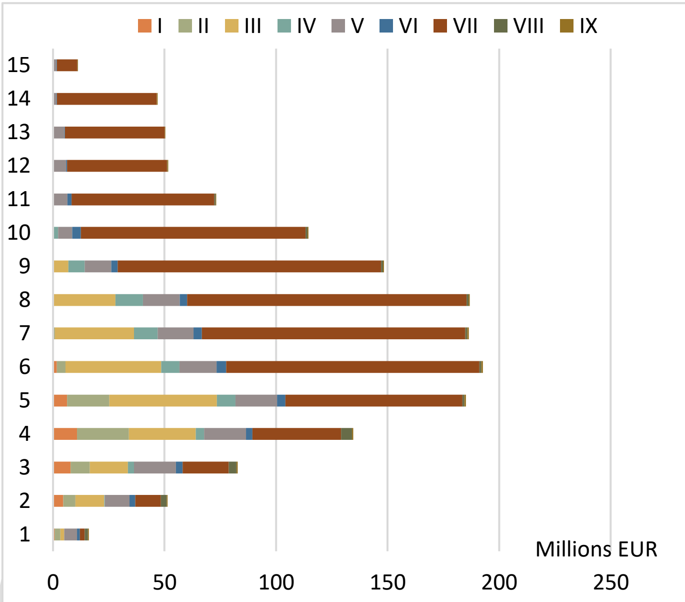

Figure 3.50. Implementation of measures by years, EUR

The investment dynamics is directly related to the dynamics of achieving the effects of defined measures and activities. Looking at cumulative effects, 90 % of the effects of measures is achieved until the year 2033.

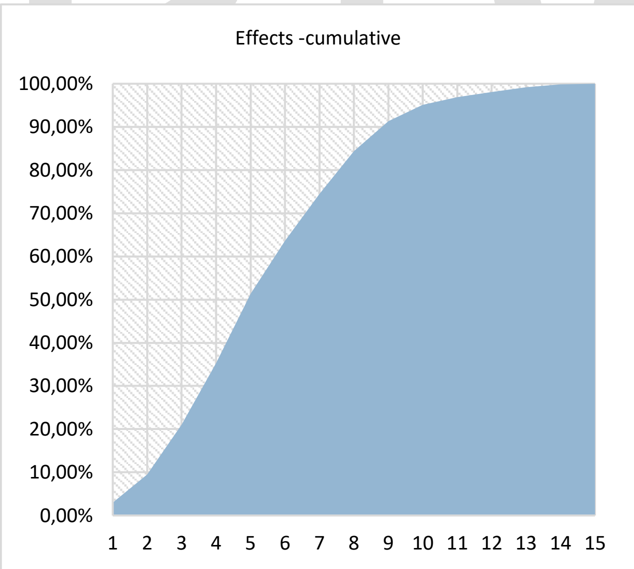

Figure 3.51. Cumulative effects of measures %

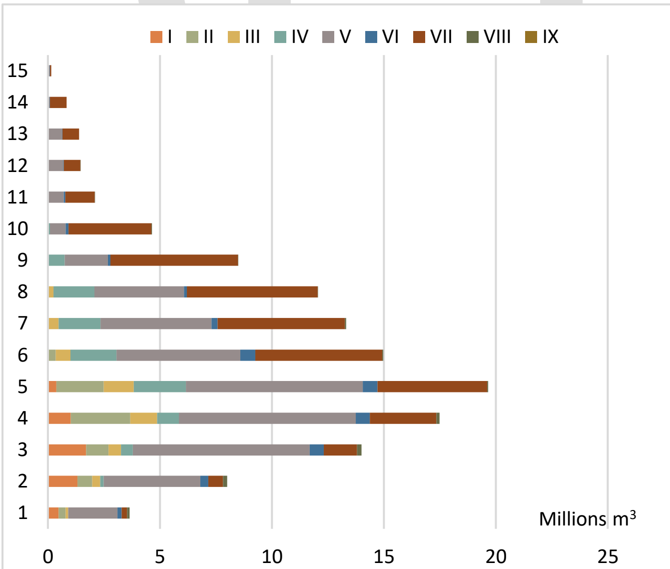

Figure 3.52. Effects of measures by years (m3)

Due to the investment dynamics and the dynamics of achieving the investment effects presented above, in the financial plans the results are considered through the prism of the water usage fee and the price of water supply. The dynamics was used to define the milestone years when more significant impacts on the price of water service are expected:

- Water usage fee:
  - the year 2022 – current state
  - the year 2023 – implementation of the new calculation of the water usage fee
  - the year 2033 – effects of NRW reduction

- Price of water supply:
  - the year 2022 – current state
  - the year 2033 – effects of NRW reduction
  - the year 2038 – full effects of the NLRAP

The investments are reflected in the price of the water service through the calculated depreciation and through co-financing by the end users.

The issue of calculated depreciation is defined as one of the major problems in fulfilling the principle of full cost recovery and in ensuring long-term financial sustainability of PWSPs' performance. For that reason, the financial model includes the calculated depreciation in the amount of 100% after the implementation of measures. The average impact of depreciation on the price is EUR 0.11 per m3 in the first phase of implementation of the NLRAP (2033), with the said amount referring to the depreciation calculated from the implementation of the identified measures.

After the completion of implementation of measures, additional inclusion of depreciation of the existing assets that currently isn't calculated is analyzed in order to achieve long-term financial sustainability of performance and to simulate impact on the affordability of the water service. This was simulated after the year 2038 when the Plan's implementation phase ends. The average impact of additional depreciation on the price is EUR 0.12 per m3.

Another significant component of the price of water service are operation and maintenance costs of the existing and future assets, in particular under the impact of inflationary pressures characteristic for the energy sector, which presents a major problem in the future performance of PWSPs. A projection of incremental operation and maintenance costs has been made respecting the effects of measures on the total volumes of abstracted water. The average impact of operation and maintenance costs is EUR – 0.02 per m3. This illustrates a positive impact on the price of water services, i.e., the reduction of overall maintenance costs due to lower costs of abstraction. The total estimated reduced costs of water abstraction (energy costs) amount to around EUR 10 million per year.

In addition to the impact on the price of water supply, the reduction of losses will also impact the correction of the amount of the water usage fee. According to the water balance, the fee of around EUR 92 million is calculated today. By implementing the new method of calculation, the amount rises to EUR 97.5 million. With the implementation of measures and activities the amount is reduced to EUR 90.8 million. The introduction of the fee results in the correction of the price calculation and has an impact on the affordability of water services. The fee in the service area increases in total by EUR 0.02 per m3 on average, with a limited effect on affordability.

The selected model of co-financing the measures also has effects on the price of water and affordability.

Model 1 presents a combination of co-financing that has a lower effect on the correction of the price of water services. With regard to the limitations in the price of water service, affordability, and financial capacities of PWSPs, Model 1 considers co-financing by the PWSP in the amount of 8% on the project level and 15% of the gap, which is an average co-financing rate used in the water and wastewater projects co-financed by the EU in recent years.

Model 2 is reflected in additional costs of co-financing the implementation of the defined measures. According to the calculation of the financial gap in the preceding chapter, Model 2 includes the co-financing of the whole gap through long-term credit arrangements which will be repaid through increasing the development fee or through increasing the existing price of water services.

