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 1

Stocktaking Report

October 2022

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

European Commission

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

DISCLAIMER

COPYRIGHT STATEMENT

This report has been delivered in October 2022, under the EC Contract No. REFORM/IM2022/004 under TF073805, signed between the European Commission and the International Bank for Reconstruction and Development. It corresponds to Output 1 for the Technical Assistance on support to reduce water loss within the reform of the water sector in Croatia under the above-mentioned agreement.

Funded by the European Union

ACTIVITY 1:

BASELINE ASSESSMENT ON THE CURRENT STATUS OF WATER SUPPLY SERVICES IN CROATIA, AN ESTIMATION OF LOSSES AND TECHNICAL CAPACITIES OF PWSPs

i. 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 is to provide an overview of the sector organization and operational efficiency in light of ongoing sector reforms. The assessment is based on a newly established PWSP structure (41 PWSPs).

ii. 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 include: (a) 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, and (b) collection and preliminary analysis of existing project documentation related to optimization of water supply systems and water losses reduction.

iii. 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 connected to water leakage levels.

STOCKTAKING REPORT

October 2022

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.

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

SUMMARY

The assessment of the current status of public water supply services in Croatia indicates that there is no integrated water loss management system established. In particular, there are 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. The national average of the rate of losses is among the highest in the European Union.

In the water sector an extended functional scheme of competences and responsibilities is in place, with these including regulations, control, national planning, national water management, 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. Over the last two decades, and in particular since joining the European Union, the sector of water and water services has been characterized by strategic advances which are the result of the adoption of a set of legal regulations, as well as of planning and intensive investment in the construction of water and wastewater structures. In that way, the baselines and visions/goals in the provision of water services have been improved on the national level, with a significant financial assistance that is provided to the local level for the development of water and wastewater infrastructure.

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 (merging more than current 160 PWSPs, of which 128 deal with water supply, into 41 more efficient 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 PWSPs' economic efficiency.

In 2020, the sector of water services had total revenues of EUR 538 million and expenses of EUR 523 million. The average total water price paid by the household category in 2020 was EUR 2.15 per m3. The specified total water price in the household category represents the total price of water paid by citizens through the bills (a fixed part reduced to m3, a variable part, VAT, compulsory water fees, PWSPs' development fees). With the aim of reducing the environmental impacts of water abstraction, i.e., reducing losses and the associated operation and maintenance costs, the method of calculating the water usage fee (fee to cover resource and environmental costs) has been modified by a regulation in effect from 1 January 2023. Efficient monitoring of activities for the reduction of losses requires the establishment of a water abstraction metering system at water abstraction points for public water supply, as well as a system to record, collect, analyze, and control data about abstracted water volumes, which is all organized by Croatian Waters (the activity is in implementation).

An IT System for Reporting on Water Directives to the EC has been established on the national level. However, it can be concluded that a system to evaluate PWSPs' operational efficiency (benchmarking system) hasn't been established yet in the water services sector on the national level. The Water Services Act (2019) introduces provisions for the establishment of PWSPs' benchmarking system, as well as provisions to monitor PWSPs' achievement of the general and special conditions for the performance of water service activities, which is planned to be regulated with two new regulations by the end of 2022.

The preparation of this "Stocktaking Report" as a supporting document of the NLRAP contributes to the implementation of the reform of the water utility sector in order to support the economy and efficiency of operations of the water utility sector by improving capacity of the PWSPs to reduce excessive losses. The conducted analyses were primarily based on the data from Croatian Waters/Ministry (SOV Database), the prepared Conceptual Solutions of water supply, and the data collected from the questionaries completed by PWSPs, which made it possible to make a realistic assessment of the water loss issue. In order to study and analyze the systems from several aspects, the public providers were grouped or divided into 4 clusters (the division into clusters based on the total number of service connections was selected: Cluster I: Zagreb; Cluster II: more than 30,000 service connections; Cluster III: 5,000-30,000 service connections; and Cluster IV: less than 5,000 service connections).

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. Water supply systems end in metered water meter shafts of end users. A large number of water supply systems was developed using analyzing and modelling software both for stationary and non-stationary

operating conditions. Extensions and modifications of water supply system layouts were most often not accompanied by adequate analyses and implementation of protection from the water hammer.

In the process of upgrading its water and wastewater infrastructure to the European Union standards, Croatia will in the near future be faced with a period when water supply improvement will again be in focus. During that period, the main priority should be improving system reliability, at the same time improving the resilience of the overall functioning of the system. In Croatia, areas of small watersheds in the Black Sea river basin and the entire Adriatic river basin are particularly sensitive to the impact of climate change. Problems are expected in the availability of water resources. 31% of PWSPs have limitations in the availability of water resources in relation to the current consumption, and as much as 34% of them expect such limitations in the future, which clearly points to the need to preserve water resources through the reduction of losses. Since the preservation of water resources creates protection from growing climate change risks, it can be a cost-efficient adaptation measure. When the physical losses are reduced, abstraction (sources and distribution) could be reduced. That would save energy and reduce greenhouse gas emissions if the production of energy includes carbon-based fuels.

An important feature in establishing the water loss management system is the lack of knowledge about own water supply systems. For example, 24% of PWSPs have no system maps, 26% of PWSPs have no updated consumer databases, and only 27% of PWSPs keep record of system age. The situation with the SCADA system is slightly more favorable, but still not satisfactory, since 81% of PWSPs have a SCADA system established.

In terms of consumer database management, the largest share of PWSPs (50%) regularly update their user databases together with network visits and field checks, with identical shares in Clusters II, III and IV, with one PWSP in Cluster I acting in the same way. In addition, a significant share of PWSPs (22%) have regularly updated user databases connected with the GIS, with their largest share in Cluster II (50%). For around 7% of PWSPs the updating of the user database is being improved, and this is characteristic exclusively for the Cluster III (11%) and IV (6%) PWSPs. Around 20% of PWSPs occasionally update their user databases, with their largest share in Cluster IV (35%), while 1% of PWSPs haven't updated their user databases for a long time.

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. A large majority of water supply systems (more than 90%) regulate pressure in the system, but primarily only to avoid excessive pressures. Many PWSPs continuously operate in unfavorable pressure conditions, with an average pressure on the national level of around 5 bar. 80% of PWSPs don't make system pressure analyses or occasionally measure the pressure and only try to make an analysis. Only a few DMAs have been established. A lack of leakage metering and detection equipment has also been identified.

The basis for the development of water loss management plans is gaining better understanding of the reasons behind the occurrence of water losses and the factors affecting them. 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 to other PWSPs), Billed Authorized Consumption (Revenue Water), and Non-Revenue Water. However, on the national level 23% of PWSPs still don't prepare even the simple water balance.

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% (the European average is around 20%, with rates even lower than 10% recorded in more developed countries). 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). On the level of Croatia, the volume or share of non-revenue water and the ILI are most frequently used as performance indicators. Around 44% of PWSPs use only the % of NRW as a performance indicator. However, over the last several years, in particular after the launch of the NWLRP in 2018, there is more frequent application of other performance indicators that derive from the extended (and simplified) water balance according to the IWA methodology, such as the total real losses, unit real losses (l/service connection/d; m3/km/h), and apparent losses.

The analyses made so far show that over the last 5 years the NRW volume on the national level has decreased slightly (by around 1.1% or by around 3 million m3/year), with almost no change over the last 4 years. However, if the status on the level of individual PWSPs is analyzed, then both positive and negative changes in NRW volumes in some PWSPs are present and clearly visible. While some PWSPs are characterized by a continuous increase in NRW volumes, some have stagnating NRW volumes, and some decreasing NRW volumes, particularly over the last several years. Some PWSPs have in a short period (1 – 2 years) managed to achieve certain reduction of NRW volumes, only for them to increase after that for certain reasons. For that reason, active help, primarily in the form of financing and technical, operational and institutional assistance related to the water loss reduction program, is assessed as much needed with the aim of establishing long-term sustainable management of water losses and water supply systems. It can be concluded that the issue related to the currently unfavorable status of water losses is not of a technical nature, but rather the result of a systematic failure so far to manage the issue, most often due to insufficient financial investment, but also due to operational and personnel issues which the PWSPs are continuously faced with.

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. All the major PWSPs have prepared or are nearing completion of the Conceptual Solutions with calibrated mathematical models and proposed future measures for the reduction of water losses. Until the year 2018, i.e., the launch of the National Water Loss Reduction Program (NWLRP) by the line Ministry and Croatian Waters, only a relatively small number of the PWSPs had managed to reduce their water losses or keep them at an acceptable level first of all with their own effort and financial resources.

The distribution of the PWSPs 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, indicates the following: the Cluster I PWSP is classified into band (category) D with the ILI higher than 8. The Cluster II PWSPs are equally distributed across all the four bands. The Cluster III PWSPs are also equally distributed across the first three bands (< 2, 2 – 4, and 4 – 8), while a somewhat smaller number of the Cluster III PWSPs is classified in the fourth band (8 or more). More than 50% of the Cluster IV PWSPs are classified into the first band (< 2), while the remaining number is equally distributed across the last three bands (2 – 4, 4 – 8, 8 or more).

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 (when calculating the water usage fee), in an effort to encourage the PWSPs to take certain improvement measures to reduce the ILI value, and thus of the amount of the water usage fee 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. Therefore, the ILI as a practical indicator of the efficient management of a water supply system is not an argument (motive) enough to address the water loss issue more actively. There is a 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 analyses of the ILI values calculated before need to be treated carefully. It is recommended to make additional analyses to confirm how efficient a PWSP is in managing the issue of water losses.

The most significant problem in water loss reduction in Croatia today 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. 61% of PWSPs have technical teams for water losses established, but these teams are not sufficient with regard to the length of the water supply network. 70% 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. 67% of PWSPs don't even adopt active leakage control plans or they adopt them, but don't report on the implemented loss reduction activities. Better results are achieved in the speed of repairs on pipelines (for around 50% of PWSPs the repair time is up to 1.5 days) and service connections (for around 68% of PWSPs the repair time is up to 2 days).

All water supply systems are faced with water losses. The reasons are numerous, and when 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.

It is precisely those reasons that call for the preparation of the NLRAP, 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.

The preparation of the initial NLRAP is at the same time a response to the requirements of the DWD Recast which also puts focus on water losses with a clear timeline to identify the (targeted) level of water losses, before that the preparation of action plans (with the defined loss reduction measures), and their presentation to the European Commission. The DWD Recast in relation to the water leakage (Article 4.3) stipulates that Member States shall ensure that an assessment of water leakage levels within their territory and of the potential for improvements in water leakage reduction is performed using the infrastructural leakage index (ILI) rating method or another appropriate method. That assessment shall consider relevant public health, environmental, technical and economic aspects and cover at least water suppliers supplying at least 10,000 m3 per day or serving at least 50,000 people. The results of the assessment shall be presented to the Commission by 12 January 2026. By preparing the NLRAP, Croatia will perform initial assessments of water leakage levels and of the potential for improvements, thus creating a solid basis for an improved assessment (update) by the end of 2025, the results of which will be presented to the Commission by the specified date.

Good practice examples of other countries indicate several steps in the development of the water loss reduction plan: develop the basic loss (or NRW) reduction plan, establish a high-quality register of the water supply system, optimize pressure and control leakages, and insist on the quality of system repair and renewal as an efficient long-term measure of water loss reduction.

1 OVERVIEW OF THE SECTOR ORGANIZATION AND OPERATIONAL EFFICIENCY

Measures under this project directly contribute to the implementation of the water utility sector reform and investments under the Croatia Recovery and Resilience Plan as well as Operational programme "Competitiveness and Cohesion 2021-2027".

The project is funded by the European Union via the Technical Support Instrument and implemented by the World Bank in cooperation with the European Commission's Directorate General for Reform Support (DG REFORM).

1.1 Current state of the water and water service sectors

1.1.1 Objectives in the water service sector

The general objectives in the water service sector can be summarized as the adoption of a quality solution for drinking water supply, and wastewater collection and treatment which must comply with the EU directives. The directives that have to be complied with are Directive 98/83/EC on the quality of water intended for human consumption and Directive 91/271/EEC concerning urban wastewater treatment, which have been transposed into the relevant national regulations. EU Directive 2020/2184 (Recast) on the quality of water intended for human consumption has not yet been transposed, it will be transposed by the deadline in January 2023.

The national strategic objectives and priorities are defined in the Treaty concerning the accession of the Republic of Croatia to the European Union, the National Environmental Protection Strategy and the National Environmental Action Plan, the National Development Strategy Until 2030 and the Water Management Strategy. The water management planning document (Multiannual Programme for Construction of Water Utility Facilities for the Period Until 2030 and the River Basin Management Plan 2016-2021) and the EU Accession Treaty define the transitional periods to meet the criteria laid down by the EU directives.

The service areas of the public providers of water services must have a quality solution for the supply of water for human consumption, thus achieving compliance with the Act on Water for Human Consumption (OG 56/13, 64/15, 104/17, 115/18, 16/20) or the Directive 98/83/EC on the quality of water intended for human consumption. Act on Water for Human Consumption need to be harmonized (pending) with the DWD Recast (Directive (EU) 2020/2184 of the European Parlament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast)). In addition, in accordance with the water management planning documents, in Croatia it is necessary to improve the services of public water supply, i.e. provide sufficient quantities of quality water for human consumption to supply the population, increase the population connection rate, reduce the losses, and increase the quality and safety of public water supply services. As for the sanitation and wastewater treatment, an appropriate solution is required for the collection, treatment and discharge of wastewater in a manner that does not put at risk the good status of the receiving water body, thus achieving compliance with the Water Act (OG 66/19, 84/21), the Ordinance on wastewater emission limit values, i.e. the EU Water Framework Directive and the EU Urban Wastewater Treatment Directive.

Another objective is to ensure the most economically efficient development of the system that brings the highest economic (hence not only financial) gain. For that reason, among the variant technical solutions for the water and wastewater systems it is necessary to propose/adopt the most cost-efficient technical solutions during the economic life of individual projects which can reasonably be expected to be approved for co-financing by the European Commission.

New Water Services Act (OG 66/19) and bylaws, proposed consolidation that provides good start for optimization of water services. Larger PWSPs, in terms of area coverage and technical/financial capacity, could provide regional or sub-regional approach, where planning and managing of the system bring much more favourable results and resilience, for both, level of service and safety of the public watersupply or sewerage systems.

The objectives:

- Compliance with the Directive on the quality of water intended for human consumption (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 (recast)) and the Act on Water for Human Consumption (OG 56/13, 64/15, 104/17, 115/18, 16/20), which define the quality standard for water intended for human consumption, i.e. compliance for areas with more than 50 people or consumption of more than 10 m^3 a day, and areas with commercial or public water supply to fewer than 50 people or consumption of less than 10 m^3 a day;

- Compliance with the Council Directive concerning urban wastewater treatment (Directive 91/271/EEC), the Water Act (OG 66/19) and the Ordinance on wastewater emission limit values (OG 26/20) which refer to the collection, treatment and discharge of urban wastewater (the objective is to protect the environment from the adverse impacts of wastewater discharges);
- Compliance with the Water Low (OG 66/19, 84/21), Water Management Financing Act (OG 153/09, 90/11, 56/13, 154/14 , 119/15, 120/16, 127/17, 66/19) and Water Service Act (OG 66/19);
- Compliance with the Water Framework Directive (2000/60/EC) and the River Basin Management Plan 2016-2021 (OG 66/16). This will in the water service sector be achieved through the following activities and measures:
  - Recovery of costs for water services and promoting efficient water use through:
    - Application of the specified criteria to define the minimum basic price of water services to ensure the recovery of costs of the supplier's operations;
    - Development of a programme on the introduction of individual water meters and implementation of the programme on the introduction of individual water meters;
    - Reduction of losses through the application of special requirements for the performance of water services, i.e. establishment of efficiency benchmarks and indicators;
  - Measures to protect the water for human consumption through:
    - Protection of sources – A programme of protection measures with the deadlines for their implementation, including preliminary activities to adopt or approve (harmonize) the Decision of the protection of sources with the sanitary protection zones;
    - Implementation of restoration measures – Continuation of activities on the implementation of restoration measures in the zones of water abstraction sites in accordance with the adopted/harmonized Decisions on the protection of sources and the prepared programmes of protection measures;
    - Harmonization with the standards on sanitary quality of water for human consumption – the public water supply systems will be gradually extended/improved;
    - Water abstraction control measures through the introduction of a practice of detailed record and interpretation of losses in the public water supply system;
  - Measures to control point sources of pollution (in accordance with the principles of: elimination of damage at its source, combined approach, and the polluter pays) through:
    - Construction/extension of urban wastewater collection systems;
    - Construction/extension of adequate urban wastewater treatment plants for all agglomerations of more than 2,000 PE;
    - Achieving good seawater quality according to the legislation;
    - Increasing the rate of connection to public wastewater collection and treatment systems;
    - Compliance with the Multiannual Programme for Construction of Water and Wastewater Structures for the Period until 2030 (Programme 2021) (OG 147/2021). One of the basic preconditions for successful implementation of the Programme 2021 is achieving progress in the ongoing reform of the water service sector. For that reason, the first group of objectives of the implementation of the Programme refers to the issues of the institutional structure in the water service sector;
  - Objectives related to the reform of the water sector:
    - Establish service areas;
    - Establish uniform provision of the water service of public water supply and sanitation;
    - Respect the principle of one service provider in one service area;
    - Ensure the affordability of the price of water service even after the completion of projects for development of water and wastewater infrastructure;
    - Establish a single price of water services in the service area;
- Objectives related to the improvement of the public water supply service derive from the provisions of the Water Management Strategy, the River Basin Management Plan, the Multiannual Programme for Construction of Water Utility Facilities for the Period Until 2030 (OG 147/21), the Accession Treaty, i.e. the requirements to comply with the Directive on the quality of water intended for human consumption, including its recast
  - Ensure access to water for human consumption for all the population, in particular for vulnerable and marginalised groups, through connection to public water supply systems or in some other way (for example by mobile means with the help of water tanker trucks or water tanker vessels);

  - Achieve sanitary quality or reduce the risks of failing to achieve sanitary quality of water intended for human consumption, including also the improvement of the system to control and monitor the parameters of sanitary quality;
  - Reduce the pressure to water from the abstraction of water intended for human consumption or reduce losses from water supply systems, as a priority if water is abstracted from water bodies failing to achieve the water/environmental protection objectives;
- Objectives related to the improvement of the public sanitation service derive from the provisions of the Water Management Strategy, the Multiannual Programme for Construction of Water Utility Facilities for the Period Until 2030, the Accession Treaty, i.e. the requirements to comply with the Directive concerning urban wastewater treatment:
  - Achieve a higher rate of connection – More than 98% of the load connected to public wastewater collecting systems for agglomerations of more than 2,000 PE;
  - Achieve a higher level of compliance with regard to the level of urban wastewater treatment for agglomerations of more than 2,000 PE according to the load and sensitivity of the receiving body (for agglomerations with a load between 2,000 PE and 10,000 PE (at least secondary treatment in sensitive areas or appropriate treatment in areas not designated as sensitive; for agglomerations with a load larger than 10,000 PE and 15,000 PE (advanced treatment – tertiary treatment in sensitive areas, secondary treatment in areas not designated as sensitive);
  - Achieve a higher level of compliance of the individual wastewater systems in agglomerations of more than 2,000 PE;
  - Reduce the water load through the discharge of untreated or insufficiently treated urban wastewater, as a priority on the water bodies failing to achieve the water protection objectives;
- Objectives related to the improvement of water supply and wastewater collection and treatment systems deriving from the National Development Strategy Until 2030 (OG 13/21):
  - Public systems of water supply and urban wastewater collection and treatment will be improved;
  - Special attention will be given to efficient reorganization of the sector of water services in order to improve efficiency and sustainability and to achieve the operational objectives of the Directive concerning urban wastewater treatment and the Directive on the quality of water intended for human consumption;
  - There will be increased investment in the modernization and extension of water supply network, public sewer system and urban wastewater treatment plants and torrential drainage;
  - There will be permanent investment in the programs to reduce losses of water from water supply systems;
  - Intensification of projects to increase climate change resilience in water supply and wastewater management and in protection from floods and wildfires;
- Operational Programme Competitiveness and Cohesion 2014-2020, the National Recovery and Resilience Programme 2021-2026, Operational Programme Competitiveness and Cohesion 2021- 2027 – The Republic of Croatia adopts the programmes in cooperation with the European Commssion aimed at investing in the priority sectors in the field of environmental protection, i.e. preservation of the quality of water for human consumption, wastewater treatment and waste management. This will in the water service sector be achieved through the following activities and measures:
  - Establishment and maintenance of a sustainable water resources management system through investment into water supply systems;
  - Construction and reconstruction of the network, construction of new water storage space (new water tanks) for the project life, increasing network connection (water supply safety), identification and elimination of leaks, reduction of losses, increasing the reliability and efficiency of the water supply system;
  - Investing into equipment for measurement and control in the public water supply systems;
  - Increasing the efficiency of the public water service providers with the aim of achieving and maintaining sustainability in financial and technical/technological terms and organizational sustainability in terms of human resources;
  - Construction/extension and reconstruction of public sanitation systems;
  - Upgrading and/or constructing new wastewater treatment plants in compliance with the UWWTD;
  - Improving the level in which the agglomeratons are furnished with water supply infrastructure;
  - Reducing emissions from urban sources of pollution into a recipient;
  - Achieving the required parameters for WWTP discharges;
  - Achieving good water quality;

- Increasing the efficiency and safety of public wastewater collection and treatment systems, with the introduction of an economic price of water (the polluter pays principle);
- Increasing the efficiency and safety of the systems of public municipal infrastructure due to oscillating numbers of users caused by the tourist season;
- The Programme for Cohesion and Competitiveness 2021-2027 (the Croatian Partnership Agreement, August 2022), referes that “All investments will ensure the availability of drinking water through public water supply systems for around 98 % of the population and reduce system losses to an average of 20-25 %”;

The basic source of data to monitor the achievement of the objectives are the water service providers and Croatian Waters.

1.1.2 Roles

1.1.2.1 Ministry of Economy and Sustainable Development

Within Ministry of Economy and Sustainable Development (MESD), in the field of water management and protection of the sea, the Directorate performs administrative and expert tasks in the field of protection from adverse effects of water, water estate, irrigation and amelioration drainage, water protection, use of water for different purposes, activities of public water supply and public sanitation, including the process of restructuring and consolidating the water and wastewater sector, and implementation of investment in the development of water and wastewater infrastructure and special activities for water management needs. The Directorate conducts administrative supervision over Croatian Waters and units of local and regional self-government in their exercise of public authorities based on acts and other regulations in the field of water management, and controls the collection of fees and investment in the development of hydraulic structures from the national funds.

Another directorate operating with the MESD is the Directorate for EU Programmes and Projects, European and International Affairs, which performs activities related to the management of the European Union programmes. The Sectors in the field of EU funds perform expert and administrative tasks related to the preparation and implementation of strategic documents and operational programmes for the use of the EU's structural instruments.

The Directorate for EU Programmes and Projects performs the tasks of an Intermediate Body level 1 under the Operational Programme Competitiveness and Cohesion 2014-2020 for the priority investments related to: strengthening the economy by applying research and innovation, business competitiveness, promoting energy efficiency, renewable sources of energy, waste management, climate change, air pollution, protection and restoration of biodiversity, strengthening the disaster management system, improvement of the public water supply systems, development of wastewater collection and treatment systems. It also coordinates the preparation of documents that enable the implementation of programmes for the use of the ESIF, and identifies the measures for the implementation of priorities under the Operational Programme Competitiveness and Cohesion 2014-2020.

The Directorate for EU Programmes and Projects performs expert tasks related to the Next Generation instruments (React – EU and the Recovery and Resilience Facility) and the Multiannual Financial Framework 2021-2027 (MFF) under the "Smarter Europe" policy objectives by promoting innovative and smart economic transition and "Greener Europe" with low-carbon emissions by promoting the shift to clean and fair energy, green and blue investment, circular economy, climate change adaptation, and risk management and prevention.

Its scope of work also includes bilateral and multilateral relations with countries and organizations, participation in the drafting of international agreements, and coordination of activities on the preparation of national standpoints and opinions for expert working groups of the EU bodies.

1.1.2.2 Croatian Waters

Croatian Waters (CW) is a legal entity for water management established by the Republic of Croatia pursuant to the Water Act. Croatian Waters is organized based on the territorial and functional principles.

The activity of CW is water management within the limits of the following tasks:

- Preparation of the national planning documents for water management (Water Management Strategy, River Basin Management Plan, Multi-annual Construction Programmes, detailed plans and programmes in addition to the River Basin Management Plans, Financial Plan, Water Management Plan);
- Studies and analytical tasks (Preparation of terms of reference, conceptual solutions, studies and investment programmes and review of design documents, with the exception of control of detailed designs in terms of regulations on physical planning and construction);
- Water regulation and protection from adverse effects of water (Monitoring and identification of hydrological conditions (including the monitoring, collection, control, processing, keeping and publication of hydrological data, analysis of the hydrological regime, forecasting extreme hydrological events, floods and droughts), assessment of

flood risks, monitoring the status of watercourses and status of water regulation and protection structures; investment tasks in the construction and maintenance of water regulation and protection facilities; supervision of construction and maintenance of water regulation and protection structures; management of flood risks; management, supervision and implementation of preventive, regular and emergency flood defence);
- Amelioration drainage (Investment tasks in the construction and maintenance of basic amelioration drainage structures, supervision of construction and maintenance of basic amelioration drainage structures);
- Water use (Identification of water reserves; care for strategic water reserves, water research works, giving opinions on implementing regulations adopted pursuant to the Water Act by local and/or regional self-government units, taking other measures for the intended and rational use of water; co-financing the construction of public water supply structures and supervision of the intended use of funds during construction);
- Water protection (Management of water quality, implementation of monitoring of surface water, including the coastal water, and groundwater, including laboratory tasks during monitoring, implementation and supervision of implementation of the measures from the National Plan of Measures for Sudden Pollution, giving opinions and exceptionally approvals on implementing regulations adopted pursuant to the Water Act by local and/or regional self-government units, co-financing the construction of public sanitation structures and supervision of the intended use of funds during construction);
- Irrigation (Management of projects for construction of irrigation structures in the ownership of regional self-government units in accordance with the national programmes and projects, co-financing the construction of irrigation structures in the ownership of regional self-government units);
- Management of the public water estate;
- Keeping water documents (In keeping water documents and the integrated water information system, and issuing water rights documents pursuant to the Water Act);
- Expert tasks (In expert tasks related to the award of concessions for commerical water use);
- Expert supervision (In expert supervision of the fulfilment of conditions from water rights documents and concession conditions, water supervision);
- Calculation of water fees (In the calculation of concession fees for commercial water use);
- Calculation and collection of water fees (In the calculation and collection of water fees pursuant to the act regulating the financing of water management);
- Management of special projects (In the management of special projects specified by the act, decision of the Government of the Republic of Croatia or the CW Management Board).

Following Croatia's accession to the European Union, the Department for EU Co-Financed Projects was formed as an Intermediate Body level 2 in the preparation and implementation of projects co-financed by the EU funds.

In that way, Croatian Waters, related to the water services sector:

- Assists the Intermediate Body level 1 (MESD) in the preparation of the guidelines for beneficiaries, particularly the parts laying down specific requirements for preliminary assessment of project compliance with the applicable rules on eligibility;
- Assesses the compliance of projects with the applicable rules on the eligibility of activities and the project and the eligibility of expenditures;
- Concludes grant agreements with the beneficiaries and the Intermediate Body level 1;
- Makes sure that the beneficiaries maintain a separate accounting system or separate accounting codification for the projects;
- Provides advisory services by enabling beneficiaries to become aware of their rights and obligations with respect to financing;
- Checks the deliveries and eligibility of project expenditures and performs administrative and on-the-spot checks;
- Monitors the project progress and reports thereon as needed and at the request of the bodies within the management and control system;
- Submits information about verified expenditures to the line ministry/financing institution as well as to the Managing Authority (Ministry of Regional Development and EU Funds);
- Looks into suspected irregularities, identifies the existence of an irregularity and reports to the competent bodies about the identified irregularities;
- Implements publicity and visibility measures, with a special focus on the measures intended for beneficiaries;

- Makes sure that the beneficiaries properly implement publicity and visibility measures;
- Prepares written internal procedures to implement its functions according to the guidelines adopted by the Coordinating Body or the Certifying Authority;
- Enters the relevant data into the information system intended for recording, storing and processing the data essential for financial monitoring and monitoring of project implementation (MIS, ESIFMIS, e-fondovi);
- Keeps documents and records on the implementation of functions in order to ensure an appropriate audit trail.

1.1.2.3 Public water service providers

The responsibility for the provision of water services to users in Croatia is shared by about 160 public providers. 15% of them provide only (based on the water price specification) 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 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 (PWSPs Novalja, Karlobag, Rab, Pag, Povljana and Senj), 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.

The number of providers by counties[1] ranges from one provider for the area of an entire county to more than ten providers in nine counties. The area of service provision is more fragmented in the Adriatic region. In addition, in the Adriatic region (Zadar and Dubrovnik-Neretva Counties and in particular Istria County) there are providers that provide only the services of public sanitation (with or without the wastewater treatment service).

The total quantities of water delivered by all the 128 public providers that deliver the water directly to their users amounted to 243.9 million m^3 in 2021, which is by app. 4% more than delivered in 2020, or close to 2019, when approximately 245.0 million m^3 were delivered. The quantities of water delivered in 2018 are within -1.4% of the quantities delivered in 2019.

The highest oscillations in water consumption in 2020, compared to the earlier and following year, occurred in the Adriatic region, which is mostly associated with reduced consumption in the tourism industry (the consequence of the Covid-19 crisis). The consumption in the Adriatic region in 2020 was on average reduced by 7%, with the highest oscillations recorded in the areas with more marked summer-winter oscillation in consumption (Makarska and Novalja stand out among the bigger consumers, recording a 25-30% reduction in consumption on the annual level).

[1] Croatia has been divided into 20 counties and the capital city of Zagreb, which has the authority and legal status of both a county and a city. The counties (Croatian: županije) of Croatia are the primary administrative subdivisions of the Republic of Croatia. The counties are subdivided into 128 towns and 428 (mostly rural) municipalities.

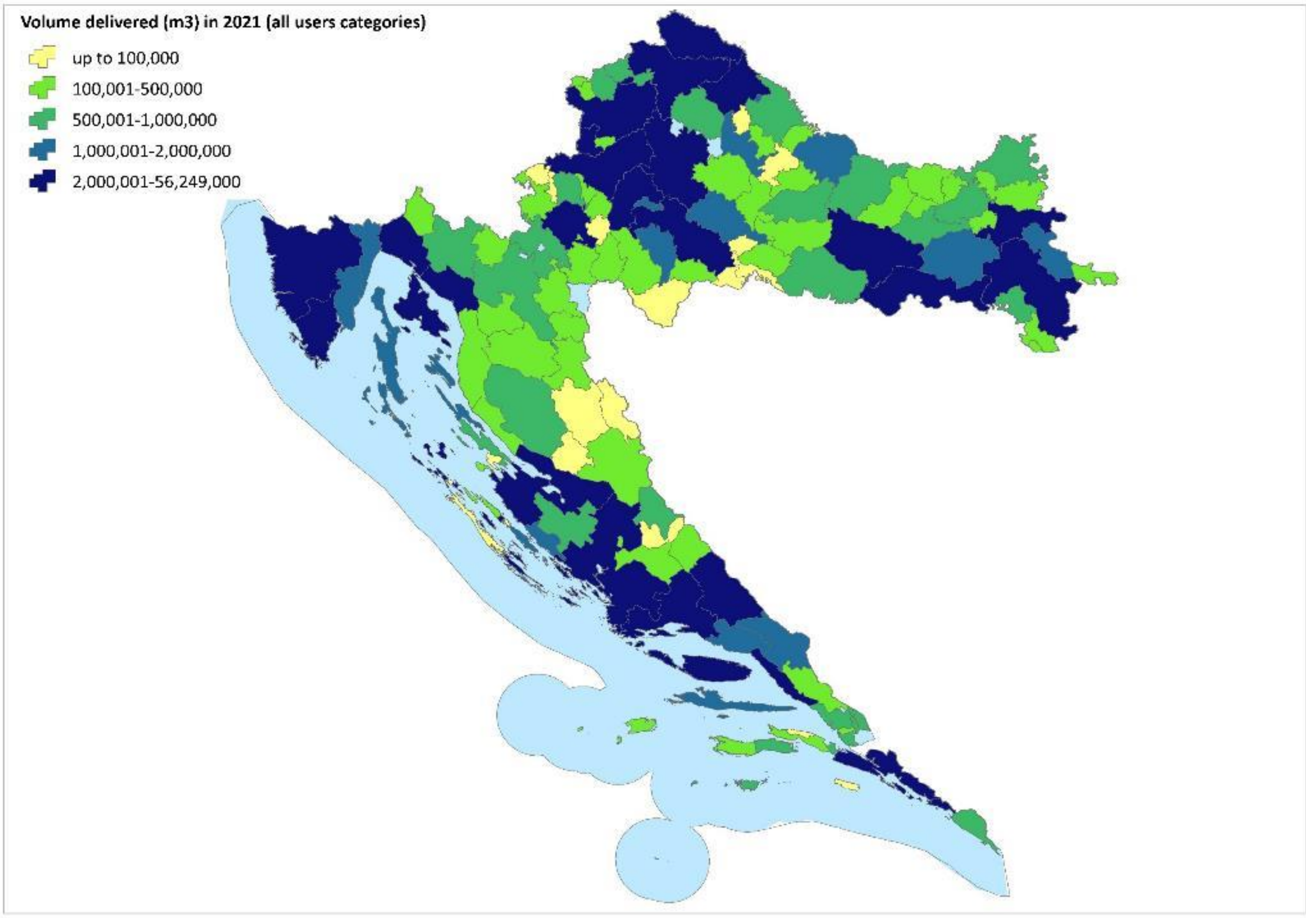


Figure 1.1. Spatial distribution of annual volume delivered (billed authorized consumption) to final users in 2021 (current PWSP level)

About 70% of the water providers deliver less than 1.0 million m^3 per year (and as much as 50% of the providers, i.e. 64 of them, deliver less than 0.5 million m^3 per year). The remaining 30% deliver on average 4.0 million m^3 per year (the Zagreb PWSP is excluded from the average as the biggest provider with annual delivery of app. 56.3 million m^3).

Table 1.1. Number of public providers based on delivered water quantity

PWSPs ranges, delivered (billed authorized consumption) volume (m^3/year)	**Number of PWSPs**
Up to 100,000	20
100,000 – 500,000	44
500,000 – 1,000,000	23
1,000,000 – 2,000,000	15
2,000,000 – 56,310,000	26
2,000,000 – 5,000,000	*17*
5,000,000 – 10,000,000	*4*
10,000,000 – 20,000,000	*4*
Over 20,000,000	*1*
Total number of PWSPs dealing with water supply	**128**

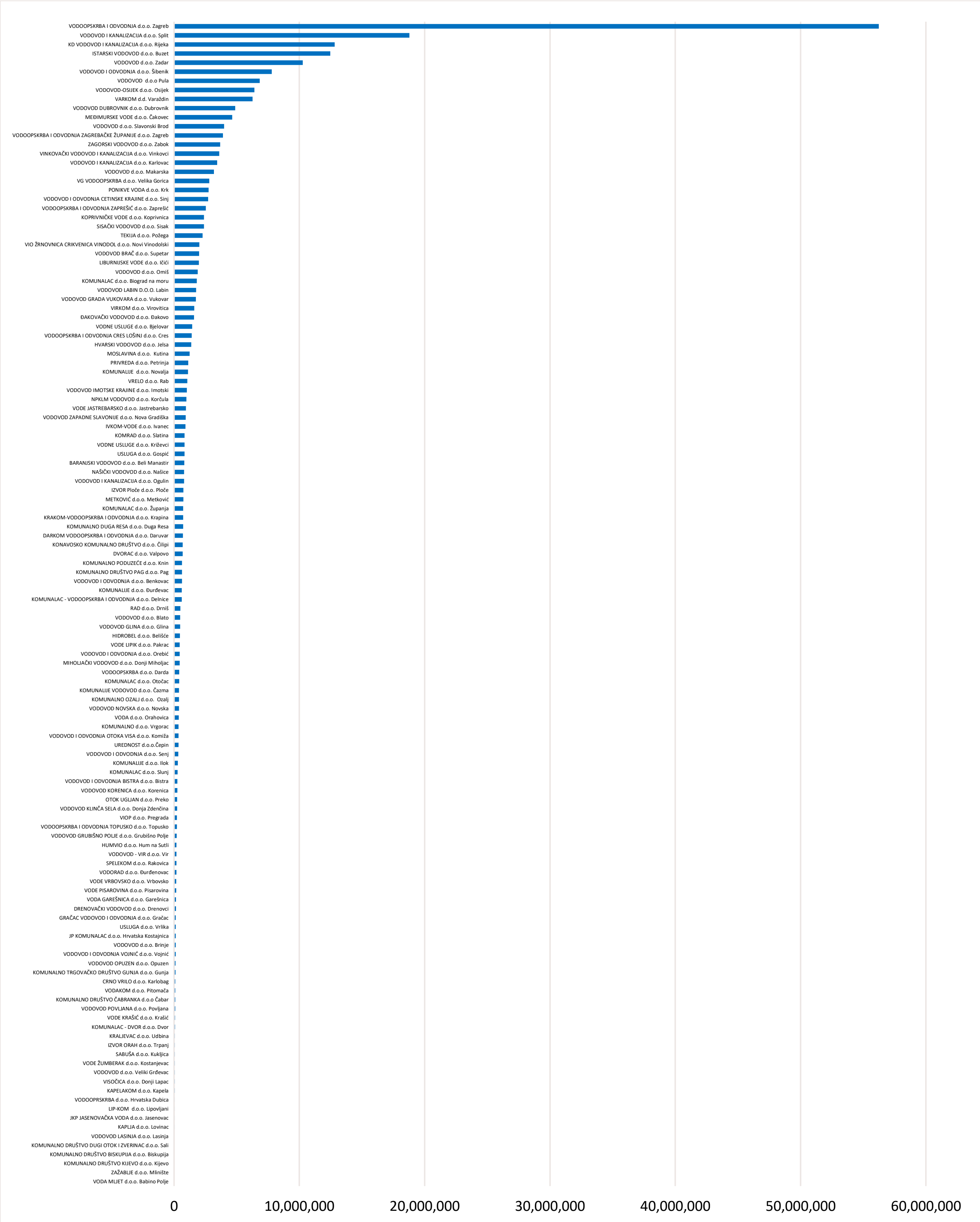


Figure 1.2. Water quantities (m^3) delivered (billed authorized consumption) to consumers (household and industry categories) in 2021, PWSP level

The Regulation on service areas (December 2021) , associated with the Water Services Act, establishes new service areas, defines their borders, and the takeover company (PWSP). It is a piece of legislation that is part of a set of regulations reforming/consolidating the water services sector (see Chapter 1.1.4). 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 physical consolidation of the PWSPs will start in 2023.

Figure 1.3. New water services areas (planned 41 services areas, OG 147/21)

Table 1.2. Size of the planned service areas in relation to water quantities delivered (billed authorized consumption) to consumers

Annual quantity of delivered water (m^3)	**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**

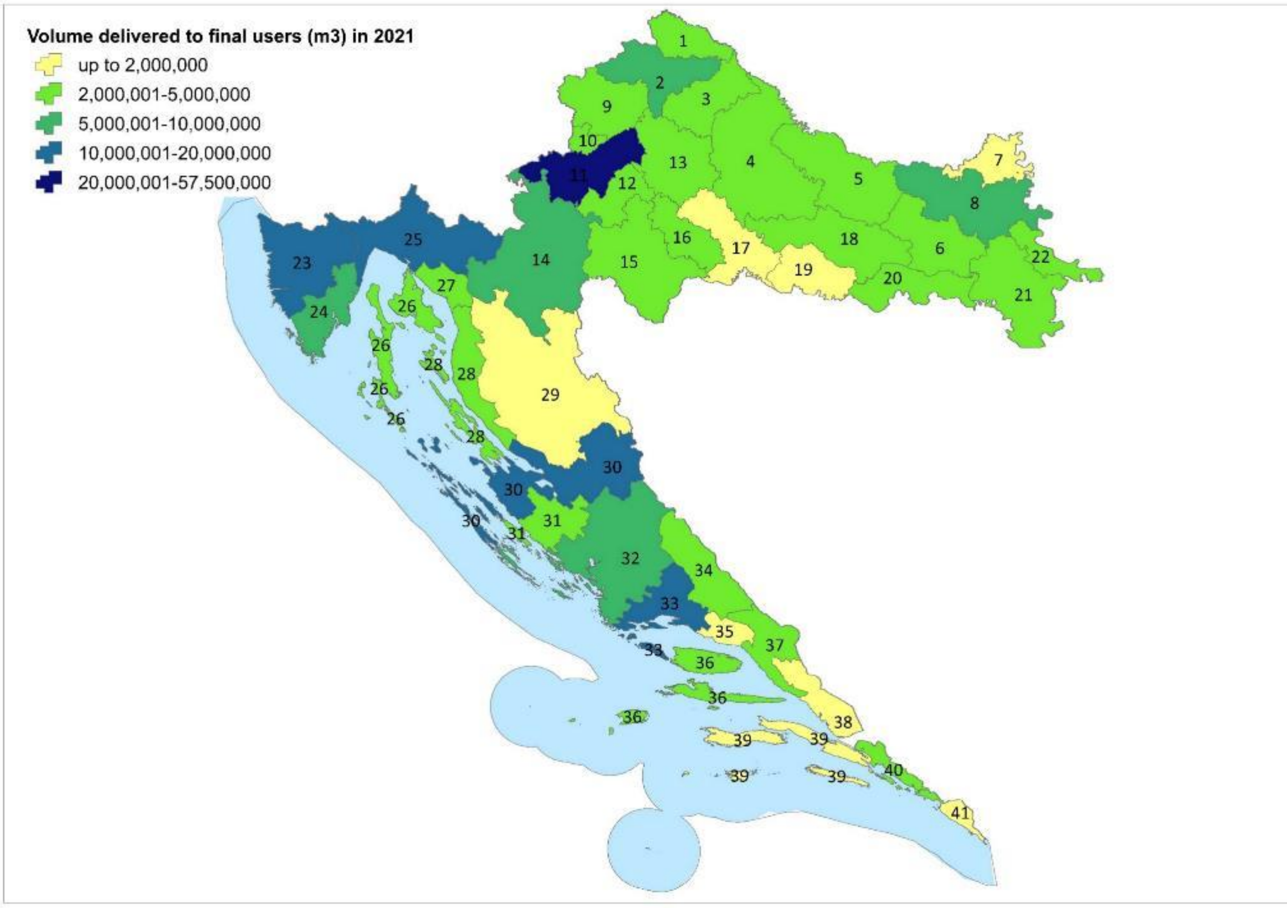


Figure 1.4. Water delivered (billed authorized consumption) to final users in 2021, new water services area level (with IDs)

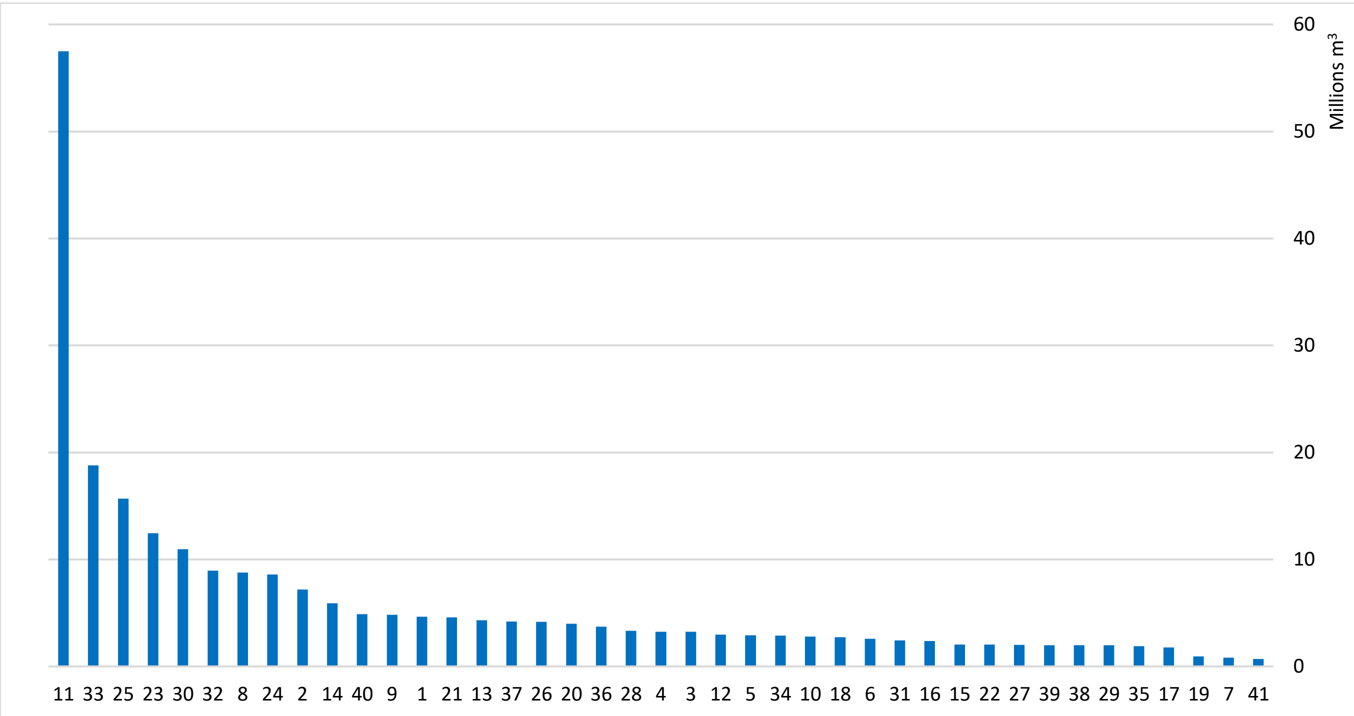


Figure 1.5. Water quantities (m^3) delivered to consumers (household and industry categories) in 2021, 41 services area level

1.1.2.4 Regulator – Water Service Council

1.1.2.4.1 Organization

The Water Service Council (WSC) was established following determinant A8 of the Water Management Strategy dated 2008 (Official Gazette 91/08), specifying the following: "*Establish an independent regulator of water services in the form of a water service council. The regulator's main duty would be to provide for the local component of the water price intended for system management (service price) in terms of achieving the principle of full recovery of maintenance costs in a service area and the social affordability of the water price for the local population. The regulator's duty is to arbitrate between an operator and local authorities, either with local authorities pursuing a tariff policy with underestimated water prices, or with the operator proposing overestimated tariffs. This would ensure professional evaluation of a request to increase the price of service.*" The primary reason behind determinant A8 is the establishment of a regulatory framework and body to implement the principle of recovery of the costs of water services referred to in Article 9 of Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive, WFD).

The WSC was established in 2009 by the Water Act as an ad-hoc body. Later, the legal basis for the establishment of the Council as a permanent body was created in 2013. The Water Services Act of 2019 further regulates the WSC's work. Still, the Council has in the period that followed (until the present day) continued to act as an ad-hoc body, without a staff service, with professional assistance provided by the ministry in charge of water management (MESD). The WSC is a State Budget user, with the funds for its work provided for in the State Budget.

The current legislation defines the WSC as an independent supervisory state body consisting of five members appointed for a five-year term among experts in the fields of water services, water management, economy, and public finances, appointed and dismissed by Croatian Parliament, at the proposal of the Government of the Republic of Croatia. It reports to Croatian Parliament once a year about the status in the water services sector and its own work.

The WSC's scope:

- Controls the legality of the decision on the price of water services;
- Controls the legality of the decision on the development fee;
- Controls the legality of setting the prices of special water deliveries;
- Keeps a data record about the price of water services and the development fee and makes it public;
- Initiates the adoption of regulations (in preparation)
    - A regulation laying down the method for a PWSP to manage regulatory accounting together with financial performance and accounting applicable to companies;
    - A regulation on the evaluation of performance efficiency by providers of water services (it lays down the performance benchmarks and indicators, method of collecting and submitting data to calculate the indicators, the method of measuring, evaluating and reporting on performance efficiency, and a data record keeping method).

In the procedures from its scope of work, the WSC is authorized to (part of the WSC's public authorities is outlined):

- Order the bodies that adopt documents which are the subject of control to harmonize their documents with the law and implementing regulations adopted based on the law;
- Reach a suspension decision for an illegal decision on the price of water services or an illegal decision on the development fee;
- Reach a suspension decision for any illegal document based on which the price of water services is charged or a document based on which the development fee is illegally charged;
- Reach a temporary decision on the price of water service and a temporary decision on the price of water service of water supply to other provider of water service, at a request of a public provider of water services or by official duty;
- Reach a temporary decision on the development fee at a request of a public provider of water services or by official duty.

The coming period is expected to bring further strengthening of the WSC, establishment of a staff service, i.e. of the WSC as a permanent body, and its stronger effort on initiating the adoption of regulations (the regulation on evaluating performance efficiency of PWSPs, the guidelines on a more detailed content and form of a decision on the price of water services, the WSC regulation, etc.).

1.1.2.4.2 Cooperation within WAREG – European Water Regulators

The WSC has since 2014[2] been active in the Association of European Regulators in the drinking water and wastewater sector (WAREG) which brings together 25 water regulators from Europe (Italy, UK – Northern Ireland, Ireland, Croatia, Bulgaria, Estonia, Belgium – Flanders, Belgium – Brussels, Georgia, Hungary, France, Greece, Moldova, Lithuania, Latvia, Malta, Romunia, Portugal, Portugal/Azores Islands, UK – Scotland, Albania, Montenegro, Kosovo, North Macedonia, and Armenia) from 20 European countries and 7 observers (UK-England and Wales, Sweden, Denmark, Poland, Spain, Italy/AP Trent, and Turkey).

After WAREG's intensive activities in 2019 (four conferences), the First European Forum on the Regulation of Water Services took place. Together with the WAREG members, that event was also attended by the representatives of the European Commission, associations of water service providers, academic community, water sector consultants, and other water stakeholders. Among other things, a mutual impact of the water services sector and circular economy was discussed.

The key messages from the WAREG's conferences on quality, innovations, and circular economy are the following:

- Regulation of technical quality is a significant driver for investment, and it can indirectly increase innovation rates of regulated providers of water services and their supply chain;
- Regulators that apply an output-based approach are deploying the rules set by EU legislation on water quality (DWD), water savings (WFD), wastewater treatment (UWWTD) in the national water sector;
- Regulators might promote circular economy practices by giving monetary incentives to those operators that are able to invest in recycling, energy saving and environmental sustainability;
- Governance and market reforms might be associated to economic regulation to ensure effective recycling and recovery of materials.

1.1.3 Recovery of costs for water services and water price affordability[3]

Implementation of the national and European legislation in the water sector and the water service sector (deriving primarily from the Water Framework Directive[4] and the Water Act[5]) requires the integration of economic and water/environment information, and includes an economic analysis of the sectors that use water and the sectors that provide water services in a basin area. An analysis of the recovery of costs for water services and an analysis of cost efficiency of actions/measures to fulfil the objectives of the WFD are also required. The cost recovery analysis includes the calculation of the rate of recovery of financial and economic costs for the water services, including environmental and resource costs, as well as an assessment of the contribution of environmental and resource costs for other significant uses.

The Water Services Act[6] which regulates the provision of water services, defines water services as services of public water supply[7] and public sanitation[8]. These are activities of general interest which are performed as a public service. The prices of

2 The WSC had an observer status at the WAREG from 2014, formally becoming a member in 2016.
3 Sources: Multi-Annual Programme for Construction of Water and Wastewater Structures (OG 117/15); Economic Analysis – Background document for the RBMP, 2015; River Basin Management Plan 2016-2021 (OG 66/16); Multi-Annual Programme for Construction of Water and Wastewater Structures for the Period until 2030 (OG 147/21)
4 Source: Directive 2000/60/EC of the European Parliament and of the Council of 23rd October 2000 establishing a framework for Community action in the field of water policy (OJ L 327/1, 22.12.2000)
5 Official Gazette 66/19, 84/21
6 Official Gazette 66/19
7 Public water supply is the activity of abstracting groundwater and surface water intended for human consumption and its treatment, and delivery to the end user of the water service or another water service provider, or to a public tap through public water supply structures, and management of such structures, as well as the delivery of water for human consumption by mobile means (by a water tanker truck, a water tanker vessel or in some other way), when so defined by this Water Services Act or an act regulating the management of the development of Croatian islands (Water Services Act, Article 3, point 5).
8 Public sanitation is the activity of urban wastewater collection, its treatment and discharge into a natural recipient through public sanitation structures and the management of such structures; public sanitation is also the activity of emptying and transporting wastewater from individual wastewater systems,

water services are defined based on the principle of the recovery of costs for water services as defined by the act regulating the financing of water management within the limits of economic efficiency and 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 use fee and the compulsory water protection fee on the territory of the Republic of Croatia (principle of the recovery of costs for water services (Article 3a, Water Management Financing Act, OG 153/09, 90/11, 56/13, 154/14, 119/15,120/16,127/17, 66/19).

Based on the results of the Economic Analysis conducted within the River Basin Management Plan 2016-2021, the following conclusions were made:

- Insight into the participation of significant users of the aquatic environment in the recovery of environmental and resource costs indicates that the costs to implement the Programme of Measures under the RBMP 2016-2021 (i.e. to cover the current environmental and resource costs) have been internalized to a high extent. It is at the same time stressed that the high rate of cost internalization also includes a high rate of fulfilling the polluter/user pays principle. In other words, there is a high share of direct participation of the pollution sources in covering the costs of implementation of the Programme of Measures (Nitrates Directive [9] / agriculture, IED [10] / industry). Urban development (population) is subsidized to a certain extent due to the unaffordability to cover the environmental and resource costs, i.e. unafforability of the future price of water for the population after a period of intensive investment and implementation of the DWD and UWWTD.
- Urban development with subsidized measures, as a reflection of the unaffordability to cover the environmental and resource costs, has a satisfactory return of environmental and resource costs, particularly looking at the population in the context of the recovery of costs for water services, where significantly higher rates of recovery of all the water service costs (includes environmental and resource costs and the recovery of operating costs and part of the capital costs) are recorded. A significant amount of proceeds is collected and returned through the compulsory water fees as a form of a public charge. The latest adjustment of the level of the compulsory water fees was done respecting the needs, i.e. taking into consideration the Programme of Measures under the RBMP 2016-2021, taking also account of the affordability of the future price of water for the population after a period of intensive investment.

The prices of water services are defined based on the principles of the recovery of costs for water services[11] within the limits of economic efficiency and the principles of equity, protection against monopoly and socially affordable price of water. According to the national definition of the principle of recovery of costs for water services, "Water has its economic value consisting of expenditures required to ensure its availability and protection and to construct, operate and maintain water systems, and that value shall be expressed in the price of water.[12] The recovery of such expenditures is on the one hand ensured by paying the prices of water services in a water supply area, an agglomeration or a service area pursuant to the Water Act and by paying the development fee, and on the other hand by paying the water use fee and the water protection fee on the territory of the Republic of Croatia (cost recovery principle)."

The financing system established by the Croatian water legislation makes sure that:

- The environmental and resources costs for water services – are covered from the water fees as public charges, from the national level, charged to water users (from the proceeds of the water use and protection fees);
- The operating costs for the provision of water services – are covered from the price of water services;

including the emptying and transport of sludge from small sanitary plants; public sanitation doesn't include the treatment of urban wastewater if an urban wastewater treatment plant is not in functional use, but includes the treatment if a sewer within the public sanitation system is connected to an industrial wastewater treatment plant (Water Services Act, Article 3, point 4).

[9] Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ L 375, 31. 12. 1991).

[10] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast) (Text with EEA relevance) (OJ L 334, 17.12.2010)

[11] The principle of the recovery of costs for water activities (including water services) is partly regulated by the Water Management Financing Act (Articles 3.a, 28 and 37), and partly by the Water Services Act (Art. 6, paragraphs 4 and 5).

[12] This is in line with the Communication from the Commission (EU) on the European Citizens' Initiative "Water and sanitation are a human right! Water is a public good, not a commodity!", Brussels, 19.03.2014, COM (2014) 177 final, which states "the price charged to water consumers reflects the true costs of water use.", page 4, last paragraph.

- The capital expenditures/investments related to water services – are covered from the proceeds of the water fees as public charges, charged to water users as follows: from the development fee on the local level and the water use and protection fees on the national level, as well as from the State Budget and the budgets of local self-government units. In that process, a legal avenue is open to the financing from the EU Cohesion Funds and to loan financing by the international banking institutions (IBRD, EBRD, EIB, etc.), the national lending institutions, and from the capital markets.

The full recovery of costs for water services implies the issue of the affordability of the price of water paid by the water service user. The affordability of the price of water is measured by the share of the annual amount of the cost paid for water by the household and the average annual net disposable household income. For that reason, projections of the future household income trends serve as the basis to assess the extent to which the costs of water and wastewater services might affect their material standard, which is one of the key factors when determining the affordability of the future price after the project completion.

The method of financing the implementation of the DWD and UWWTD is made even more complex by the share of an EU grant (which is today about 60% of the funds directed into infrastructural development investments) and the project feasibility/affordability, which directly depends on the future price of water. Hence, the highest risk for project implementation comes precisely from an increase in the price of water due to essential new operation, maintenance and depreciation costs which are charged in the project area. Depending on the estimation of the affordability threshold, measured by the share of annual household expenditures for water services in the average annual net disposable household income, it can be expected that in a significant number of cases affordability will be brought into question, which is particularly marked in some counties/regions with a large number of water service providers.

The affordability of the future price of water is exactly one of the leading reasons behind the reform of water service providers in a service area aimed at increasing the level of the service, reducing the costs and consequently the share of the price of water in the average annual net disposable household income. Such an approach optimizes the burden put on the population through new costs, with desired improved absorption of EU grants. The affordability of the price of water is analysed for each individual project through a feasibility study.

In accordance with a survey conducted by the European Commission and the World Bank, the upper threshold for the share of water services is estimated at maximum 4% of the average total monthly household income. When preparing projects for EU financing a more conservative approach is applied. As such, “The Guidelines for Cost-Benefit Analysis of Water and Wastewater Projects in Croatia” (2012) lay down that the annual price of water services including fees and VAT shall be between 2.5% and 3% of the average annual household income. When reviewing and approving water and wastewater projects for financing from the OPCC 2014-2020, the JASPERS consultants have recommended that the affordability threshold of between 3% and 3.5% of the average annual household income be used.

When making analyses as part of the preparation of project application forms for EU financing, the affordability rate of water services (water supply and wastewater collection and treatment) is analysed based on the following assumptions:

- The final price of water services includes the current prices for water supply and wastewater collection and treatment and an additional increase in the price of these services.
- An average household is considered to be formed by 2.9 members.
- Per capita water consumption is calculated based on a demand analysis (i.e. the average water consumption per capita per year is calculated, i.e. the average water consumption per household per year over 30 years, which is a reference economic life of a project for EU co-financed projects).
- The average annual household income in the year of submitting the project application form, which is calculated based on the available statistics (e.g. from the Croatian Tax Administration), including also available reference data about the share of shadow economy (e.g. according to the study “The Shadow Economy in Europe“ (Kearney, 2013), the shadow economy in Croatia has a share of 28.4% in the population’s income).
- The affordability rate is calculated for the project’s entire economic life.

1.1.4 Reform of the water service sector or consolidation of public water service providers

In order to strengthen the implementation and investment capacities as well as financial and technical self-sustainability of public water service providers, a comprehensive reform in the water service sector has been launched. It implies a mutually coordinated process of adopting a legislative framework and implementing investments, i.e. water and wastewater infrastructure development projects. The legislative framework consists of the Water Services Act, which is the legal basis for going through with the integration of the public providers in the water service sector, and of subordinate legislation adopted based on that Act, the most important of which is the Regulation on service areas which establishes service areas as the basic territorial units for the provision of water services.

The service areas are established in order to:

- Ensure the recovery of costs for water services as defined by the act regulating the financing of water management through a socially affordable price of water;
- Establish a single public provider of water services capable of sustainable development and maintenance of water and wastewater structures, including being capable to fulfill the commitments laid down in the Accession Treaty in the manner defined by the Water Services Act; and
- Ensure operational self-sufficiency, financial stability, and a high level of efficiency of the public providers of water services.

The Croatian Government, through the MESD and CW, prepares/implements a comprehensive reform/restructuring of the water service sector focused on merging currently more than 160 PWSPs (that provide the services of public water supply and wastewater collection and treatment in an area) into 41 more efficient providers (Regulation on service areas). The proposed integration provides good start for optimization. Larger PWSPs, in terms of area coverage and technical/financial capacity, could provide regional or sub-regional approach, where planning and managing of the system bring much more favourable results for the level of service, more sustainable long-term maintenance and harmonization with increasing standards.

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

Having analysed the stakeholders and the overall functioning of the water sector and the water service sector, it is clear that the sectors have to be considered in their integrity, i.e. nationally, but also specifically for certain areas of water service provision. For that reason, the analyses and conclusions under this Project will be done both locally/regionally (for the areas of water service provision) and on the level of Croatia in order to better connect them with the national principles and objectives, i.e. the European regulations and objectives.

1.2 Current state of water supply services provision

The Water Services Act defines **water services** as the services of:

- Public water supply[13];
- Public sanitation[14];

[13] Public water supply is the activity of abstracting groundwater and surface water intended for human consumption and its treatment, and delivery to the end user of the water service or another water service provider, or to a public tap through public water supply structures, and management of such structures, as well as the delivery of water for human consumption by mobile means (by a water tanker truck, a water tanker vessel or in some other way).

[14] Public sanitation is the activity of urban wastewater collection, its treatment and discharge into a natural recipient through public sanitation structures and the management of such structures; public sanitation is also the activity of emptying and transporting wastewater from individual wastewater systems, including the emptying and transport of sludge from small sanitary plants; public sanitation doesn't include the treatment of urban wastewater if an urban wastewater treatment plant is not in functional use, but includes the treatment if a sewer within the public sanitation system is connected to an industrial wastewater treatment plant.

A PWSP cannot perform other activities except water services. Exceptionally, a PWSP can also perform **additional activities**:

- Sampling and testing the sanitary quality of water for human consumption for its own needs;
- Building connections for users in its service area;
- Validation of water meters and preparing water meters for validation for users in its service area;
- Special water deliveries (public water supply for other suppliers, public water supply by a water tanker truck, public water supply by a water tanker vessel, acceptance of urban wastewater and sewage sludge from another provider of water services, acceptance of urban wastewater and sewage sludge into an industrial wastewater treatment plant);
- Production of energy in the process of performing water services, including sale of energy;
- Delivery of water treated at a wastewater treatment plant for its re-use, including sale;
- Management of sewage sludge generated in the process of wastewater treatment;
- Management of construction and other non-hazardous waste generated during operation and maintenance of water and wastewater structures;
- Management of a construction project when the public provider of water services is its employer;

1.2.1 Public water service coverage

When it comes to the public water supply systems, the connection rate is 89.4 %, while the coverage rate is 96% (source: Multi-Annual Programme for Construction of Water and Wastewater Structures for the Period until 2030). There are differences in the coverage rate among counties, and in particular among municipalities and towns, with lower connection rates in areas with lower population density.

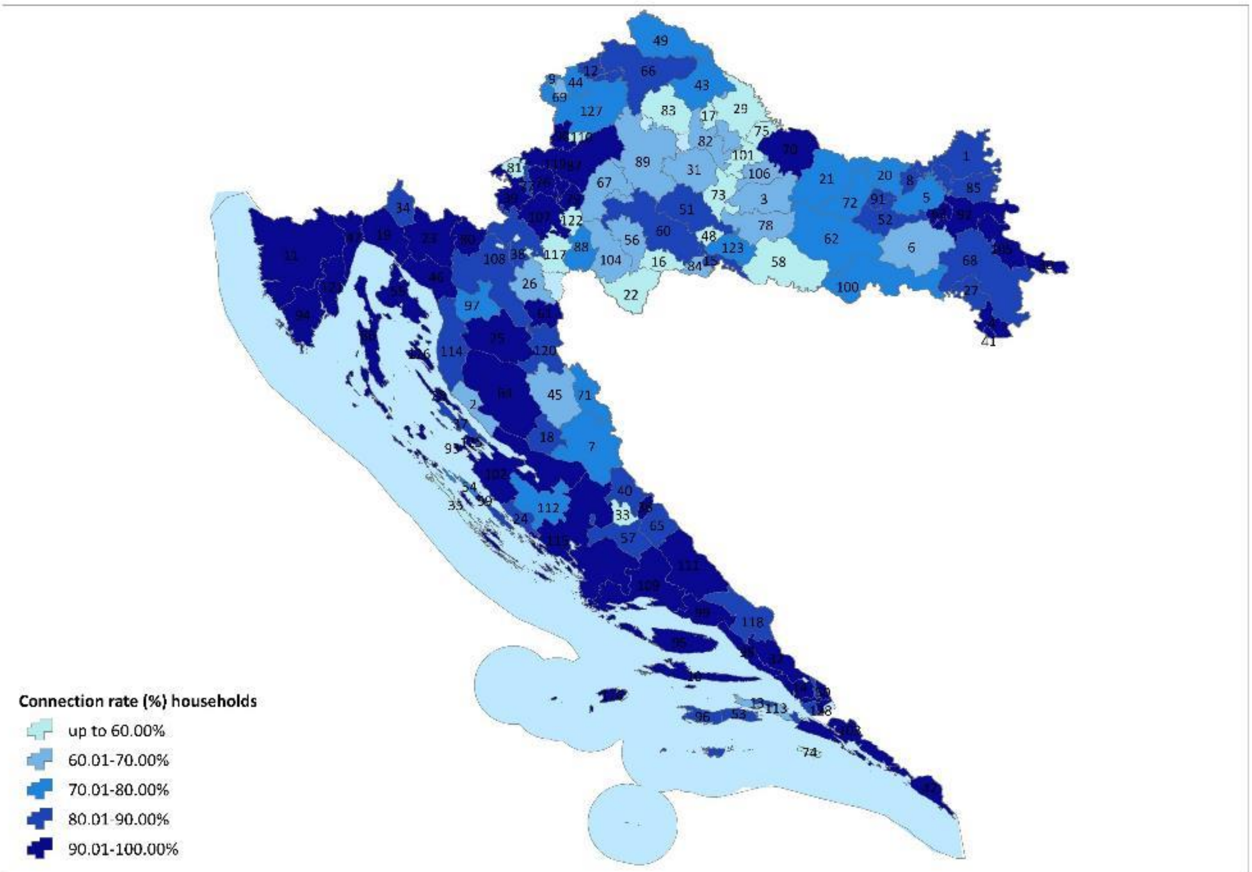


Figure 1.6. Public water supply connection rate in 2021 (PWSP level with IDs)

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 Programme for Construction of Water and Wastewater Structures for the Period until 2030).

1.2.2 Basic data about financial performance of the water services sector

For the purpose of analyzing the financial performance of PWSPs, data was collected about their performance in the last three years (Annual Financial Statements from the Financial Agency (FINA) and Audit Reports).

The financial statements are specified by the financial reporting standards, and they refer to the profit and loss account, the cash flow, and the balance sheet. However, those statements analyze/connect in detail the elements of revenues and expenses, and they don't separate them into main activities (water services) and other permitted activities. Therefore, this chapter will give estimates/distribution of elements of PWSPs' financial plans, while Chapter 1.2.5.2. will indicate the needs to prepare PWSPs' more detailed financial plans which will show the interconnection of all the elements of the financial plan, revenues and expenses, including the connection between the sources of financing and subject of financing, as well as decisions on the price of water and decisions on the development fee which have to be connected with the financial/business plan.

According to the available data[15], in 2020 the water sector had total revenues of EUR 538 million and expenses of EUR 523 million. Around 160 providers of water services (water supply, sanitation, and treatment) were analyzed. The chart presents trends in the sector's revenues and expenses in the 2017-2020 period[16], with a clear trend of higher increase of expenses in relation to revenues, resulting in a decreased profit in that period. The whole sector in the aggregate recorded a positive result for the year 2020. Pre-tax profit amounted to EUR 15 million or 2.72% of the total sector revenues, whereas profit after tax amounted to EUR 8 million or 1.46% of the total sector revenues, which indicates that the whole sector in the aggregate doesn't exceed 5% of the permitted margin.

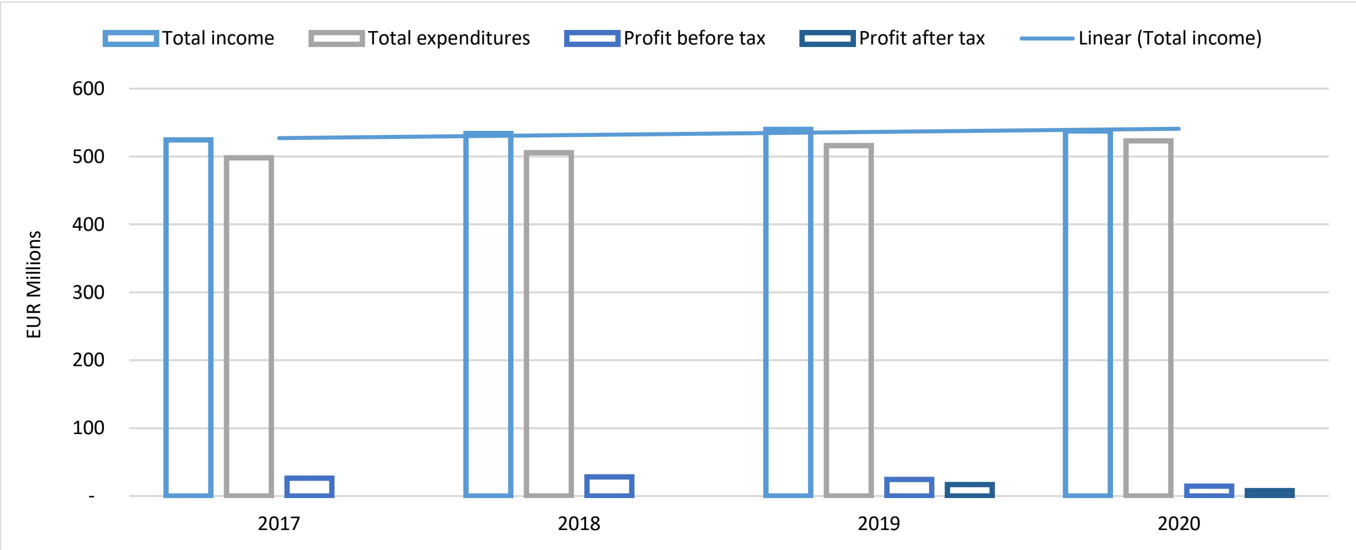


Figure 1.7. Financial performance of PWSPs (water services and other permitted activities), 2017-2020

In the basic data and reports (Annual Financial Statements, Water Service Council Report) there is no data available about expenses separately for water services and other activities, and these cannot be reliably estimated based on available data. Due to the characteristics of PWSPs' performance, the majority of their operating expenses have to with material costs, staff

[15] Annual Financial Statements and Reports on the Status in the Water Services Sector and on the Work of the Water Service Council for 2020; 2019

[16] The analyzed period covers the period from 2017 to 2020; data for the financial year 2021 isn't available.

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.

Unlike operating expenses, in part of the operating revenues it is possible to estimate the total revenues generated from water services and other activities. Based on the data about the average prices of water service providers, the volumes of delivered water, and total financial data, an analysis of financial data was made to get a picture of performance related to the water supply sector. According to the data from the recent years, total operating revenues from water services account for around 93 % of the total revenues. Operating revenues have to do with revenues generated from the performance of water services (revenues based on the price of water services and the development fee). Total operating revenues in 2020 amounted to 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 EUR 252 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.

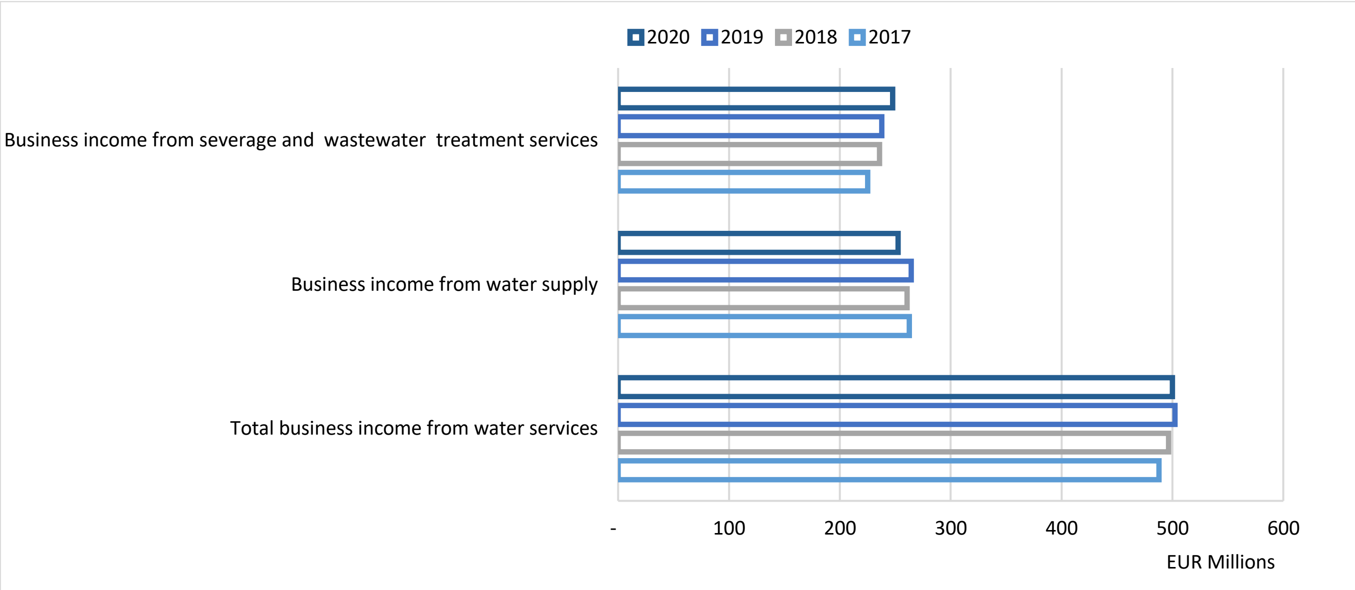


Figure 1.8. Estimated shares of revenues from individual water services (water supply, sanitation, and treatment) in total revenues from water services

Based on the analyses made, total operating revenues from water sales (water services of water supply) were also estimated at the level of 41 service areas. Total revenues from water sales are the highest in Service Area 11, amounting to a total of EUR 44 million, with average revenues from water sales on the service area level amounting to EUR 6 million. The analyses also show that the share of revenues generated from water sales to industry is higher in Adriatic Croatia, i.e., in the service areas under a higher impact of the tourist activity.

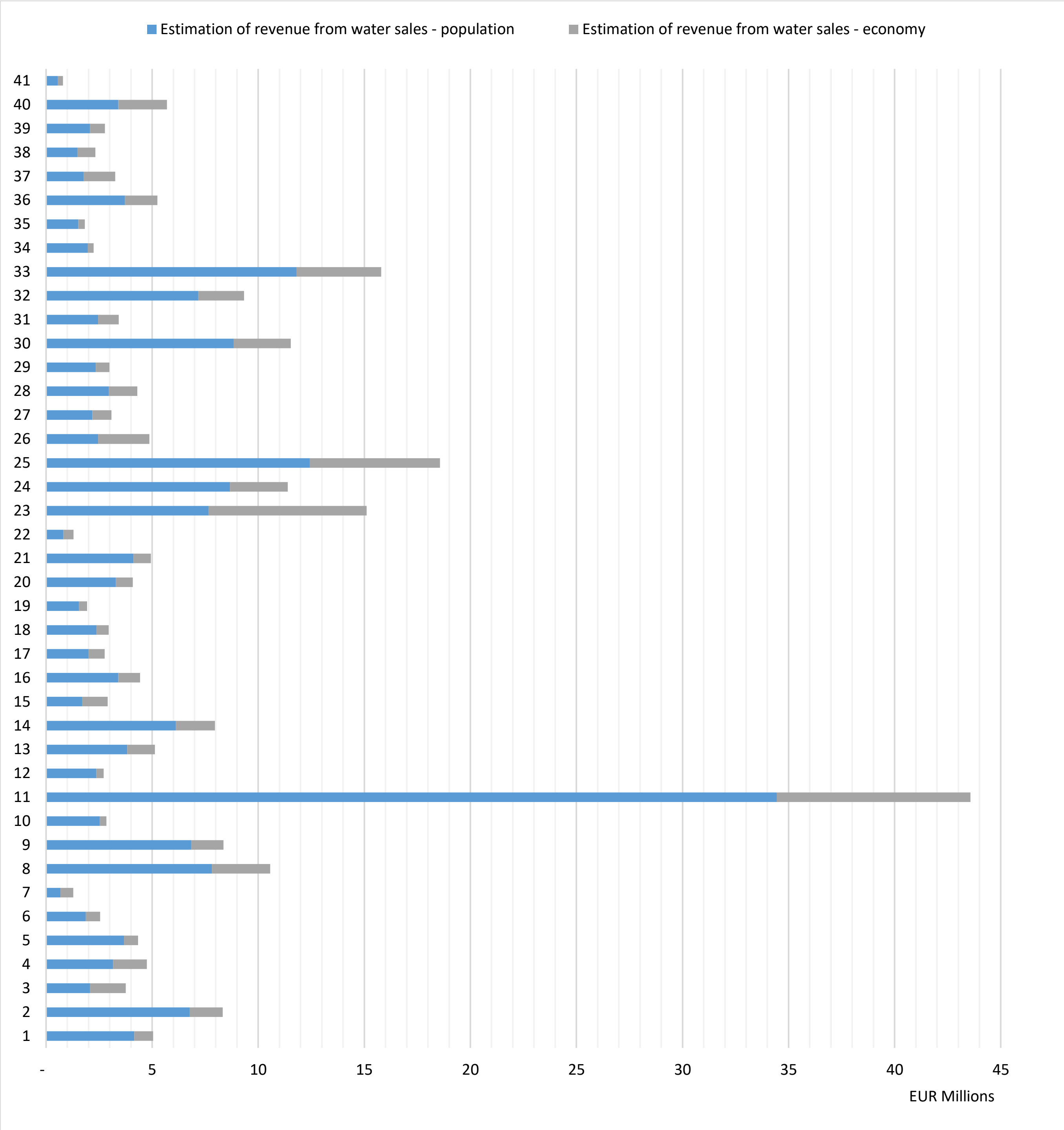


Figure 1.9. Operating revenues from water services of water supply, divided into household and industry categories (with IDs)

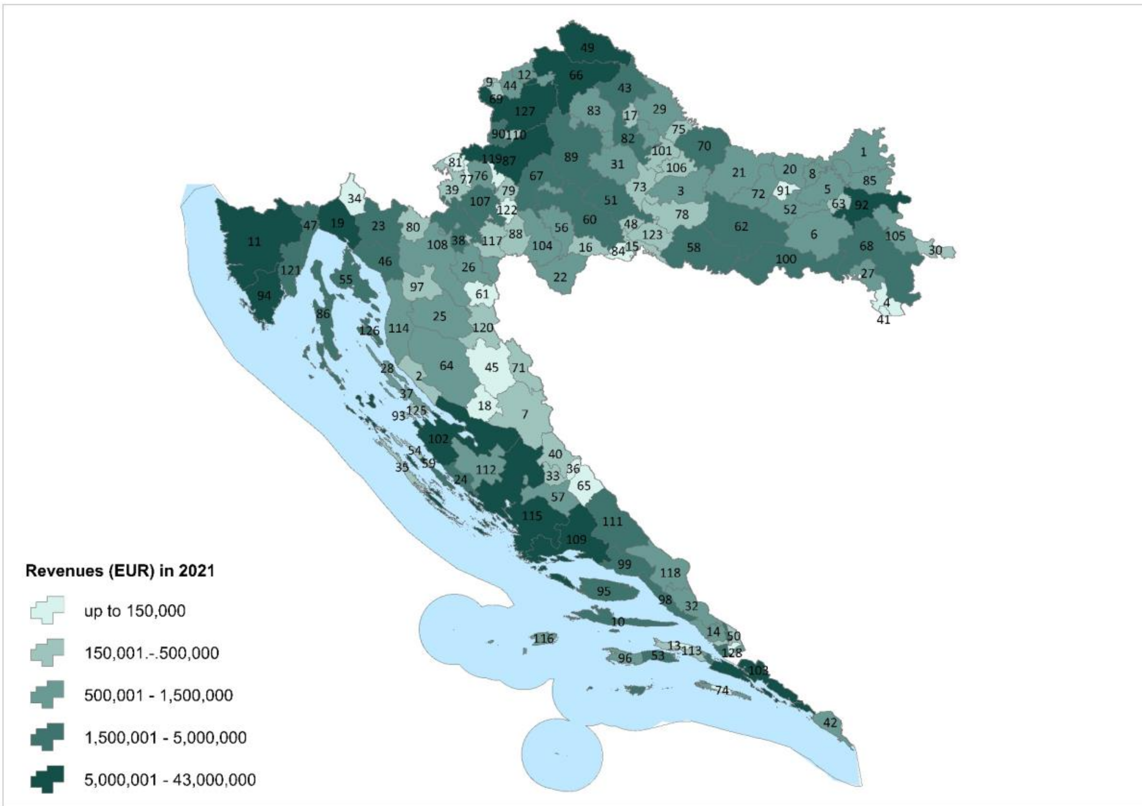


Figure 1.10. PWSPs' revenues generated from water services of water supply, 2021 (with IDs)

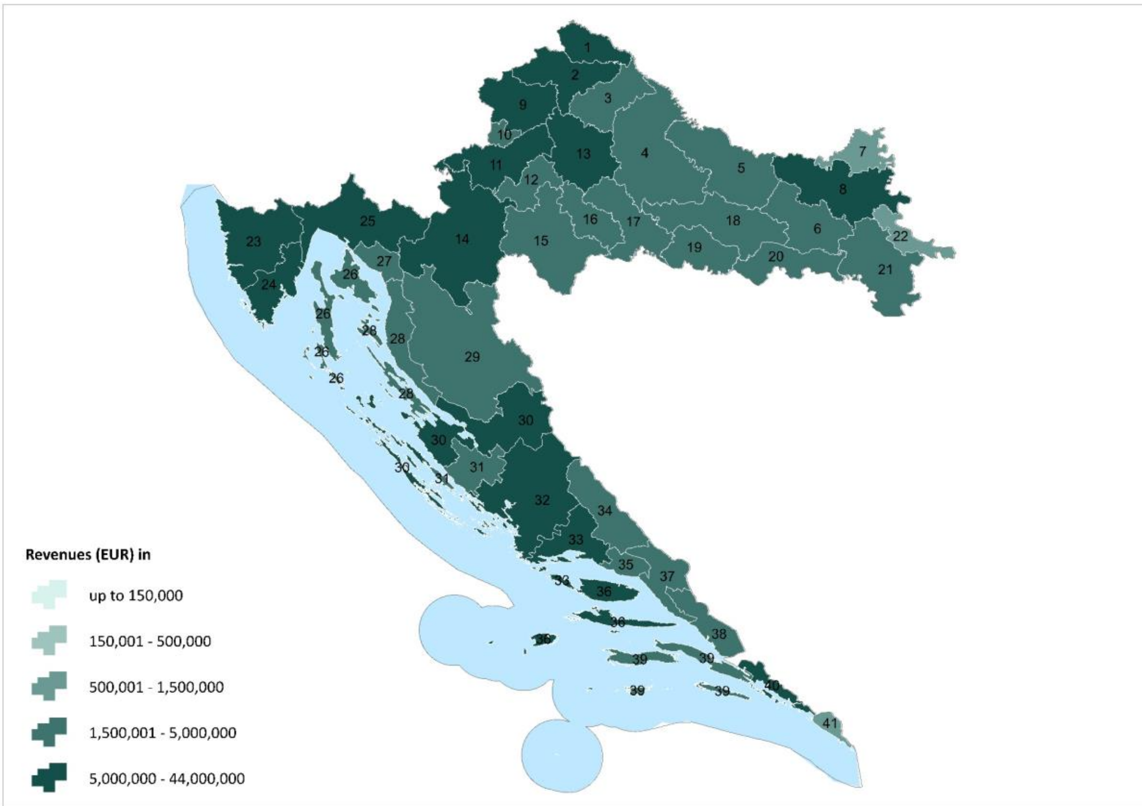


Figure 1.11. PWSPs' revenues in consolidated service areas (41) generated from water services of water supply, 2021. (with IDs)

1.2.3 Current water price

The average water price paid by the household category in 2020[17] was EUR 2.15 per m^3. The prices ranged from EUR 1.26 per m^3 to EUR 4,41 per m^3. 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 m^3, 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, or whether the water price reflects the cost generated from the provision of the services.

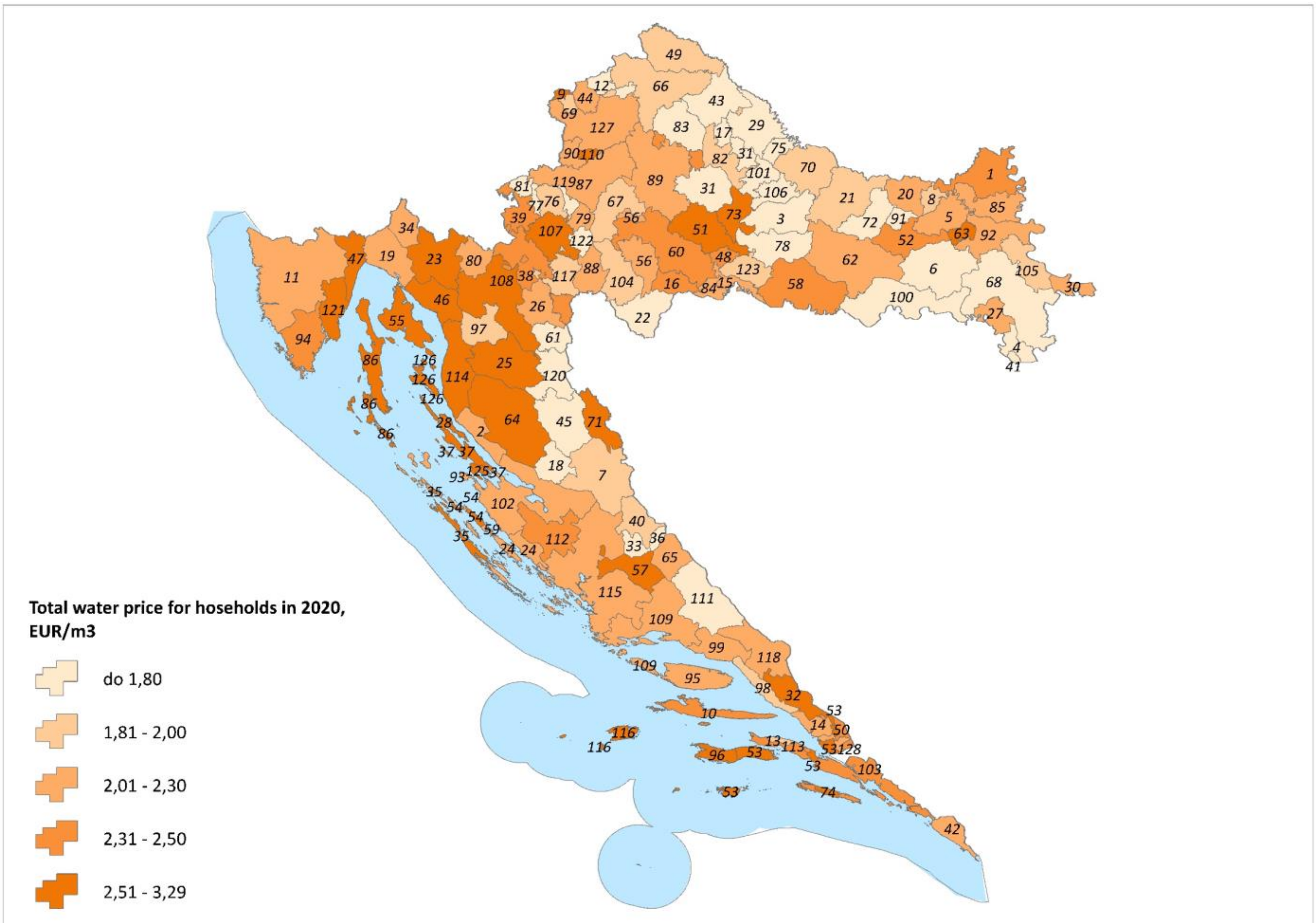


Figure 1.12. Average water price in 2020 for the household category, PWSP level (with IDs)

[17] Last available year.

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%.

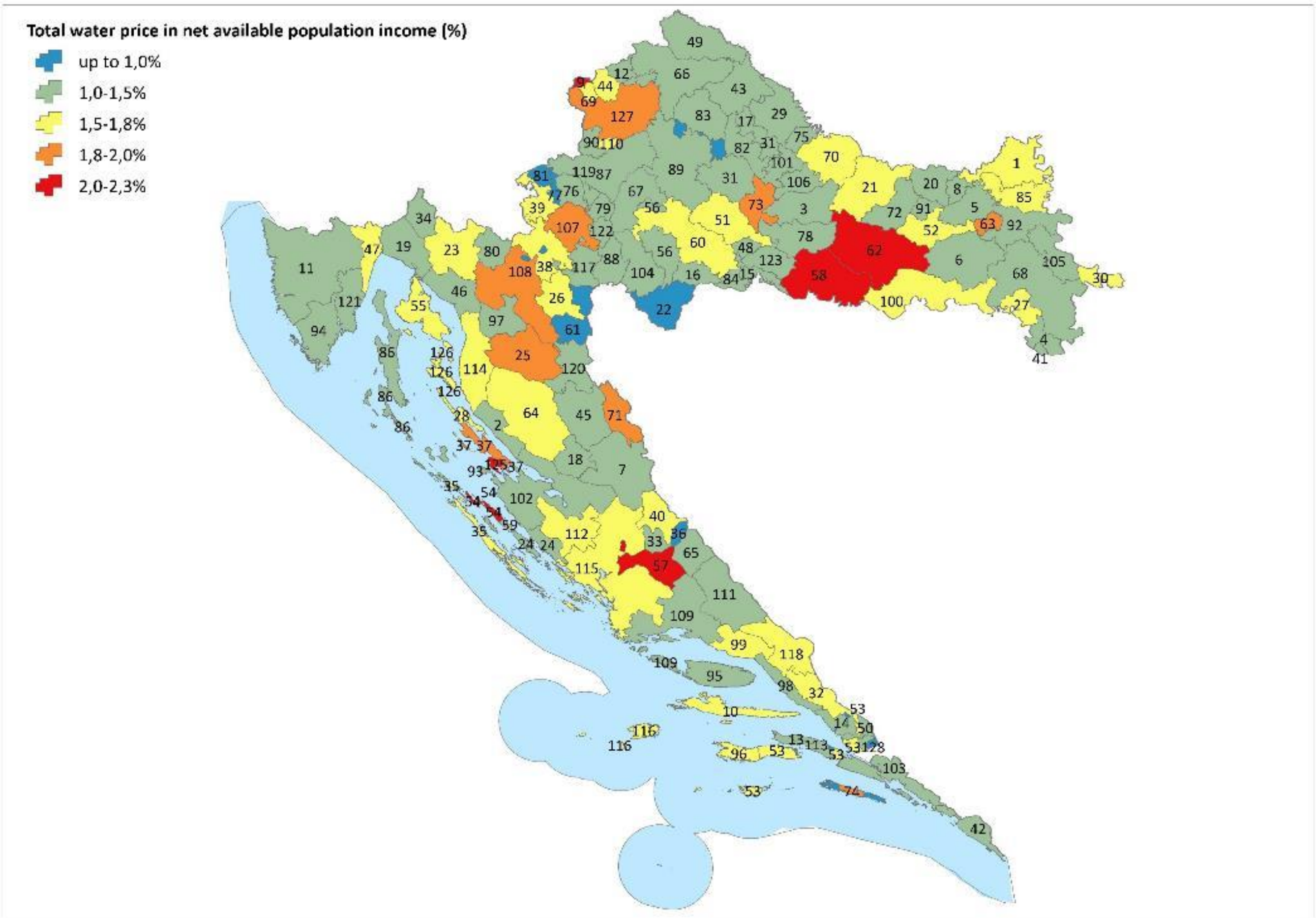


Figure 1.13. Share in net disposable household income of the average total water price in 2020 paid by citizens, PWSP level (with IDs)

For the provided service the providers form a water price which as a rule has to be correlated with the type of services. Some providers, even though they provide the services of water supply, sanitation and wastewater treatment, in the water price express only the service of water supply and sanitation (without wastewater treatment). There have been no cases recorded that the water price is composed of components which are not related to the type of services for which a particular water service provider is registered. Hereinafter the providers are classified into groups based on the type of services they specify in the water price.