With regard to the presented methodology for the calculation of effects of implementation of the measures and activities identified within the NLRAP, an estimate was made of the impact of the measures and activities on the total water price on the one hand and the impact on affordability on the other hand. The results are presented based on the two potential models and include the presentation of the current price of water services, the impact of implementation of the new Regulation (2023), the total price in 2033 when a significant impact of the measures identified in the Plan is expected, and the total price in 2038 as the last year of the Plan's implementation.

The charts below present the impact of implementing the Plan according to the presented **Model 1** on the total price of water services and on the affordability of the service for the end users.

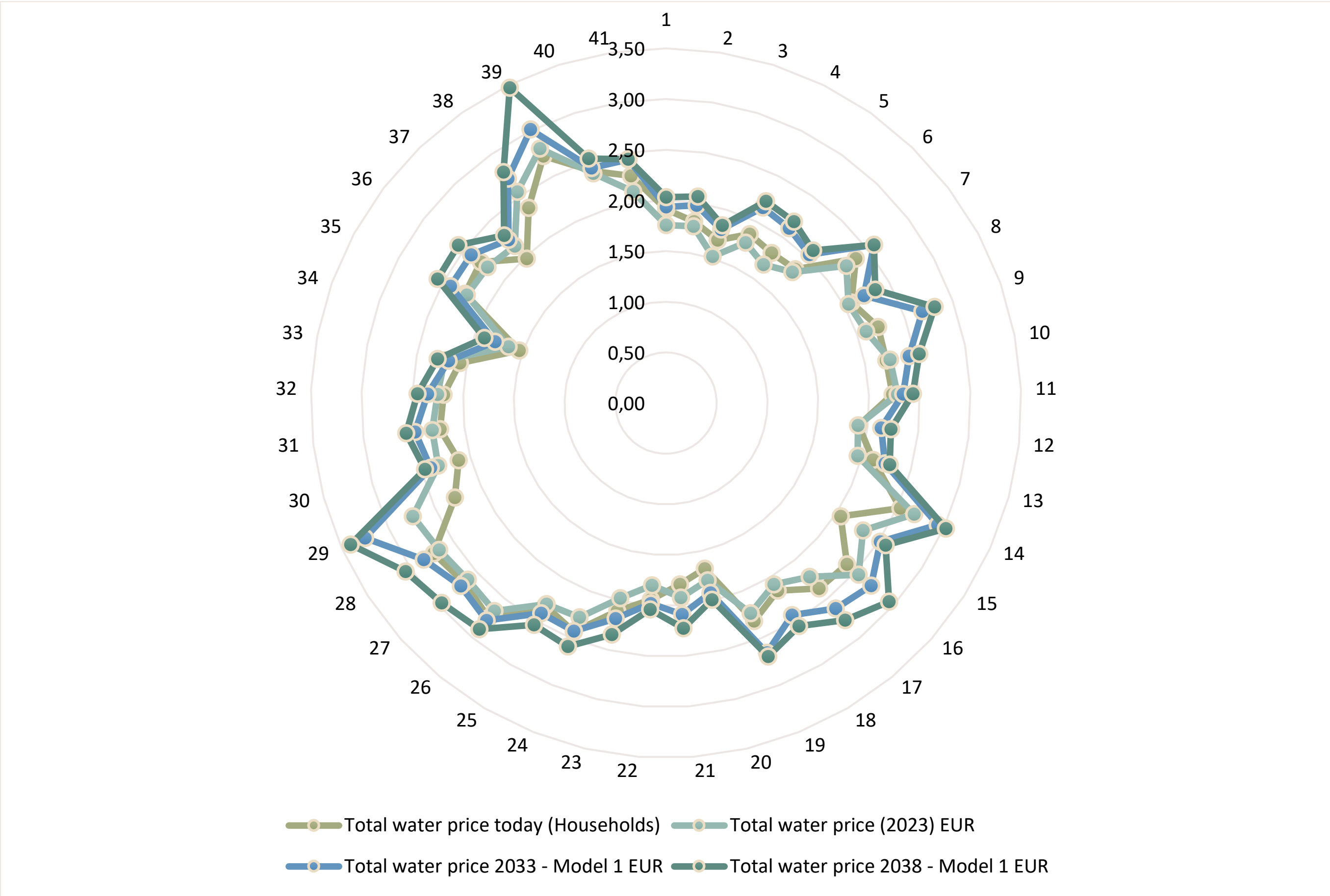

Figure 3.53. Impact of measures on the price of water services (EUR/m3), Model 1

The correction of the price of water service has an impact on the affordability of water service, too. The chart below presents the affordability of the water service according to the price correction due to the implementation of the identified measures and activities. It is visible that the implementation of measures doesn't significantly affect the affordability of water services, but it is important to note that besides the identified measures, numerous projects are in implementation across Croatia, particularly in the sector of wastewater collection and treatment, which will significantly affect the overall affordability of the service. The chart below shows that the affordability issue occurs in areas with a lower level of development.