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 (OG 112/10), 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 legal basis for the water fees is: (i) for the water protection fee, Water Management Financing Act (compulsory water fee), (ii) for the water use fee, Water Management Financing Act (compulsory water fee), (iii) for the development fee, Water Management Financing Act based on a decision by units of local self-government or units of regional self-government (voluntary water fee).

Table 1.3. Components of the total water price paid by users (households or industry)

Type of cost	Description of cost	
Basic water price	Fixed part (PWSP income)	Fixed part of the basic price of public water supply EUR/month
		Fixed part of the basic price of public sanitation EUR/month
		Fixed part of the basic price of wastewater treatment EUR/month
		Total fixed part of the basic price (excl. VAT) EUR/month
	Variable part (PWSP income)	Basic price of water service of public water supply EUR/m³
		Basic price of water service of public sanitation EUR/m³
		Basic price of water service of wastewater treatment EUR/m³
		Total basic price (excl. VAT) EUR/m³
VAT	VAT on variable and fixed parts (State Budget income)	VAT – Basic price of the water service EUR/m³
Water fees	Water fees (voluntary, PWSP income)	Development fee for public water supply EUR/m³
		Development fee for public sanitation EUR/m³
	Water fees (compulsory, Croatian Waters income)	Water use fee EUR/m³
		Water protection fee EUR/m³

The average water price for the PWSPs from the WST and WS groups (EUR 2.13 per m^3) is lower than the water price for the W and S groups together (2.41). This means that a slightly more favorable price of water is achieved when all the services are provided by one PWSP (WST or WS), and not when one PWSP provides only the water supply (W) service, and another PWSP only the sanitation and treatment (S) service.

Comparing the total water price paid by the population of 2.12 for the WST group (with wastewater treatment) and 2.21 for the WS group (without wastewater treatment) - one can notice that the water price doesn't "increase" with the treatment service, but rather the opposite, it decreases. First of all, the average price decreases for the WST group due to the water protection fee which decreases, but also due to the specific fixed and variable prices which are lower for the WST group because this group mostly includes larger PWSPs which achieve a lower water price on average.

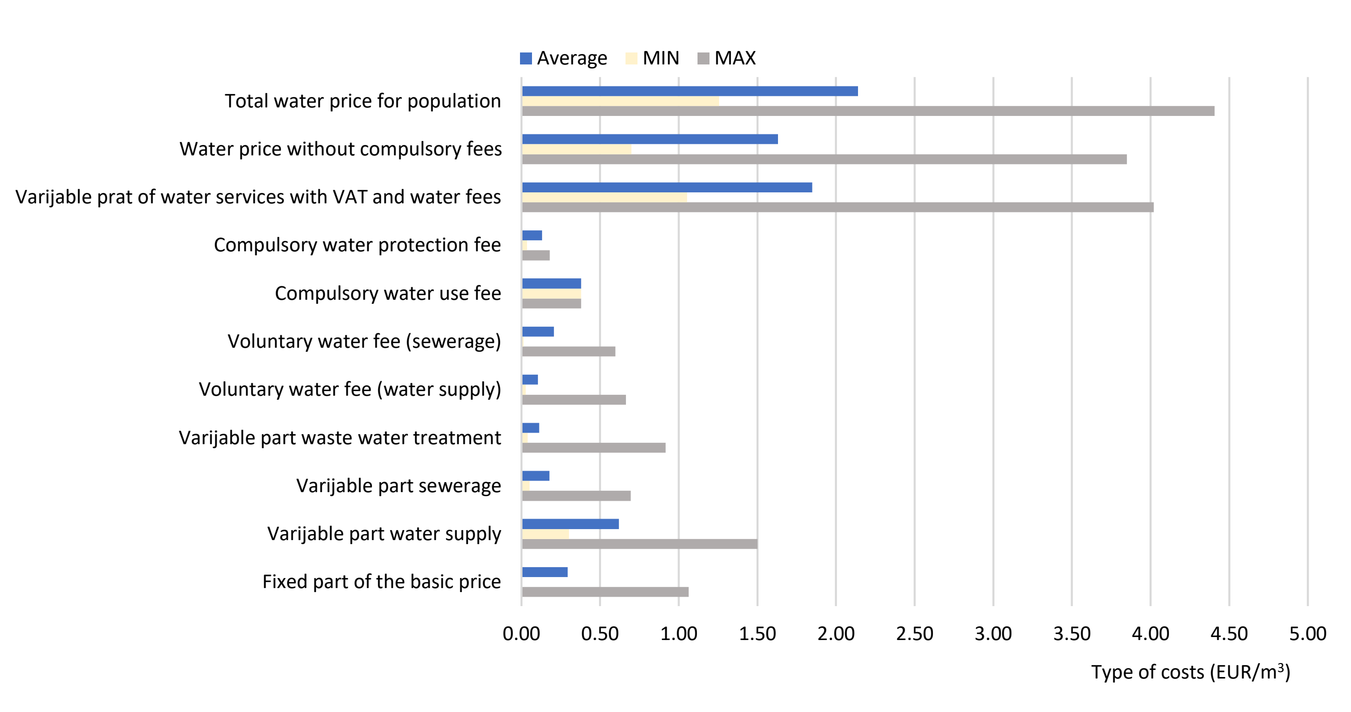


Figure 1.14. Water price structure in 2020, average of all the groups of PWSPs

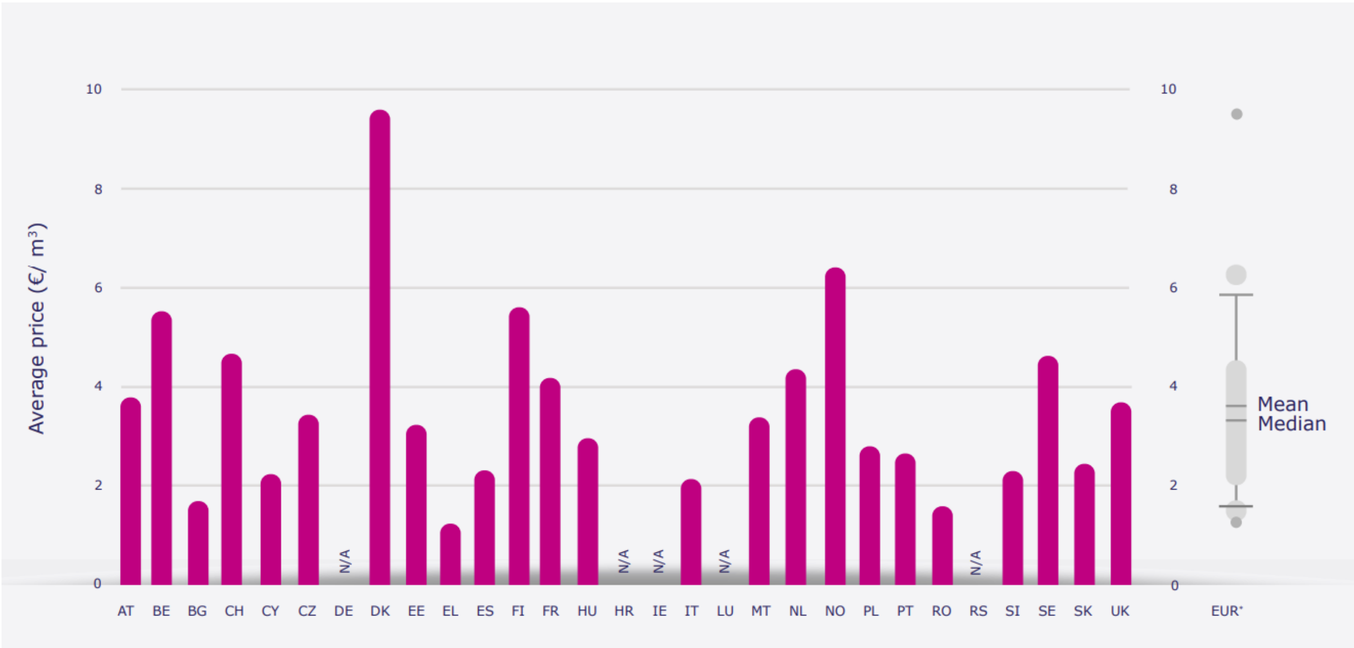


Figure 1.15. EU Countries, average price per cubic metre of water considering both drinking and waste water (2017-2019)[18]

1.2.4 Financing of services

For the provided water service, water service providers generate revenues based on the basic price of the service paid by users. In addition to the costs of water service providers, the water price also includes the VAT and the compulsory and voluntary water fees laid down by the law. These are the water price components intended for the recovery of costs of construction and development of water and wastewater infrastructure (capital costs) and water management costs (administrative costs), i.e., for the internalization of the environmental and water resource costs.

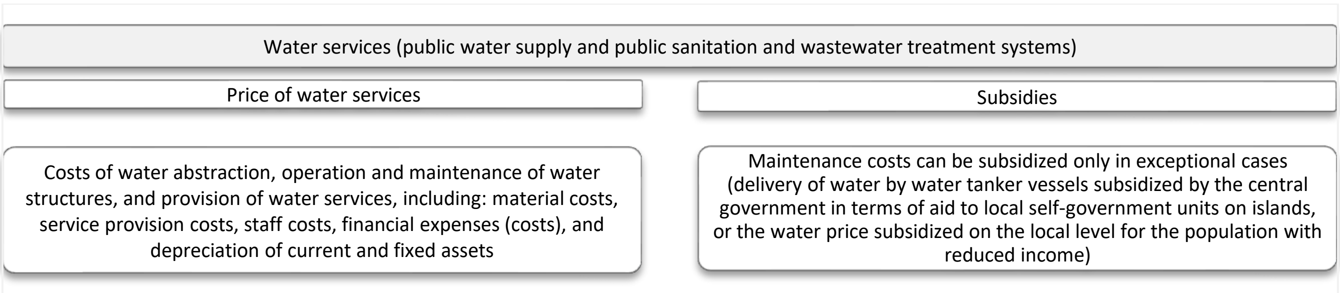


Figure 1.16. Financing of water service costs

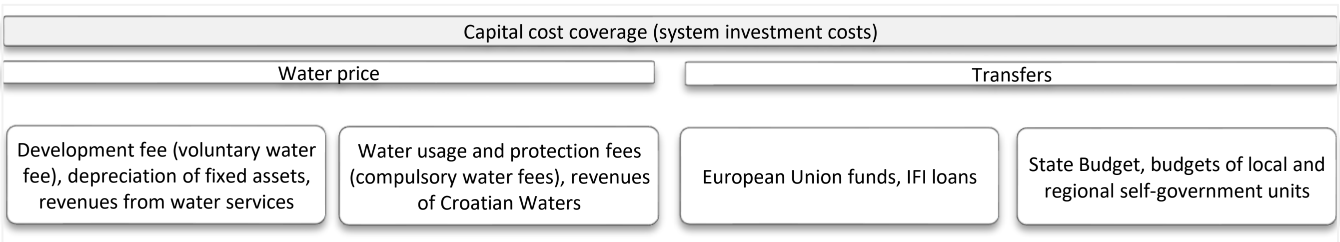


Figure 1.17. Financing of investment costs for fixed assets (costs of construction of public water supply and sanitation systems) through a combined model

[18] Source: https://www.eureau.org/resources/publications/eureau-publications/5824-europe-s-water-in-figures-2021/file

The water usage and protection fees are regulated, collected, and allocated on the national level. The development fee is regulated on the level of local self-government units and is collected and allocated in the service area. The revenues from water services are collected and spent in the area where the service is provided.

The water price is structured in line with that. The water price is the broadest category that includes 3 general and 6 particular components.

Table 1.4. Water price components[19]

According to revenue recipient	General components	Particular components	Purpose	Legal nature	Revenue of
Local	Prices of water services (PWS)	Fixed part of PWS	Operating expenses (OPEX[20]) and depreciation	Price of public service	Public provider of water services
		Variable part of PWS			
	Water fees	Development fee (DF)	Capital expenses (CAPEX[21])	Non-tax public levies (of strict purpose)	
National		Water usage fee (WUF)			Croatian Waters
		Water protection fee (WPF)			
	Tax	VAT on PWS (13%)	General budgetary spending	Tax	State Budget

The costs of PWSPs are financed according to the scheme below.

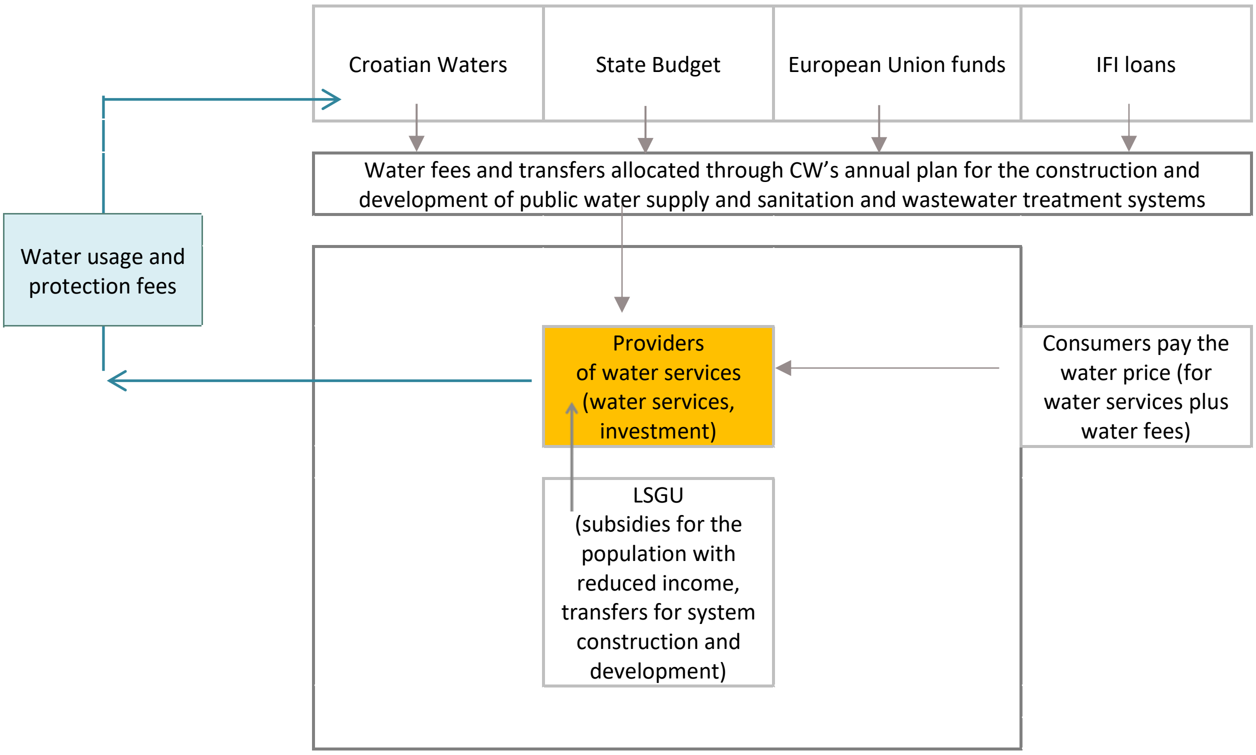


Figure 1.18. PWSPs' financing scheme

[19] Source: Report on the Status in the Water Services Sector and on the Work of the Water Service Council for 2018
[20] OPEX – Acronym for operating expenses, including costs of management, maintenance and operation of water and wastewater infrastructure; alongside OPEX, fixed assets depreciation costs are also charged, but only from the variable part of the price of water services.
[21] CAPEX – Acronym for capital expenses, including investment expenditures for the development and reconstruction of water and wastewater infrastructure.

1.2.4.1 Financing the costs of water services

The costs of providing water services are recovered through the price of water services (the components of the price of water and the way in which they are defined are described in Chapter 1.2.3) charged to the users of water services – households and industry.

The price of water service consists of fixed and variable parts. The variable part of the lowest basic price of water services depends on the quantity of provided water services, measured in cubic meters (m^3). Revenues from the variable part of the price of water services cover all the costs of management of water and wastewater structures (does not refer to the costs of development of new infrastructure) and operating costs of a PWSP, which are not fixed. The fixed part of the price of water service is paid in a fixed amount and needs to cover the fixed costs of the provision of water services laid down by the regulation on the methodology to define the prices of water services. The fixed part of the lowest basic price of water services covers the costs that don't depend on the quantity of provided water services and are incurred as the result of connecting property to water and wastewater structures.

The costs that the price of water services needs to cover are the following:

- Management costs for water and wastewater structures;
- Maintenance costs for water and wastewater structures;
- Operating costs of a PWSP;

As for the calculation of depreciation in the price of water services, according to the provisions of International Accounting Standard IAS 30, Section 13, the providers of water services in Croatia use two approaches to state aid accounting: a capital-based approach according to which aid is approved directly on behalf of shareholders' equity (equity capital aid), and an income-based approach according to which aid is entered into income over one or several periods. The providers of water services in the majority of cases use the income-based approach, book the financing source as a deferred income, and don't include the depreciation cost into the price of water service. Such an approach was particularly encouraged by towns and municipalities as the founders of public providers of water services, with the aim of keeping the price at low levels as long as possible. Consequently, certain PWSPs have developed infrastructure, i.e., valuable fixed assets and low capitalization, basing their future development on expectations of new public aid. The said approach guides the development and maintenance of systems towards further external sources of financing.

The Value Added Tax rate is laid down by the Value Added Tax Act. The VAT rate on water services is 13%.

1.2.4.2 Financing of system investment costs

The financing of costs of investment in fixed assets (costs of constructing public water supply and sanitation systems) is done through a combined model, i.e., through the price of water and through transfers. Transfers are resources from the European Union funds and IFI loans, and on the other side, from the State Budget and budgets of local and regional self-government units.

The components of the water price, i.e., the components important for the water supply sector which are included in the financing of water supply system investment costs are the following:

- Water usage fee (compulsory water fee);
- Development fee (voluntary water fee);
- Depreciation;

1.2.4.3 Water usage fee

The water usage fee is paid for the abstraction of water and other water usage and for the usage of water power, except for general water usage and free water usage. 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 amount of the water usage fee is laid down by the Regulation on the amount of the water usage fee. The current amount of the water usage fee for public water supply is 0.38 EUR/m^3 [22]. According to the data of Croatian Waters, an average of around EUR 99 million per year of the water usage fee was calculated over the last three years.

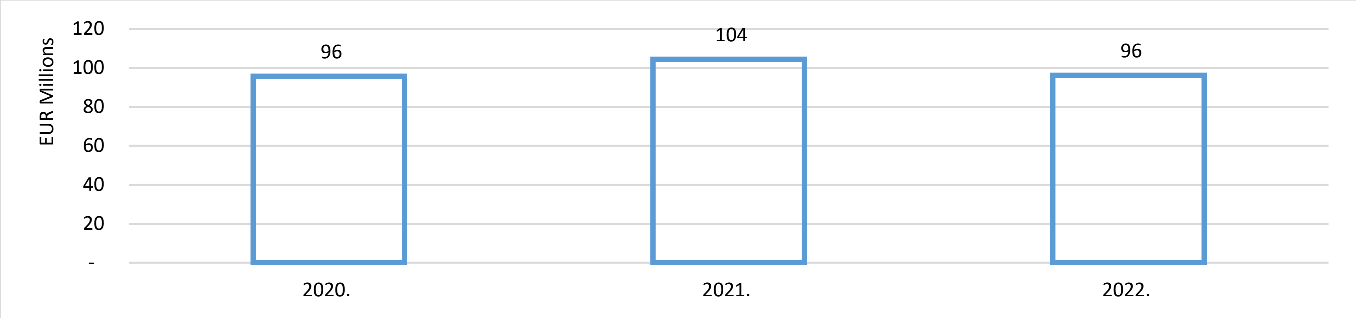


Figure 1.19. Amounts of the calculated water usage fee (in EUR per year) [23]

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 (Official Gazette 82/10, 83/12, 10/14, 32/20). It regulates the models of calculating the water usage fee (fee to cover resource and environmental costs), which is one of the original revenues of CW (the intended use of this water fee is described in Chapter 1.2.4.3). Since the specified models of calculating the water usage fee also include the level of losses from public water supply systems and make it possible to reduce the fee amount for those providers that reduce the losses to below 25 %, 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.

Activities for the reduction of losses will be monitored with the installation of meters at water abstraction points of the public water supply system 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[24]). 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.

Table 1.5. Analysis of introducing the new calculation model for the water usage fee

Water service area ID	Fee for water use from January 2023 (EUR/year)	Fee for water use until January 2022 (EUR/year)	Reduction/increase of the annual fee
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

[22] Article 4 of the Regulation amending the Regulation on the amount of the water usage fee (OG 32/20)
[23] Source: Water Management Plan 2020, 2021, 2022, authors' analysis.
[24] 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.

Water service area ID	Fee for water use from January 2023 (EUR/year)	Fee for water use until January 2022 (EUR/year)	Reduction/increase of the annual fee
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
Total	**92.245.000**	**97.154.000**	**4.910.000**

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.

The map in the figure below shows an analysis of the total amount of the water usage fee after the introduction of the new model and the incremental difference from the payment of the fee (comparison of the old and new fee payment models) by PWSPs.

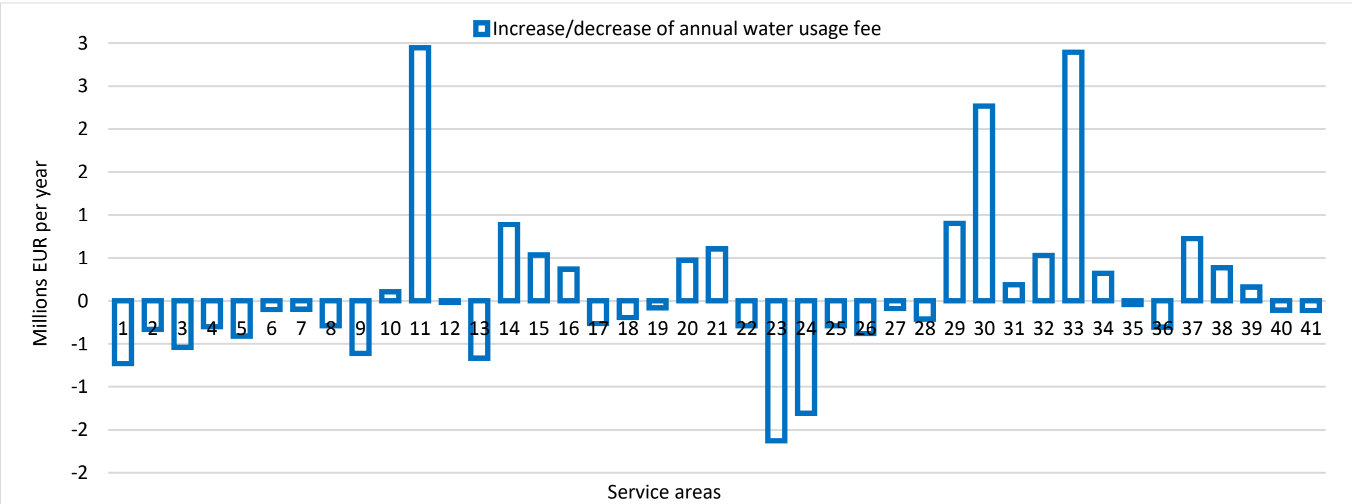


Figure 1.20. Changes in the calculation of the water usage fee after the introduction of the new model by service areas

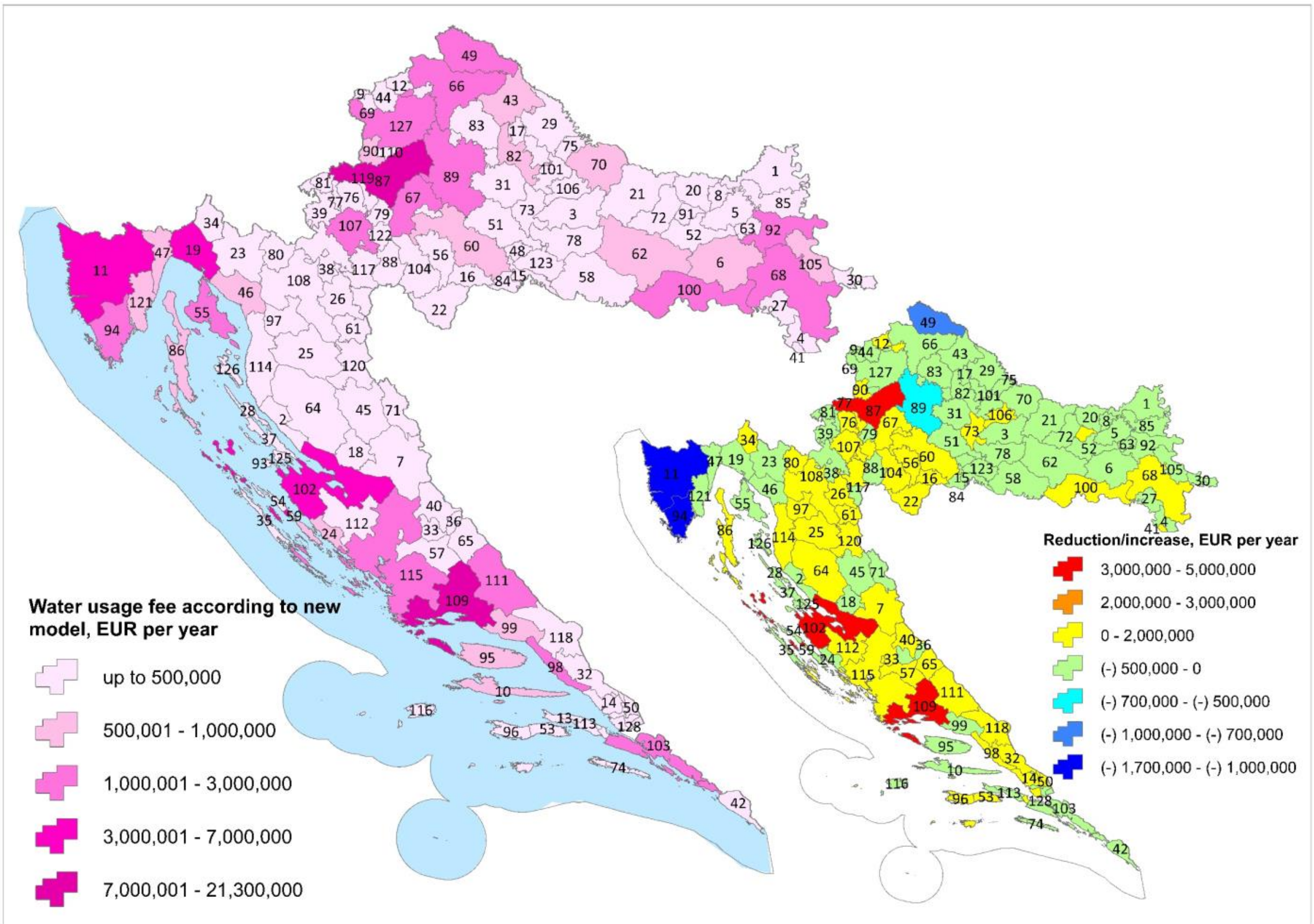


Figure 1.21. Revenues from the compulsory water usage fee according to the new model (left) and difference in revenues from the compulsory water usage fee according to the old and new models (right), PWSP level (with IDs)

1.2.4.4 Development fee

The development fee is set voluntarily alongside the price of public water supply, if so decided by a representative body of a local self-government unit. The development fee has to be paid by those who are obliged to pay the price of water service, alongside which the development fee is calculated, at an amount defined by a decision on the calculation and collection of the development fee, which also specifies in more detail the purpose for which its proceeds can be used. The basis can be the unit of measure of delivered water service or the amount of the water service price. The development fee needs to be used in such a way to ensure balanced development of the public water supply and sanitation systems in a water supply area or an agglomeration. The development fee is defined in accordance with the Water Management Financing Act, with subsidiary application of the provisions of the Water Services Act and the Water Act to the method of its definition. As of the year 2020, the development fee has been introduced by 364 of the total 555 local self-government units, accounting for 66% of the total number of LSGUs. Looking at LSGUs with the introduced development fee, their share in the total delivered water volumes amounts to 80.84%.

Analyzing the financial aspects of the development fee, based on the billed water volumes and introduced water supply development fees, in 2020 the PWSPs calculated a total of EUR 35 million of the development fee for the development of water supply systems.

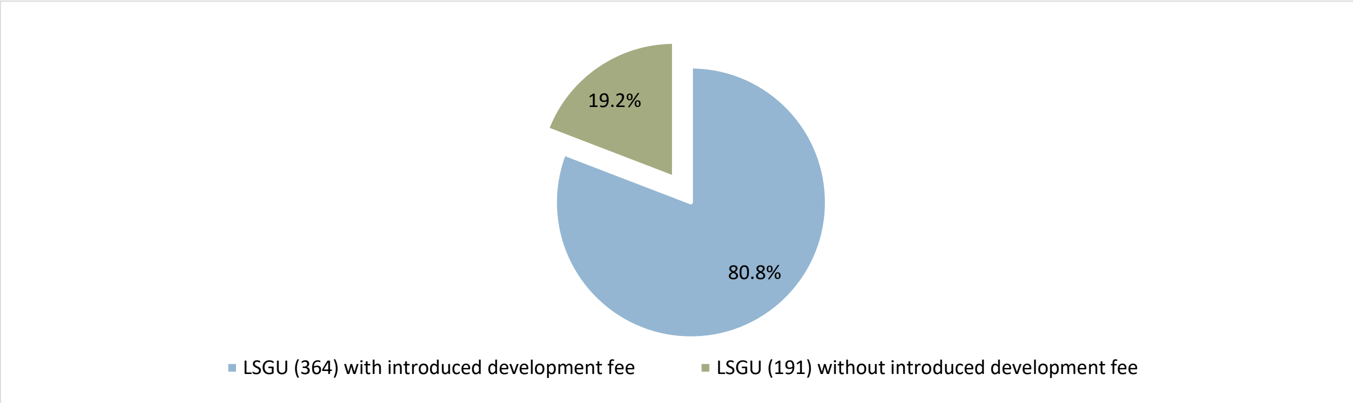


Figure 1.22. Share of local self-government units (LSGU) with introduced development fee (DF) in the total delivered volumes[25]

1.2.4.5 Depreciation

Nowadays, public providers almost as a rule don't include an adequate depreciation cost in the price of water service. This will have to change, particularly in the context of the preparation and implementation of EU projects, where the costs are analyzed in detail and the principles of applying depreciation will soon become mandatory. During EU project preparation, depreciation costs are included in the calculation of the future price of water with the following annual depreciation rates: (i) for mechanical and electrical equipment – 6.67%, (ii) for the structural part - 2%. It is assumed that depreciation will be gradually introduced until the full depreciation rate is achieved.

Using the income approach (chosen by the mayority of Public Servise Water Providers), received funds are recorded as deferred income and the depreciation of fixed (long-term) assets financed from the funds is not calculated in the price of the service. By analysing a certain number of PSWPs and the share of depreciation in total costs, the share ranges from 5 to 10% in the total costs that participate in the price of water services. Depreciation is covered by revenues from the variable part of the price of water services, regardless of the fact that, according to accounting standards, it is undoubtedly a fixed cost (maintaining low prices of water services). During preparation and implementation of water infrastructure projects, the competent Ministry issued a Guide defining that a full refund of depreciation should be achieved during the project period in the amount between 50% and 60%. In view of the obligations for the Republic of Croatia arising from Article 9 of the EU Water Framework Directive and the rules on the use of EU funds for water projects on the recovery of costs from water services, it is expected that the regulation on the methodology for determining the price of water services will address this issue.

The need for the depreciation issue to be regulated in greater detail and consistency through legislation has also been recognized in the Water Service Council Report on the Status in the Water Services Sector and on the Work of the Water Service Council for the year 2019" (January, 2021): "*The providers have widely, wherever that was allowed (and exceptionally even where it wasn't allowed), used the income-based approach, booked the financing sources as a deferred income, compensating it with the depreciation cost (distributed over a years-long depreciation period), and not always including the depreciation cost in the price of water service. Such an approach was particularly encouraged by towns and municipalities as the founders of public providers of water services, with the aim of keeping the price at low levels as long as possible. Consequently, certain PWSPs have developed infrastructure, i.e., valuable fixed assets and low capitalization, basing their future development on expectations of new public aid. Contrary to that, some providers have included the total costs of depreciation of water structures into the calculation of the lowest basic price of water services, even though part of that amount refers to the depreciation of fixed assets financed from the aid received from Croatian Waters or the State Budget, which was intended for the construction of water structures, the amounts of which were in no way allowed to be included in the price of water services. It's a fact that the Regulation on the lowest basic price of water services and the types of costs covered by the price of water services didn't select between the two models provided by the IAS. However, due to Croatia's obligations stemming from WFD Article 9 and rules on the use of EU funds for water projects related to the recovery of costs of water*

[25] Source: Report on the Status in the Water Services Sector and on the Work of the Water Service Council for 2020; authors' analysis

services, it is to be expected that this issue will be regulated with a regulation on the methodology to define the price of water services."

1.2.4.6 Investment in water supply systems over the last 3 years

According to available data, the costs of financing of water supply systems over the last three years are presented. The main sources of funds to finance the development of systems are the capital funds of Croatian Waters and transfers, which primarily refer to the EU funds.

CW's capital expenses over the last three years amounted to around EUR 40 million, and they refer to investment in the renewal and development of water supply, one third of which (EUR 13.3 million) is foreseen for co-financing the program of reduction of water losses in public water supply systems. The chart below presents trends of capital expenses in 2020 and 2021 and CW's plan for 2022. An analysis shows a significant relative increase in investment, with a comparison of the 2020 investments and the 2022 investment plan showing CW's capital expenses increasing by 36%.

The majority of funds for the development of systems in recent years has come from transfers. PWSPs are currently using funds from the 2014-2020 financial envelope. In the 2014-2020 programming period, the total financial envelope from the Structural Funds for Croatia amounts to EUR 10.676 billion. Out of that amount, EUR 6.881 billion is available from the OP Competitiveness and Cohesion for investment in growth and development – EUR 4.321 billion from the European Regional Development Fund and EUR 2.559 billion from the Cohesion Fund. From the said amounts, EUR 1.05 billion is available to Croatia from the Cohesion Fund for the process of water sector reform.

Croatian Waters and providers of water services are currently implementing a large number of projects in the sector of water supply and sanitation and treatment. Based on CW data, an estimate was made of the annual absorption of EU funds in the water supply sector. On average, around EUR 66.4 million of water supply investment was made over the last three years, but there's a visible trend of increasing absorption. During 2020, a total of EUR 41.14 million was absorbed, and the 2022 plan foresees the absorption to double to a total of EUR 82.23 million.

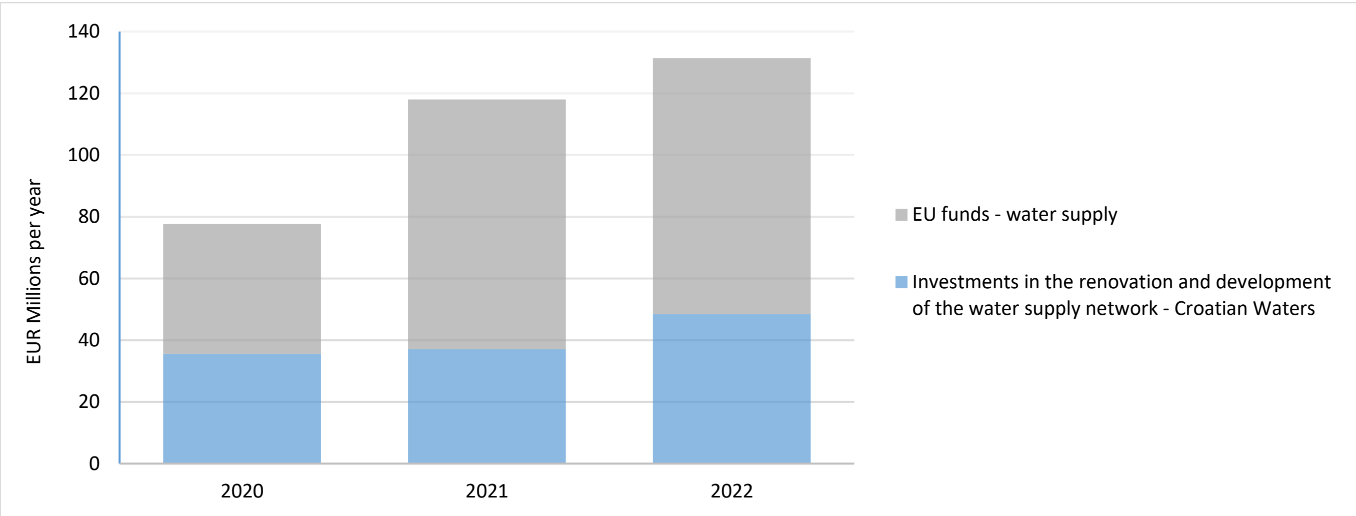


Figure 1.23. Investments in the water supply sector, 2020-2022 (EUR per year)

There's a clear constant increase of investment in the renewal and development of the water supply network. According to available data and comparing the 2022 plan and funds invested in 2020, there's a significant increse of investment by 69%, and in absolute terms the 2022 investment amounts to an estimated total of EUR 131.40 million.

1.2.5 Operational efficiency

1.2.5.1 Benchmarks and indicators of PWSPs' operational efficiency

An IT System for Reporting on Water Directives to the EC, Croatian Waters' SOV database, has been established on the national level. On the national level PWSPs enter data into the SOV through the Application for input of data on wastewater collection and treatment, and water supply. The SOV database contains data about the characteristics of water supply systems (lengths by mains categories, data about storage tanks, pumping stations, water intakes, user connection rates, etc.), as well as multi-annual data series about the abstracted[26] volumes, volumes input into the system, volumes supplied, and NRW calculations. The PWSPs also report whether they prepared the extended water balance, and if so, in what year and the ILI.

However, it can be concluded that a system to evaluate PWSPs' operational efficiency 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 operatonal 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 Water Services Act (2019) defines the following:

- Monitoring the fulfillment of general and particular conditions to perform water service activities, where the ministry in charge of water management (MESD) shall monitor the fulfillment of general and particular conditions to perform water service activities, submit an annual report to the Croatian Government and publish it on its website. The MESD shall agree on the draft report with the Water Service Council;
- With regard to evaluation of operational efficiency, PWSPs shall collect data on their operational efficiency, submit data on their operational efficiency to the WSC, and report on it;
- The WSC shall keep a record of data about the benchmarks and indicators of operational efficiency of PWSPs and publish it, if required. The MESD shall have a permanent and unlimited access to the record of data about operational efficiency of PWSPs.
- The Croatian Government shall adopt a regulation on the evaluation of operational efficiency of providers of water services. The regulation shall lay 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 keeping27;

The key performance (operational efficiency) indicators will make it possible for the national bodies to monitor the PWSPs and will provide information about the possibilities to improve the operational efficiency of public providers. They will also encourage the providers in their efforts to improve their performance and will improve the internal adoption of decisions based on the analysis of data about efficiency, with the assistance of the improved management information tools and reporting by key indicators.

A combination of adequate indicators can give an insight into the overall status of a public provider. However, indicators are a discursive tool, so they have to be easily understandable.

[26] For a full insight into and control of information about the abstracted water volumes it is necessary to install meters at water abstraction points of the public water supply system and establish a system to record, collect, analyze and control data about abstracted water volumes, which is all organized by CW (the activity is in implementation).

[27] The regulation is being drafted.

The selection of key performance indicators is a highly demanding issue which will (during the preparation of the Action Plan) be discussed at the level of the MESD-Croatian Waters-Croatian Association of Water and Wastewater Companies-PWSPs, with the initial proposal of groups of indicators presented below:

- Indicator group 1 – Costs and revenues separated by types of users and types of services (the indicators are used for the assessment of the rate of recovery of costs of water services)
  - Costs by categories of users, industry and households (industry EUR/year, households EUR/year)
  - Revenues from water services by categories of users, industry and households (industry EUR/year, households EUR/year)
  - Costs by types of services, water supply, sanitation, treatment (water supply EUR/year, sanitation EUR/year, treatment EUR/year)
  - Revenues from water services by types of services, water supply, sanitation, treatment (water supply EUR/year, sanitation EUR/year, treatment EUR/year)
  - Costs of drinking water treatment, with a reference to costs by the type of pollution removed, in order to relate them with the costs of pressure to aquatic environment (pollution indicator EUR/year)
  - Costs of wastewater treatment, with a reference to costs by the type of pollution removed, and, if applicable, pollution not originating in urban wastewater but reaching the system through seepage from urban areas or through storm drainage, in order to relate them with the costs related with different water users (pollution indicator EUR/year)
  - Revenues from compulsory water fees by categories of users, industry and households (industry EUR/year, households EUR/year)
  - Revenues from voluntary water fees by categories of users, industry and households (industry EUR/year, households EUR/year)
  - Expenses from voluntary water fees by types of use (type EUR/year)

- Indicator group 2 – Scope of services
  - Delivered water volumes by types of user categories (households m^3/year, industry m^3/year)
  - Population connected to the public water supply system and population with individual water supply (number, %, m^3/year)
  - Population connected to the public sanitation system (with or without treatment) and population connected to individual sanitation (septic tanks/cesspits) (number, %)
  - Ratio of summer-winter consumption (%)
  - Water losses in the water supply network (%, m^3/year, ILI, m3/service connection/year, m3/km/year)
  - Individual consumption meters (number, % of the total number of metered places)

- Indicator group 3 – Specific costs
  - Total costs of public water supply / Invoiced volume (EUR/m^3)
  - Total costs of public sanitation / Invoiced volume (EUR /m^3)
  - Total costs of treatment / Invoiced volume (EUR /m^3)
  - Total current costs (EUR/year)
  - Staff costs as a share of current costs (%)
  - Electric energy costs as a share of current costs (%)
  - Costs of outsourced services as a share of current costs (%)

- Indicator group 4 – Cost/revenue ratio
  - Total billed water supply revenues (EUR/year)
  - Total really collected revenues from water supply service (EUR/year)
  - Total billed sanitation revenues (EUR/year)
  - Total collected revenues from sanitation service (EUR/year)
  - Collection rate (%)
  - Ratio of total revenue and total costs (%)
  - Ratio of revenues and operating costs (%)
  - Rate of debt service coverage and cash payments (%)
  - Debt ratio (%)

- Indicator group 5 – Specific indicators
  - Total revenues per population to which the water supply service is provided (EUR/pop./year)
  - Total income per population to which the sanitation service with or without wastewater treatment is provided (EUR/pop./year)
  - Average price of a new water supply connection – investment (EUR/connection)
  - Average price of a new sanitation connection – investment (EUR/connection)
  - Number of employees per 1000 water supply connections and per 1km (empl./1000 connections, empl./1km)
  - Number of employees per 1000 sanitation connections and per 1km (empl./1000 connections, empl./1km)
  - Employee structure (% of employees in administration, % employees in technical service, and % of employees by educational qualifications)
  - Employee structure (number of employees, separately by administration and technical service, by water supply connection, number of employees, separately by educational qualifications, by water supply connection[28])
  - Employee structure (number of employees, separately by administration and technical service, by sanitation connection, number of employees, separately by educational qualifications, by sanitation connection)

- Indicator group 6 – Renewal of infrastructure and new investment
  - Applied depreciation rate (%)
  - Investment in the renewal of water supply network (EUR/year, km/year)
  - Investment in the restoration of sanitation network (EUR/year, km/year)
  - Investment in the reduction of losses, water supply (EUR/year, EUR/m^3 of reduced loss)
  - Leakage repair, sanitation (intervention/year, intervention/total number of km of network)
  - Capital investment in the development of water supply system, new structures (EUR/year)
  - Capital investment in the development of sanitation system, new structures (EUR/year)

1.2.5.2 PWSPs' business plans

The main indicator of the sustainability of provision of services of any public provider is its business plan. The business plan has to be complete and straightforward and shall provide the key information about the planned activities and goals in the service area.

Looking at the practice of water service providers within the European Union, the business plan should be directed at:

- An affordable price of water services for users (water price);
- A high level of water services for users (service coverage and quality);
- Long-term resilience to change (demand, water availability, pressures in the basin, climate change);
- A higher level of innovation and digitization, with an environmental footprint as small as possible (water status)

Over the last two decades, and in particular since joining the European Union, the sector of water and water services in Croatia has been characterized by strategic advances which are the result of the adoption of a set of legal regulations, as well as of planning and intensive investment in the construction of water and wastewater structures. In that way, the baselines and visions/goals in the provision of water services have been improved on the national level, with a significant financial assistance that is provided to the local level for the development of water and wastewater infrastructure.

The same period lacked stronger planning on the local level or the level of service areas, which is understandable since the sector was significantly transformed and a clear guidance and assistance from the central government was expected. It can be concluded that the course today is clear and that it needs to be consistently integrated into the business plans of public providers of water services. Such an approach will strengthen the established institutional framework (line ministry, Croatian Waters, PWSPs) and will complete the planning/cycle, which will lead to improved sustainability of the provision of water services.

The principles and goals in terms of regulations and plans lowered from the national to the regional/local level or the business level of PWSPs are controlled through the indicators of PWSPs' performance. Such a system gives an insight into legality in the

[28] In case of collective meters (buildings and the like)

field of setting the price of water services, but also into the level of application of incentive water service pricing policies which affects the PWSPs' performance, users, and the aquatic environment.

The business plan essentially shows where a PWSP stands today, where a PWSP wants to be in a four years' time, what activities/measures will get it there (structural or non-structural), and with what costs and mechanisms of financing. The plan is prepared by the PWSP in cooperation with its founders, preferably in consultation with service users (in particularly households) and contains the results/effects that the PWSP intends to deliver to the service users and the environment.

The Water Services Act requires the PWSPs to adopt a business plan for a four-year period, to be reviewed and revised once in a calendar year. Organized by the MESD, **guidelines are being prepared** for the preparation of an improved PWSPs' business plan, which identify the type of information or structured data of PWSPs' business planning, which are intended to be used (or are necessary) to monitor performance, i.e., to monitor the prices of water services. Consistent, reliable, and connected data will make it possible to assess the business plan, revenues, costs, business results, and the related prices of water services and development fees.

In contextual terms, the business plan needs to show that a PWSP is strong enough to remain sustainable even under the impact of changes in its surroundings, and to, within realistic limitations, present the most feasible plan for the provision of water services in a service area. When adopting business plans, it is important for a PWSP to properly recognize the potential in the improvement of its operation and management capacities. The actions that need to be taken can be identified at different levels, for example, installing individual water meters for all users (households and industry), updating the user database, introducing an improved collection system, connecting collection and water supply/sanitation system with the exact location (establishment and work in GIS environment), extending the area of service provision (capital investment, new users), measures (investments and/or processes) which will improve the technical and financial impacts of service provision, including the reduction of losses.

In terms of content, the business plan needs to contain the following:

- Basic information
  - Physical scope of services
  - Risk analysis (safety of water supply, climate change)
  - Connection with goals in the sector of water services
  - Basic objectives of the business plan for a four-year period

- Planning indicators
  - Planned drinking water and sanitation sales
  - Planned number of employees

- Financial plan
  - Revenues
    - From water services from revenue from other permitted activities
    - From the price of water services from revenue from the development fee
    - From public water supply, public sanitation, and wastewater treatment
    - From the fixed network from revenue from mobile delivery of water services
    - From credit, loans, and other borrowing
    - From capital (project financing) and non-capital revenue (water price subsidies to be separated from other non-capital income)
  - Expenses
    - Fixed costs and variable costs
    - Costs of water services and costs of other permitted activities
    - Costs attributable to the price of water services and costs attributable to the development fee
    - Costs of public water supply, costs of public sanitation, and costs of wastewater treatment
    - Costs of fixed network and costs of mobile delivery of water services
    - Expenses by categories OPEX, CAPEX, and depreciation
    - Expenses at least into: material costs (incl. staff costs, energy costs, costs to procure chemicals to maintain water quality) and depreciation costs
    - Depreciation costs for water and wastewater structures and depreciation costs for premises

    - Depreciation costs related to expenses and not related to expenses
    - Costs of own work and outsourcing costs
  - Profit
    - Profit and loss from water services and other permitted activities

- Fixed assets investment plan
- Plan of construction of water and wastewater structures
  - Planned funds
  - Sources of financing for the Plan of construction of water and wastewater structures

- Plan of maintenance for water and wastewater structures
- Organizational structure (development of capacities) and a general job plan

From all the regulations that regulate the water services, it can be concluded that PWSPs' business plans aim to show that the water services are provided in a sustainable manner, which means that the systems are self-sustainable, that the PWSPs in addition to (together with their owners) having financial and institutional obligations to provide the services also have financial, management and technical capacities to reliably achieve the required effect in the specified period. Improvements of PWSPs' operation and management capacities include good knowledge about the current status, structuring and connecting finances, integrated IT system management, improvement of human resources, setting clear goals, investing, and monitoring results.

Although the majority of PWSPs have established the baseline (record of the current status), the coming integration of the PWSPs requires the revision of baseline values as the key information for the future business plan. Achieving financial sustainability, increasing revenues and/or reducing costs, developing short- and long-term objectives in the provision of services need to be transformed into sustainable business plans. On the one hand, it is expected that the process of integration of the PWSPs will contribute to the availability of human resources. On the other hand, nationally set (ambitious) goals are characterized by high investment cots (construction of systems, and partly also investment into IT systems). Furthermore, a significant number of PWSPs is already implementing investment projects with the help of EU or government grants, a component part of which is also the establishment of a formal project/system/PWSP structure. This illustrates the complexity of the process of creating the first business plan of the integrated PWSPs through which it is necessary to integrate the existing system/PWSP actions, projects in implementation, plan further system development, as well as improvement of operation and management capacities. The development of business plans for the coming planning periods should be made easier because already from the preparation of the first "new" plans it will be possible to obtain measurable results and improve the most critical aspects in the planning.

1.2.5.3 Efficiency benchmarks and indicators related to the reduction of losses

The reduction water losses from water supply systems is often considered one of the important methods of improving the efficiency of water supply services in terms of resource use. However, the costs and effects of water loss reduction have to be analyzed in relation to its benefits in order to define the optimum targeted level of water losses.

A cost-benefit analysis should analyze the main methods of reducing system leakages which are based on investing in:

- Metering;
- Pressure reduction;
- System reconstruction (rehabilitation of pipes);

The selection/proposal of adequate indicators is key when identifying the national water loss reduction goals (policies). It is therefore beneficial to make a related analysis of uncertainty and sensitivity of investment costs (metering, pressure reduction or system reconstruction) in order to define the most relevant data for the analysis and establishment of loss reduction policies on the national level. Experience of EU countries shows that water loss management isn't always directly cost-effective for the providers of water services that operate with moderate levels of system leakages. Costs of investment in metering and system reconstruction were the most influential factors in the sensitivity analysis but were, as demonstrated by experience, precise enough to establish the loss reduction policy.

The calculations of the economic levels of leakage applied so far (in the conceptual solutions) didn't give uniform (targeted) levels of leakage which might be generalized for all providers of water services. The Croatian example shows that the targeted levels have to be defined individually, for each PWSP.

Within this project, available data related to the water losses were collected. Futher more, the efficiency benchmarks (indicators) for water loss reduction were calculated and presented in greater details in Chapter 2. (IWA water balance, share/volume of the non-revenue water and comparison of water (extended) balance components in Chapter 2.4.2; ILI values, l/service connection/day, l/service connection/day/m of pressure, m3/km of mains/hour in Chapter 2.5). References on good practice on leakage management are presented in Chapter 1.3.2.2.

1.3 Analysis of DWD RECAST connected to water leakage levels

1.3.1 Provisions, required assessments

The DWD Recast also puts focus on water losses with a clear timeline to identify the (targeted) level of water losses, preparation of action plans (with the defined loss reduction measures), and their presentation to the European Commission.

DWD Recast in relation to the water leakage (Article 4.3) stipulates that Member States shall ensure that an assessment of water leakage levels within their territory and of the potential for improvements in water leakage reduction is performed using the infrastructural leakage index (ILI) rating method or another appropriate method. That assessment shall consider relevant public health, environmental, technical and economic aspects and cover at least water suppliers supplying at least 10,000 m 3 per day or serving at least 50,000 people.

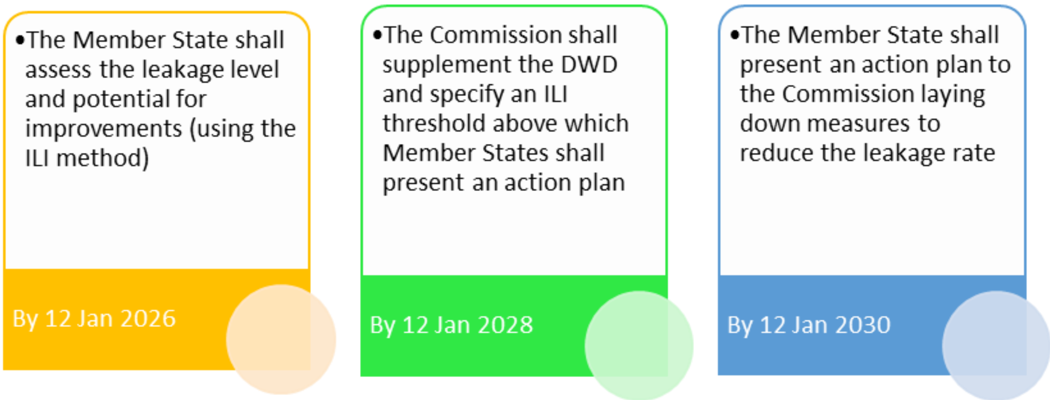


Figure 1.24. DWD Recast timetable related to action plans and ILI indexes

Even though the requirements concerning the potential for improvements in water leakage reduction using the ILI rating method or another appropriate method can be interpreted very widely, and even though the question which "relevant" public health, environmental, and economic aspects shall be considered when assessing the levels of losses and potential for their reduction is vague, by preparing a draft Action Plan within this project (end of 2023) Croatia will perform initial assessments of water leakage levels and of the potential for improvements (using the ILI method or appropriate method), thus creating a solid basis for an improved assessment (update) by the end of 2025, the results of which will be presented to the Commission by the specified date (12 January 2026).

The provisions of the DWD Recast and the required assessments related to water leakages have to be read in relation to Article 4.3, but also in relation to the risk assessment (Articles 7 and 8), and in particular Article 9 which refers to risk assessment and risk management of the supply system.

Article 7 of the DWD Recast states that Member States shall ensure that the supply, treatment, and distribution of water intended for human consumption is subject to a risk-based approach that covers the whole supply chain from the catchment area, abstraction, treatment, storage and distribution of water.

The risk-based approach shall entail the following elements:

- risk assessment and risk management of the catchment areas for abstraction points of water intended for human consumption (the assessment shall be carried out by 12 July 2027);
- risk assessment and risk management for each supply system that includes the abstraction, treatment, storage, and distribution of water intended for human consumption to the point of supply carried out by the water suppliers (the assessment shall be carried out by 12 January 2029);
- risk assessment of the domestic distribution systems (the assessment shall be carried out by 12 January 2029);

In particular, the provisions of Article 9 "Risk assessment and risk management of the supply system" require:

- that the risk assessment identifies the hazards and hazardous events in the supply system and includes an assessment of the risks they could pose to human health through use of water intended for human consumption, taking into consideration risks stemming from climate change, leakages and leaking pipes;
- that on the basis of the outcome of the risk assessment Member States ensure that risk management measures are taken.

The time schedule for the risk assessment corresponds to a significant extent to the time schedule for the assessment of leakage levels and potential for improvements in water leakage reduction, and there is clear mutual impact of these two elements. The main risks will be identified in this Action Plan and the related measures, which will be a good basis for more detailed risk assessment and risk management for abstraction points, systems, and domestic distribution systems. In addition, more detailed risk assessment (2027, 2029) will definitely to the relevant extent be integrated into the coming Loss Reduction Action Plan which will be presented to the European Commission (2028, 2030).

1.3.2 Expected reporting obligations connected to water leakage levels

It is to be expected that the reporting obligations (connected to water leakages) will focus on the annual averages of the leakage indicators identified/selected on the basis of good practice and reasonable level of accuracy. In order to calculate the indicators, it will be necessary to apply consistent and reliable methods and the usual assumptions. That will ensure consistency in PWSPs' reporting and comparison of their efficiency.

In order to ensure transparency of calculating the indicators and reporting, it is necessary to develop a national methodology/guidelines or develop a reporting content and form which will be used by PWSPSs and which will be harmonized if needed. The guidelines have to establish the concepts of good practice and consistent approach which PWSPs have to follow. The focus definitely has to be put on the quality of data and application of valid statistical approaches.

It has to be noted that the selection of measures will define the approach to leakage reduction that a PWSP is taking in a certain planning period. There is an assumption of a continuous improvement of access to the analysis of PWSPs' leakages through innovations, new technologies, and improvement in data quality, so the reporting approach must not prevent PWSPs from applying more innovative measures based on the improvement of data quality, which will probably be achieved in the long run.

Accurate and clear reporting on leakages is an important part of leakage management and reduction, for which available data and resources have to be used. It is necessary to come up with a water leakage monitoring and reporting program that gives insight into that program to create trust in data and processes, improve the resilience of processes, and give better reporting accuracy and consistency.

Reports definitely have to encompass the following key results distributed by the following groups:

- Improvement in data quality;
- Simplifying/digitizing the water balance;
- Key performance indicators (strategic, implementing);
- Information on PWSP's leakage management capacity and teams' capacities;

1.3.2.1 Relevant reports and views

Reporting (May 2021, EurEau - European Federation of National Associations of Water Services) [29]

The majority of EU countries have schemes for collecting data related to leakage. In most cases, the data is collected by a national authority or agency such as a statistics agency. In fewer cases, this role is covered by the national association or a national utility. In most cases, there is a national law or regulation requiring data collection. However, the level of response to this requirement or the level of data consistency and accuracy is not clear.

Despite the fact that data must be communicated to central agencies or authorities, EurEau research showed that there are only a few national schemes or norms established for the network water balance and leakage calculations and certainly there is no EU guideline on this.

The DWD recast will no doubt 'shake the scene' of leakage reporting for the first time. Although the Commission has not dealt with this subject in depth, they are expected to be more involved if poor local and national figures are reported.

A recent poll amongst EurEau members indicated that by far most countries prefer to report losses:

- in m^3, or
- as percentages to the supplied or abstracted water, with
- m^3/km (losses/network length) coming a close third.

ILI is the least popular indicator, only used by some large water companies. From the same poll, it is evident that a national harmonized framework, rules for calculating the water balance and reporting the indicators is not always established. Even in the cases where a national framework exists, the compatibility between the different systems is not known. Significant differences may exist in the calculation timeframe, the level of data reliability required and the uncertainty evaluation.

Most of the utilities serving more than 50,000 people can produce and report data regarding water abstraction and consumption as well as data for network length and number of connections. For the group of smaller utilities, this capability is limited and probably not as reliable as a proper reporting would require. 'Small' utilities must not be underestimated; they supply approximately 50% of the EU population.

IWA Water Loss Specialist Group (WLSG), Position Statement (March 2022), Use of the Infrastructure Leakage Index (ILI) in EU Directives and Regulations

Economic level of leakage and leakage targets

The WLSG (Water Loss Strategic Group) promotes an approach by which the targets set for leakage reduction by water supply companies take account of what is technically and financially possible, and consider the views of all stakeholders including environmental, social and other factors as well as economics.

The WLSG supports the use of a volume metric such as m^3/d or Ml/day for target setting rather than any scaled measure.

The WLSG recommends that ILI should not be used to set targets in isolation from other parameters. As the current pressure regime may not be optimal, ILI should always be interpreted with some measure of pressure, and only used for tracking progress provided all justifiable pressure reduction is achieved.

Managing leakage

The WLSG promotes the importance of leakage reduction in the management of water supplies and its contribution to the sustainable management of water resources. In this context it supports the efforts of all stakeholders in the water industry to manage leakage effectively and economically.

[29] https://www.eureau.org/about
https://www.eureau.org/resources/briefing-notes/5735-eureau-briefing-note-on-drinking-water-supply-and-leakage-management/file

The WLSG recognizes that there is high political and media interest in leakage, and whilst low leakage is desirable, the cost to achieve and maintain low leakage levels needs to be understood by all stakeholders. In this respect there is a need to effectively communicate the measurement of leakage performance, the economics and environmental benefits of leakage and how leakage targets are set and expressed.

The WLSG supports the approach set out in the 2015 EU Reference Document ('Good Practices on Leakage Management WFD CIS WG PoM' (© European Union, 2015)) which is a key source document for this Position Statement.

The WLSG understands that the threshold values set in the Directive (EU) 2020/2184 and Annex 1 of the EU Taxonomy Climate Delegated Act for ILI and Energy Consumption are for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. The WLSG considers that to meet these it may be necessary to aim below simple economic levels of water loss, particularly in countries where the cost of water production and distribution is very low, which financially may be undesirable, particularly by "water rich" countries.

Performance measures

The WLSG promotes the use of leakage performance indicators which are fit for purpose for European comparisons; this does not include any measure based on percentages of System Input Volume. Percentages are misleading for comparisons because of differences and changes in consumption, and it is a zero-sum calculation which cannot identify true reductions in leakage and consumption in the same time period.

The WLSG supports the conclusion of the 2015 EU Reference Document that there is no single leakage performance indicator that is suitable for all purposes, and measures used should be fit for the particular purpose. For expressing targets and tracking progress in individual organizations and systems, m^3/d (Ml/day) and liters/connection/day (l/conn/d) are preferred; m^3/km mains is acceptable for very low connection densities. Infrastructure Leakage Index (ILI) used in conjunction with some measure of operating pressure is more reliable for international comparisons of technical performance.

European and other international evidence suggest that an ILI between 1 and 3 is appropriate for most water resource zones in a high-income country. Where the estimated sustainable economic level of leakage is an ILI of below 1 or above 3, the local circumstances should be reviewed to ensure that the methodology and data used are robust. Whilst measures of total water lost are useful, they should not be the sole criteria on which water utilities are judged.

1.3.2.2 Setting of targets, benchmarks and indicators of leakage management efficiency[30]

The setting of targets, benchmarks and indicators of leakage management efficiency will be based on a methodology to improve leakage management which will be presented within the Loss Reduction Action Plan. At the same time, it will be a guideline for PWSPs which are obliged to prepare their loss reduction action plans, including setting targets, benchmarks and indicators of leakage management efficiency.

The framework for the establishment of the methodology to improve leakage management:

- National level
  - Development of initial water balances on the national level based on the existing database on water balances of individual water supply systems (the objective is to estimate losses, get the first initial estimate of the NRW and NRW components). The water balance is used to compare/correlate/balance the estimated losses with other elements (prices, services, quality, i.e. other performance indicators);
  - Development of the National Loss Reduction Action Plan;
  - Preparation of a proposal of technical performance indicators to monitor losses in an individual water supply system (The proposal of technical performance indicators is based on good practice, technical considerations (notably the density of connections per km of mains, and service connections per billed property), or another unit, in relation to the data that is traditionally used or familiar on the national level)[31]

[30] Document used: Good Practices on Leakage Management WFD CIS WG PoM (ISBN 978-92-79-45069-3 © European Union, 2015).
[31] These performance indicators aren't used for comparisons of leakage management performance between different systems or sub-systems with different infrastructure characteristics, notably service connection density, network length, and operating pressures.

    - Volume of real losses per service connection per year (m^3/service connection/year), day or hour;
    - Volume of real losses per km of distribution mains per year, day or hour (m^3/km/year);
    - Volume of real losses per billed property per year (m^3/user/year), day or hour;
  - Preparation of a proposal of indicators of environmental, social, economic, and other aspects of efficiency;
  - Preparation of a proposal of performance indicators to compare the technical leakage performance between different water supply systems:
    - Use Infrastructure Leakage Index (ILI) for comparison of leakage management performance between different systems with different infrastructure characteristics (connection density, network length, average pressure);
  - Setting strategic targets
    - Potentially the most appropriate measure for this purpose is an annual volume expressed as a total amount for the year, e.g., in millions of cubic meters (Mm^3/year) or as an average in thousand m^3 per day (Tm^3/day). The volume measure for a PWSP as a whole should be the sum of the volume targets for individual supply zones (or water supply systems) or water resource zones (groups of abstractions from one water body). The measure should be set as a rate for each year of a planning period to monitor the achievement of strategic targets from the current leakage level in relation to the short-, medium- or long-term objective. The volume target should allow for extensions to the network for new users (system development), asset deterioration, and asset renewal/management, and it may be above or below the current leakage level. The strategic annual volume targets for each water supply system (supply zone or group of sources) and the PWSP as a whole can be cascaded down to DMAs, in order to compare/monitor leakage management performance monthly or seasonally, with the performance required to meet the strategic target;
    - The ideal strategic target[32] will be a compromise between a number of competing factors, though it is likely that one or two factors will predominate. The ideal target should be: (i) Based on economic principles to ensure efficient operations, (ii) Practical to apply in practice; in terms of data and analytical needs, (iii) Sustainable in the long term and flexible in the short term. Any target should reflect the ability of the PWSP to maintain water loss at a reduced level over a certain time horizon. In the short term, it is likely that new information will become available as water loss reduction projects are carried out. So, it is important that there is some degree of flexibility in the target until specific experience is gained or more data collected. (iv) Consistent with the water resources status and the demand forecast to safeguard future water supplies. There will be more incentive to reduce water loss when there is insufficient 'headroom' between demand and the available supply capacity of the system. (v) Understandable, transparent, simple and consistent in order to demonstrate continual improvements to owners (LSGUs), in order to improve public perception. (vi) Founded on a sound understanding of water loss elements, taking a component-based approach. (vii) Applicable to meet/control regulatory requirements. (viii) Able to allow for fair technical comparisons between PWSPs. (ix) Allow for/Recognize differences between systems (topography; which affects the economics of pressure management, or Inherited infrastructure condition; which affects the economics of active leakage control and the need for investment in network asset management). (x) Set as a rate for each year of a planning period to take account of the transition from the current level of leakage to the short-/long-term target;
  - Updating water balances based on the water meters installed at abstraction points (the installation of meters at abstraction points is an activity organized by Croatian Waters);
  - Updating balances based on the detailed balances prepared on the PWSP level;
  - Continuous (annual) monitoring of indicators
    - Technical performance in individual water supply systems;
    - Performance indicators to compare the technical leakage performance between different water supply systems;
    - Environmental, social, economic and other aspects of performance;
    - Achievement of the strategic targets;

- PWSP level or level of service areas (41)

[32] The target can be set using a mathematical model, or (initially) using default values and based on experiences in similar organisations, which can be updated from the practical achievements and costs of leakage management works. The target can/should be set based on Sustainable economic level of leakage. Due to the variation between zones in network density (mains length per connection), system pressure, inherited infrastructure condition, cost and value of water, water resource availability and other factors, it is not possible to set targets for leakage using a performance measure such as litres/connection/day or ILI. Although performance measures are useful for understanding the current level of leakage, and the potential for leakage reduction, none of them take all the relevant factors into account. Therefore, strategic targets should be set in an annual volume expressed as a total for the year (e.g., m3/year or m3/day).

- Preparation of water balances of individual water supply zones at the level of DMAs or night flow analysis (Water balance assessment according to the IWA methodology, additionally, a night flow analysis to assess or check annual leakage in systems where water balance is less reliable (fewer metering in the system or lack of customer metering);
- Identification/Assessment of the current status of losses using the key technical performance indicators and strategic targets set on the national level;
- Analysis of existing data, identification of missing data, and setting of priorities;
- Preparation of detailed PWSP Action Plans with a program of measures to achieve the strategic targets (ULRAP);
- Implementation of measures, monitoring (and continuous learning) during implementation;

1.3.2.3 Water Services Act

The Water Services Act lays down that the providers of water services shall fulfill the general and particular conditions to perform water service activities.

In the context of water loss reduction, the provisions related to the particular conditions to be fulfilled by a PWSP are outlined below:

- Conditions to start performance (number and qualifications of key staff);
- Conditions for efficient performance, including among other things in particular:
  - Ability to manage water losses in water and wastewater structures;
  - Ability to manage a treatment plant for water intended for human consumption;
  - Ability to react in emergencies (interruptions in supply, shortage of water, etc.);
  - Obligation of permanent staff training;
  - Achieving certain performance efficiency indicators from the (future) regulation on the evaluation of operational efficiency of providers of water services

The particular conditions to perform water service activities are laid down by the Croatian Government in the form of a regulation. The MESD shall monitor the fulfillment of the particular conditions to perform water service activities and submit an annual report (the MESD shall agree on the draft report with the Water Service Council) to the Croatian Government, and publish it on its website.

The legal provisions make it clear that the legislation will through the (future) regulation on the evaluation of operational efficiency of providers of water services lay down the benchmarks and indicators of operational eficiency, 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 (see Chapter 1.2.5.1), which definitely includes the benchmarks and indicators of loss reduction efficiency as well.

1.4 Basic water balance[33]

The basic water balance considers the relationship between water supplied (volume from own sources + water imported - water exported) and water delivered to final users (billed authorized consumption).

In 2021 total volume of water supplied amounted to 479 million m^3. Water supplied per capita is around 110 m^3.

The total amount of water delivered through the system to the final users in 2021. amounted to 244 million m^3.

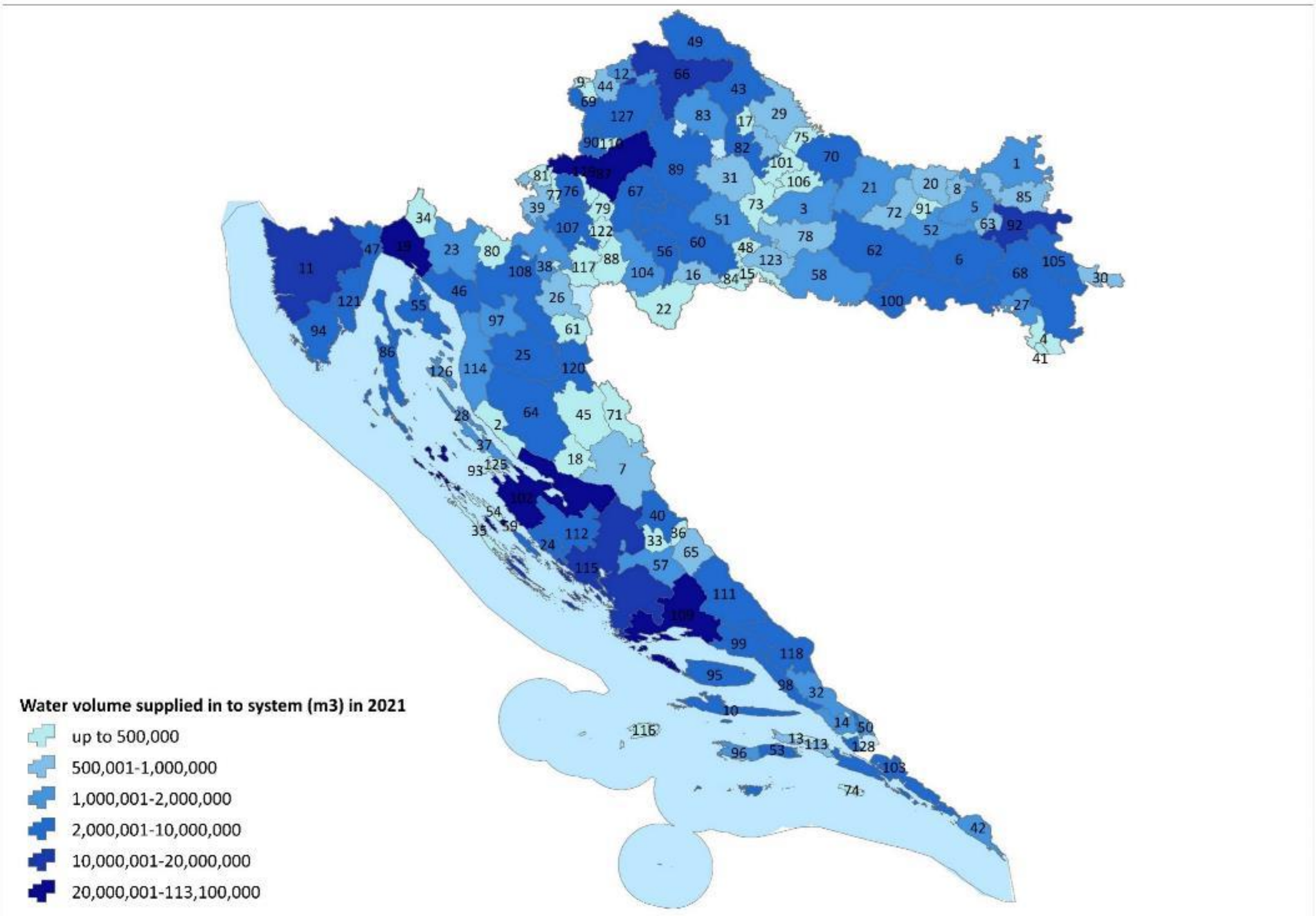


Figure 1.25. Spatial distribution of water supplied, PWSP level (with IDs)

[33] An initial overview of NRW. Detail analysis of NRW is provided in Chapter 2.4.2.1

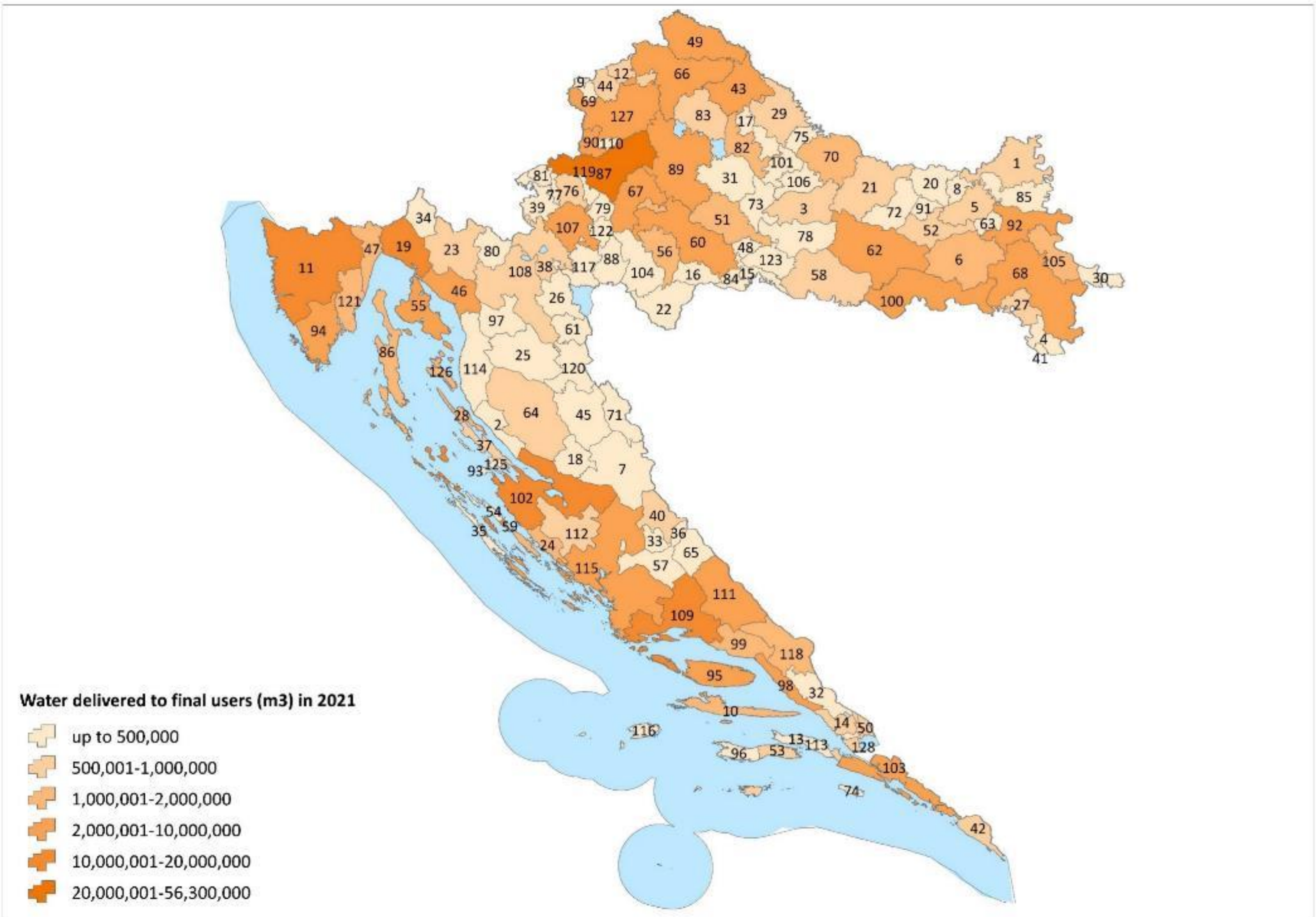


Figure 1.26. Spatial distribution of annual volume delivered to final users (Billed Authorized Consumption), PWSP level (with IDs)

NRW of around 49% is extremely high and corresponds to total water demand. On the county level, NRW varies from les than 20% to 88%. The reasons for such NRW are related mostly to the age of the mains and lack of maintenance over time. Parts of the systems are 50-70 years old (40-50 on average, whole systems), in which not much was invested (in the reconstruction of the main parts of the system). The funds were invested mainly in the development of the network, which resulted in a relatively high level of connection rate (taking into account the unfavorable spatial and geographical characteristics of the area).

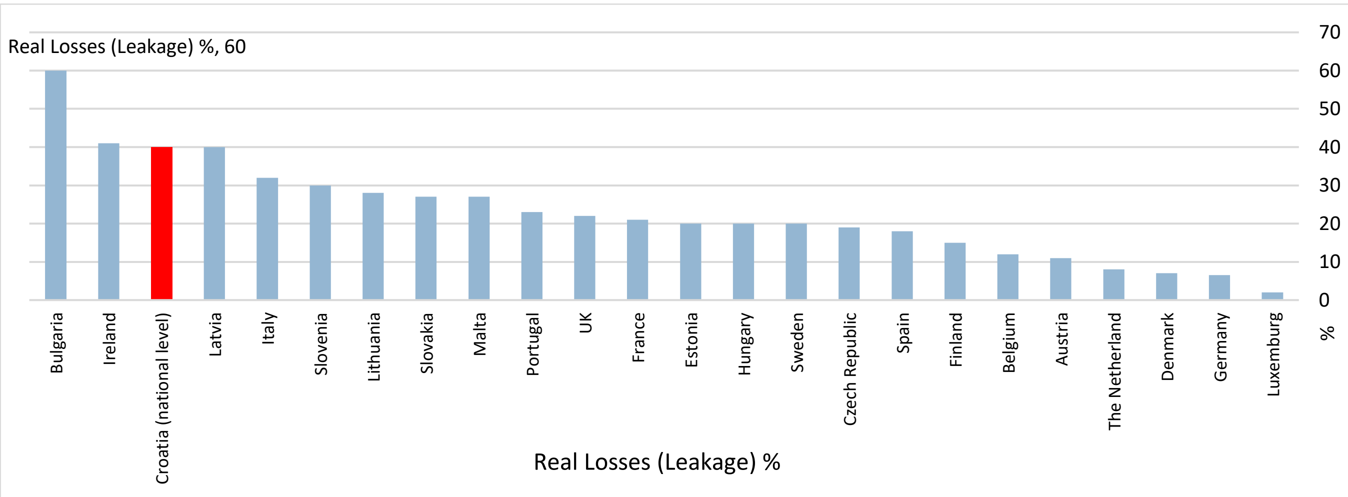


Figure 1.27. Real water losses of water supply network in the EU

An initial overview of NRW by service areas (41) and by PWSPs is provided below (based on data provided in national SOV data base). Detail analasis of Water balance or NRW is provided in Chapter 2.4.22.4.2.1.

Table 1.6. Initial water balance, service area and PWSP level (based on national SOV database for 2021)

Planed services areas ID	PWSP ID	Current PWSP	Water Supplied (m³/year)	Delivered to final users[34] (m³/year)	NRW (m³/year)	NRW (%)
1	49	MEĐIMURSKE VODE d.o.o. Čakovec	6.021.267	4.649.067	1.372.200	23%
1 Total			**6.021.267**	**4.649.067**	**1.372.200**	**23%**
2	12	IVKOM-VODE d.o.o. Ivanec	1.868.935	904.140	964.795	52%
	66	VARKOM d.d. Varaždin	10.605.705	6.270.618	4.335.087	41%
2 Total			**12.474.640**	**7.174.758**	**5.299.882**	**42%**
3	43	KOPRIVNIČKE VODE d.o.o. Koprivnica	2.797.417	2.396.838	400.579	14%
	83	VODNE USLUGE d.o.o. Križevci	1.176.020	831.336	344.684	29%
3 Total			**3.973.437**	**3.228.174**	**745.263**	**19%**
4	3	DARKOM VODOOPSKRBA I ODVODNJA d.o.o. Daruvar	1.190.300	711.310	478.990	40%
	17	KAPELAKOM d.o.o. Kapela	61.606	54.175	7.431	12%
	29	KOMUNALIJE d.o.o. Đurđevac	837.413	615.730	221.683	26%
	73	VODA GAREŠNICA d.o.o. Garešnica	396.723	162.116	234.607	59%
	82	VODNE USLUGE d.o.o. Bjelovar	2.168.211	1.438.575	729.636	34%
	101	VODOVOD d.o.o. Veliki Grđevac	63.434	57.482	5.952	9%
	106	VODOVOD GRUBIŠNO POLJE d.o.o. Grubišno Polje	413.235	213.507	199.728	48%
4 Total			**5.130.922**	**3.252.895**	**1.878.027**	**37%**
5	21	KOMRAD d.o.o. Slatina	1.340.421	836.334	504.087	38%
	70	VIRKOM d.o.o. Virovitica	2.504.828	1.609.161	895.667	36%
	72	VODA d.o.o. Orahovica	540.012	370.027	169.985	31%
	75	VODAKOM d.o.o. Pitomača	133.259	102.569	30.691	23%
5 Total			**4.518.520**	**2.918.091**	**1.600.430**	**35%**
6	6	ĐAKOVAČKI VODOVOD d.o.o. Đakovo	2.370.343	1.598.816	771.527	33%
	52	NAŠIČKI VODOVOD d.o.o. Našice	1.580.193	806.239	773.954	49%
	91	VODORAD d.o.o. Đurđenovac	478.534	188.573	289.961	61%
6 Total			**4.429.070**	**2.593.628**	**1.835.442**	**41%**
7	1	BARANJSKI VODOVOD d.o.o. Beli Manastir	1.400.781	820.811	579.970	41%
7 Total			**1.400.781**	**820.811**	**579.970**	**41%**
8	5	DVORAC d.o.o. Valpovo	1.080.881	688.476	392.405	36%
	8	HIDROBEL d.o.o. Belišće	639.702	461.206	178.496	28%
	20	MIHOLJAČKI VODOVOD d.o.o. Donji Miholjac	614.206	443.581	170.625	28%
	63	UREDNOST d.o.o.Čepin	511.979	351.635	160.344	31%
	85	VODOOPSKRBA d.o.o. Darda	515.048	418.138	96.910	19%
	92	VODOVOD-OSIJEK d.o.o. Osijek	10.831.879	6.412.216	4.419.663	41%
8 Total			**14.193.696**	**8.775.252**	**5.418.444**	**38%**
9	9	HUMVIO d.o.o. Hum na Sutli	308.133	194.257	113.876	37%
	44	KRAKOM-VODOOPSKRBA I ODVODNJA d.o.o. Krapina	854.905	723.237	131.668	15%
	69	VIOP d.o.o. Pregrada	375.361	227.669	147.692	39%
	127	ZAGORSKI VODOVOD d.o.o. Zabok	6.287.452	3.671.817	2.615.635	42%
9 Total			**7.825.851**	**4.816.980**	**3.008.871**	**38%**
10	90	VODOOPSKRBA I ODVODNJA ZAPREŠIĆ d.o.o. Zaprešić	4.745.968	2.527.202	2.218.766	47%
	110	VODOVOD I ODVODNJA BISTRA d.o.o. Bistra	404.619	271.363	133.256	33%
10 Total			**5.150.587**	**2.798.565**	**2.352.022**	**46%**
11	76	VODE JASTREBARSKO d.o.o. Jastrebarsko	2.278.184	954.717	1.323.467	58%
	81	VODE ŽUMBERAK d.o.o. Kostanjevac	77.178	58.233	18.945	25%
	87	VODOOPSKRBA I ODVODNJA d.o.o. Zagreb	113.073.582	56.249.026	56.824.556	50%

[34] Billed Authorized Consumption.