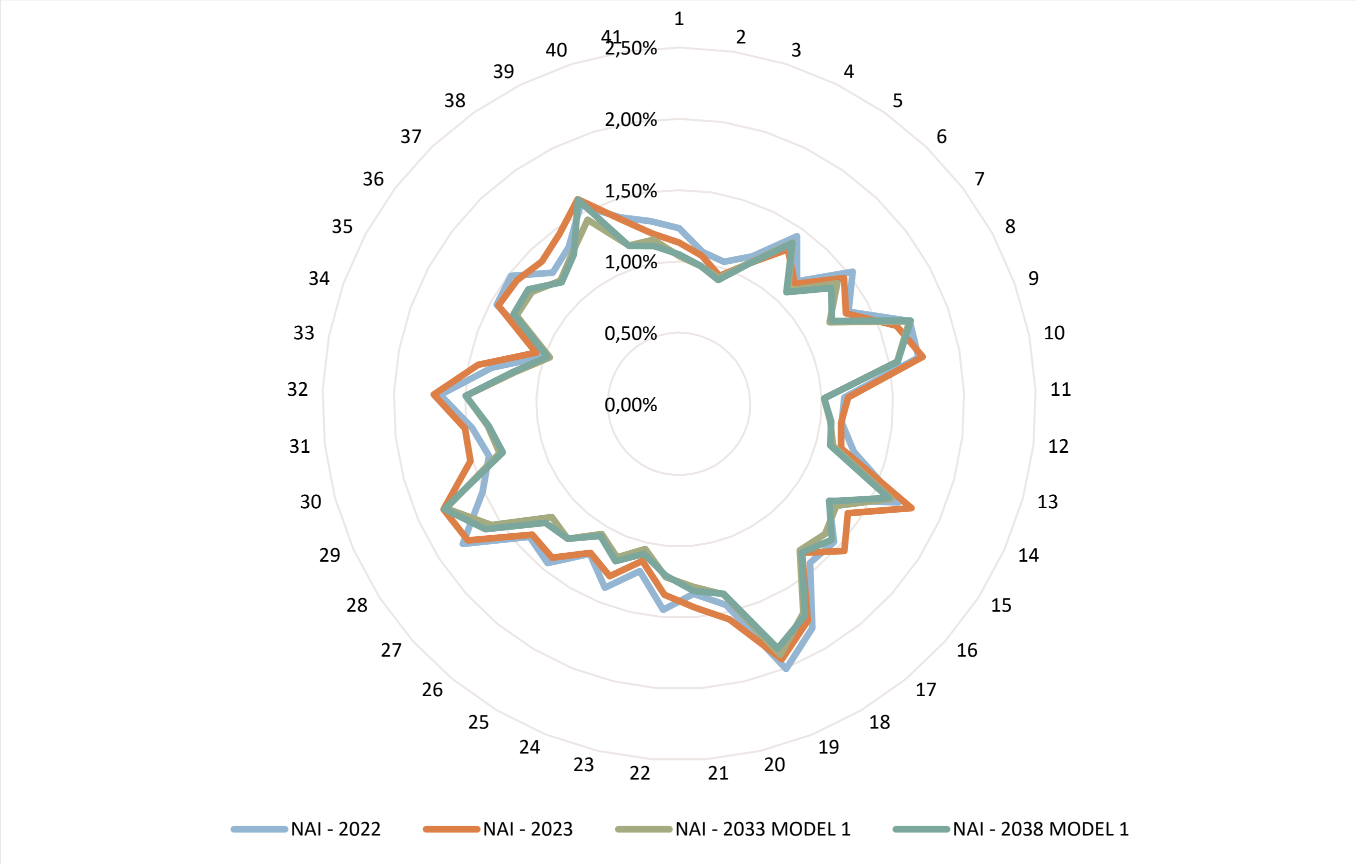

Figure 3.54. Impact of measures on affordability (%), Model 1

If **Model 2** is selected as a means to close the financing scheme, the impact on the price of the water service is more considerable, i.e., the share that is not covered by the grants is fully co-financed through the price of the water supply service or through the development fee, which has implications on the affordability of the water service. According to the presented methodological basis, the results of Model 2 on the total price of water services and on affordability are presented below. Just like the first model, it presents the critical years, the current price of water services, the impact of implementation of the new Regulation (2023), the total price in 2033 when a significant impact of the measures identified in the Plan is expected, and the total price in 2038 as the last year of the Plan's implementation.

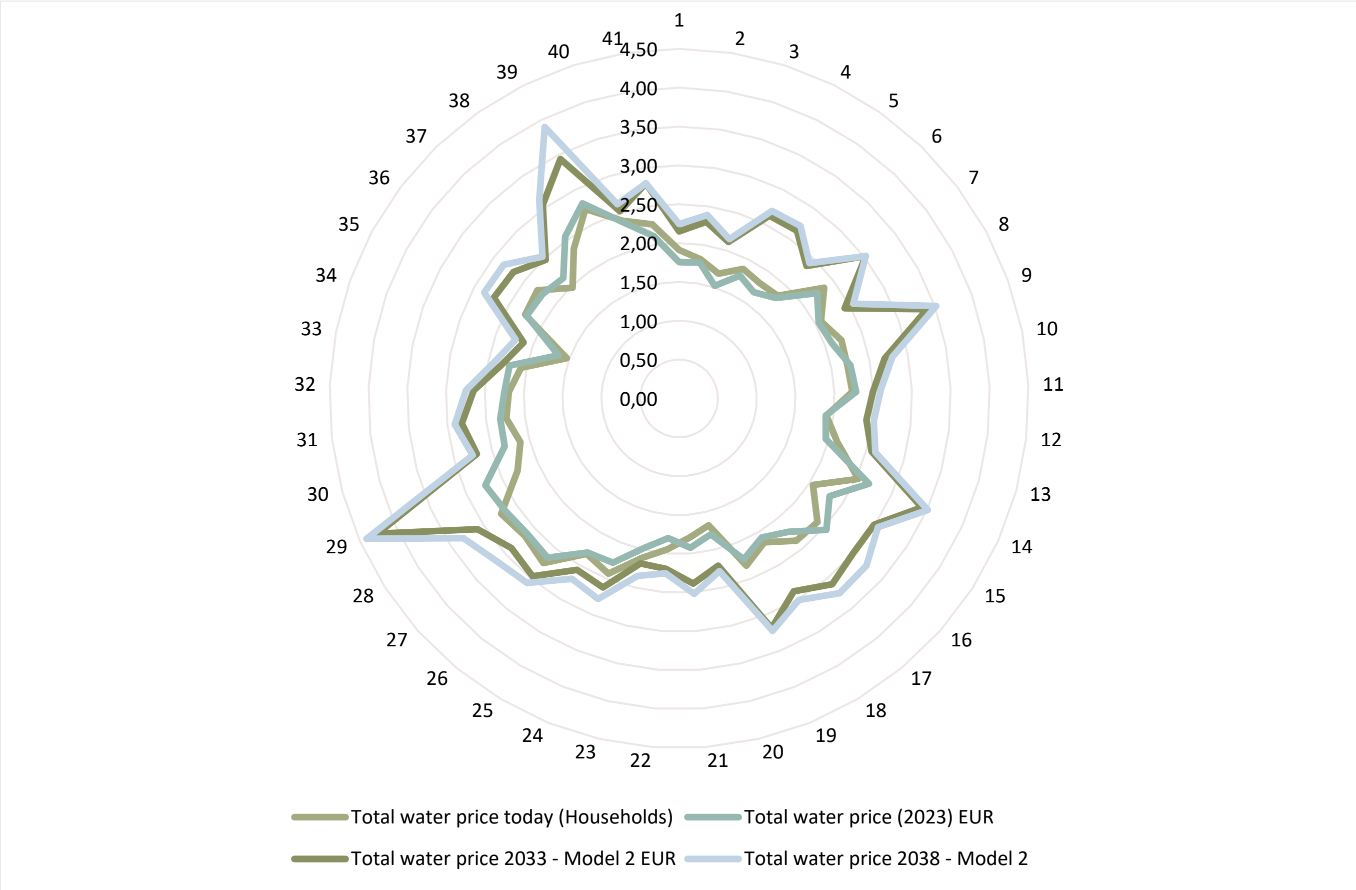

Figure 3.55. Impact of measures on the price of water services (EUR/m3), Model 2

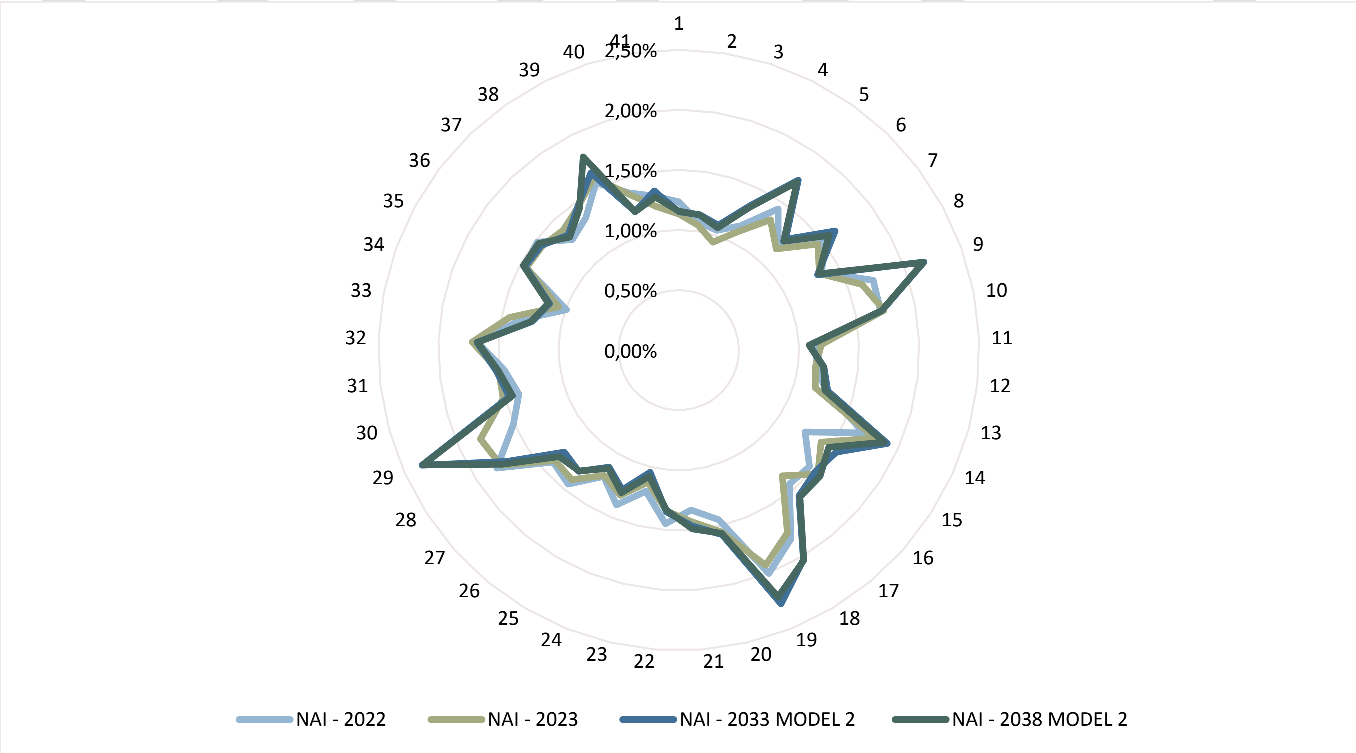

Figure 3.56. Impact of measures on affordability (%), Model 2

The differences between the selected models are reflected primarily in the selected co-financing model. Comparing the results of Model 1 and Model 2 for the price of water and affordability, Model 1 presents a more favorable model for end users from the aspect of burdening the average income with the price of the water service. The differences between the models are also presented on the chart below. The chart presents the average price of the water service (EUR/m3) in the service areas according to Model 1 and Model 2 in the reference year 2033 when significant effects of the identified measures are expected.

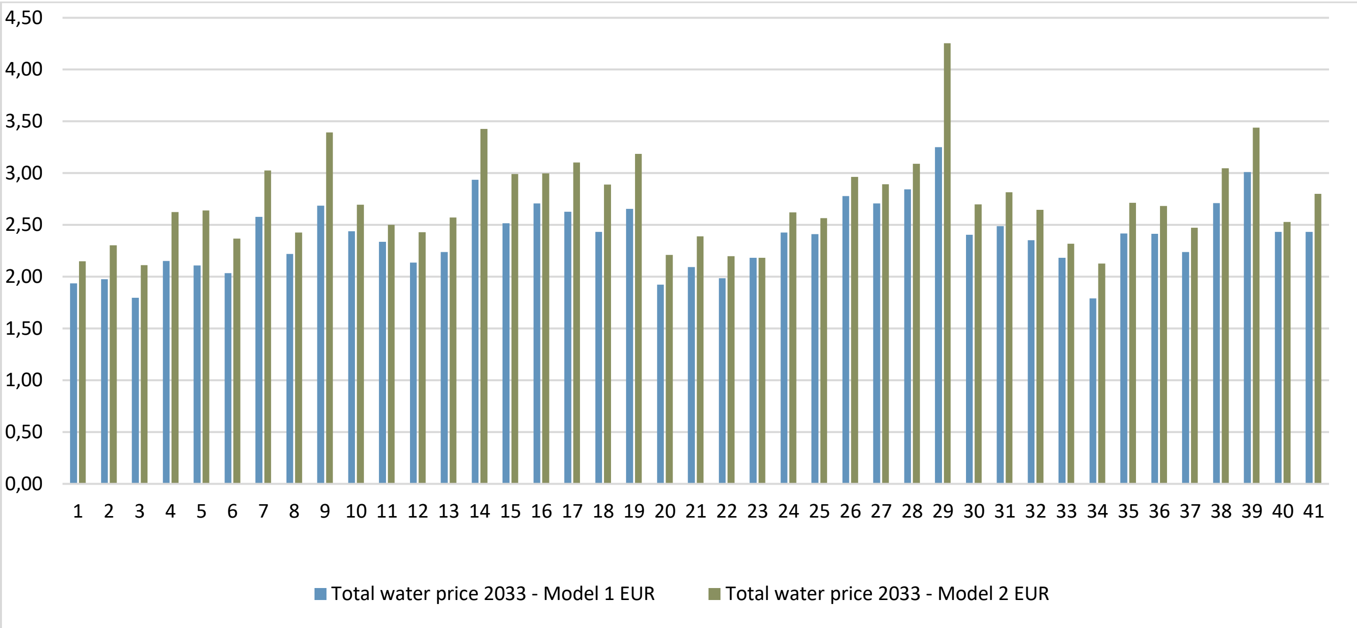

Figure 3.57. Comparison of total prices of water services in 2033 according to the selected model by service areas (EUR/m3)

Different models have different impacts on the share of the water service price in affordability. The chart below presents the analysis of the net available income (NAI) for Model 1 and Model 2 for the reference year when significant effects of the implementation of the measures and activities identified in the Plan are expected.