Planed services areas ID	PWSP ID	Current PWSP	Water Supplied (m^3/year)	Delivered to final users[34] (m^3/year)	NRW (m^3/year)	NRW (%)
	119	VODOVOD KLINČA SELA d.o.o. Donja Zdenčina	427.979	240.090	187.889	44%
11 Total			**115.856.924**	**57.502.066**	**58.354.858**	**50%**
12	67	VG VODOOPSKRBA d.o.o. Velika Gorica	4.589.883	2.805.535	1.784.348	39%
	79	VODE PISAROVINA d.o.o. Pisarovina	211.736	165.277	46.459	22%
12 Total			**4.801.619**	**2.970.812**	**1.830.807**	**38%**
13	31	KOMUNALIJE VODOVOD d.o.o. Čazma	580.515	401.891	178.624	31%
	89	VODOOPSKRBA I ODVODNJA ZAGREBAČKE ŽUPANIJE. d.o.o.	5.345.824	3.901.754	1.444.070	27%
13 Total			**5.926.339**	**4.303.645**	**1.622.694**	**27%**
14	26	KOMUNALAC d.o.o. Slunj	932.209	282.316	649.893	70%
	38	KOMUNALNO DUGA RESA d.o.o. Duga Resa	1.474.656	721.488	753.168	51%
	39	KOMUNALNO OZALJ d.o.o. Ozalj	629.996	400.817	229.179	36%
	77	VODE KRAŠIĆ d.o.o. Krašić	164.050	89.415	74.635	45%
	107	VODOVOD I KANALIZACIJA d.o.o. Karlovac	9.550.045	3.433.380	6.116.665	64%
	108	VODOVOD I KANALIZACIJA d.o.o. Ogulin	2.228.147	805.725	1.422.422	64%
	117	VODOVOD I ODVODNJA VOJNIĆ d.o.o. Vojnić	371.482	126.577	244.905	66%
	122	VODOVOD LASINJA d.o.o. Lasinja	138.339	32.975	105.365	76%
14 Total			**15.488.924**	**5.892.693**	**9.596.231**	**62%**
15	16	JP KOMUNALAC d.o.o. Hrvatska Kostajnica	767.966	136.798	631.168	82%
	22	KOMUNALAC - DVOR d.o.o. Dvor	334.453	79.277	255.176	76%
	56	PRIVREDA d.o.o. Petrinja	3.661.122	1.137.987	2.523.135	69%
	88	VODOOPSKRBA I ODVODNJA TOPUSKO d.o.o. Topusko	438.039	220.770	217.269	50%
	104	VODOVOD GLINA d.o.o. Glina	1.355.287	484.550	870.736	64%
15 Total			**6.556.867**	**2.059.382**	**4.497.485**	**69%**
16	60	SISAČKI VODOVOD d.o.o. Sisak	6.332.592	2.384.460	3.948.132	62%
16 Total			**6.332.592**	**2.384.460**	**3.948.132**	**62%**
17	15	JKP JASENOVAČKA VODA d.o.o. Jasenovac	133.262	44.939	88.323	66%
	48	LIP-KOM d.o.o. Lipovljani	57.832	47.625	10.207	18%
	51	MOSLAVINA d.o.o. Kutina	1.716.288	1.250.161	466.127	27%
	84	VODOOPSKRBA d.o.o. Hrvatska Dubica	59.149	49.878	9.271	16%
	123	VODOVOD NOVSKA d.o.o. Novska	574.567	392.024	182.543	32%
17 Total			**2.541.098**	**1.784.627**	**756.471**	**30%**
18	62	TEKIJA d.o.o. Požega	3.750.128	2.271.076	1.479.052	39%
	78	VODE LIPIK d.o.o. Pakrac	739.804	447.638	292.166	39%
18 Total			**4.489.932**	**2.718.714**	**1.771.217**	**39%**
19	58	VODOVOD ZAPADNE SLAVONIJE d.o.o. Nova Gradiška	1.771.567	936.257	835.310	47%
19 Total			**1.771.567**	**936.257**	**835.310**	**47%**
20	100	VODOVOD d.o.o. Slavonski Brod	9.727.788	3.995.028	5.732.760	59%
20 Total			**9.727.788**	**3.995.028**	**5.732.760**	**59%**
21	4	DRENOVAČKI VODOVOD d.o.o. Drenovci	262.673	149.906	112.767	43%
	27	KOMUNALAC d.o.o. Županja	1.237.835	732.879	504.956	41%
	41	KOM. TRGOVAČKO DRUŠTVO GUNJA d.o.o. Gunja	218.989	108.439	110.550	50%
	68	VINKOVAČKI VODOVOD I KANALIZACIJA d.o.o. Vinkovci	9.409.712	3.603.958	5.805.754	62%
21 Total			**11.129.209**	**4.595.182**	**6.534.027**	**59%**
22	30	KOMUNALIJE d.o.o. Ilok	523.515	306.581	216.934	41%
	105	VODOVOD GRADA VUKOVARA d.o.o. Vukovar	2.288.954	1.743.131	545.823	24%
22 Total			**2.812.469**	**2.049.712**	**762.757**	**27%**
23	11	ISTARSKI VODOVOD d.o.o. Buzet	17.166.608	12.464.268	4.702.340	27%
23 Total			**17.166.608**	**12.464.268**	**4.702.340**	**27%**
24	94	VODOVOD d.o.o Pula	8.367.637	6.828.598	1.539.039	18%
	121	VODOVOD LABIN D.O.O. Labin	2.468.986	1.757.077	711.909	29%
24 Total			**10.836.623**	**8.585.675**	**2.250.948**	**21%**

Planed services areas ID	PWSP ID	Current PWSP	Water Supplied (m³/year)	Delivered to final users[34] (m³/year)	NRW (m³/year)	NRW (%)
25	19	KD VODOVOD I KANALIZACIJA d.o.o. Rijeka	21.793.068	12.827.348	8.965.720	41%
	23	KOM. - VODOOPSKRBA I ODVODNJA d.o.o. Delnice	1.126.064	608.272	517.792	46%
	34	KOMUNALNO DRUŠTVO ČABRANKA d.o.o Čabar	246.163	101.530	144.633	59%
	47	LIBURNIJSKE VODE d.o.o. Ičići	2.860.261	1.979.563	880.698	31%
	80	VODE VRBOVSKO d.o.o. Vrbovsko	417.305	165.523	251.781	60%
25 Total			**26.442.861**	**15.682.236**	**10.760.624**	**41%**
26	55	PONIKVE VODA d.o.o. Krk	3.391.794	2.759.943	631.851	19%
	86	VODOOPSKRBA I ODVODNJA CRES LOŠINJ d.o.o. Cres	2.714.737	1.418.407	1.296.330	48%
26 Total			**6.106.531**	**4.178.350**	**1.928.181**	**32%**
27	46	VIO ŽRNOVNICA CRIKVENICA VINODOL d.o.o. Novi Vinodolski	3.396.341	2.015.782	1.380.559	41%
27 Total			**3.396.341**	**2.015.782**	**1.380.559**	**41%**
28	2	CRNO VRILO d.o.o. Karlobag	141.743	104.282	37.461	26%
	28	KOMUNALIJE d.o.o. Novalja	1.395.197	1.116.294	278.903	20%
	37	KOMUNALNO DRUŠTVO PAG d.o.o. Pag	1.119.545	631.975	487.570	44%
	114	VODOVOD I ODVODNJA d.o.o. Senj	1.103.713	340.680	763.033	69%
	125	VODOVOD POVLJANA d.o.o. Povljana	153.634	98.372	55.262	36%
	126	VRELO d.o.o. Rab	1.558.471	1.052.878	505.593	32%
28 Total			**5.472.303**	**3.344.481**	**2.127.822**	**39%**
29	18	KAPLJA d.o.o. Lovinac	64.227	37.892	26.335	41%
	25	KOMUNALAC d.o.o. Otočac	2.268.015	416.389	1.851.626	82%
	45	KRALJEVAC d.o.o. Udbina	88.212	67.855	20.357	23%
	61	SPELEKOM d.o.o. Rakovica	435.290	191.392	243.898	56%
	64	USLUGA d.o.o. Gospić	2.482.267	829.113	1.653.154	67%
	71	VISOČICA d.o.o. Donji Lapac	194.715	56.329	138.386	71%
	97	VODOVOD d.o.o. Brinje	1.024.644	127.529	897.116	88%
	120	VODOVOD KORENICA d.o.o. Korenica	2.190.686	258.809	1.931.877	88%
29 Total			**8.748.056**	**1.985.308**	**6.762.748**	**77%**
30	7	GRAČAC VODOVOD I ODVODNJA d.o.o. Gračac	918.942	139.678	779.264	85%
	35	Kom. DRUŠTVO DUGI OTOK I ZVERINAC d.o.o. Sali	38.153	31.794	6.359	17%
	54	OTOK UGLJAN d.o.o. Preko	365.242	251.089	114.153	31%
	59	SABUŠA d.o.o. Kukljica	137.573	61.123	76.450	56%
	93	VODOVOD - VIR d.o.o. Vir	220.598	191.824	28.774	13%
	102	VODOVOD d.o.o. Zadar	29.160.209	10.277.080	18.883.129	65%
30 Total			**30.840.716**	**10.952.588**	**19.888.128**	**64%**
31	24	KOMUNALAC d.o.o. Biograd na moru	2.944.039	1.808.535	1.135.504	39%
	112	VODOVOD I ODVODNJA d.o.o. Benkovac	2.202.754	627.782	1.574.972	72%
31 Total			**5.146.793**	**2.436.317**	**2.710.476**	**53%**
32	33	KOMUNALNO DRUŠTVO BISKUPIJA d.o.o. Biskupija	57.898	31.378	26.520	46%
	40	KOMUNALNO PODUZEĆE d.o.o. Knin	2.277.544	633.301	1.644.243	72%
	57	RAD d.o.o. Drniš	1.464.799	495.974	968.825	66%
	115	VODOVOD I ODVODNJA d.o.o. Šibenik	16.194.894	7.794.128	8.400.766	52%
32 Total			**19.995.135**	**8.954.781**	**11.040.354**	**55%**
33	109	VODOVOD I KANALIZACIJA d.o.o. Split	46.507.977	18.784.645	27.723.332	60%
33 Total			**46.507.977**	**18.784.645**	**27.723.332**	**60%**
34	36	KOMUNALNO DRUŠTVO KIJEVO d.o.o. Kijevo	32.550	21.157	11.393	35%
	65	USLUGA d.o.o. Vrlika	527.829	137.185	390.644	74%
	111	VODOVOD I ODVODNJA CETINSKE KRAJINE d.o.o. Sinj	5.887.541	2.721.548	3.165.993	54%
34 Total			**6.447.920**	**2.879.890**	**3.568.030**	**55%**
35	99	VODOVOD d.o.o. Omiš	3.346.874	1.893.984	1.452.890	43%
35 Total			**3.346.874**	**1.893.984**	**1.452.890**	**43%**
36	10	HVARSKI VODOVOD d.o.o. Jelsa	2.013.479	1.366.076	647.403	32%

Planed services areas ID	PWSP ID	Current PWSP	Water Supplied (m³/year)	Delivered to final users[34] (m³/year)	NRW (m³/year)	NRW (%)
	95	VODOVOD BRAČ d.o.o. Supetar	3.046.989	2.008.926	1.038.063	34%
	116	VODOVOD I ODVODNJA OTOKA VISA d.o.o. Komiža	477.926	356.436	121.490	25%
36 Total			**5.538.394**	**3.731.438**	**1.806.956**	**33%**
37	98	VODOVOD d.o.o. Makarska	7.043.835	3.183.345	3.860.490	55%
	118	VODOVOD IMOTSKE KRAJINE d.o.o. Imotski	4.269.359	1.021.639	3.247.720	76%
37 Total			**11.313.194**	**4.204.984**	**7.108.210**	**63%**
38	14	IZVOR Ploče d.o.o. Ploče	1.964.002	749.058	1.214.944	62%
	32	KOMUNALNO d.o.o. Vrgorac	1.990.129	365.500	1.624.629	82%
	50	METKOVIĆ d.o.o. Metković	1.308.852	740.714	568.138	43%
	124	VODOVOD OPUZEN d.o.o. Opuzen	173.286	117.133	56.153	32%
	128	ZAŽABLJE d.o.o. Mlinište	28.619	14.233	14.386	50%
38 Total			**5.464.888**	**1.986.638**	**3.478.250**	**64%**
39	13	IZVOR ORAH d.o.o. Trpanj	102.825	67.645	35.180	34%
	53	NPKLM VODOVOD d.o.o. Korčula	2.361.249	987.882	1.373.367	58%
	74	VODA MLJET d.o.o. Babino Polje	7.231	7.231	0	0%
	96	VODOVOD d.o.o. Blato	1.407.877	485.734	922.143	65%
	113	VODOVOD I ODVODNJA d.o.o. Orebić	768.235	444.970	323.265	42%
39 Total			**4.647.417**	**1.993.462**	**2.653.955**	**57%**
40	103	VODOVOD DUBROVNIK d.o.o. Dubrovnik	7.627.185	4.871.474	2.755.711	36%
40 Total			**7.627.185**	**4.871.474**	**2.755.711**	**36%**
41	42	KONAVOSKO KOMUNALNO DRUŠTVO d.o.o. Čilipi	1.032.604	698.648	333.956	32%
41 Total			**1.032.604**	**698.648**	**333.956**	**32%**
Grand Total			**478.632.517**	**243.865.747**	**234.766.771**	**49%**

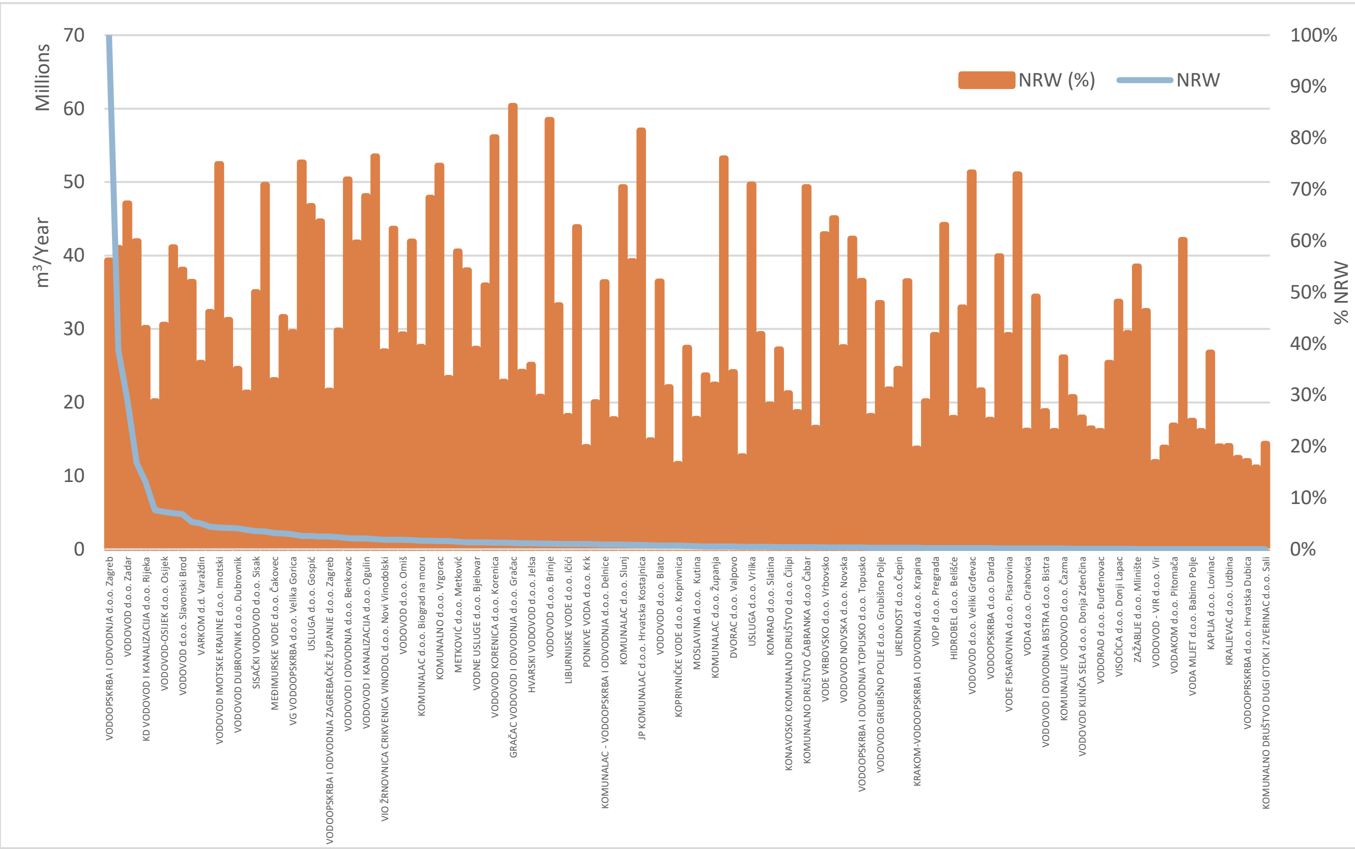
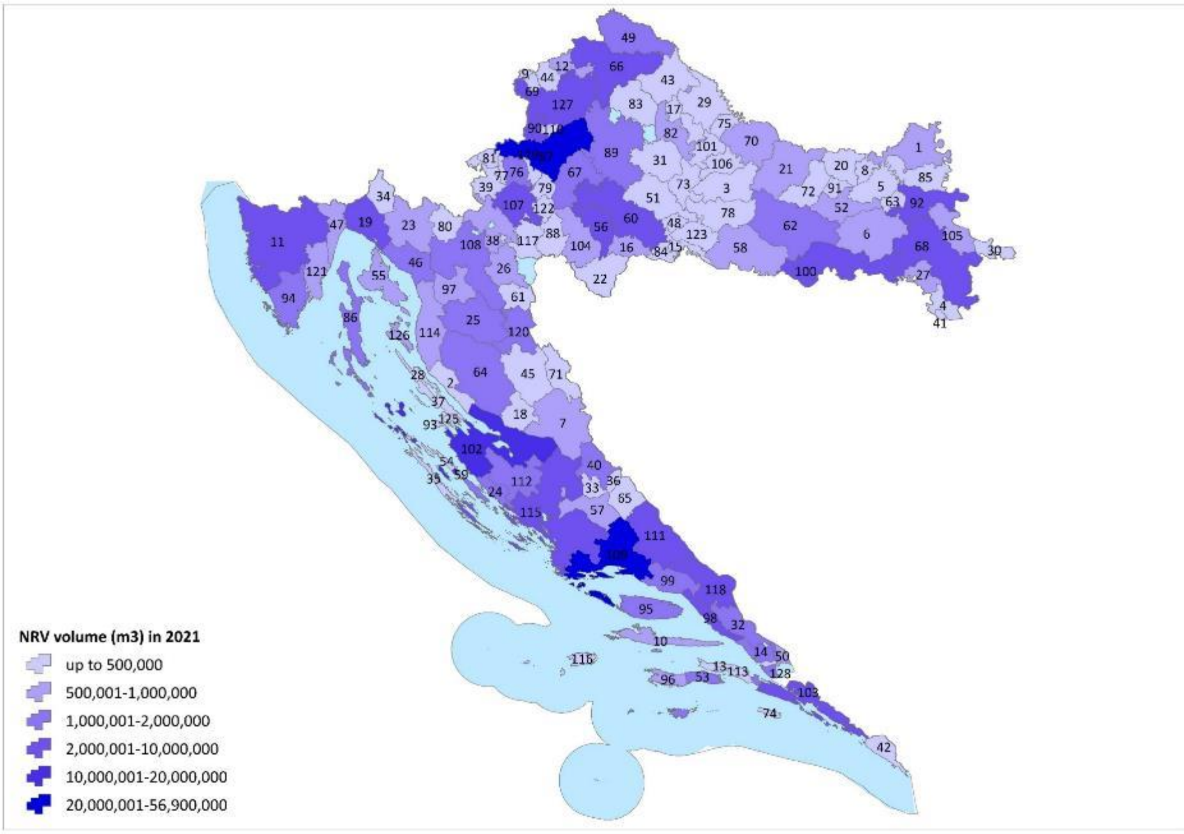


Figure 1.28. Relation between NRW volume (m³/year) and % NRW in total abstracted volume, PWSP level



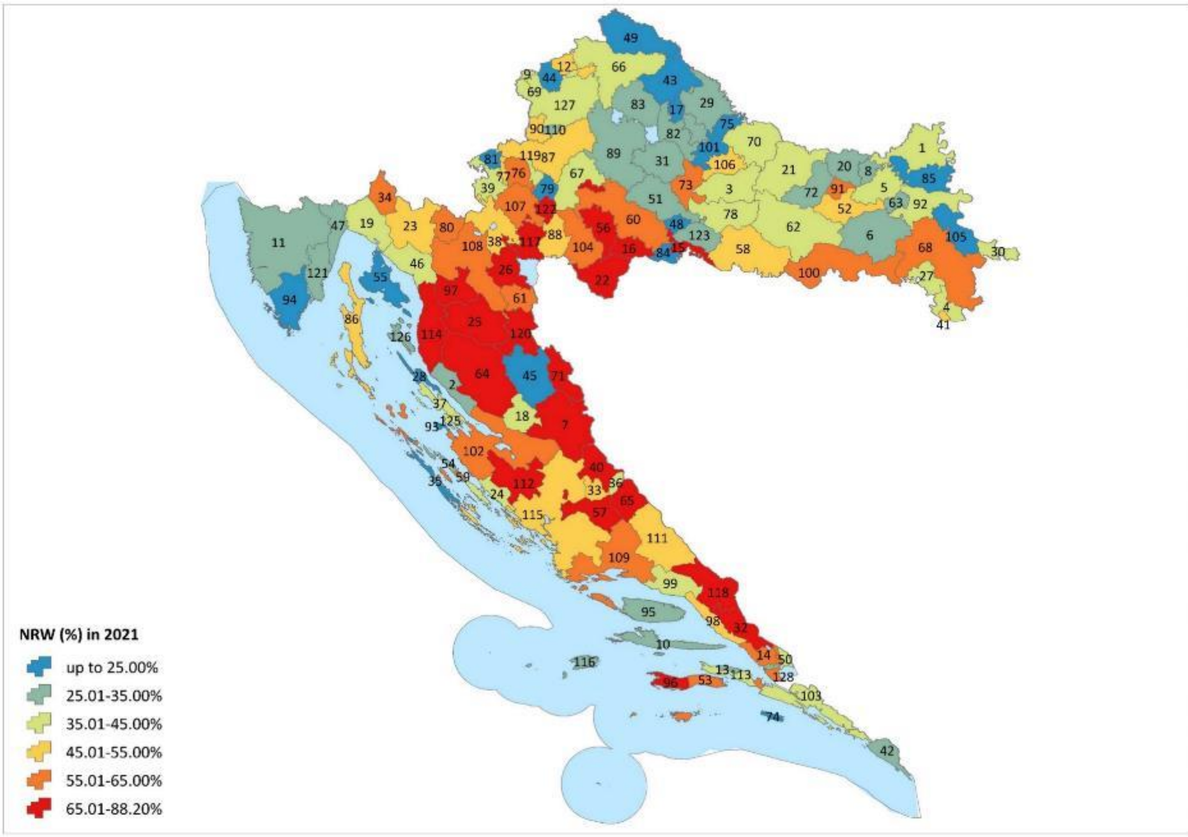
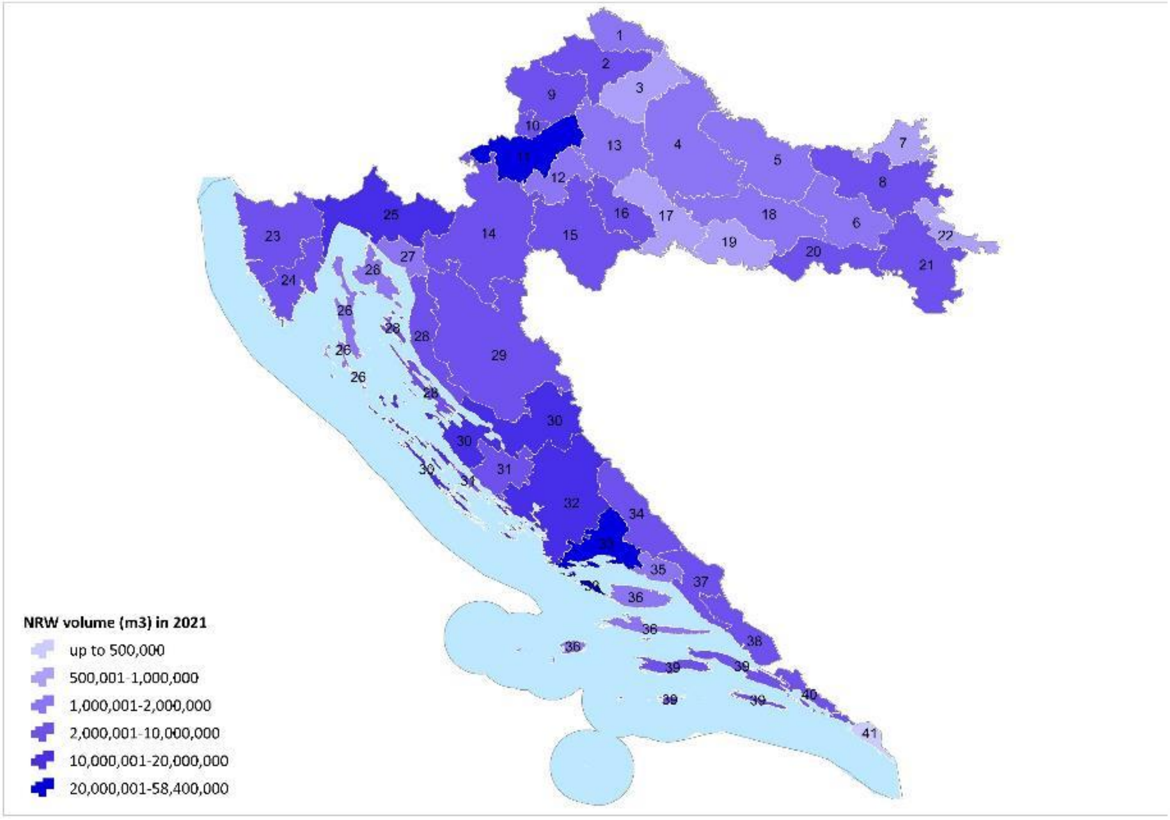


Figure 1.29. Spatial distribution of NRW (initial assessment), PWSP level (with IDs)



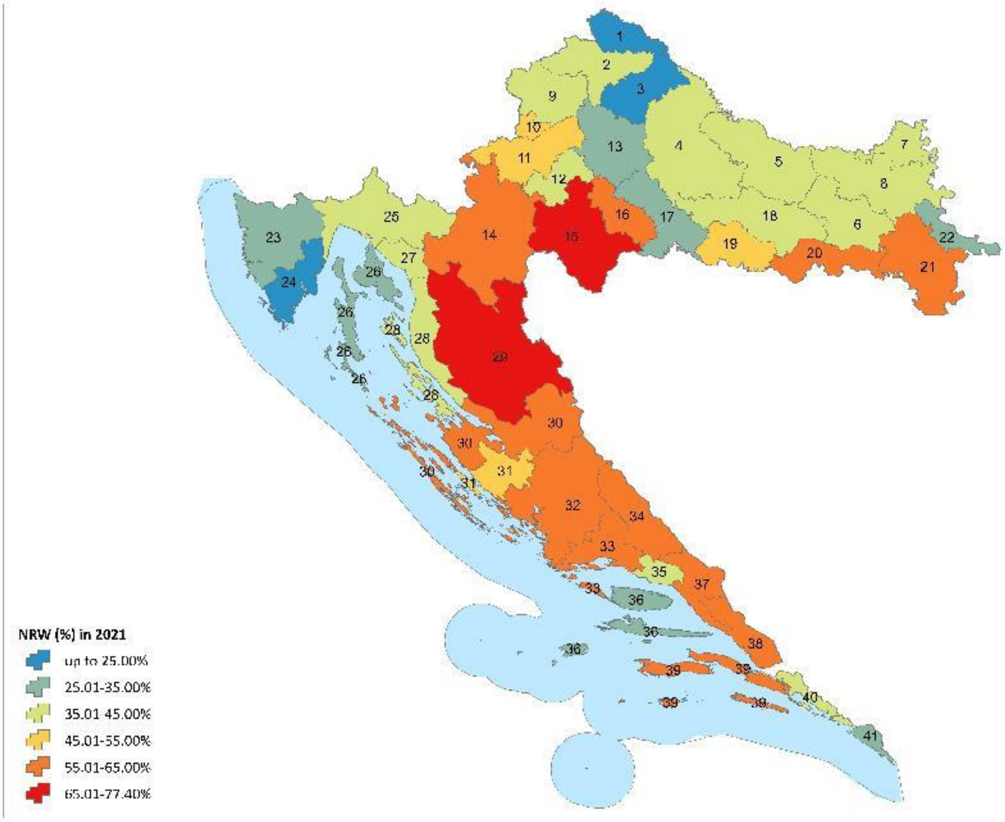


Figure 1.30. Spatial distribution of NRW (initial assessment), 41 water services areas level (with IDs)

2 CURRENT STATUS OF THE WATER SUPPLY SYSTEMS AND WATER LOSSES

Chapter 1.4. of this report presents the PWSPs that supply water to end users in Croatia, as well as those among them that provide the water supply service and that will be the subject of the analysis of the current status. Croatia has begun with a reform of its water sector; however, some PWSPs have already merged, some have started the merging processes, and some smaller PWSPs (with smaller territorial coverage, number of customers, or quantity of delivered water) have yielded operational management to a neighboring, larger PWSP. It is for that reason that the total number of PWSPs, particularly when it comes to the smaller ones, might change slightly during the preparation of the **Analysis of the Current Status** and preparation of the **National Loss Reduction Action Plan** (NLRAP). Analyses have been made for 128 PWSPs that deliver water to end users, or actually for 129, since the analyses also included the regional company Vodovod Hrvatsko primorje - Južni ogranak d.o.o. Senj that performs the service of intermediary delivery of significant water volumes to 6 other PWSPs, and whose size, technical complexity, and capacities require it to be included in these analyses.

For the purpose of analyzing the water supply systems and the issue of water losses in Croatia, 4 data sources were primarily used:

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. Croatian Waters, IT System for Reporting on Water Directives to the EC, Croatian Waters ***SOV database from the Application*** for input of data on wastewater collection and treatment, and water supply;
3. ***Questionaries*** sent out to the addresses of all the 129 analyzed PWSPs;
4. ***Conceptual Solutions for water supply*** and other available technical documents (water supply plans, feasibility studies, etc.).

The document ***"Study – Analysis of Performance by Water Service Providers in Croatia, Technical and Technological Aspects of Performance"*** dated 2017 analyzes the public 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.

From the ***Croatian Waters SOV database*** current data was requested and obtained about the characteristics of water supply systems (lengths by mains categories, data about storage tanks, pumping stations, water intakes, water treatment plants, etc.), as well as data for the last 5-year period (2017-2021) referring to the abstracted, supplied, and delivered volumes and the calculation of NRW. The PWSPs also stated whether they had prepared the extended water balance, and if so, in what year and the ILI amount.

The ***Questionaries*** submitted to the addresses of 129 PWSPs (distribution of the questionaries and collection of the data: May 2022 – August 2022) covered in detail all the questions related to the data about water supply systems and PWSPs, focusing on the issue of water losses. As such, in addition to the general data about the system characteristics (lengths by categories, materials, age, storage tanks, water treatment plants, pumping stations, water intakes, etc.), questions were also asked about the hydraulic optimization of the system in stationary state (system pressures, valves, particularly hydraulic valves to regulate downstream pressures) and for non-stationary events (protection from the water hammer, air release/intake valves, frequency converters on pumps), since events with excessive pressures lead to unfavorable hydraulic states with the consequent increased number of bursts, and thus of water leaks as well.

Furthermore, data was also requested about consumers and connections by categories for the current and planned states, and data related to estimates about the sufficiency of basic resources today and in the future period (capacities of the main input routes, of water storage tanks, sources, etc.). Detailed questions were then asked about apparent and real water losses, and about the capacities of the suppliers in terms of the IWA matrices, related to data about the supplier's technical equipment (GIS, SCADA, loss measurement and control equipment), the supplier's personnel structure (staff, engineers, teams), and the efficiency in water loss management (plans, establishment of DMAs, measurements, analyses, leakage detection, speed of repair, system maintenance, reconstruction plans, preparation of water balances, economic value of water losses, reporting, etc.).

In the end, a set of questions was asked related to energy consumption and production. The questionary with all the questions asked is presented in Annex of this report. The analyses collected in this way can be considered realistic because the collected data covers the PWSPs that deliver in total more than 95% of water to end users. Nevertheless, the obtained data will be cross-checked and harmonized with the data collected from the other specified available sources.

The last such source, at the same time the most detailed one, are ***Conceptual Solutions for water supply*** and other available technical documents (water supply plans, feasibility studies, etc.). The conceptual solutions which among other things started addressing the issue of water losses more actively have been prepared in the period from 2004 onwards. A considerable number of additional conceptual solutions is also nearing completion, which significantly increases the amount of information about systems that cover a large water supply area. This particularly refers to the conceptual solutions prepared after the year 2017, when the National Water Loss Reduction Plan (NWLRP) was launched. It includes standardized terms of reference for the development of conceptual solutions, imposing an obligation to measure flows, pressures, and even residual chlorine in the systems, and calibration of mathematical models. The differences were primarily in the planned development and implementation of the GIS and its modules (basic module, register of failures, link with the business IT system, monitoring of losses,...). In addition to the conceptual solutions of a recent date, the water supply systems were also analyzed using the county-level water supply plans which cover the entire national territory, i.e., all the counties, and individual feasibility studies that were prepared for co-financing the construction of water supply systems from the EU funds.

In order to study and analyze the systems from several aspects, ***the PWSPs were grouped, i.e., divided into 4 clusters***. In that way, in addition for the integrated area with all the 129 PWSPs, as well as 41 PWSPs according to the planned reforming Regulation on service areas in Croatia, it will be possible to present results by clusters as well. It needs to be stressed that the division into clusters serves only to better present certain similarities or differences for comparable PWSPs. The prioritization of the measures planned in the NWLRP will depend on other factors as well (availability of water resources, economic effects of the reduction of losses, risks, etc.). Some PWSPs may in organizational, technical, and capacity terms significantly deviate from similar PWSPs in their cluster. However, adding additional clusters would unnecessarily burden this document the purpose of which is to analyze the issue of water losses on the national level and present it in a clear and straightforward way.

There are several indicators which could be used for the appropriate division into clusters when it comes to analyzing water supply systems and water loss management, such as: the total length of the water supply system, the total volume of abstracted or even better billed water, or simply the total number of connections. Each of the said indicators has some advantages and disadvantages, particularly due to the specifics of Croatia where due to variations in tourist consumption there might be deviations in the correlation between pipeline length and total billed water volumes and the related economic strength and capacities of individual PWSPs. The results obtained from the said indicators don’t differ much in the end, and due to the fact that water losses happen regardless of the financial capacity of a PWSP, the division into clusters based on the total number of connections was selected. The company Vodoopskrba i odvodnja d.o.o. Zagreb, although comparable in many segments of water loss management with other larger PWSPs, was classified into a separate cluster because of its size, consumption, but also overall contribution to water losses

Table 2.1. PWSPs in Cluster I

CLUSTER	PWSP	Total billed water volume 2021 (m^3)	Total water supply system length (km)	Total number of service connections
I	VODOOPSKRBA I ODVODNJA d.o.o. Zagreb	56.249.026	3.328	**102.322**

Cluster II is defined by the total number of connections of more than 30,000 and is presented in Table 2.2.

Table 2.2. PWSPs in Cluster II

CLUSTER	PWSP	Total billed water volume 2021 (m^3)	Total water supply system length (km)	Total number of service connections
II	ISTARSKI VODOVOD d.o.o. Buzet	12.464.268	2.425	**73.066**
II	VODOVOD I KANALIZACIJA d.o.o. Split	18.784.645	1.427	**66.739**
II	VODOVOD d.o.o Pula	6.828.598	993	**58.793**
II	VODOVOD I ODVODNJA d.o.o. Šibenik	7.794.128	1.496	**52.075**
II	VARKOM d.d. Varaždin	6.270.618	1.671	**48.389**

CLUSTER	PWSP	Total billed water volume 2021 (m³)	Total water supply system length (km)	Total number of service connections
II	VODOVOD d.o.o. Zadar	10.277.080	1.546	**47.398**
II	KD VODOVOD I KANALIZACIJA d.o.o. Rijeka	12.827.348	958	**40.851**
II	MEĐIMURSKE VODE d.o.o. Čakovec	4.649.067	1.121	**40.850**
II	VODOVOD d.o.o. Slavonski Brod	3.995.028	976	**34.806**
II	VINKOVAČKI VODOVOD I KANALIZACIJA d.o.o. Vinkovci	3.603.958	860	**33.982**
II	ZAGORSKI VODOVOD d.o.o. Zabok	3.671.817	2.227	**33.226**
II	VODOVOD-OSIJEK d.o.o. Osijek	6.412.216	769	**31.450**

Cluster III is defined by the total number of connections in the range between 5,000 and 30,000 and is presented in Table 2.3.

Table 2.3. PWSPs in Cluster III

CLUSTER	PWSP	Total billed water volume 2021 (m³)	Total water supply system length (km)	Total number of service connections
III	VODOOPSKRBA I ODVODNJA ZAGREBAČKE ŽUPANIJE d.o.o. Zagreb	3.901.754	1.084	**27.369**
III	PONIKVE VODA d.o.o. Krk	2.759.943	546	**27.105**
III	VODOVOD I KANALIZACIJA d.o.o. Karlovac	3.433.380	750	**27.023**
III	VODOVOD DUBROVNIK d.o.o. Dubrovnik	4.871.474	325	**26.195**
III	VG VODOOPSKRBA d.o.o. Velika Gorica	2.805.535	633	**21.555**
III	VODOVOD GRADA VUKOVARA d.o.o. Vukovar	1.743.131	387	**20.814**
III	VODOVOD d.o.o. Makarska	3.183.345	300	**20.004**
III	VIO ŽRNOVNICA CRIKVENICA VINODOL d.o.o. Novi Vinodolski	2.015.782	352	**19.983**
III	TEKIJA d.o.o. Požega	2.271.076	868	**16.744**
III	VIRKOM d.o.o. Virovitica	1.609.161	667	**15.681**
III	VODOVOD I ODVODNJA CETINSKE KRAJINE d.o.o. Sinj	2.721.548	576	**15.344**
III	SISAČKI VODOVOD d.o.o. Sisak	2.384.460	519	**14.462**
III	VODOVOD BRAČ d.o.o. Supetar	2.008.926	303	**14.372**
III	ĐAKOVAČKI VODOVOD d.o.o. Đakovo	1.598.816	480	**14.336**
III	KOMUNALAC d.o.o. Biograd na moru	1.808.535	320	**14.266**
III	KOPRIVNIČKE VODE d.o.o. Koprivnica	2.396.838	606	**13.992**
III	LIBURNIJSKE VODE d.o.o. Ičići	1.979.563	482	**13.721**
III	VODOVOD LABIN D.O.O. Labin	1.757.077	478	**12.855**
III	VODOVOD IMOTSKE KRAJINE d.o.o. Imotski	1.021.639	428	**12.779**
III	VODOVOD d.o.o. Omiš	1.893.984	480	**12.459**
III	VODOVOD ZAPADNE SLAVONIJE d.o.o. Nova Gradiška	936.257	556	**11.694**
III	MOSLAVINA d.o.o. Kutina	1.250.161	398	**11.682**
III	VODOOPSKRBA I ODVODNJA ZAPREŠIĆ d.o.o. Zaprešić	2.527.202	599	**11.483**
III	VODOOPSKRBA I ODVODNJA CRES LOŠINJ d.o.o. Cres	1.418.407	275	**10.681**
III	KOMUNALIJE d.o.o. Novalja	1.116.294	179	**10.446**
III	VODNE USLUGE d.o.o. Bjelovar	1.438.575	396	**9.531**
III	VODOVOD I KANALIZACIJA d.o.o. Ogulin	805.725	514	**9.352**
III	HVARSKI VODOVOD d.o.o. Jelsa	1.366.076	305	**9.148**
III	PRIVREDA d.o.o. Petrinja	1.137.987	277	**8.979**
III	BARANJSKI VODOVOD d.o.o. Beli Manastir	820.811	395	**8.847**
III	IVKOM-VODE d.o.o. Ivanec	904.140	440	**8.629**
III	KOMUNALAC - VODOOPSKRBA I ODVODNJA d.o.o. Delnice	608.272	315	**8.403**
III	KOMUNALNO DUGA RESA d.o.o. Duga Resa	721.488	477	**8.103**
III	KOMRAD d.o.o. Slatina	836.334	385	**7.844**
III	USLUGA d.o.o. Gospić	829.113	520	**7.715**

CLUSTER	PWSP	Total billed water volume 2021 (m^3)	Total water supply system length (km)	Total number of service connections
III	KRAKOM-VODOOPSKRBA I ODVODNJA d.o.o. Krapina	723.237	538	**7.486**
III	KOMUNALIJE d.o.o. Đurđevac	615.730	620	**7.457**
III	KOMUNALAC d.o.o. Županja	732.879	120	**7.386**
III	VRELO d.o.o. Rab	1.052.878	178	**7.272**
III	NAŠIČKI VODOVOD d.o.o. Našice	806.239	295	**7.202**
III	VODNE USLUGE d.o.o. Križevci	831.336	383	**7.174**
III	VODE JASTREBARSKO d.o.o. Jastrebarsko	954.717	483	**6.983**
III	DARKOM VODOOPSKRBA I ODVODNJA d.o.o. Daruvar	711.310	180	**6.830**
III	DVORAC d.o.o. Valpovo	688.476	299	**6.731**
III	KOMUNALNO DRUŠTVO PAG d.o.o. Pag	631.975	106	**6.568**
III	NPKLM VODOVOD d.o.o. Korčula	987.882	400	**5.724**
III	VODOVOD d.o.o. Blato	485.734	97	**5.446**
III	VODOVOD I ODVODNJA d.o.o. Benkovac	627.782	333	**5.430**
III	METKOVIĆ d.o.o. Metković	740.714	103	**5.217**
III	KOMUNALNO OZALJ d.o.o. Ozalj	400.817	365	**5.123**

Cluster IV is defined by the total number of connections of less than 5,000 and is presented in Table 2.4.

Table 2.4. PWSPs in Cluster IV

CLUSTER	PWSP	Total billed water volume 2021 (m^3)	Total water supply system length (km)	Total number of service connections
IV	RAD d.o.o. Drniš	495.974	223	**4.861**
IV	VODOOPSKRBA d.o.o. Darda	418.138	180	**4.839**
IV	HIDROBEL d.o.o. Belišće	461.206	121	**4.834**
IV	VODE LIPIK d.o.o. Pakrac	447.638	260	**4.822**
IV	IZVOR Ploče d.o.o. Ploče	749.058	122	**4.657**
IV	KOMUNALAC d.o.o. Otočac	416.389	479	**4.392**
IV	KOMUNALNO PODUZEĆE d.o.o. Knin	633.301	150	**4.321**
IV	VODOVOD I ODVODNJA OTOKA VISA d.o.o. Komiža	356.436	85	**4.045**
IV	KONAVOSKO KOMUNALNO DRUŠTVO d.o.o. Čilipi	698.648	261	**3.880**
IV	VODOVOD I ODVODNJA d.o.o. Senj	340.680	120	**3.866**
IV	MIHOLJAČKI VODOVOD d.o.o. Donji Miholjac	443.581	180	**3.710**
IV	VODOVOD I ODVODNJA d.o.o. Orebić	444.970	89	**3.605**
IV	KOMUNALIJE d.o.o. Ilok	306.581	131	**3.596**
IV	VODA d.o.o. Orahovica	370.027	185	**3.458**
IV	UREDNOST d.o.o. Čepin	351.635	78	**3.430**
IV	VODOVOD NOVSKA d.o.o. Novska	392.024	122	**3.392**
IV	KOMUNALNO d.o.o. Vrgorac	365.500	250	**3.228**
IV	OTOK UGLJAN d.o.o. Preko	251.089	70	**2.913**
IV	VODOVOD GLINA d.o.o. Glina	484.550	141	**2.912**
IV	VIOP d.o.o. Pregrada	227.669	247	**2.779**
IV	KOMUNALIJE VODOVOD d.o.o. Čazma	401.891	429	**2.743**
IV	VODOOPSKRBA I ODVODNJA TOPUSKO d.o.o. Topusko	220.770	226	**2.580**
IV	VODE VRBOVSKO d.o.o. Vrbovsko	165.523	180	**2.457**
IV	DRENOVAČKI VODOVOD d.o.o. Drenovci	149.906	69	**2.227**
IV	VODOVOD KLINČA SELA d.o.o. Donja Zdenčina	240.090	87	**2.143**
IV	KOMUNALAC d.o.o. Slunj	282.316	222	**2.134**
IV	VODORAD d.o.o. Đurđenovac	188.573	60	**2.073**

CLUSTER	PWSP	Total billed water volume 2021 (m³)	Total water supply system length (km)	Total number of service connections
IV	VODOVOD GRUBIŠNO POLJE d.o.o. Grubišno Polje	213.507	100	**1.948**
IV	GRAČAC VODOVOD I ODVODNJA d.o.o. Gračac	139.678	76	**1.946**
IV	VODOVOD POVLJANA d.o.o. Povljana	98.372	25	**1.851**
IV	VODOVOD - VIR d.o.o. Vir	191.824	31	**1.846**
IV	VODOVOD KORENICA d.o.o. Korenica	258.809	85	**1.816**
IV	VODOVOD OPUZEN d.o.o. Opuzen	117.133	45	**1.775**
IV	JP KOMUNALAC d.o.o. Hrvatska Kostajnica	136.798	136	**1.659**
IV	VODE PISAROVINA d.o.o. Pisarovina	165.277	136	**1.657**
IV	KOMUNALNO DRUŠTVO ČABRANKA d.o.o. Čabar	101.530	134	**1.570**
IV	HUMVIO d.o.o. Hum na Sutli	194.257	215	**1.549**
IV	VODOVOD I ODVODNJA VOJNIĆ d.o.o. Vojnić	126.577	170	**1.547**
IV	KOMUNALNO TRGOVAČKO DRUŠTVO GUNJA d.o.o. Gunja	108.439	38	**1.470**
IV	CRNO VRILO d.o.o. Karlobag	104.282	27	**1.410**
IV	VODOVOD d.o.o. Brinje	127.529	176	**1.336**
IV	VODAKOM d.o.o. Pitomača	102.569	146	**1.327**
IV	USLUGA d.o.o. Vrlika	137.185	105	**1.200**
IV	KOMUNALAC - DVOR d.o.o. Dvor	79.277	45	**1.061**
IV	VODE KRAŠIĆ d.o.o. Krašić	89.415	44	**1.030**
IV	SPELEKOM d.o.o. Rakovica	191.392	80	**987**
IV	VISOČICA d.o.o. Donji Lapac	56.329	170	**909**
IV	JKP JASENOVAČKA VODA d.o.o. Jasenovac	44.939	113	**813**
IV	VODOOPRSKRBA d.o.o. Hrvatska Dubica	49.878	92	**799**
IV	SABUŠA d.o.o. Kukljica	61.123	10	**747**
IV	IZVOR ORAH d.o.o. Trpanj	67.645	16	**733**
IV	KRALJEVAC d.o.o. Udbina	67.855	75	**683**
IV	VODOVOD d.o.o. Veliki Grđevac	57.482	91	**657**
IV	KAPELAKOM d.o.o. Kapela	54.175	92	**637**
IV	LIP-KOM d.o.o. Lipovljani	47.625	41	**625**
IV	KAPLJA d.o.o. Lovinac	37.892	59	**523**
IV	VODOVOD LASINJA d.o.o. Lasinja	32.975	123	**514**
IV	KOMUNALNO DRUŠTVO KIJEVO d.o.o. Kijevo	21.157	25	**432**
IV	VODE ŽUMBERAK d.o.o. Kostanjevac	58.233	190	**429**
IV	ZAŽABLJE d.o.o. Mlinište	14.233	17	**270**
IV	VODOVOD HRVATSKO PRIMORJE-JUŽNI OGRANAK d.o.o. / Senj		65	**16**
IV	KOMUNALNO DRUŠTVO BISKUPIJA d.o.o. Biskupija	31.378		**0**
IV	KOMUNALNO DRUŠTVO DUGI OTOK I ZVERINAC d.o.o. Sali	31.794	19	**0**
IV	VODA GAREŠNICA d.o.o. Garešnica	162.116	63	**0**
IV	VODA MLJET d.o.o. Babino Polje	7.231		**0**
IV	VODOVOD I ODVODNJA BISTRA d.o.o. Bistra	271.363		**0**

2.1 Estimation of water losses in public supply systems (general)

2.1.1 Water losses in general

The losses of water from the pipeline network represent a significant problem for every provider of water services and an inseparable part of every water supply system, with the only thing that varies the volume of water losses. Water losses are also present in countries with well-developed infrastructure and good business practice.

Water losses depend on the characteristics of the pipeline network and other local factors, operating practice of a particular provider of water services, and the level of technology and expertise applied for their management. The volumes lost vary strongly not only among countries and regions, but also within a country and a region, and from one water service provider to another. The components of water losses and their relative weights also vary depending on the country, region, and water service provider.

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 the theoretical assumptions that define the term "water losses" and their components within the overall water balance. Hence, the basic theoretical assumptions related to water losses will be presented concisely below in order to provide a better understanding of the overall issue.

Defining water losses

The terms "water loss" and "non-revenue water" are internationally accepted terms. It is necessary to make a distinction between the two. In the global practice so far, the term "water losses" has most often been associated with the term "non-revenue water" (NRW), which is defined as the difference between the system input volume (water supplied) and billed volume (revenue water):

$$\text{NRW (m}^3\text{/year)} = \text{Water Supplied (m}^3\text{/year)} - \text{Revenue Water (m}^3\text{/year)}$$

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

$$\text{NRW (\%)} = \frac{NRW\ (m^3/year)}{Water\ Supplied(m^3/year)} \cdot 100$$

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.

The figure below shows a symbolic example of a changed % of NRW depending on the change in revenue water, with no change in the volume of water losses (in year 1, due to an increased demand by a new industrial consumer a bigger volume of water needs to be abstracted as well as delivered, while the volume of water losses remains the same, with NRW expressed in percentages apparently decreasing at the same time).

As a response to the weaknesses 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. In the year 2000, the IWA Water Loss Task Force (WLTF) (since 2010 Water Loss Specialist Group (WLSG)) proposed a methodology for the preparation of a water balance of a water supply system (IWA methodology), which was then adopted on the global level.

Developing a 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.

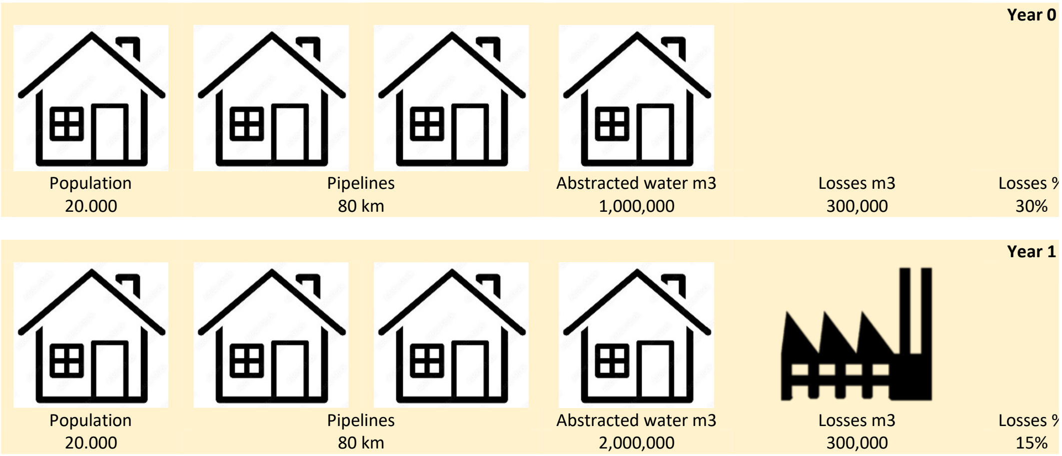


Figure 2.1. Change in losses depending on the change in revenue water (source: A. Lambert)

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 measurement 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 defines water losses as follows:

Water Losses (m^3/year) = Water Supplied (m^3/year) – Authorized Consumption (m^3/year)

Water Losses (m^3/year) = Real losses (m^3/year) + 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).

Figure 2.2. below illustrates a leakage on a supply main (which would be visible on the surface of the ground, would usually be instantly reported, separated from the system and eliminated) and a leakage on a house connection pipe (which might, if buried, might remain unnoticed for a long time).

Figure 2.2. Leakages on a supply main (street main) and a house connection pipe (Losses in Water Distribution Networks – A Practitioner's Guide to Assessment, Monitoring and Control, Malcolm Farley and Stuart Trow, IWA Publishing, 2003)

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.

The tables below present the extended and simplified water balances in accordance with the IWA methodology.

Table 2.5. Extended water balance according to the IWA methodology (all the categories expressed in m³/year)

Volume from Own Sources	System Input Volume (corrected for known errors)	Water Exported				Billed Water Exported
Water Imported		Water Supplied	Authorized Consumption	Billed Authorized Consumption	Revenue Water	Billed Metered Consumption
						Billed Unmetered Consumption
				Unbilled Authorized Consumption	Non-Revenue Water	Unbilled Metered Consumption
						Unbilled Unmetered Consumption
			Water Losses	Apparent Losses		Unauthorized Consumption
						Customer Metering Inaccuracies (and data handling errors)
				Real Losses		Leakage on Mains
						Leakage and Overflows at Storage Tanks
						Leakage on Service Connections up to point of customer metering

Table 2.6. Simplified water balance according to the IWA methodology (all the categories expressed in m³/year)

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption (customer water meters read)	Revenue Water
			Billed Unmetered Consumption (lump)	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Customer Metering Errors (and data handling errors)	
			Unauthorized Consumption	
		Real Losses	Leakage on Mains	
			Leakage and Overflows at Storage Tanks	
			Leakage on Service Connections up to point of customer metering	

Table 2.7. Description of the main terms in the extended and simplified water balance:

Term	Description
Volume from Own Sources	Volume of water entering the system from own sources of the water service provider
Water Imported	Volume of water taken over from other water service providers
Water Exported	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 Water exported
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.)

Term	Description
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)

It is only after the individual segments of the NRW are known that it is possible to realistically plan particular measures and activities aimed at the reduction of water losses. In that process, the following recommendations are given:

A. Unbilled metered volume must mandatorily be integrated into the water balance (water service providers often neglect this volume in their final annual account).

B. Unbilled unmetered volume (as part of the unbilled authorized consumption) eventually represents the real (authorized) consumption, and it is necessary to implement measures which will enable its quantification (metering exact volumes), thus reducing the volume of real losses.

C. Apparent losses also represent the really consumed volume which isn't properly registered, and if there are no exact indicators then at least a rough estimate is needed. Dealing with this segment of water losses requires a special approach (methodology and technology), which will result in an increase of revenue water, but also in a decrease of the assumed real losses.

D. Real losses, i.e., the water physically lost from the water supply system (leakages, overflows), is what primarily comes to mind when talking about addressing the issue of water losses, making it essential to know the exact volume (which will clearly be smaller than the volume obtained in the calculation expressing the percentage share of the NRW in relation to Water Supplied).

All the components of the water balance and performance indicators derived therefrom 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, 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.

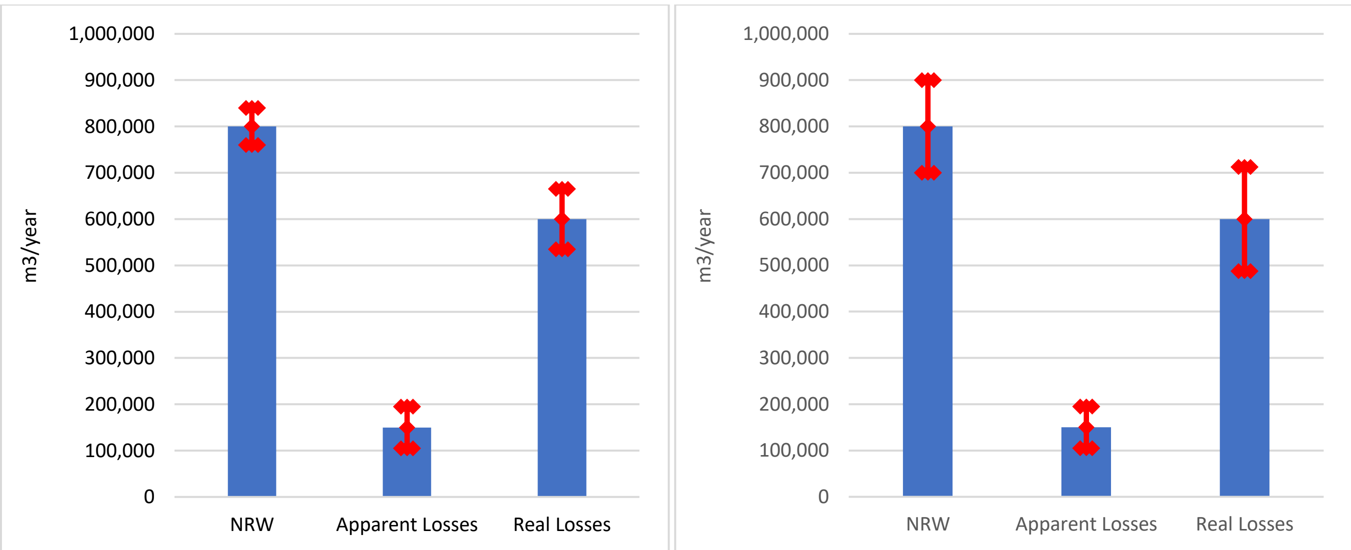
The analysis implies applying a method of calculating confidence with 95% certainty of accuracy, with initial definition of the value of the 95% confidence limit for Water Supplied, Billed Authorized Consumption, Unbilled Authorized Consumption, and Apparent Losses, and with automatic calculation of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

A hypothetic example of the analysis of 95% certainty of the calculation of the water balance components is presented in Table 2.8, assuming Water Supplied in the volume of 2,000,000 m^3/year, Billed Authorized Consumption in the volume of 1,200,000 m^3/year, Unbilled Authorized Consumption in the volume of 50,000 m^3/year, and Apparent Losses in the volume of 150,000 m^3/year. In doing so, two different scenarios were analyzed in relation to defining the value of the 95% confidence limit for the Water Supplied and Billed Authorized Consumption. One can notice that an increasing value of the 95% confidence limit of individual water balance components leads to an increasing value of NRW, water losses, and real losses, which makes the overall analysis and making specific conclusions about the water losses less certain.

Table 2.8. Example analysis of 95% confidence of the calculation of water balance components

IWA water balance components	Volume (V) in m³/year	95% confidence limit (CL)		+/- m³	Standard deviation (SD) [=V x CL / 1.96]		Variance (Va) [=SD2]
a) 95% confidence limit for Water Supplied of 2%, and for Billed Consumption of 0%							
Water Supplied	2,000,000	+/-*	2%	40,000	20,408	→	416,493,128
-							+
Billed Authorized Consumption	1,200,000	+/-*	0%	0	0	→	0
NRW	**800,000**	**+/-**	**5%**	40,000	**20,408**	←	**416,493,128**
		[=SD/Vx1,96]					
-							+
Unbilled Authorized Consumption	50,000	+/-*	50%	25,000	12,755	→	162,692,628
Water Losses	**750,000**	**+/-**	**6%**	47,170	**24,066**	←	**579,185,756**
-		[=SD/V/0,5]					+
Apparent Losses	150,000	+/-*	30%	45,000	22,959	→	527,124,115
Real Losses	**600,000**	**+/-**	**11%**	65,192	**33,261**	←	**1,106,309,871**
b) 95% confidence limit for Water Supplied of 5%, and for Billed Consumption of 5%							
Water Supplied	2,000,000	+/-*	5%	100,000	51,020	→	2,603,082,049
-							+
Billed Authorized Consumption	1,200,000	+/-*	0%	0	0	→	0
NRW	**800,000**	**+/-**	**13%**	100,000	**51,020**	←	**2,603,082,049**
		[=SD/Vx1,96]					
-							+
Unbilled Authorized Consumption	50,000	+/-*	50%	25,000	12,755	→	162,692,628
Water Losses	**750,000**	**+/-**	**14%**	103,078	**52,591**	←	**2,765,774,677**
-		[=SD/V/0,5]					+
Apparent Losses	150,000	+/-*	30%	45,000	22,959	→	527,124,115
Real Losses	**600,000**	**+/-**	**19%**	112,472	**57,384**	←	**3,292,898,792**

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



a) b)

Figure 2.3. Result of analysis of 95% certainty of the calculation of individual water balance components according to example a) left and b) right from Table 2.8.

Performance indicators for water loss management

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.

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;
- “Bottom-Up” method.

Top-Down method

The application of the “Top-Down” method to identify the CARL comes down to the development of an extended or simplified IWA water balance, with the definition of Real Losses presenting the last phase in the water balance preparation. In that process, the CARL are defined as the volume remaining once the Authorized Consumption and Apparent Losses are deducted from the Water Supplied. It is recommended to do an analysis of 95% certainty of the calculation of the key water balance components, including the CARL.

Identifying the CARL using the Top-Down method doesn’t give information about the components of Real Losses. The Top-Down method cannot split Real Losses into losses due to detectable bursts (through active leakage control with fast and quality repair of failures) and unavoidable real losses (which can be reduced/eliminated with/through pressure management or replacement of infrastructure). This analysis also doesn’t give information about Real Losses due to different elements in infrastructure without which real loss control strategies cannot be developed. It is therefore recommended to use, where possible, the Top-Down method when calculating the CARL together with the Bottom-Up calculation method.

Bottom-Up method

The application of the “Bottom-Up” method to identify the CARL is based on the calculation of Real Losses from the results of flow measurements in small, discrete areas of a water distribution system – District Metered Areas (DMA). DMAs 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 CARL. 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. 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 the 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 global practice.

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), as illustrated in the hypothetic example presented in the figure below. For that reason, the identified 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 a FAVAD method, which is explained in more detail at the end of Chapter 2.1.1. Multiplying the average value of real losses over a 24-hour period by the number of days in a year gives the CARL.

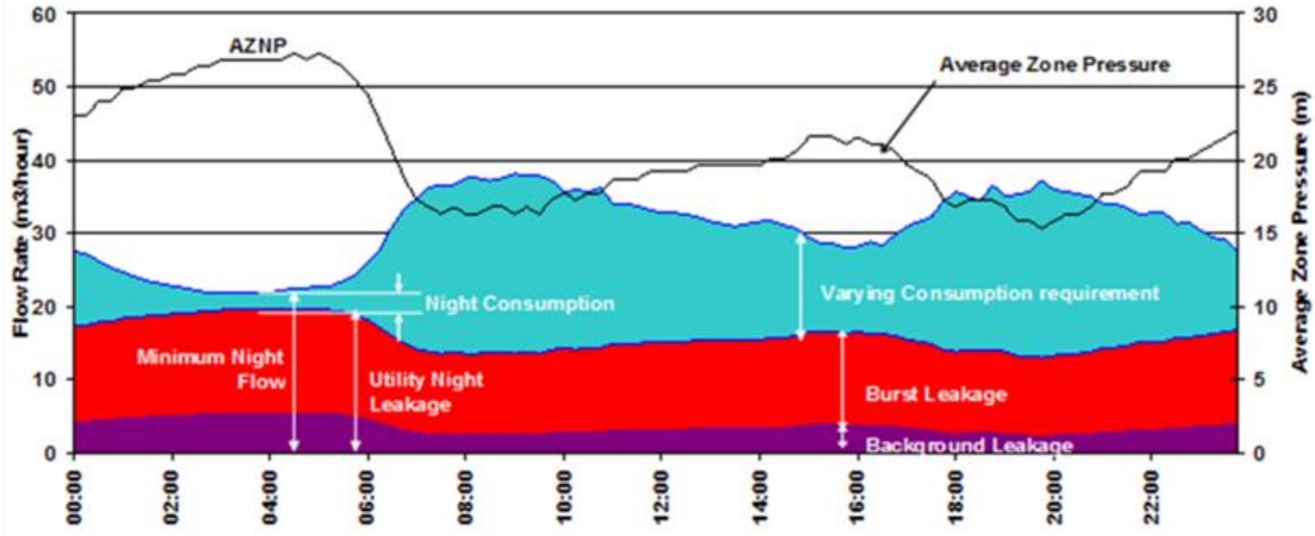


Figure 2.4. Hypothetic example of oscillations in flow, pressure, and water losses over a 24-hour period (source: R. Liemberger)

The benefit of the Bottom-Up method for the estimate of the CARL is that it ensures independent definition of the CARL. 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 seasonal water demand (watering of gardens, filling of pools,...), particularly in drier coastal regions, a distorted image of night flows can be obtained.

This method is also a check of the CARL identified using the Top-Down method. It is noted that the two results of calculation 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 real losses calculated using the Bottom-Up method refer to the current condition identified during a short-lasting metering campaign over a period within a year, while the real losses identified using the Top-Down method refer to a full-year period. The precision of the CARL calculation using the Bottom-Up method can be improved if additional more detailed field data can be collected which is needed to define the pressure/losses ratio (N1) and the Infrastructure Condition Factor (ICF).

Unavoidable Annual Real Losses (UARL)

The UARL represents the volume of real losses which also includes the impact of pressure within the water supply network. They actually represent the losses of very low intensity due to the formation of small cracks and leaks at joints and valves (background leakage). They are defined by empirical equations (shown below) 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).

$$UARL = \frac{18 \cdot L_m + 0{,}8 \cdot N_c + 25 \cdot L_p) \; x \; P_{av}}{L_m} \; (l/km \; mains/d)$$

$$UARL = \frac{18 \cdot L_m + 0{,}8 \cdot N_c + 25 \cdot L_p) \; x \; P_{av}}{N_c} \; (l/service \; connection/d)$$

Where:

- L_m – Mains length (km)
- N_c – Number of service connections (1)
- L_p – Total length of service pipes – from property line to meter (km)
- P_{av} – Average operating pressure (m)

As shown above, the UARL depends on several factors, very important among them being the number of service connections in the system. It is important to point out that the term “service connection” is used and that it represents a link from one connecting pipe (from a joint or a direct connection to the street main) to the consumer, i.e., to the first water meter, because that is also part of the main under the responsibility of the PWSP managing the system. It is important to distinguish the term "connection" which is sometimes used for registering or identifying a water customer, because that term can represent a larger number of water customers on one service connection (an example of this is one service connection in a building with a large number of apartments or water customers), and as such isn't applicable in the calculation of the ILI according to the IWA methodology and of other indicators of real losses.

Infrastructure Leakage Index (ILI)

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.

The ILI represents the ratio of the CARL to the UARL. 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-systems, 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).

Additional analyses related to water losses through the ILI can be done following the guidelines of the World Bank Institute. As one of the bases for the adoption of an optimum plan for future management of water supply systems, the table below lists the guideline description of real loss management performance categories in accordance with the World Bank guidelines.

Table 2.9. Assessment of the condition of water supply systems in relation to the ILI (according to the World Bank guidelines)

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

According to the obtained assessment of system condition, based on the ILI values, below is a list of standard measures that should be applied in order to reduce water losses and improve the current condition (Table 2.10).

Table 2.10. List of improvement measures based on the results of ILI criteria – World Bank Institute (WBI)

No.	WBI recommendations	A	B	C	D
1	Investigate pressure management options	YES	YES	YES	
2	Investigate speed and quality of repairs	YES	YES	YES	
3	Check economic intervention frequency	YES	YES		
4	Introduce/improve active leakage control		YES	YES	
5	Identify options for improved maintenance		YES	YES	
6	Assess economic leakage level	YES	YES		
7	Review burst frequencies		YES	YES	
8	Review asset management policy		YES	YES	YES
9	Deal with deficiencies in manpower, training and communications			YES	YES
10	5-year plan to achieve next lowest band			YES	YES
11	Fundamental peer review of all characteristics of the company and the system				YES

Real Losses Management

The main elements of efficient management of real losses are presented in Figure 2.5. The rectangle of the Current Annual Real Losses (CARL) tends to increase as the system ages (as well as an increase or changes in other causes of losses), but the impact on the condition of the system which is represented with the 4 arrows tends to the reduction of these losses. The yellow rectangle which represents a part of the real losses – Unavoidable Annual Real Losses (UARL) – is symbolically positioned in the upper part of the CARL rectangle because it depends on the system pressure, and its reduction can be impacted only through pressure management or reduction (the two-way arrows serve as a warning that if a pressure increase or hydraulic disturbances – water hammers are allowed, an increase of water losses can be expected as well).

The Economic Level of Leakage (ELL) is represented by a dashed line and gives information up to what limit it is realistic to expect a reduction in real water losses with economic efficiency, with its calculation depending on the economic calculation of all the costs.

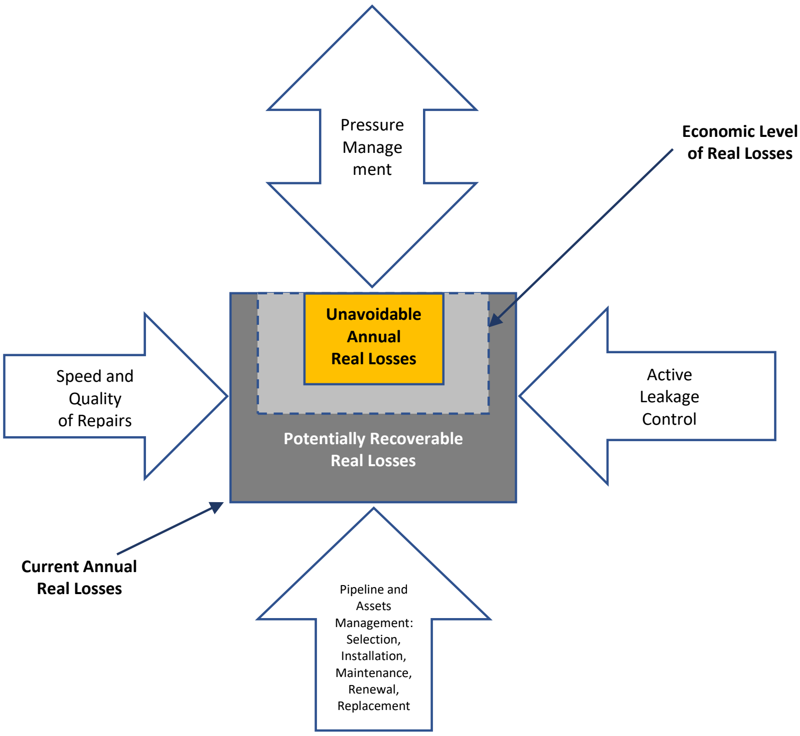


Figure 2.5. Main components of Real Losses management

Apparent Losses Management

Apparent (or commercial) losses represent the water volume that is actually delivered to consumers but is not calculated since it is not registered by a meter, or the water doesn't even through a meter, when it's a case of unauthorized consumption or simply water theft, either from hydrants, other elements available in the system, or illegal connections. When talking about metering accuracy, it is clear that is not absolute, deviations are possible, even acknowledged by the manufacturers of metering devices. Errors are also possible during the processing and calculation of the delivered service through a billing system. Figure 2.6. presents the possible courses of action which should ensure positive steps in the reduction of Apparent Losses, i.e., in nearing economically acceptable (targeted) Apparent Losses.

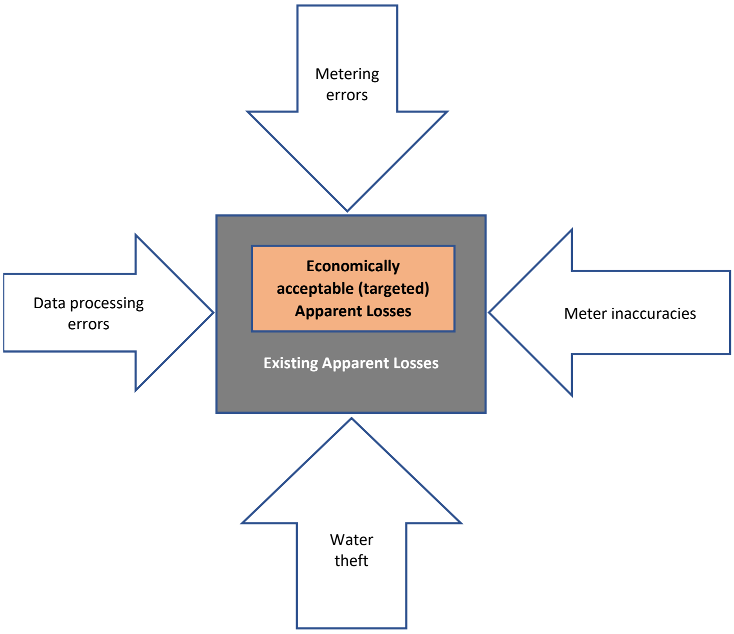


Figure 2.6. Main components of Apparent Losses management

The IWA WLSG members recommend that the goal in the reduction of Apparent Losses should be the volume of 5% of the Revenue Water (Billed Authorized Consumption).

Effects of pressure on leakage rate – FAVAD method

The effect of pressure on the Real Losses along the mains network (leakage rate) can nowadays be very well defined using some of the developed globally recognized methods. One of the most frequently used methods is a FAVAD (Fixed and Variable Area of Discharge Paths) concept which defines the dependence of the leakage rate on an increase or decrease in pressure within the system as a whole or within its individual sections (May, J. (1994), Leakage, Presssure and Control, BICS International Conference on Leakage Control, London; Thornton. J. (2003), Managing Leakage by managing pressure: A practical approach, Water 21, October issue, P43-44). A more simplified application of the FAVAD concept uses an exponent N1:

$$L_1 = L_0 \cdot \left(\frac{P_1}{P_0}\right)^{N1}$$

Where:

- L_1 – New volume of real leakage, after change in pressure [l/s]
- L_0 – Current volume of real leakage [l/s]
- P_1 – New pressure after change [m]
- P_0 – Current pressure before change [m]

The exponent N1 usually varies from 0.5 to 1.5(2.5) for individual areas and depends on the prevailing type of leaks and the type of pipe material (rigid or flexible pipes). It is often assumed that the average N1 value in large systems with mixed pipe materials is 1.0, implying a linear relationship between the loss (leakage) rate and pressure. However, for a higher share of rigid materials (asbestos cement and cast iron pipes), the N1 exponent reaches 0.5, while for a higher share of plastic pipes (PEHD, PP) the N1 exponent reaches 1.5(2.5). That is so because the size of leak hole at plastic pipes is sensitive to changes in pressure and increases with increasing pressure. Contrary to that, the leaks from rigid pipes have the N1 exponent close to 0.5 and are less sensitive to changes in pressure. For example, a reduction in pressure from 5.0 to 2.5 bars, with the N1 exponent of 1.25, results in a 58% reduction of leakage in existing bursts, at the same time reducing the likelihood of new damage and extending the pipe life (Lambert, A. and Thornton, J. (2011). The Relationships Between Pressure and Bursts – A State of the Art Update, Water21-April 2011, International Water Association, pp. 37-38).

So, the reduction in leakage rate, and thus of real losses as well, depends not only on the reduction of pressure (as an improvement measure), but also on the characteristics of the mains network which describes the value of the N1 exponent. In such circumstances, the ILI value, which is calculated as a ratio between the CARL and the UARL, if system improvement measures are implemented with a reduction of network pressure, significantly depends on the characteristics of the mains network and the N1 value. It happens that in systems with N1 values lower than 1.0 the UARL is reduced more intensively than the CARL, resulting in an increasing ILI value, regardless of the implemented improvement measures with pressure reduction and reduction of real losses.

2.1.2 Water losses in public water supply systems

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. Based on the globally recognized IWA methodology, losses are generally divided into “**apparent**” and “**real**” losses, as explained in the preceding chapter.

High **apparent** losses (customer meter inaccuracies and unauthorized consumption) are characteristic for the systems and areas which are less technologically and even socially developed. Investments in increasing the water meter precision class, regular replacement and maintenance have to be supported by appropriate financial policy of public water suppliers, i.e., the price of water services, which is also related to the national income. Unauthorized consumption or water theft in general are characteristic for systems which are technically not developed sufficiently through the development of the Geographic Information System (GIS), a SCADA system, division of the system into smaller metering and management units (DMAs). They often correlate with areas with scarce rainfall, agricultural areas, and areas where local regulations and procedures cannot appropriately prevent such behavior.

The matter is much more complex when it comes to **real** water losses which are generally divided into leakage on mains, leakage at storage tanks, and leakage on service connections up to point of customer meter. The first, maybe even the most important reason behind the losses of water in all the above elements is the structural inadequacy of the systems. The development of water supply systems went hand in hand with the development and expansion primarily of towns, where the water losses today are the highest. The water abstracted from wells or water intakes would be transported to a storage tank, from which it would be supplied further. Towns spread to higher or lower elevations, due to which the system structure was upgraded, branch systems were turned into ring or combined systems, and new abstraction sites moved further away from the centers of consumption. The frequent result of such practice are systems with inadequate pressures which have a significant effect on water losses, with system inadequacy also reflected in the growing demand for energy consumption.

Changes in system structure are the most demanding in technical and financial terms and will have to take place in accordance with available financial resources and plans. Dividing systems into smaller units, District Metered Areas (DMAs) and Pressure Management Areas (PMAs) where pressures can be managed, with certain weaknesses (age of water in the mains, need to optimize branch profiles, need for more frequent flushing and additional disinfection), brings significant advantages in system management and control and reduction of water losses, becoming more and more a standard in system development, in particular in the need to reduce water losses.

When the issue of frequent pressure changes due to different operating regimes, even more unfavorable if there is no 24-hour water supply, is added to the long and inadequate systems, water losses become unavoidable. A particular problem occurs at non-stationary operating regimes, primarily when pumps fall out of operation due to an interruption in power supply or sudden closure or opening of valves. The system which is not hydraulically optimized with storage tanks (their filling and emptying), not protected with compressed air vessels in pressure boosters, air release/intake valves, and frequency converters, as well as appropriate valves on the network mains will have an impact on excessive pressures due to water hammer, and consequently on burst mains and increased water losses.

Over last several decades software has been developed which can with maximum detail and with minimum time increments calculate and present all the hydraulic patterns in water supply systems, optimize them with an analysis of an infinite number of variant solutions, both for stationary and non-stationary operation. This can help foresee and prevent overflows at storage tanks, particularly with regard to the fact that today there are sophisticated flow and (upstream and downstream) pressure regulation valves and SCADA systems with which, based on operating algorithms obtained from hydraulic mathematical modelling, these losses, which are regretfully still present in water supply system, can be prevented.

In order for all of that to be possible, detailed knowledge of one's own system is required. This primarily refers to establishing a consumer database, positioning consumers in space using the GIS, entering all the water supply elements into the GIS by entering materials, profiles, and age of mains, developing hydraulic models which are calibrated based on the measurement of flows, pressure, and disinfectant in order to fully know the system in each of its segments. It then serves as the basis for further detailed analyses of current condition, identification of all irregularities and deficiencies, and needs to implement appropriate improvement measures, and finally the definition of further water loss reduction measures. Luckily, the application of such principles is becoming more and more frequent, or at least the awareness about the necessity of technological solutions, primarily through the first phase of analysis of the overall issue of individual PWSPs, which consists of the preparation of conceptual solutions, i.e., more detailed studies or analyses that include considerations of everything mentioned above.

Real water losses, which refer to leakage on mains and leakage on service connections up to point of customer meter, depend on several factors. The first one is definitely the system age, where the measures of regular rehabilitation/replacement of mains, connections and in particular service connections are most often not implemented. The quality of construction and of built-in materials has an impact on the occurrence of bursts and, consequently, of water losses, the poor quality of which particularly stands out on service connections to customer water meters. Registering failures and connecting with the GIS is crucial for the implementation of optimum future rehabilitation of systems.

In addition to the weaknesses in terms of systems (not) equipped with the GIS and its modules and hydraulic models, there is also a problem of PWSPs being poorly technically equipped. The lack of portable flow and pressure meters, correlators, geophones, noise loggers, etc. makes it impossible to carry out active leakage control, leading to continuous deterioration of system condition and increase in water losses.

In addition to all of the above, **the most significant problem in the reduction of water losses has to do with human resources**. A problem that is so specific requires various know-how and abilities to lead teams, manage staff, etc. Investing in knowledge, if needed outsourcing, formation of teams which need to include an engineer, motivated staff, all of which requires continuous financial investment, are the **basic precondition to adequately manage water losses**. It is exactly the lack of human resources and technical know-how that is the biggest problem today for adequate implementation of water loss reduction measures.

2.2 Characteristics and status of water supply systems

Croatia belongs to countries rich in water resources. Years of intensive development, in particular after gaining independence in 1991, made it possible for the rate of connection to the water supply system be at around 95%. The level of development and rate of coverage are higher in urban areas, while in certain PWSPs with more developed areas this figure can be lower. Water supply is continuous, 24/7, which means that pipelines are constantly under pressure, except in drier years when in some areas parts of the system can fall out of regular operation.

Water supply systems can generally be divided into those which were through history developed from the centres of settlements towards peripheral, newer parts of settlements, and more recent water supply systems which were planned and built at times of more modern technical know-how (software tools for hydraulic modelling, equipment for dynamic regulation of flows and pressures, frequency regulators of pumps, equipment to protect from the water hammer, etc.).

Water supply systems which were through history most often developed from town centres towards their edges were conceived based on the principles of abstrating water in upland or lowland intakes, transporting water to a storage tank, and distributing water through distribution mains (ring and tree systems). They are most often characterized by not being hydraulically optimal in terms of the capacities of the main transport routes, optimum position of storage tanks in relation to the more recent parts of the settlement often with a more dominant number of consumers, and lower system regulation flexibility. At the same time, they have a marked problem with the old network and lack of information about the exact positions and profiles. In such systems, the average pressures are often above or below the optimum values (3-4 bar). The equipment in the key structures (pressure boosters and storage tanks) can be out-of-date, and the protection from water hammer inadequate.

When conceiving more recent water supply systems, whether individual systems were integrated into a regional system based on the integration of new regional water intake/abstraction sites or fully new systems were simply planned for new settlements or whole areas, appropriate hydraulic analyses were used that were based on modern software tools, primarily for stationary regimes. Luckily, the impact of the knowledge of and education about the issue related to nonstationary phenomena, and even the development of a software package within the national system, has been such that many big water supply systems have been properly conceived and appropriately protected from exceeded pressures (at least those above 7 to 8 bar). The result of such an approach is that pressures in such newer systems are more favorable.

The future development of water supply systems will be based on changes in the water supply layout in order to optimize operation, pressures and energy where possible (e.g., Vodoopskrba i odvodnja d.o.o. Zagreb through the establishment of Zone 0 as the largest PWSP, followed by some smaller ones), with the development of DMAs and PMAs, to those water supply systems the optimization of which will be based exclusively on the establishment of DMAs and PMAs.

2.2.1 General technical data about water supply systems

A large majority of the PWSPs have their own sources, some import or partly import water and partly export water to other PWSPs. The water supply network is developed, built of different materials, and practically all the PWSPs have storage tanks and pumping stations. Where the abstracted water doesn't comply with the Ordinance on sanitary quality of drinking water, adequate water treatment plants have been built. Water disinfection plants have also been built in the systems, making the water from the public water supply system potable throughout Croatia.

2.2.1.1 Technical characteristics of water supply systems by PWSPs

The tables below present the basic data about water supply systems by PWSPs, divided by clusters.

Table 2.11. General data about Cluster I PWSP

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other PWSPs)	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
I	VODOOPSKRBA I ODVODNJA d.o.o. Zagreb	113,073,582	50%	3,328	59	131,760	28%	74	14	37	102,322

Table 2.12. General data about Cluster II PWSPs

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other PWSPs)	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
II	ISTARSKI VODOVOD d.o.o. Buzet	17,166,608	27%	2,425	96	99,248	141%	50	2	24	73,066
II	VODOVOD I KANALIZACIJA d.o.o. Split	46,507,977	60%	1,427	51	66,842	35%	48	11	5	66,739
II	VODOVOD d.o.o Pula	8,367,637	18%	993	32	39,431	115%	16	0	13	58,793
II	VODOVOD I ODVODNJA d.o.o. Šibenik	16,194,894	52%	1,496	55	74,800	112%	15	5	9	52,075
II	VARKOM d.d. Varaždin	10,605,705	41%	1,671	20	15,250	35%	16	27	5	48,389
II	VODOVOD d.o.o. Zadar	29,160,209	65%	1,546	29	41,185	34%	24	0	12	47,398
II	KD VODOVOD I KANALIZACIJA d.o.o. Rijeka	21,793,068	41%	958	54	114,368	128%	32	1	15	40,851
II	MEĐIMURSKE VODE d.o.o. Čakovec	6,021,267	23%	1,121	8	3,650	15%	1	6	10	40,850
II	VODOVOD d.o.o. Slavonski Brod	9,727,788	59%	976	14	9,243	23%	18	0	13	34,806
II	VINKOVAČKI VODOVOD I KANALIZACIJA d.o.o. Vinkovci	9,409,712	62%	860	4	6,200	16%	4	0	21	33,982
II	ZAGORSKI VODOVOD d.o.o. Zabok	6,287,452	42%	2,227	60	22,055	85%	34	66	5	33,226

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
II	VODOVOD-OSIJEK d.o.o. Osijek	10,831,879	41%	769	7	10,580	24%	2	4	7	31,450

Table 2.13. General data about Cluster III PWSPs

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other PWSPs)	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
III	VODOOPSKRBA I ODVODNJA ZAGREBAČKE ŽUPANIJE d.o.o. Zagreb	5,345,824	27%	1,084	15	6,200	28%	11	22	6	27,369
III	PONIKVE VODA d.o.o. Krk	3,391,794	19%	546	33	29,726	213%	17	3	18	27,105
III	VODOVOD I KANALIZACIJA d.o.o. Karlovac	9,550,045	64%	750	13	15,870	40%	17	1	7	27,023
III	VODOVOD DUBROVNIK d.o.o. Dubrovnik	7,627,185	36%	325	38	23,248	74%	19	11	13	26,195
III	VG VODOOPSKRBA d.o.o. Velika Gorica	4,589,883	39%	633	6	3,800	20%	5	2	13	21,555
III	VODOVOD GRADA VUKOVARA d.o.o. Vukovar	2,288,954	24%	387	2	3,660	39%	0	4	7	20,814
III	VODOVOD d.o.o. Makarska	7,043,835	55%	300	31	27,700	96%	11	0	11	20,004
III	VIO ŽRNOVNICA CRIKVENICA VINODOL d.o.o. Novi Vinodolski	3,396,341	41%	352	34	3,118	22%	12	1	3	19,983
III	TEKIJA d.o.o. Požega	3,750,128	39%	868	12	9,280	60%	20	0	18	16,744
III	VIRKOM d.o.o. Virovitica	2,504,828	36%	667	2	2,220	22%	5	0	1	15,681
III	VODOVOD I ODVODNJA CETINSKE KRAJINE d.o.o. Sinj	5,887,541	54%	576	25	16,650	69%	20	0	5	15,344
III	SISAČKI VODOVOD d.o.o. Sisak	6,332,592	62%	519	1	10,000	38%	0	4	4	14,462
III	VODOVOD BRAČ d.o.o. Supetar	3,046,989	34%	303	24	19,077	152%	10	1	4	14,372
III	ĐAKOVAČKI VODOVOD d.o.o. Đakovo	2,370,343	33%	480	8	4,200	43%	0	9	5	14,336
III	KOMUNALAC d.o.o. Biograd na moru	2,944,039	39%	320	3	6,500	54%	7	0	4	14,266
III	KOPRIVNIČKE VODE d.o.o. Koprivnica	2,797,417	14%	606	6	5,400	47%	4	8	4	13,992
III	LIBURNIJSKE VODE d.o.o. Ičići	2,860,261	31%	482	38	25,394	216%	12	0	10	13,721
III	VODOVOD LABIN D.O.O. Labin	2,468,986	29%	478	29	18,147	179%	9	10	11	12,855
III	VODOVOD IMOTSKE KRAJINE d.o.o. Imotski	4,269,359	76%	428	21	13,480	77%	8	0	3	12,779
III	VODOVOD d.o.o. Omiš	3,346,874	43%	480	20	8,666	63%	14	0	4	12,459
III	VODOVOD ZAPADNE SLAVONIJE d.o.o. Nova Gradiška	1,771,567	47%	556	4	6,900	95%	14	0	8	11,694
III	MOSLAVINA d.o.o. Kutina	1,716,288	27%	398	3	7,500	106%	1	13	4	11,682
III	VODOOPSKRBA I ODVODNJA ZAPREŠIĆ d.o.o. Zaprešić	4,745,968	47%	599	14	11,940	61%	7	1	2	11,483
III	VODOOPSKRBA I ODVODNJA CRES LOŠINJ d.o.o. Cres	2,714,737	48%	275	24	16,155	145%	7	3	11	10,681
III	KOMUNALIJE d.o.o. Novalja	1,395,197	20%	179	10	6,760	118%	0	0	2	10,446
III	VODNE USLUGE d.o.o. Bjelovar	2,168,211	34%	396	2	6,100	68%	1	0	1	9,531
III	VODOVOD I KANALIZACIJA d.o.o. Ogulin	2,228,147	64%	514	17	6,892	75%	23	9	10	9,352
III	HVARSKI VODOVOD d.o.o. Jelsa	2,013,479	32%	305	18	13,670	165%	4	2	4	9,148
III	PRIVREDA d.o.o. Petrinja	3,661,122	69%	277	9	7,930	53%	3	5	7	8,979
III	BARANJSKI VODOVOD d.o.o. Beli Manastir	1,400,781	41%	395	2	3,200	56%	0	2	3	8,847
III	IVKOM-VODE d.o.o. Ivanec	1,868,935	52%	440	16	3,350	44%	5	15	6	8,629
III	KOMUNALAC - VODOOPSKRBA I ODVODNJA d.o.o. Delnice	1,126,064	46%	315	44	12,790	276%	26	4	18	8,403
III	KOMUNALNO DUGA RESA d.o.o. Duga Resa	1,474,656	51%	477	12	5,525	91%	15	0	6	8,103
III	KOMRAD d.o.o. Slatina	1,340,421	38%	385	2	1,250	23%	2	1	3	7,844

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other PWSPs)	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
III	USLUGA d.o.o. Gospić	2,482,267	67%	520	8	3,050	30%	8	4	8	7,715
III	KRAKOM-VODOOPSKRBA I ODVODNJA d.o.o. Krapina	854,905	15%	538	36	6,380	182%	19	0	9	7,486
III	KOMUNALIJE d.o.o. Đurđevac	837,413	26%	620	4	800	23%	8	0	2	7,457
III	KOMUNALAC d.o.o. Županja	1,237,835	41%	120	0	0	0%	0	0	0	7,386
III	VRELO d.o.o. Rab	1,558,471	32%	178	11	4,015	63%	4	0	5	7,272
III	NAŠIČKI VODOVOD d.o.o. Našice	1,580,193	49%	295	1	330	5%	0	0	2	7,202
III	VODNE USLUGE d.o.o. Križevci	1,176,020	29%	383	7	4,980	103%	11	7	0	7,174
III	VODE JASTREBARSKO d.o.o. Jastrebarsko	2,278,184	58%	483	15	3,526	38%	3	0	9	6,983
III	DARKOM VODOOPSKRBA I ODVODNJA d.o.o. Daruvar	1,190,300	40%	180	6	2,750	56%	4	0	2	6,830
III	DVORAC d.o.o. Valpovo	1,080,881	36%	299	2	660	15%	1	0	1	6,731
III	KOMUNALNO DRUŠTVO PAG d.o.o. Pag	1,119,545	44%	106	12	8,130	177%	2	0	5	6,568
III	NPKLM VODOVOD d.o.o. Korčula	2,361,249	58%	400	17	15,100	156%	6	0	9	5,724
III	VODOVOD d.o.o. Blato	1,407,877	65%	97	8	4,445	77%	6	0	5	5,446
III	VODOVOD I ODVODNJA d.o.o. Benkovac	2,202,754	72%	333	6	8,900	98%	6	4	4	5,430
III	METKOVIĆ d.o.o. Metković	1,308,852	43%	103	4	2,700	50%	1	0	2	5,217
III	KOMUNALNO OZALJ d.o.o. Ozalj	629,996	36%	365	13	3,613	140%	9	3	2	5,123

Table 2.14. General data about Cluster IV PWSPs

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other PWSPs)	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
IV	RAD d.o.o. Drniš	1,464,799	66%	223	10	4,660	77%	6	0	2	4,861
IV	VODOOPSKRBA d.o.o. Darda	515,048	19%	180	2	750	35%	0	0	1	4,839
IV	HIDROBEL d.o.o. Belišće	639,702	28%	121	1	500	19%	0	0	1	4,834
IV	VODE LIPIK d.o.o. Pakrac	739,804	39%	260	1	2,300	76%	3	0	7	4,822
IV	IZVOR Ploče d.o.o. Ploče	1,964,002	62%	122	5	4,150	51%	0	0	2	4,657
IV	KOMUNALAC d.o.o. Otočac	2,268,015	82%	479	11	8,210	88%	6	4	1	4,392
IV	KOMUNALNO PODUZEĆE d.o.o. Knin	2,277,544	72%	150	7	3,500	37%	6	1	2	4,321
IV	VODOVOD I ODVODNJA OTOKA VISA d.o.o. Komiža	477,926	25%	85	16	6,825	347%	3	0	4	4,045
IV	KONAVOSKO KOMUNALNO DRUŠTVO d.o.o. Čilipi	1,032,604	32%	261	24	5,035	119%	15	4	3	3,880
IV	VODOVOD I ODVODNJA d.o.o. Senj	1,103,713	69%	120	15	4,600	101%	0	1	3	3,866
IV	MIHOLJAČKI VODOVOD d.o.o. Donji Miholjac	614,206	28%	180	3	400	16%	4	0	1	3,710
IV	VODOVOD I ODVODNJA d.o.o. Orebić	768,235	42%	89	8	5,500	174%	1	0	2	3,605
IV	KOMUNALIJE d.o.o. Ilok	523,515	41%	131	1	1,600	74%	7	5	5	3,596
IV	VODA d.o.o. Orahovica	540,012	31%	185	2	750	34%	1	4	2	3,458
IV	UREDNOST d.o.o.Čepin	511,979	31%	78	1	500	24%	0	1	0	3,430
IV	VODOVOD NOVSKA d.o.o. Novska	574,567	32%	122	2	4,000	169%	0	2	2	3,392
IV	KOMUNALNO d.o.o. Vrgorac	1,990,129	82%	250	17	5,220	64%	16	6	4	3,228
IV	OTOK UGLJAN d.o.o. Preko	365,242	31%	70	0	0	0%	0	0	0	2,913
IV	VODOVOD GLINA d.o.o. Glina	1,355,287	64%	141	3	1,690	30%	0	3	2	2,912
IV	VIOP d.o.o. Pregrada	375,361	39%	247	7	1,400	91%	6	2	2	2,779
IV	KOMUNALIJE VODOVOD d.o.o. Čazma	580,515	31%	429	5	2,773	116%	15	0	3	2,743

CLUSTER	PWSP	Water supplied 2021, m³ (Abstracted+Imported-Exported to other PWSPs)	NRW % 2021	Total length of water supply system (km)	Number of storage tanks	Total storage tank volume m³	% of water tank volume to max. daily consumption	Number of pump stations	Number of booster stations	Number of disinfection plants	Total number of service connections
IV	VODOOPSKRBA I ODVODNJA TOPUSKO d.o.o. Topusko	438,039	50%	226	4	2,080	116%	0	1	1	2,580
IV	VODE VRBOVSKO d.o.o. Vrbovsko	417,305	60%	180	12	2,690	157%	3	5	6	2,457
IV	DRENOVAČKI VODOVOD d.o.o. Drenovci	262,673	43%	69	2	100	9%	0	0	4	2,227
IV	VODOVOD KLINČA SELA d.o.o. Donja Zdenčina	427,979	44%	87	6	920	52%	1	0	6	2,143
IV	KOMUNALAC d.o.o. Slunj	932,209	70%	222	5	1,250	33%	3	0	1	2,134
IV	VODORAD d.o.o. Đurđenovac	478,534	61%	60	3	370	19%	0	0	1	2,073
IV	VODOVOD GRUBIŠNO POLJE d.o.o. Grubišno Polje	413,235	48%	100	2	700	41%	5	0	3	1,948
IV	GRAČAC VODOVOD I ODVODNJA d.o.o. Gračac	918,942	85%	76	3	1,050	28%	1	0	2	1,946
IV	VODOVOD POVLJANA d.o.o. Povljana	153,634	36%	25	2	1,500	238%	1	0	3	1,851
IV	VODOVOD - VIR d.o.o. Vir	220,598	13%	31	0	0	0%	0	0	0	1,846
IV	VODOVOD KORENICA d.o.o. Korenica	2,190,686	88%	85	3	650	7%	4	0	2	1,816
IV	VODOVOD OPUZEN d.o.o. Opuzen	173,286	32%	45	1	1,000	140%	0	0	1	1,775
IV	JP KOMUNALAC d.o.o. Hrvatska Kostajnica	767,966	82%	136	3	1,240	39%	5	0	1	1,659
IV	VODE PISAROVINA d.o.o. Pisarovina	211,736	22%	136	2	1,200	138%	3	0	3	1,657
IV	KOMUNALNO DRUŠTVO ČABRANKA d.o.o Čabar	246,163	59%	134	11	2,320	229%	1	1	12	1,570
IV	HUMVIO d.o.o. Hum na Sutli	308,133	37%	215	5	1,300	103%	2	0	0	1,549
IV	VODOVOD I ODVODNJA VOJNIĆ d.o.o. Vojnić	371,482	66%	170	5	1,550	102%	5	0	3	1,547
IV	KOMUNALNO TRGOVAČKO DRUŠTVO GUNJA d.o.o. Gunja	218,989	50%	38	1	100	11%	0	0	0	1,470
IV	CRNO VRILO d.o.o. Karlobag	141,743	26%	27	3	930	160%	1	0	2	1,410
IV	VODOVOD d.o.o. Brinje	1,024,644	88%	176	5	1,400	33%	3	0	3	1,336
IV	VODAKOM d.o.o. Pitomača	133,259	23%	146	2	1,103	201%	3	0	1	1,327
IV	USLUGA d.o.o. Vrlika	527,829	74%	105	4	2,100	97%	1	0	1	1,200
IV	KOMUNALAC - DVOR d.o.o. Dvor	334,453	76%	45	1	250	18%	1	0	2	1,061
IV	VODE KRAŠIĆ d.o.o. Krašić	164,050	45%	44	2	180	27%	2	0	2	1,030
IV	SPELEKOM d.o.o. Rakovica	435,290	56%	80	2	1,300	73%	0	1	1	987
IV	VISOČICA d.o.o. Donji Lapac	194,715	71%	170	4	1,400	175%	3	0	2	909
IV	JKP JASENOVAČKA VODA d.o.o. Jasenovac	133,262	66%	113	1	150	27%	1	0	1	813
IV	VODOOPRSKRBA d.o.o. Hrvatska Dubica	59,149	16%	92	1	143	59%	2	0	1	799
IV	SABUŠA d.o.o. Kukljica	137,573	56%	10	0	0	0%	0	0	0	747
IV	IZVOR ORAH d.o.o. Trpanj	102,825	34%	16	2	580	137%	0	0	1	733
IV	KRALJEVAC d.o.o. Udbina	88,212	23%	75	2	1,100	303%	2	0	2	683
IV	VODOVOD d.o.o. Veliki Grđevac	63,434	9%	91	1	250	96%	1	1	1	657
IV	KAPELAKOM d.o.o. Kapela	61,606	12%	92	1	250	99%	0	0	0	637
IV	LIP-KOM d.o.o. Lipovljani	57,832	18%	41	0	0	0%	1	0	0	625
IV	KAPLJA d.o.o. Lovinac	64,227	41%	59	0	0	0%	0	0	3	523
IV	VODOVOD LASINJA d.o.o. Lasinja	138,339	76%	123	1	400	70%	0	0	1	514
IV	KOMUNALNO DRUŠTVO KIJEVO d.o.o. Kijevo	32,550	35%	25	1	1,000	748%	0	0	0	432
IV	VODE ŽUMBERAK d.o.o. Kostanjevac	77,178	25%	190	4	550	173%	3	2	2	429
IV	ZAŽABLJE d.o.o. Mlinište	28,619	50%	17	0	0	0%	0	0	0	270
IV	VODOVOD HRVATSKO PRIMORJE-JUŽNI OGRANAK d.o.o. / Senj	190,906	5%	65	1	1,000	127%	1	0	3	16
IV	KOMUNALNO DRUŠTVO BISKUPIJA d.o.o. Biskupija	57,898	46%				0%				0
IV	KOMUNALNO DRUŠTVO DUGI OTOK I ZVERINAC d.o.o. Sali	38,153	17%	19	7	2,410	1537%	0	0	1	0
IV	VODA GAREŠNICA d.o.o. Garešnica	396,723	59%	63	3	900	55%	1	0	1	0
IV	VODA MLJET d.o.o. Babino Polje	7,231	0%				0%				0
IV	VODOVOD I ODVODNJA BISTRA d.o.o. Bistra	404,619	33%				0%				0

In the tables above, next to the column with the Storage Tank Volume there is an added column with a calculated share of the storage tank volume in relation to the maximum daily consumption which is calculated as an average day of the Water Supplied (minus the Water Exported to other PWSPs) plus a maximum day factor of 1.5. Namely, the generally required storage tank volume can be defined based on the daily water consumption. It also depends on the system size; as such, according to some references (e.g., Dieter Sshulze: “Die Wasserspeicherung”) it ranges from more than 100% for smaller systems (less than 2,000 m^3/day) to around 40% for systems with more than 4,000 m^3/day. It also depends on the availability of water resources and the flexibility of supply from the water intake. Looking at the table, it can be concluded that the majority of water supply systems have a sufficient storage tank volume, with the needs for new storage tanks arising to the largest extent in certain separated areas or areas where water supply is at higher risk (decreased stability), so there is a need to ensure higher coverage rates for daily consumption.

Figure 2.7. makes it clear that on the national level 79% of the PWSPs have a sufficent storage tank volume, while in terms of coverage by the storage tank volume in the planned period that figure is lower, amounting to 57% (Figure 2.8).

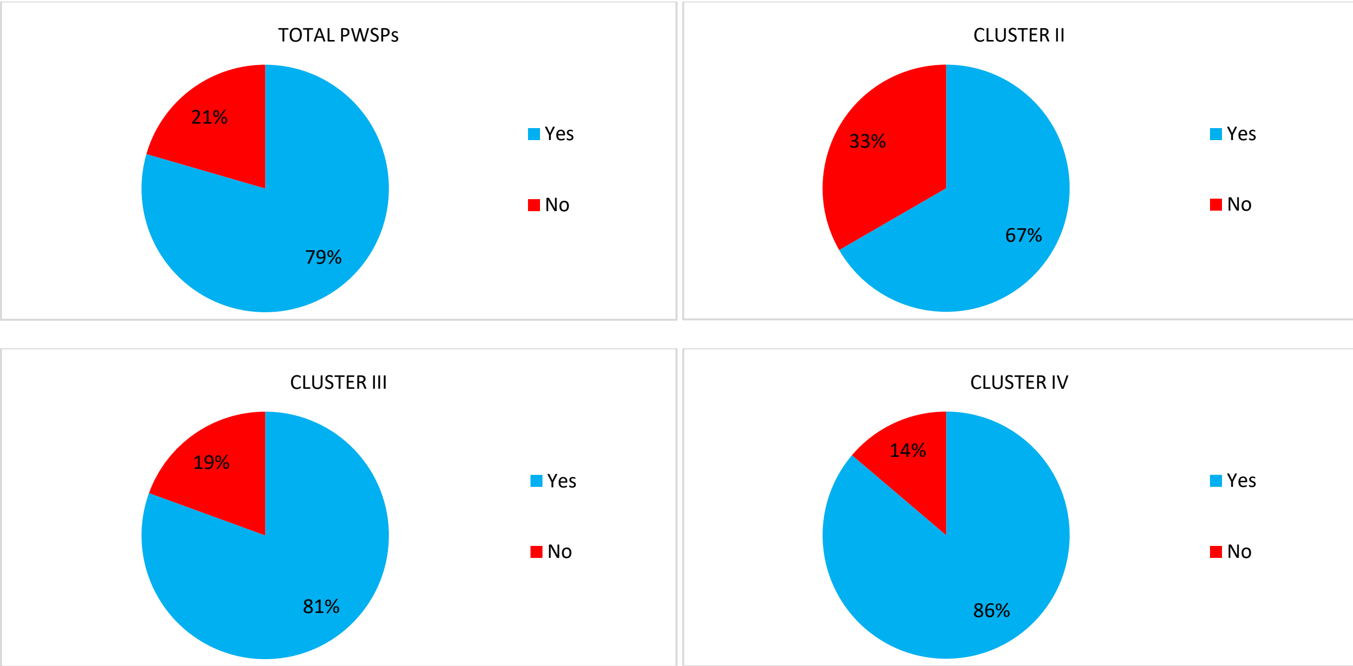


Figure 2.7. Coverage by storage tank volume in the current state on the national level and by PWSP clusters

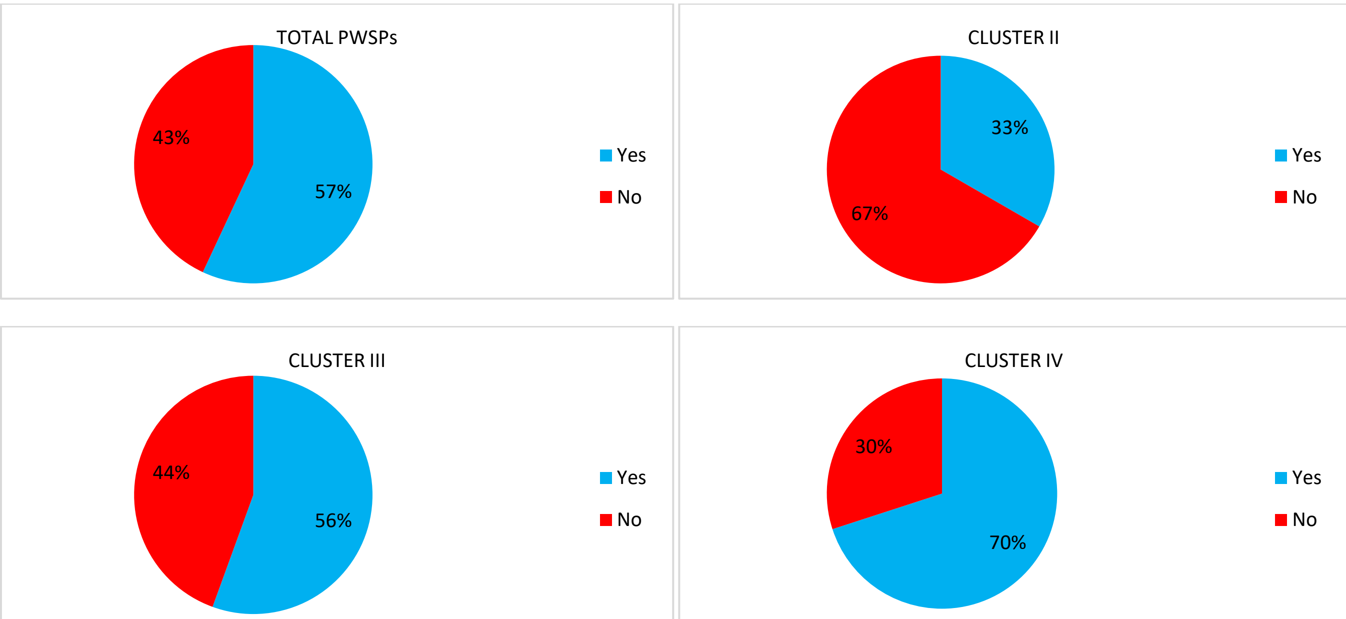


Figure 2.8. Coverage by storage tank volume for the future state on the national level and by PWSP clusters

In order to provide water suitable for drinking, and where the abstracted water doesn't comply with the relevant legislation, water treatment plants have been built and are in use. In the Black Sea basin, it is primarily manganese, iron and arsenic (to the largest extent in Eastern Slavonia) that are removed, sometimes ammonia as well. The Adriatic, primarily karstic, basin is characterized by occasional turbidity which is removed or planned to be removed with the construction of new water treatment plants, and with disinfection (mostly chlorination) in certain smaller systems.

Water supply systems end at the water meter shafts of the final consumers, practically all of which are measured. Chapter 2.4. presents the metering method from water abstraction to consumers' water meters, the way in which water meters are maintained, the frequency of their replacement, etc. Figure 2.9. below will present the precision classes of the water meters used in Croatia. The existing water meters enable adequate measurements, but for more reliable data and analyses it would be beneficial to increase the precision classes.

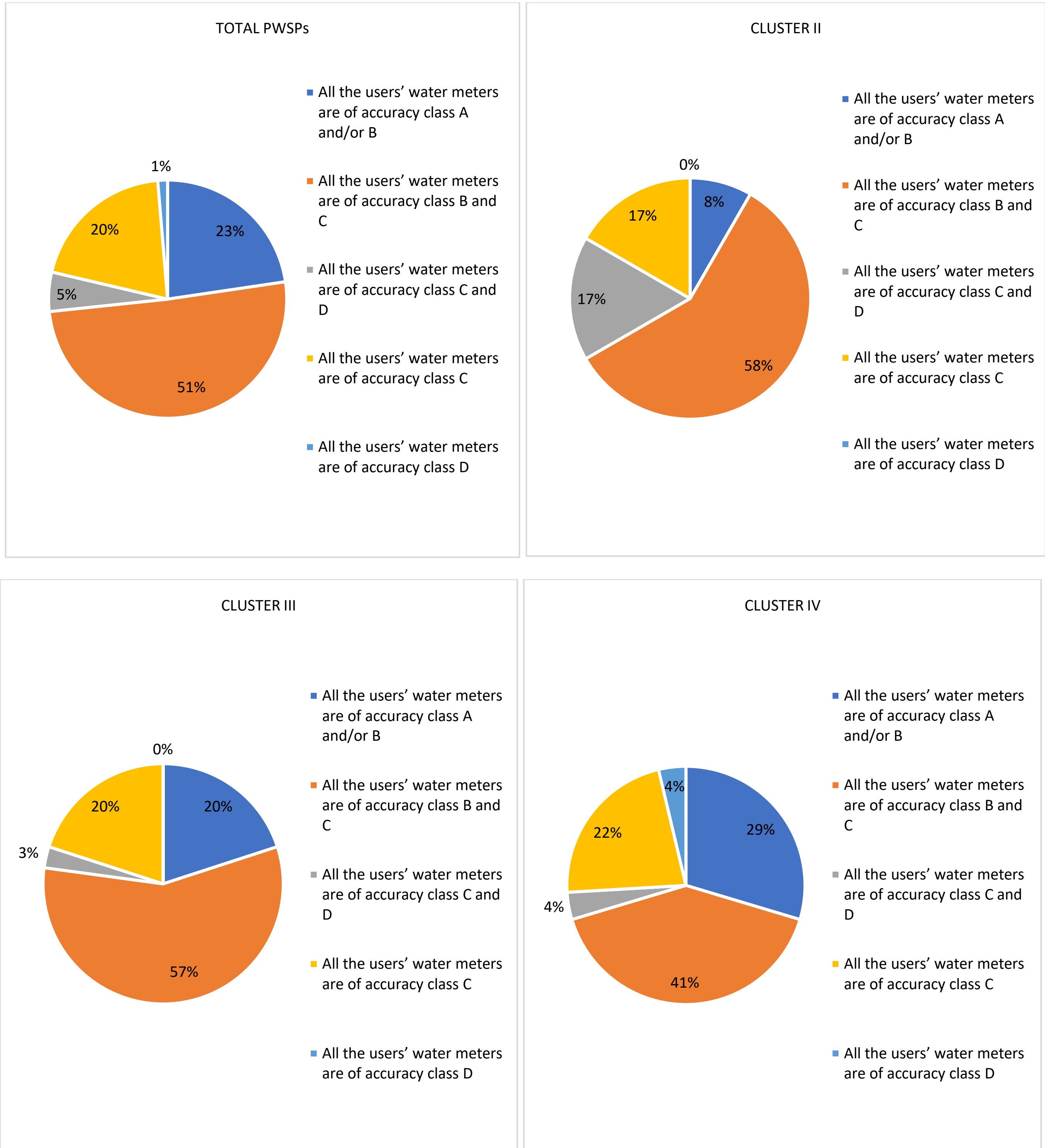


Figure 2.9. Precision (classes) of water meters on the national level and by PWSP clusters

2.2.1.2 Statistical data about water supply systems

The general technical data is presented in Table 2.11, Table 2.12, Table 2.13. and Table 2.14. In order to know the system and for future planning, it is very important to keep record of pipe materials, profiles and age. Figure 2.10. shows that only around 61% of the PWSPs keep record of materials. The Cluster I PWSP keeps record, with the situation worsening in the lower clusters. Pipe materials are diverse, as presented in Figure 2.11. It can be seen that there are ductile cast iron and PEHD pipes which have recently been used more frequently with profiles of up to DN 250 (DN 300), that there are still many PVC materials on which bursts are recorded more frequently in Croatia, and ACC pipes which even aren't that bad in terms of quality, but should gradually be replaced due to their age and type of material.

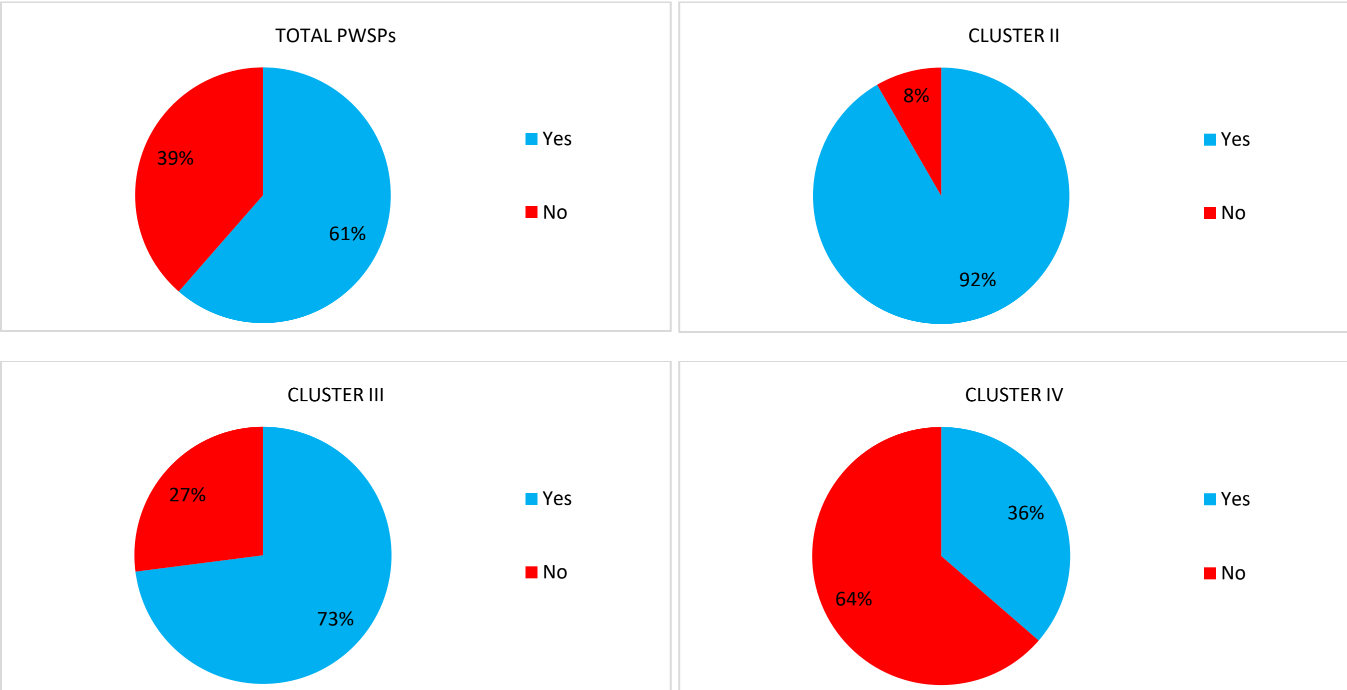


Figure 2.10. Record of pipe material statistics on the national level and by PWSP clusters

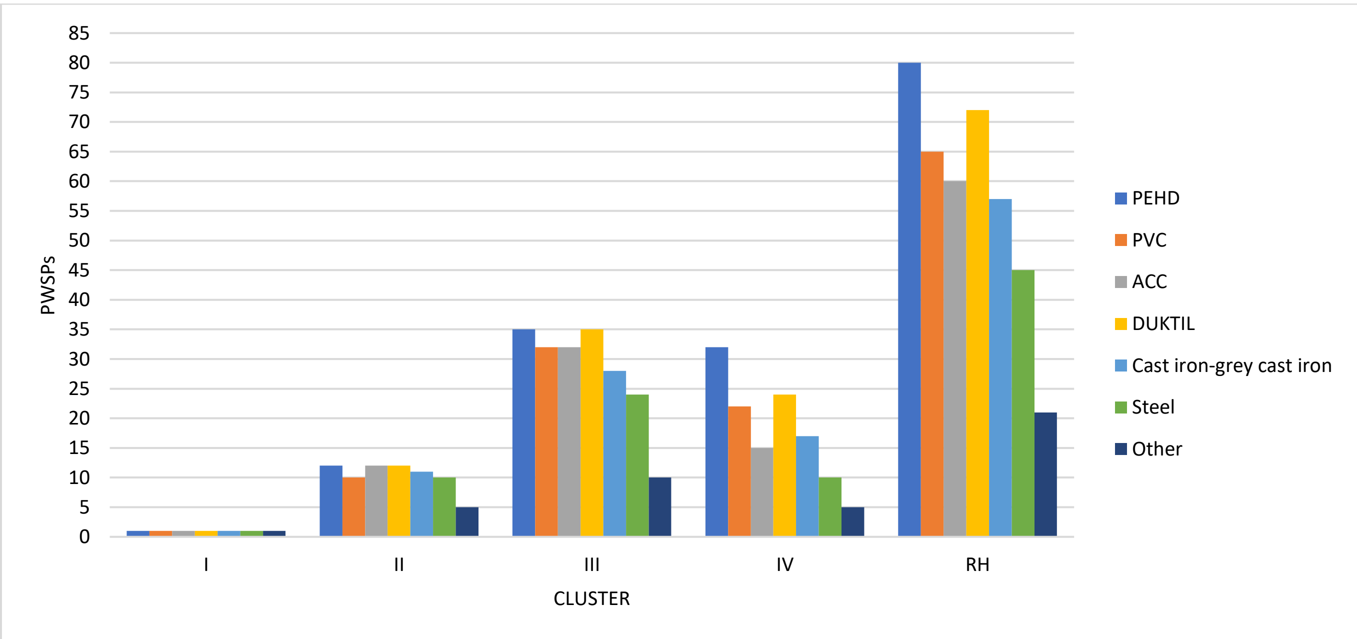


Figure 2.11. Pipe statistics by materials on the national level and by PWSP clusters

A certain share of the water mains network in Croatia was built of inadequate pipe materials (in relation to real operating conditions), which for example implies the laying of pipes of too low nominal pressure in relation to real pressures that are generated. Likewise, in certain sections there are pipes made of materials that cannot tolerate intensive changes of hydraulic operating conditions of flow, resulting in frequent bursts. Along certain sections of the mains network the quality of pipe laying is poor (e.g., no pipe bed in rocky soils, at relatively low depths, etc.). Certain sections of the mains network were built without the required pipe protection (e.g., cathodic protection, etc.).

When it comes to mains profiles and keeping record of them, the share on the national level is slightly higher (65%) than the share of recording of the pipe material, but still not sufficient to know the water supply system. The Cluster I PWSP records the profiles, with the level of knowledge/keeping record about profiles, just like materials, dropping by clusters (Figure 2.12).

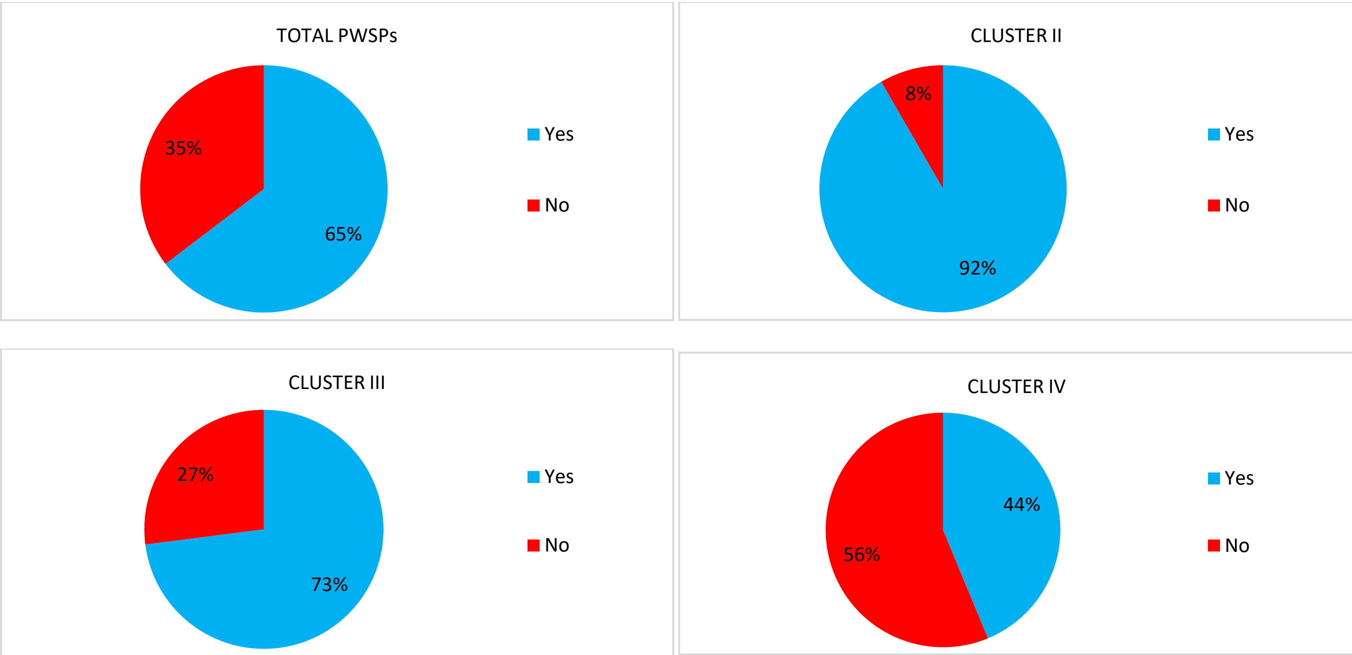


Figure 2.12. Record of pipe profile statistics on the national level and by PWSP clusters

A significant share of the water supply network in Croatia has a relatively high age, i.e., the design life of the pipes and supporting equipment has been exceeded (by even more than 50 years), and it is rational to expect their replacement. However, a large number of PWSPs, primarily the smaller ones classified into Clusters III and IV, don't keep the pipe statistics by age. The problem also partly comes from the fact that almost all the PWSPs on the annual level replace less than 2% of the water supply network, which together with the fact that the average pipe age is relatively high (Figure 2.14. through Figure 2.16.), continuously additionally increases the average age of water supply networks. For the purpose long-term sustainable management of water supply systems, such practice must be changed, i.e., the competent institutions must introduce mechanisms for mandatory pipe replacement in a certain share.

Figure 2.13. presents data about keeping record of the pipeline age, which shows that it is not satisfactory and drops in the lower clusters. The average age of the mains network by PWSPs is presented in Figure 2.14, while the ranges of the average age of the mains network by PWSP clusters are presented in Figure 2.15.

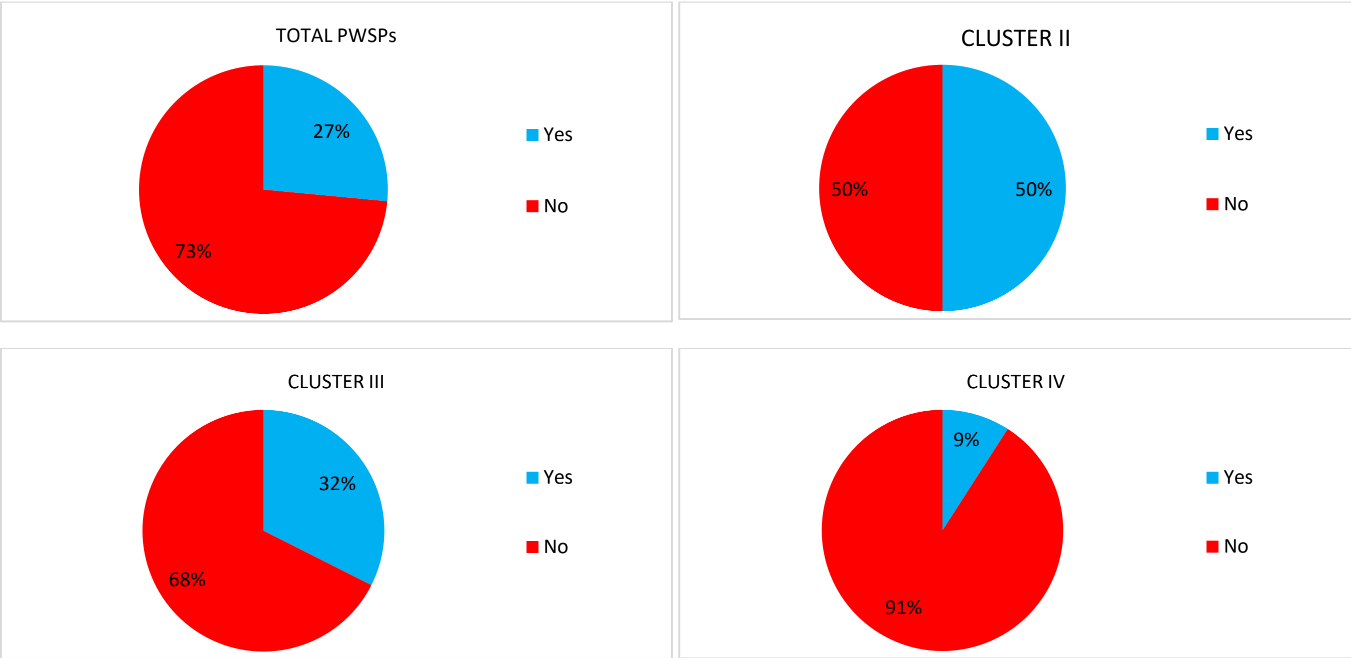


Figure 2.13. Record of pipe age statistics on the national level and by PWSP clusters

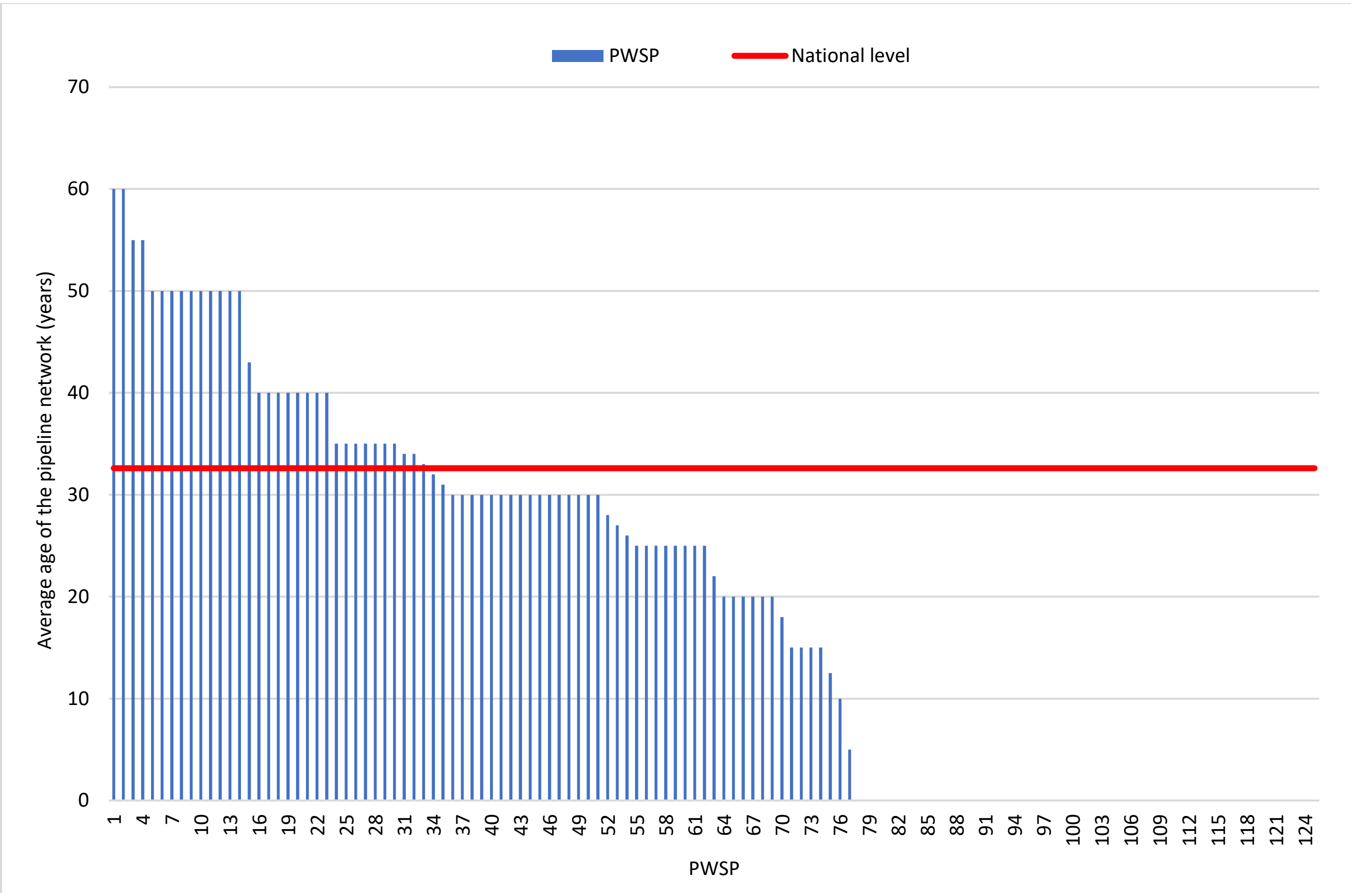


Figure 2.14. Distribution of the average age of the mains network by PWSPs

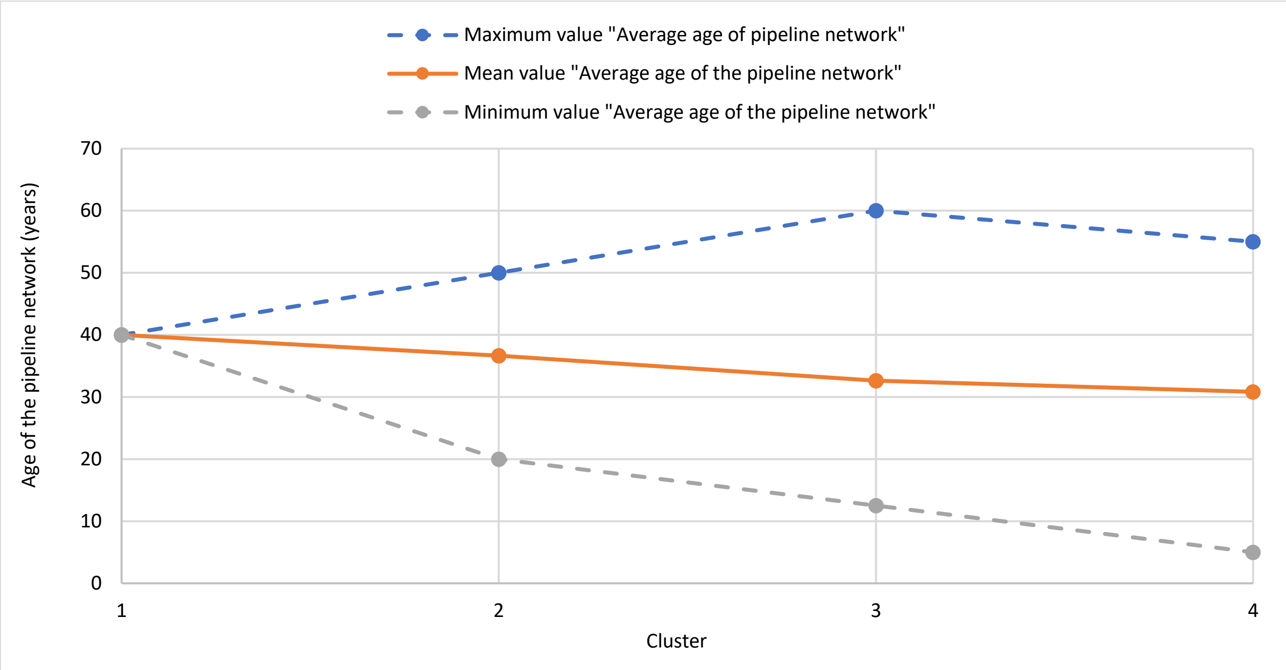


Figure 2.15. Ranges of the average age of the mains network by PWSP clusters

The relation between the average mains network age and the mains network length by PWSP clusters is presented in Figure 2.16.

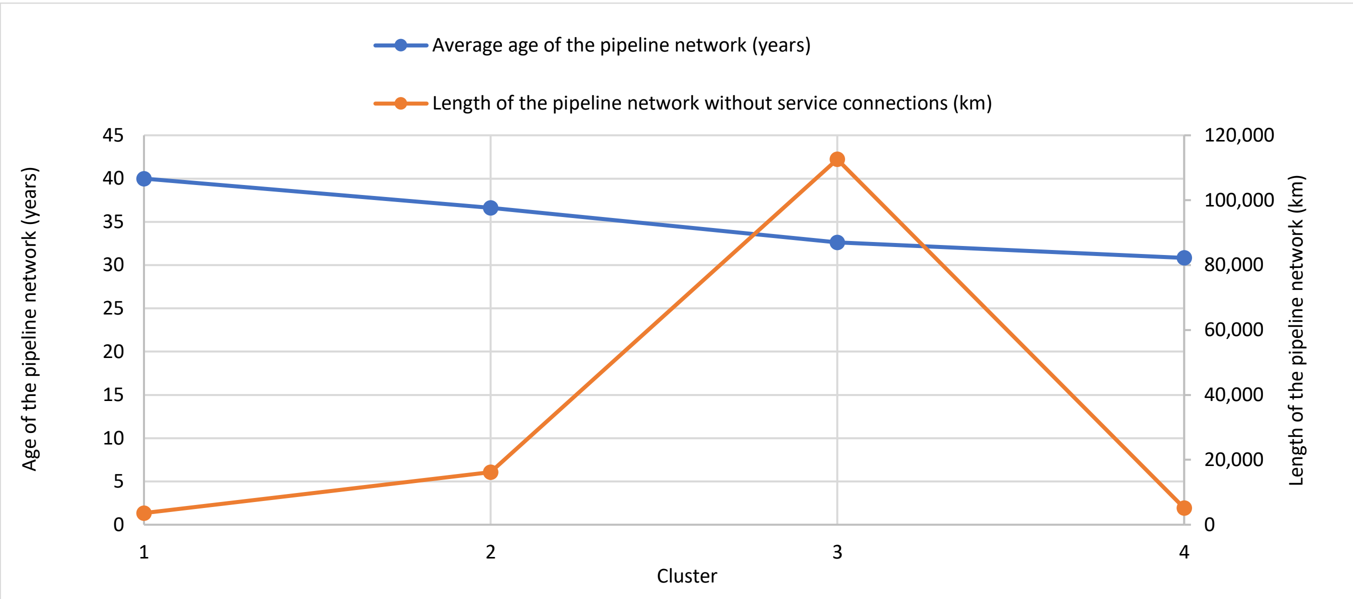


Figure 2.16. Relation between the average mains network age and the mains network length by PWSP clusters

A large majority of water supply systems regulate pressure in the system, more than 90% of them. The need for pressure regulation, primarily reduction, comes from the need to avoid unwanted situations with high pressure in the systems which directly through leakages, but also an increased number of new breaks, has an impact on water losses. The practice so far shows that the so called spring valves are still in use, together with hydraulic valves. The problem with spring valves is that outgoing pressures are related to incoming pressures, and they vary, usually in such a way that when pressures in the system are lower, the outgoing pressures are also lower, while at higher pressures, most often night pressures, the outgoing pressures are also higher. In other words, when because of lower consumption lower pressures at regulation valves are sufficient, when spring valves are used pressures remain higher in the hours of peak consumption, which, as already said, has an adverse effect on water losses. Figure 2.17. presents the shares of hydraulic valves to the total number of pressure regulation valves on the national level and by clusters. One can see that on the national level that share is 63% in favor of hydraulic valves.

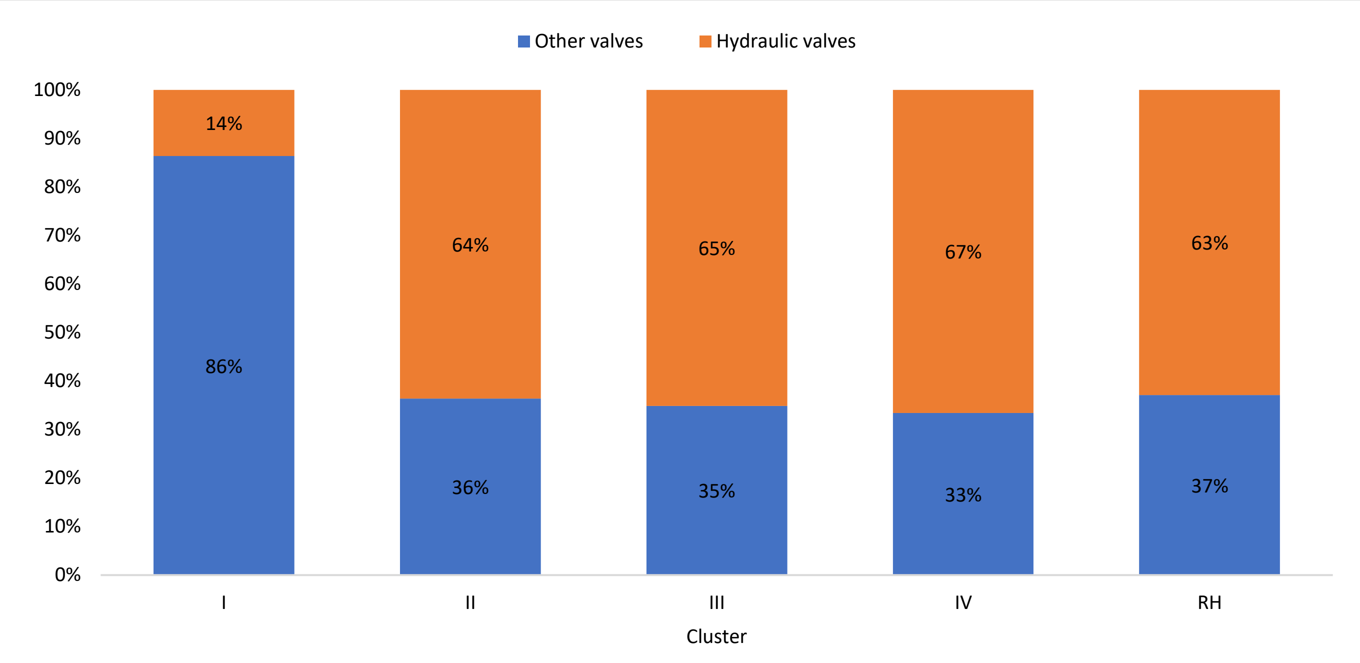


Figure 2.17. Share of use of hydraulic valves for pressure regulation on the national level and by PWSP clusters

2.2.2 Hydraulic characteristics of 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. The descriptions of hydraulic characteristics of water supply systems in Croatia will be given through a look at water supply layouts and operating conditions, separately for stationary and nonstationary regimes.

2.2.2.1 Water supply layout and hydraulic operations for stationary regime

In order to become familiar with operating conditions and optimize water supply layouts, it is necessary to prepare conceptual solutions including the development of calibrated mathematical models. The status of completion of such solutions is presented in Chapter 2.4., which shows that for all the PWSPs in Clusters I and II (save one) such solution has been prepared or nears completion, as well as in the majority of Cluster III PWSPs. The results are slightly weaker in Cluster IV, but it includes a large number of PWSPs which can be rated as very small.

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 2.18), with a range between 2.0 to 10.0 bar, with the exception of one PWSP which due to its topographic specifics has an average pressure of around 20 bar. The global and EU trends suggest economical operating conditions with an average pressure of up to 3.0 bar. The ranges of average pressures by PWSP clusters in Croatia are presented in Figure 2.19.

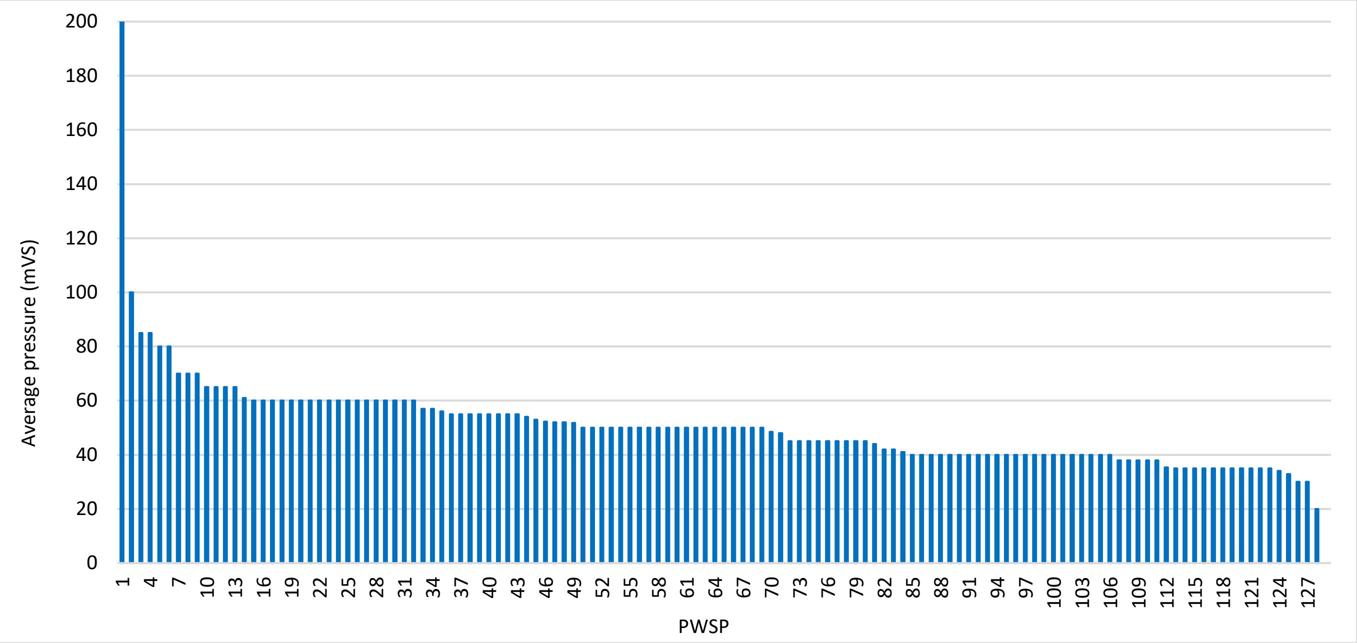


Figure 2.18. Average pressure in water supply systems in Croatia

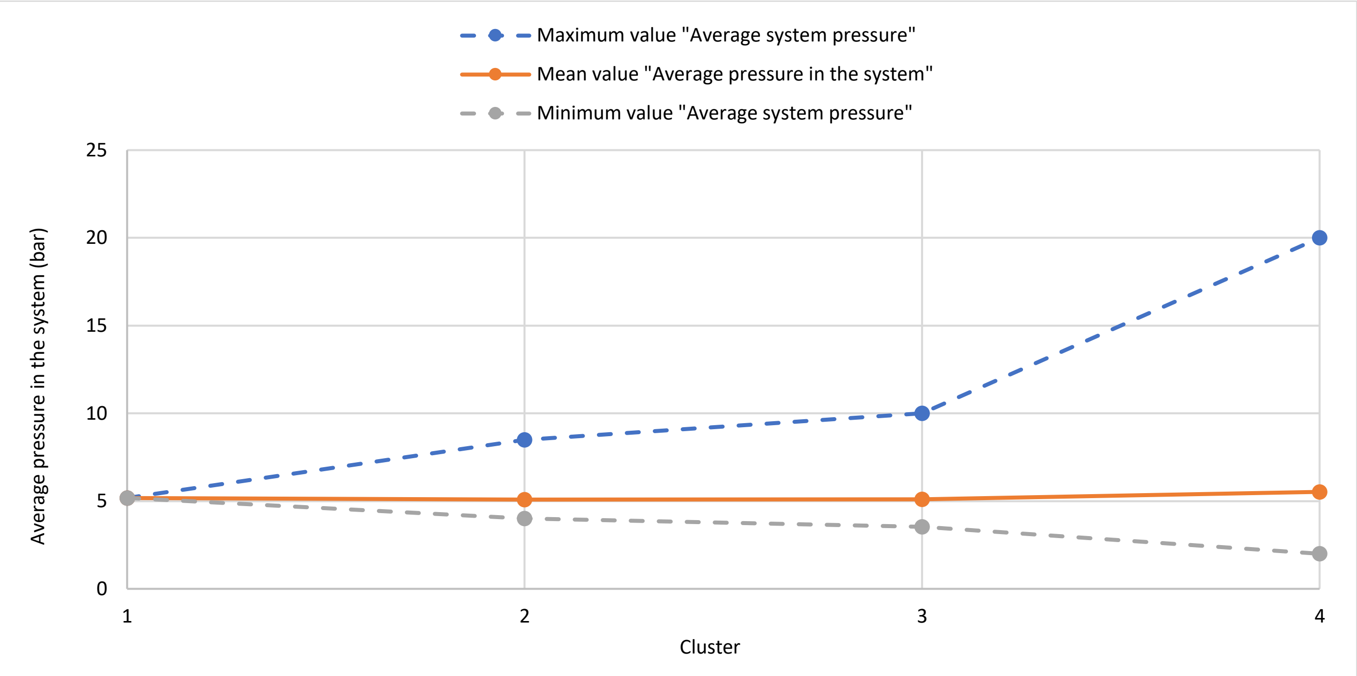


Figure 2.19. Ranges of average pressures by PWSP clusters in Croatia

However, the presented distribution of the average pressure in water supply systems in the figures above doesn't fully show what part of the mains network is under increased pressures. For that reason, Figure 2.20. additionally presents the relationship between the average system pressure and length of the mains network by PWSP clusters, while Figure 2.21. presents the lengths of mains within individual pressure ranges by PWSP clusters in Croatia.

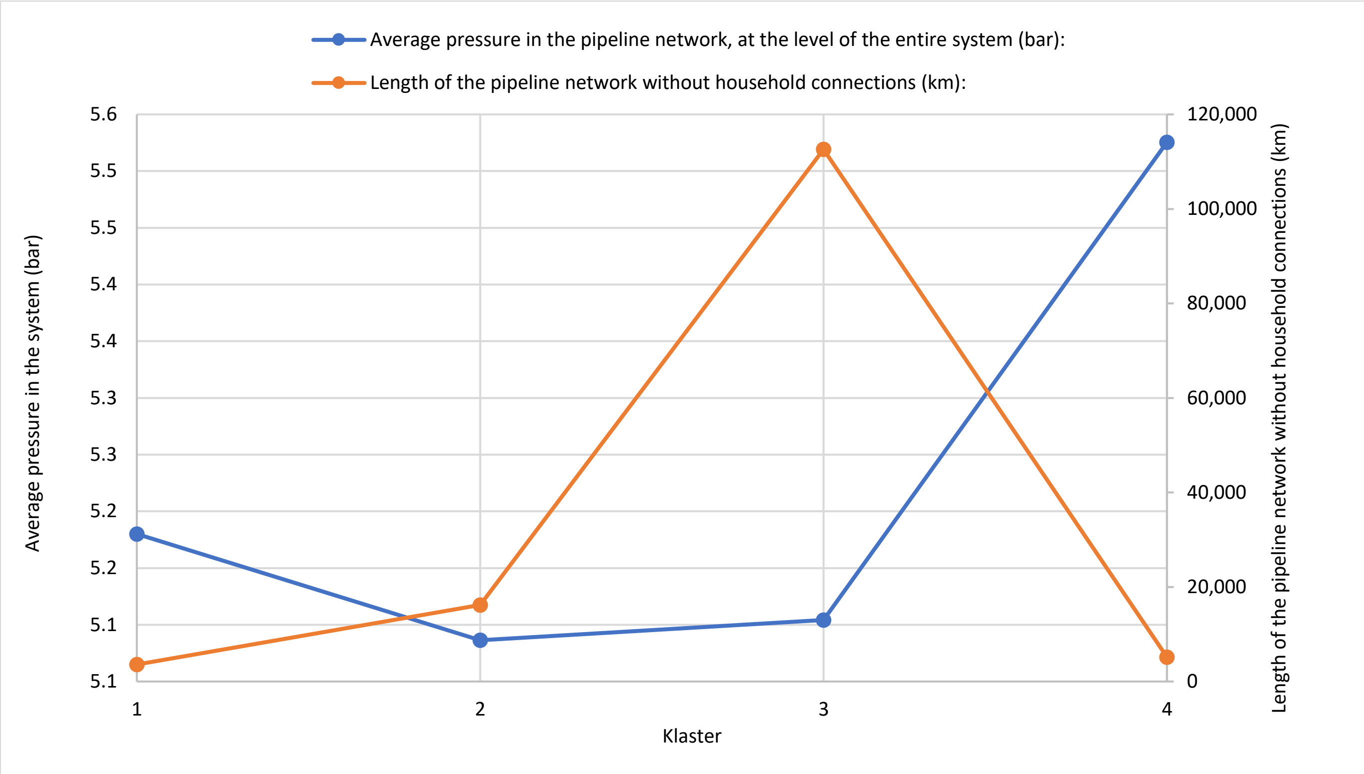


Figure 2.20. Ranges of average pressures by PWSP clusters in Croatia

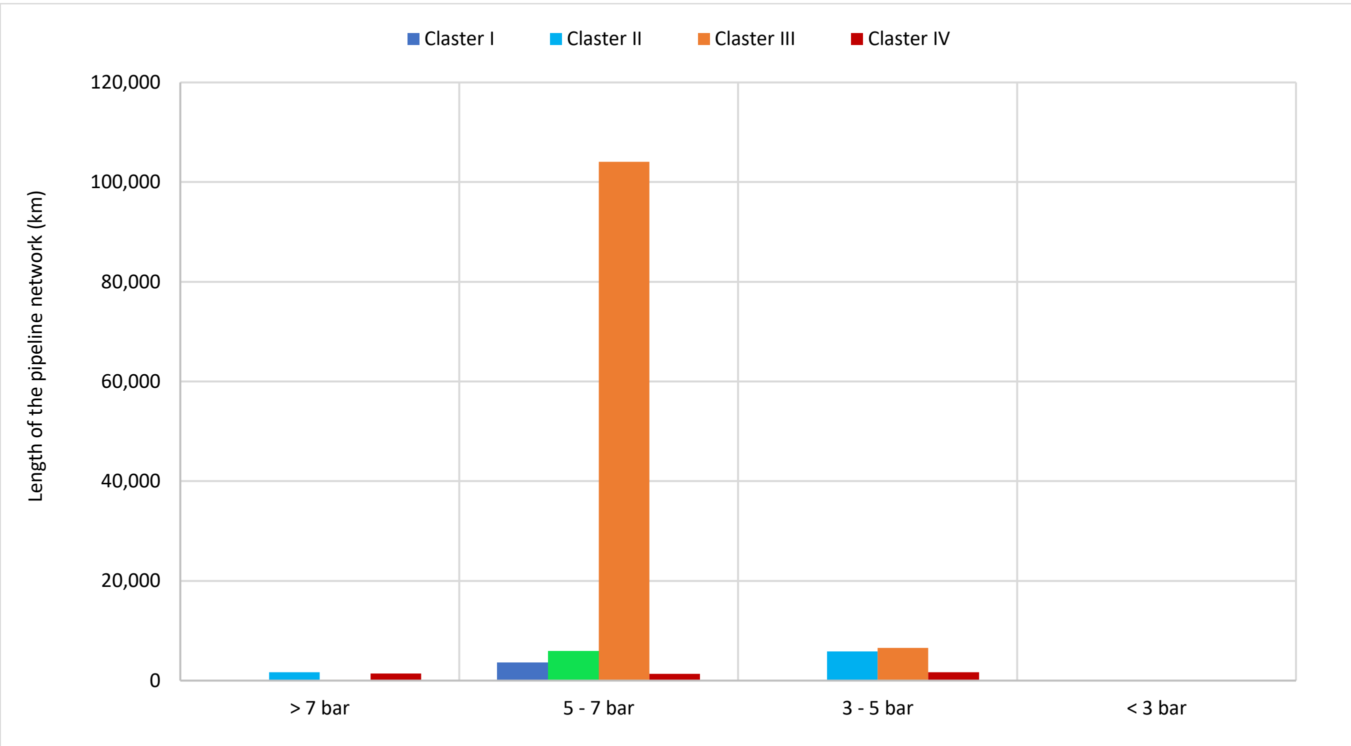


Figure 2.21. Lengths of mains within individual pressure ranges by PWSP clusters in Croatia

For the needs of the presented analyses, a factor of the impact of network pressure and length has been calculated, presented in Figure 2.22. The factor of the impact of network pressure and length is calculated using the following expression:

$$Impact\ factor\ = \frac{\mathrm{P}_{avg} \cdot \mathrm{L}_{n}}{1000}$$

Where:

- P_{avg} – Average pressure in the water supply network (m of the water column)
- L_n – Total water supply network length (transmission and distribution mains) (km)

Based on the analyses made, it can be concluded that the average pressure, as a weighted value against the total length of the water supply network, equals 5.4 bar (55 m of the water column).

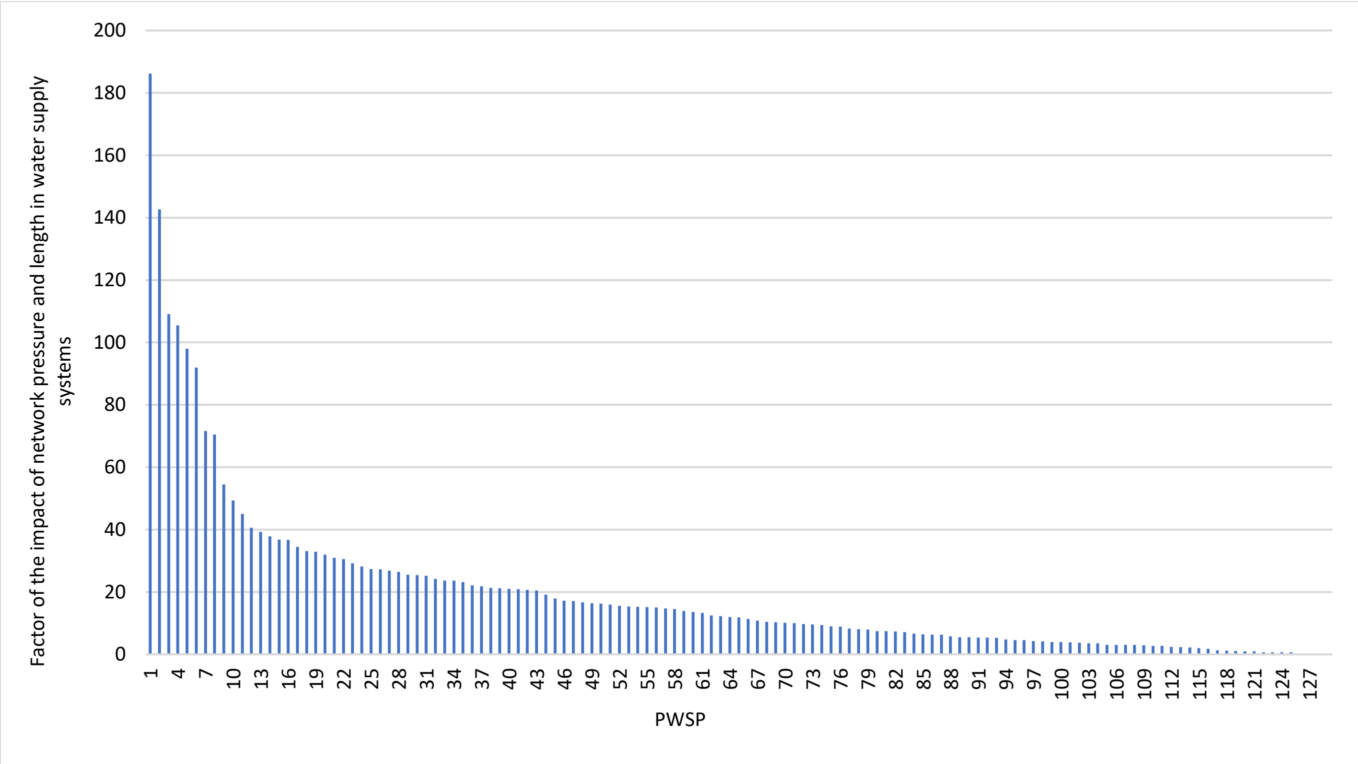


Figure 2.22. Factor of the impact of network pressure and length in water supply systems in Croatia

The biggest problem associated with uneconomically increased pressures is increasing leakage. The well-known dependence between pressure and leakage rate (the higher the pressure, the bigger water volume leaking through a pipe crack or burst) is mathematically decribed by the FAVAD method (Chapter 2.1.1).

When faced with a question about the construction of new storage tank capacities for hydraulic modification of the system, i.e. establishment of new pressure zones, as much as more than 50% of the PWSPs respond positively. Analyzing the planned solutions, one can see that these are still largely 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 2.23).

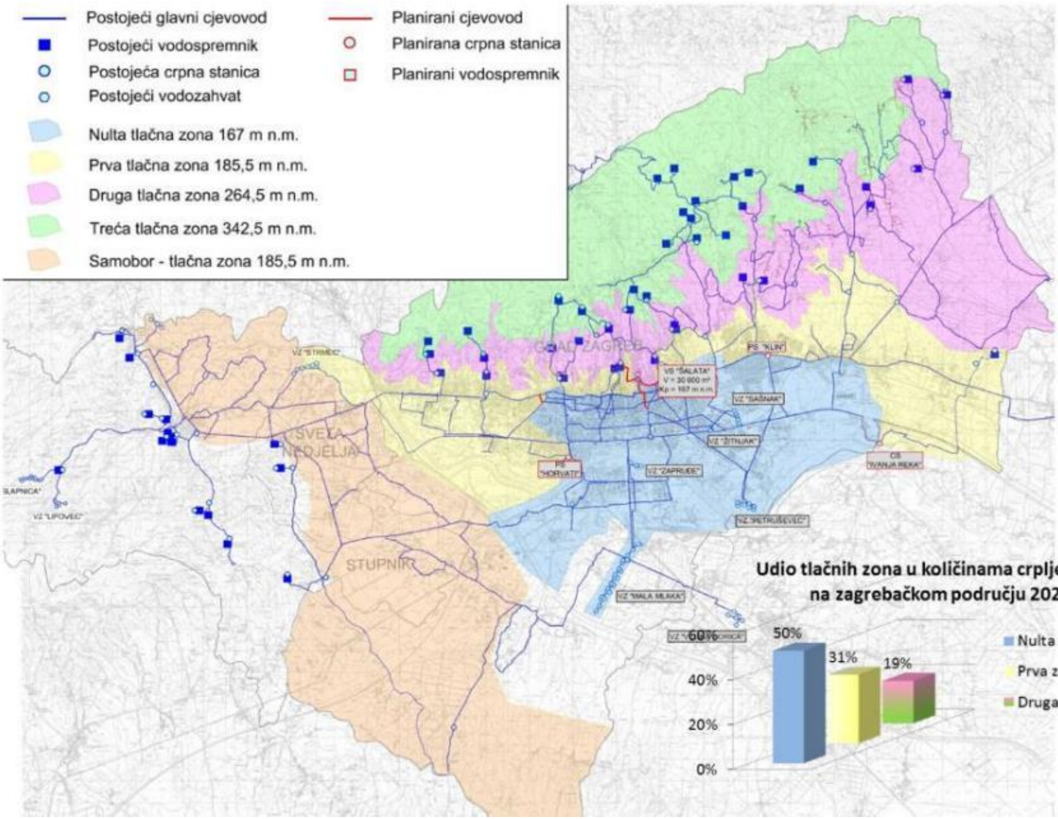


Figure 2.23. Establishment of the so called “Zone 0” in the area marked in blue

The effects of thus modified water supply 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.

Once the possibilities for hydraulic system optimization by modifying the hydraulic layout have been exhausted, it is necessary to conduct pressure optimization by dividing the system into DMAs and/or PMAs in which pressure reduction valves will additionally optimize operating conditions. The analytics of the current status of establishment of such zones, as well as of the planned ones, is presented in Chapter 2.6.1.

2.2.2.2 Water supply layout and hydraulic operations for nonstationary regime

A large number of water supply systems in Croatia was developed using software tools which calculated operating conditions both for stationary conditions and for events when pressures are exceeded (nonstationary conditions – water hammers). That is definitely a good practice example, because properly foreseen protection significantly reduces the occurrence of bursts. Figure 2.24. presents the results of implementing protection from water hammers on the national level and by clusters. For around 60% of the PWSPs, protection from the water hammer exists either both at the water intake/abstraction site and at the pumping stations with the system (26%) or both at the water intake/abstraction site and at the pumping stations within the system and in the mains network (34%). Cluster I PWSP implements protection from the water hammer both at the water intake/abstraction site and at the pumping stations within the system.

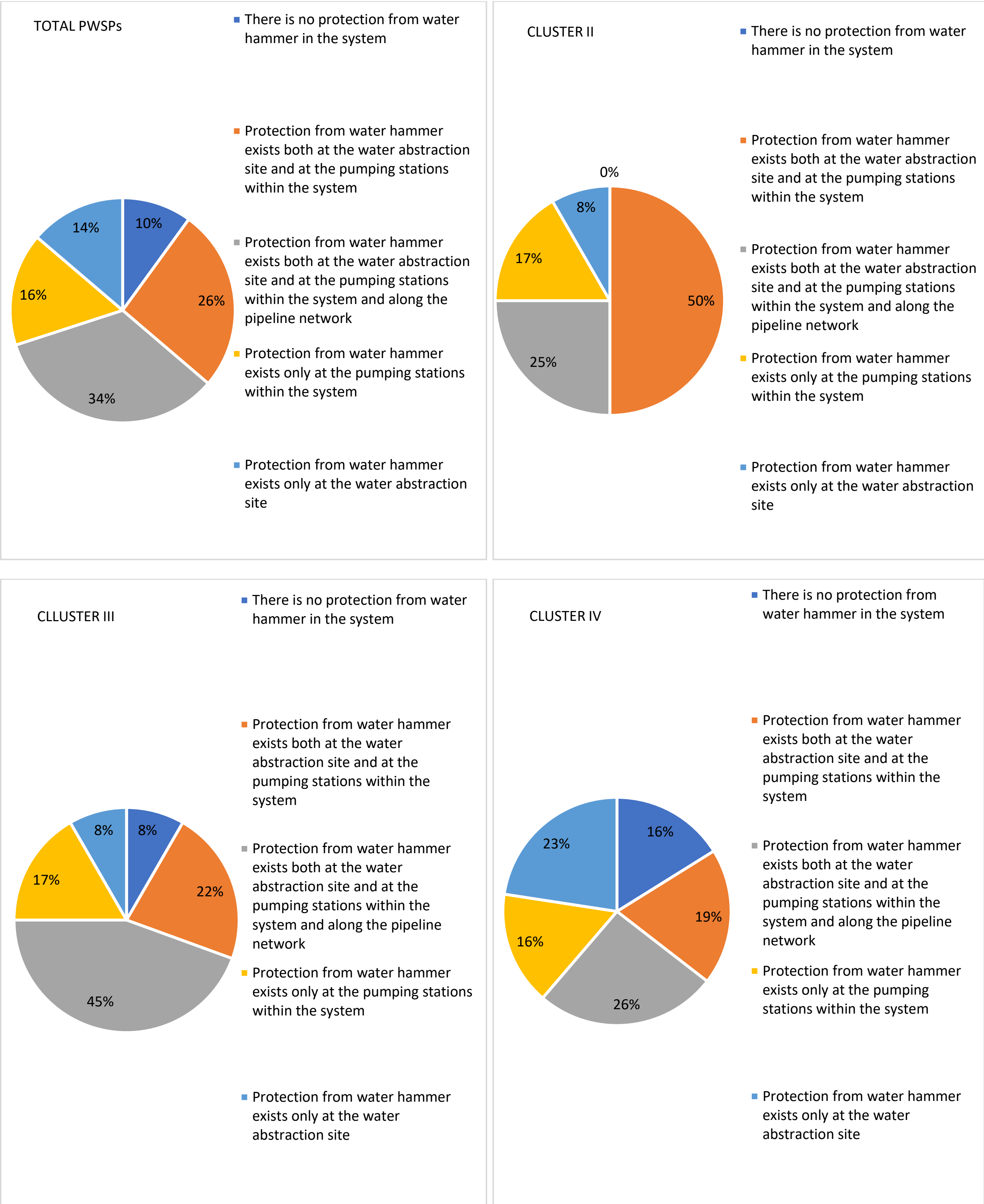


Figure 2.24. How water hammer protection is implemented on the national level and by PWSP clusters

The charts above regretfully don't fully illustrate the current problems related to water hammer protection and can give a wrong picture of the current status. Namely, the problem occurs when such systems are extended, modified, when their operating parameters are modified, without updating the analyses and without implementing water hammer protection, which is regretfully a dominant situation in Croatia. The results presented in Figure 2.24. indicate that water hammer protection is implemented, but not necessarily in its entirety. In almost all the systems boosters and hydroblocks were added which didn't foresee the protection from the water hammer, but just pressure vessels the purpose of which is not to protect from the water hammer, but rather to ensure pressure during night periods with minimum consumption without the need to frequently turn on/off the pumps. Water supply networks were extended, without making additional hydraulic analyses of nonstationary state. The conceptual solutions and measurements of pressure in seconds have again increased awareness about water losses, because the results showed that the protection was not sufficient. For that reason, future measures have to encompass this issue as well, primarily through the need to revise hydraulic analyses for events with exceeded pressures, and after that through measures of installing the required equipment.

One of the important items for the flow of water in the systems to become steady is the application of frequency regulation at pumping stations. The collected data shows that a significant number of pumping stations still doesn't have pumps with frequency regulation. The results on the national level and by clusters are presented in Figure 2.25.

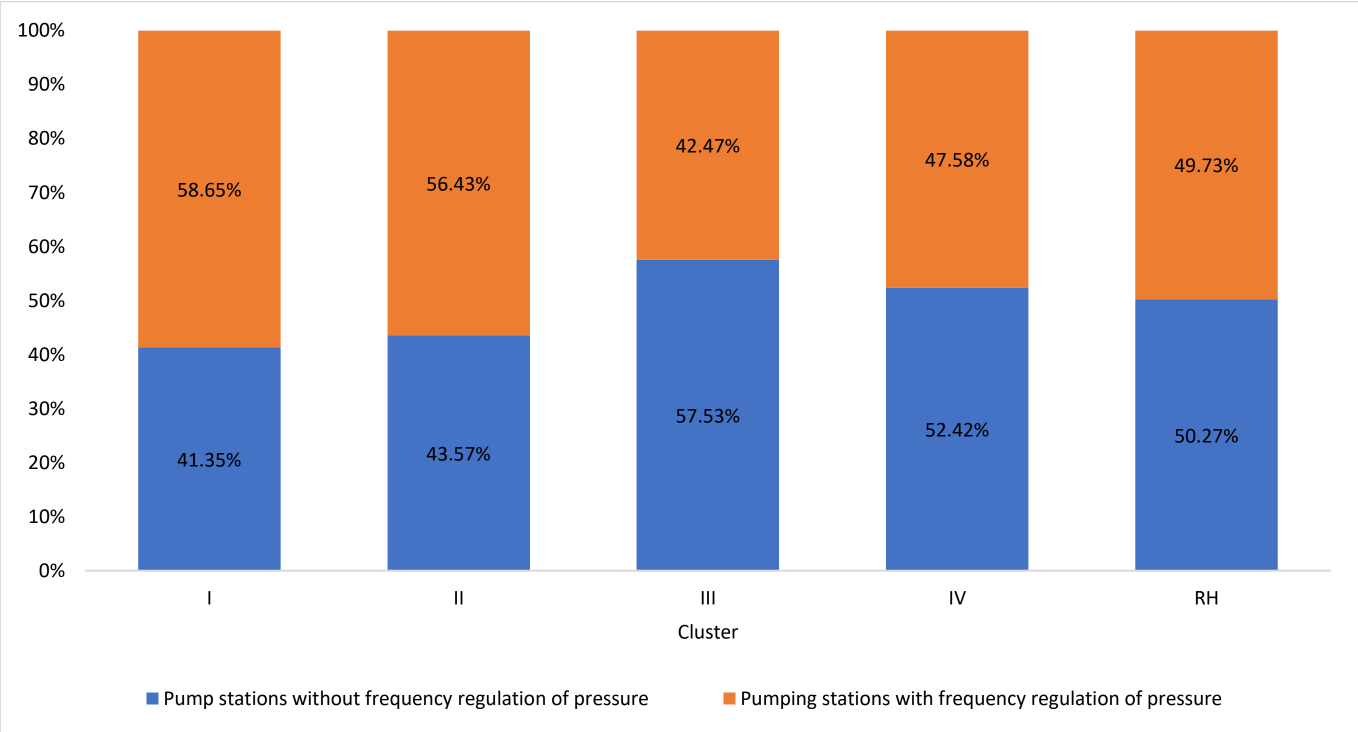


Figure 2.25. Share of pumping stations with frequency regulation on the national level and by PWSP clusters

Continuous measurements and analysis of pressures indicate changes in the system which may lead to increased water losses. Measurements have to be incremented in sufficiently small intervals to better capture such events (from 0.1 to 1.0 second). The way in which pressure is controlled is presented in Figure 2.26. The Cluster I PWSP has permanently installed devices to measure and register the pressure values and continuously controls the pressure in the facilities and in the system.

Figure 2.26. How pressure is controlled on the national level and by PWSP clusters

2.2.3 Planned development of water supply systems

Climate change and the development of settlements, especially in tourist regions, and industry will have the highest impact on the expected increase, stagnation, or decrease of consumption in Croatia. Figure 2.27. presents the expected forecasts of water consumption on the national level and by clusters. The majority of the PWSPs (66%) expect the total consumption to increase. 79% of the PWSPs don't expect the supply of water to be at risk during dry years/months in relation to the development plans which is, as well as by clusters, presented in Figure 2.28. In terms of capacities of the main supply routes in relation to present consumption, 71% of the PWSPs have no limitations (Figure 2.29), while for the planned increased consumption 67% of the PWSPs have no such limitations (Figure 2.30).

As for limitations in the available water supply volumes in relation to demand (today) and identified capacities, 69% of the PWSPs have no such limitations, i.e., as much as 31% have them (Figure 2.31). Only a slightly higher share of the PWSPs (70%) express limitations for the planned increased consumption (Figure 2.32). 60% of those limited available water volumes refer to quantity, 5% to quality, and 35% to quantity and quality (Figure 2.33).

In case of limitations in available water volumes today or in the planned state, it is necessary to analyze the possibility to increase available water volumes, which is presented in Figure 2.34. It shows that 75% of the PWSPs have the possibility to increase capacities by expanding the abstraction permits (42%) and by opening up new identified abstraction sites (33%), while as much as 25% of them don't have such possibilities.

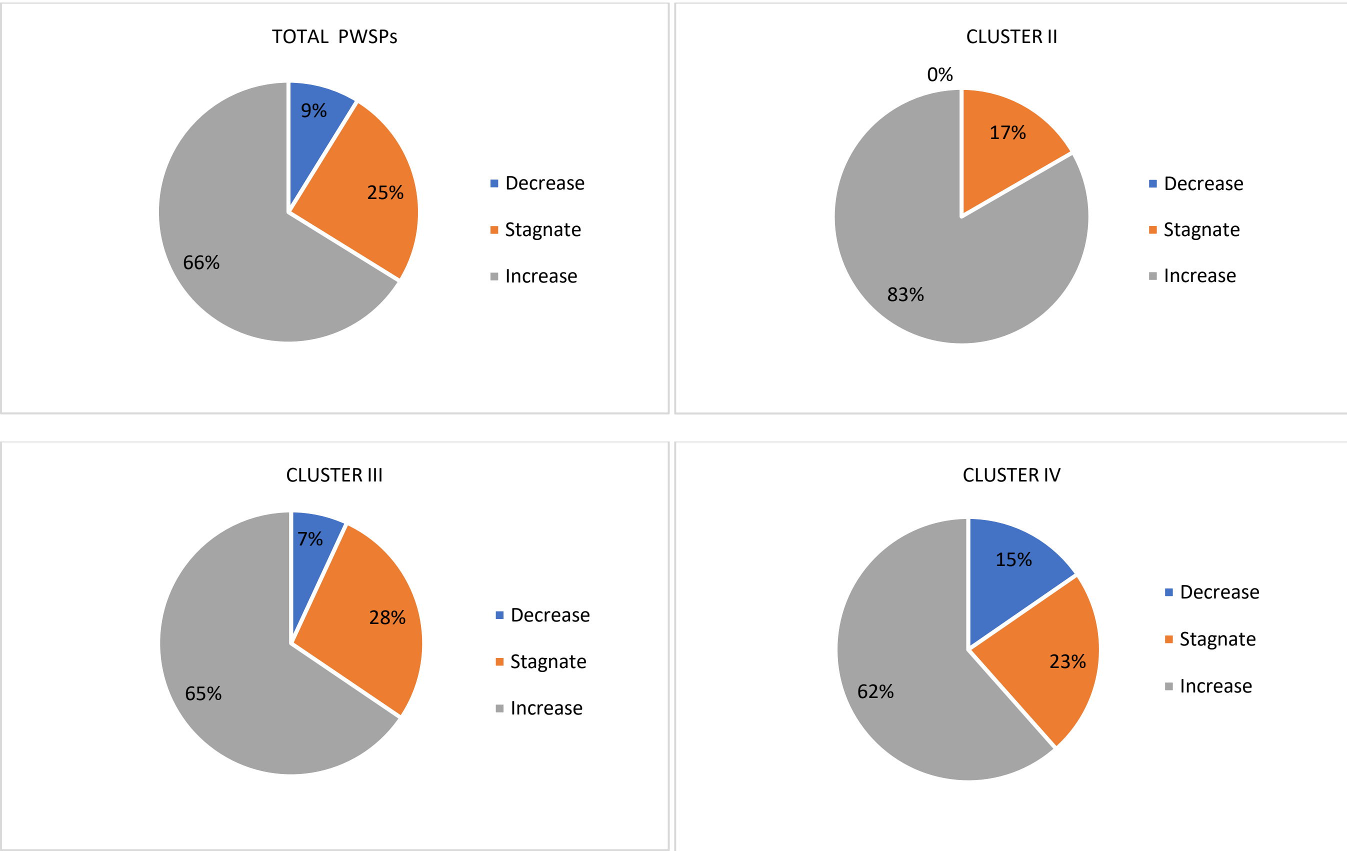


Figure 2.27. Forecast water consumption on the national level and by PWSP clusters

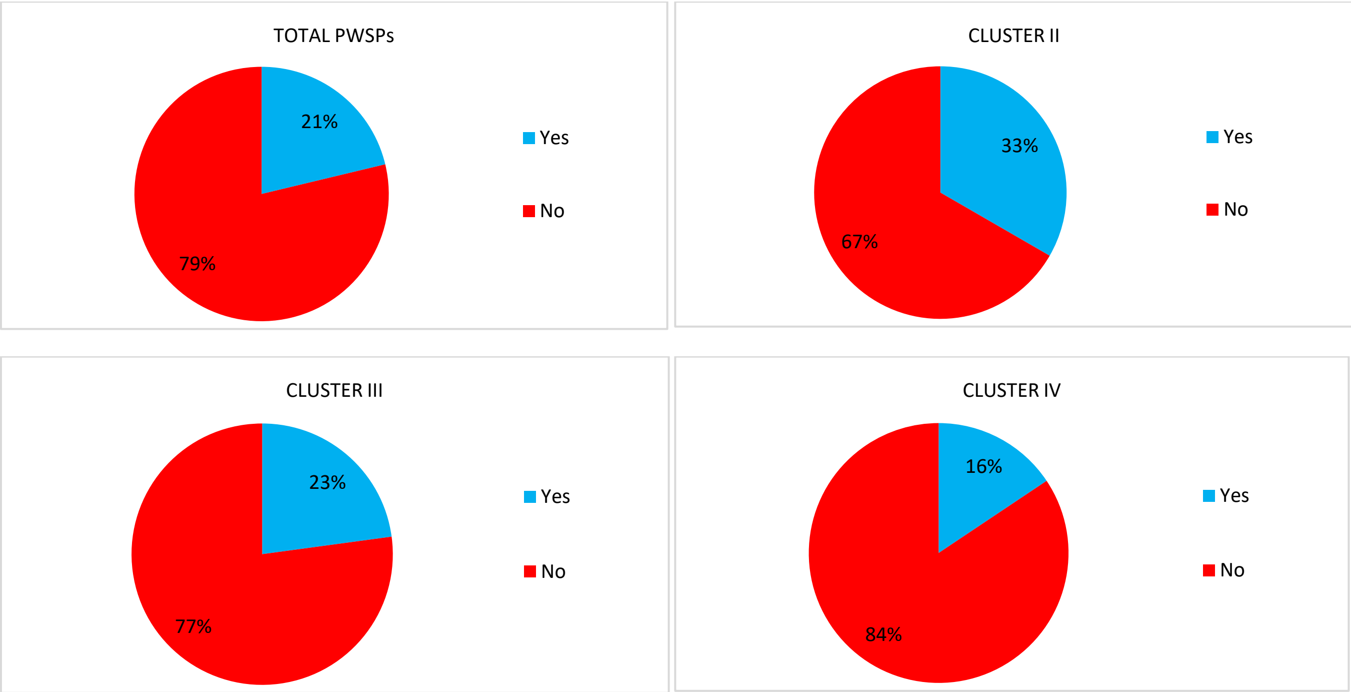


Figure 2.28. Water supply at risk in dry years on the national level and by PWSP clusters

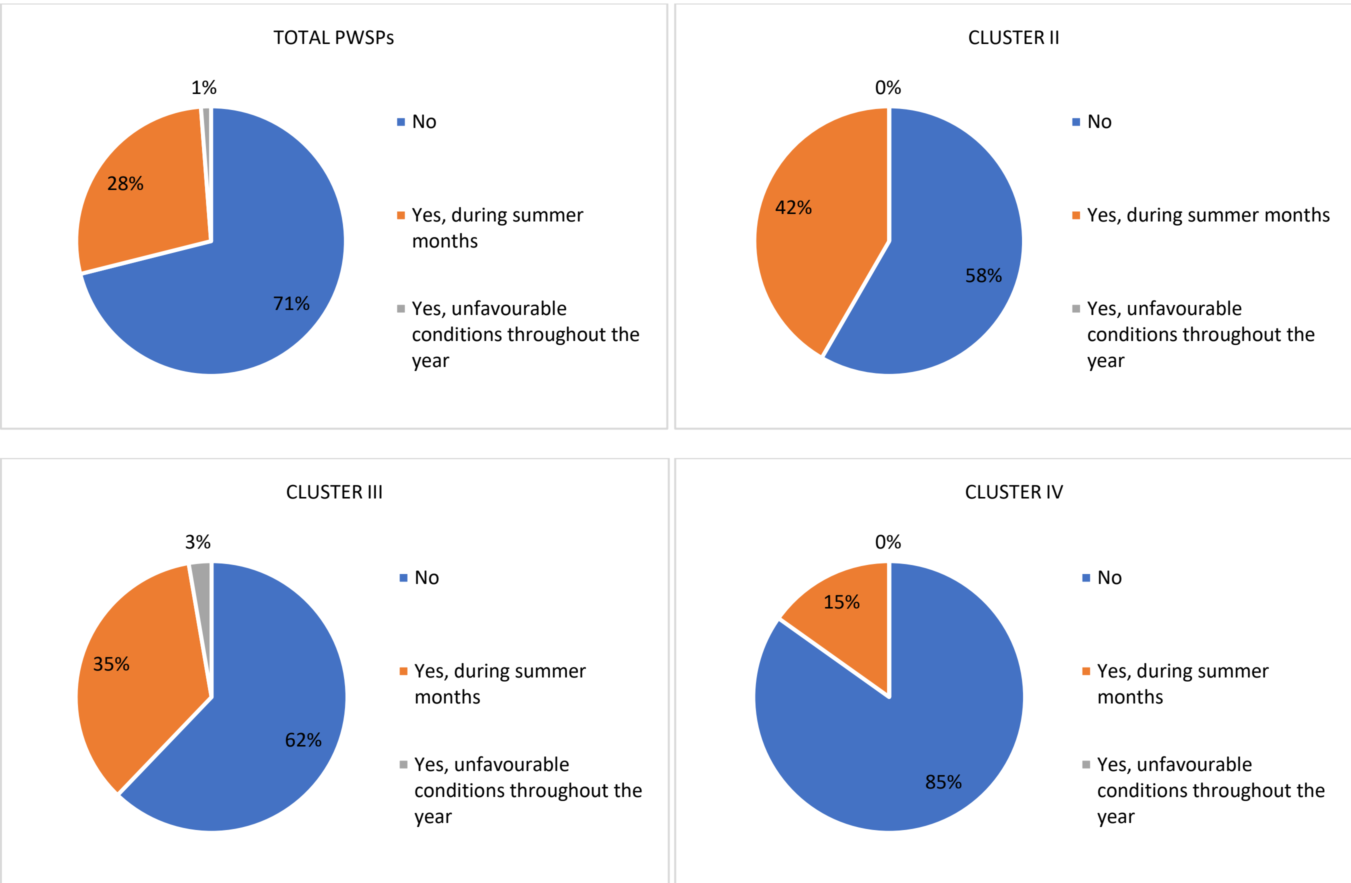


Figure 2.29. Limited capacities of the main supply routes in relation to present demand on the national level and by PWSP clusters

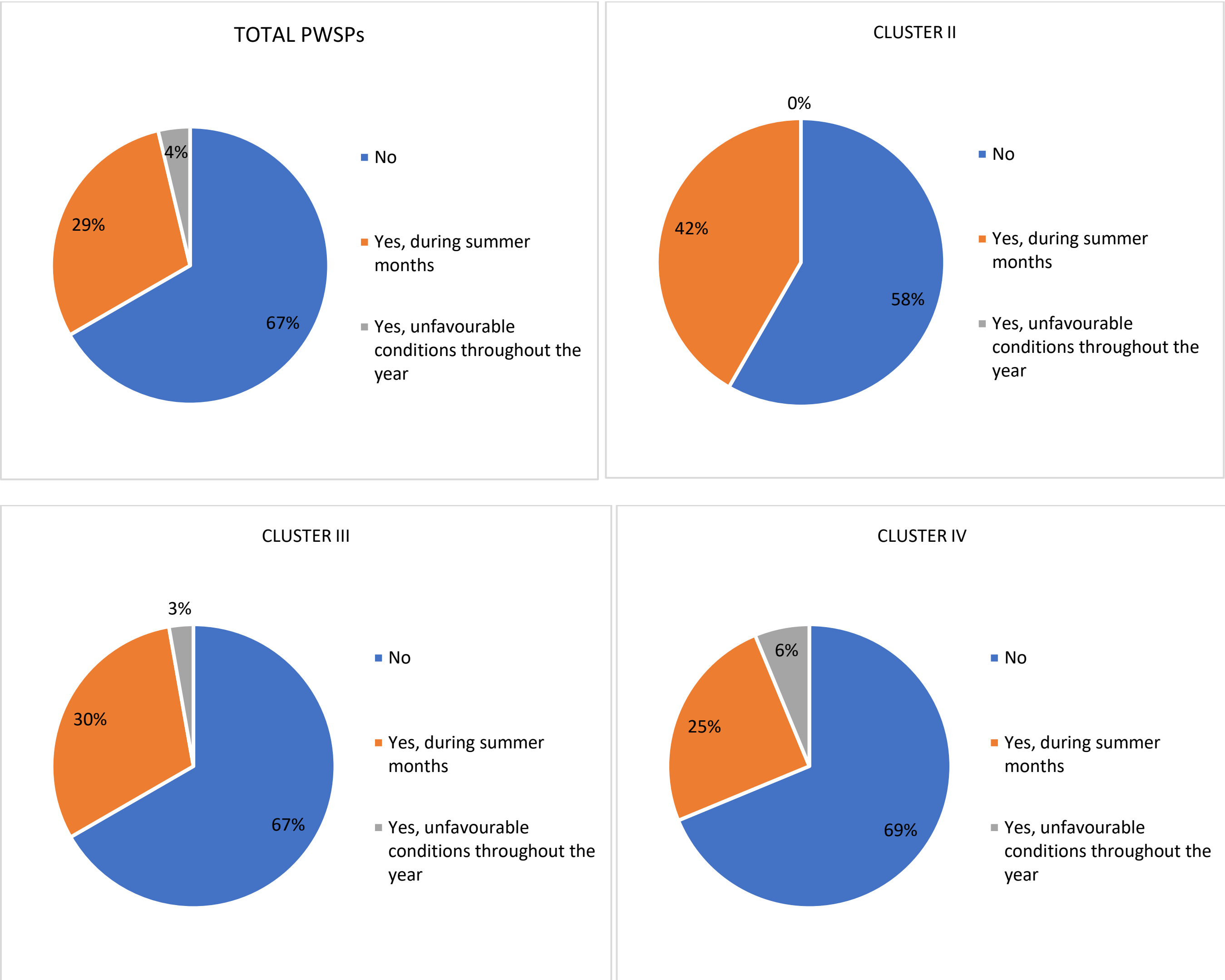


Figure 2.30. Limited capacities of the main supply routes in relation to the planned increased demand on the national level and by PWSP clusters

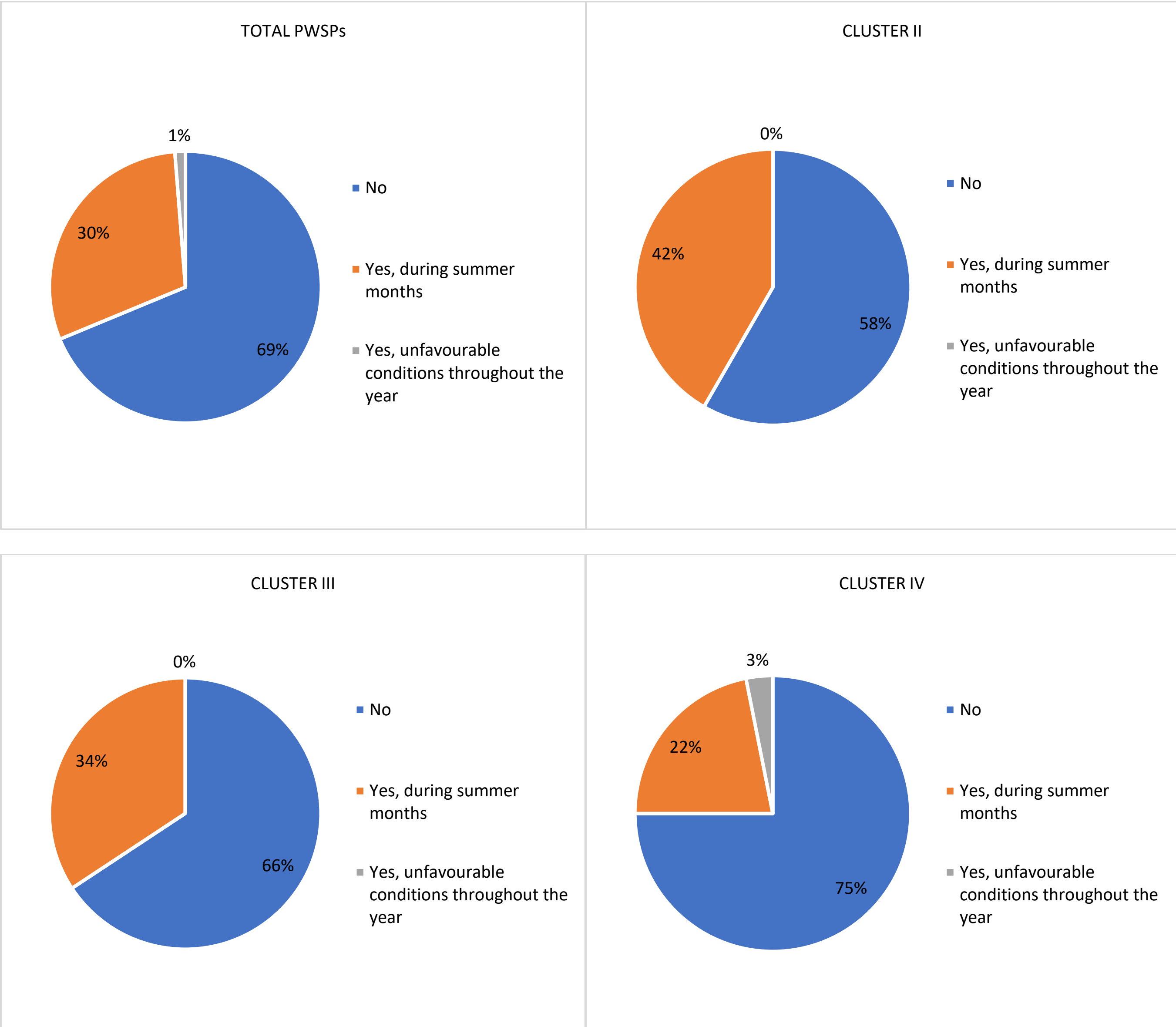


Figure 2.31. Limitations in available water supply volumes in relation to demand (today) and identified capacities on the national level and by PWSP clusters

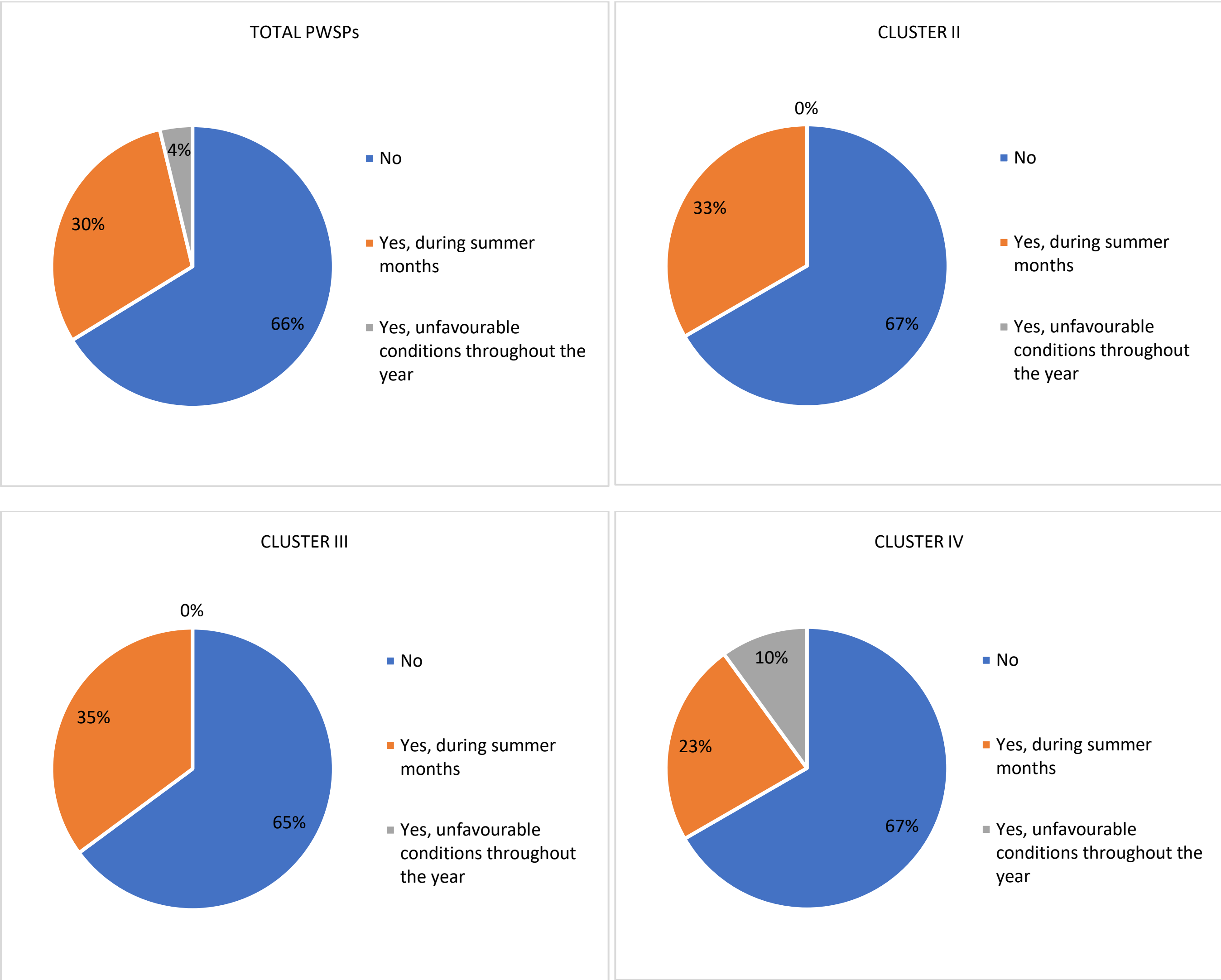


Figure 2.32. Limitations in available water supply volumes in relation to increased demand and identified capacities on the national level and by PWSP clusters

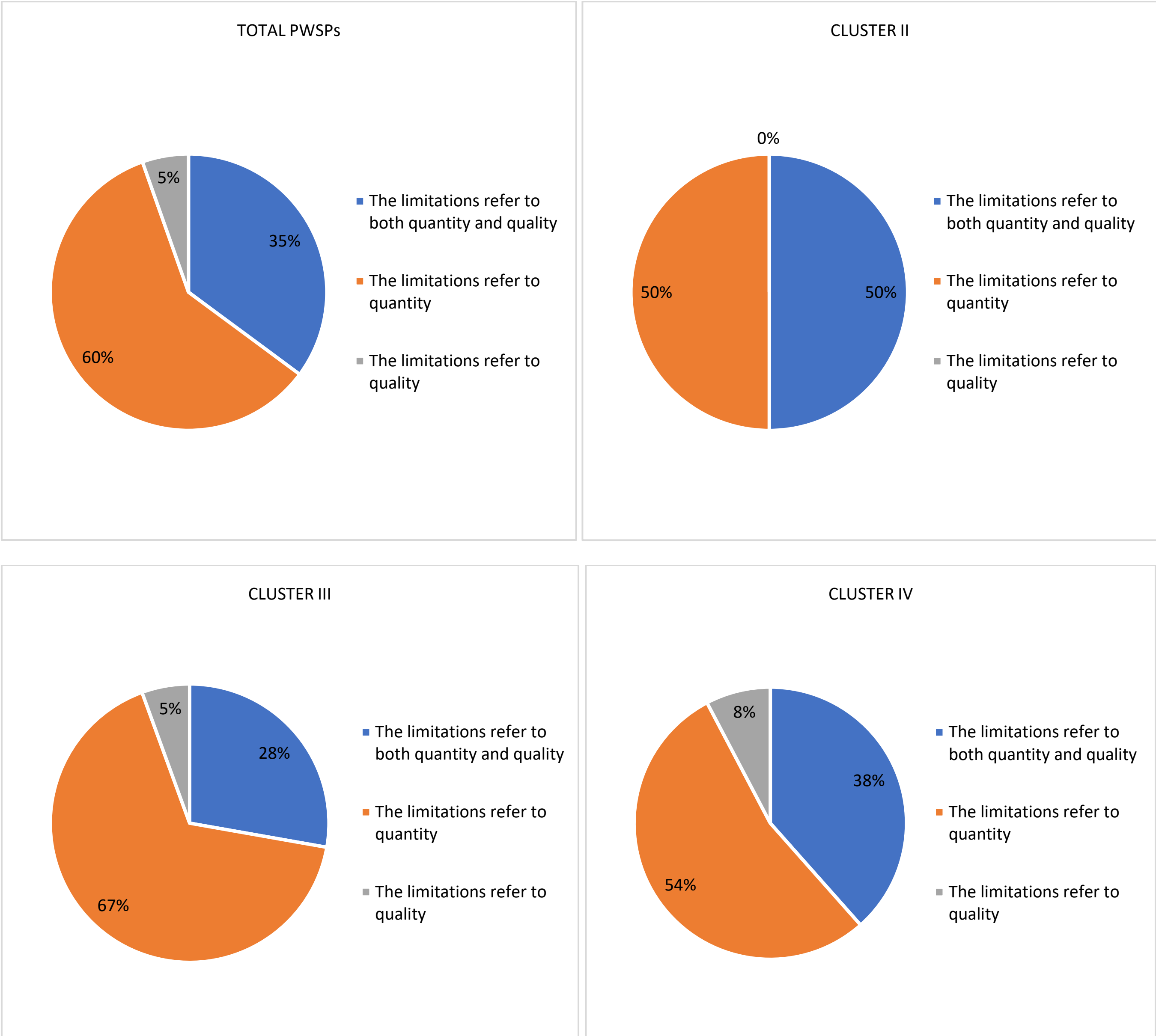


Figure 2.33. Types of limitations in available water supply volumes on the national level and by PWSP clusters

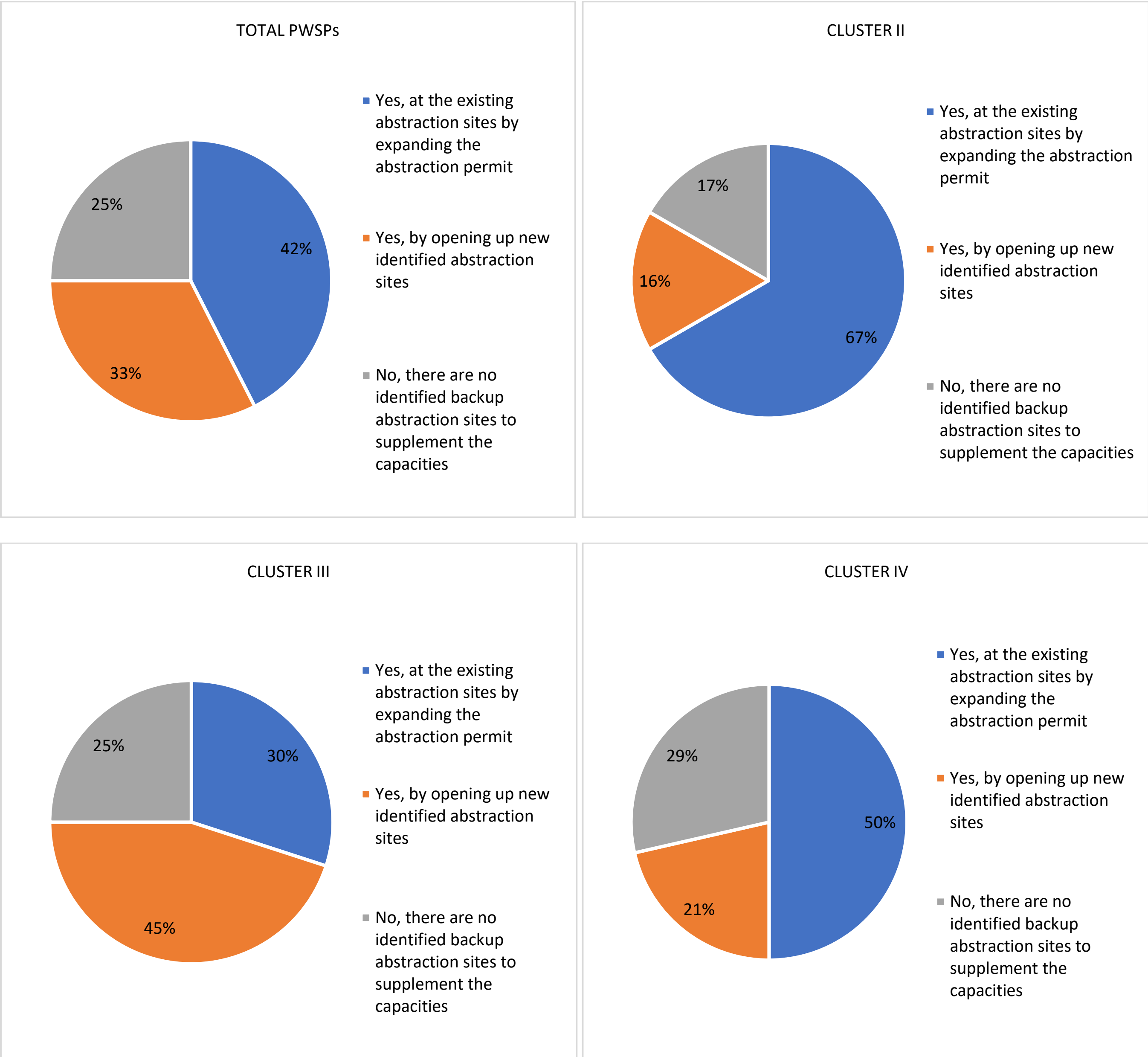


Figure 2.34. Possibilities to increase available water volumes on the national level and by PWSP clusters

As VIO Zagreb (Cluster I) is a large system less susceptible to changes, it foresees water consumption to stagnate and doesn't expect water supply to be at risk. In the current state VIO Zagreb has no limitations in terms of capacities of the main supply routes and it doesn't expect any limitations during increased consumption. There are no limitations in available water volumes in relation to consumption and identified capacities of abstraction sites today, and no limitations are expected during increased consumption.