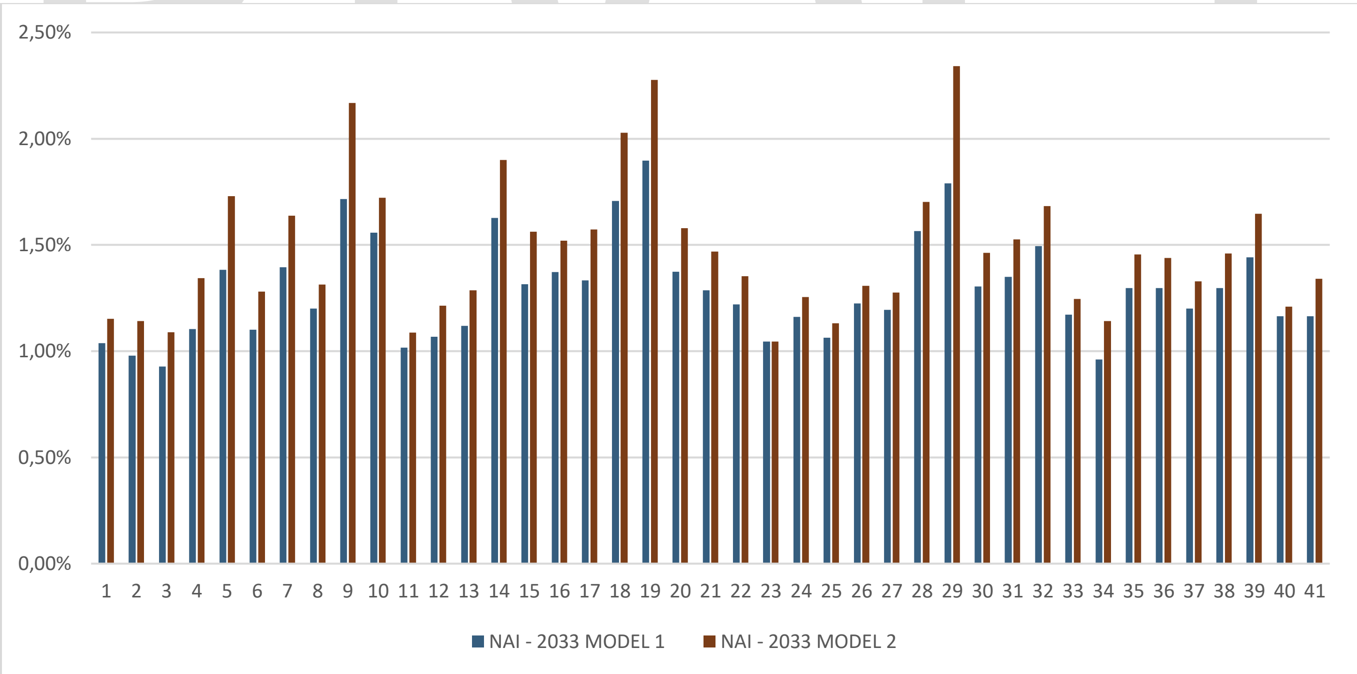

Figure 3.58. Comparison of affordability rates of total price of water services in 2033 according to the selected model by service areas(%)

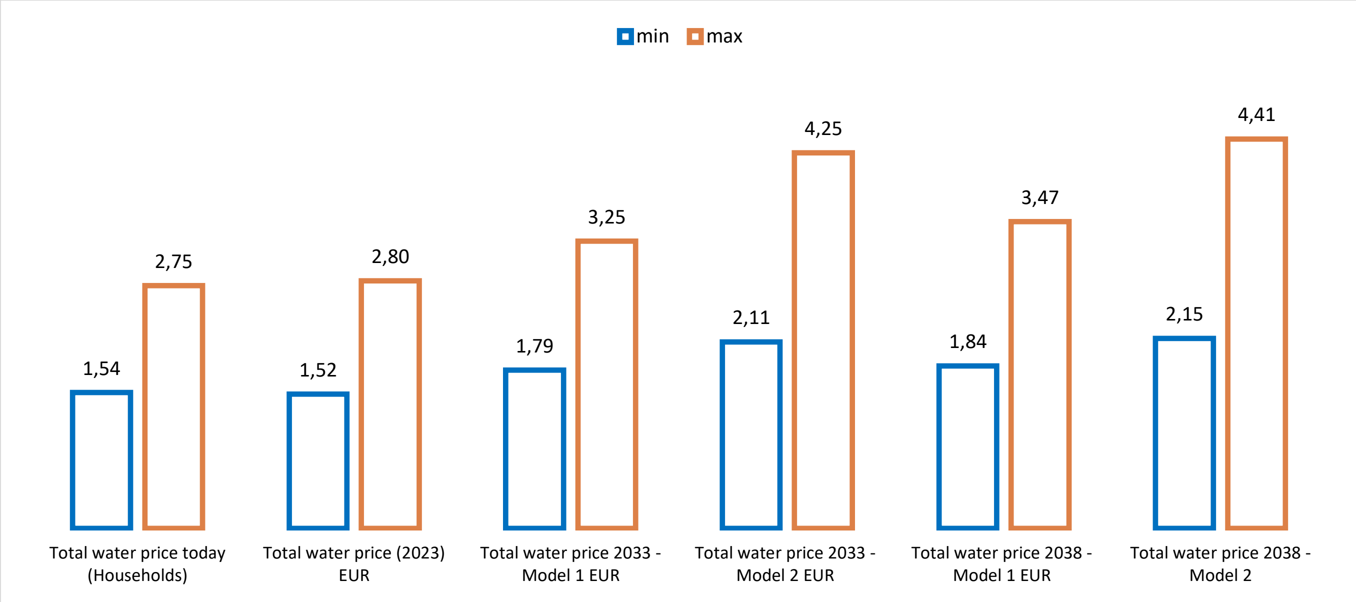

Figure 3.59. Minimum and maximum price of water service arising in service areas with regard to the selected model (EUR/m3)

Analyzing the maximum and minimum projected prices of water service one can see big regional differences. Currently the highest average price is in SA 38, while with the implementation of the measures the highest price of water services is recorded in service area 29 (area of Lika-Senj County) in both Model 1 and Model 2. The currently lowest average price in a service area is recorded in service area 34, while with the implementation of the measures the lowest price will also be in service area 34. With regard to different impacts on the price of water services, the analysis of maximum and minimum service affordability is presented below.

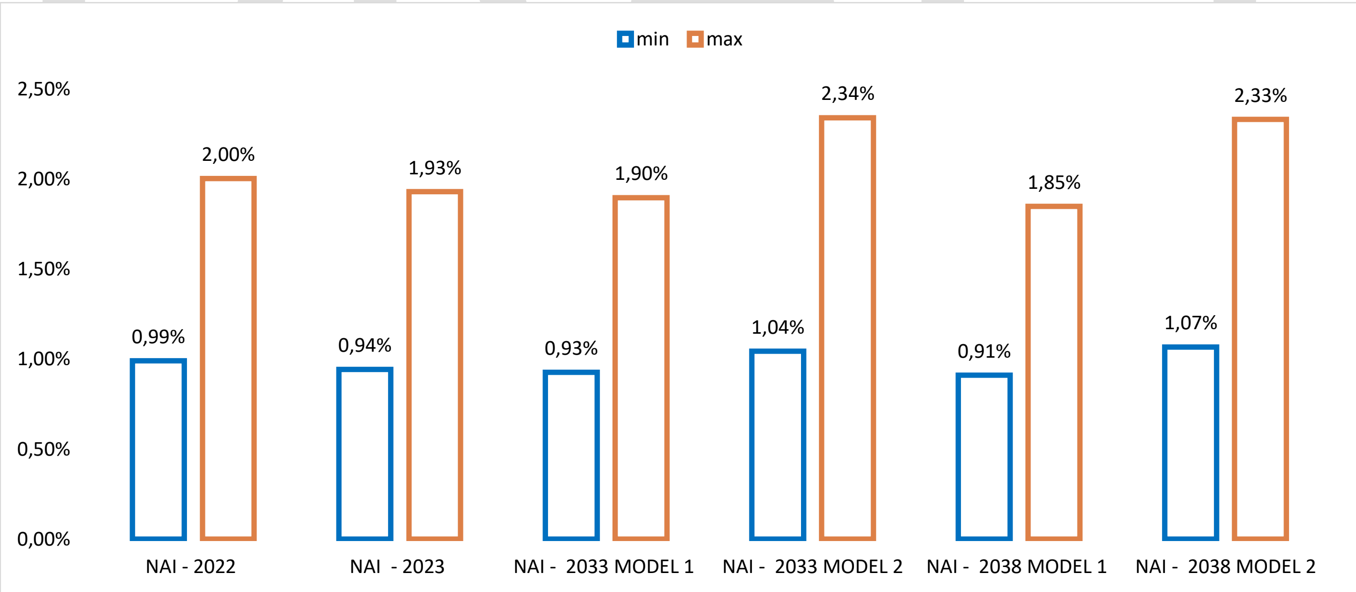

Figure 3.60. Affordability of the minimum and maximum price of water service arising in service areas with regard to the selected model (%)

The comparison of minimum and maximum affordability on the level of 41 service areas is presented on Figure 3.60. There is a significant range in the water service affordability (more than 1% difference between the minimum and maximum affordability). With regard to the range of the water service affordability, its regional distribution is also important: the lowest level of affordability is achieved in service areas 34 and 23, while the highest level is achieved in service area 29.