As regards the planned hydraulic balance of the system with improvement measures, as much as 48% of the PWSPs expect this activity to be implemented which is a precondition for future analysis and evaluation of the system. It consists either of modifying the water supply layout or of establishing DMAs/PMAs. The results on the national level and by clusters are presented in Figure 2.35.

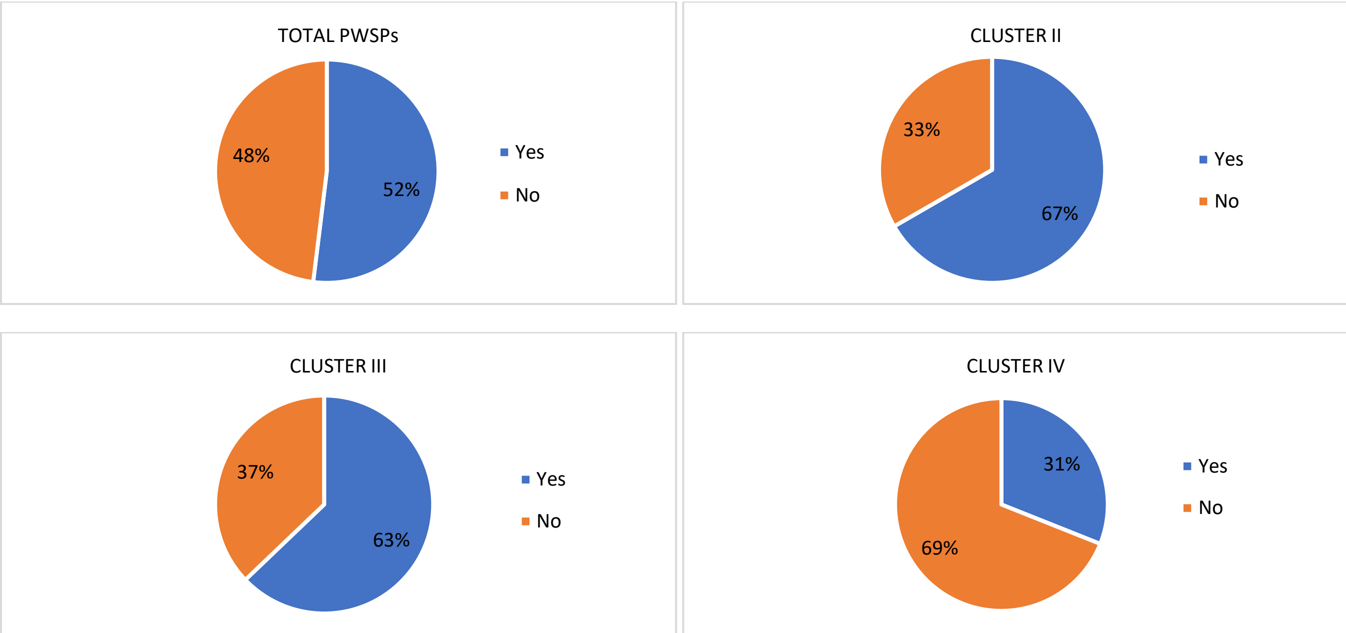


Figure 2.35. Hydraulic balance implemented for the planned state with improvement measures on the national level and by PWSPs

Further system improvement measures foreseen by the PWSPs are presented in Figure 2.36. However, the management system needs to be more comprehensive, systematic and standardized, with clearly defined performance indicators. For that reason, all the planned measures will be foreseen by the Water Loss Reduction Action Plan, and the implementation of the measures will be prioritized in accordance with needs, risks, and available financial resources.

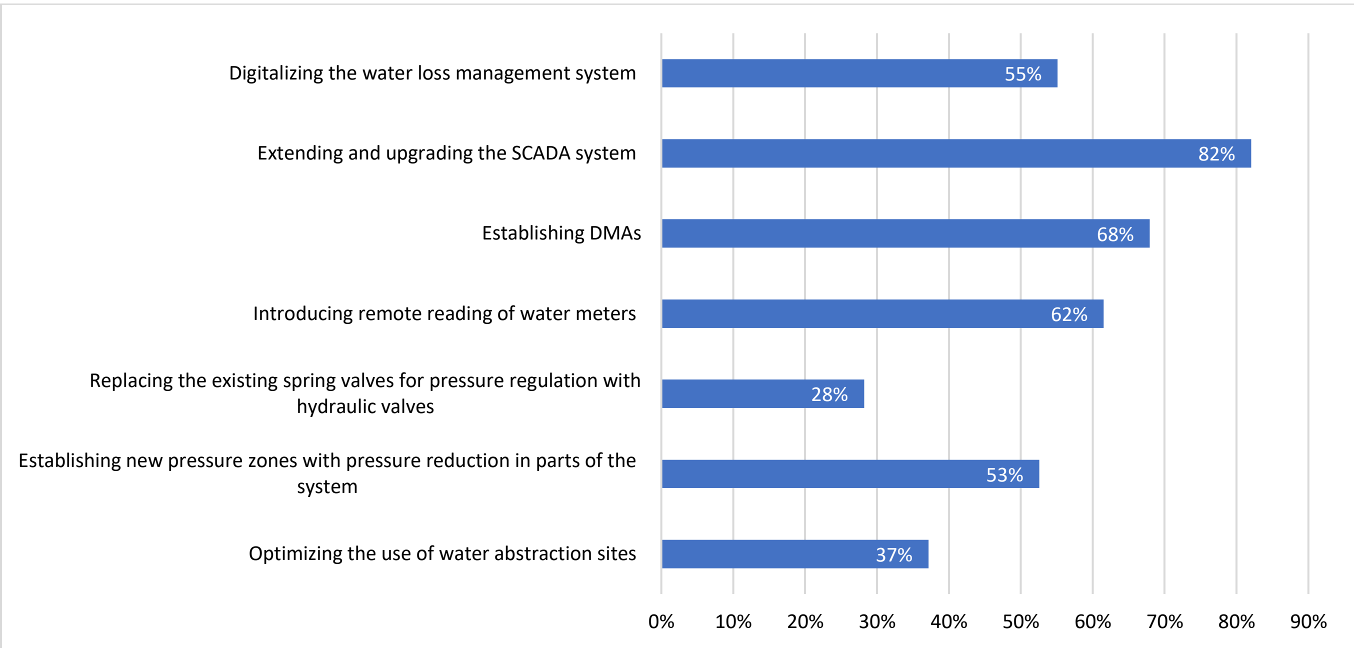


Figure 2.36. Further system improvement measures on the national level and by PWSP

2.3 Technical capacities of PWSPs to identify and reduce water losses

The technical 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 (128 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 manage an integrated and highly complex water loss management system, 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.

2.3.1 Technical equipment

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, 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.

2.3.1.1 Technical equipment – Lacking knowledge about own system

Looking at the current status of the PWSPs, one can notice that the use of the GIS correlates with the PWSP size. Figure 2.37. shows a decrease in the GIS use by clusters, with the highest share of use in the clusters that include larger PWSPs. 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. 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 2.38. Cluster I uses the GIS and regularly updates its maps.

The PWSPs that use the GIS mostly use the basic viewer, with the share reducing for the modules for the registration of leaks (39%), link to business IT system (36%), link to the SCADA (29%), and other modules.

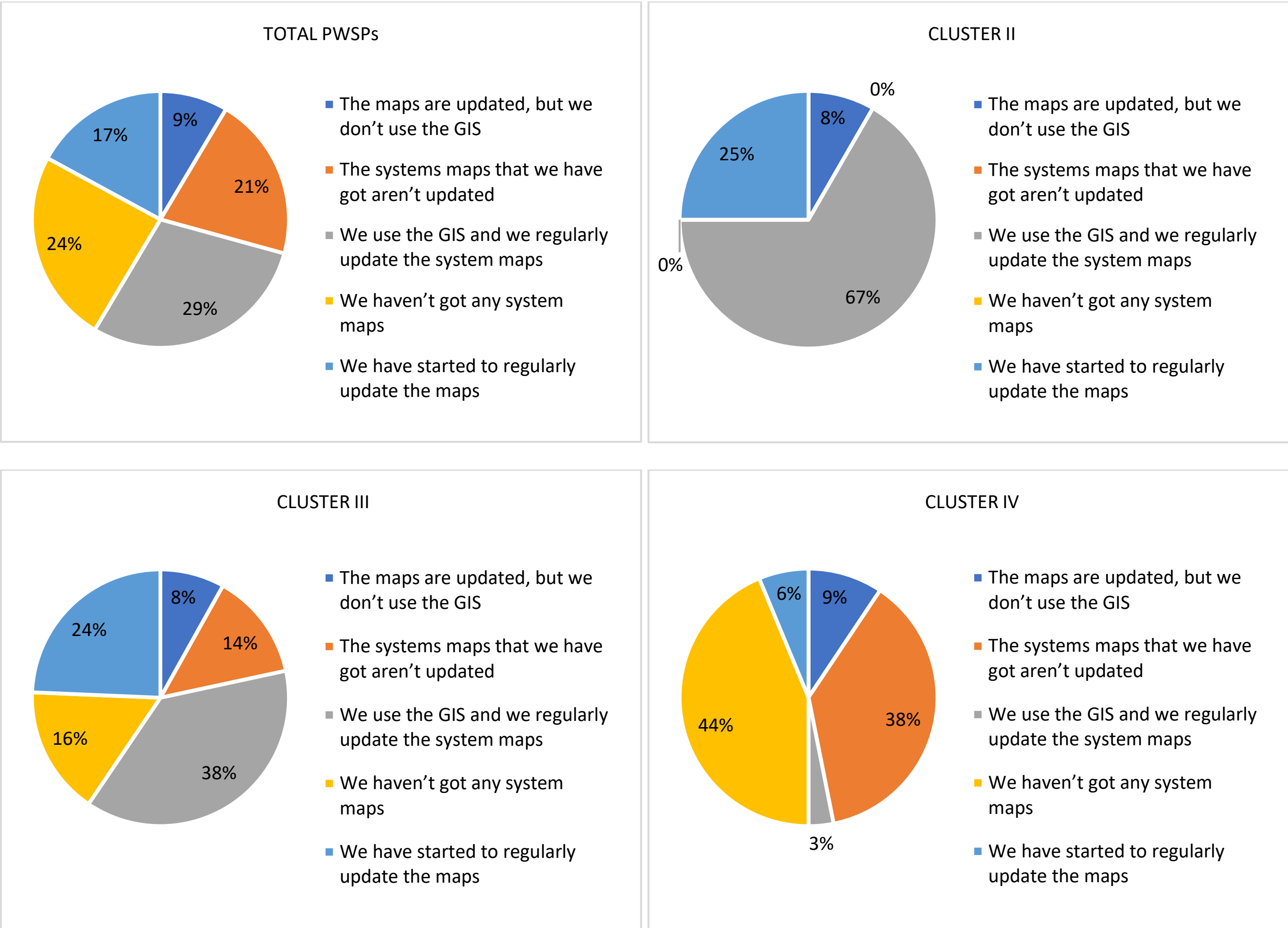


Figure 2.37. Status of GIS development by individual PWSPs on the national levels and by PWSP clusters

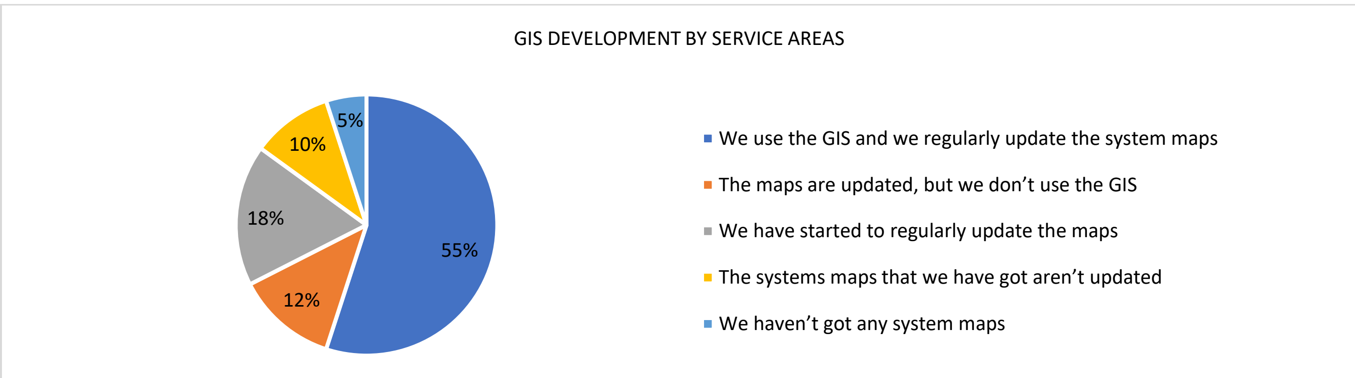


Figure 2.38. Status of GIS development by the most up-to-date PWSPs grouped by service areas

The analysis of the level of completion of conceptual solutions which included detailed hydraulic modelling is presented in Chapter 2.4. Those solutions prepared in such detail, with implemented measurements and calibration of models, present good practice and good basis for the planning and implementation of further loss reduction measures (see Chapter 2.6). Using the calibrated mathematical model of the current status enables realistic insight into the way in which the integrated system functions and identification of numerous problems the elimination of which results in the reduction of water losses. In the practice so far, the use of calibrated mathematical models among some PWSPs proved to be extremely successful in identifying numerous problems (first of all, identifying parts of the system with uneconomically high pressures) and reducing water losses.

The situation with the level of completion of conceptual solutions shows that the percentage of completion nevertheless decreases by clusters and that it is still necessary to develop the remaining solutions (Figure 2.79).

Looking at the way in which consumer databases are managed by individual PWSPs on the national level and by PWSP clusters, also presented in Chapter 2.4., it is clear that as much as 26% of the PWSPs don't have updated consumer databases, with the situation particularly bad in Cluster IV (42%).

Analyzing the registration of leaks as an important indicator when making future decisions on optimum system rehabilitation activities, it is clear that a high percentage is expressed. For example, VIO Zagreb registers leaks, with the effort reducing in the lower clusters (Figure 2.39). Looking at the quality of the entry of data and connection with the GIS, the situation is worse and reduces the possibility to properly plan rehabilitation and reconstruction activities (Figure 2.40), which decreases significantly in the lower clusters.

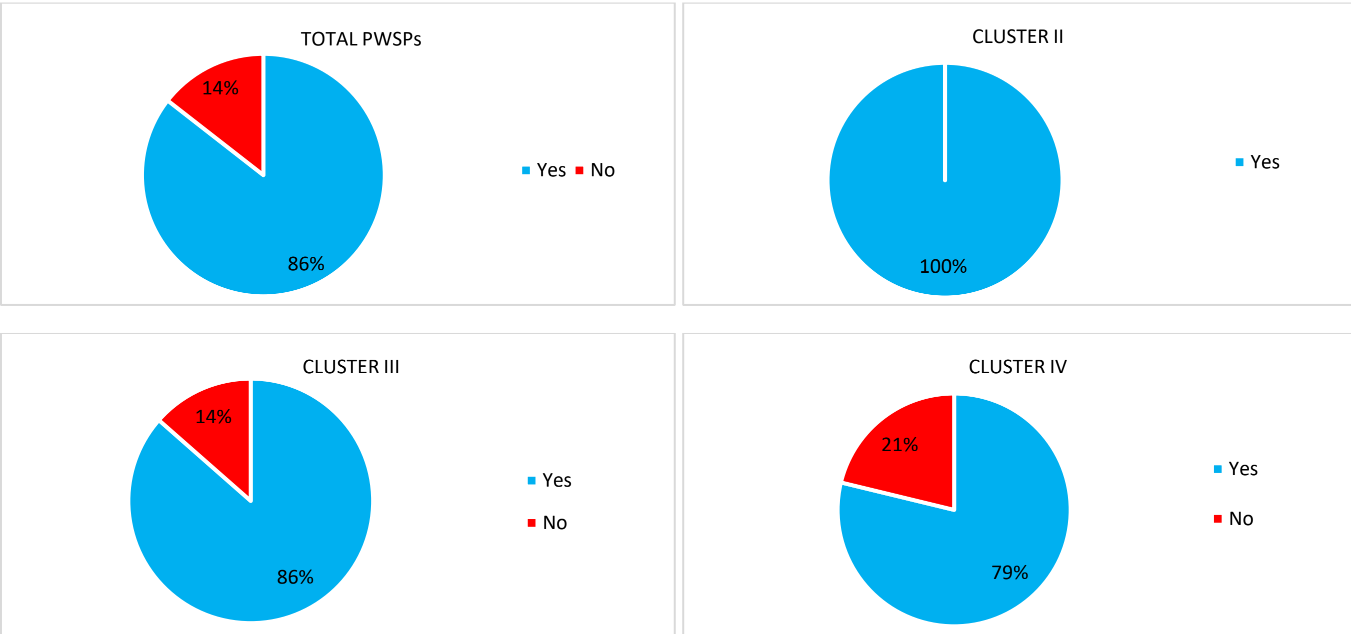


Figure 2.39. Registration of leaks over a 5-year period by individual PWSPs on the national level and by PWSP clusters

Figure 2.40. How leak record is kept by individual PWSPs on the national level and by PWSP clusters

As for the SCADA, the situation is more favorable (Figure 2.41) and it is clear that the importance of controlling the system operation has been recognized. The PWSP in Cluster I has an implemented SCADA system, as well as 81% of the PWSPs. The situation is slightly less favorable in Clusters III and IV. If during the consolidation on the level of 41 PWSPs one would analyze the practice of the most advanced PWSPs, which would with their software tools and experience include into their control and management the structures of the remaining PWSPs, the indicators would be maximum (100%), i.e., all the PWSPs would have the SCADA implemented. The situation is also better with the type of structures that are controlled (Figure 2.42), where the focus is still given to controlling the structures of pumping stations, storage tanks, sources, and water treatment plants (a smaller expressed percentage for the water treatment plants has nothing to do with lower control, but rather with the fact that many PWSPs don't have such plants). The situation with measurement and control valves is more unfavorable, which indicates that the systems are not zoned nor hydraulically optimized in terms of pressures. The PWSPs which have the SCADA available generally store the data in such a way and with an appropriate time increment to enable making analyses of losses, but the storing itself isn't standardized, and is often not used for water loss analyses.

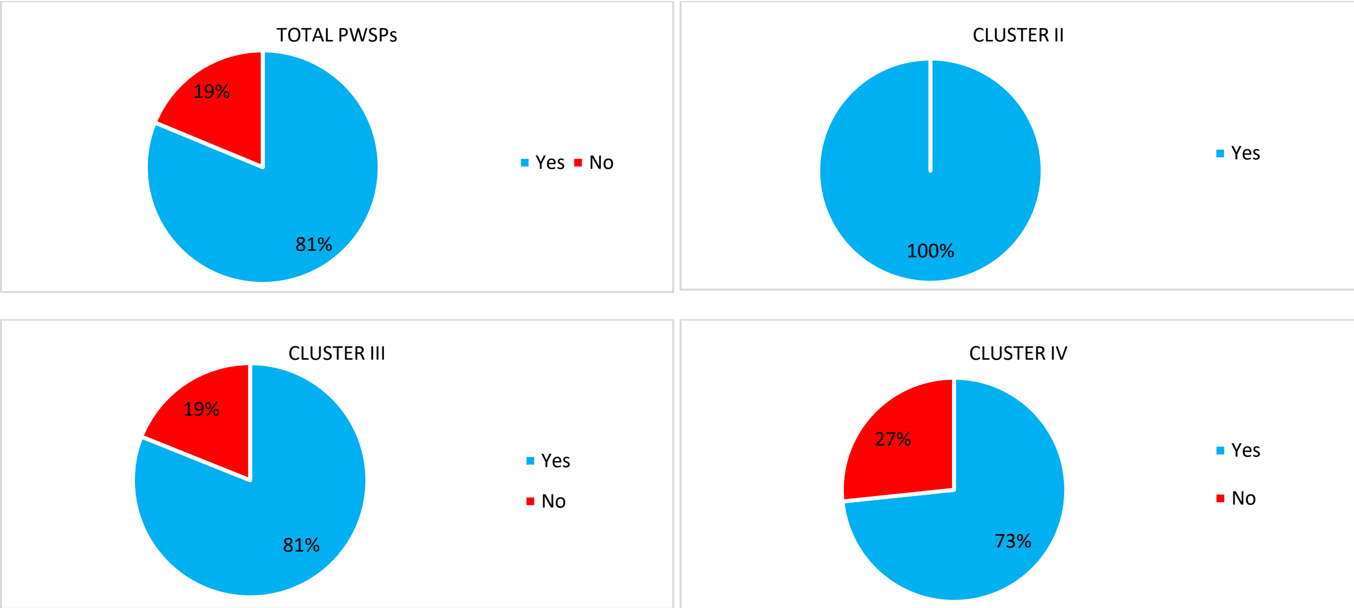


Figure 2.41. Status of SCADA implementation by individual PWSPs on the national level and by PWSP clusters

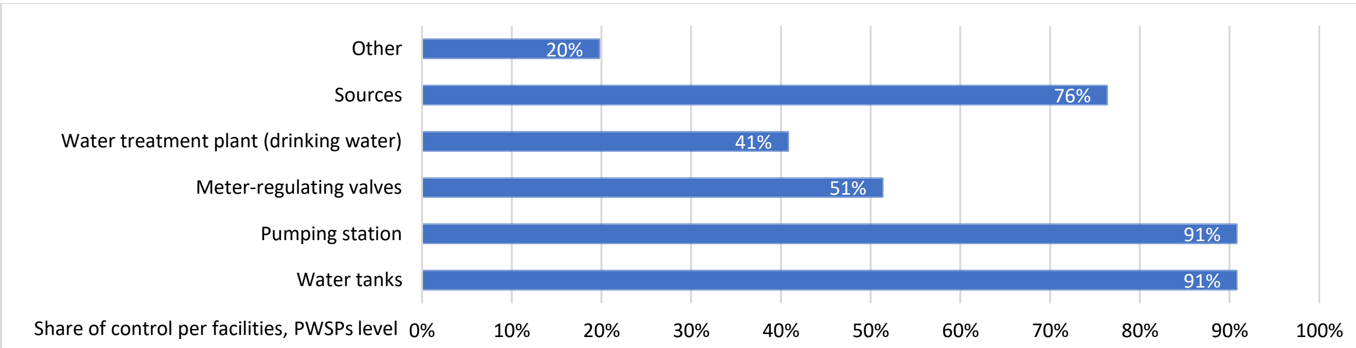


Figure 2.42. Overview of structures controlled on the national level

2.3.1.2 Technical equipment – Leakage metering and detection equipment

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 should as a minimum have at its disposal three portable flow meters and two portable pressure meters, and a correlator, a geophone, and a locator of pipes and fittings. 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.

Figure 2.43. presents the total number and average value of the number of portable flow meters by the PWSPs for which data was collected. When the number of flow meters is analyzed by the length of mains by PWSPs, i.e., by the number of teams (according to the average global practice value of 350 km/team), the number of portable flow meters per team by individual

PWSPs is obtained, also presenting the averaged value by all the PWSPs for which data was collected (Figure 2.44). The number of portable flow meters per team is presented on the national level and by clusters (Figure 2.45).

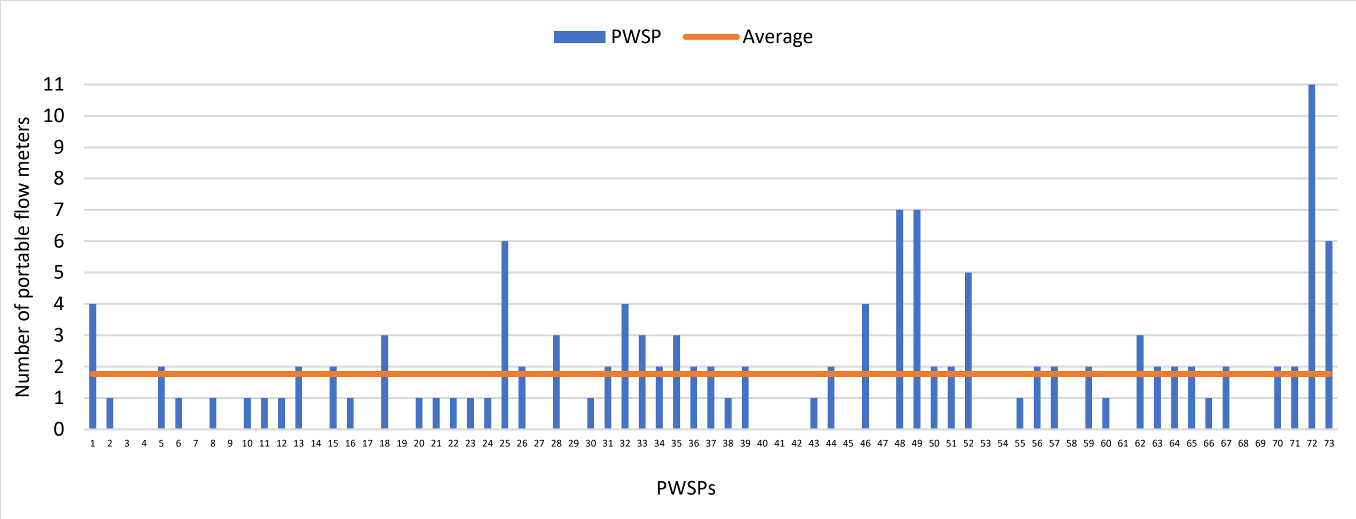


Figure 2.43. Number of portable flow meters by PWSPs

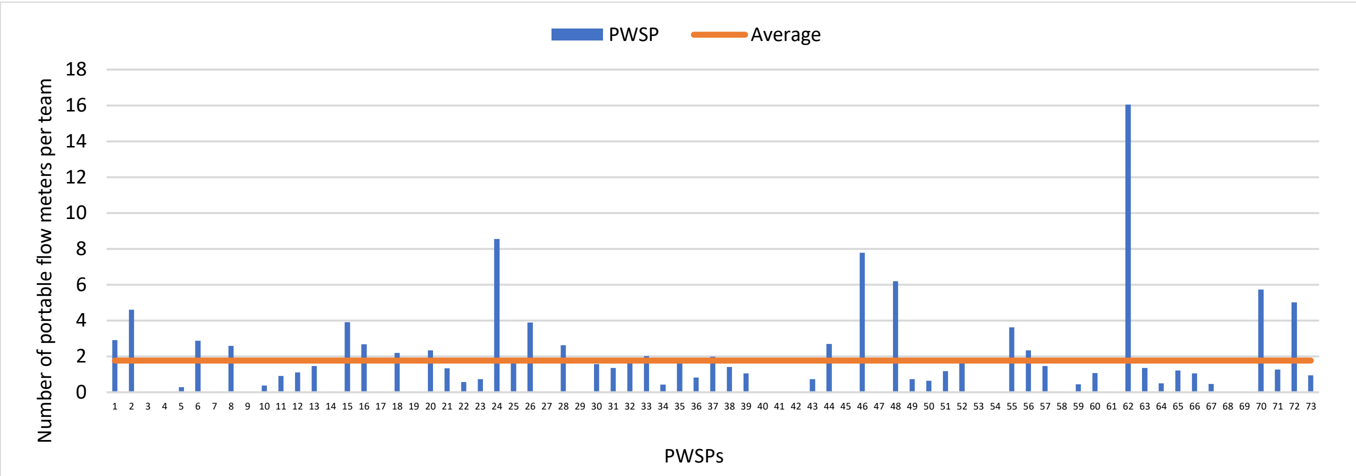


Figure 2.44. Number of portable flow meters per team divided by PWSPs

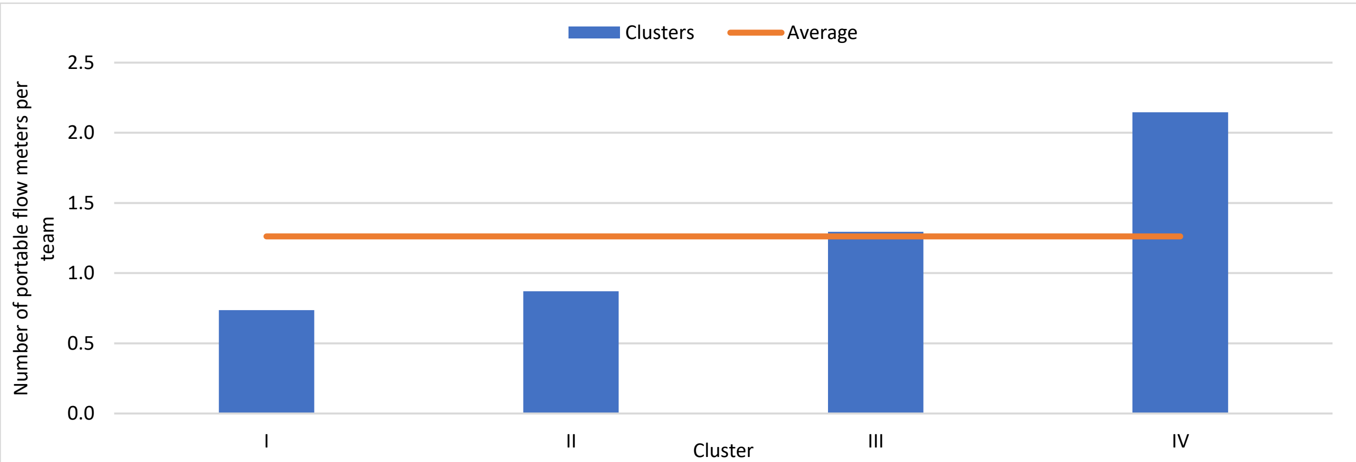


Figure 2.45. Number of portable flow meters per team on the national level and by PWSP clusters

A similar overview with analyses of capacities in terms of the number of portable pressure meters per team is presented in Figure 2.46, Figure 2.47 and Figure 2.48. Figure 2.49. presents the statistics of collected data for other equipment required for the detection of leaks.

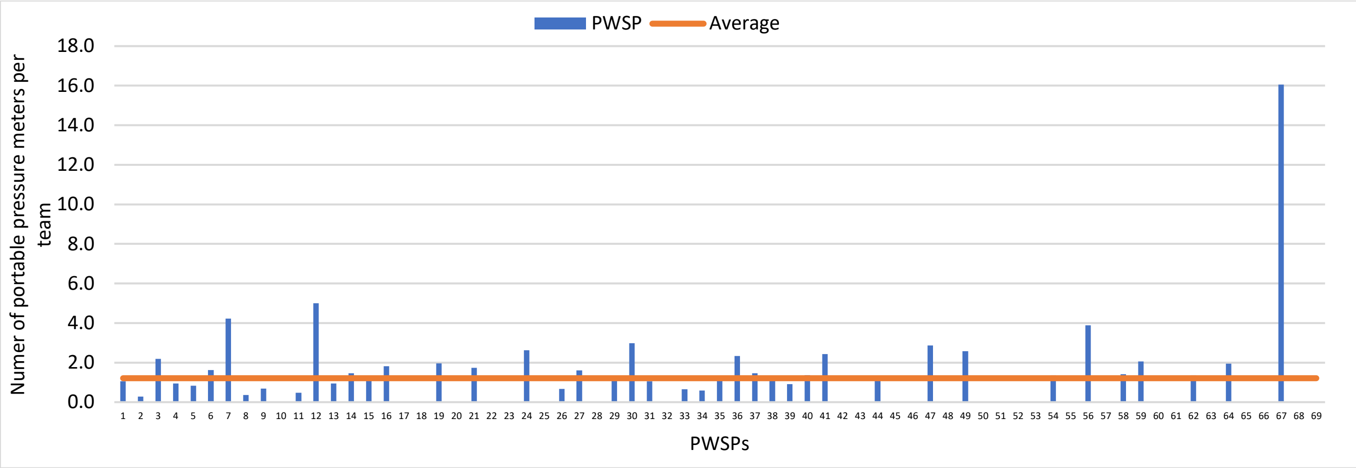


Figure 2.46. Number of portable pressure meters by PWSPs

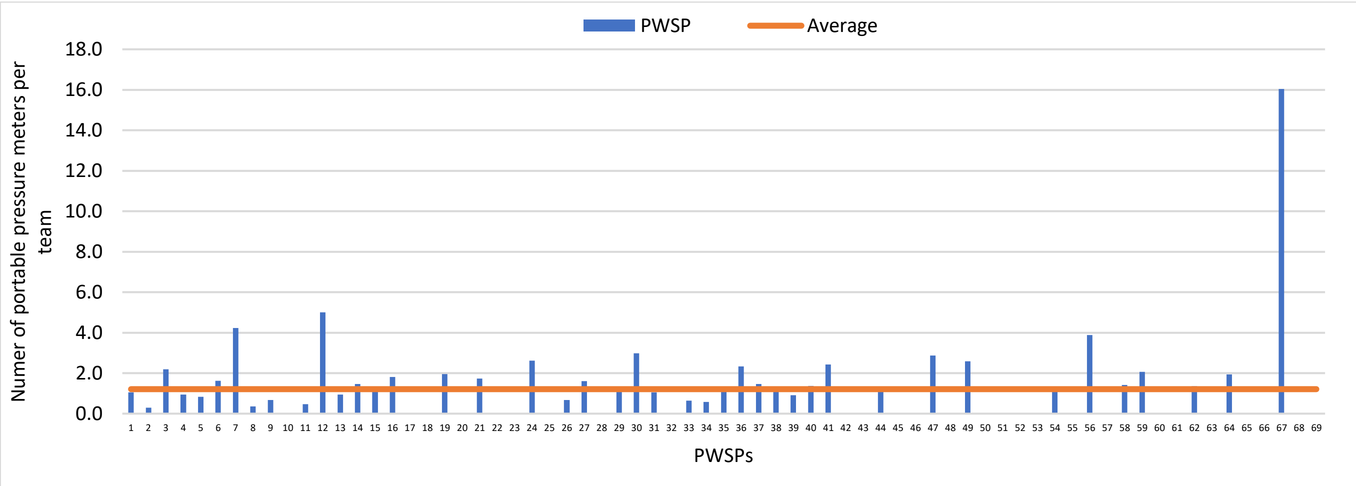


Figure 2.47. Number of portable pressure meters per team divided by PWSPs

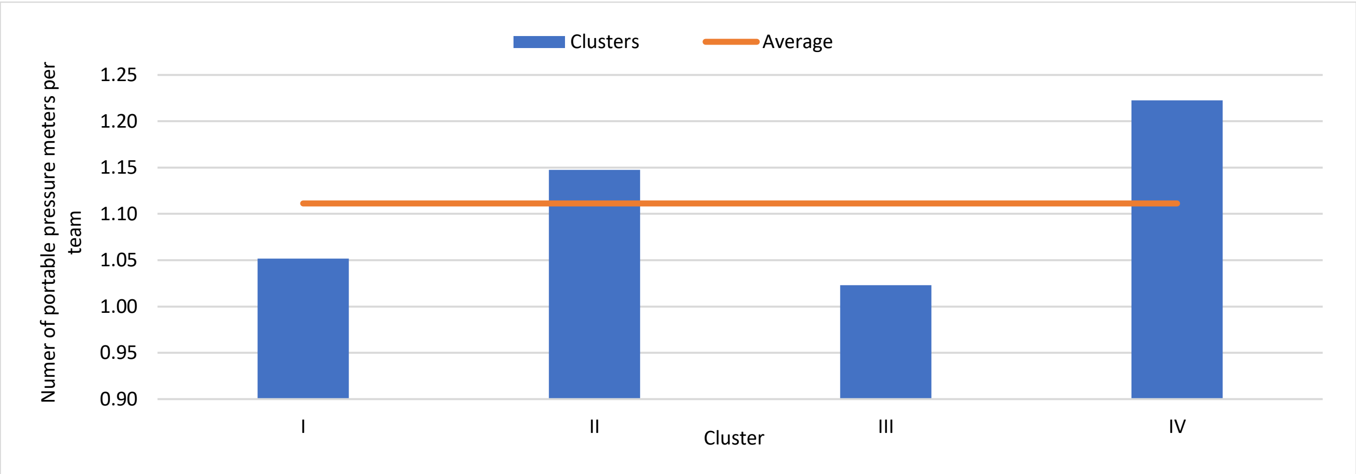


Figure 2.48. Number of portable pressure meters per team on the national level and by PWSP clusters

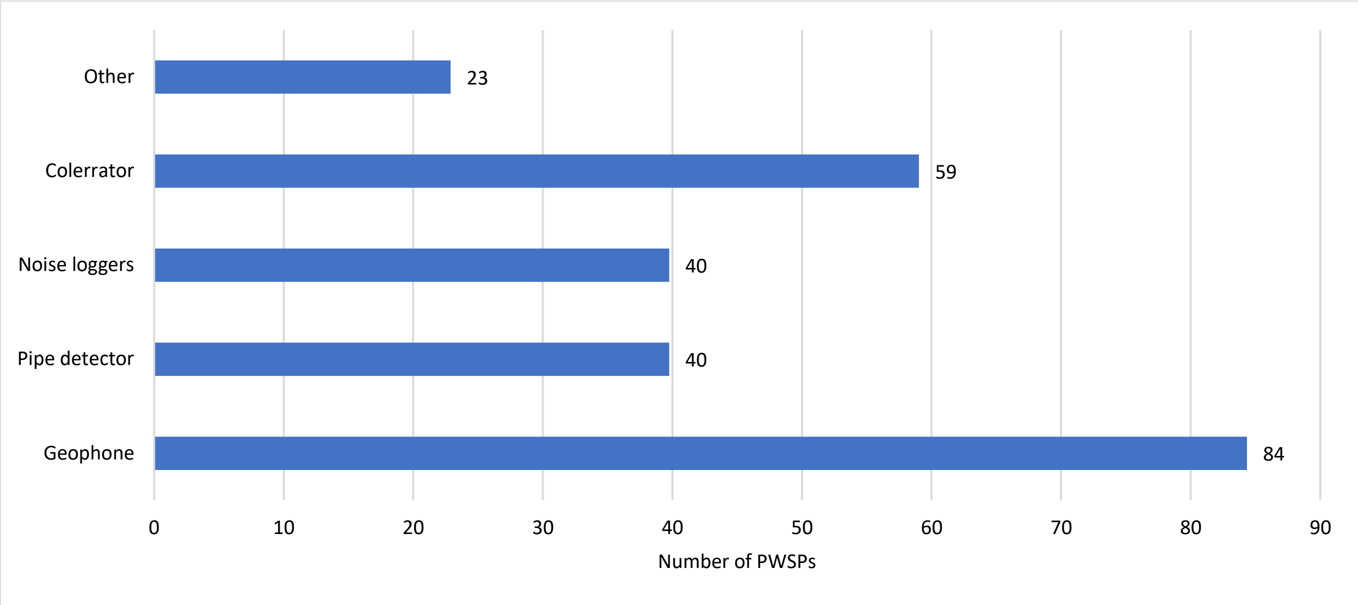


Figure 2.49. Other equipment for active leakage control on the national level

Based on the above it is possible to identify a significant lack of technical equipment – portable equipment for leakage metering and detection. If the total numbers are reduced to the national level, the teams are equipped with 1.3 flow meters and 1.1 pressure meters. Some smaller PWSPs have procured this equipment, and since they have a small length of the water supply network, the data is slightly more favorable in the lower clusters with regard to flow meters, whereas the results are more balanced with regard to pressure meters. If there is no metering equipment, active leakage control cannot be carried out. When this lack is joined with insufficient establishment of DMAs where measurements are taken using fixed meters, it becomes clear that the procurement of equipment needs to be foreseen by the future measures. It has to be pointed out that the metering equipment is in practice rarely calibrated or checked for precision, and that in certain PWSPs part of the existing metering equipment operates with faults, as the result of which wrong conclusions are made. Inaccuracy of metering equipment, primarily flow meters, can be the result of a number of different factors – the wrong selection of metering equipment, inadequate installation of metering equipment, not controlling the proper operation of metering equipment, etc.

2.3.2 Human resources

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, staff management, water loss management, field work, etc. Investing in knowledge, technical teams, implementation of active leakage control, and an organizational structure that respects these issues are the basic preconditions to adequately manage water losses.

It can already from the short analysis of the responses to the questionaries be concluded that a certain number of PWSPs, particularly in the lower clusters, have no interest in this matter or have no adequate staff and background to address it (Figure 2.50). For Clusters I and II all the responses were received, while in Clusters III and IV responses were received from 74% and 52% of the PWSPs, respectively, accounting for 65% of the number of PWSPs on the national level. However, the received responses were submitted by the PWSPs which deliver more than 95% of water.

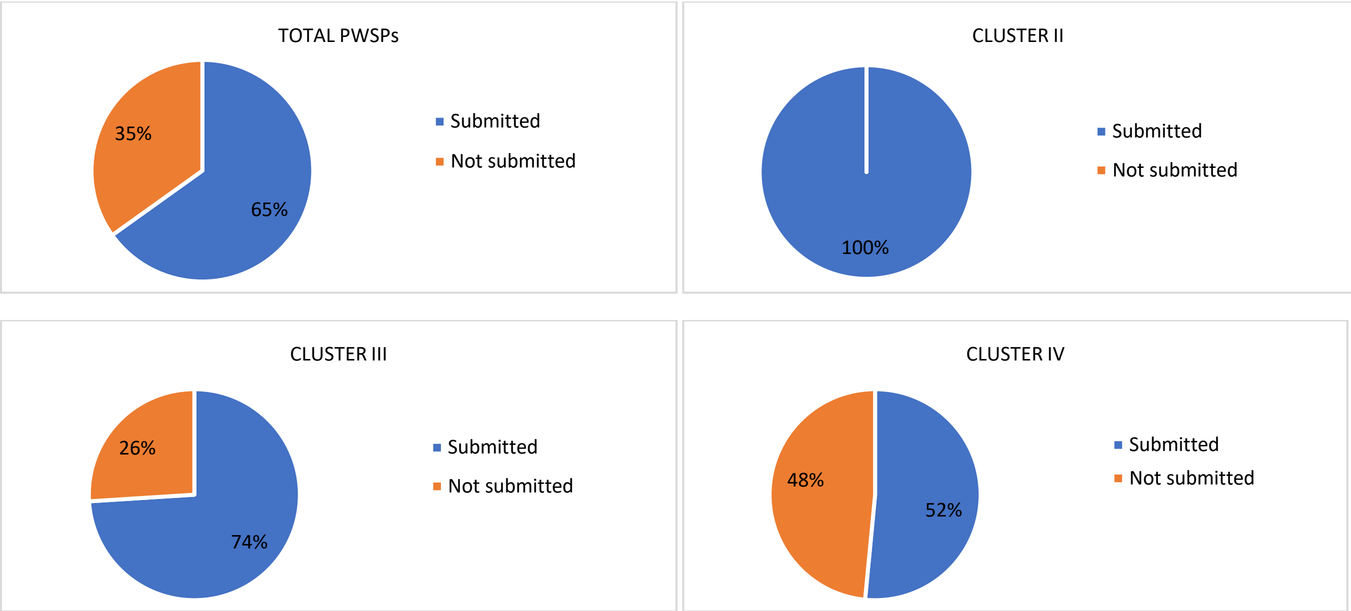


Figure 2.50. Analysis of received responses to questionaries by individual PWSPs on the national level and by PWSP clusters

2.3.2.1 Technical knowledge about the water loss issue

The majority of the PWSPs lack theoretical knowledge essential for making adequate system analyses (water balance, IWA methodology, division of systems into zones, etc.), as well as practical knowledge related to the implementation of active leakage control (using equipment, looking for micro-locations of leaks, etc.). It is a fact that certain PWSPs have at their disposal certain equipment but fail to use it because they don't have the knowledge. Even in cases when water losses are identified (recognized) in a certain part of the system, the lack of knowledge can result in relatively long periods until their removal, which increases the total leakage and NRW volumes on the annual level. Nowadays, almost all activities are faced with exceptional fluctuation of labor force. Relatively low earnings of the PWSP employees, lower skilled staff who actually make the majority of technical teams for water losses, are not motivating and are often the reason behind labor force fluctuation. When a worker who has been working on the reduction of water losses for some time resigns, his/her position is most often filled by an untrained worker whose efficiency in water loss reduction is then lower. There are no training programs for efficient training of technical staff for water loss management/reduction on the national level.

Looking at the way in which the staff working on water losses are trained, it is clear that already in the Cluster I PWSP only occasionally a small number of people attend conferences, fairs, events, and lectures. Figure 2.51. presents the situation by PWSPs on the national level and by clusters.

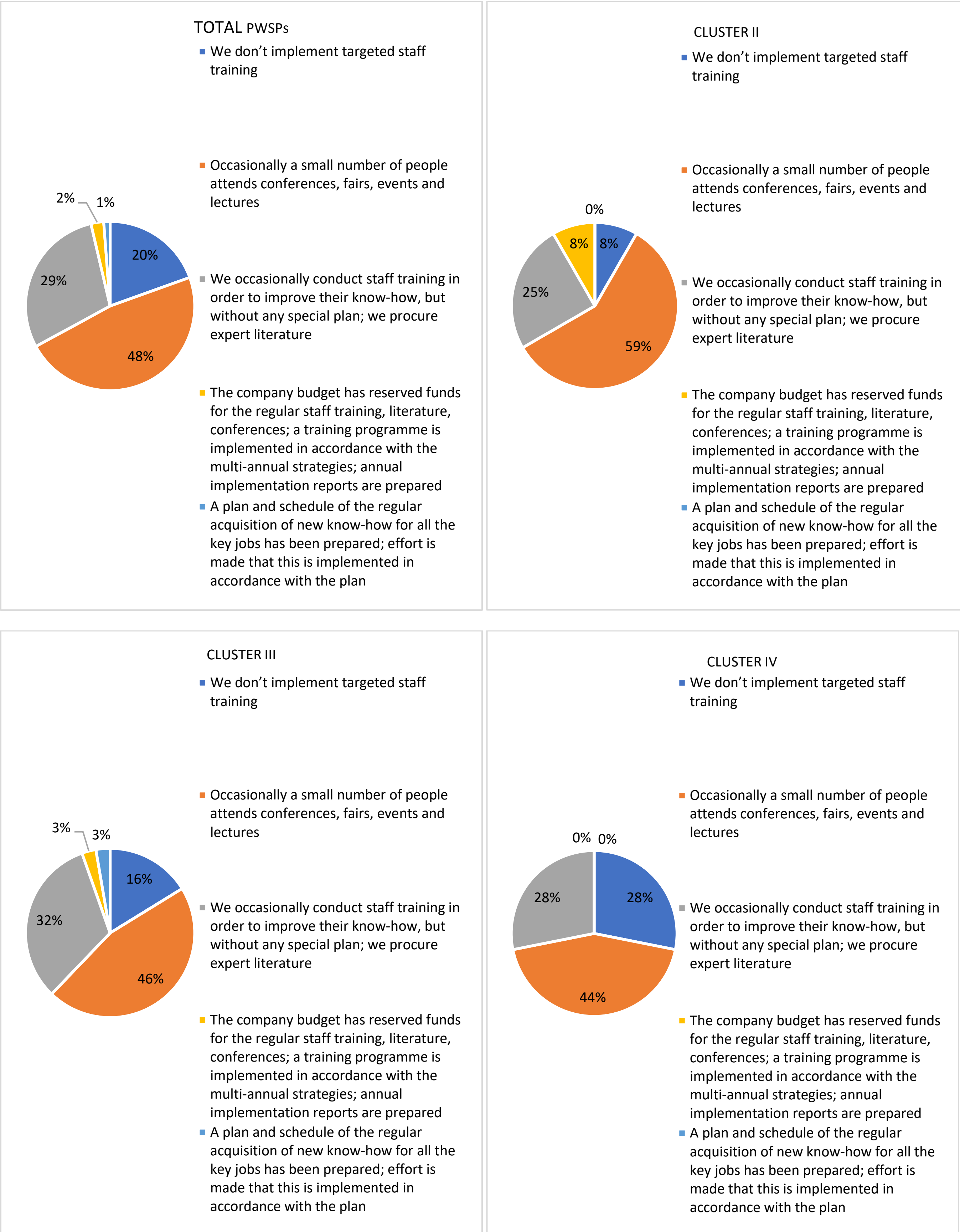


Figure 2.51. How staff training is done by individual PWSPs on the national level and by PWSP clusters

2.3.2.2 PWSPs' technical teams for water loss management (active leakage control)

In order to implement active leakage control, as an unavoidable segment of long-term efficient management of water losses, it is essential that the PWSPs form a technical team (technical teams) which will work full time exclusively on water losses, i.e., on active leakage control. Experience suggests that one technical team requires at least two people in the field and one engineer in the office who can cover several technical teams. As already mentioned, the global and EU guidelines vary among countries and even regions in terms of defining the required number of technical teams, but they all range from 200 to 500 km of the water supply network per one technical team. The majority of the PWSPs in Croatia don't even have a single technical team dedicated full time exclusively to water losses. A large number of PWSPs don't have a sufficient number of technical teams in relation to the size of their networks. There are few PWSPs where the number of technical teams working on water loss reduction is adequate to system size (length of the water supply network).

Figure 2.52. presents the total number of employees, the number of employees in development and maintenance, and the number of employees who work on water losses on a daily basis, all by the PWSPs for which data was collected. More balanced numbers of employees are presented in Figure 2.53. when the length of the mains is divided by the number of PWSP employees. Figure 2.54. presents the length of mains per employee, per employee in development and maintenance, and per employee who works on water losses on a daily basis, divided by clusters.

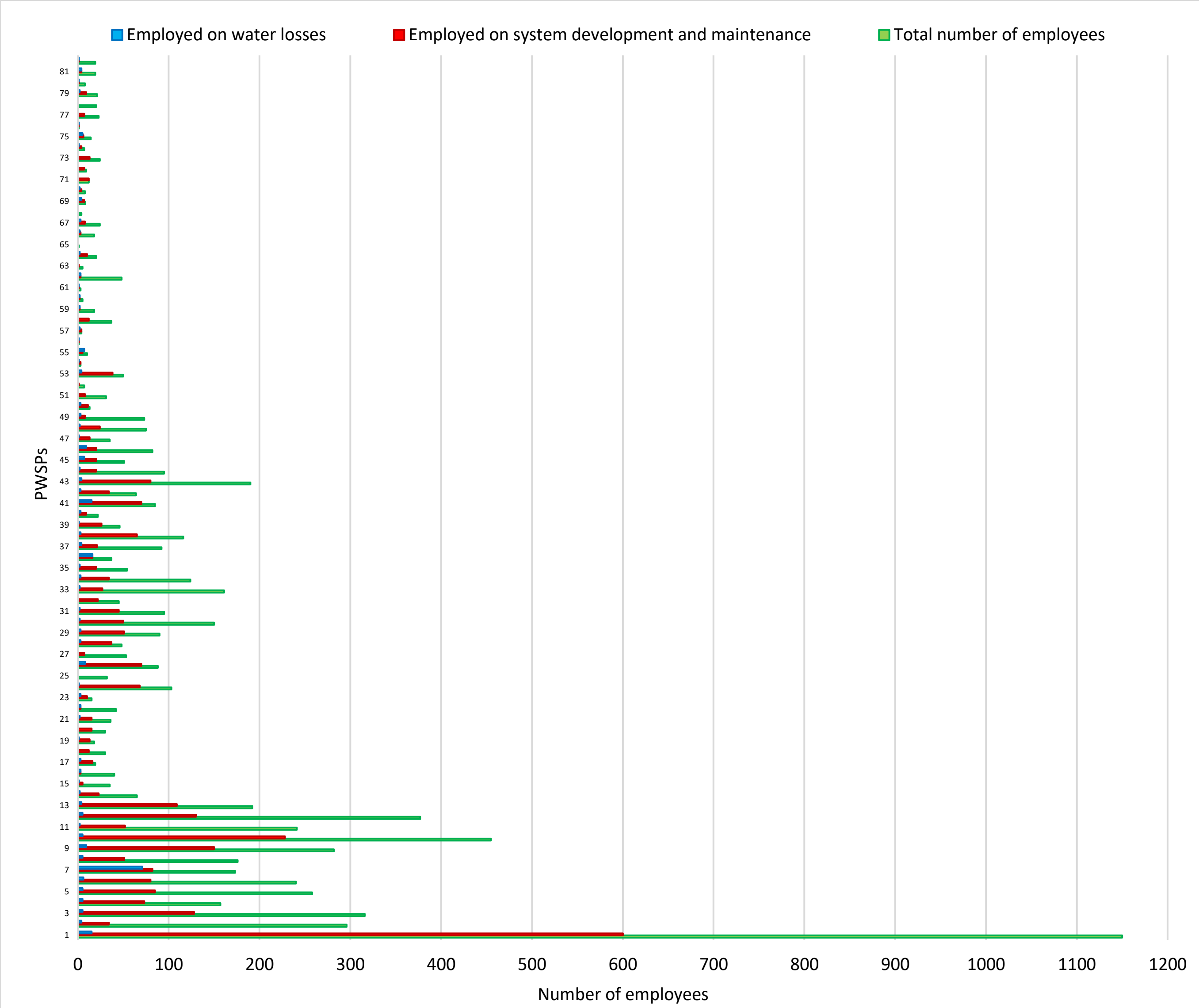


Figure 2.52. Total number of employees, employees in development and maintenance, and employees working on water losses by PWSPs

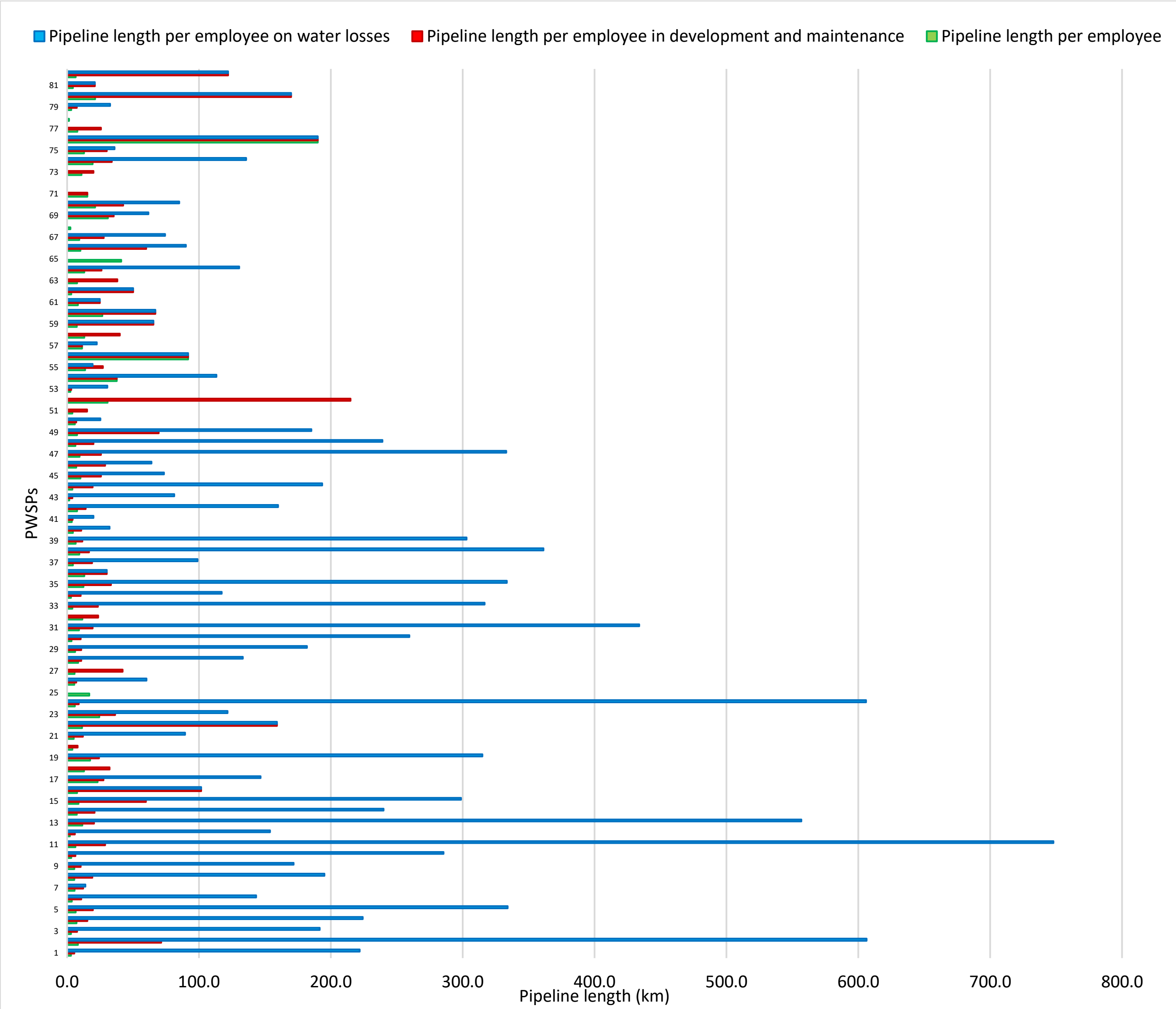


Figure 2.53. Mains length by employee categories, divided by PWSPs

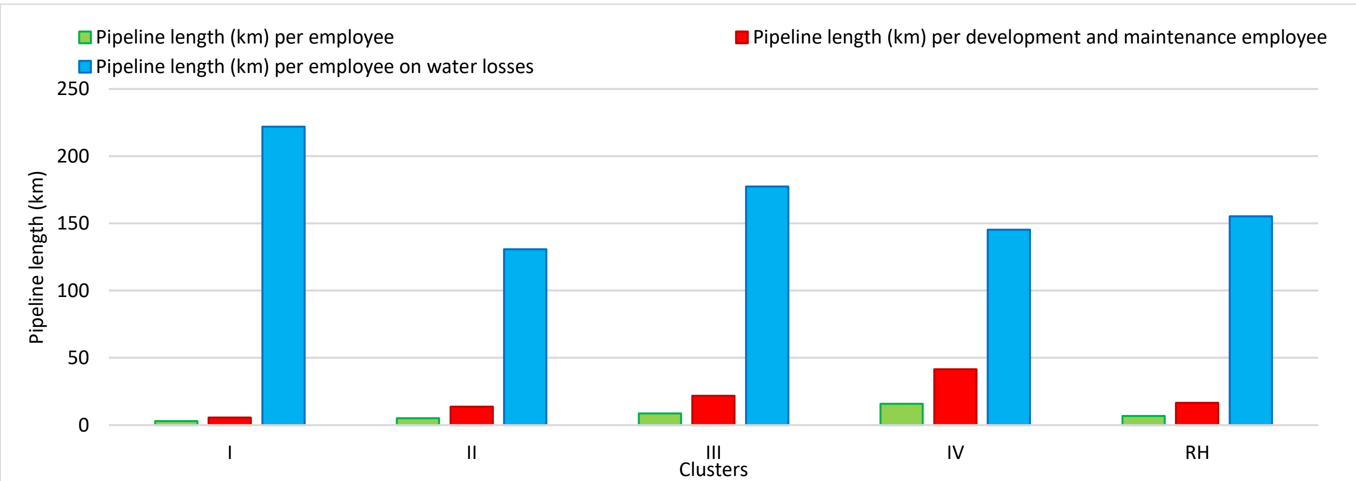


Figure 2.54. Mains length by employee categories, divided by PWSP clusters

The presented figures show that the numbers of employees, particularly those working on water losses on a daily basis, are not sufficient or are not even foreseen by many PWSPs. The situation is nothing better when analyzing the establishment of technical teams for water losses (Figure 2.55. When the situation would be analyzed based on the proposal of the future service areas Figure 2.56. Establishment of technical teams for water losses by service areas, the result in terms of the establishment of technical teams would look better, but their number would still definitely be insufficient according to the mentioned global and EU guidelines. Figure 2.57 presents the network length covered by one team by PWSPs, and Figure 2.58. presents the network length covered by one team divided by clusters, from which one can see that the length of the network covered by technical teams by far surpasses the recommended guidelines. The average number of employees per team, divided into the number of engineers and low-skilled workers, is presented on the national level and by clusters in Figure 2.59.

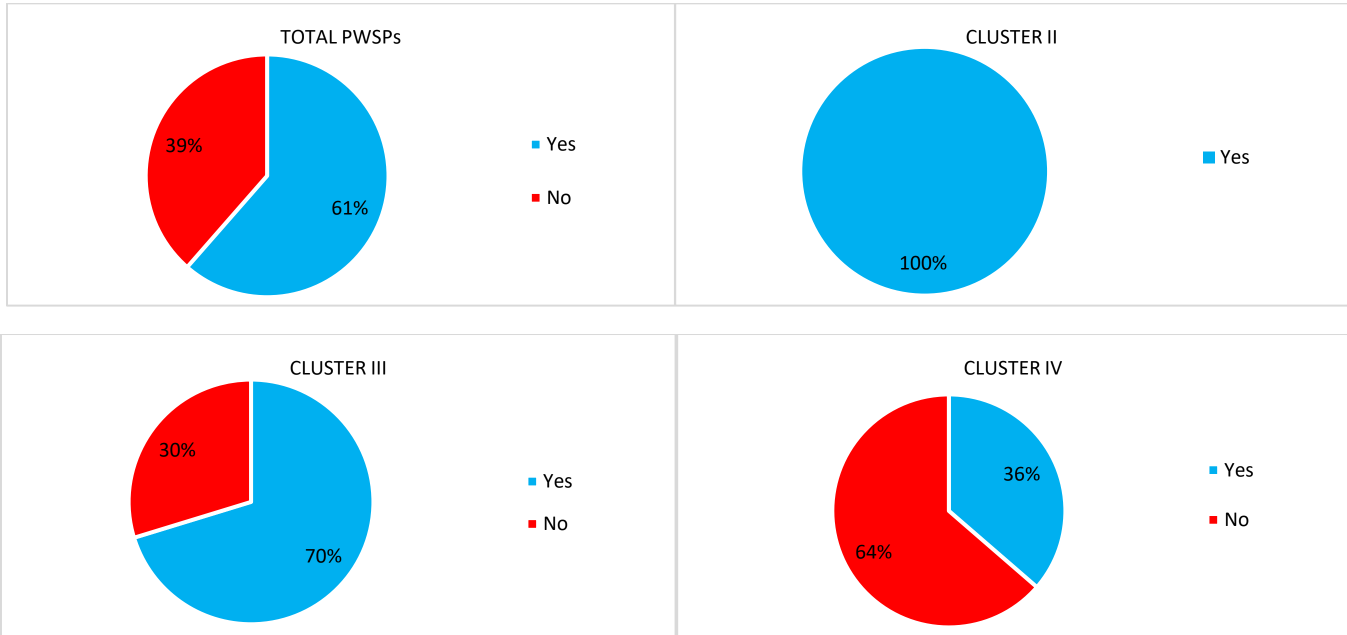


Figure 2.55. Establishment of technical teams for water losses by PWSPs on the national level and by PWSP clusters

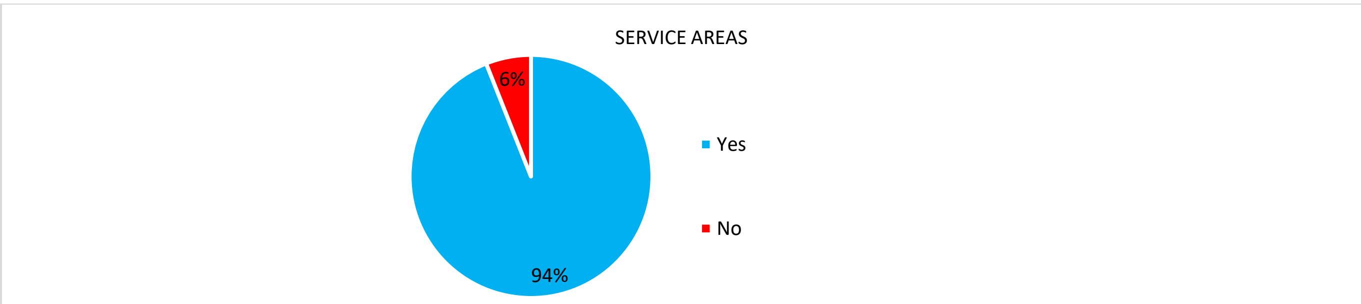


Figure 2.56. Establishment of technical teams for water losses by service areas

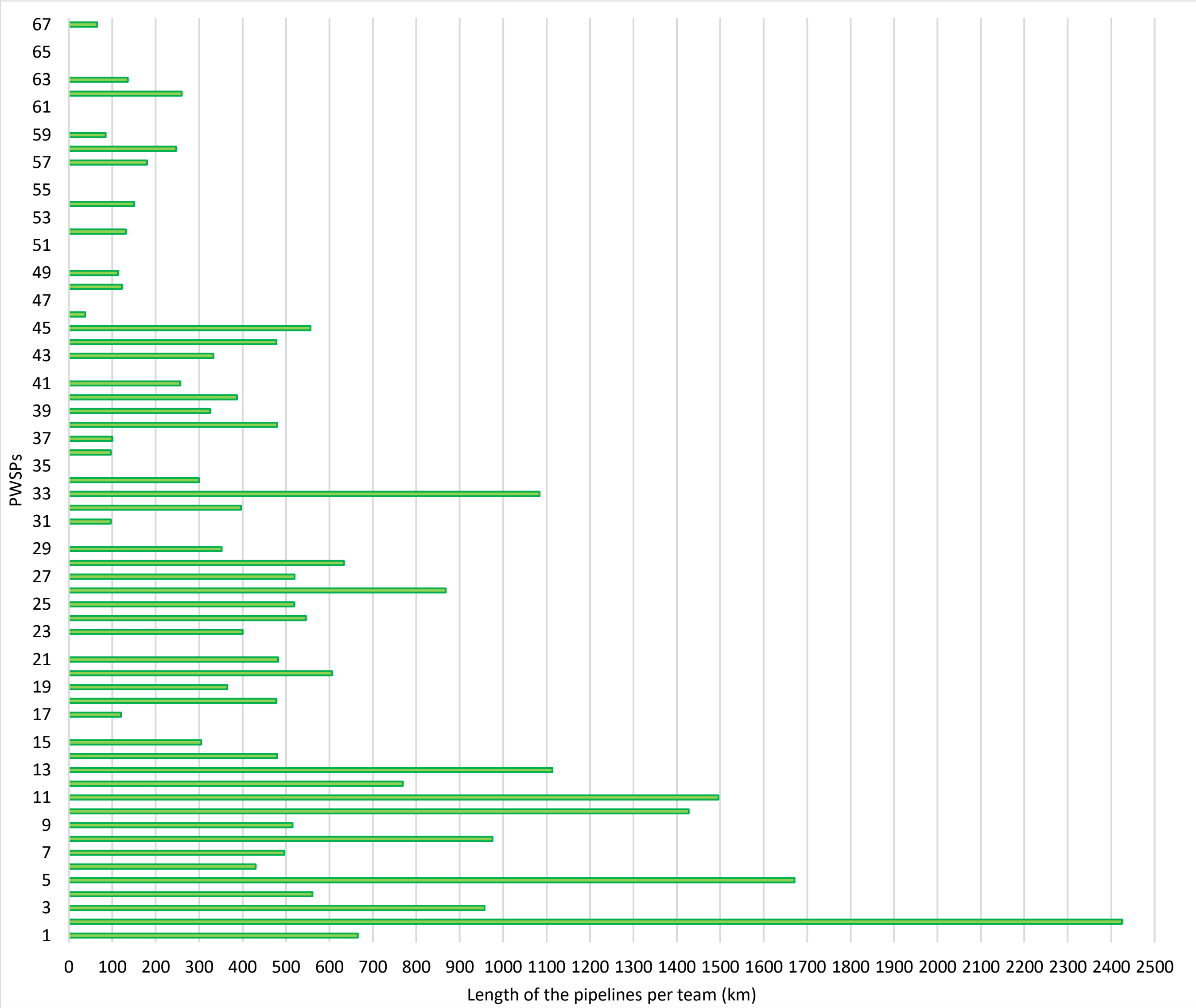


Figure 2.57. Mains length per team divided by PWSPs

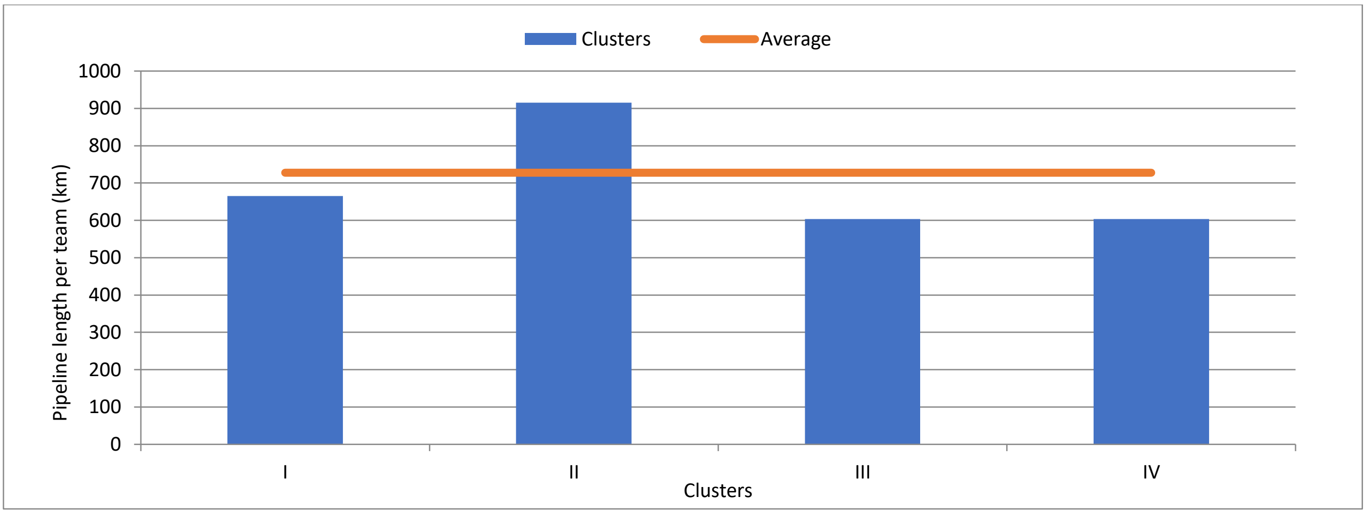


Figure 2.58. Mains length per team divided by PWSP clusters

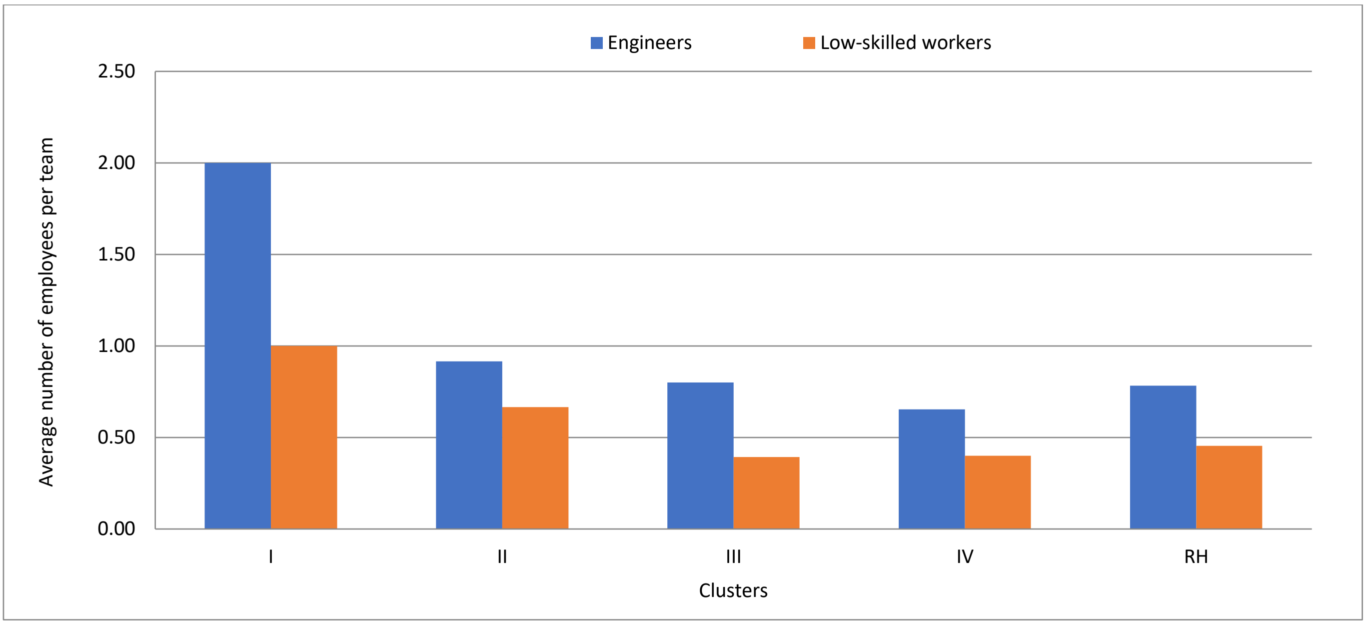


Figure 2.59. Average number of employees per team, divided into the numbers of engineers and low-skilled workers, presented on the national level and by PWSP clusters

2.3.2.3 Active leakage control and repair of invisible bursts (breaks) (leakage taking place below the surface of ground, without the water appearing on the surface)

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, which eventually manifest themselves through water losses.

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, roads collapsing, 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 break), after which the necessary works on its removal and registration are carried out.

Active leakage and repair control can be divided into service activities and activities related to the very leakage and repair control. The most significant service activities include servicing the pressure regulation valves, servicing the air release or air release/intake valves, and releasing the air from the water supply network to prevent the air from accumulating in the pipes. The frequency of servicing the pressure regulation valves on the national level and by clusters is presented in Figure 2.60. and is higher than the frequency of servicing air release/intake valves (Figure 2.61). This is understandable since problems in the system become apparent more clearly and rapidly due to problems with pressure regulation valves than with air release/intake valves where a direct connection is not seen between bursts and losses and risks from exceeded pressures due to the water hammer. Figure 2.62. presents the ways in which the air is released from water supply networks on the national level and by PWSP clusters.

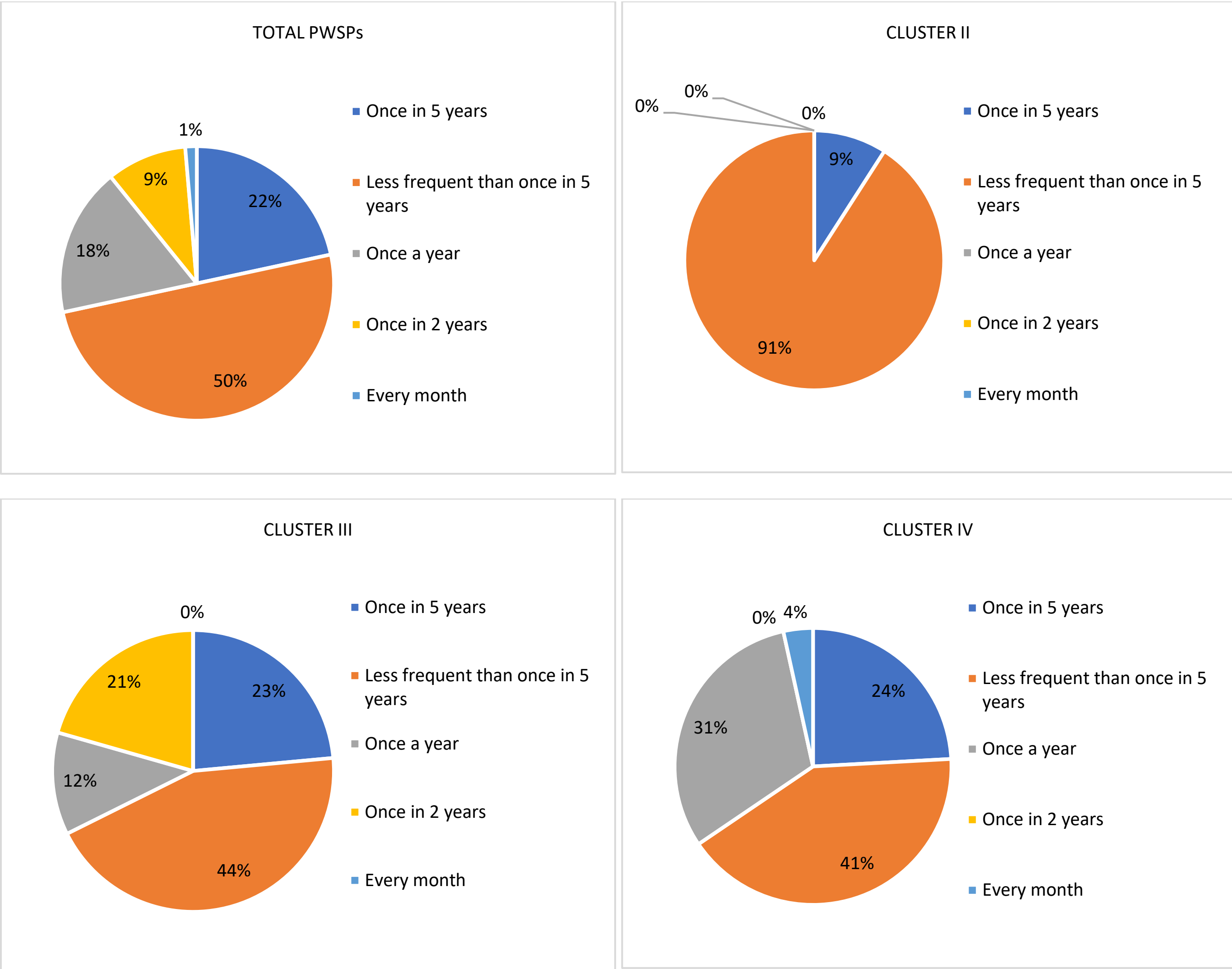


Figure 2.60. Frequency of servicing pressure regulation valves on the national level and by PWSP clusters

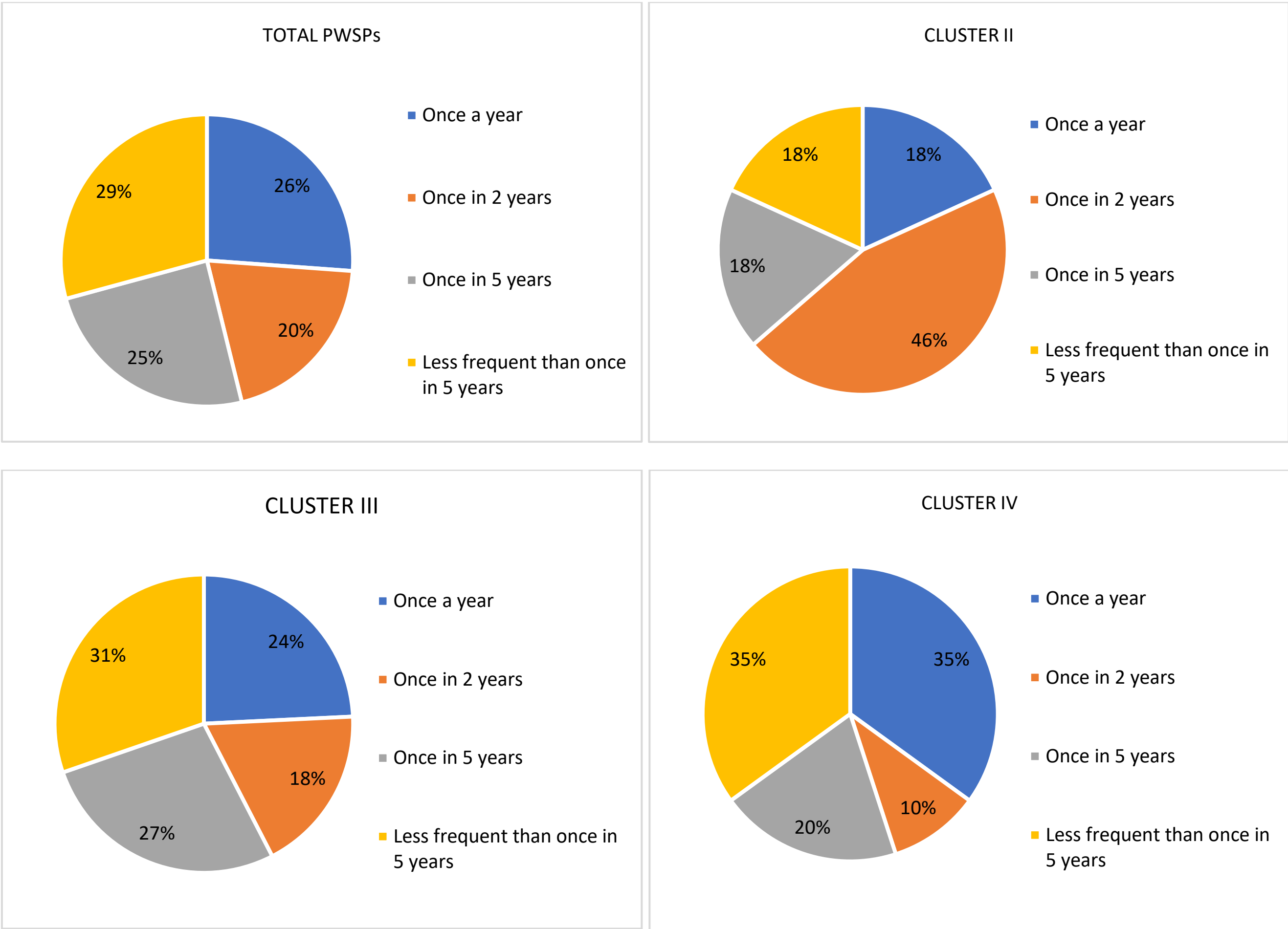


Figure 2.61. Frequency of servicing air release/intake valves on the national level and by PWSP clusters

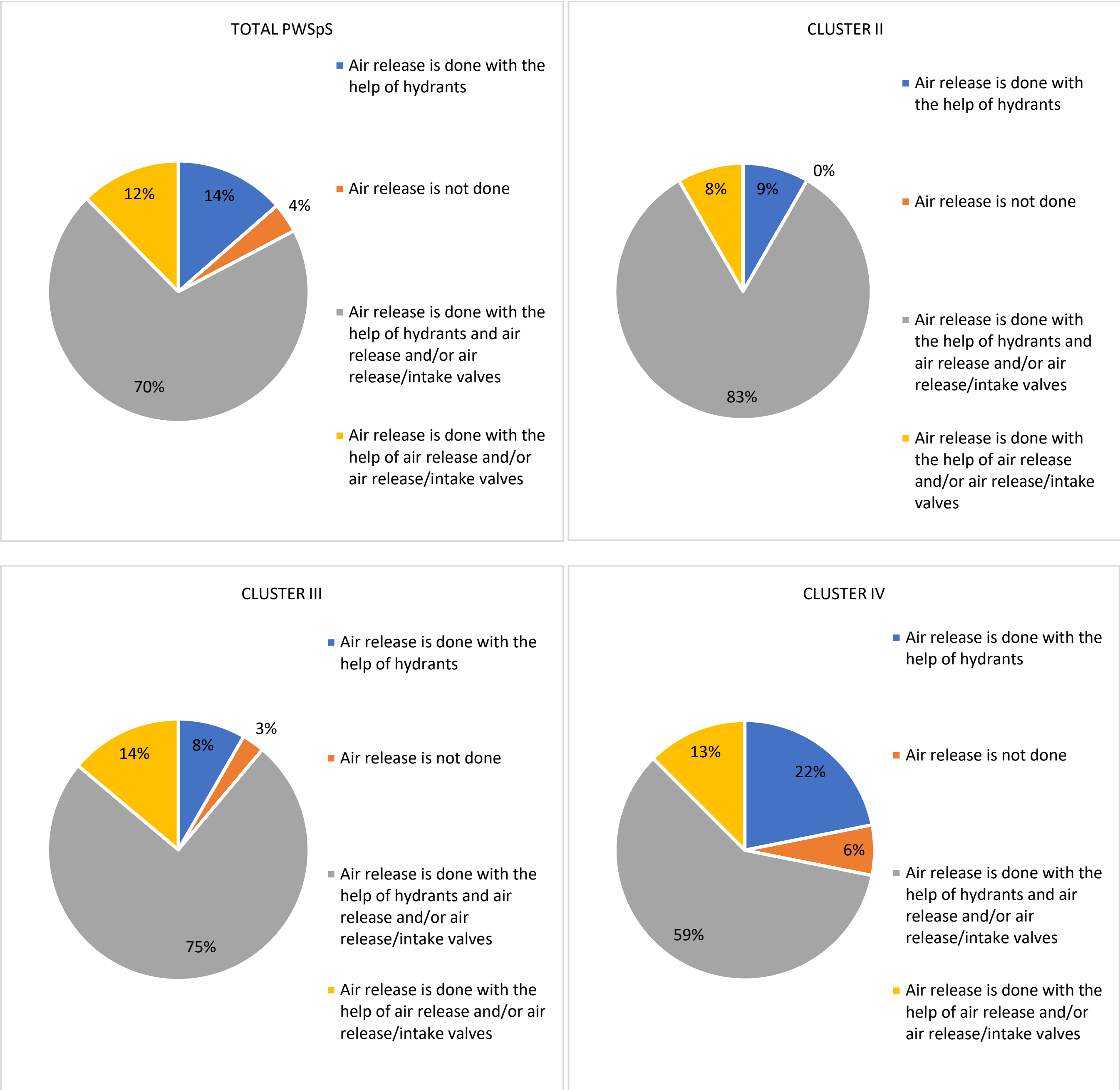


Figure 2.62. How the air is released from water supply networks on the national level and by PWSP clusters

The analytics related to the water balance and indicators will be described in detail in Chapters 2.4. and 2.5. There are several indicators of the method and quality of implementing active leakage and repair control. When the problem of insufficient resources in terms of equipment and teams is put aside, and the implementation is analyzed in terms of the way in which active leakage control is performed, the results are somewhat better, but still insufficient, particularly when analyzing the results in the lower clusters. 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. Figure 2.63. presents the results of the active leakage control methods on the national level and by clusters. DMAs will be addressed in greater detail in Chapter 2.6. Here, the method of establishing DMAs on the national level and by clusters is presented (Figure 2.64). It is clear that these activities are mostly only in the development phase according to the results of the conceptual solutions prepared recently.

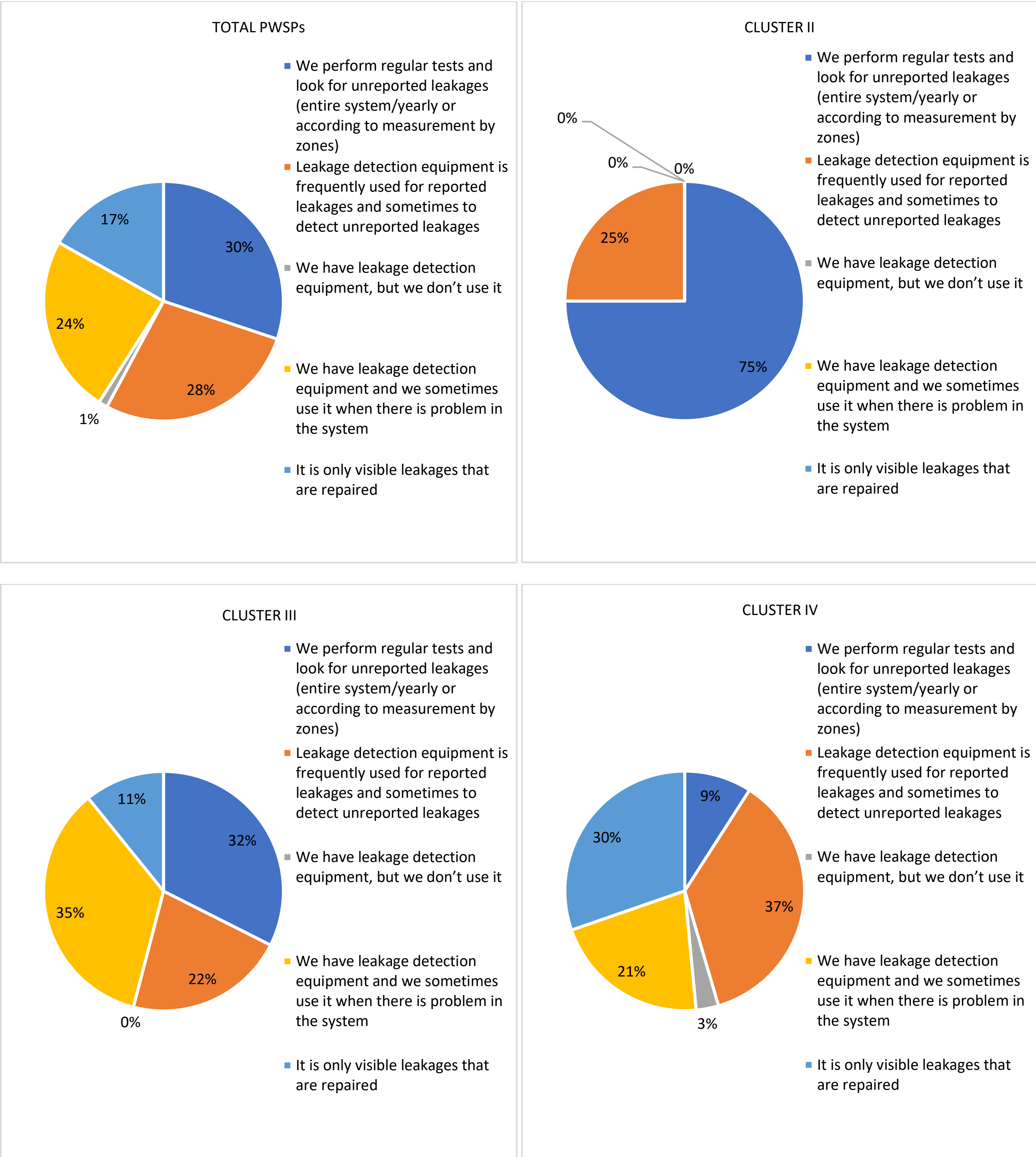


Figure 2.63. Active leakage control methods on the national level and by PWSP clusters

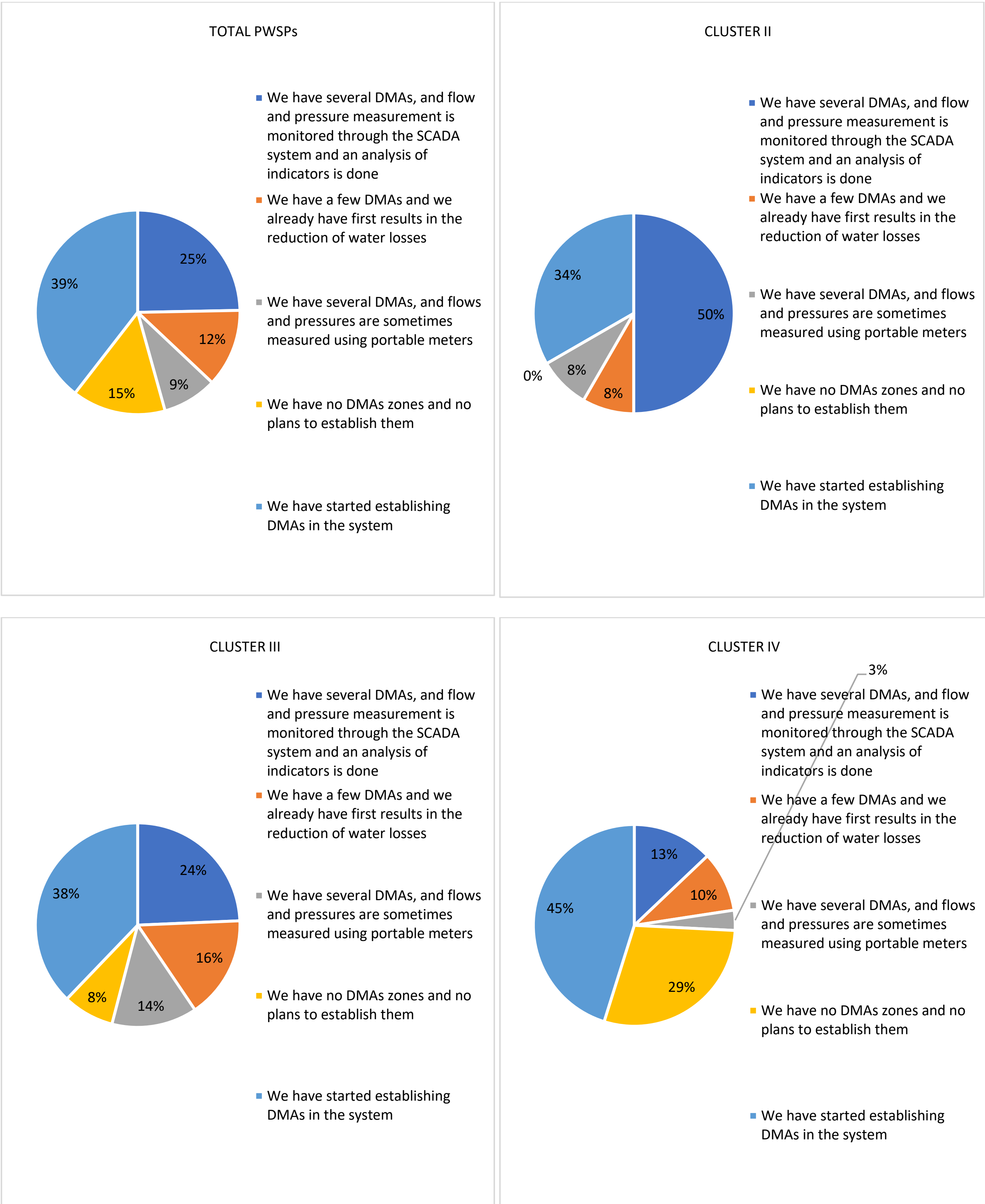


Figure 2.64. Method of establishing DMAs on the national level and by PWSP clusters

Much better results are achieved in the speed of repair on transmission (Figure 2.65) and distribution mains (Figure 2.66) and service connections (Figure 2.67).

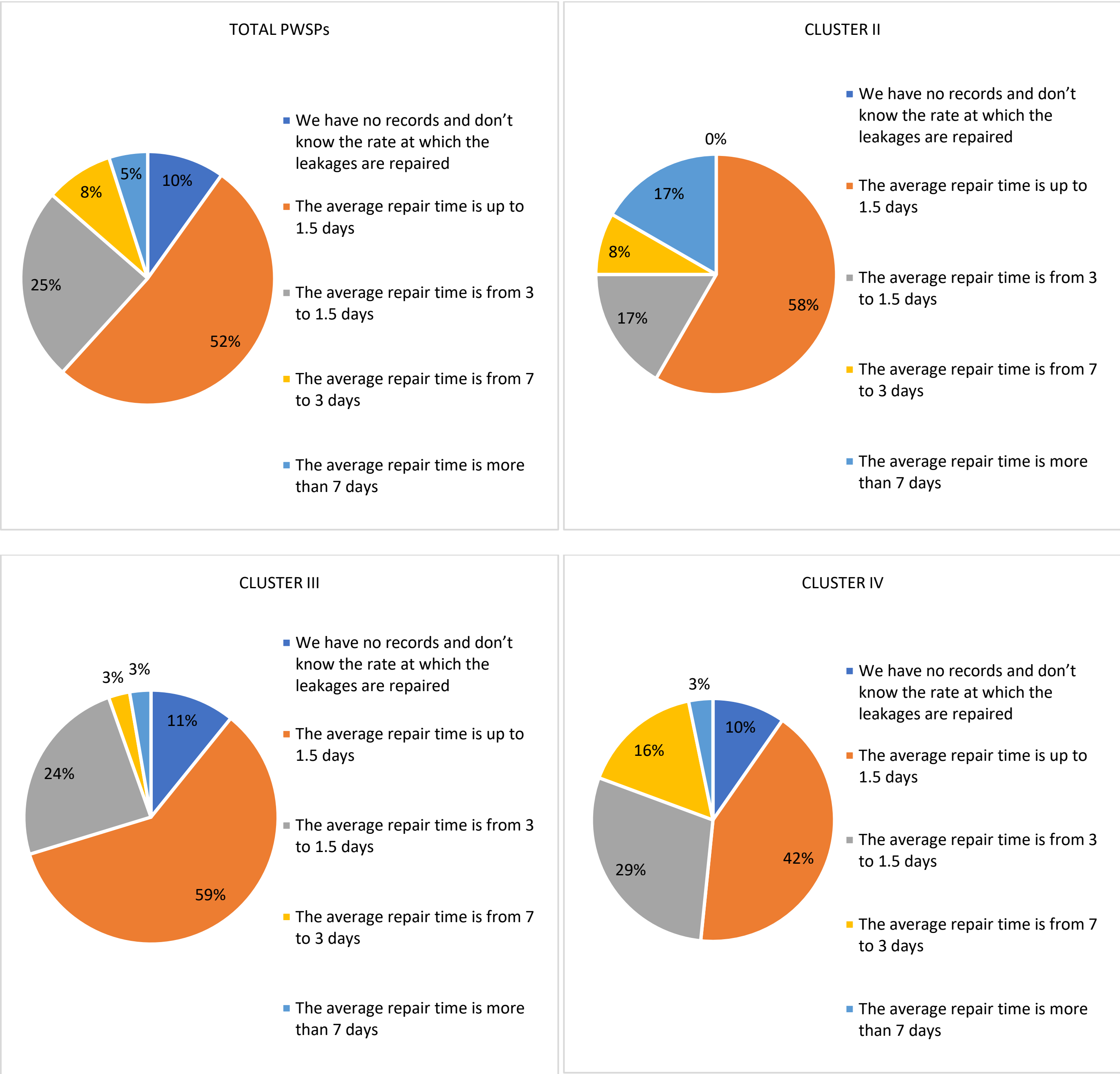


Figure 2.65. Duration of leakage repair on transmission mains on the national level and by PWSP clusters

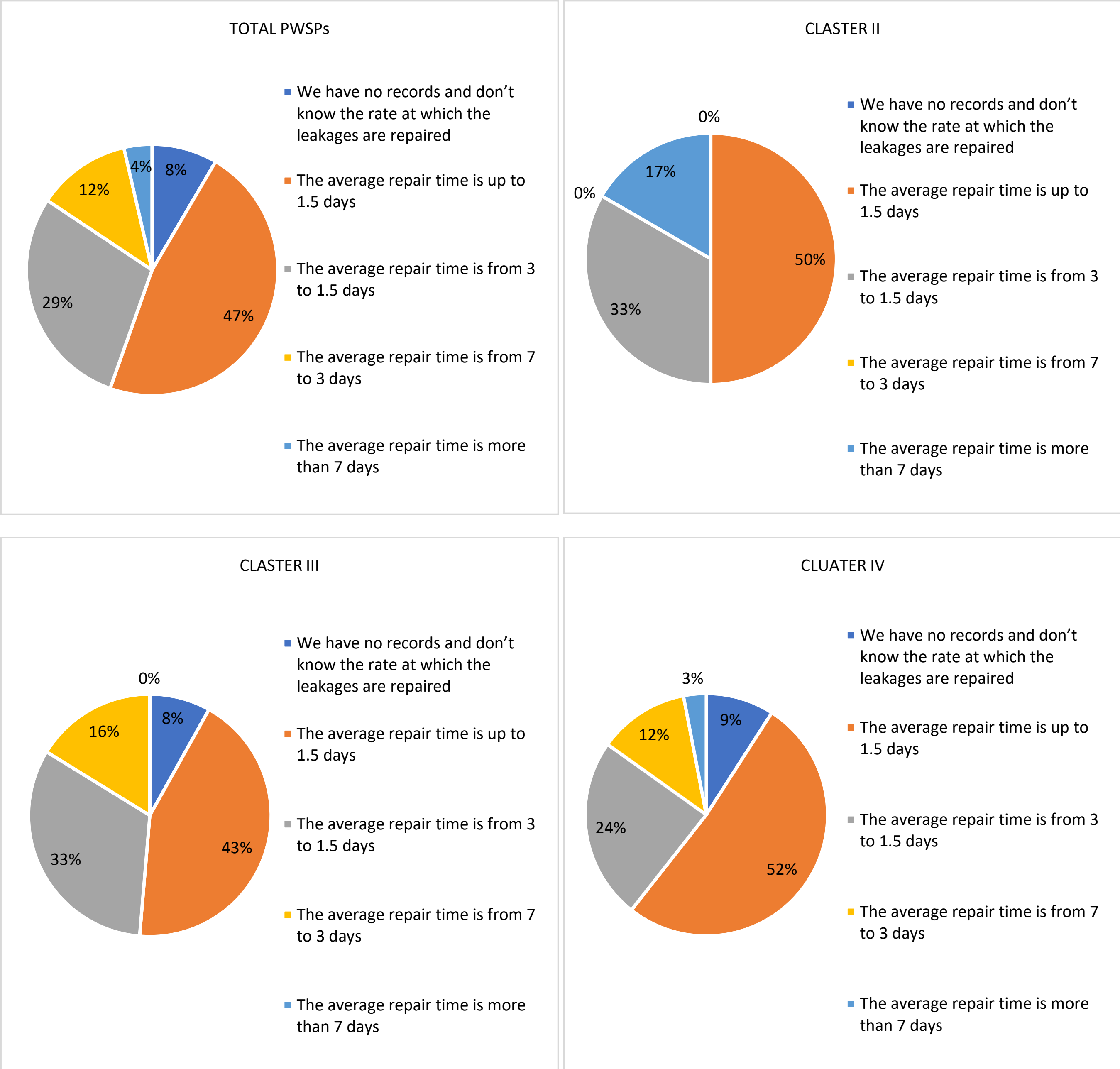


Figure 2.66. Duration of leakage repair on distribution mains on the national level and by PWSP clusters

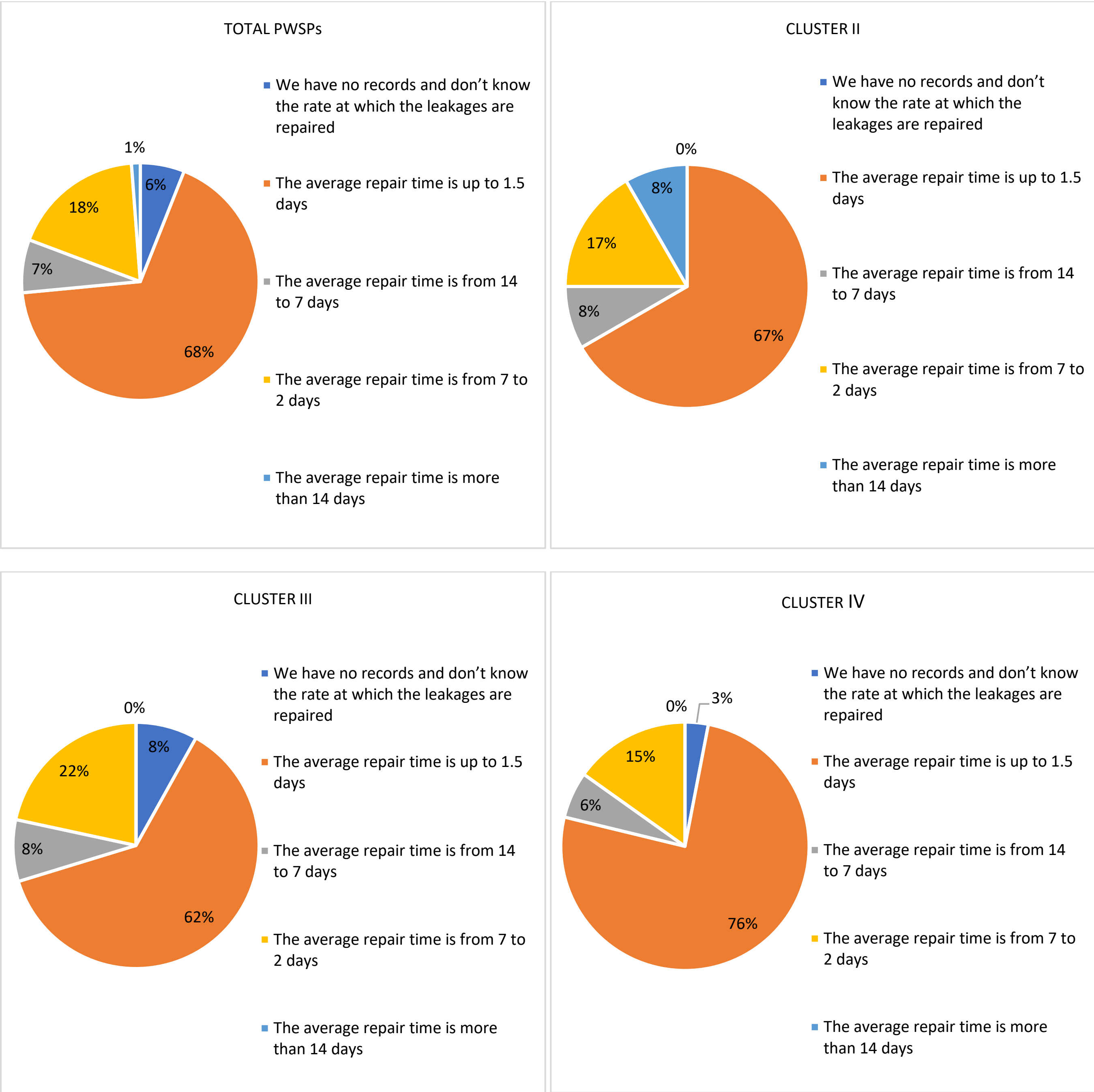


Figure 2.67. Duration of leakage repair on service connections on the national level and by PWSP clusters

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 Figure 2.68. as much as 80% of them don’t make analyses of system pressures or only occasionally measure the pressure and try to make analyses, with the situation even less favorable in the lower clusters. The situation isn’t favorable either when it comes to the way in which system pressure is regulated (Figure 2.69): around 20% of the PWSPs have no special pressure regulation to control water losses, and for example around 37% have a few areas (zones), but still with mostly spring valves for pressure regulation.

Figure 2.68. How potential for system pressure management is analyzed on the national level and by PWSP clusters

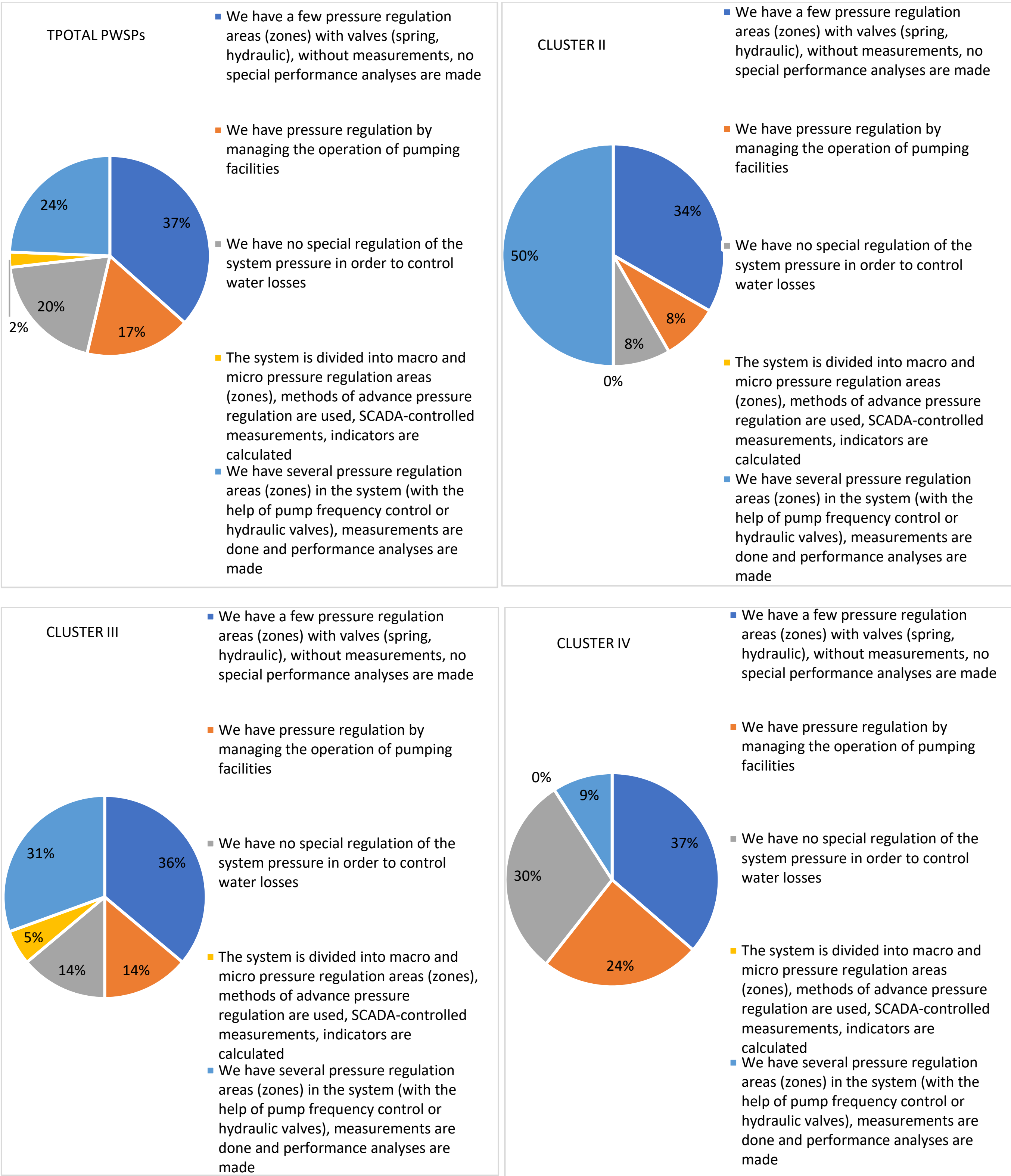


Figure 2.69. How system pressure is regulated on the national level and by PWSP clusters

2.3.2.4 Organizational structure

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 reconstruction 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 also do other work when needed (Figure 2.70). Looking at clusters, the situation in Cluster IV is considerably more unfavorable than in the other clusters. When the practice of the most organized PWSPs by service areas would be analyzed as a standard to be developed throughout the service area, the situation would be slightly more favorable (Figure 2.71), but still far away from the required one.

The situation in terms of the way in which different departments in a company are coordinated is slightly more favorable, as presented in Figure 2.72.

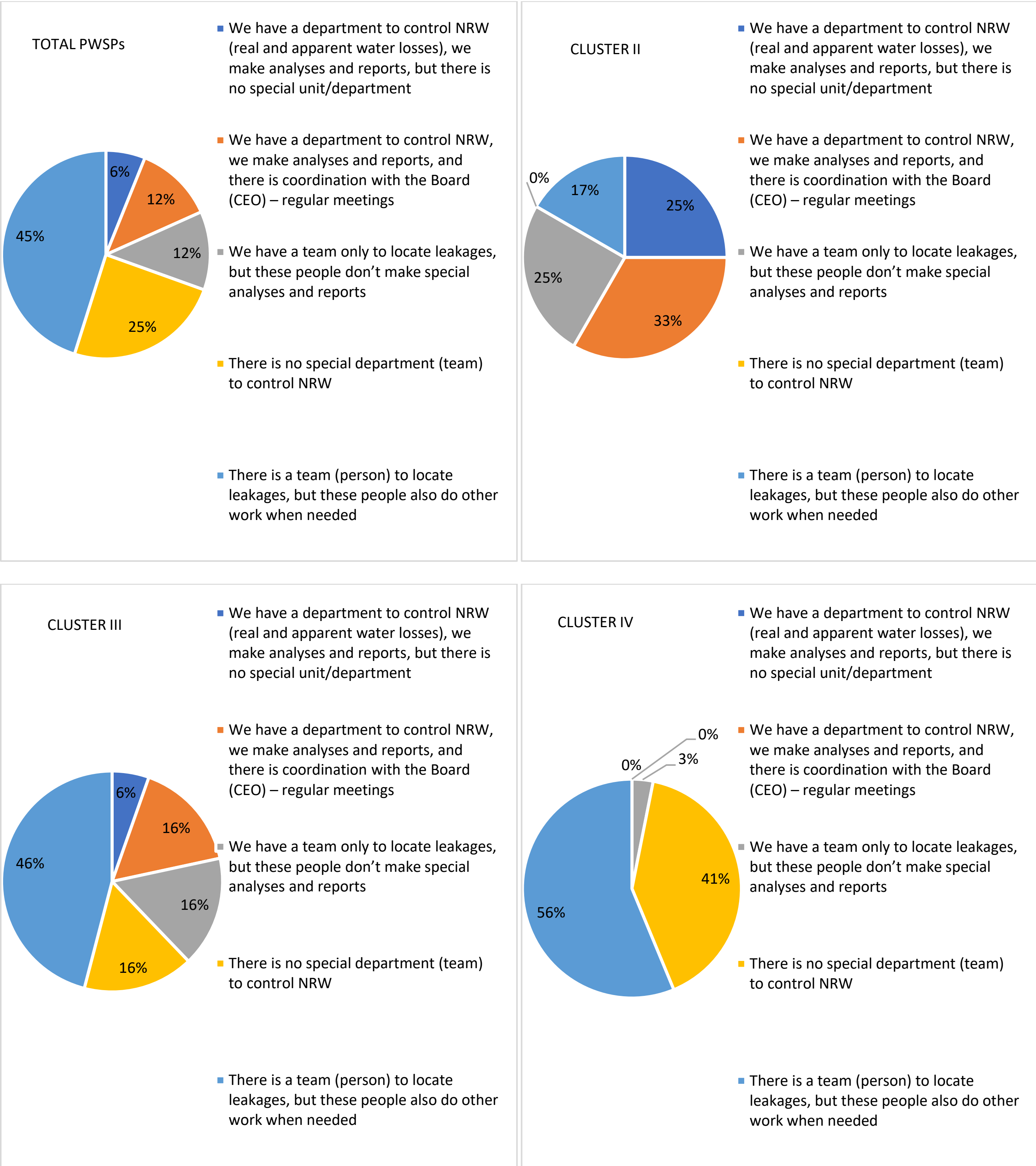


Figure 2.70. How work in a company is organized on the national level and by PWSP clusters

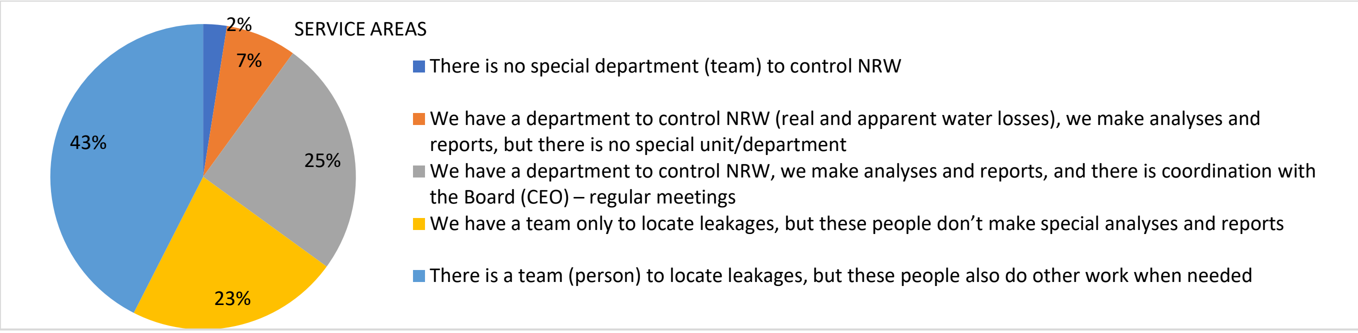


Figure 2.71. How work in a company is organized by the most organized PWSPs grouped by service areas

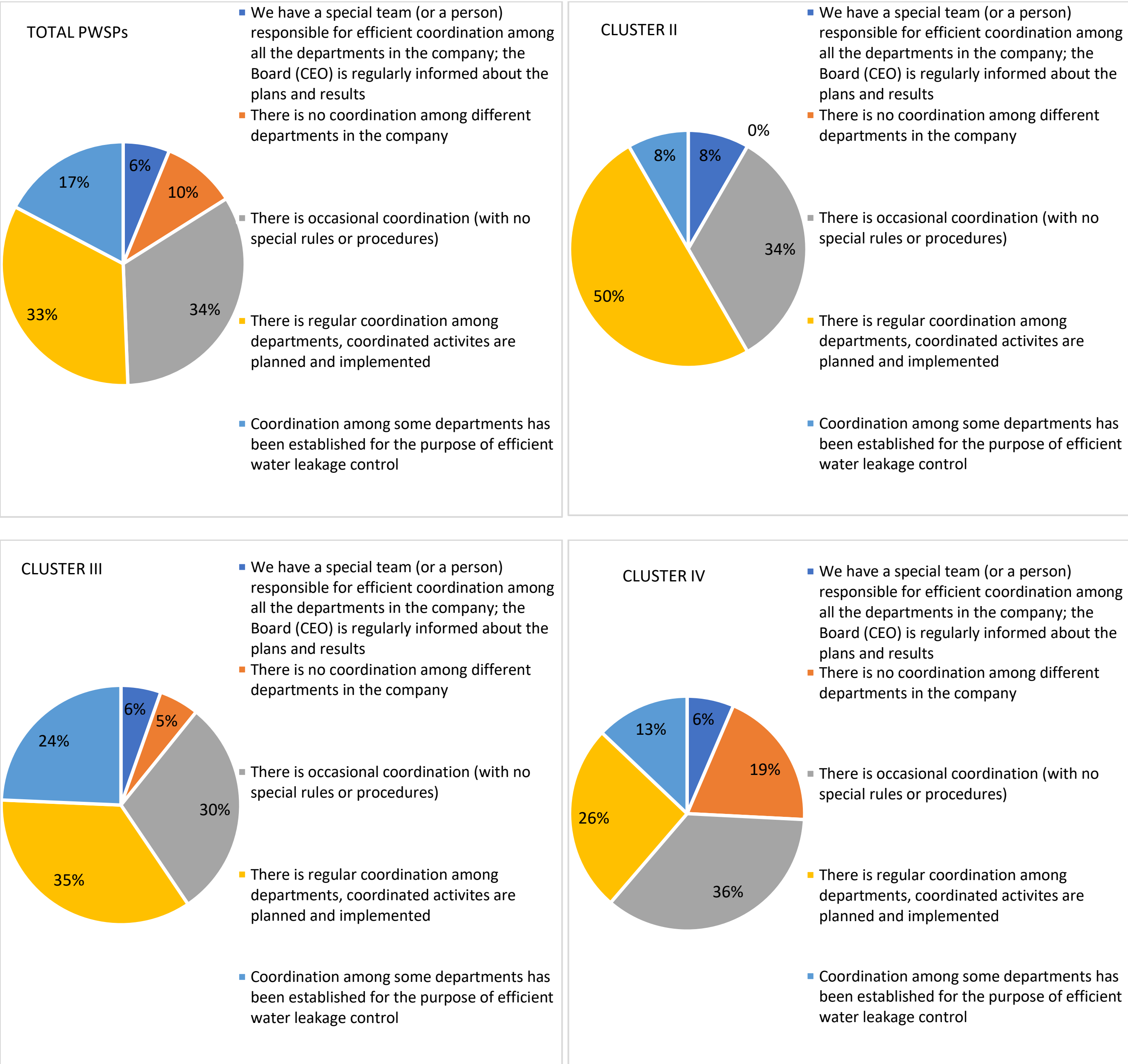


Figure 2.72. How different departments in a company are coordinated on the national level and by PWSP clusters

When it comes to the way in which a water loss control program is planned and implemented, the situation is at a very low level (Figure 2.73). 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. Even a large number of the PWSPs in the higher clusters don't make plans or reports on the implementation of water loss control activities.

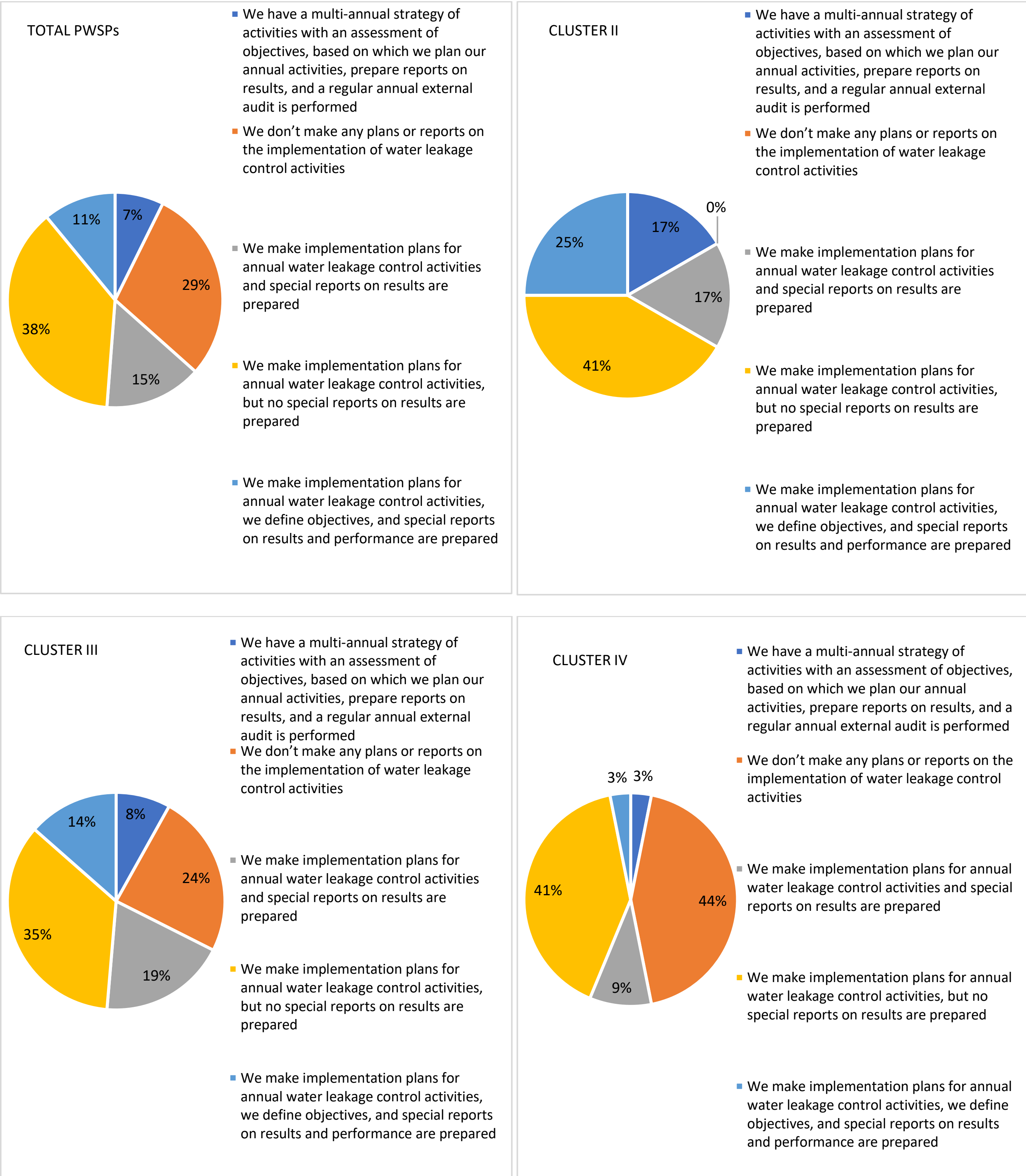


Figure 2.73. How water loss control programs are planned and controlled on the national level and by PWSP clusters

As for the planning and implementation of the program of annual reconstruction of water supply systems, a high share of the PWSPs does the planning, but not in a way to perform optimum network rehabilitation (reconstruction and repair) in order for the system to be restored efficiently and functionally over a long term (it would be optimum to rehabilitate 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 (Figure 2.74). This results in a small average annual quantity of the mains restored, as presented in Figure 2.75, and a low average annual rate of restoration of service connections (a pipe from connection to the main to the water meter), as presented in Figure 2.76.

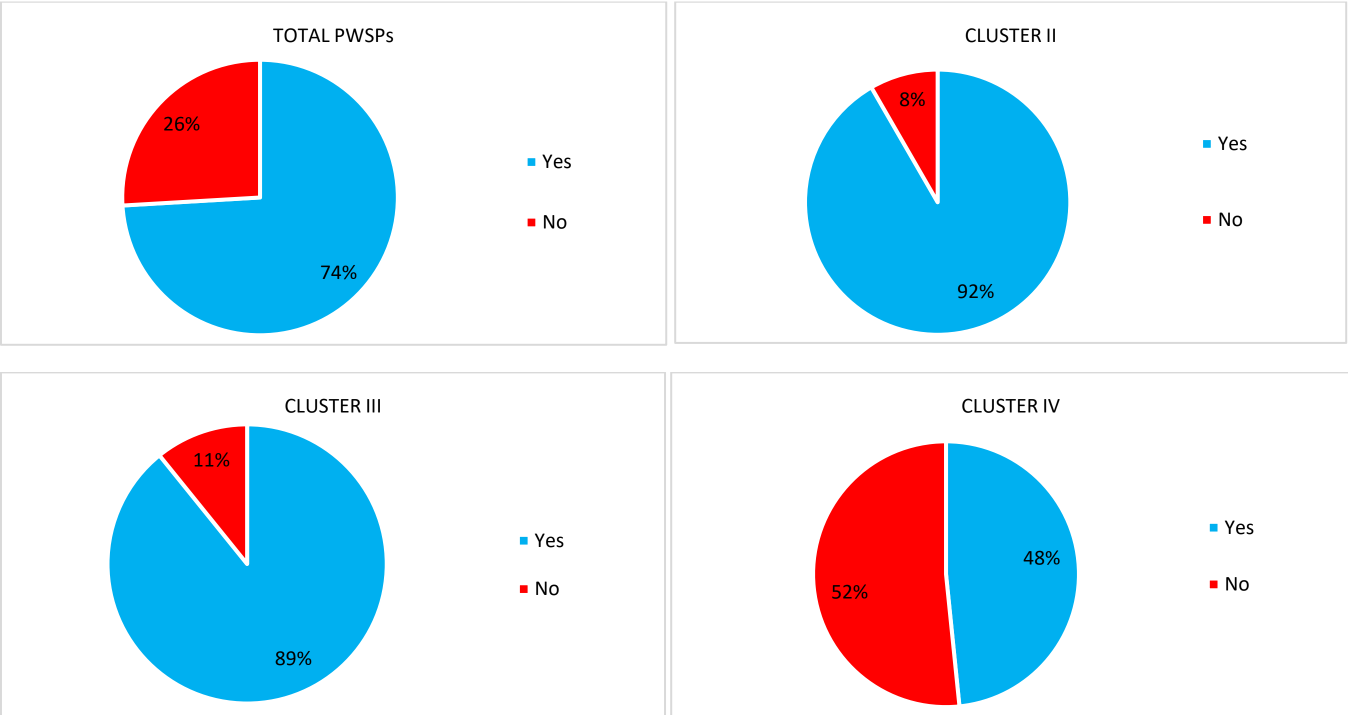


Figure 2.74. Planning and implementation of programs of annual reconstruction of water supply system on the national level and by PWSP clusters

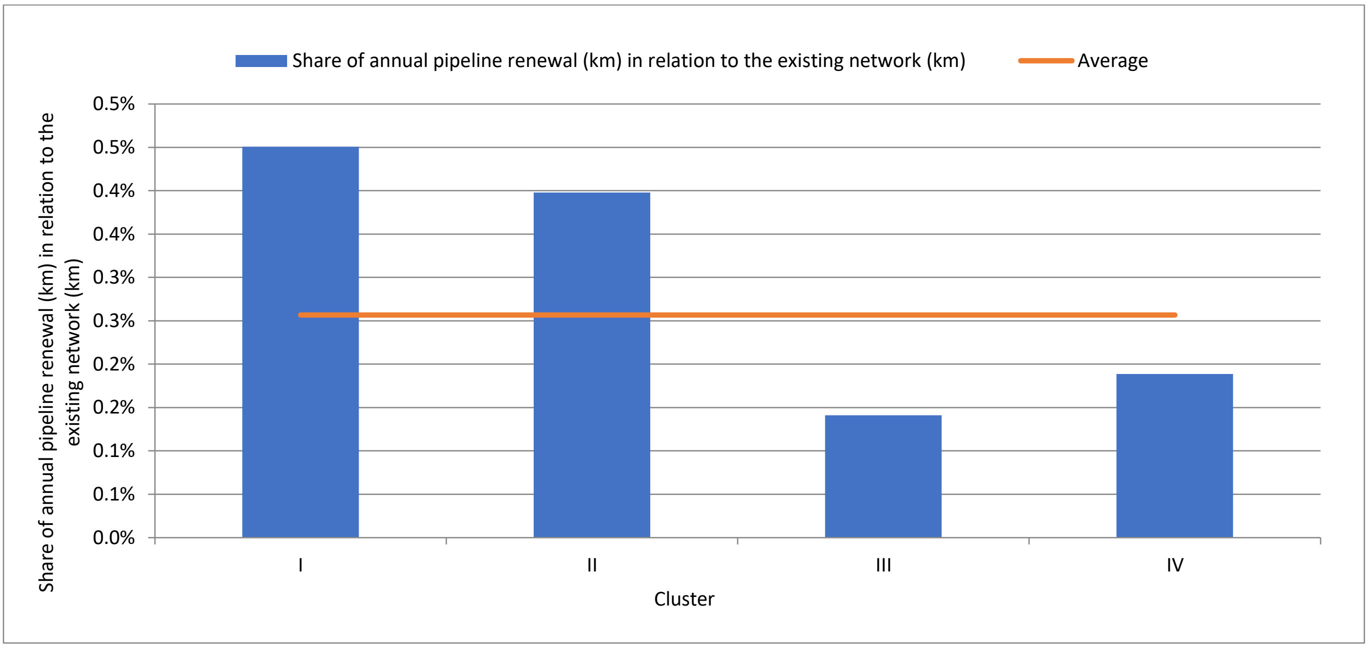


Figure 2.75. Average annual quantity of mains restored on the national level and by PWSP clusters

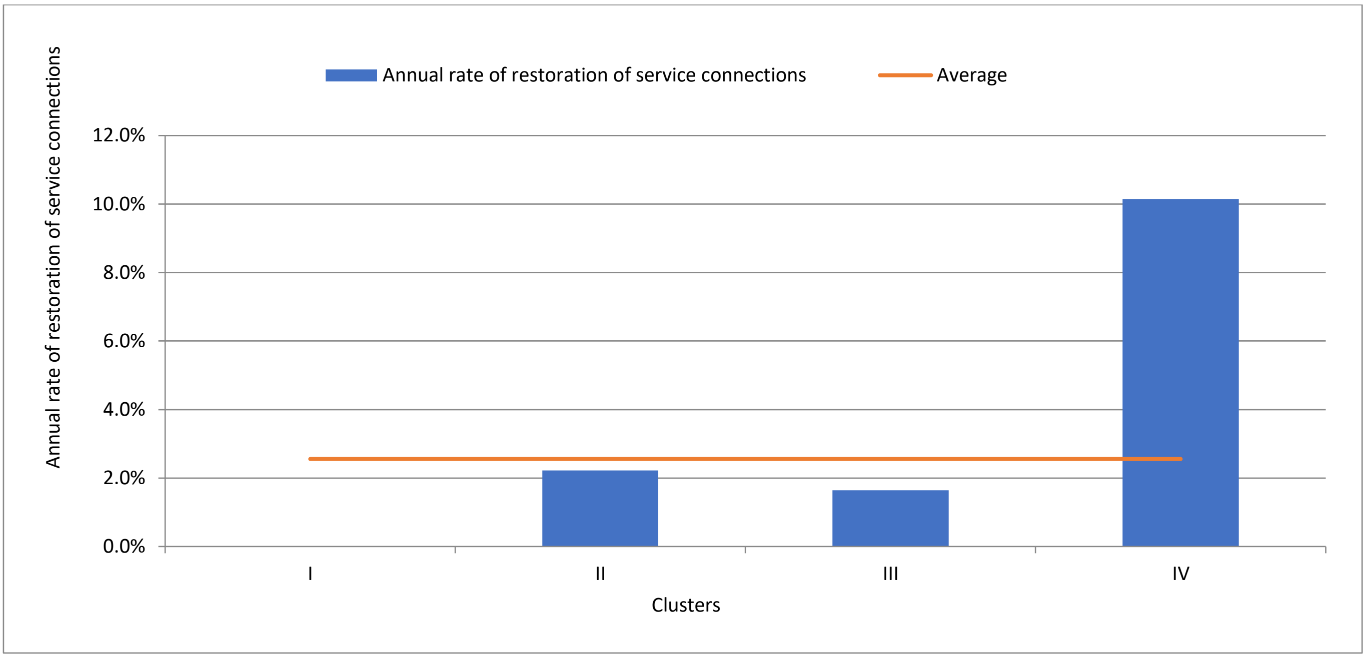


Figure 2.76. Average annual rate of restoration of service connections (a pipe from connection to the main to the water meter) on the national level and by PWSP clusters

In the end, analyzing plans of short- and long-term improvement measures, which is vital for water loss management, it is visible that based on the prepared conceptual solutions the measures have mostly been planned, i.e., for around 25% of the PWSPs neither short- nor long-term measures have been planned (Figure 2.77). A special problem comes from the lack of coordination of further measures by PWSPs, which will be clarified in more detail in Chapter 2.6.

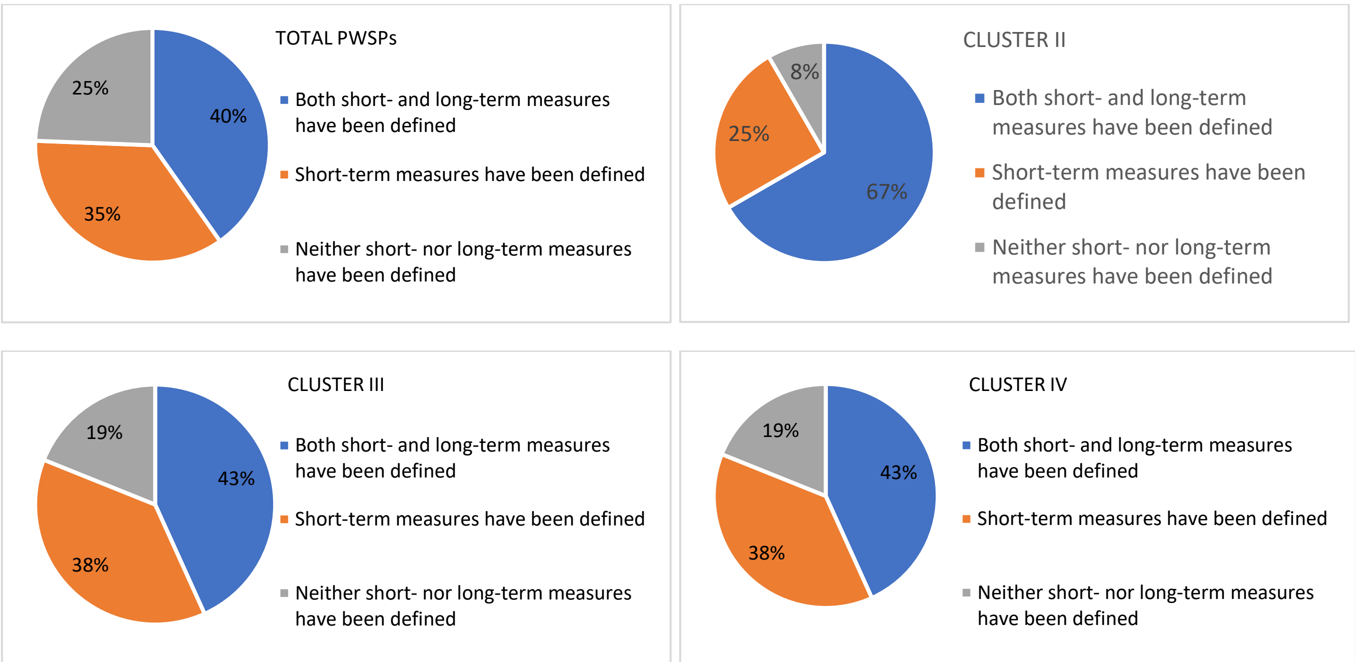


Figure 2.77. Definition of short- and long-term improvement measures on the national level and by PWSP clusters

2.4 Present water losses, potential and risk for future water losses

2.4.1 Description of current problems related to water losses

The efficiency of water loss management to the largest extent depends on the capacities (financial, technical, personnel, organizational) of PWSPs. Among some PWSPs in Croatia these capacities are quite marked, and in recent recent years they have significantly reduced their losses over a relatively short period. However, for a large number of PWSPs the status of water losses is deteriorating year after after, and for some, water losses persist on an uneconomically high level even with relatively high financial investments.

Analyzing the current status in Croatia, it can be concluded the problems in financial, technical, personnel, and organization terms are the heaviest among smaller PWSPs (which deliver small water volumes). However, with adequate expert help, in smaller systems significant advances in the reduction of losses in relative terms are achieved with relatively small investments, but at the same time the achieved results are lost very easily if the PWSP doesn’t continue to maintain its water supply system. In larger systems, which mostly implies more complex water supply systems, the achievement of the same results often requires more intensive investment, over a number of years, with every action in the system often revealing the consequences of maintenance neglected for a long time. Sometimes it can even seem that the expected results aren’t being achieved despite significant investment. It is exactly in this segment that the advantages of consolidation (reform of the water service sector) become prominent, in terms that even after the completion of the loss reduction program the achieved results are retained in the organizationally well established PWSPs, and are even improved if there is additional room for improvement. The positive practice examples are described in Chapter 2.4.3.

In service areas with smaller water deliveries, and particularly in rural, poorly populated areas where the number of service connections in relation to the length of water supply mains is relatively low, it is difficult to achieve the required affordability of the water service price, which will be particularly marked once the integrated wastewater collection and treatment systems are built and when the price of those water services is included in the price of water service. An additional circumstance which will negatively affect the affordability of the water service price among a large number of PWSPs is the introduction of charging the water usage fee based on the abstracted volume, and not on the billed volume as regulated today. In accordance with the Ordinance on collecting and charging the water usage fee (OG 36/20) that regulates this matter, it will come into effect on 1 January 2023.

The affordability of the water service price is one of the main criteria for the approval of projects for EU co-financing. On the other hand, the sustainability of PWSPs’ operations will also depend on achieving a positive operating balance, which will be disturbed for many PWSPs due to the water usage fee charged based on the abstracted volume after 1 January 2023 and the fact that those PWSPs already in the current state have a high share of water losses.

The practice of managing water losses in water supply systems so far can generally be assessed as deficient in numerous technical, organizational, and economic aspects. The majority of PWSPs so far haven’t demonstrated efficiency in addressing that issue, most often justifying that by the lack of financial resources to take specific measures, from the preparation of studies and design documents to implementation on site itself. Further expectations that the existing practice will change significantly without additional financial, technical, and institutional assistance to the PWSPs are assessed as difficult to achieve (unrealistic). This claim is supported by the fact that the water loss issue has been actively discussed for a number of years now, that the majority is aware about the extent of the issue, but the required measures haven’t been taken so far. Still, there are some positive practice examples, especially after the launch of the National Water Loss Reduction Program (NWLRP) in Croatia in 2018 by the competent Ministry and Croatian Waters. With certain financial investment, even bearing in mind the fact that it was the initial step in the implementation of the NWLRP with the primary preparation of studies and design documents, it has resulted with certain PWSPs reducing their water losses.

2.4.2 Water balance

The water balance can be calculated in a number of ways, from simpler forms which imply the quantification of only the most basic components (Volume from Own Sources, Water Imported from other PWSPs, Water Exported to other PWSPs, Revenue Water, and Non-Revenue Water) to more complex forms such as the extended and simplifed water balance according to the

IWA methodology, quantifying many 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.

The majority of PWSPs (76%) regularly (on the annual level) independently prepare a simple water balance, presenting the most basic components. However, a simple water balance for all the PWSPs is prepared by Croatian Waters using the SOV application, with the main inputs based on the raw data submitted by the PWSPs themselves. In other words, all the PWSPs have at their disposal the main inputs for the preparation of the simplest water balance with the most basic components. Yet, the fact is that a significant share of the PWSPs don't use this data on their own for the preparation of the water balance, not even in Cluster II (25%), while the largest share of such PWSPs is in Cluster IV (31%), as expected (Figure 2.78).

For 44% of the PWSPs the Conceptual Solution for Water Supply has been prepared (for 100% of the Cluster I PWSPs, 92% of the Cluster II PWSPs, 57% of the Cluster III PWSPs, and 24% of the Cluster IV PWSPs), including an extended IWA water balance (Figure 2.79). However, it relates to a period of one year which was relevant at the time of preparing the Conceptual Solution, with around 60% of the PWSPs continuing with the annual preparation of the extended or simplified IWA water balance. The largest number of the Conceptual Solutions was prepared in the 2017-2022 period (Figure 2.80), i.e., corresponds with the launch of the NWLRP in 2018. A considerable share of Conceptual Solutions has been prepared in the last three years.

The main results of the water balance in the current state will be presented below by individual PWSPs grouped into clusters and on the level of Croatia as a whole.

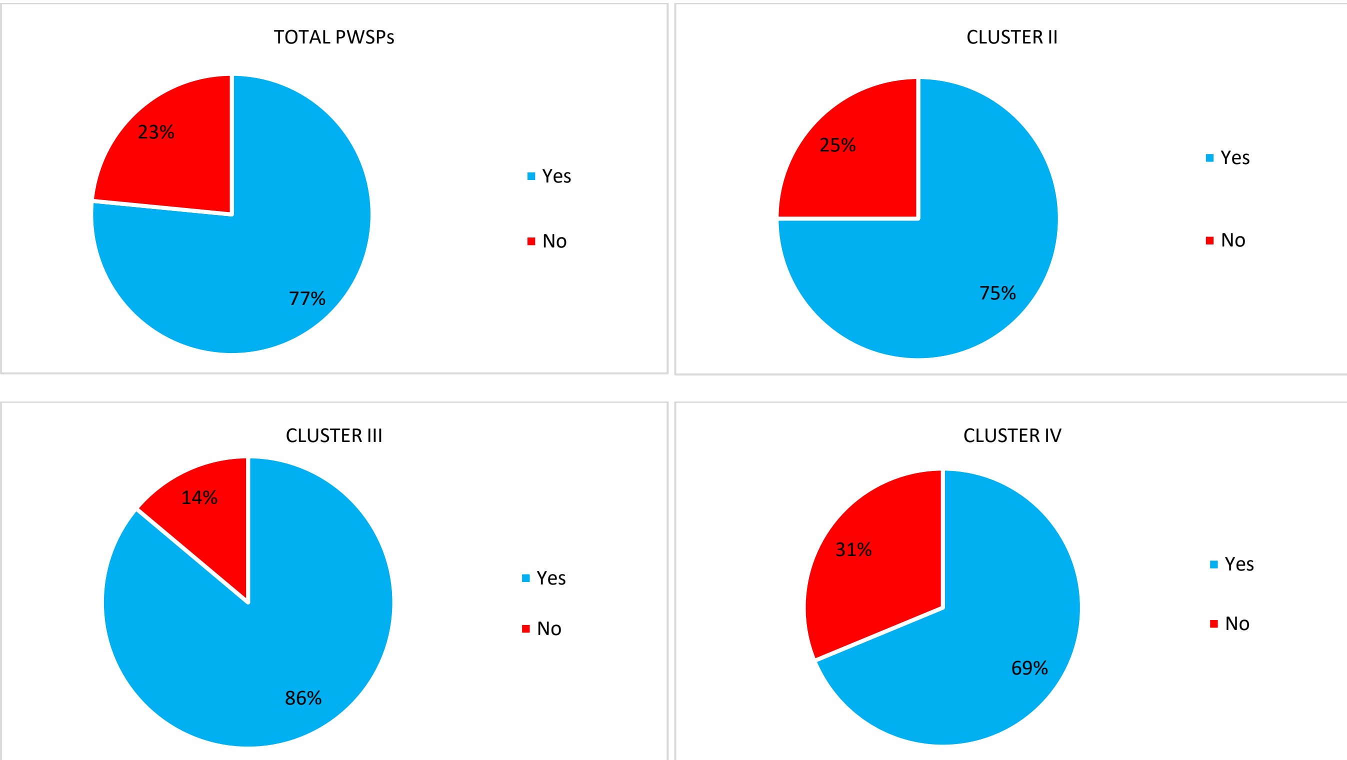


Figure 2.78. Do the PWSPs themselves prepare a simple water balance on the annual level

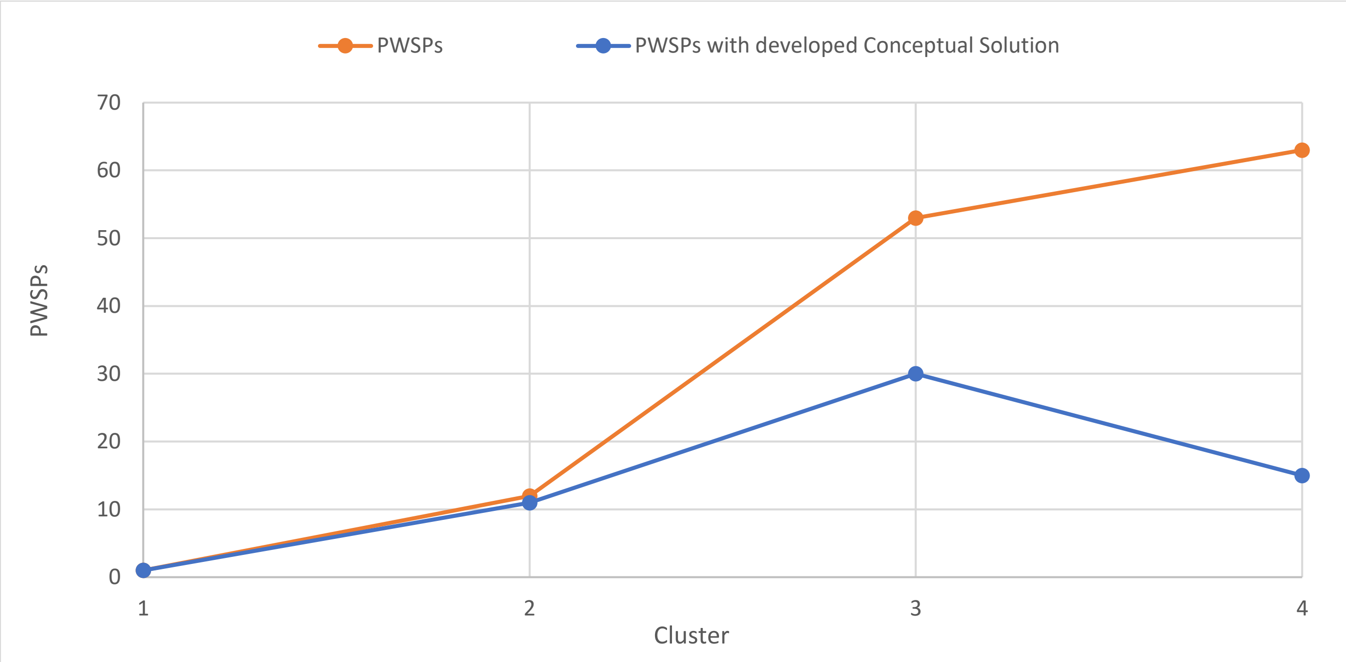


Figure 2.79. Analysis of clustered PWSPs in relation to prepared Conceptual Solutions of water supply

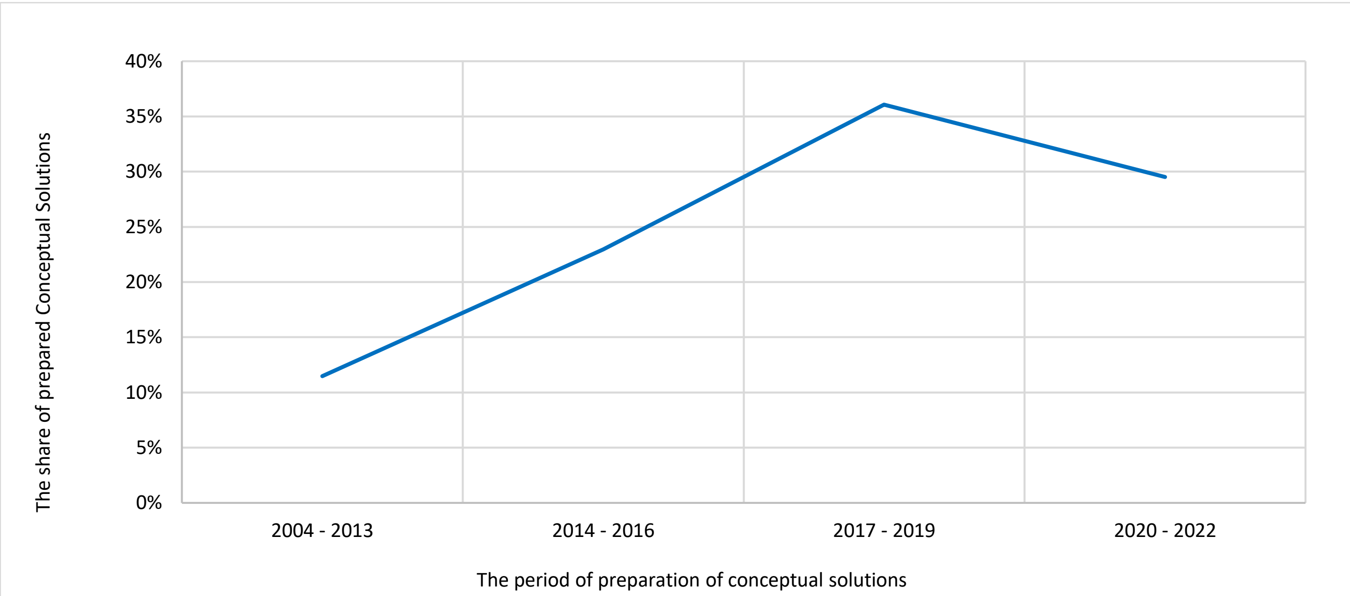


Figure 2.80. Analysis of PWSPs by periods of preparation of Conceptual Solutions of water supply

2.4.2.1 Non-revenue water

It's a fact that today on the national level around 49% of non-revenue water (water losses) is generated in relation ot the water supplied (Volume from own sources + Water imported – Water exported), amounting to around 235 million m^3/year.

Analysing the available water balance data by individual PWSPs for the last 5 years (2017-2021) one can notice that there are no significant differences in either Water Supplied, Revenue Water (volume delivered to the households and industry), or Non-Revenue Water (Table 2.15, Figure 2.81). There are certain minor differences in the year 2020, but these are attributed to the pandemic conditions, and it is assessed as a non-representative period to reach any conclusions.

Table 2.15. Water balance on the national level in the 2017-2021 period (the most basic components)

Description	2017	2018	2019	2020	2021
Volume from own sources (Abstracted volume), m^3	480,939,387	477,369,579	480,351,533	468,454,258	479,123,913
Water imported from another PWSP, m^3	46,563,003	45,623,487	41,889,951	37,930,933	42,853,707
System input volume, m^3	527,502,390	522,993,066	522,241,484	506,385,190	521,977,620
Water exported to another PWSP, m^3	46,236,404	46,409,609	41,788,041	37,490,112	43,154,197
Water supplied, m^3	481,265,986	476,583,457	480,453,443	468,895,078	478,823,423
Volume supplied to Industry, m^3	70,929,876	70,771,187	74,434,116	60,744,618	67,515,721
Volume supplied to Households, m^3	172,681,310	170,750,939	170,588,066	173,878,026	176,305,570
Volume supplied to I+H (Billed authorized consumption), m^3	243,611,187	241,522,126	245,022,181	234,622,644	243,865,747
Number of water service providers	136	132	131	129	127
Non-revenue water, m^3	237,654,800	235,061,331	235,431,262	234,272,434	234,957,677
Non-revenue water, %	49.38	49.32	49.00	49.96	49.07

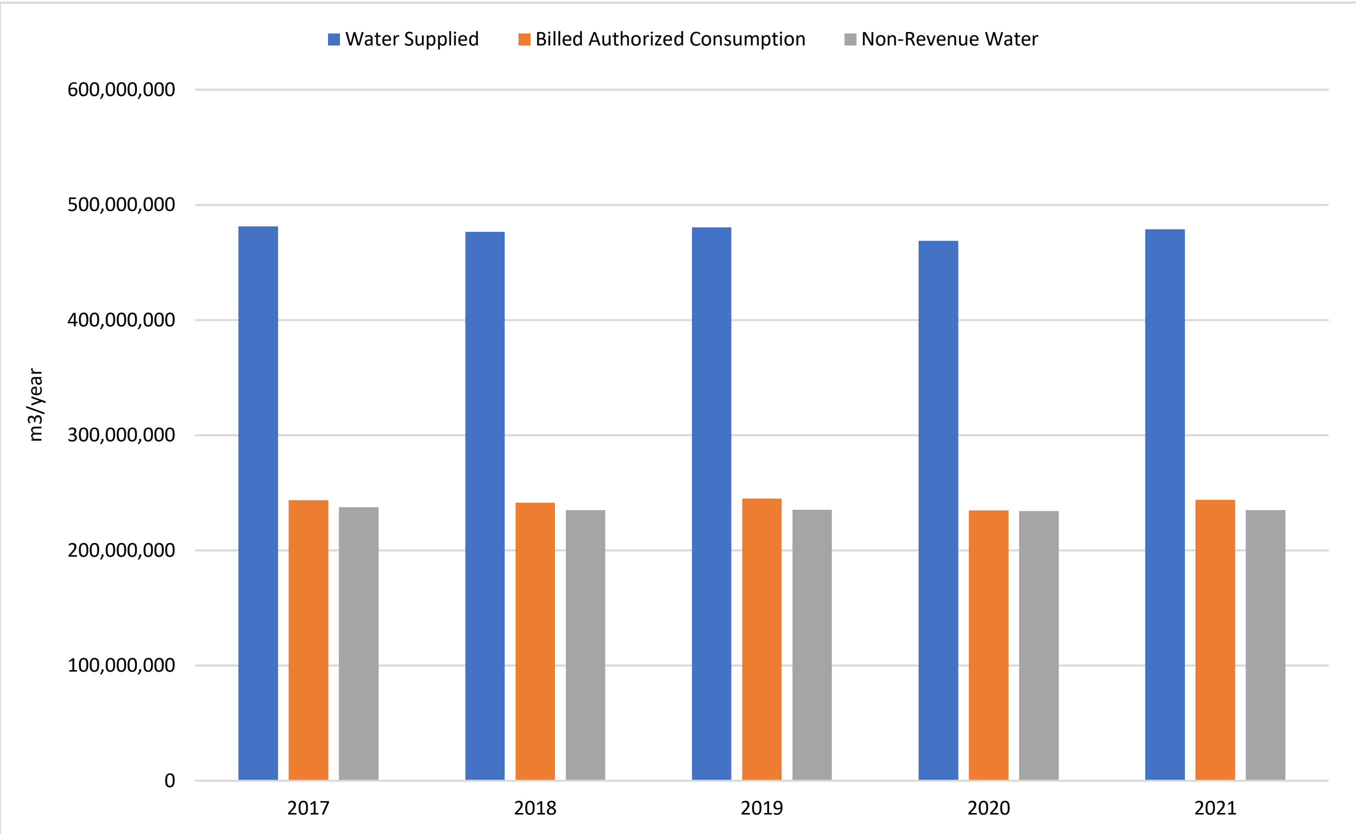


Figure 2.81. Water balance according to three main components on the national level in the 2017-2021 period

Figure 2.82. presents the trend of the NRW by clusters (Chapter 2, introduction) with the aim of better analyzing the current status, identifying certain patterns, and subsequently defining the improvement measures. The trend of the NRW by clusters is presented for the period of the last 5 years (2017-2021). It shows that Clusters I and II, which cover the PWSPs with the largest number of service connections (more than 30,000), have a mild trend of decreasing NRW over the last 5 years, while Clusters III and IV, which cover the PWSPs with the smallest number of service connections (less than 30,000), have a mild trend of increasing NRW over the last 5 years.

Figure 2.83. presents the trend of the NRW by the planned service areas in Croatia (Chapter 1.1.2.3). The trend of the NRW by the planned service areas is also presented for the period of the last 5 years (2017-2021). It shows that over the last 5 years at the level of certain planned service areas there is a trend of decreasing NRW, certain service areas have an increasing NRW trend, and certain services areas have stagnating NRW.

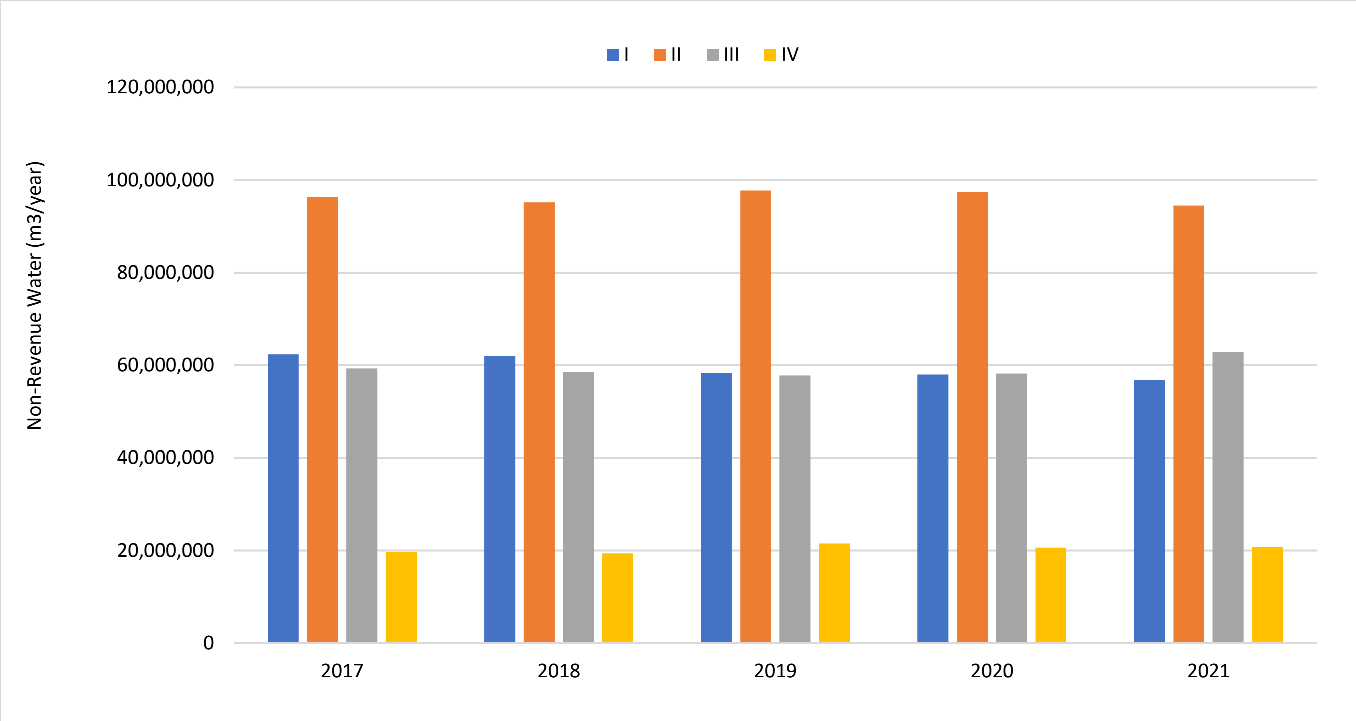


Figure 2.82. NRW by PWSP clusters in the 2017-2021 period

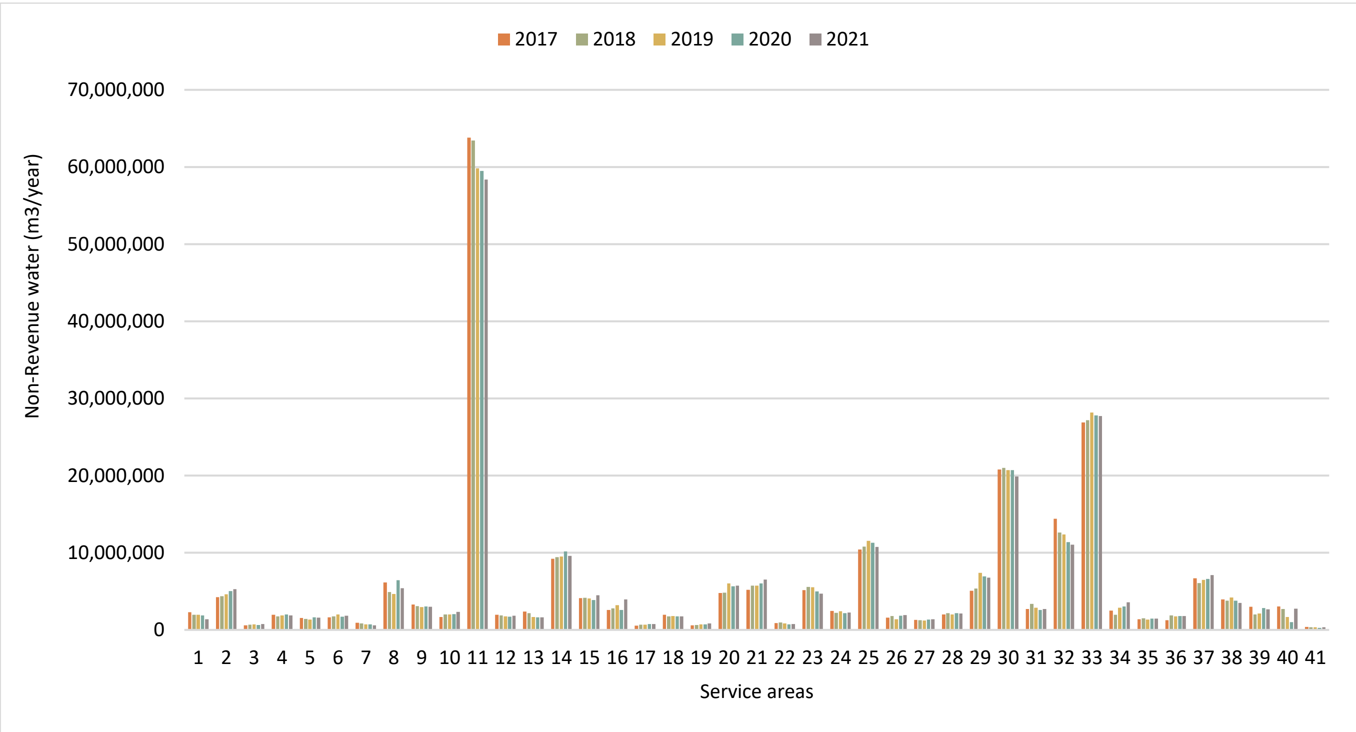


Figure 2.83. NRW by service areas in the 2017-2021 period

Analyzing the NRW volumes at the level of individual PWSPs, it can be concluded that the distribution of the NRW volumes is highly uneven (Figure 2.84). A few PWSPs in Croatia account for the majority of NRW volumes on the national level.

For example, 5 PWSPs with biggest highest NRW volume account for 51.4% (120,797,503 m^3/year) of the total NRW volume on the national level (234,957,677 m^3/year).

10 PWSPs with the biggest NRW volume account for 62.8% (147,574,685 m^3/year) of the total NRW volume on the national level (234,957,677 m^3/year).

15 PWSPs with the biggest NRW volume account for 70.7% (166,132,107 m^3/year) of the total NRW volume on the national level (234,957,677 m^3/year).

20 PWSPs with the biggest NRW volume account for 75.8% (178,177,231 m^3/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 4.0% (9,398,599 m^3/year) of the total NRW volume on the national level (234,957,677 m^3/year).

80 PWSPs with the smallest NRW volume account for 9.3% (21,934,324 m^3/year) of the total NRW volume on the national level (234,957,677 m^3/year).

90 PWSPs with the smallest NRW volume account for 13.3% (31,343,181 m^3/year) of the total NRW volume on the national level (233,706,601 m^3/year).

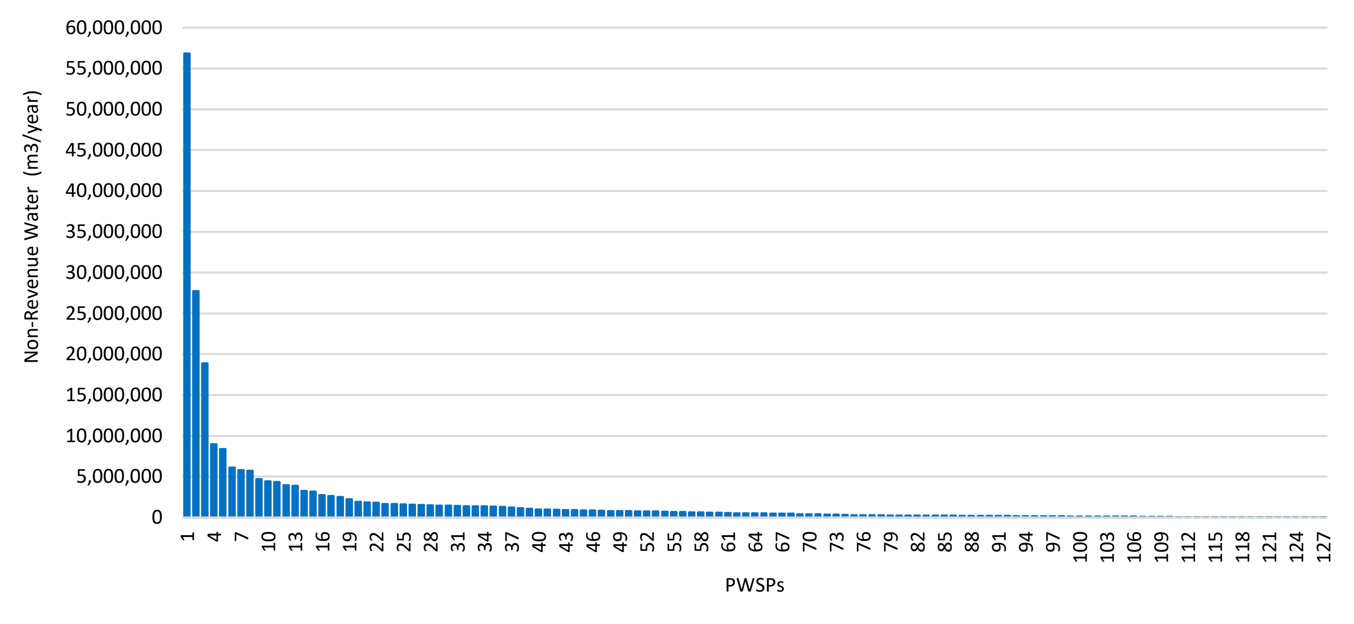


Figure 2.84. Distribution of NRW among PWSPs (on a sample of 121 PWSPs)

Table 2.16. List of 20 PWSPs with the biggest NRW volumes in 2021

PWSP	m^3/year
VODOOPSKRBA I ODVODNJA d.o.o. / Zagreb	56,824,556
VODOVOD I KANALIZACIJA, d.o.o. / Split	27,723,332
VODOVOD D.O.O. / Zadar	18,883,129
KOMUNALNO DRUŠTVO VODOVOD I KANALIZACIJA d.o.o. / Rijeka	8,965,720
VODOVOD I ODVODNJA D.O.O. / Šibenik	8,400,766
VODOVOD I KANALIZACIJA d.o.o. Karlovac / Karlovac	6,116,665

PWSP	m³/year
VINKOVAČKI VODOVOD I KANALIZACIJA, D.O.O. / Vinkovci	5,805,754
VODOVOD D.O.O. / Slavonski Brod	5,732,760
ISTARSKI VODOVOD d.o.o. / Sveti Ivan	4,702,340
VODOVOD-OSIJEK D.O.O. / Osijek	4,419,663
VARKOM d.d. / Varaždin	4,335,087
SISAČKI VODOVOD D.O.O. / Sisak	3,948,132
VODOVOD D.O.O. / Makarska	3,860,490
VODOVOD IMOTSKE KRAJINE, d.o.o. / Imotski	3,247,720
VODOVOD I ODVODNJA CETINSKE KRAJINE, d.o.o. / Sinj	3,165,993
VODOVOD DUBROVNIK D.O.O. / Dubrovnik	2,755,711
ZAGORSKI VODOVOD d.o.o. / Zabok	2,615,635
PRIVREDA d.o.o. / Petrinja	2,523,135
VODOOPSKRBA I ODVODNJA ZAPREŠIĆ d.o.o. / Zaprešić	2,218,766
Vodovod Korenica d.o.o. / Korenica	1,931,877

Table 2.17. below presents the efficiency of different NRW reduction scenarios among PWSPs with smaller and bigger NRW volumes. At first, 5 PWSPs with the biggest NRW volumes were grouped, and then the reduction of NRW in relation to different assumptions of reduction of the NRW share in the range 10-50% was calculated. It can be observed that by reducing the NRW by 50% in all the 5 PWSPs, the NRW share is reduced from the current 49% to 33% on the national level.

After that, 10 PWSPs with the biggest NRW volumes were grouped, and the reduction of NRW in relation to the same assumptions of reduction of the NRW share in the range 10-50% was calculated. It can be observed that by reducing the NRW by 50% in all the 10 PWSPs, the NRW share is reduced from the current 49% to 31% on the national level.

Grouping 15 PWSPs with the biggest NRW volumes, the calculated reduction of the NRW in relation to the assumed 50% reduction of the NRW share in all the 15 PWSPs, the NRW share is reduced from the current 49% to 29% on the national level.

Grouping 20 PWSPs with the biggest NRW volumes, the calculated reduction of the NRW in relation to the assumed 50% reduction of the NRW share in all the 20 PWSPs, the NRW share is reduced from the current 49% to 28% on the national level.

Table 2.17. Presentation of the efficiency of different NRW reduction scenarios among PWSPs with smaller and bigger NRW volumes

Scenario	NRW reduction on PWSP level		NRW reduction on the national level
	%	m³/year	%
NRW reduction in 5 PWSPs with the biggest NRW volumes	10%	12,079.750	43
	20%	24,159.501	40
	30%	36,239.251	38
	40%	48,319.001	36
	50%	60,398.752	33
NRW reduction in 10 PWSPs with the biggest NRW volumes	10%	14,757.469	42
	20%	29,514,937	39
	30%	44,272,406	37
	40%	59,029,874	34
	50%	73,787,343	31
NRW reduction in 15 PWSPs with the biggest NRW volumes	10%	16,613,211	42
	20%	33,226,421	39
	30%	49,839,632	36
	40%	66,452,843	32
	50%	83,066,054	29

Scenario	NRW reduction on PWSP level		NRW reduction on the national level
	%	m^3/year	%
NRW reduction in 20 PWSPs with the biggest NRW volumes	10%	17,817,723	42
	20%	35,635,446	38
	30%	53,453,169	35
	40%	71,270,892	31
	50%	89,088,616	28
NRW reduction in 60 PWSPs with the smallest NRW volumes	10%	939,860	45
	20%	1,879,720	45
	30%	2,819,580	45
	40%	3,759,440	44
	50%	4,699,300	44
NRW reduction in 80 PWSPs with the smallest NRW volumes	10%	2,193,432	45
	20%	4,386,865	44
	30%	6,580,297	44
	40%	8,773,730	43
	50%	10,967,162	43
NRW reduction in 90 PWSPs with the smallest NRW volumes	10%	3,134,318	44
	20%	6,268,636	44
	30%	9,402,954	43
	40%	12,537,273	43
	50%	15,671,591	42

On the other hand, grouping 60 PWSPs with the smallest NRW volumes for which a 50% NRW reduction is assumed results in the reduction of the NRW share on the national level from the current 49% to only 44%.

Grouping 80 PWSPs with the smallest NRW volumes for which a 50% NRW reduction is assumed results in the reduction of the NRW share on the national level from the current 49% to only 43%.

Grouping 90 PWSPs with the smallest NRW volumes for which a 50% NRW reduction is assumed results in the reduction of the NRW share on the national level from the current 49% to only 42%.

A bigger impact on the national level is achieved at a 10% reduction of the NRW share among the 20 largest PWSPs than at a 50% reduction of the NRW share among the 90 smallest PWSPs.

The analyses made lead to the conclusion 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.

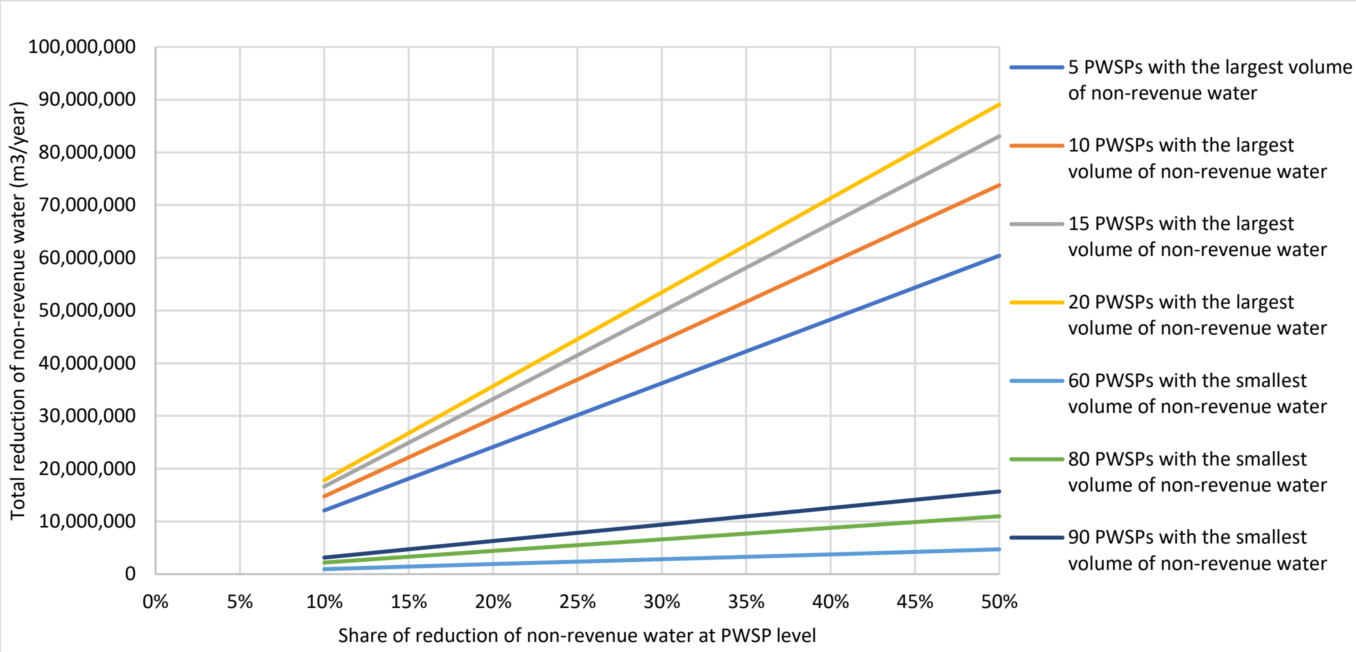


Figure 2.85. Presentation of the efficiency of different NRW reduction scenarios among PWSPs with smaller and bigger NRW volumes in in the current state

So far, water losses in Croatia were mostly expressed as NRW in terms of the volume on the annual level (m³/year) or more frequently as a share of the Water Supplied (% of Water Supplied). The Water Supplied was calculated as the sum of 'Volume from Own Sources' and 'Water Imported' from another PWSP minus 'Water Exported to another PWSP'. The standard indicator in this approach is presenting water losses (NRW) as % of the volume input into the system.

The average value of water losses in Croatia expressed as a NRW share based on the 2021 data amounts to around 49%. Over the last five years (2017-2021), the NRW share on the national level ranged from 49.00 to 49.96% (Table 2.15). Here it is important to note that the share of average water losses on the national level has been stagnating over the last 5 years. However, in some PWSPs the NRW share reaches more than 80% (Figure 2.86). It is precisely that share which is one of the currently prevailing indicators of the status of a water supply system.