Analyzing the impact of the identified measures and activities on the price of water service and on overall affordability, it is concluded that in the existing price there is sufficient room to finance and implement the said measures, particularly from the aspect of an incremental impact of reduced operating costs which have a positive impact on the reduction of PWSP's overall operation costs. An analysis of the maximum affordability rates by service areas shows that they don't exceed 2.5%.

A strong investment cycle in the water and wastewater sector is now taking place in Croatia, with a significant impact expected on affordability from the aspect of numerous wastewater collection and treatment projects, which needs to be taken into account when selecting the financing models for the presented measures in order for the overall price of water services to remain affordable for the end users. If the projections of future water price take account of available data about estimated burdens on the price of water as the result of investment in wastewater collection and treatment projects, it can be concluded that on the level of service areas the affordability rate of 3.0% - 3.5% won't be exceeded (this also includes the "less favorable" Model 2). Still, on the level of loss reduction action plans it is definitely necessary to carefully approach this issue and to include in the affordability projections all the measures/investments in water and wastewater projects in a service area.

3.7 Implementation safeguards and protection of invested public funds

The collection of data about the status of water losses started with the preparation of the NLRAP and will continue during its implementation. This document presents the baseline data, analyses of status by PWSPs, and draws conclusions on the national level and the level of future service areas, and it is on these levels that the total costs of water loss reduction measures and the impacts of the measures are estimated.

Since a single national financial fund or a project unit/organization to implement exclusively loss reduction projects hasn't been established (and it's not likely that it will be established), the loss reduction measures or projects deriving from the NLRAP will be implemented through several national financial/operational programs and/or through individual measures/activities of individual PWSPs. At the same time, the NLRAP points to the need for a comprehensive analysis of water losses, monitoring the implementation of measures, and evaluation of results, including monitoring the achievement of the national objectives. In such form of implementation, it is extremely important to establish mechanisms for monitoring, control, and expert evaluation of, including approval, activities on the reduction of losses deriving from the NLRAP.

The establishment of a National Body for NLRAP Implementation (National Body for Water Losses) is proposed. It would report to the MESD and would be composed of the representatives of the MESD, Croatian Waters, Water Institute, the Croatian Association of Water and Wastewater Companies, and independent experts experienced in loss management.

In addition to controlling the implementation of the NLRAP, the MESD would be responsible for coordinating the entire process, i.e., for communicating with Croatian Waters and indirectly with PWSPs, which would submit to the MESD their loss reduction action plans and project reports for all the projects with the loss reduction component. The MESD would forward the loss reduction action plans and project reports to the National Body for Water Losses for verification, approval, and monitoring of loss reduction activities.

Monitoring the implementation of individual loss reduction projects (which are implemented independently or through joint projects of development of water and wastewater infrastructure) differs from monitoring the implementation of the overall NLRAP. Croatian Waters will collect, tabulate, and analyze data for the annual monitoring of results of individual projects. The collected project implementation reports will be systematized by CW's Water Management Departments, service areas and counties. The reports have to contain data about physical and operational progress, and about results of each project. The data will be collected parallel with the development of projects and each year during their implementation. The basic data will be organized into a database, thus facilitating future monitoring, evaluation, and analysis. The project monitoring indicators, their interpretation and analysis will be included in the annual progress reports of individual projects.

The National Body for Water Losses will function as an independent expert and operating body with the following responsibilities:

- Verifying PWSPs' action and investment plans;
- Verifying priorities in implementing certain activities (this can, but doesn't have to, be part of PWSPs' action plans; the priority in implementing certain activities can be modified and adjusted to real needs and situations);
- Approving the implementation of all the activities in certain scope and time and in appropriate financial limits;

- Evaluating the implemented activities from technical and economic aspects;
- Defining the forms based on which Measure IX (Analysis and reporting) will be implemented;
- Assisting in and controlling the implementation of Measure IX (Analysis and reporting);
- Assisting in and coordinating the establishment of the PWSPs' benchmarking system and performance indicators;
- Assisting in and coordinating the establishment of the national database;
- Designing and implementing training programs for PWSPs' staff on all the levels.

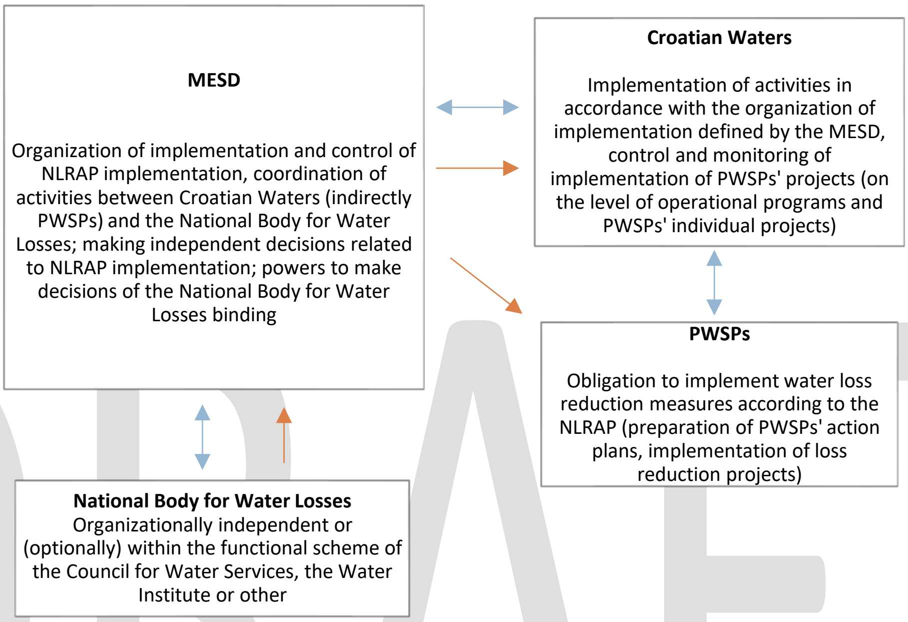

Figure 3.61. NLRAP implementation mechanisms (project monitoring, NLRAP monitoring – blue, decisions – red)

The National Body for Water Losses will verify reports and publish annual NLRAP progress reports. The implementation of the NLRAP will be controlled every 5 years and will include a comprehensive analysis of NLRAP implementation and propose potential improvements. The data will be collected parallel with the development of projects and each year during their implementation. The basic data can be collected and integrated into a database for future monitoring, evaluation, and analysis in the specified form. The monitoring indicators, their interpretation and analysis will every year be included in the annual NLRAP progress reports. These will be analyzed, and their benefits will be evaluated within the analysis of NLRAP implementation status every 5 years. In that way, harmonization of all activities and participants in the project will be ensured.