This way of presenting water losses doesn't give a realistic picture of the problem, i.e., of how efficiently a water supply system is managed from the aspect of water losses (see Chapter 2.1.2).

Today's global and EU trends indicate a decrease in the Revenue Water as the result of growing awareness about the importance of water as a resource, increasing prices of water services, the production and use of more water-saving sanitary facilities, etc.

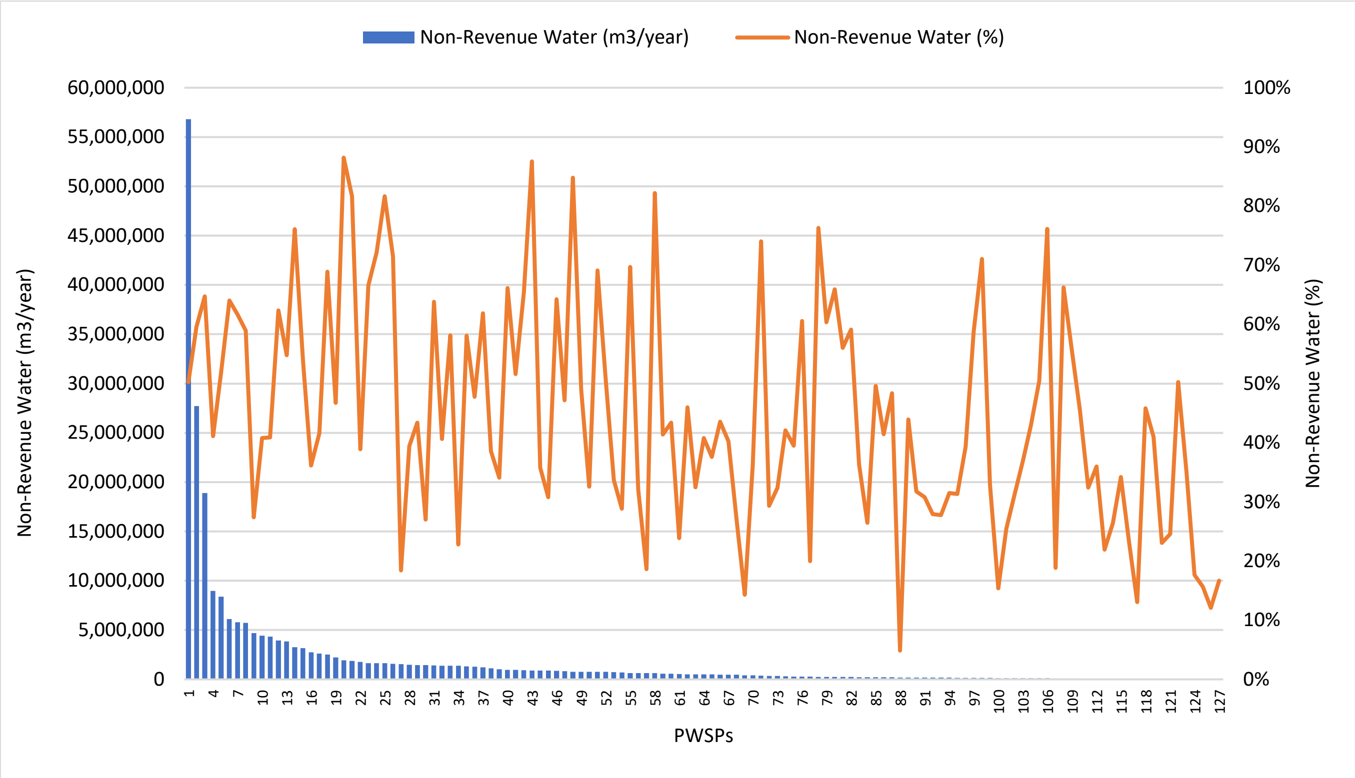


Figure 2.86. Presentation of the NRW expressed in terms of volume and % by individual PWSPs

The sensitivity of the change in the NRW share to changes in the Billed Authorized Consumption (Revenue Water) is presented below on the national level, with a realistic range of change from 0 to 15% (Figure 2.87). In other words, it is presented that, assuming that the NRW volumes don't change, there is a change in the NRW share as the result of reduction in the Revenue Water. This makes it clear then that water losses (NRW) expressed as a % of the Water Supplied cannot be a transparent indicator of the assessment of the status of an individual PWSP, and even of a country, in relation to efficiency in water loss management.

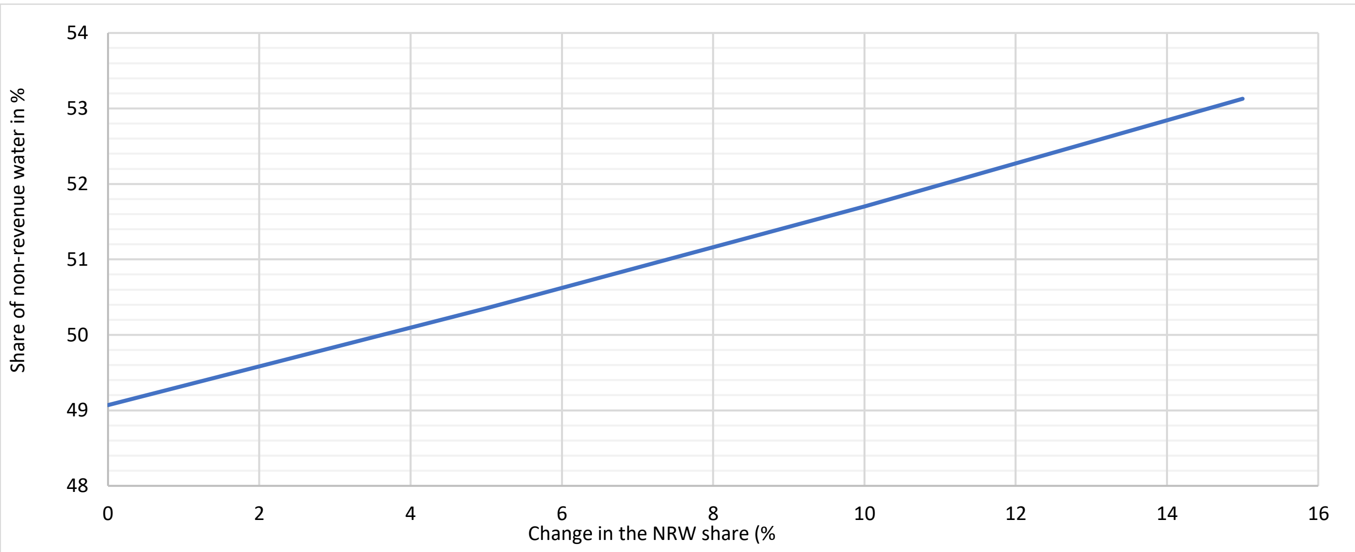


Figure 2.87. Sensitivity of the change in the NRW share to changes in the Revenue Water on the national level

Particular care must also be taken when associating the water loss management objectives with the achievement of a particular NRW share in % of the Water Supplied. Namely, a value that varies over time is not only the NRW, but potentially the Revenue

Water as well. Figure 2.88. shows the dependence of the reduction of the NRW on the targeted NRW share at different volumes of the Revenue Water on the national level. It is evident that if the Revenue Water is reduced it is necessary to achieve a reduction of bigger NRW volumes in order to achieve the same targeted NRW share. This makes it clear that the objectives of achieving certain levels of water losses cannot be related exclusively to the presentation of water losses as a NRW share, because eventually the NRW reduction objectives are related primarily to the reduction of NRW volumes, with the purpose of all the other indirect and direct objectives being the reduction of NRW volumes.

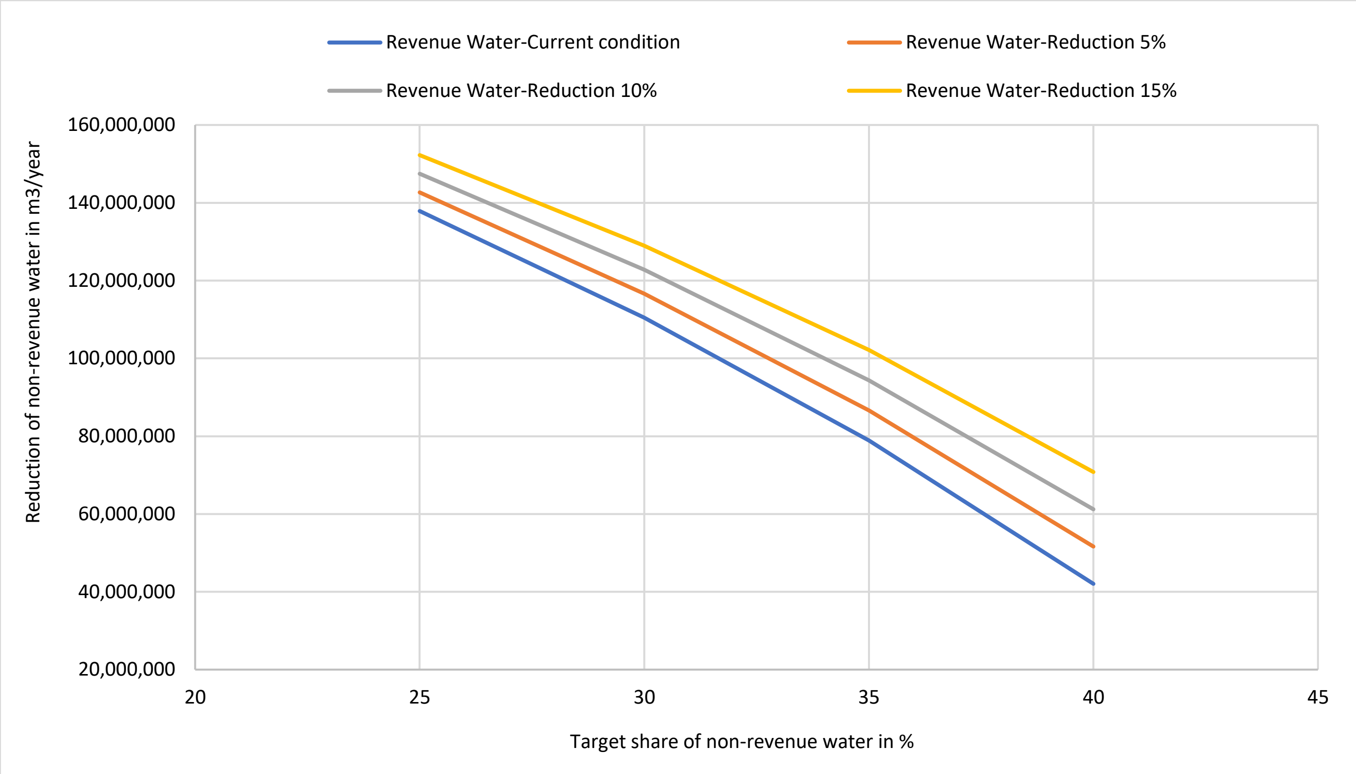


Figure 2.88. Dependence of NRW reduction on the targeted NRW share at different volumes of Revenue Water on the national level (in relation to the current status according to the 2021 data)

2.4.2.2 Main water balance

As a response to the weaknesses in expressing water losses as a NRW share, 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 consumption and water losses to be understood better, the International Water Association (IWA) defined a new IWA methodology, introducing a new water balance standard (Chapter2.1.1).. The IWA water balance methodology for water supply systems was adopted on the global level. It is also important to note that the implementation of the IWA methodology in Croatia has become more widespread in the last 10 years.

Table 2.18. presents an extended water balance on the national level according to the data for the year 2021. After that, Table 2.19. through Table 2.22. present the extended water balance by the clusters into which PWSPs are grouped according to the 2021 data.

Certain water balance components (Volume from Own Sources, Water Imported from other PWSPs, Water Exported to other PWSps, and Bill Authorized Consumption) were taken over from the registers (water balance basics) that are filled in by the PWSPs themselves.

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. 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 2.89). Figure 2.90. presents the averaged values of the Unbilled Authorized Consumption weighted against the Billed Authorized Consumption by individual clusters. 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 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 2.91). The survey conducted among all the PWSPs included a question “With which intensity would you rate the theft of water in the system, as a component of apparent losses?”. The results are presented in Figure 2.93. Among the PWSPs that confirmed that there was no water theft, the Unauthorized Consumption of 0.2% was adopted. Among the PWSPs that confirmed minor volumes were stolen, the Unauthorized Consumption of 0.5% was adopted. Among the PWSPs that confirmed that significant volumes were stolen, the Unauthorized Consumption of 5.0% was adopted. Only one PWSP stated that enormous volumes were stolen, for which a 15% share of the Unauthorized Consumption in relation to the absolute amount of Billed Authorized Consumption was adopted. For the PWSPs that failed to respond, the shares of Unauthorized Consumption were taken over from the studies and conceptual solutions prepared before. Figure 2.92. presents the distribution of the averaged value of the Unauthorized Consumption weighted against the Billed Authorized Consumption by individual clusters. Cluster I includes one PWSP that reported that significant volumes were stolen, and for that PWSP a 5% share of the Unauthorized Consumption was adopted.

The Unauthorized Consumption can also indirectly depend on the way in which illegal connections are controlled. The results of statistical analysis by clusters, as well as on the level of entire Croatia, are presented in Figure 2.99. A significant share of the PWSPs in Croatia (23%) didn’t make estimates and has no program to control illegal water consumption. It has to be noted that the largest share of such PWSPs belongs to Cluster IV (42%), with a slightly smaller, but still significant, share in Cluster III as well (16%). A significant share of the PWSPs in Croatia occasionally detects illegal connections (29%), with the share largest in Cluster IV (35%), and a slightly smaller share in Cluster III (26%). Around 40% of the PWSPs in Croatia occasionally detect illegal connections with other forms of illegal water consumption, with the largest shares of such PWSPs in Clusters III (55%) and II (50%). Implementation of the program to detect illegal connection with active work on the detection of bypasses and other forms of water theft is characteristic for only 7% of the PWSPs in Croatia, with the largest share of such PWSPs characteristic for Cluster II (17%).

Customer Metering Inaccuracies (and data handling errors) were 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, based on certain indicators and experience of individual PWSPs, in combination with the results of studies and conceptual solutions prepared before. The survey conducted among all the PWSPs included questions “Are all the connections equipped with water meters?” and “In what way is the consumption by users measured?”. The results are presented in Figure 2.94. and Figure 2.95. In Cluster I there is one PWSP that reported that not all connections are equipped with water meters, but that all big consumers and most of the small consumers (households) have water meters. For around 53% of the PWSPs in Croatia all water consumers are measured with water meters and the consumption of water for system maintenance is measured (controlled), with the dominant share of such PWSPs in Clusters II (67%) and III (60%). Among a third of the PWSPs all the consumers have water meters except public fountains, public taps, firefighters and other special users (33%), while for a third of the PWSPs all big consumers and most of the small consumers (households) have water meters (30%). When the presented number of service connections without water meters is analysed, it is clear that in general these are individual cases in negligible percentage. In other words, the share of consumers with metered consumption of water on the national level is highly significant.

Metering Inaccuracies (and data handling errors) can indirectly depend on the frequency at which water meter readings are taken, as well as on the way in which water meter readings are controlled, the practice related to the replacement of water meters, the age of water meters, the state related to the water meter precision class, and the way in which consumer databases are managed. The results of statistical analysis of these two pieces of data collected from the PWSPs are presented in Figure 2.96. through Figure 2.100. The presented results indicate that the majority of PWSPs do water meter readings once a month (70%), but also that a significant share of the PWSPs does water meter readings once in 3 months (22%), even in Clusters II (25%) and III (13%), with a not insignificant number of PWSPs doing water meter readings once in 6 months (8%), exclusively in Clusters III (14%) and IV (3%).

In terms of the way in which the reading of water meters is controlled, the situation is uneven on the national level, although 32% of the PWSPs apply the most practical control method by using manual/remote water meter readers in the entire system and control the work of staff working on readings and data processing, with the Cluster II PWSPs dominating (59%). However, 21% of the PWSPs have no program to control the work of staff reading the water meters, with a significant share belonging to Clusters III (22%) and IV (25%), while 14% of the PWSPs rotate the staff doing the manual reading only if they suspect inaccuracies (their number is the largest in Cluster III with a share of 17%), and it is questionable how often a suspicion of inaccuracy rises.

Concerning the water meter replacement practice, the largest share of the PWSPs regularly conduct the water meter replacement program and regularly replace (calibrate) all their water meters within 5 years or less (46%), noting that the PWSP in Cluster I has the same practice, as well as 67% and 57% of the PWSPs in Clusters II and III, respectively. Out of the remaining PWSPs, the largest share have a program of regular water meter replacement, but don't manage to replace them within a period of 5 years and have a considerable number of water meters that are more than 5 years old (31%), with the largest number of such PWSPs belonging to Clusters II (33%) and III (43%). Cluster IV includes the PWSPs that replace only those water meteres which are clearly defective (15%) and the PWSPs where many users' water meters are more than 10 years old and have no program of regular water meter replacement (3%).

In terms of user database management, the largest share of the PWSPs (53%) regularly update their user databases together with network visits and field checks, with identical shares in Clusters II, III and IV, with one PWSP in Cluster I acting in the same way. In addition, a significant share of the PWSPs in Croatia (22%) have regularly updated user databases connected with the GIS, with their largest share in Cluster II (50%). For around 7% of the PWSPs in Croatia the updating of the user database is being improved, and this is characteristic exclusively for the Cluster III (11%) and IV (6%) PWSPs. Around 20% of the PWSPs in Croatia occasionally update their user databases, with their largest share in Cluster IV (35%), while 1% of the PWSPs haven't updated their user databases for a long time.

All the aspects analysed above were taken into account when esimating Customer Metering Inaccuracies (and data handling errors). The reference value of Customer Metering Inaccuracies is 5% in relation to the Billed Authorized Consumption, which was corrected in relation to the earlier analyses of the questionaire results that relate to the frequency of water meter readings, the way in which water meter readings are controllled, 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. Figure 2.101. presents the distribution of the adopted Customer Metering Inaccuracies by PWSPs, based on the results of the analyses made earlier.

Table 2.18. Extended Water Balance on the level of Croatia based on the 2021 data (values in m³/year)

<table>
<tr><td rowspan="2">Volume from Own Sources
479,123,913</td><td rowspan="10">System Input Volume (corrected for known errors)
521,977,620</td><td>Water Exported
43,154,197</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<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 rowspan="8">Water Imported
42,853,707</td><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 2.19. Extended Water Balance for Cluster I based on the 2021 data (values in m³/year)

<table>
<tr><td rowspan="2">Volume from Own Sources
110,550,424</td><td rowspan="10">System Input Volume (corrected for known errors)
116,968,601</td><td>Water Exported
3,895,019</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied
113,073,582</td><td rowspan="4">Authorized Consumption
56,530,560</td><td rowspan="2">Billed Authorized Consumption
56,249,026</td><td rowspan="2">Revenue Water
56,249,026</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="8">Water Imported
6,418,177</td><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
281.534</td><td rowspan="7">Non-Revenue Water
56,824,556</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
56,543,022</td><td rowspan="2">Apparent Losses
5,815,756</td><td>Unauthorized Consumption
2,815,339</td></tr>
<tr><td>Customer Metering Inaccuracies
(and data handling errors)
3,000,417</td></tr>
<tr><td rowspan="3">Real Losses
50,727,266</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 2.20. Extended Water Balance for Cluster II based on the 2021 data (values in m³/year)

<table>
<tr><td rowspan="2">Volume from Own Sources
195,236,259</td><td rowspan="10">System Input Volume (corrected for known errors)
202,612,289</td><td>Water Exported
10,538,093</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied
192,074,196</td><td rowspan="4">Authorized Consumption
101,818,208</td><td rowspan="2">Billed Authorized Consumption
97,578,771</td><td rowspan="2">Revenue Water
97,578,771</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="8">Water Imported
7,376,030</td><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
4,239,437</td><td rowspan="7">Non-Revenue Water
94,495,425</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
90,255,988</td><td rowspan="2">Apparent Losses
5,154,163</td><td>Unauthorized Consumption
3,456,181</td></tr>
<tr><td>Customer Metering Inaccuracies (and data handling errors)
1,697,982</td></tr>
<tr><td rowspan="3">Real Losses
85,101,826</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 2.21. Extended Water Balance for Cluster III based on the 2021 data (values in m³/year)

<table>
<tr><td rowspan="2">Volume from Own Sources
139,390,270</td><td rowspan="10">System Input Volume (corrected for known errors)
162,390,476</td><td>Water Exported
23,644,943</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied
138,745,533</td><td rowspan="4">Authorized Consumption
77,600,612</td><td rowspan="2">Billed Authorized Consumption
75,874,515</td><td rowspan="2">Revenue Water
75,874,515</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="8">Water Imported
23,000,206</td><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
1,726,098</td><td rowspan="7">Non-Revenue Water
62,871,018</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
61,144,921</td><td rowspan="2">Apparent Losses
2,179,746</td><td>Unauthorized Consumption
625,384</td></tr>
<tr><td>Customer Metering Inaccuracies (and data handling errors)
1,554,361</td></tr>
<tr><td rowspan="3">Real Losses
58,965,175</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 2.22. Extended Water Balance for Cluster IV based on the 2021 data (values in m³/year)

<table>
<tr><td rowspan="2">Volume from Own Sources
33,946,960</td><td rowspan="10">System Input Volume (corrected for known errors)
40,006,254</td><td>Water Exported
5,076,142</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied
34,930,112</td><td rowspan="4">Authorized Consumption
14,550,452</td><td rowspan="2">Billed Authorized Consumption
14,163,435</td><td rowspan="2">Revenue Water
14,163,435</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="8">Water Imported
6,059,294</td><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
387,017</td><td rowspan="7">Non-Revenue Water
20,766,677</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
20,379,660</td><td rowspan="2">Apparent Losses
427,481</td><td>Unauthorized Consumption
154,709</td></tr>
<tr><td>Customer Metering Inaccuracies (and data handling errors)
272,772</td></tr>
<tr><td rowspan="3">Real Losses
19,952,179</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>

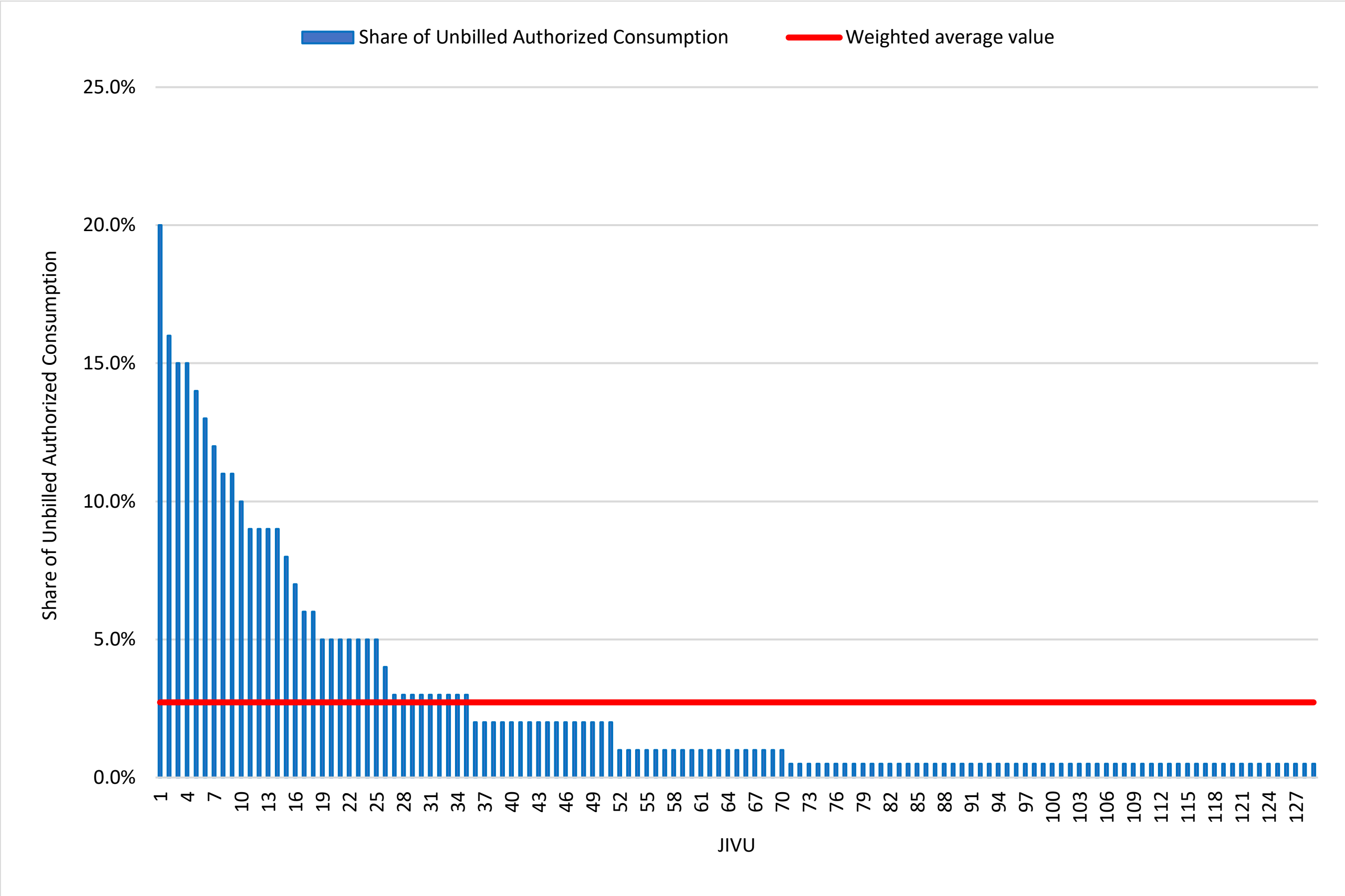


Figure 2.89. Share of 'Unbilled Authorized Consumption' in relation to 'Billed Authorized Consumption' by PWSPs

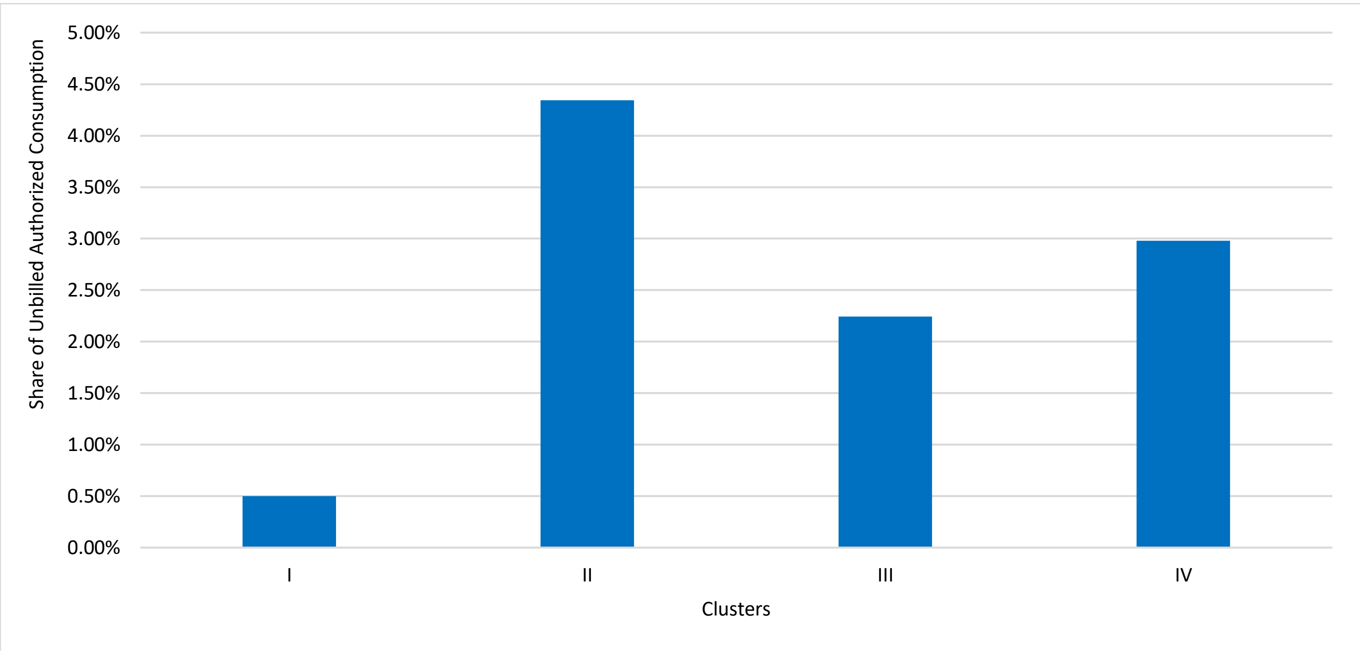


Figure 2.90. Unbilled Authorized Consumption (weighted average in relation to Billed Authorized Consumption) by clusters

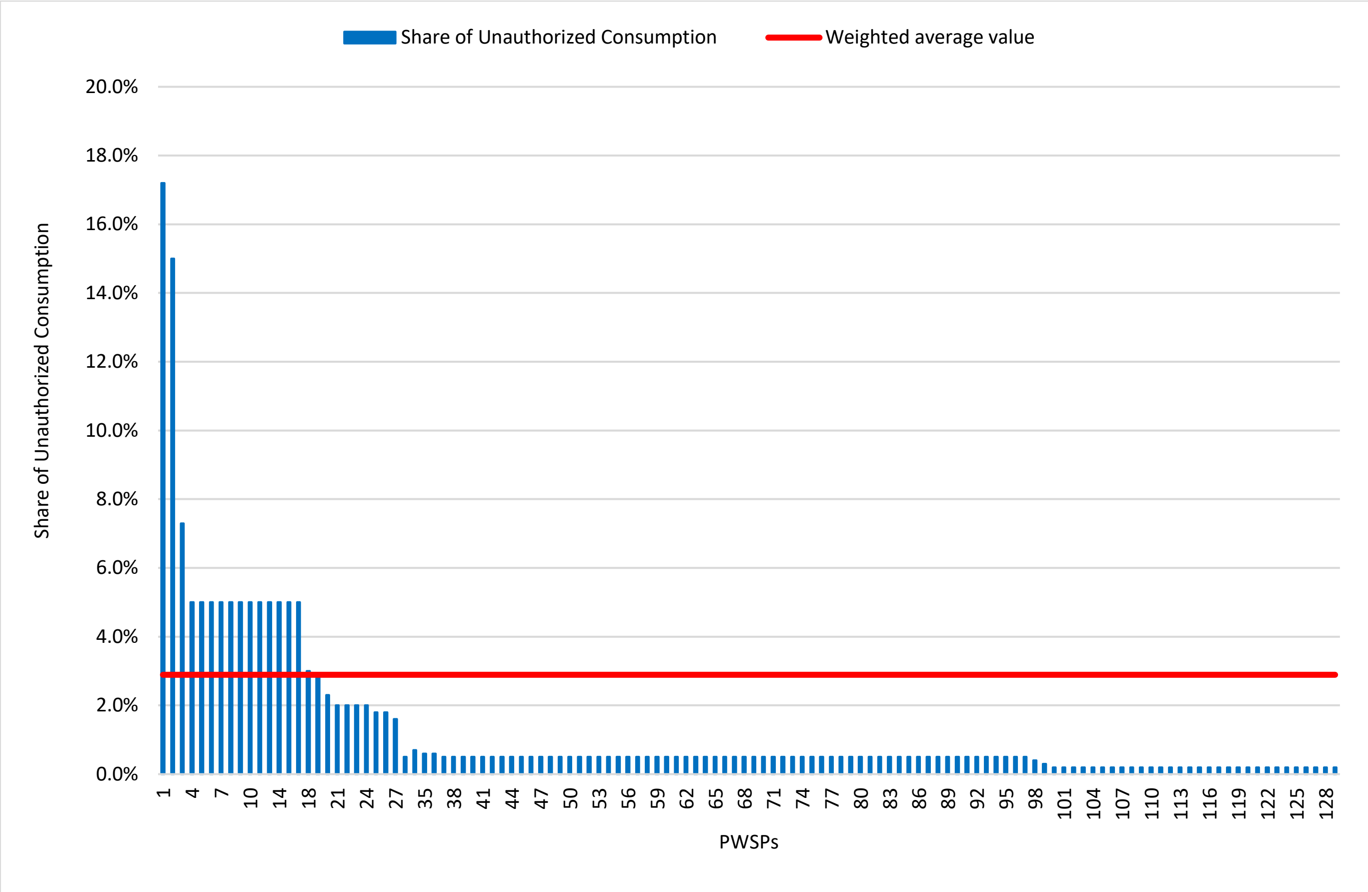


Figure 2.91. Share of 'Unauthorized Consumption' in relation to 'Billed Authorized Consumption' by PWSPs

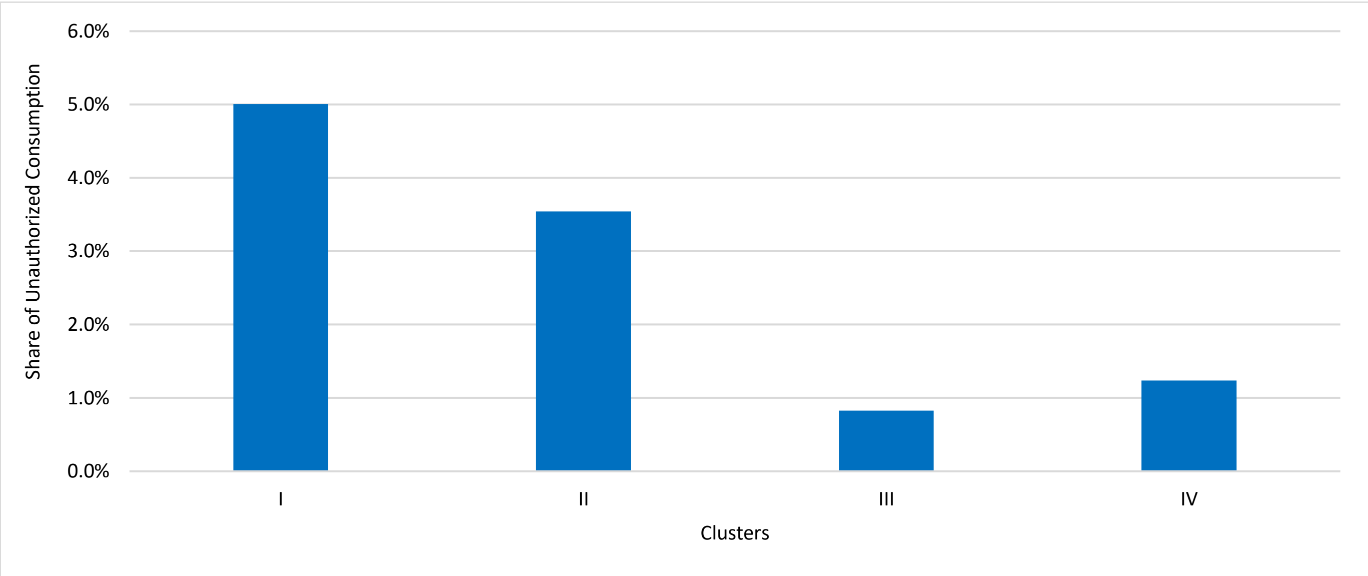


Figure 2.92. Unauthorized Consumption (weighted average in relation to Billed Authorized Consumption) by clusters

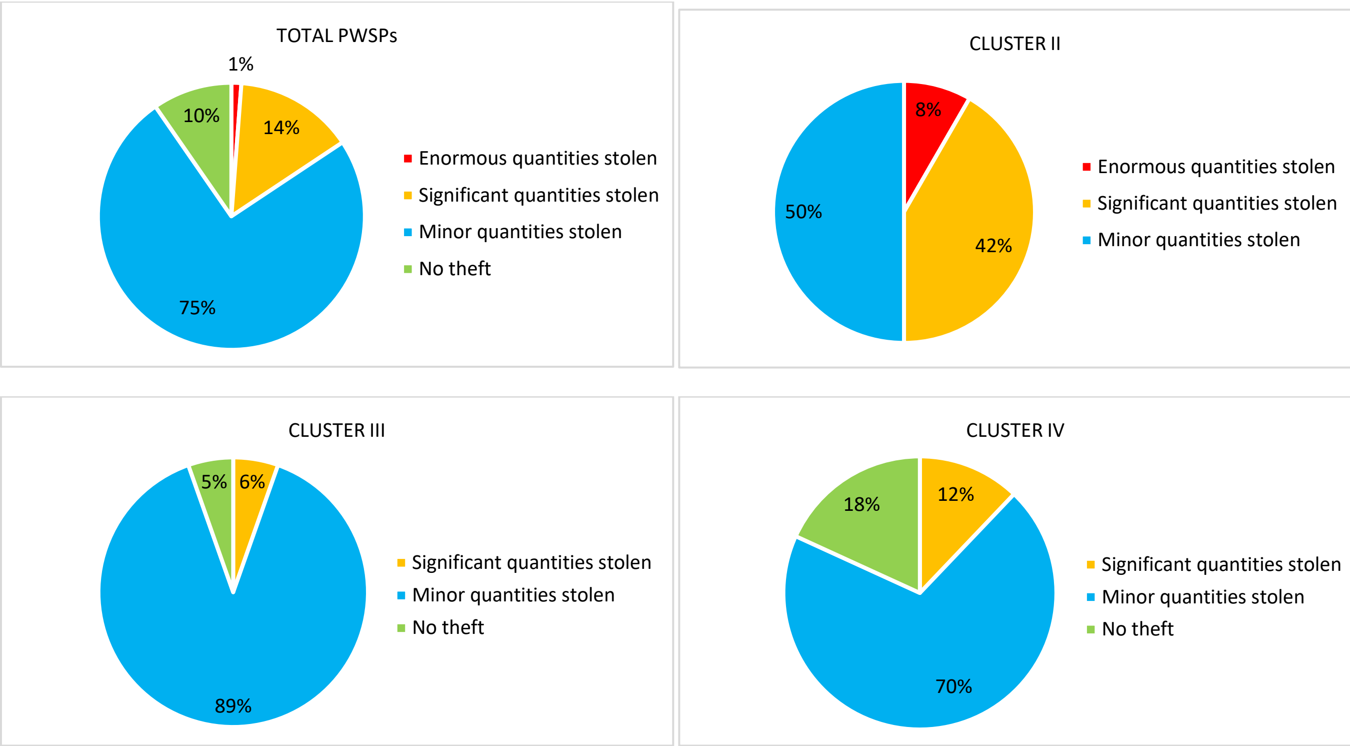


Figure 2.93. Intensity of water theft in the system assessed by PWSPs on the national level and by clusters

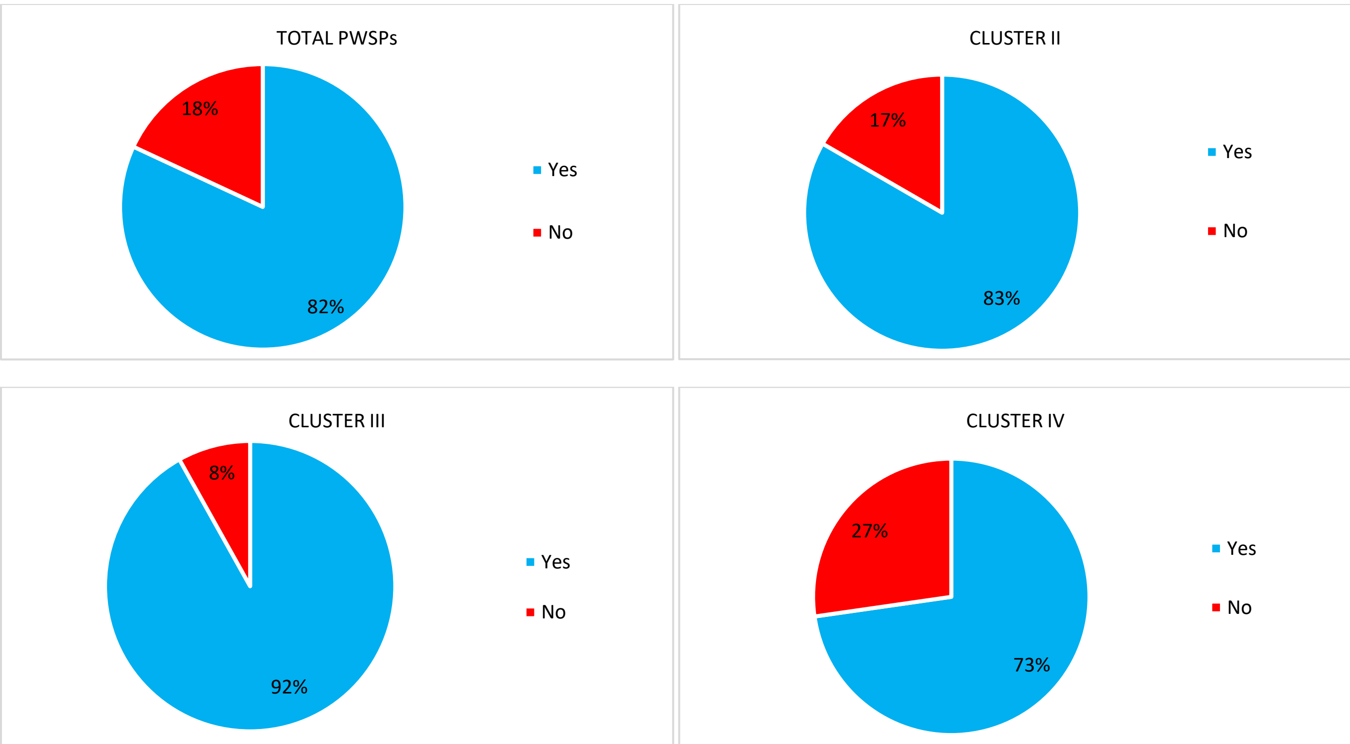


Figure 2.94. Statistical analysis of data received from the question "Are all the connections equipped with water meters?" on the national level and by clusters[35]

[35] Note: The fact is that even in the PWSPs that stated that not all connections have water meters the share of connections without water meters is negligible.

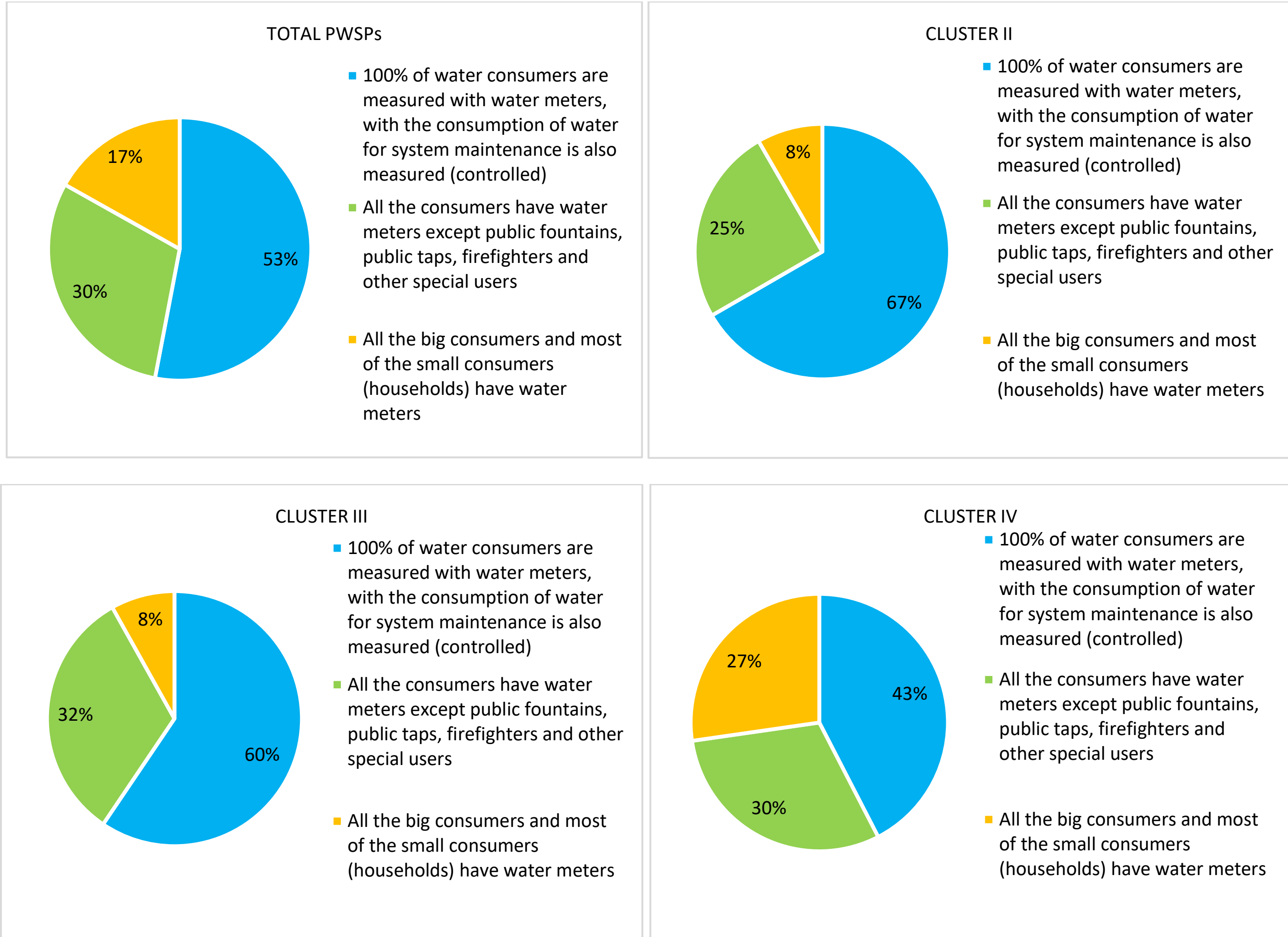


Figure 2.95. Way in which consumption by users is measured by individual PWSPs on the national level and by clusters[36]

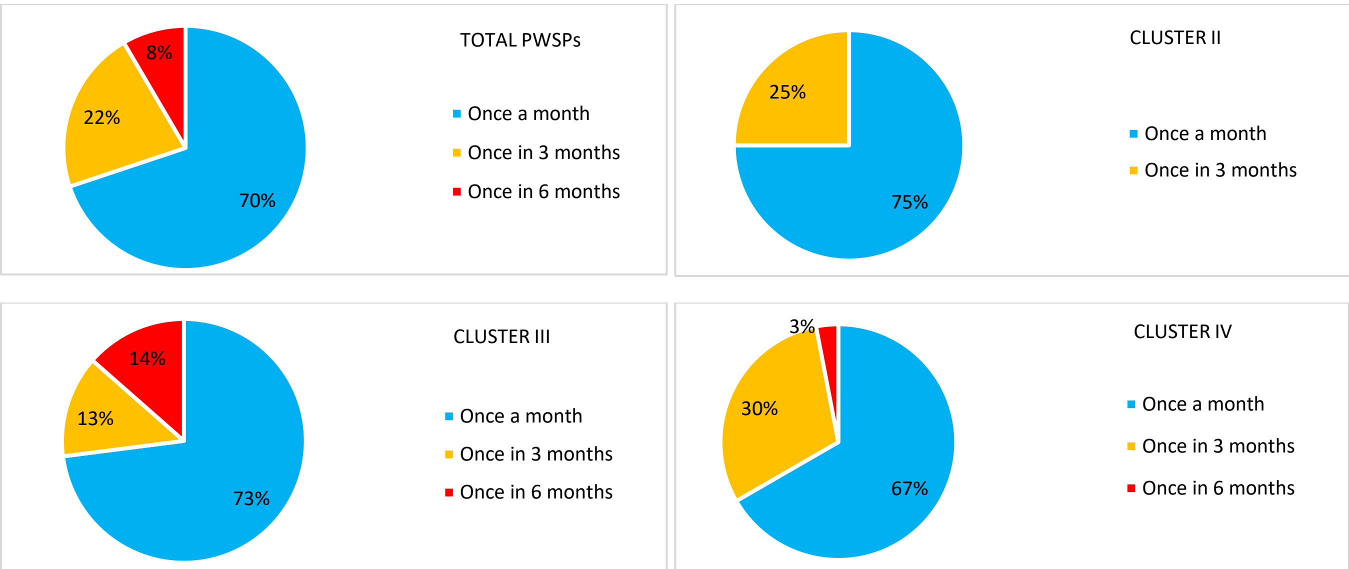


Figure 2.96. Frequency of water meter readings by individual PWSPs on the national level and by clusters

[36] Notea: The fact is that even in the PWSPs where not all connections have water meters the share of connections without water meters is negligible.

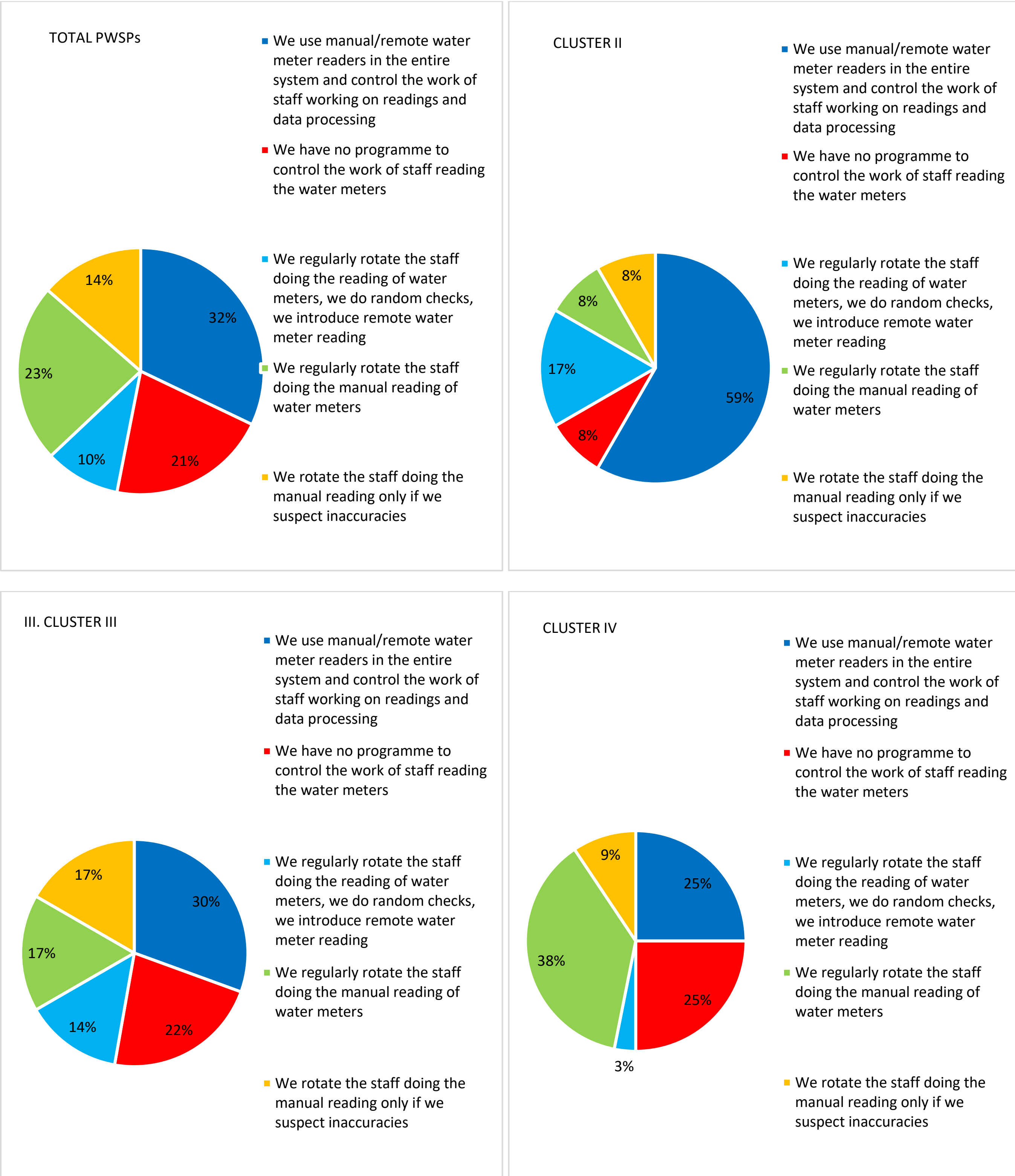


Figure 2.97. Way in which the reading of water meters is controlled by individual PWSPs on the national level and by clusters

Figure 2.98. PWSPs' practice related to the replacement of water meters and age of water meters on the national level and by clusters

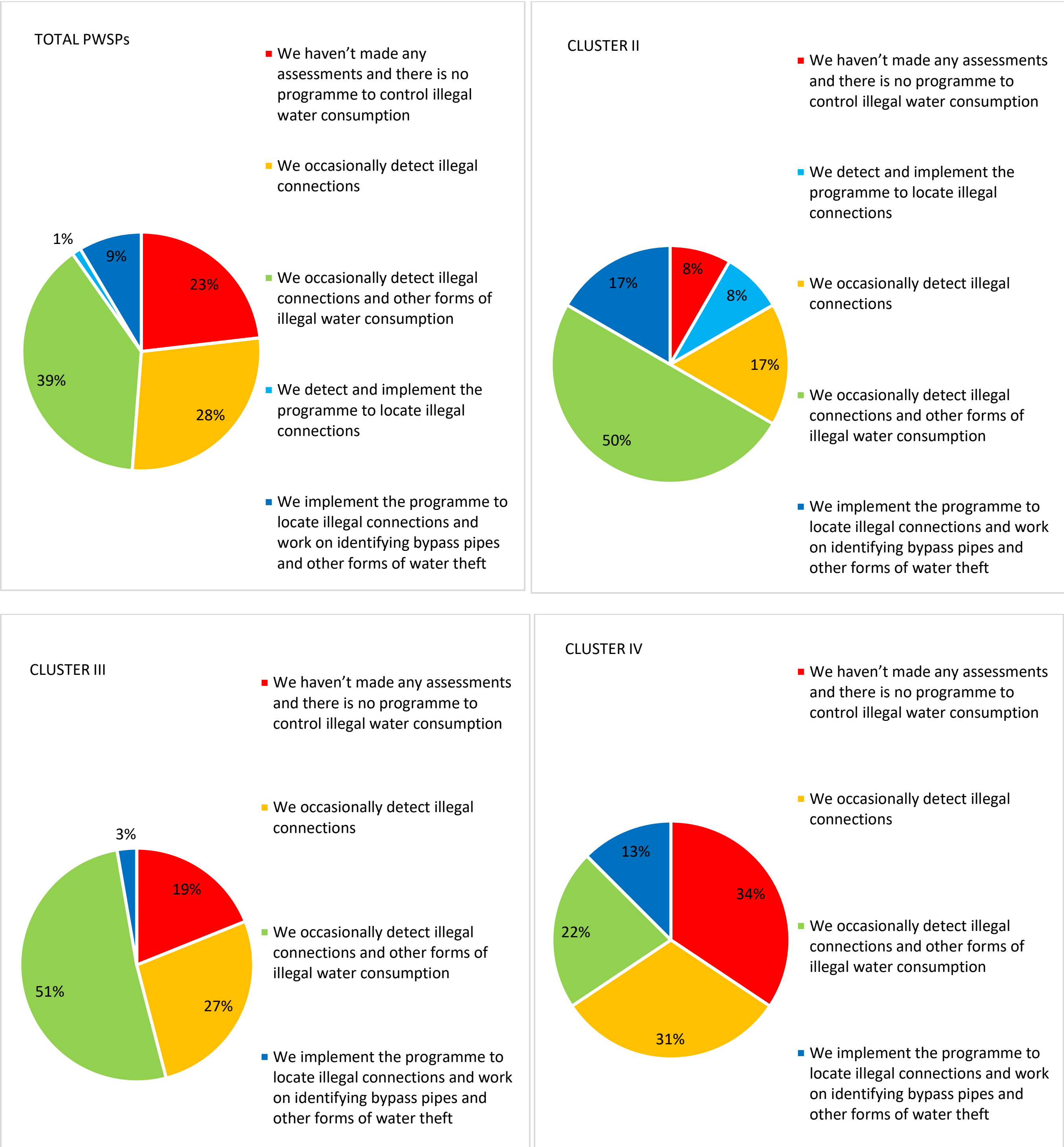


Figure 2.99. Way in which illegal connections are controlled by individual PWSPs on the national level and by clusters

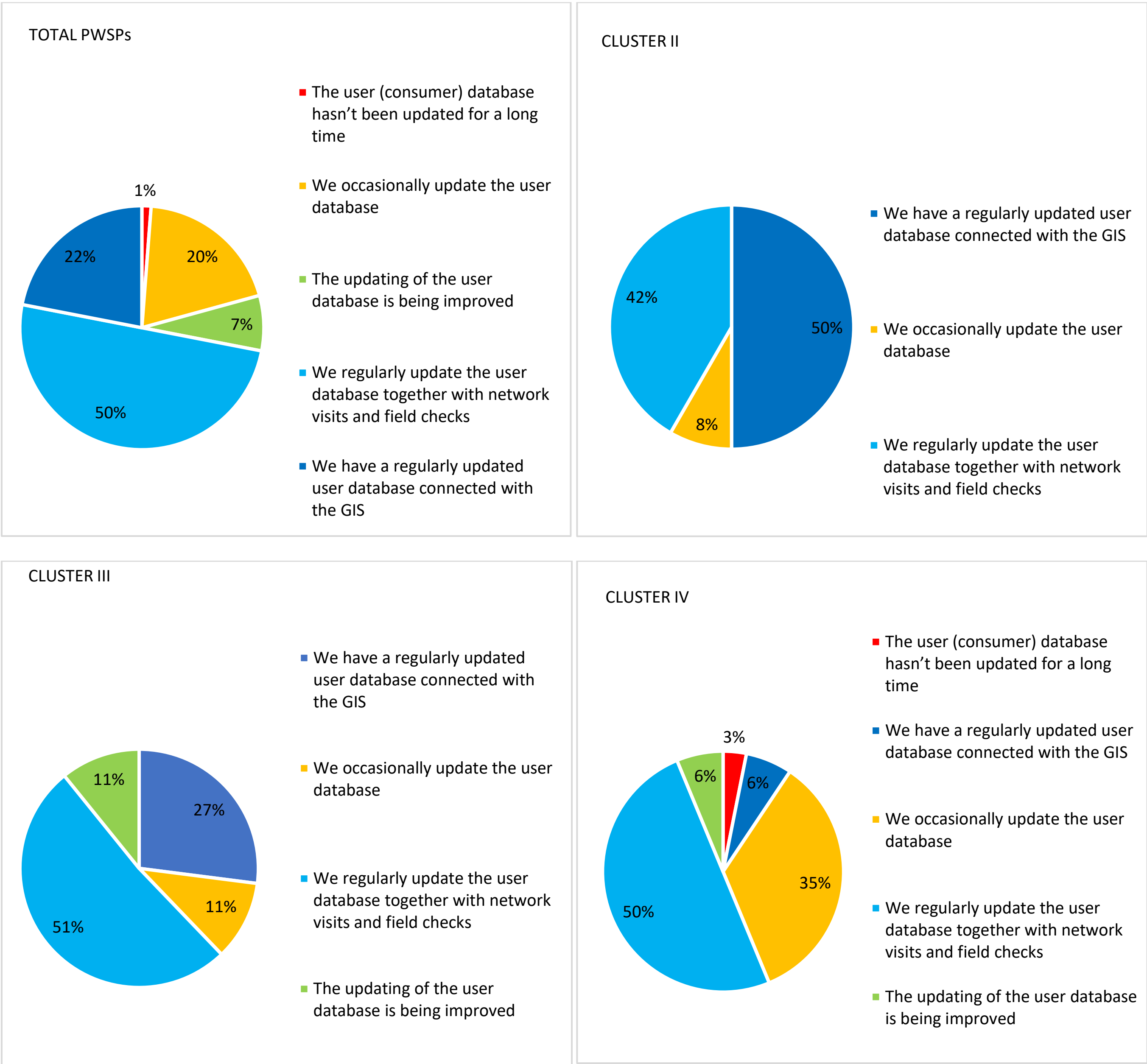


Figure 2.100. Way in which consumer database is managed by individual PWSPs on the national level and by clusters

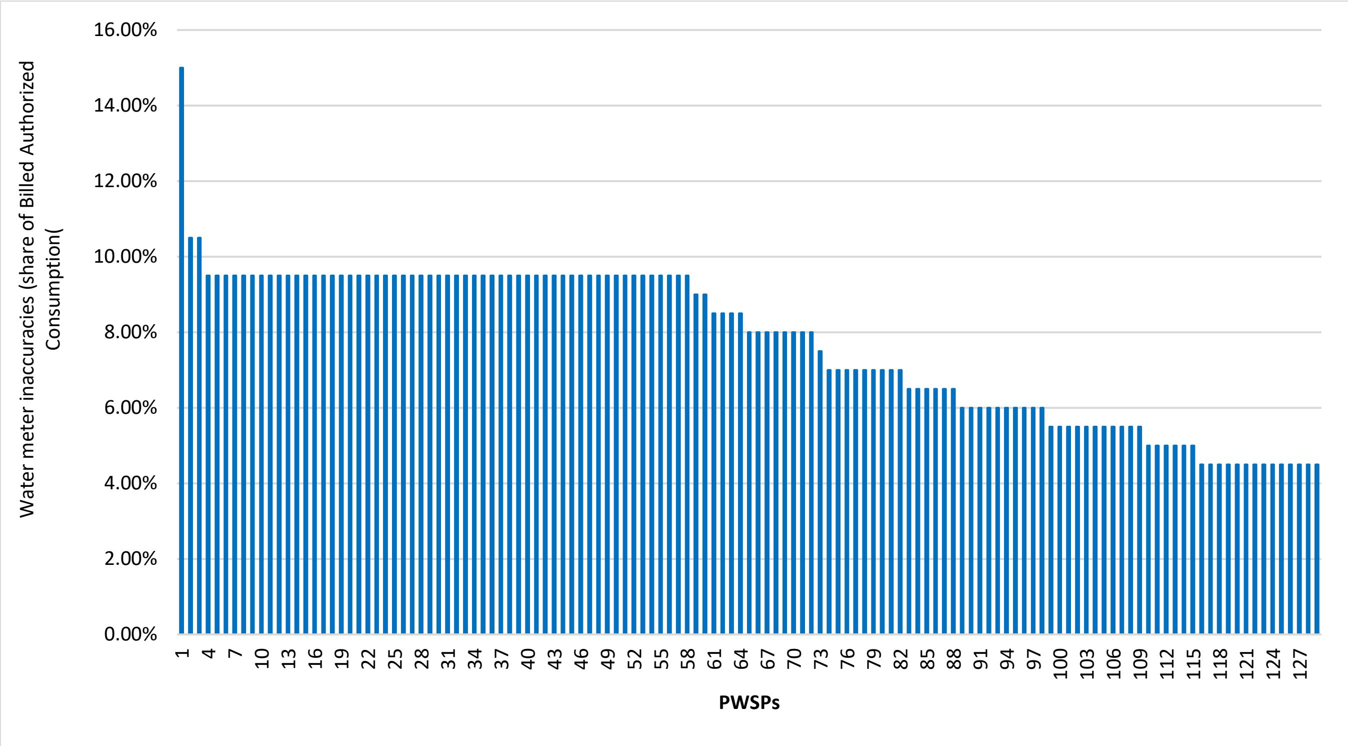


Figure 2.101. Water meter inaccuracies as a share of Billed Authorized Consumption

Figure 2.102. presents the individual water balance components by clusters of PWSPs, according to the 2021 data.

The dominant volumes of water from own sources relate to the first three clusters, with similar values of the Water Supplied too.

The Water Imported from other PWSPs dominates in Cluster III, as well as the Water Exported to other PWSPs.

The volumes of Revenue Water and Non-Revenue Water by clusters are similar, with significantly bigger volumes in the first three clusters in relation to Cluster IV.

The Unbilled Authorized Consumption is the highest in Cluster II (64% of the total Unbilled Authorized Consumption on the national level), then in Cluster III (26% of the total Unbilled Authorized Consumption on the national level), and in Cluster I (4% of the total Unbilled Authorized Consumption on the national level), and the lowest in Cluster IV (6% of the total Unbilled Authorized Consumption on the national level).

The Apparent Losses are the highest in Cluster I (43% of the total Apparent Losses on the national level), then in Cluster II (38% of the total Apparent Losses on the national level), and in Cluster III (16% of the total Apparent Losses on the national level), and the lowest in Cluster IV (3% of the total Apparent Losses on the national level). The Unauthorized Consumption is the highest in Cluster II (49% of the total Unauthorized Consumption on the national level), then in Cluster I (40% of the total Unauthorized Consumption on the national level) and in Cluster III (9% of the total Unauthorized Consumption on the national level), and the lowest in Cluster IV (2% of the total Unauthorized Consumption on the national level). As for the ranking of the Apparent Losses component related to water meter inaccuracies, the volumes are the highest in Cluster I (46% of the total volume on the national level), then in Cluster II (26% of the total volume on the national level) and in Cluster III (24% of the total volume on the national level), and the lowest in Cluster IV (3% of the total volume on the national level).

The Real Losses are the highest in Cluster II (40% of the total Real Losses on the national level), then in Cluster III (28% of the total Real Losses on the national level) and Cluster I (24% of the total Real Losses on the national level), and the lowest in Cluster IV (8% of the total Real Losses on the national level).

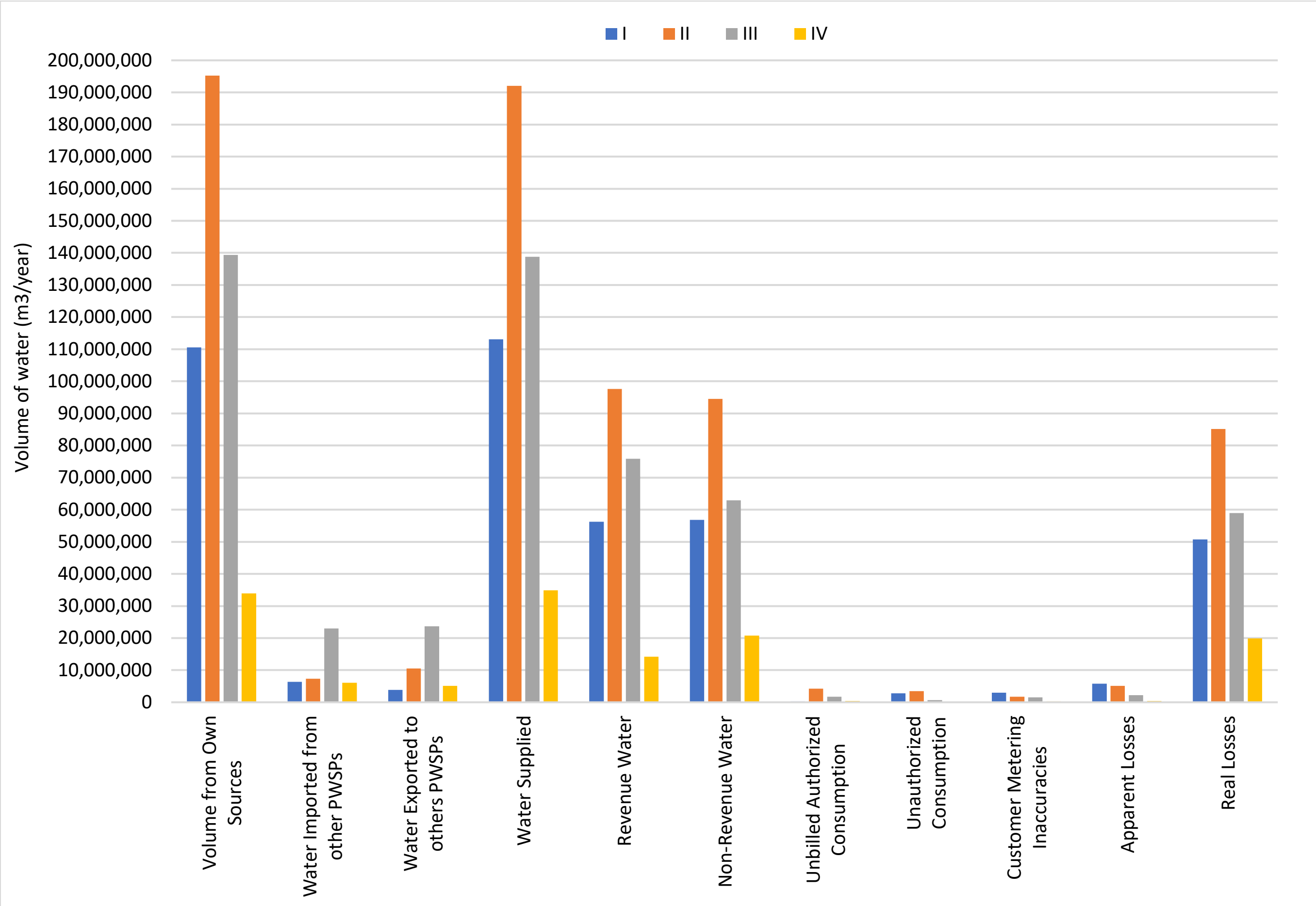


Figure 2.102. Comparison of individual water balance components by PWSP clusters

Below is an analysis of 95% confidence of the calculation of the water balance components on the national level and by clusters. 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 the Water Supplied, Billed Authorized Consumption, Unbilled Authorized Consumption, and Apparent Losses, and with automatic calculation of the values of the 95% confidence interval for the NRW, Water Losses, and Real Losses. The methodology for making the analysis is presented in Chapter 2.1.1.

Table 2.23. contains an analysis of 95% certainty of the calculation of the water balance components on the national level. The obtained results are also graphically analysed and presented in Figure 2.103. The adopted 95% confidence limit for the Water Supplied is 5% and was estimated based on the results of the questionaires 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 survey conducted among all the PWSPs included a question "How is the abstracted water measured?" The results are presented in Figure 2.104. The same results also refer to the Water Imported from other PWSPs, as well as the Water Exported to other PWSPs. Cluster I has one PWSP that stated that the abstracted volume is measured with electromagnetic flow meters which are regularly calibrated (checked for precision). The abstracted water is measured in the same way by 44% of the PWSPs in Croatia, with the highest share of such PWSPs in Cluster II (46%), while their shares in Cluster III and IV are 41% and 43%, respectively. Around 35% of the PWSPs measure the abstrated volume with mechanical and electromagnetic flow meters that are rarely calibrated, with the highest share in Cluster III (48%), followed by Clusters IV (27%) and II (25%). Around 15% of the PWSPs measure the abstracted volume, but are not sure of the accuracy of measurement (and some water meters are more than 10 years old), with the share of such PWSPs the highest in Clusters II (25%) and IV (20%). Around 4% of the PWSPs report that they measure more than 50% of abstracted water with flow meters, which means that not all water abstracted is measured, with such PWSPs classified exclusively in Clusters III (5%) and IV (3%). A relatively small share of the PWSPs (7%), classified exclusively in Cluster IV, don't measure the majority of water abstracted using flow meters.

The adopted 95% confidence limit for the Billed Authorized Consumption is 5% 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 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 2.23. 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

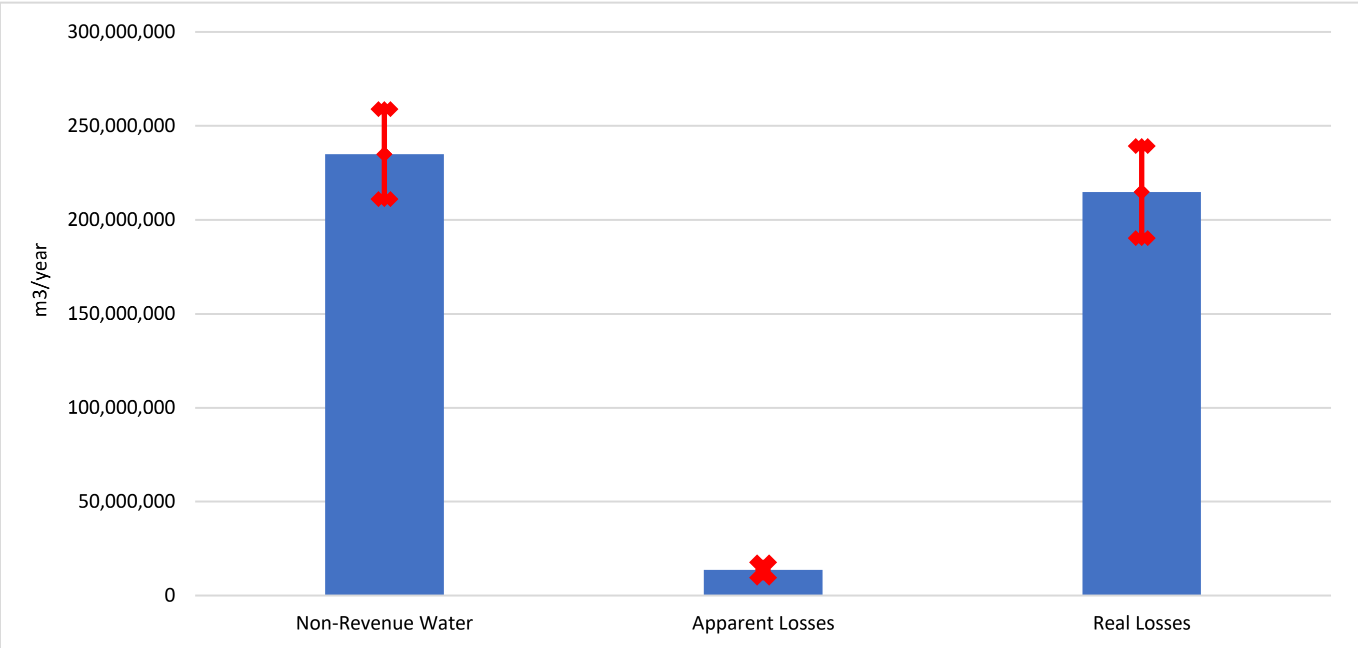


Figure 2.103. Result of analysis of 95% confidence of the calculation of Water Balance components on the national level

Figure 2.104. Way in which abstracted water is measured by individual PWSPs on the national level by clusters

The tables and figures below present the results of analysis of 95% confidence of the calculation of the Water Balance components by individual clusters.

Table 2.24. Analysis of 95% confidence of the calculation of Water Balance components for Cluster I

IWA Water Balance components	Volume (V) in m^3/year	95% confidence limit (CL)		+/- m^3	Standard deviation (SD) [=V x Pt / 1.96]		Variance (Va) [=SD2]
Water Supplied	113,073,582	+/-*	2%	2,261,472	1,153,812	→	1,331,282,272,627
-							+
Billed Authorized Consumption	56,249,026	+/-*	0%	0	0	→	0
NRW	56,824,556	+/-	4%	2,261,472	1,153,812	←	1,331,282,272,627
		[=SD/Vx1.96]					
-							+
Unbilled Authorized Consumption	281,534	+/-*	30%	84,460	43,092	→	1,856,913,736
Water Losses	56,543,022	+/-	4%	2,263,048	1,154,616	←	1,333,139,186,363
-		[=SD/V/0.5]					+
Apparent Losses	5,815,756	+/-*	30%	1,744,727	890,167	→	792,396,761,056
Real Losses	50,727,266	+/-	6%	2,857,527	1,457,922	←	2,125,535,947,419

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

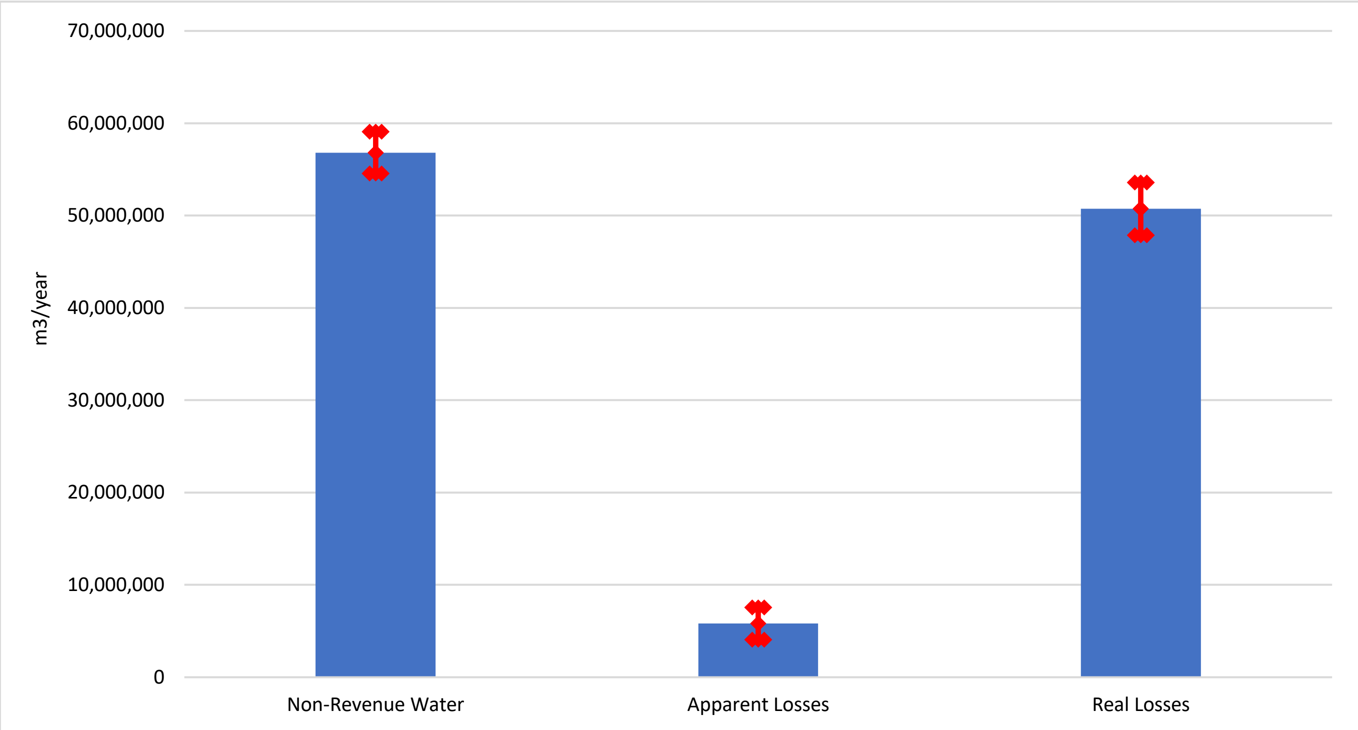


Figure 2.105. Results of analysis of 95% confidence of the calculation of Water Balance components for Cluster I

Table 2.25. Analysis of 95% confidence of the calculation of Water Balance components for Cluster II

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	192,074,196	+/-*	3%	5,762,226	2,939,911	→	8,643,077,647,892
-							+
Billed Authorized Consumption	97,578,771	+/-*	0%	0	0	→	0
NRW	94,495,425	+/-	6%	5,762,226	2,939,911	←	8,643,077,647,892
		[=SD/Vx1.96]					
-							+
Unbilled Authorized Consumption	4,239,437	+/-*	40%	1,695,775	865,191	→	748,555,855,640
Water Losses	90,255,988	+/-	7%	6,006,571	3,064,577	←	9,391,633,503,532
-		[=SD/V/0.5]					+
Apparent Losses	5,154,163	+/-*	30%	1,546,249	788,902	→	622,367,050,661
Real Losses	85,101,826	+/-	7%	6,202,402	3,164,491	←	10,014,000,554,193

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

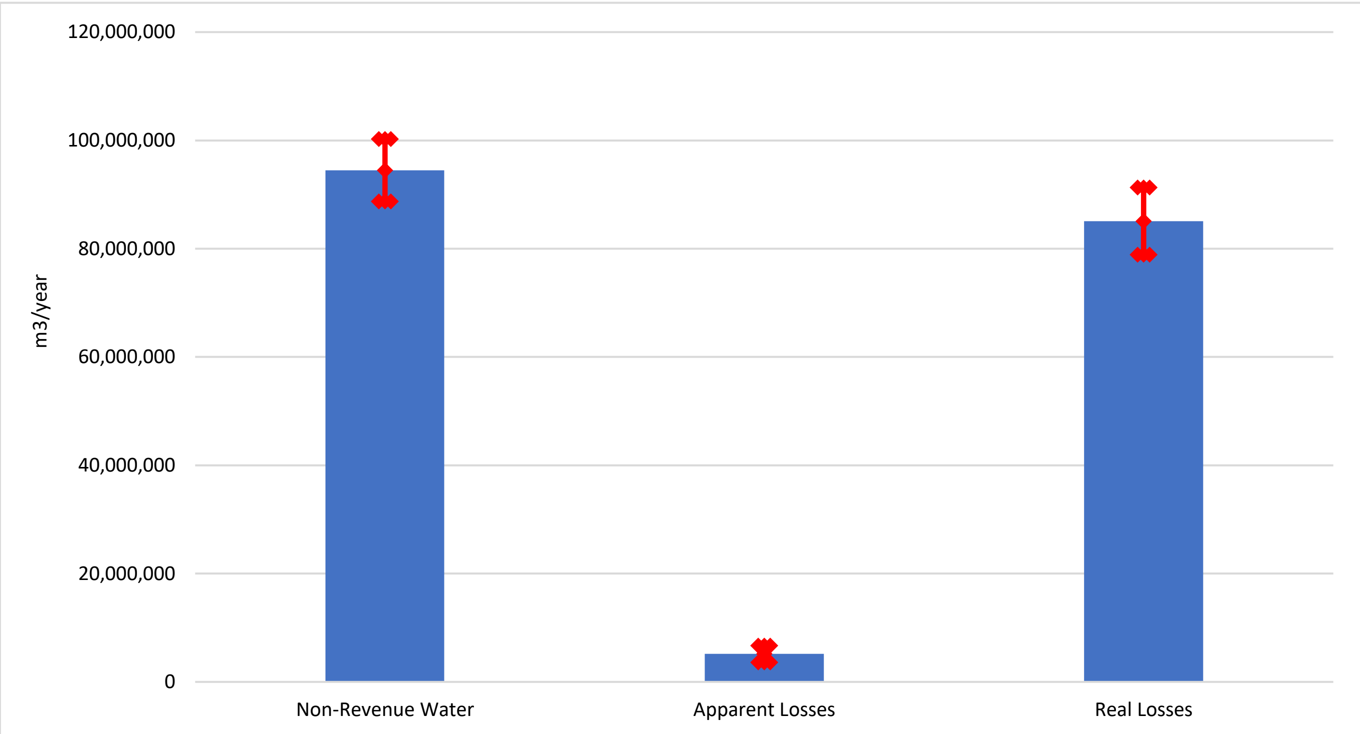


Figure 2.106. Result of analysis of 95% confidence of the calculation of Water Balance components for Cluster II

Table 2.26. Analysis of 95% confidence of the calculation of Water Balance components for Cluster III

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	138,745,533	+/-*	4%	5,549,821	2,831,541	→	8,017,627,208,436
-							+
Billed Authorized Consumption	75,874,515	+/-*	0%	0	0	→	0
NRW	62,871,018	+/-	9%	5,549,821	2,831,541	←	8,017,627,208,436
		[=SD/Vx1.96]					
-							+
Unbilled Authorized Consumption	1,726,098	+/-*	50%	863,049	440,331	→	193,891,399,918
Water Losses	61,144,921	+/-	9%	5,616,526	2,865,575	←	8,211,518,608,353
-		[=SD/V/0.5]					+
Apparent Losses	2,179,746	+/-*	30%	653,924	333,635	→	111,311,989,869
Real Losses	58,965,175	+/-	10%	5,654,466	2,884,932	←	8,322,830,598,222

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

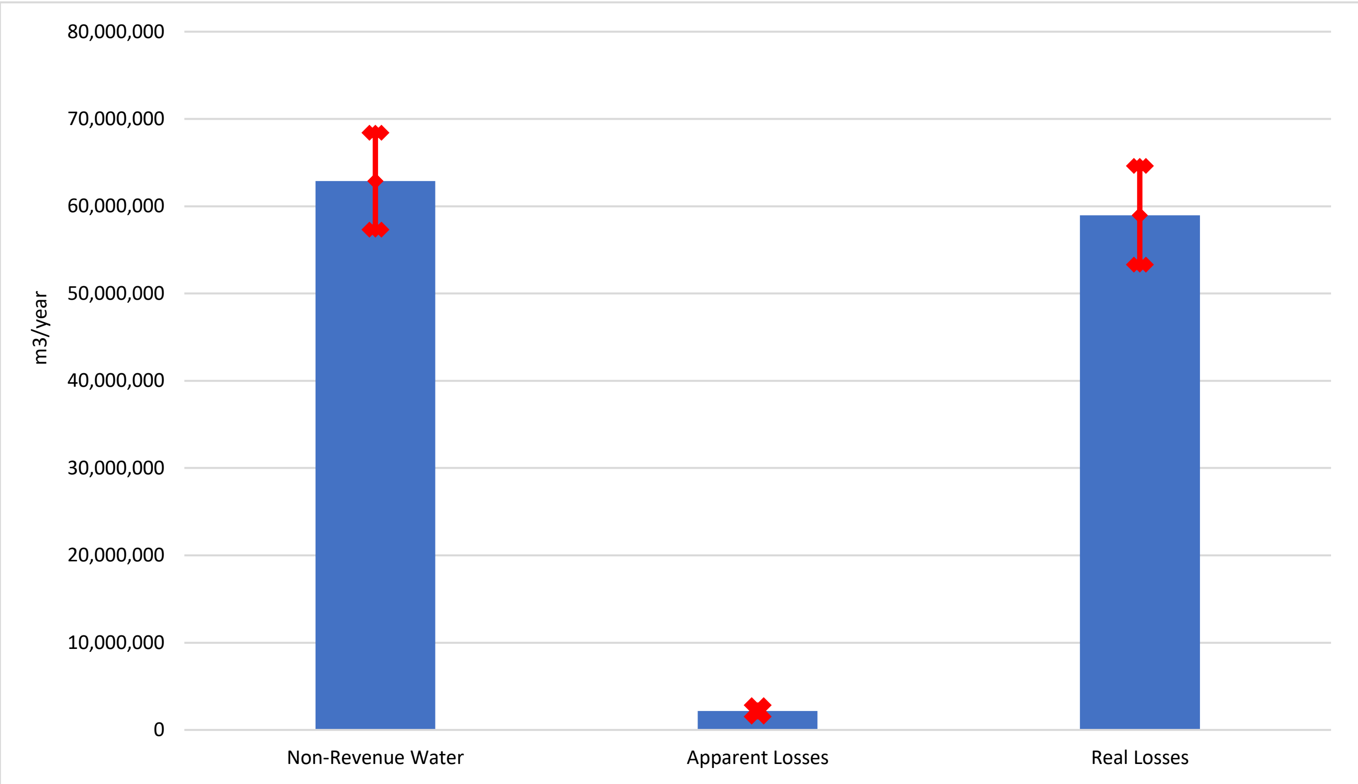


Figure 2.107. Result of analysis of 95% confidence of the calculation of Water Balance components for Cluster III

Table 2.27. Analysis of 95% confidence of the calculation of Water Balance components for Cluster IV

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	34,930,112	+/-*	10%	3,493,011	1,782,149	→	3,176,053,572,471
-							+
Billed Authorized Consumption	14,163,435	+/-*	0%	0	0	→	0
NRW	20,766,677	+/-	17%	3,493,011	1,782,149	←	3,176,053,572,471
		[=SD/Vx1.96]					
-							+
Unbilled Authorized Consumption	387,017	+/-*	50%	193,509	98,729	→	9,747,405,457
Water Losses	20,379,660	+/-	17%	3,498,367	1,784,881	←	3,185,800,977,928
-		[=SD/V/0.5]					+
Apparent Losses	427,481	+/-*	50%	213,740	109,051	→	11,892,171,034
Real Losses	19,952,179	+/-	18%	3,504,891	1,788,209	←	3,197,693,148,962

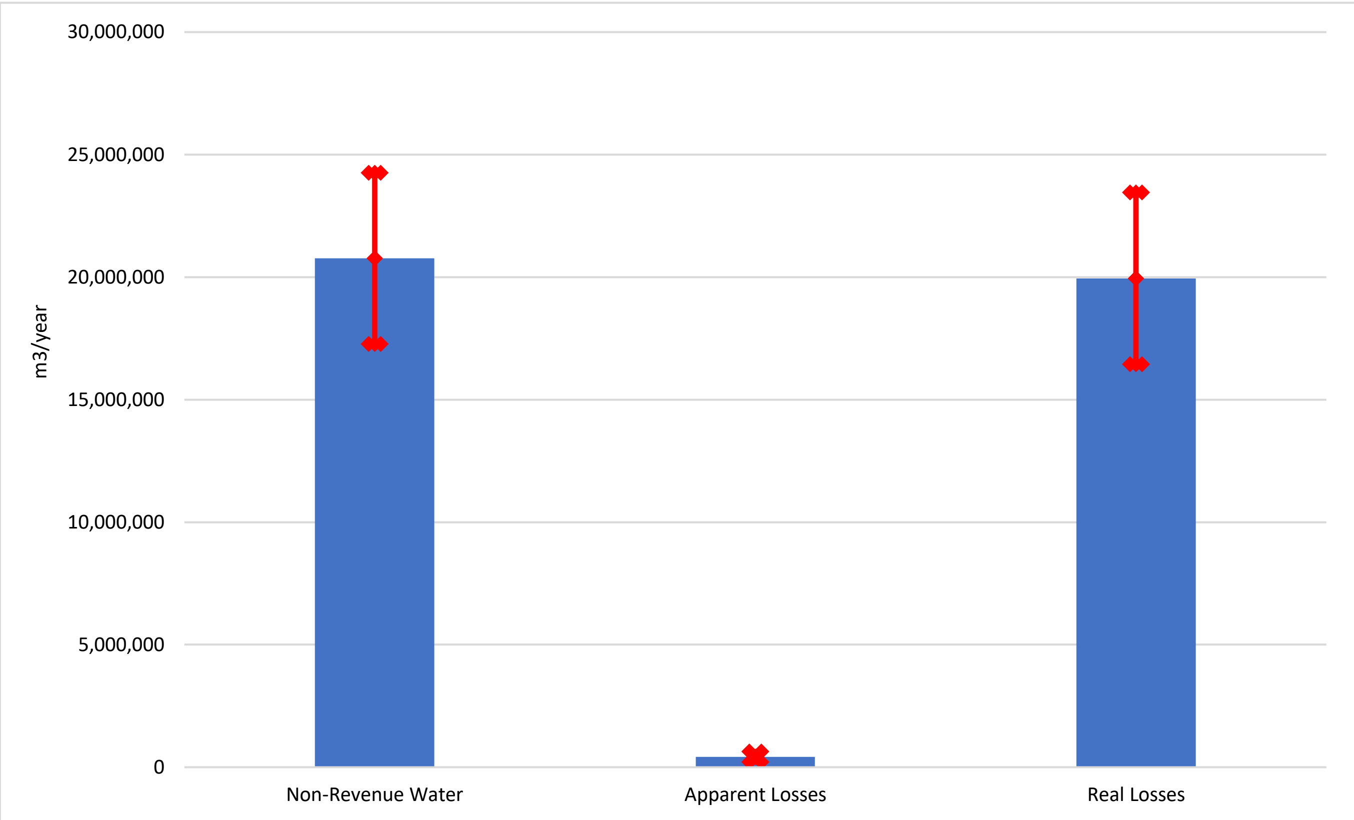


Figure 2.108. Result of analysis of 95% confidence of the calculation of Water Balance components for Cluster IV

2.4.3 Potential and risk for future water losses

The analyses made so far show that over the last 5 years the NRW volume on the national level has decreased slightly (by around 1.1% or by around 3 million m^3/year), with almost no change over the last 4 years (Table 2.15, Figure 2.81). However, if the status on the level of individual PWSPs is analyzed, then both positive and negative changes in NRW volumes in some PWSPs are present and clearly visible (Figure 2.109). While some PWSPs are characterized by a continuous increase in NRW volumes, some have stagnating NRW volumes, and some decreasing NRW volumes, particularly over the last several years. Some PWSPs have in a short period (1 – 2 years) managed to achieve certain reduction of NRW volumes, only for them to increase after that for certain reasons.