All the projects financed with public funds have to undergo control by Croatian Waters which includes the control of allocated funds, i.e., compliance of project proposals with the conditions of operational/investment programs within which individual PWSP loss reduction projects are implemented (on their own or together with other water and wastewater investments). In addition, the National Body for Water Losses will as an expert and operating body verify the PWSPs' loss reduction action plans and give opinions/decisions about priorities in implementing individual activities (investment plans), which will through the MESD become binding in terms of the eligibility of measures for the financing of loss reduction measures which are aimed at achieving the effects foreseen by the NLRAP. This will also ensure that the invested public funds are protected.

3.8 Establishment of indicators to monitor the implementation of the Plan

3.8.1 Indicators of PWSPs' operational efficiency (national benchmarking system)

There are several reporting databases established on the national level. On the annual level PWSPs enter data about wastewater collection and treatment and about water supply, i.e., data about the characteristics of water supply systems, user connection rates, as well as multi-annual data series about abstracted volumes, volumes of water supplied into the system, volumes of water delivered to users, and calculation of the NRW. PWSPs also report whether they have prepared the extended water balance, and if so, in what year and the ILI value. **However, it can be concluded that a system to evaluate PWSPs' operational efficiency (performance) hasn't been established yet in the water services sector on the national level.**

Namely, an important step in the implementation of the full reform of the water services sector, in addition to operational implementation of the integration of PWSPs, is the adoption of a number of pieces of subordinate legislation, including the establishment of benchmarks and indicators of operational efficiency of public providers of water services. Its purpose is to improve performance and achieve the quality and standard of provision of water services complying with the requirements of the EU water directives, the purpose of which is to regulate and improve the sector of water services in order for it to become efficient and effective in the implementation of national investments, financially stable and self-sustainable, ensuring an affordable price of water services for households and industry even after the implementation of investments.

The Regulation on evaluation of PWSPs' operational efficiency is being drafted (November 2022), planned to be adopted by the end of 2022. The Regulation lays down the benchmarks and indicators of operational efficiency, the method of collecting and submitting data to calculate the indicators, the method of measuring, evaluating, and reporting on operational efficiency, and the method of data record keeping. Water service providers shall collect data about their operational efficiency, submit data about their operational efficiency to the Council for Water Services, and report about it. The Council for Water Services keeps record of data about the benchmarks and indicators of operational efficiency of water service providers and makes it public. The MESD has a permanent and unlimited access to the record of data about operational efficiency of PWSPs. The Draft Regulation foresees 7 groups of indicators with 81 key performance indicators. The data is collected through its submission to the Council for Water Services in the form of filled-in tables until the establishment/adoption of a software platform, and after the establishment/adoption of the software platform PWSPs will themselves enter the data into the application. The software platform (DANUBIS Data Collection and Management Platform, UBP Platform, Sigma, or something else) will be defined by a guideline of the Council for Water Services.

An important part of **evaluating PWSPs' operational efficiency** is the management of water losses. For that reason, the Draft Regulation also lays down the following indicators for which it is **assessed that they will enable monitoring the progress in water loss management on the PWSP level**:

- In the group "Adequacy of employment"
  - Number of employees per water supply network length
  - Number of employees in the technical service for water supply per service connection and connected population
  - Number of employees on water loss reduction in the specialized service (in the office and on the field) in relation to the kilometers of mains and number of service connections

- In the group "Operational indicators"
  - Non-revenue water expressed in m^3/year and in % of water supplied
  - Infrastructural leakage index (ILI)
  - Real losses of water per service connection, annual volume in m3 and in liters per day
  - Real losses of water per water supply network length, volume in m3 per hour
  - Real losses of water per service connection in relation to network pressure in liters per day
  - Control of losses (network length under active control in relation to total network length) on the annual level
  - Apparent losses in relation to water supplied
  - Number of house connection failures per year
  - Interruptions in water supply (in relation to the number of interruptions, duration of interruption, number of people affected by the interruption, total duration of water supply and total population)
  - Average costs of repair on the water supply main

  - Average costs of repair on the water supply service connection pipe

- In the group “Energy efficiency indicators”
  - Unit consumption of electric energy in relation to total volume of water input (supplied)

- In the group “Assets indicators”
  - Gross fixed water supply assets
  - Average assets age (ratio between total assets written-off value and total assets acquisition value)

- In the group “Depreciation indicators”
  - Average depreciation rate for water supply assets

3.8.2 Monitoring the implementation and achievement of NLRAP objectives

3.8.2.1 Monitoring the achievement of national objectives

The most suitable indicator of the achievement of national objectives is the reduction of the annual volume of non-revenue water. The NLRAP-targeted reduction of NRW volume in the 15-year period is defined for each PWSP (Figure 3.62), with their sum giving the total targeted national volume of NRW reduction (Table 3.15).

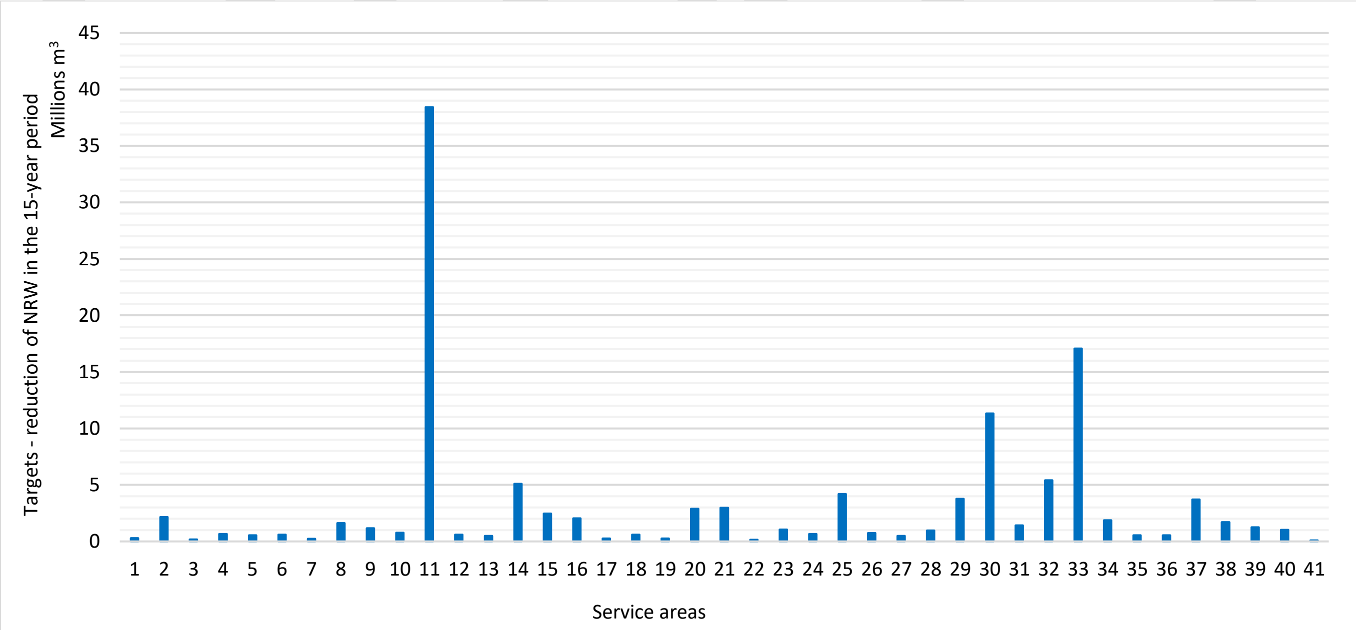

Figure 3.62. Effects of loss reduction measures in the 15-year period on the level of service areas

Table 3.15. National target values of NRW reduction after 15 years of NLRAP implementation

National target values	Result of implementation of measures foreseen by the NLRAP		
	After 5 years (m3)	After 10 years (m3)	After 15 years (m3)
Annual NRW reduction	45,000,000	55,000,000	22,000,000
Cumulative NRW reduction	45,000,000	100,000,000	122,000,000

According to Figure 3.35., the implementation of measures in the foreseen time frame indicates potential achievement of earlier effects of investment in the initial periods (after 5 or 10 years). However, due to the time needed to prove that the losses have been reduced (metering, checks, verifications, reports), the national objectives as presented in Table 3.15. have been defined.

As the result of loss management improvement measures in the first 15-year period, which includes significant strengthening of PWSPs to cope with water losses, and with continued implementation of active leakage control measures and continued rehabilitation/replacement of mains (with proposed investment in replacement of at least 2% per year), further significant advances in the reduction of losses are also expected after the first 15-year period, which it will only be possible to estimate in a certain phase of implementing the measures from this NLRAP and analyzing the actual effects of measures (and the required modifications of the approach/measures).

The NRW is calculated using the methodology from Chapter 3.1.2.

3.8.2.2 Monitoring the progress in NLRAP implementation

The implementation of the NLRAP by PWSPs will be monitored through the establishment of an indicator-based progress monitoring system (Table 3.16). Certain indicators will be collected as part of the benchmarking system, while other indicators will be collected and monitored only for the needs of the NLRAP.

The specific indicators within the benchmarking system have to indicate performance levels, which is why they require the establishment of objectives or thresholds (indicator target value or indicator reference value) in order to put the results into context and show whether performance (operations) is on track or not. However, it is only after the establishment of the functional benchmarking system (a few years of data collection, then analysis and comparison of annual data, indexation, clustering) that it will be possible to define the target or reference values of performance. Therefore, the Draft Regulation (from Chapter 3.8.1) authorizes the Council for Water Services to define the indicator reference values (thresholds)[14] after the establishment of the benchmarking system, except where the MESD is responsible for their definition for the purpose of the Regulation on special conditions to perform water service activities.

Table 3.16. System to monitor the progress in NLRAP implementation

Indicator	Monitoring type	Reference period	Data collection and verification	Target or reference values
NRW reduction, m^3/year	Monitoring the achievement of PWSPs' results and achievement of national objectives in relation to the results of measures	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	Figure 3.62
ILI	Monitoring of results and comparing PWSPs in relation to the results of measures	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	Defined by the Council for Water Services after the establishment of the benchmarking system, except where the MESD is responsible for their definition for the purpose of the Regulation on special conditions to perform water service activities.
Unit Real Loss, l/service connection/day	Monitoring of results and comparing PWSPs in relation to the	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	Defined by the Council for Water Services after the establishment of the benchmarking system, except where the MESD is responsible for their definition for the purpose of the Regulation on special

[14] The integration of public water service providers also implies PWSPs including local water supply systems into their management based on a decision by the MESD once the technical usability of local water supply systems has been established. Following their takeover by the competent PWSPs, local water supply systems will be gradually restored and reconstructed, while those which are so worn out that they are not usable will be replaced with the new ones. It can therefore be expected that in the initial years the inclusion of local water supply systems into the public system will to a certain extent disturb the image/indicators of losses of public water supply systems, which should improve with the development of the systems and with the launch of a sustainable loss management system. (Local water supply systems are water supply structures from a source or another abstraction point to the point of connection of the final user or to a public tap (Local water supply systems are outside of the public water supply systems or individual systems of water supply, the construction of which was financed directly by natural persons and exceptionally by legal persons, in order to provide water for human consumption for one settlement, several settlements or part of a settlement). Data by competent institutions suggests that there are around 200 local water supply systems recorded in Croatia to which around 50,000 people or 1.4% of the population is connected).

Indicator	Monitoring type	Reference period	Data collection and verification	Target or reference values
	results of measures			conditions to perform water service activities.
Unit Real Loss, l/ service connection /day/m of pressure	Monitoring of results and comparing PWSPs in relation to the results of measures	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	Defined by the Council for Water Services after the establishment of the benchmarking system, except where the MESD is responsible for their definition for the purpose of the Regulation on special conditions to perform water service activities.
Unit Real Loss, l/km of mains/hours	Monitoring the results of progress by individual PWSP in relation to the results of measures	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	Defined by the Council for Water Services after the establishment of the benchmarking system, except where the MESD is responsible for their definition for the purpose of the Regulation on special conditions to perform water service activities.
PWSP Action Plan prepared	Monitoring the progress of individual PWSP	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	2 years for PWSPs with very high and high relevance of losses 3 years for PWSPs with medium and moderate relevance of losses
Employees (office and field) working on reduction of losses, number/km or mains or number/service connection	Monitoring the progress of individual PWSP	Annual	Derived from the national benchmarking system	Defined by the Council for Water Services after the establishment of the benchmarking system, except where the MESD is responsible for their definition for the purpose of the Regulation on special conditions to perform water service activities.
Specific energy consumption, kWh (m^3 of water supplied)	Monitoring of results and comparing PWSPs in relation to the results of measures	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	(0.5-0.6) kWh/m^3
Implementation of measures (by groups of measures), EUR/year	Monitoring of results and comparing PWSPs in relation to the results of measures	Annual	PWSP Project Reports and data verification by the National Body monitoring the NLRAP implementation	PWSPs action plans goals in a line with the NLRAP goals
Implementation of measures (by groups of measures), % of investment in relation to total identified value of measure/s	Monitoring of results and comparing PWSPs in relation to the results of measures	Annual	PWSP Project Reports and data verification by the National Body monitoring the NLRAP implementation	PWSPs action plans goals in a line with the NLRAP goals
Reduction of pressures to water bodies (reduction of abstracted water volumes) m^3/year	Monitoring the results of progress of individual PWSP in relation to the results of measures	Annual	Derived from the national benchmarking system and data verification by the National Body monitoring the NLRAP implementation	PWSP loss reduction action plans in line with the NLRAP goals

The ILI and indicators of unit Real Losses are calculated using the methodology from Chapters 3.1.3. and Chapters 3.2.4.2. 3.2.4.3.

DRAFT

22HR06 CROATIA: SUPPORT TO REDUCE WATER LOSS WITHIN THE REFORM OF THE WATER SECTOR

ACTIVITY 2:

DRAFT NATIONAL LOSS REDUCTION ACTION PLAN

December 2022.