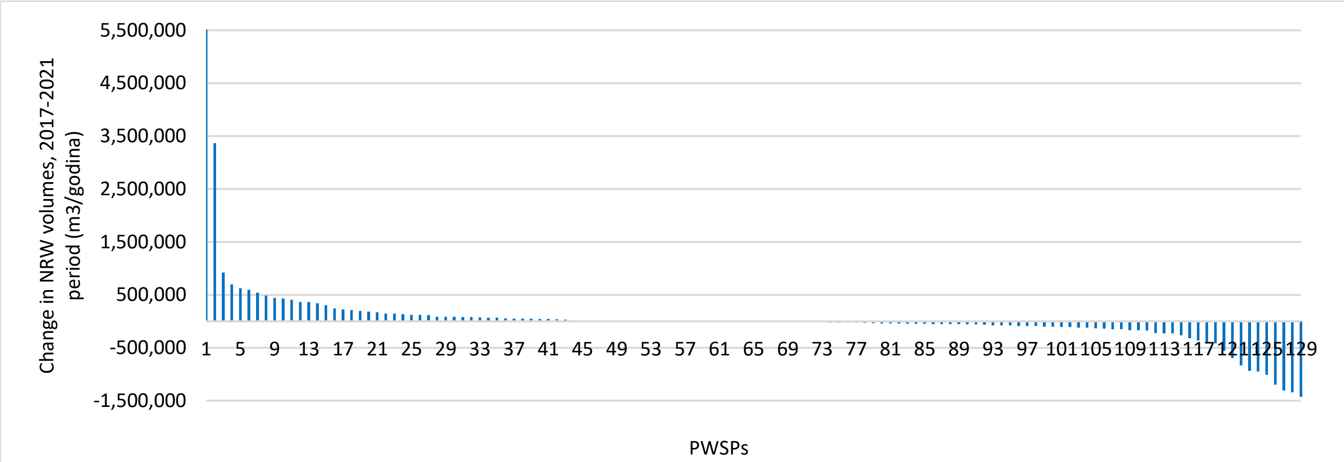


Figure 2.109. Change in NRW volumes by individual PWSPs in the 2017-2021 period

The trend of the volumes of NRW and water losses (apparent and real) in the future is hard to assume because they are affected by a large number of influential factors. However, the positive practice so far among certain PWSPs has shown that impressive results on water losses reduction can be achieved with certain financial investment not only in infrastructure, but also in technical staff and know-how, equipment, and digitalization, and with a modified organization structure (merging, personnel policy, human resources management, etc.).

For that reason, active help, primarily in the form of financing and technical, operational and institutional assistance related to the water loss reduction program, is assessed as much needed with the aim of establishing long-term sustainable mangement of water losses and water supply systems.

2.4.3.1 Potential for water loss reduction

Analyzing the total NRW volumes on the national level, as well as their share in the Water Supplied, a potential for their reduction is obvious. That potential is made even more clear if all the factors by individual PWSPs which affect the currently unfavorable status are analyzed in more detail. It can be concluded that the issue related to the currently unfavorable status of water losses is not of a technical nature, but rather the result of a systematic failure so far to manage the issue, most often due to insufficient financial investment, but also due to operational and personnel issues which the PWSPs are continuously faced with.

Until the year 2018, i.e. the launch of the “National Water Loss Reduction Program” (NWLRP) by the line Ministry and Croatian Waters (see Chapter 2.6.1), only a relatively small number of the PWSPs had managed to reduce their water losses or keep them at an acceptable level first of all with their own effort and financial resources (for example, the PWSPs that stand out with a NRW share lower than 20% are Pula, Koprivnica, Krapina, Vir, and a few smaller systems). From the moment of their inclusion into the NWLRP, many other PWSPs started reducing their water losses. That is first of all the result of the preparation of high-quality documents in the form of conceptual solutions (see Chapter 2.6.2) which made it possible for them to know in detail the current status (among other things, the spatial and quantitative distribution of water losses) and problems (deficiencies) in the system and which defined specific improvement measures according to priorities and implementatoin of the specific measures with their significant co-financing through the NWLRP, as well as the implementation of training of the technical staff working on the system maintenance (flow and pressure measurement, use of loss detection equipment, 'step' tests, etc.) and management (development and use of mathematical models, pressure management, etc.). Based on the positive results achieved so far among individual PWSPs included in the NWLRP, it is justified to expect the reduction of water losses among many other PWSPs to which a certain form of financing or co-financing will be provided to implement specific improvement measures. The merging of the PWSPs has so far even in a relatively short period shown some positive changes related to the reduction of water losses. The positive practice examples are the three water supply areas merged so far.

In 2016, the company Vodoopskrba i odvodnja Zagrebačke županije d.o.o., which for the purpose of submitting an EU co-financing application for the “Regonal Water Supply System of Zagreb County – Zagreb East” Project from the Cohesion Fund and its implementation, merged the PWSPs from the areas of Dugo Selo, Ivanić-Grad, Vrbovec, and Sveti Ivan Zelina. Additional objectives were: (a) ensuring technical and technological integrity of the public water supply structures from the source to the end user, and (b) ensuring the delivery of water intended for human consumption at a single price, with the aim to optimize and rationalize operational performance and achieve lower operating costs and lower prices of water services (https://viozz.hr/o-drustvu). The merging of the PWSPs in the said area has resulted in a significant reduction of water losses in individual sub-systems (e.g. in 2018-2020, the losses in the Dugo Selo and Vrbovec areas were reduced by 34% and 38%, respectively), while on the level of the overall merged water supply system the water losses were reduced by around 7%, i.e., around 0.5 million m^3/year (Annual Report on Implemented Water Loss Reduction Activities in 2020, Vodoopskrba i odvodnja zagrebačke županije d.o.o. Zagreb, Technical Sector, Department for Reduction of Losses and Maintenance of Equipment).

The second positive practice example is the company Vodovod Korenica d.o.o. from Korenica which took over the water supply system within the Plitvice Lakes National Park. Since the moment of taking over the system and through its inclusion into the NWLRP, launched in 2018, it has been achieving positive results in water loss reduction (in 2019-2021, the water losses were reduced by around 17%, i.e., by around 0.4 million m^3/year).

The third positive practice example is the PWSP Vodovod i kanalizacija d.o.o. Ogulin, which took over the management of the Plaški and Saborsko water supply systems in 2020. The PWSPs merging and their simultaneous inclusion into the NWLRP resulted in a very short period with a significant reduction of water losses in the Plaški and Saborsko water supply systems. In a relatively short period (2020-2022) in the Ogulin-Plaški-Saborsko area, the water losses in the Saborsko area were reduced by 96% (with the activities implemented over a period of one year), and in the Plaški area by 50% (with the activities implemented over a period of two years). The same levels of water losses have been retained in these areas until the present day, with a significant effort by the competent provider of water services.

Based on the above, it is justified to expect that water losses will reduce further as the result of new PWSPs merging in the future.

Some PWSPs have problems with the capacities of their yields and introduce water conservation measures in the summer months during dry years. Climate change is in some areas reflected through the reduction in the total rainfall, more frequent prolonged periods of drought, groundwater lowering, etc. As such, during the summer of 2022 due to an exceptionally long dry period, water conservation measures were introduced in the areas of Istria, Zadar, Daruvar, Dvor, etc. Due to climate change and its possible consequences mentioned above, it is expected that certain PWSPs will in the future invest bigger efforts and financial resources in the reduction of water losses.

With legislative amendements that will penalize the PWSPs with higher water losses, long-term reduction of water losses is definitely expected. The Ordinance on collecting and charging the water usage fee (OG 36/20) that comes into effect on 1 January 2023 introduces the charging of the water usage fee based on the abstracted volume, and not on the billed volume as regulated today. In that context, the PWSPs will as a rule be charged higher volumes, because the calculation of that fee includes the volumes of water losses, which will motivate many PWSPs to active and continuous implementation of numerous water loss reduction activities.

2.4.3.2 Risks related to water loss reduction

In addition to the potentials for water loss reduction presented above, there are also numerous risks which on the other hand can have an impact on increasing water losses for some PWSPs.

The risks associated with the reduction of water losses can generally be divided into:

- Internal risks, and
- External risks;

2.4.3.2.1 Internal risks

Internal risks are related to the status within the PWSPs themselves, be it in financial, organizational and personnel terms, and to the condition of infrastructural facilities. Many internal risks also derive from the negative practice so far among by PWSPs. The most significant internal risks are the following:

- Lack of financial resources for continuous implementation of water loss reduction measures;
- Implementation of active leakage control rendered more difficult which can be the result of:
  - Water service providers not having expert teams for water loss management (active leakage control);
  - Staff working on water loss management lacking motivation;
  - Inability to outsource high-quality companies to implement water loss reduction measures;
- Growing age of the water supply network;
- Using inapppropriate pipe materials; poor development of joints and protection of pipes and fittings when building new systems, improving the existing ones and removing failures, reconstrucing/replacing the mains network and fittings;
- Etc.;

2.4.3.2.2 External risks

External risks are related to natural disasters that may affect a region, such as earthquakes.

The Zagreb area and its surroundings were hit by a powerful 5.5-magnitude earthquake on the Richter scale in March 2020, followed by several aftershocks of smaller intensity. There was an even more powerful, 6.3-magnitude earthquake on the Richter scale in December 2020, with an epicentre near the town of Petrinja. It was felt in a radius of more than 200 km (covering a major part of central Croatia with larger PWSPs such as Zagreb, Sisak, Petrinja, Zagorski vodovod, Karlovac, Zagrebačka županija, Kutina, Glina, and many smaller water supply systems). Because of the earthquake destruction, the method of operation of water supply systems in the impacted area didn't change, but in relation to the noticed and potential damage the sustainable water supply for end users is still at risk even today to a considerable extent. The earthquake destruction resulted in:

- A considerable increase in the number of failures in the water supply networks;
- A considerable increase of water losses in the water supply networks;
- Property and human lives on the route of the water supply networks put at risk due to the occurrence of new failures or increasing impact of the existing ones (which can manifest themselves in the future too – increased leakage, soil washout, roads collapsing, deterioriated stability of the foundation soil of structures, etc.).

A large part of the Croatian territory is classified as an area on the level VII or higher on the MSC scale. The Banovina region still experiences earthquakes of smaller intensity. Potential new earthquake destruction might make the condition of the water supply systems even more difficult, with a consequent increase in water losses.

External risks are also associated with other unfavorable events on the global, regional and local levels, such as wars. Some 30 years ago (1991-1995), Croatia suffered the Homeland War during which part of its territory was occupied, numerous regions suffered destruction, and part of the water supply infrastructure wasn't maintained. That led to the deterioration of infrastructure, which had an impact on the increase in water losses, which are still felt today in some areas. For many water supply systems studies and design documents were lost, and part of the staff that was familiar with the system emigrated. Consequently, for some systems the current status of completion isn't fully known even today, which is reflected in the level of water losses as well.

2.5 Calculated water loss performance indicators (ILI and others)

Numerous performance indicators are used in the global practice, while in Croatia the application of the volume or share of the non-revenue water (Chapter 2.4.2.1) and the infrastructure leakage index (ILI) is the most frequent. However, over the last several years, in particular after the launch of the NWLRP in 2018, there is more frequent application of other performance indicators that derive from the extended (and simplified) IWA water balance, such as the total real losses, unit real losses (l/service connection/d; m^3/km/h), and apparent losses.

Around 44% of the PWSPs in Croatia use only the % of NRW as a performance indicator, with their shares the largest in Clusters IV (50%) and III (43%). Around 18% of the PWSPs in Croatia have tried to calculate the performance indicators, but still continue to use only the % of NRW, with their share the largest in Cluster IV (30%), but also with significant shares in Cluster II (16%) and III (9%). An equal share of the PWSPs (14-16%) regularly calculates the indicators for physical (real) water losses presenting them in m^3, as well as for real and apparent losses according to the IWA methodology, and the ILI. Around 9% of the PWSPs in Croatia regularly calculate real and apparent losses and the ILI according to the IWA methodology, presenting them in their official annual reports (Figure 2.110).

Figure 2.110. Way in which PSWPs use performance indicators on the national level and by clusters

The results of analyses of the ILI by individual PWSPs grouped into clusters and on the national level are presented in detail below. Based on the results obtained from additional analyses made, a critical review of the use of the ILI when making certain conclusions is also given.

2.5.1 ILI

The ILI represents the first indicator that was defined to give a better insight into the efficiency of managing a water supply system, i.e. to show how successful a PWSP is in managing its water losses, and was defined within the generally accepted IWA methodology. The ILI presents the share of the Current Annual Real Losses (CARL) to the Unavoidable Annual Real Losses (UARL), with the methodology of its calculation explained in detail in Chapter 2.1.1.

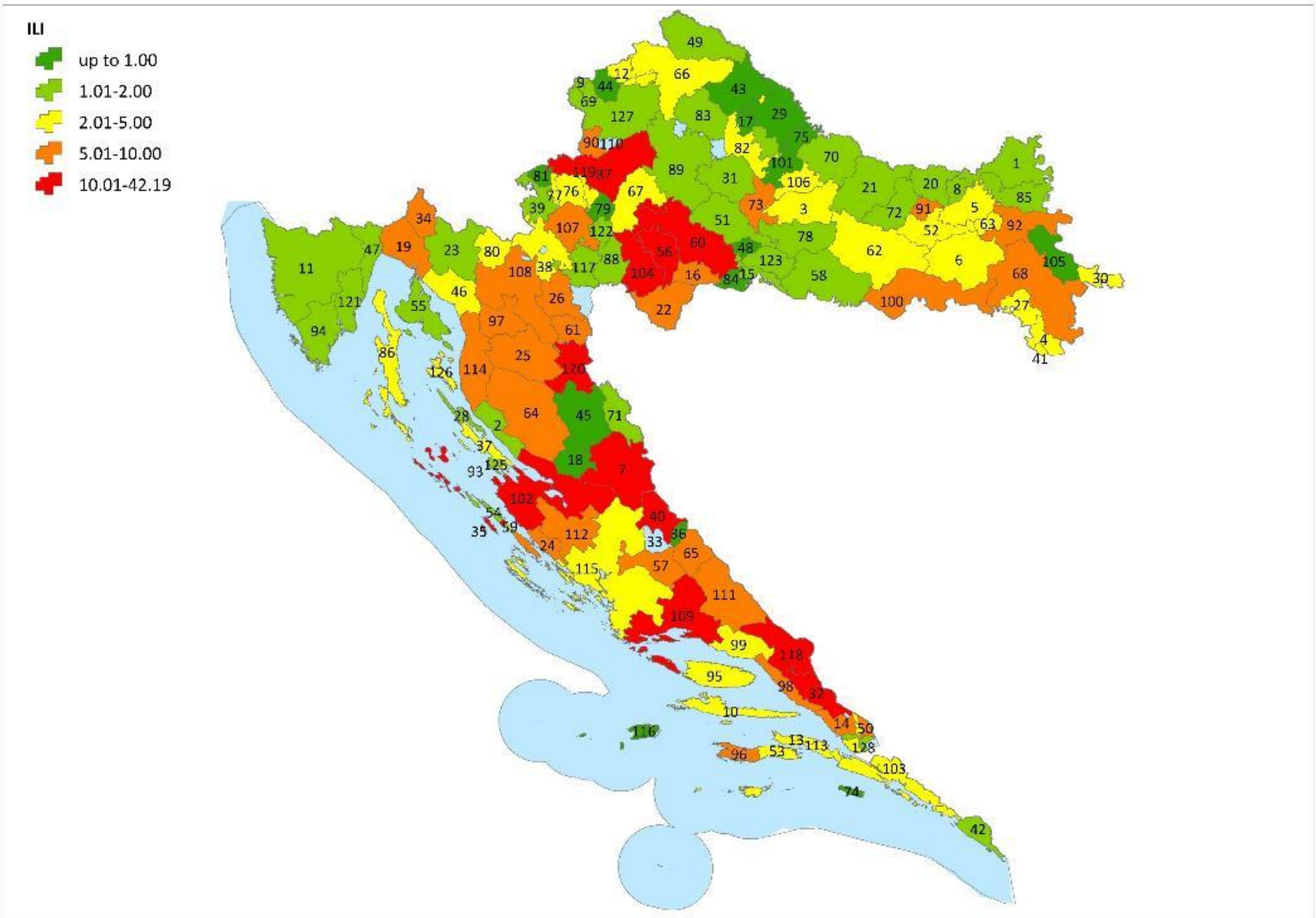


Figure 2.111. Calculated ILI Indicator, PWSP level (with IDs)

The distribution of the ILI by the PWSPs in Croatia presented in a descending order is shown in Figure 2.112. The distribution of the ILI by the proposed service areas in Croatia is presented in Figure 2.113.

Since the calculation of the national (uniform) ILI is not completely clear in methodological terms, several calculation methods are presented below. A decision on the adopted methodology, or a decision whether a uniform ILI needs to be expressed at all on the national level, will be presented in the document "Loss Reduction Action Plan".

The average ILI value on the national level expressed as an arithmetic mean of the values of all ILIs of the PWSPs amounts to 4.18.

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

The calculated ILI value on the national level, taking into consideration the weighted value of the average pressure against the network length of individual PWSPs, amounts to 2.9.

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

Table 2.28. 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. In that table the PWSPs are distributed by clusters as well.

The Cluster I PWSP is classified into band (category) D with the ILI higher than 8. The Cluster II PWSPs are equally distributed across all the four bands. The Cluster III PWSPs are also equally distributed across the first three bands (< 2, 2 – 4, and 4 – 8), while a somewhat smaller number of the Cluster III PWSPs is classified in the fourth band (8 or more). More than 50% of the Cluster IV PWSPs are classified into the first band (< 2), while the remaining number is equally distributed across the last three bands (2 – 4, 4 – 8, 8 or more).

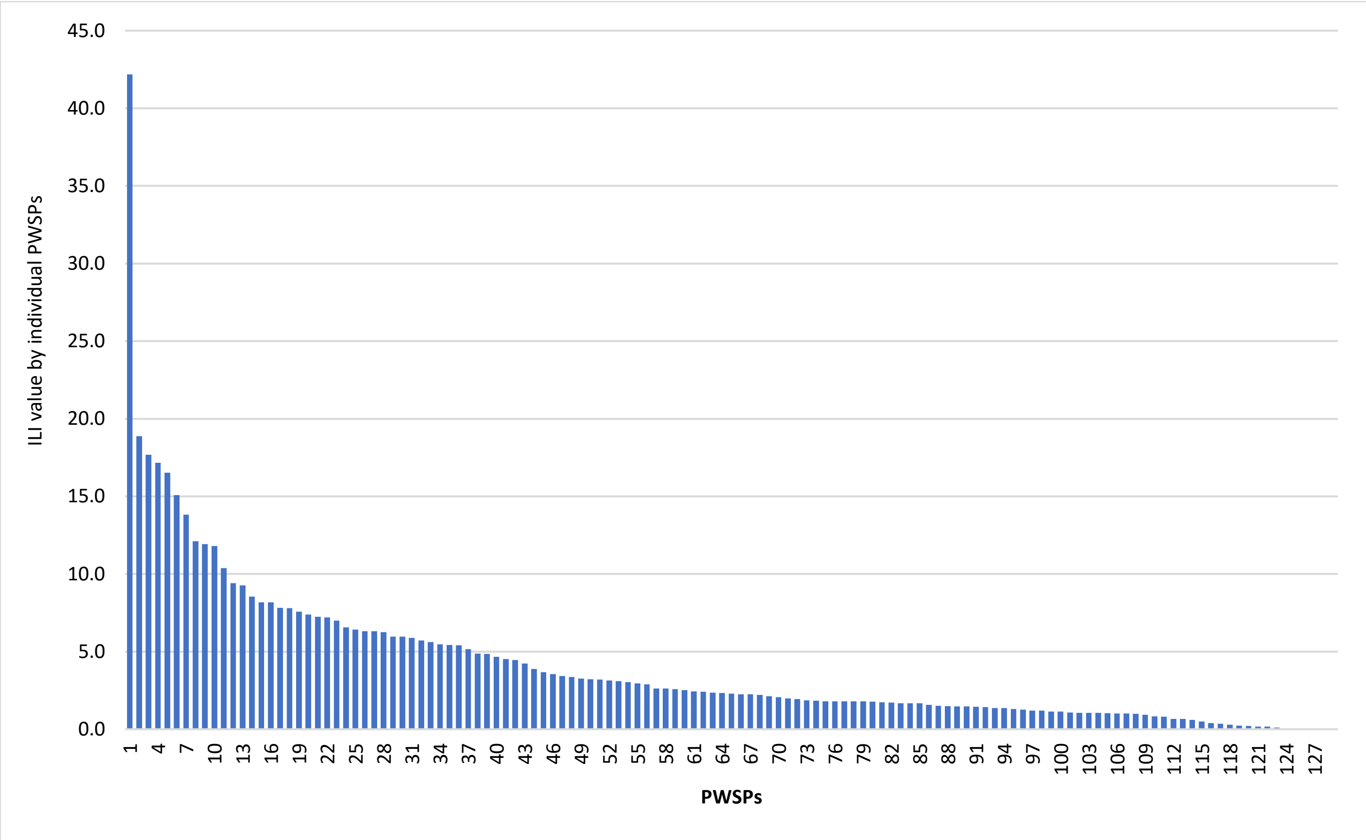


Figure 2.112. Distribution of the ILI value by individual PWSPs in Croatia

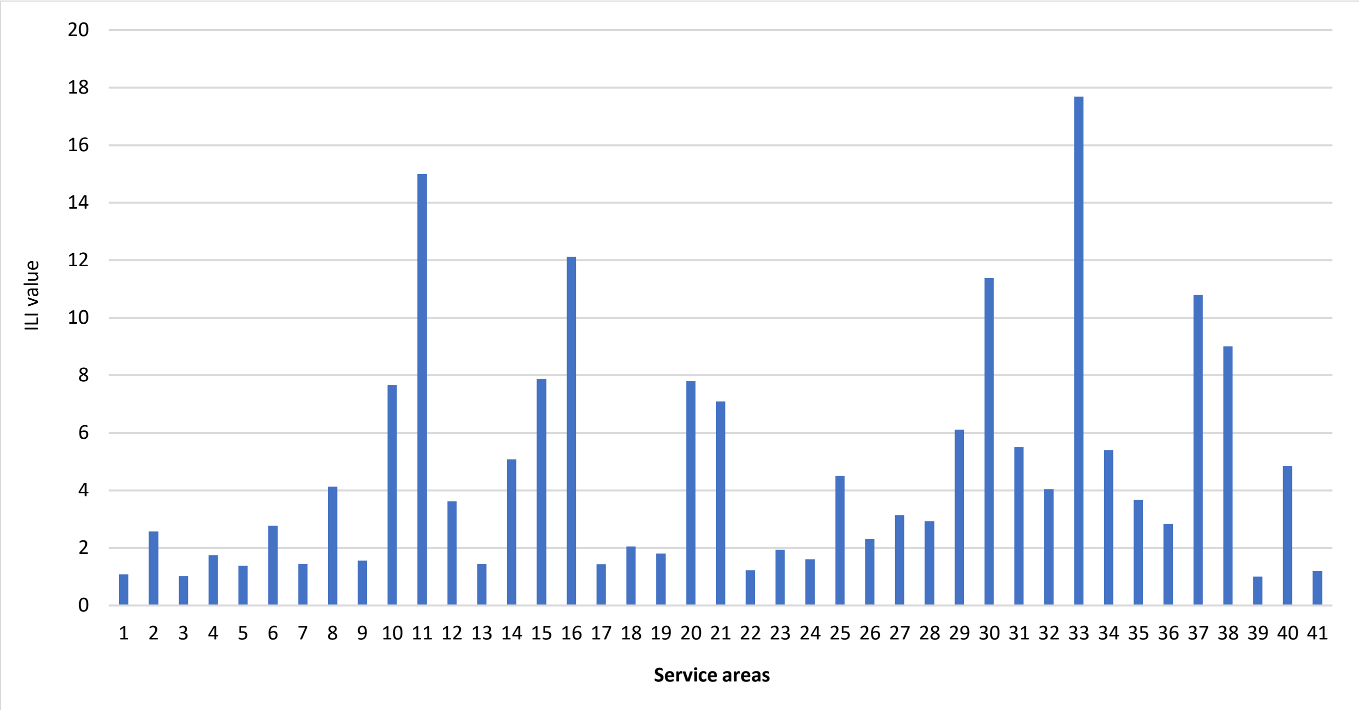


Figure 2.113. Distribution of the ILI value by the proposed service areas (41)

Table 2.28. 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	Cluster I	0	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective leakage management
		Cluster II	5		
		Cluster III	15		
		Cluster IV	36		
2 – 4	28	Cluster I	0	B	Possibilities for further improvement; consider pressure management, better active leakage control, better maintenance
		Cluster II	3		
		Cluster III	14		
		Cluster IV	11		
4 – 8	27	Cluster I	0	C	Poor leakage management, tolerable only if plentiful cheap resources; even then, analyse level and nature of leakage, intensify reduction efforts
		Cluster II	3		
		Cluster III	12		
		Cluster IV	12		
8 or more	16	Cluster I	1	D	Very inefficient use of resources, leakage reduction programs imperative and high priority
		Cluster II	3		
		Cluster III	4		
		Cluster IV	8		

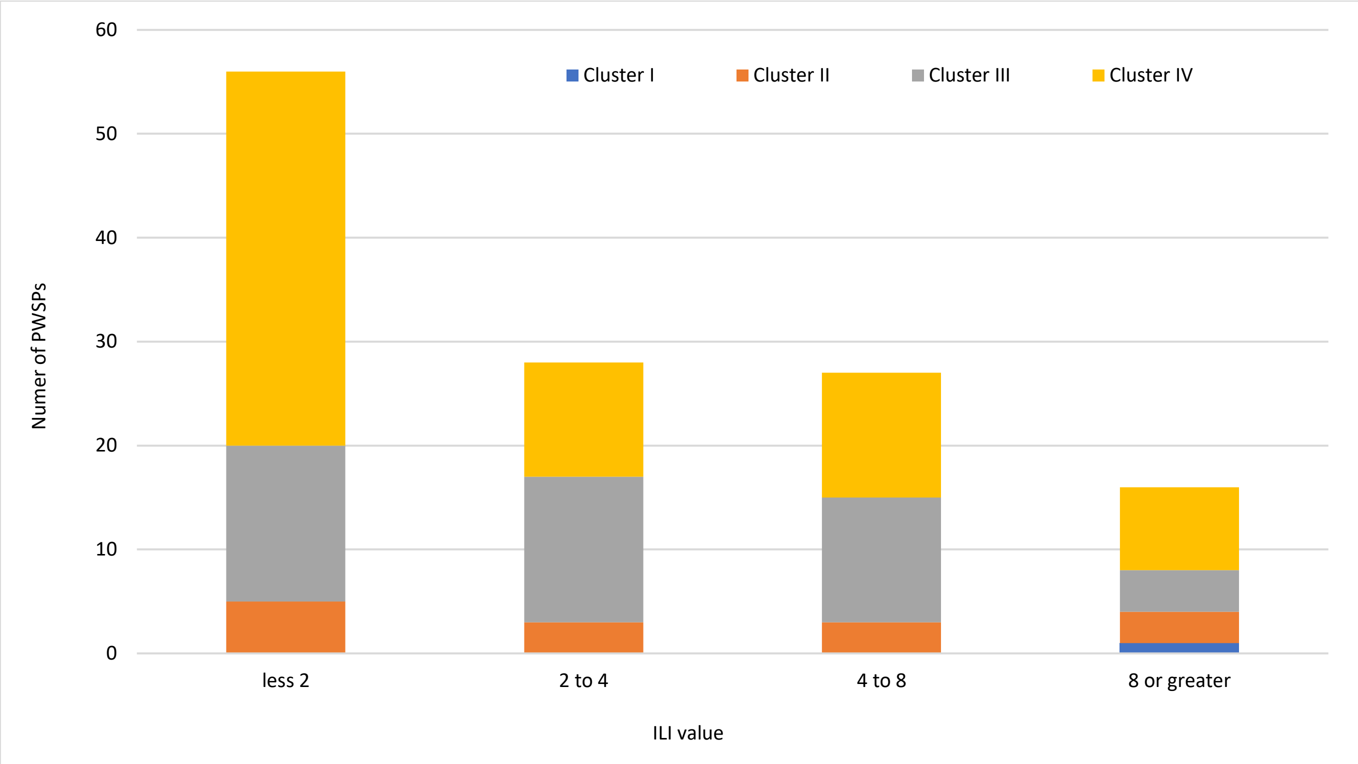


Figure 2.114. Water supply systems in Croatia grouped according to the ILI value

The ILI value can be associated with the NRW volumes by using the following expression which actually calculates the modified ILI value, giving importance to the ILI in relation to the NRW volumes as well:

$$ILI_{mod,PWSP} = ILI \cdot \frac{NRW_{PWSP} \cdot 1000}{NRW_{CRO,tot}}$$

Where: ILImod,PWSP – Modified ILI value for a particular PWSP; – The ILI for a particular PWSP defined before using the standard equation; NRWPWSP – NRW for a particular PWSP; NRWCRO,tot – Total NRW on the national level.

The modified (weighted) ILI value against the NRW volume is 10.5. So, in the majority of cases (according to the average ILI value on the national level of around 2.9) it is possible to confirm the conclusions that in the current status of management of the majority of water supply systems there is a potential for a general improvement and that it is necessary to consider implementation of additional pressure management, better active leakage control, and better management and maintenance of the entire system, or that there is poor leakage management and that these can be tolerated only if water is cheap and plentiful; even then, it is recommended to analyze the level and nature of leakage, and intensify efforts on their reduction.

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, Figure 2.116, which presents the relationship between the ILI and the average system pressure among the PWSPs in Croatia, contradicts such conclusions. One can notice that high ILI values are present even in systems with average pressures of below 5 bar.

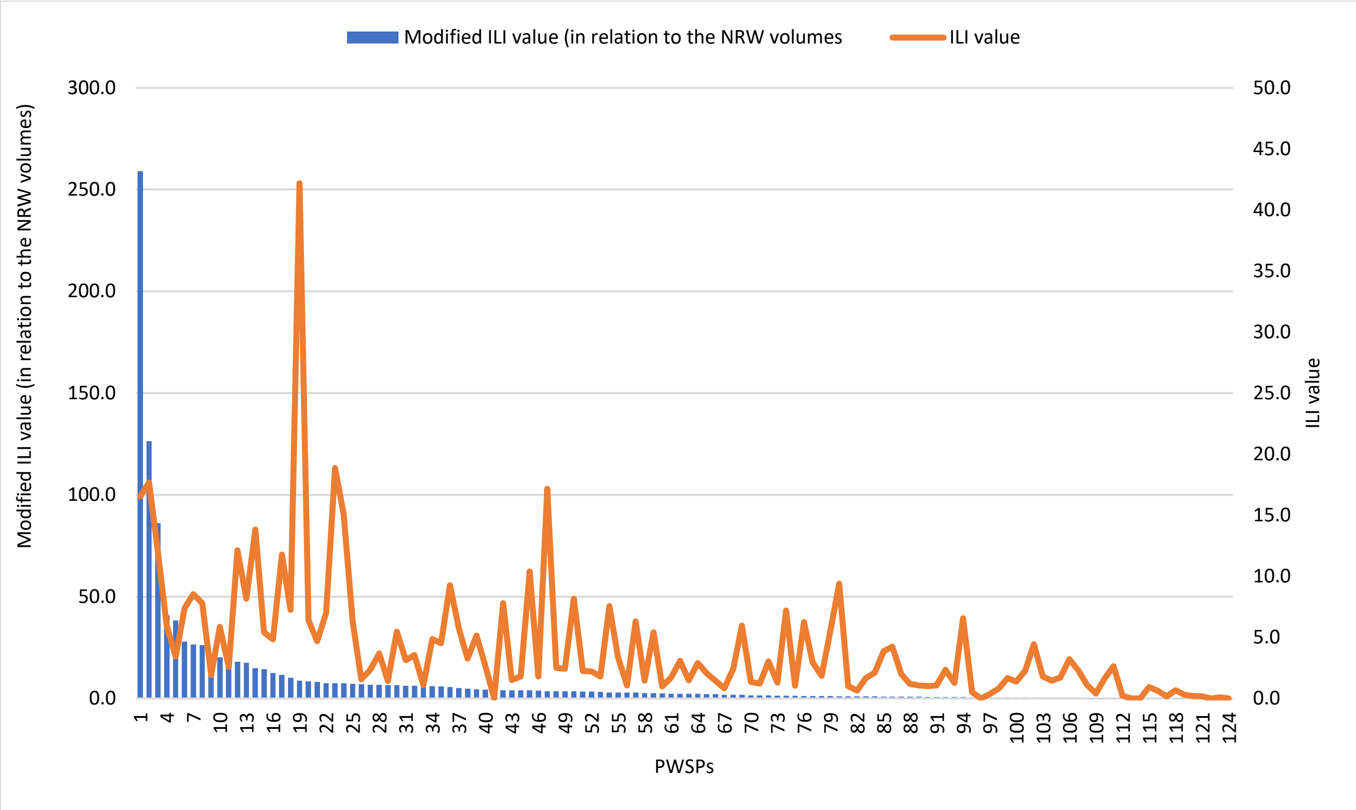


Figure 2.115. Relationship between the ILI and the modified ILI (in relation to the NRW volumes)

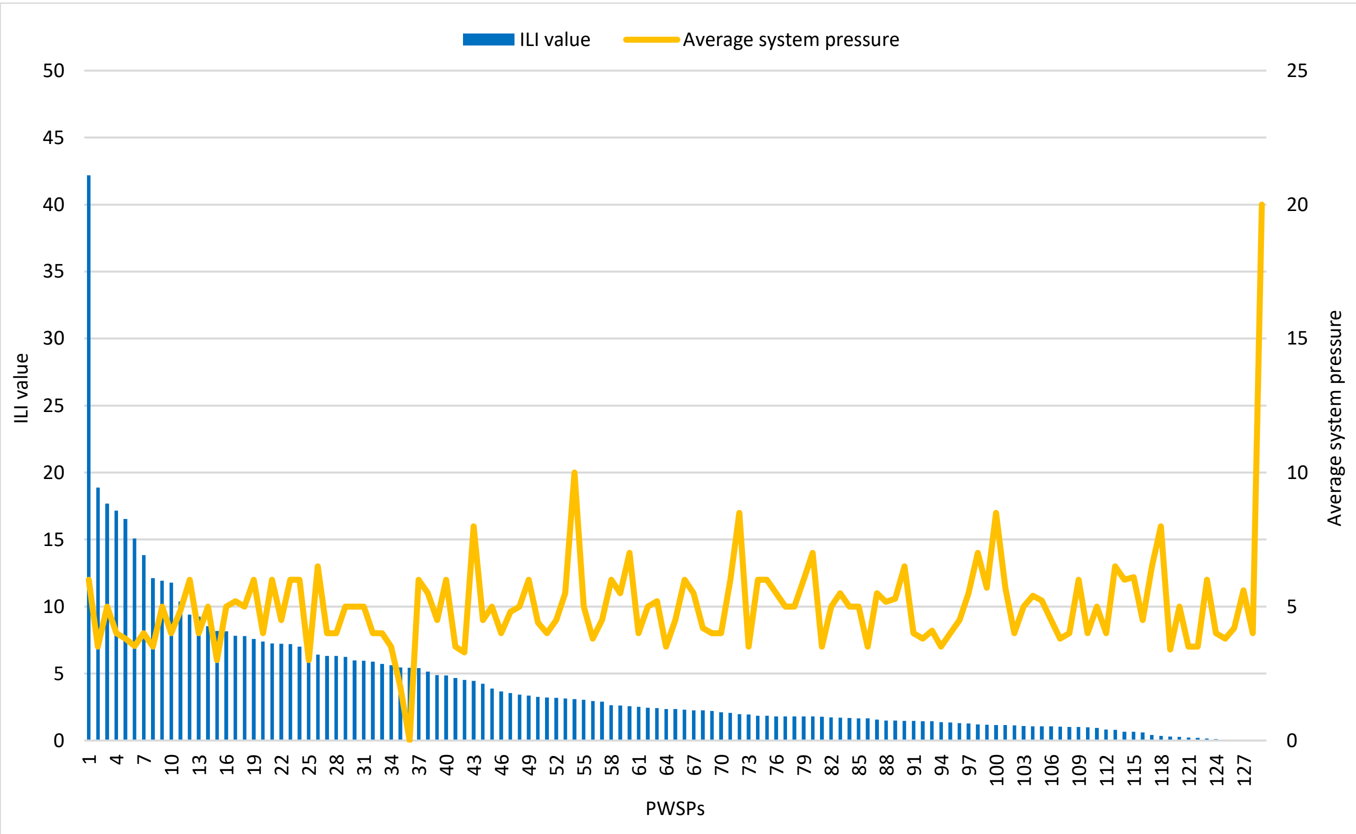


Figure 2.116. Relationship between the ILI and the average system pressure by individual PWSPs

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 2.117, 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 2.118. illustrates that some systems, although having a high share of the NRW, are characterized by low ILI values.

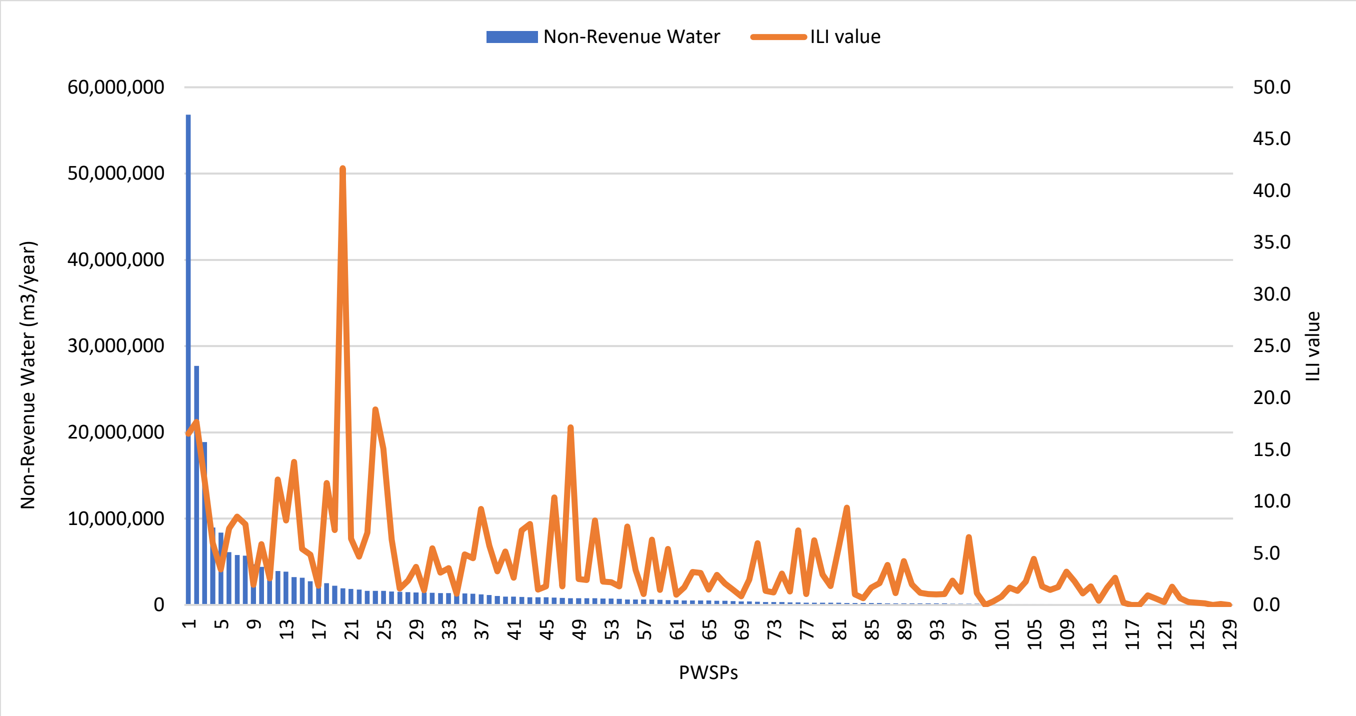


Figure 2.117. Relationship between the ILI and NRW in m³/year by individual PWSPs

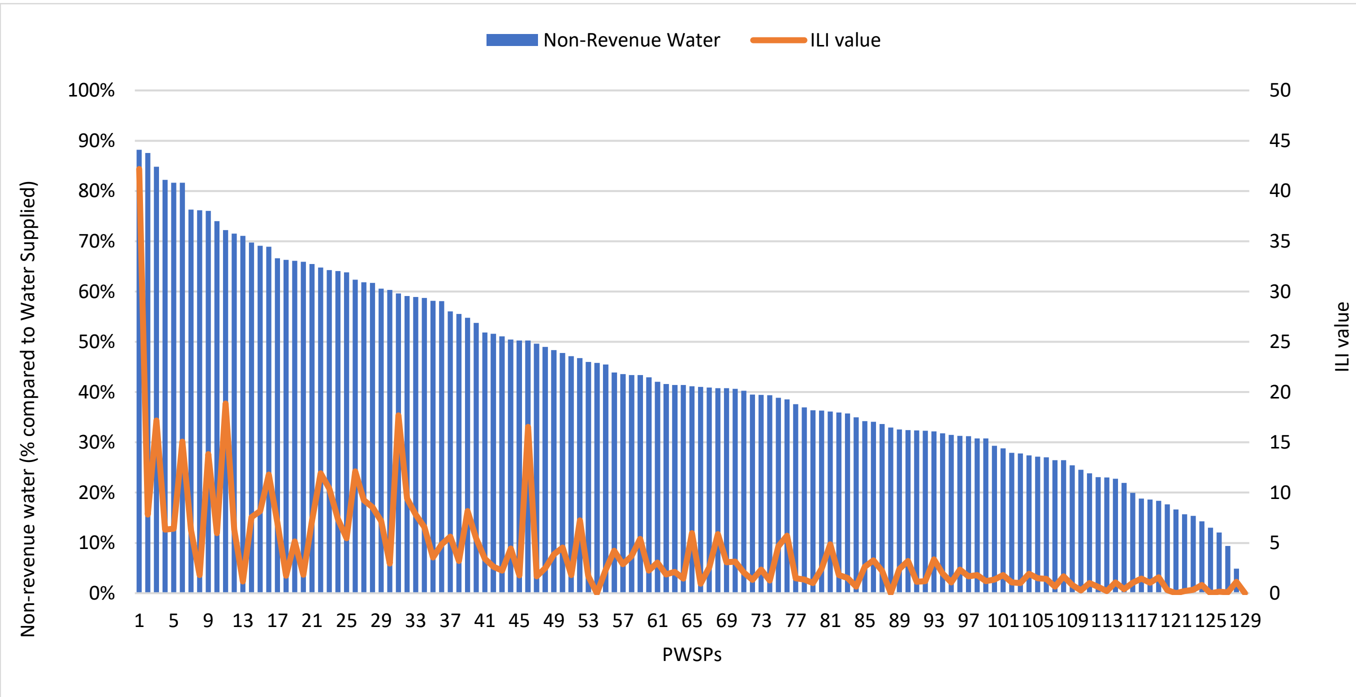


Figure 2.118. Relationship between the ILI and NRW in % (compared to Supplied Water) by individual PWSPs

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 Ordinance on the calculation and collection of the water usage fee (OG 36/20), 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. In order to fully understand the statement above, it is necessary to properly understand the method of calculating the ILI as well as the UARL, and the dependence of a change in leakage (real losses) on the change in pressure within the system. Namely, the UARL equation contains the value of average system pressure. By reducing the average pressure in a system, the resulting UARL is reduced, but so is the CARL.

Figure 2.119. presents the dependence of the ILI on the change in pressure at N1=0.75 for individual PWSPs in Croatia. One can notice that in PWSPs the ILI value increase with an increasing share of pressure reduction as the result of more intensive UARL reduction in relation to the CARL.

Figure 2.120. presents the dependence of the ILI on the change in pressure at N1=1.0 for individual PWSPs in Croatia. One can notice that in PWSPs the ILI value stagnates with an increasing share of pressure reduction as the result of equally intensive reduction of the UARL and the CARL

Figure 2.121. presents the dependence of the ILI on the change in pressure at N1=1.25 for individual PWSPs in Croatia. One can notice that in PWSPs the ILI value decreases with an increasing share of pressure reduction as the result of more intensive reduction of the UARL reduction in relation to the CARL.

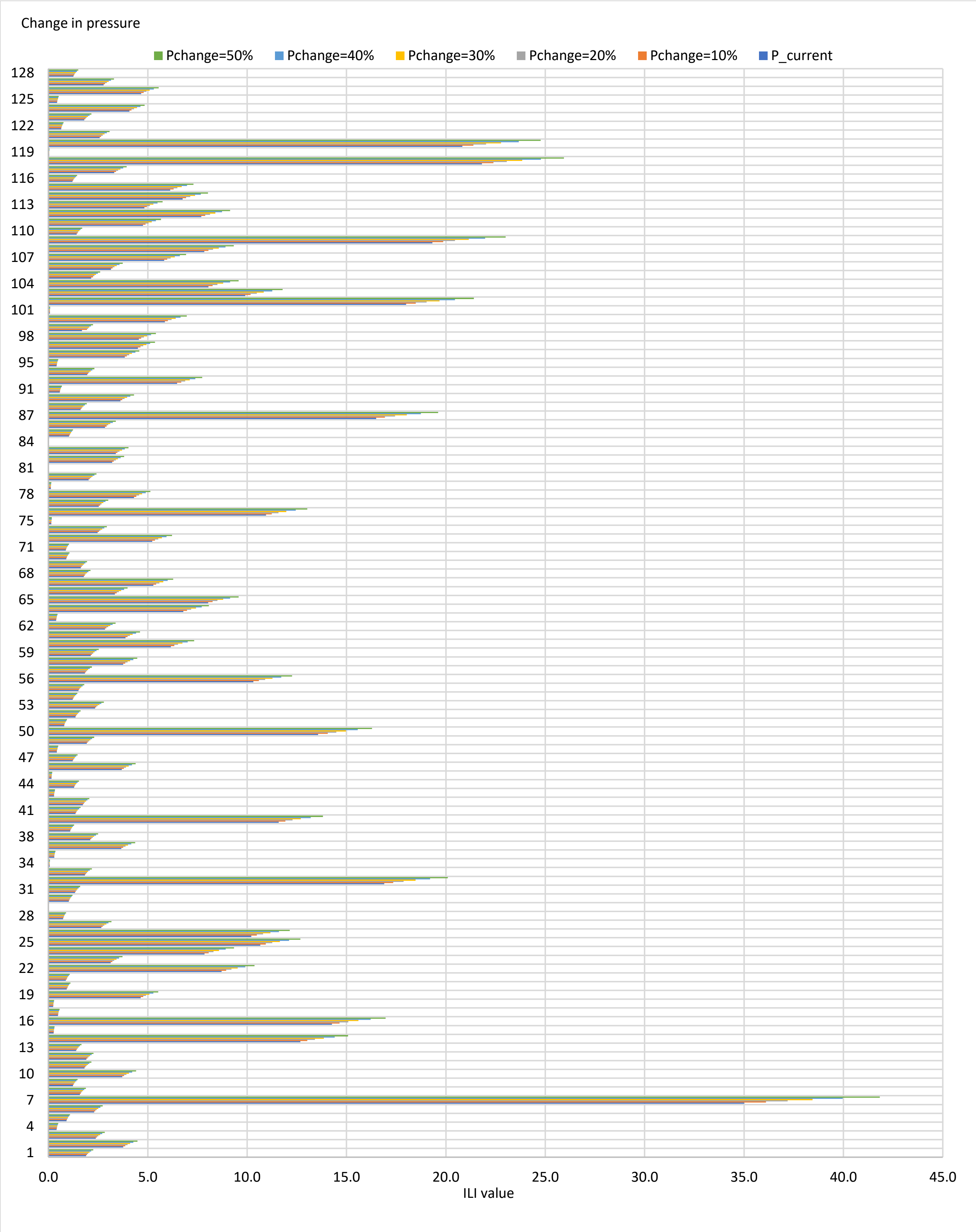


Figure 2.119. Dependence of the ILI on the change in pressure at N1=0.75 for individual PWSPs

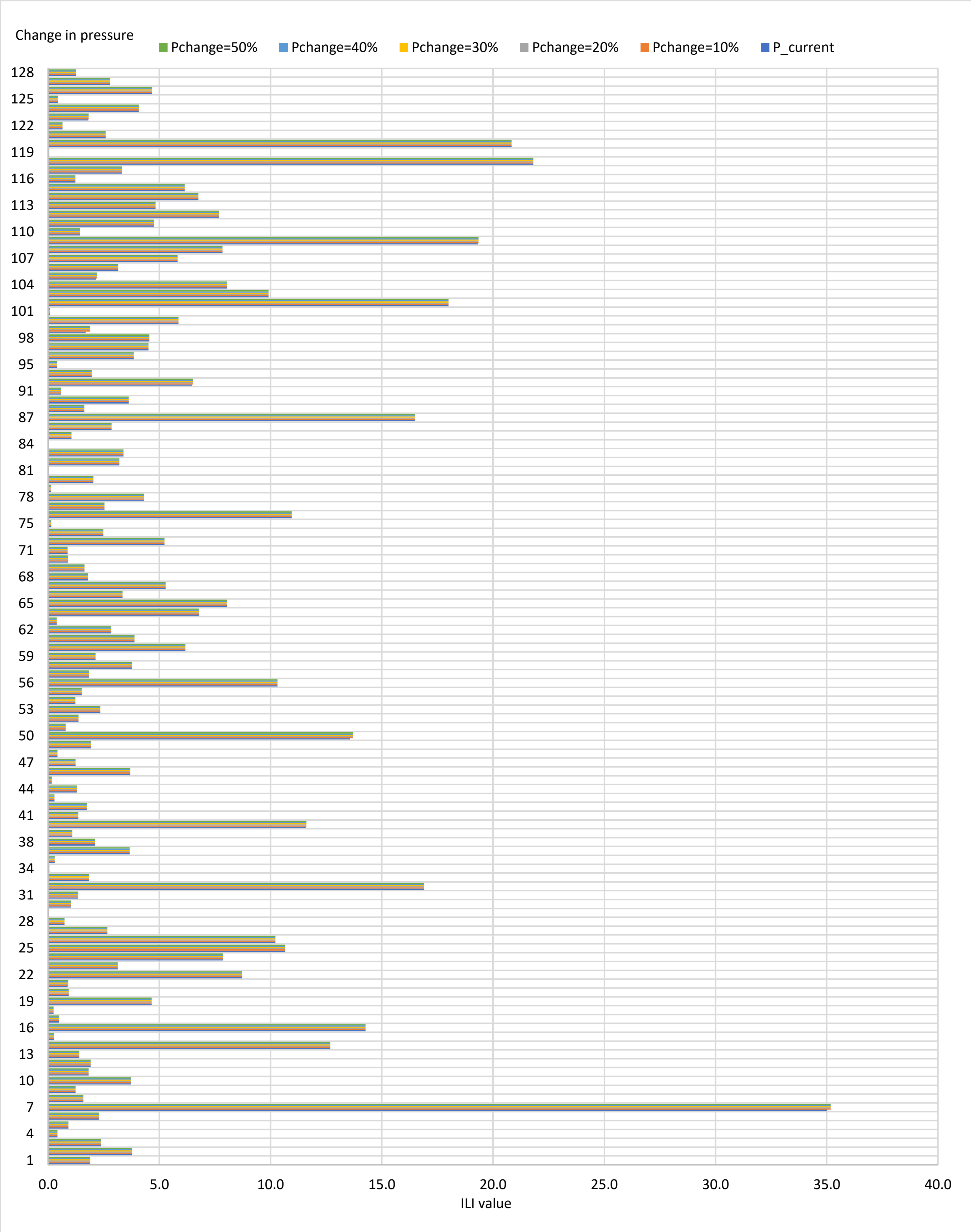


Figure 2.120. Dependence of the ILI on the change in pressure at N1=1.00 for individual PWSPs

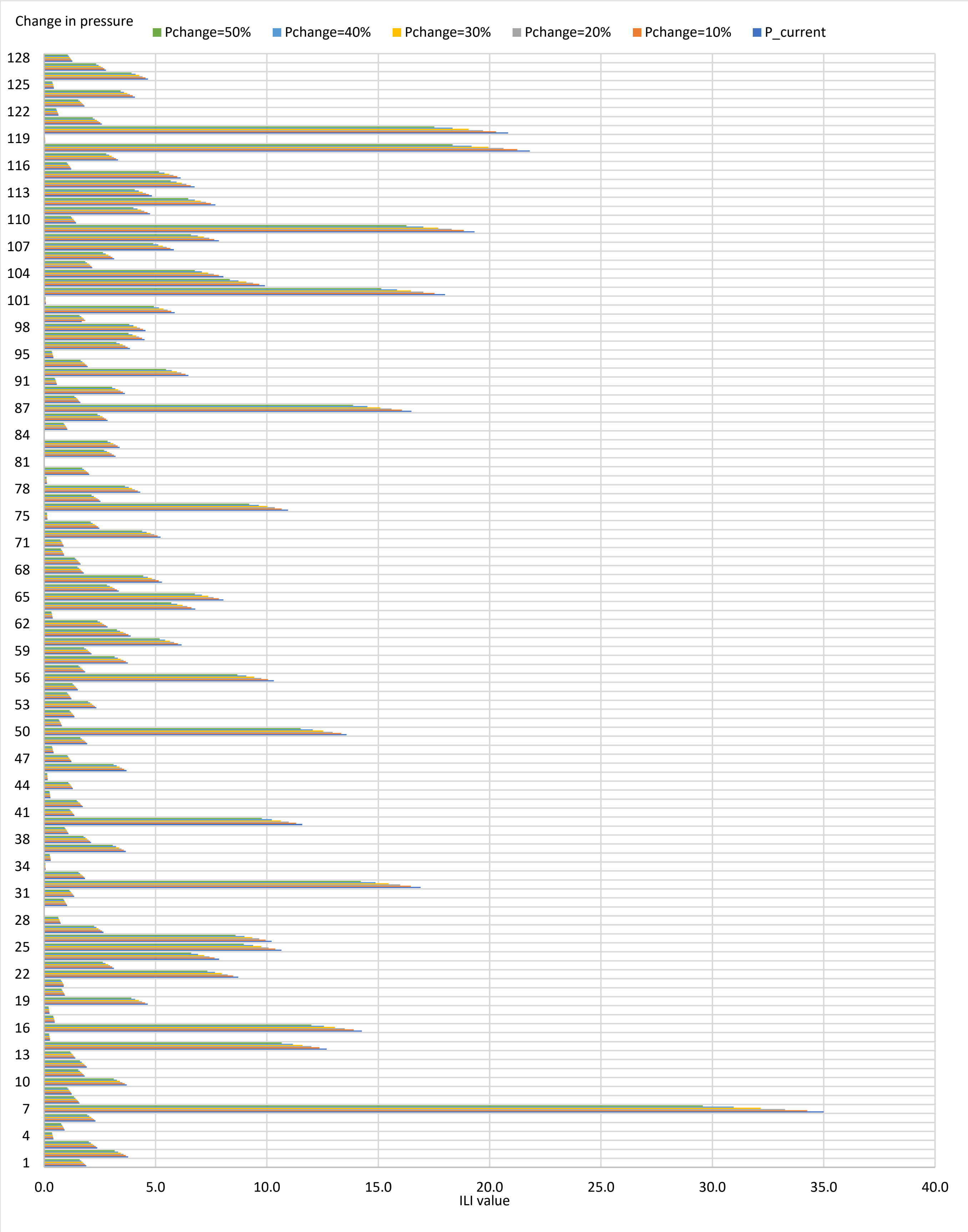


Figure 2.121. Dependence of the ILI on the change in pressure at N1=1.25 for individual PWSPs

The practice so far, since more intensive application of the IWA methodology started in Croatia, 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.

Not rarely, the ILI fails to give the real picture of water losses due to specific topographic features, incorrect calculation of the UARL, wrongly defined water balance components or other technical characteristics of the water supply system. For example, certain systems can have small shares of the NRW and real losses, but can have a very high ILI value which incorrectly indicates that the efficiency in water loss management is very low. Likewise, certain systems can have high volumes (shares) of the NRW and real losses, but can have a very low ILI value which incorrectly indicates that the efficiency in water loss management is very good and that additional improvement measures are not justified.

Also, comparing the ILIs in relative terms can also give a wrong picture about the state of water losses. For example, if for an analysed water supply system the ILI is calculated with a value of 4.5 and it is compared with other water supply systems within a benchmarking system (Figure 2.112), a PWSP might reach a conclusion that its system is average compared to the others, which is not that bad. If the calculated ILI value is accidentally just a little bit above the average, a conclusion might also be made that it’s not so bad and that the PWSP is relatively efficiently managing its own system (in terms of water losses).

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

Likewise, 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 analyses of the ILI values calculated before need to be treated carefully. It is recommended to make additional analyses to confirm how efficient a PWSP is in managing the issue of water losses.

2.5.2 Other performance indicators

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; m^3/km/h).

Figure 2.123. presents the distribution of unit values of the Real Losses in liters/service connection/day by individual PWSPs in Croatia, while Figure 2.124. presents their distribution by the service areas.

Figure 2.127. presents the distribution of unit values of the Real Losses in m^3/km of mains/hour by individual PWSPs in Croatia, while Figure 2.128. presents their distribution by the service areas.

Figure 2.131. 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 2.132. presents their distribution by the service areas.

In Table 2.29. and Figure 2.125. the water supply systems in Croatia are grouped by the unit values of Real Losses in liters/service connection/day.

In Table 2.30. and Figure 2.129. the water supply systems in Croatia are grouped by the unit values of Real Losses in m^3/km of mains/hour.

In Table 2.31. and Figure 2.133. the water supply systems in Croatia are grouped by the unit values of Real Losses in liters/service connection/day/m of pressure.

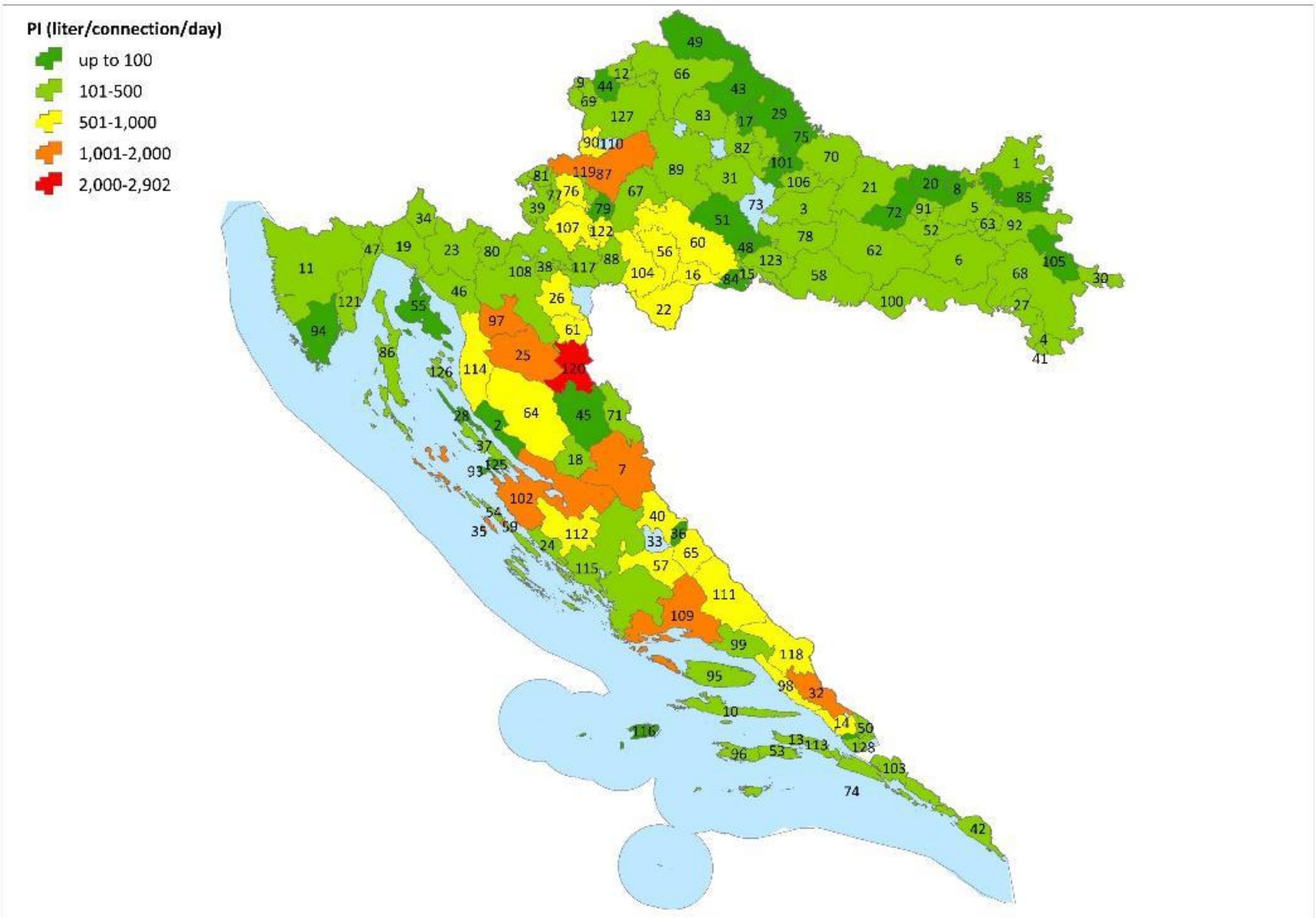


Figure 2.122. Calculated unit values of Real Losses in liters/service connection/day, by individual PWSPs (with IDs)

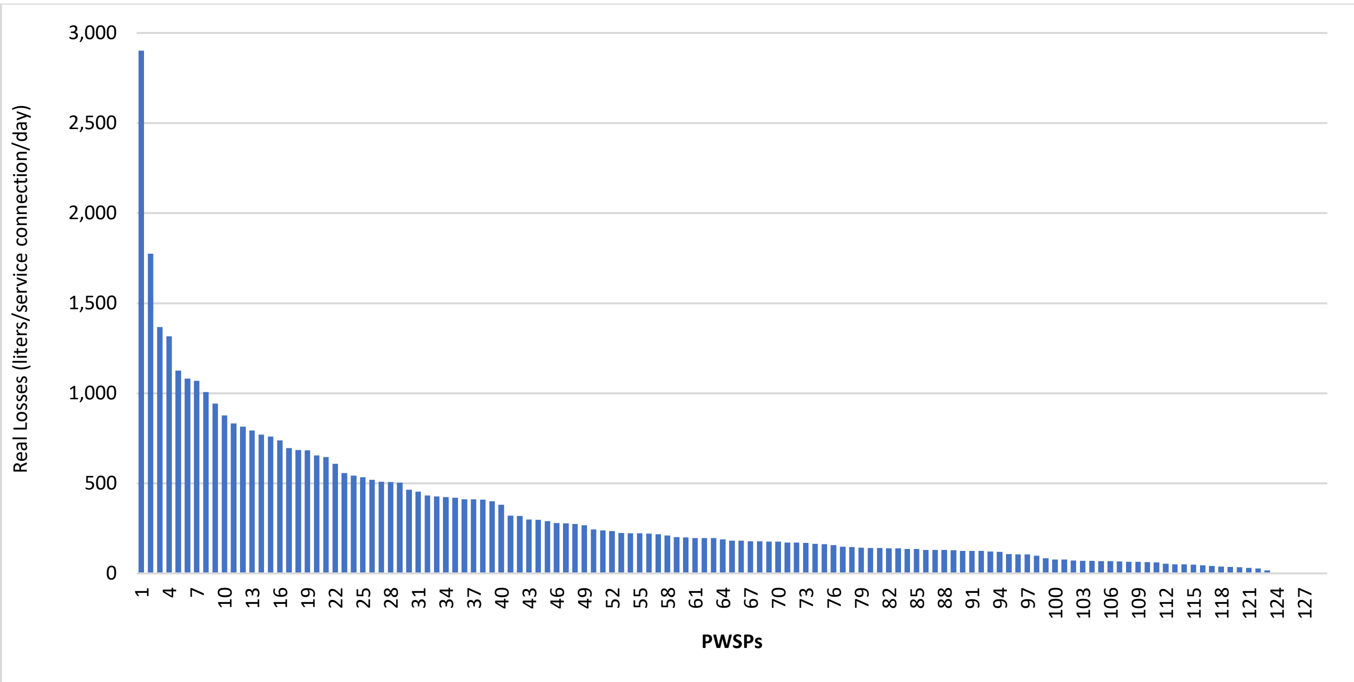


Figure 2.123. Distribution of unit values of Real Losses in liters/service connection/day, by individual PWSPs

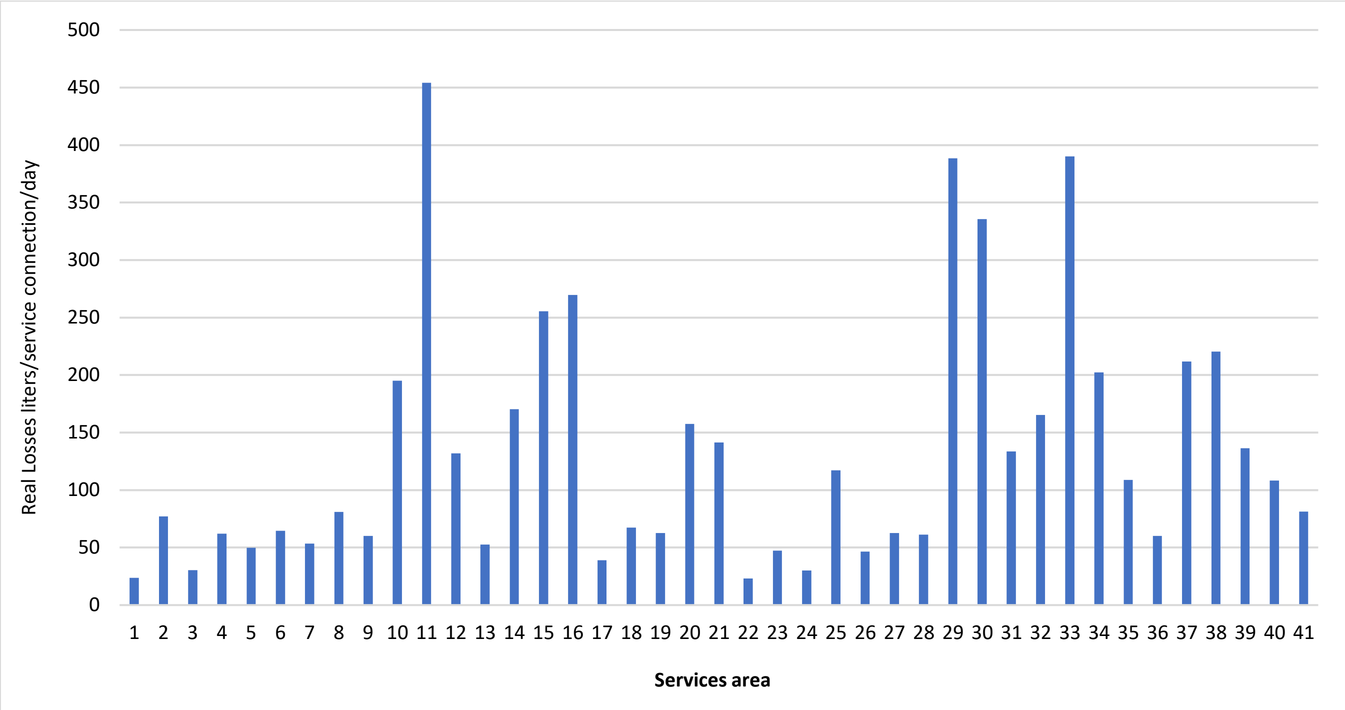


Figure 2.124. unit values of Real Losses in liters/service connection/day

Table 2.29. Water supply systems in Croatia grouped by the unit values of Real Losses in l/service connection/day

Unit Real Loss range (l/service connection/day)	NUMBER OF PWSPs IN CROATIA ACCORDING TO UNIT REAL LOSS (l/service connection/day)		
< 100	30	Cluster I	0
		Cluster II	2
		Cluster III	7
		Cluster IV	21
100 – 500	68	Cluster I	0
		Cluster II	8
		Cluster III	33
		Cluster IV	27
500 – 1000	21	Cluster I	0
		Cluster II	0
		Cluster III	10
		Cluster IV	11
1000 or more	8	Cluster I	1
		Cluster II	2
		Cluster III	0
		Cluster IV	5

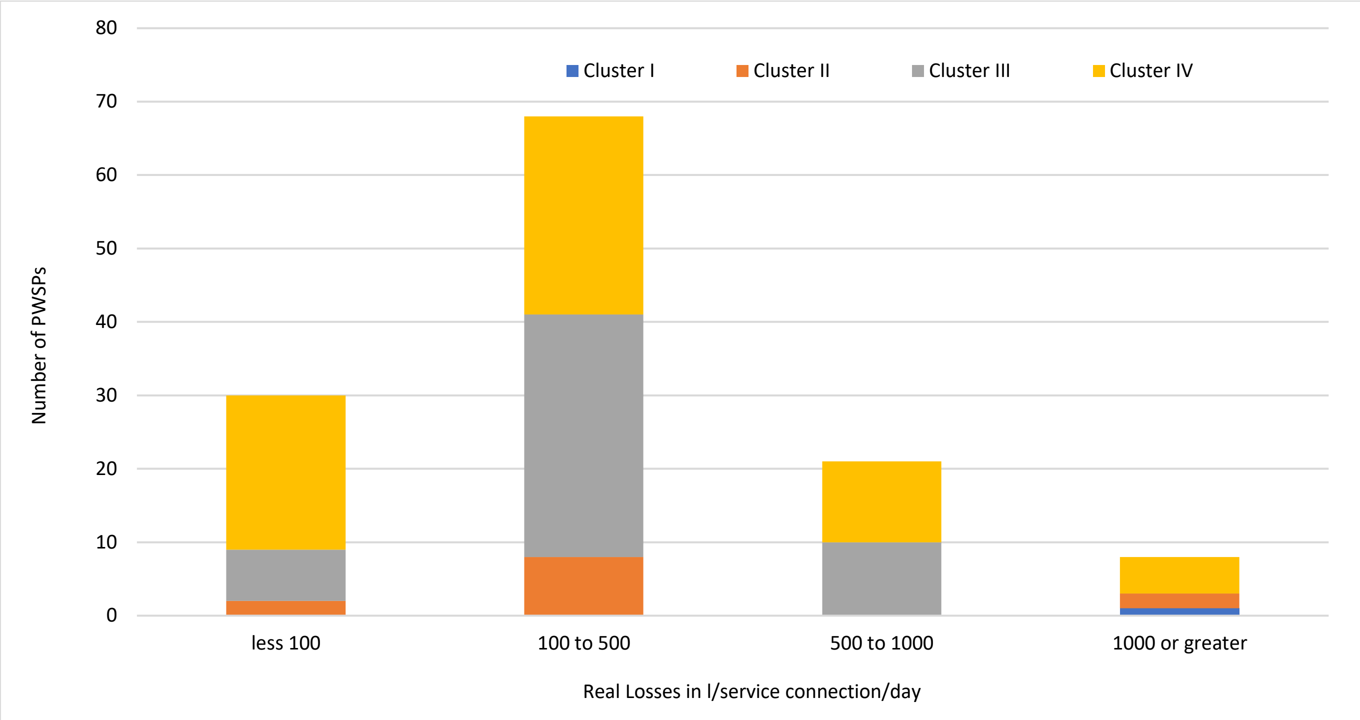


Figure 2.125. Water supply systems in Croatia grouped by the unit values of Real Losses in l/service connection/day

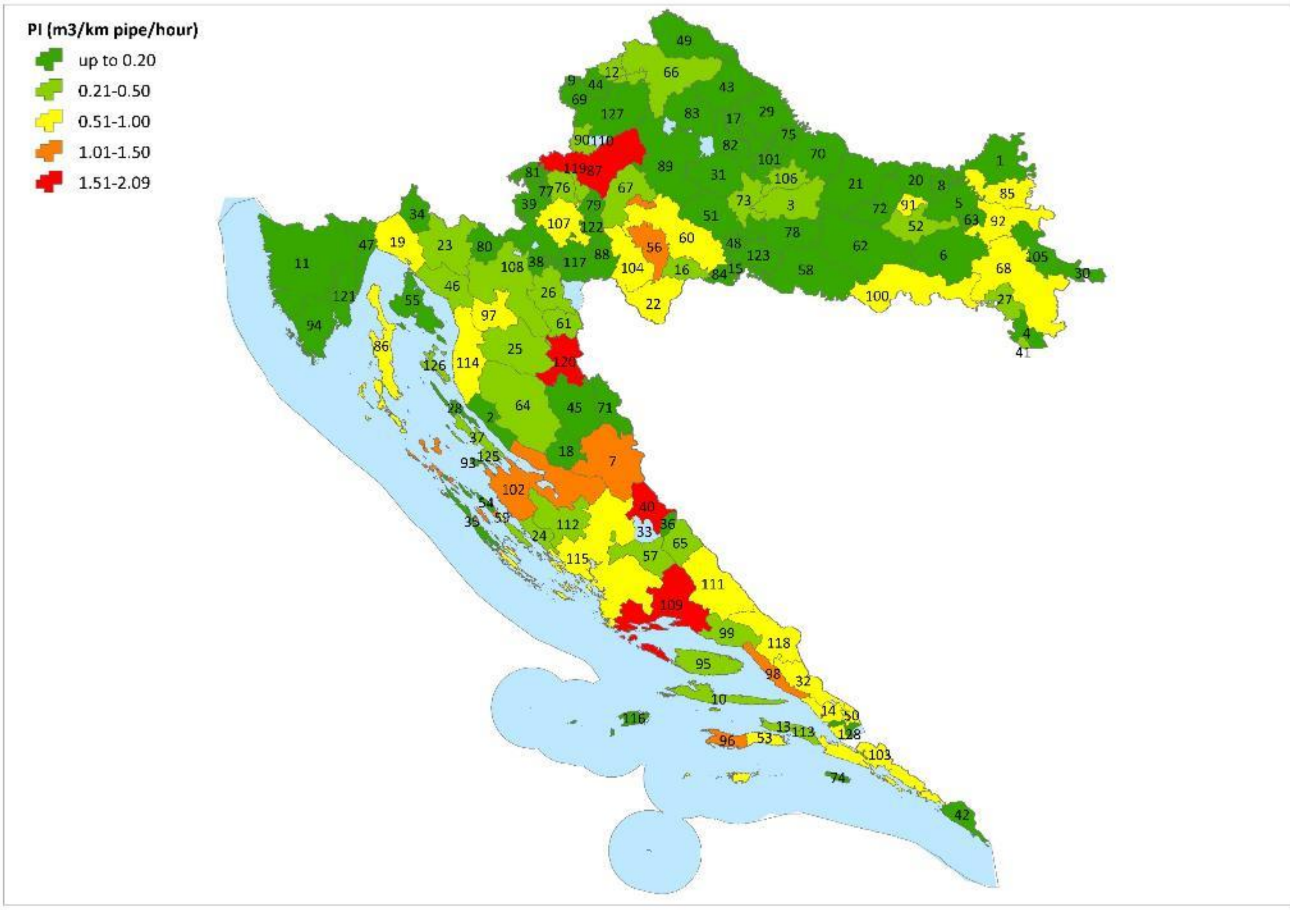


Figure 2.126. Calculated unit values of Real Losses in m³/km of mains/hour, by individual PWSPs

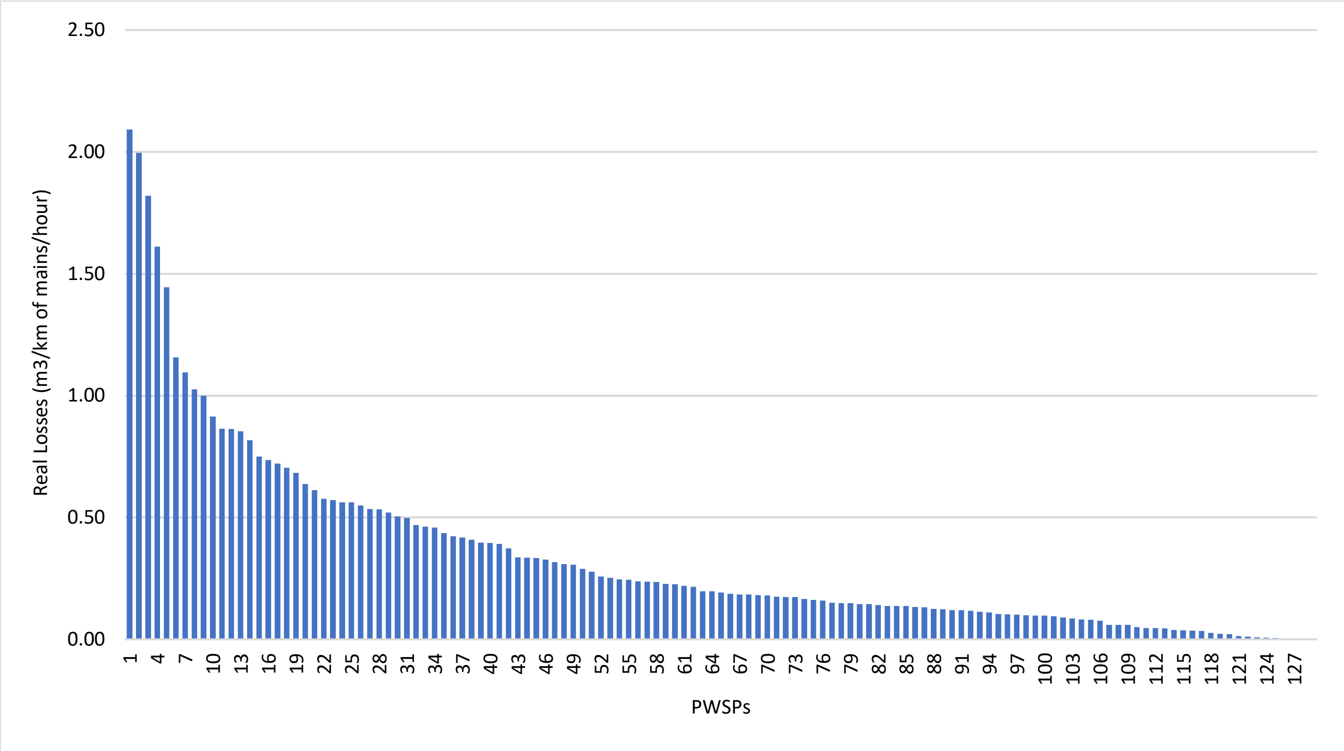


Figure 2.127. Distribution of unit values of Real Losses in m³/km of mains/hour, by individual PWSPs

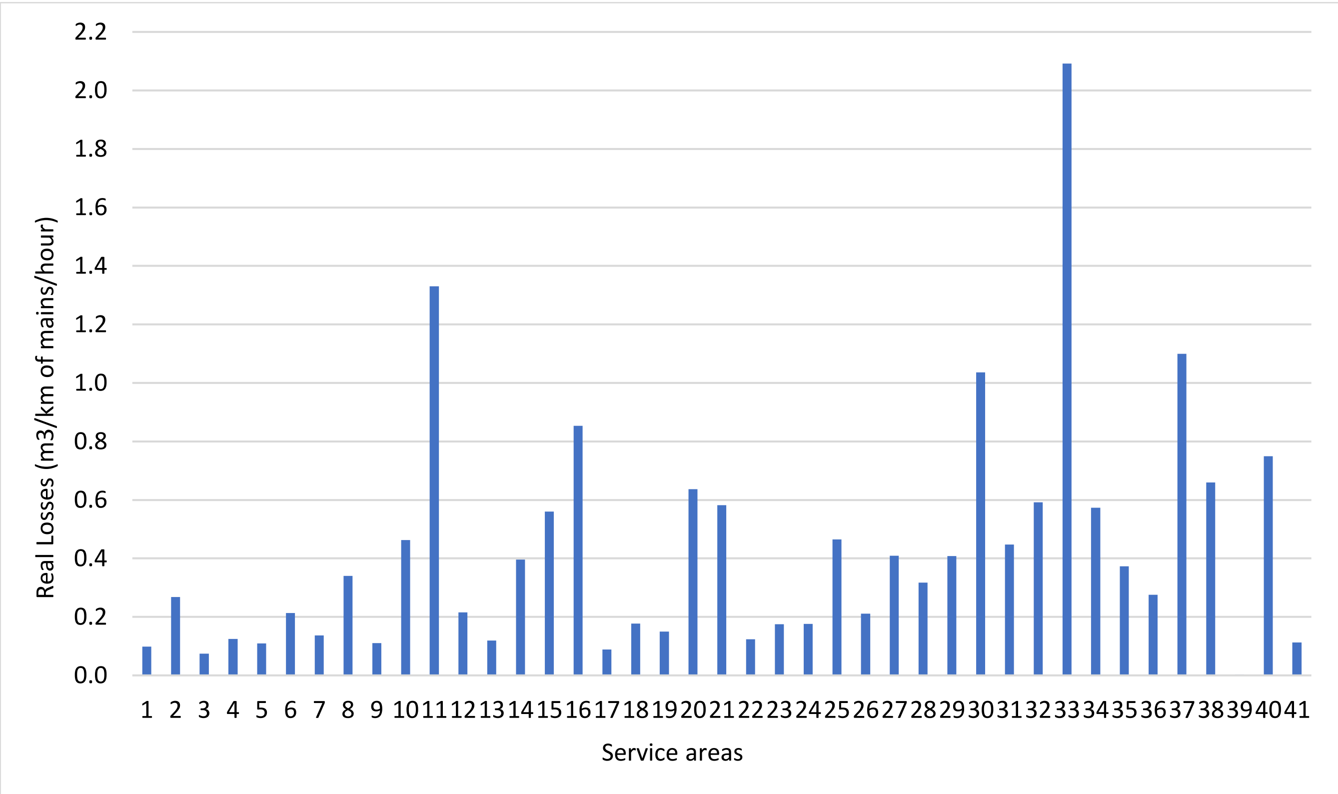


Figure 2.128. Distribution of unit values of Real Losses in m³/km of mains/hour, by service areas

Table 2.30. Water supply systems in Croatia grouped by the unit values of Real Losses in m³/km of mains/hour

Unit Real Loss range (m³/km of mains/hour)	NUMBER OF PWSPs IN CROATIA ACCORDING TO UNIT REAL LOSS (m³/km of mains/hour)		
< 0.2	63	Cluster I	0
		Cluster II	4
		Cluster III	21
		Cluster IV	38
0.2 - 0.5	32	Cluster I	0
		Cluster II	1
		Cluster III	18
		Cluster IV	13
0.5 - 1.0	22	Cluster I	0
		Cluster II	5
		Cluster III	8
		Cluster IV	9
1.0 or more	9	Cluster I	1
		Cluster II	2
		Cluster III	3
		Cluster IV	3

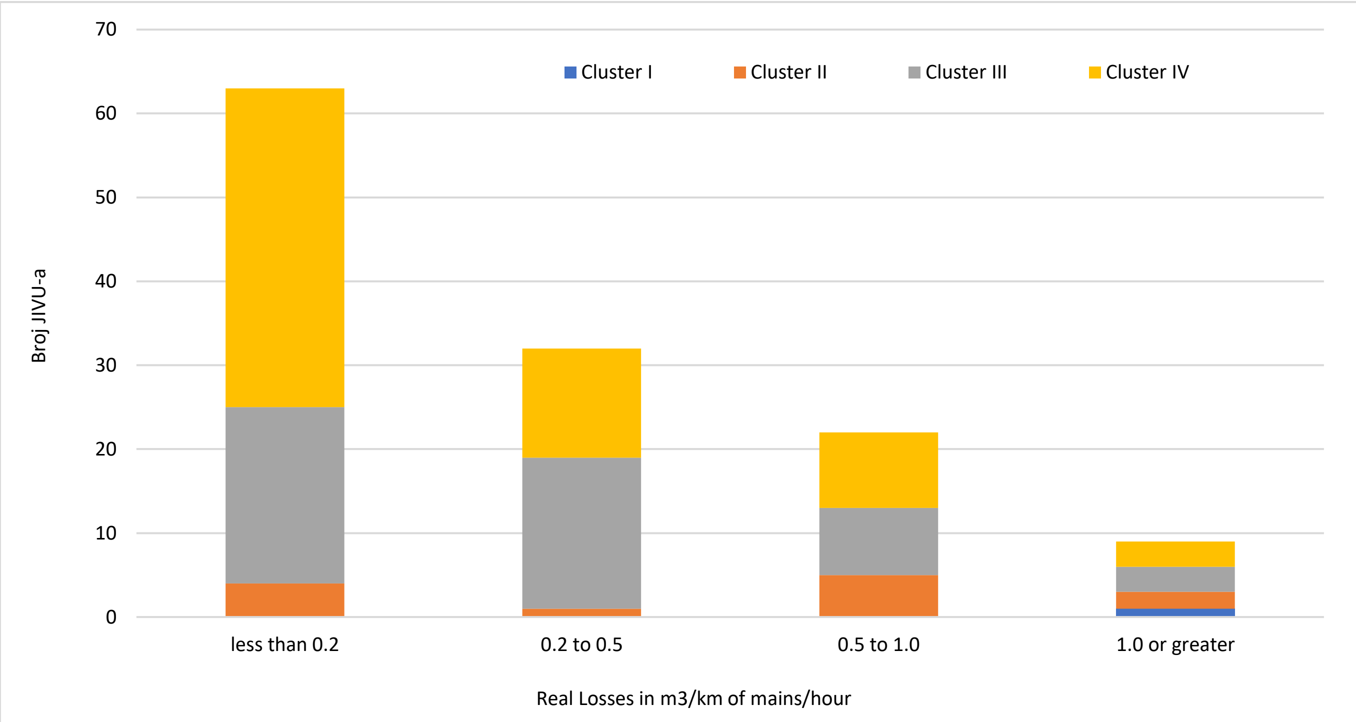


Figure 2.129. Water supply systems in Croatia grouped by the unit values of Real Losses in m³/km of mains/hour

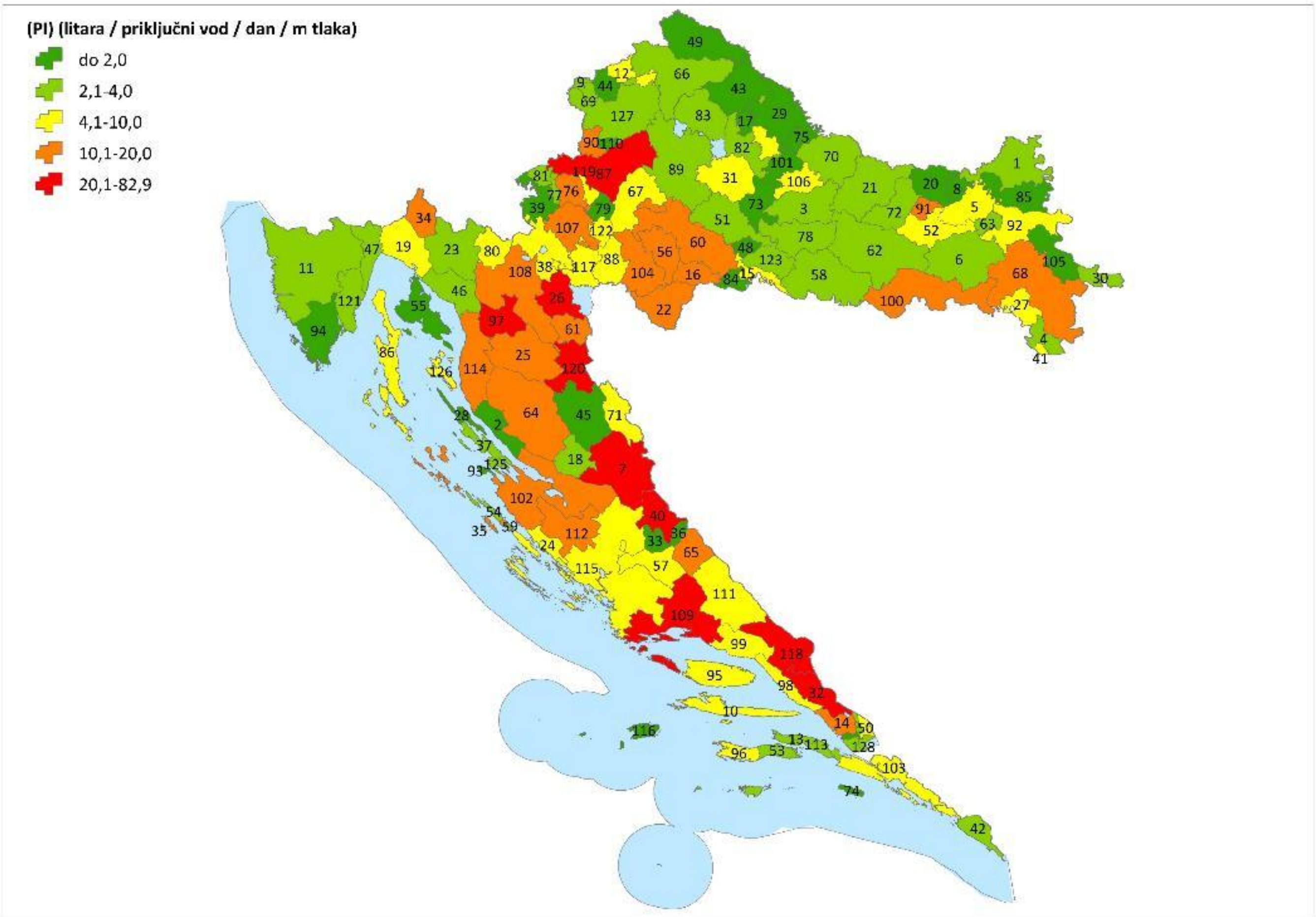


Figure 2.130. Calculated unit values of Real Losses in liters/service connection/day/m of pressure, by individual PWSPs (with IDs)

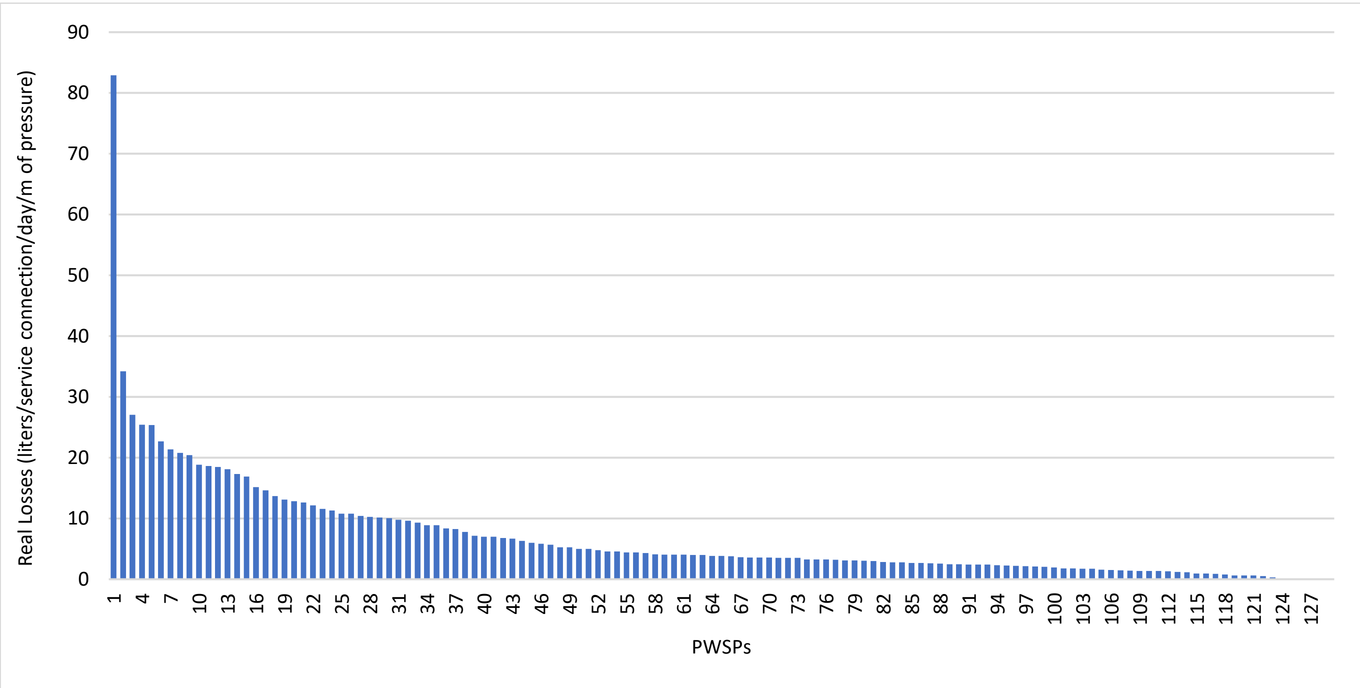


Figure 2.131. Distribution of unit values of Real Losses in liters/service connection/day/m of pressure, by individual PWSPs

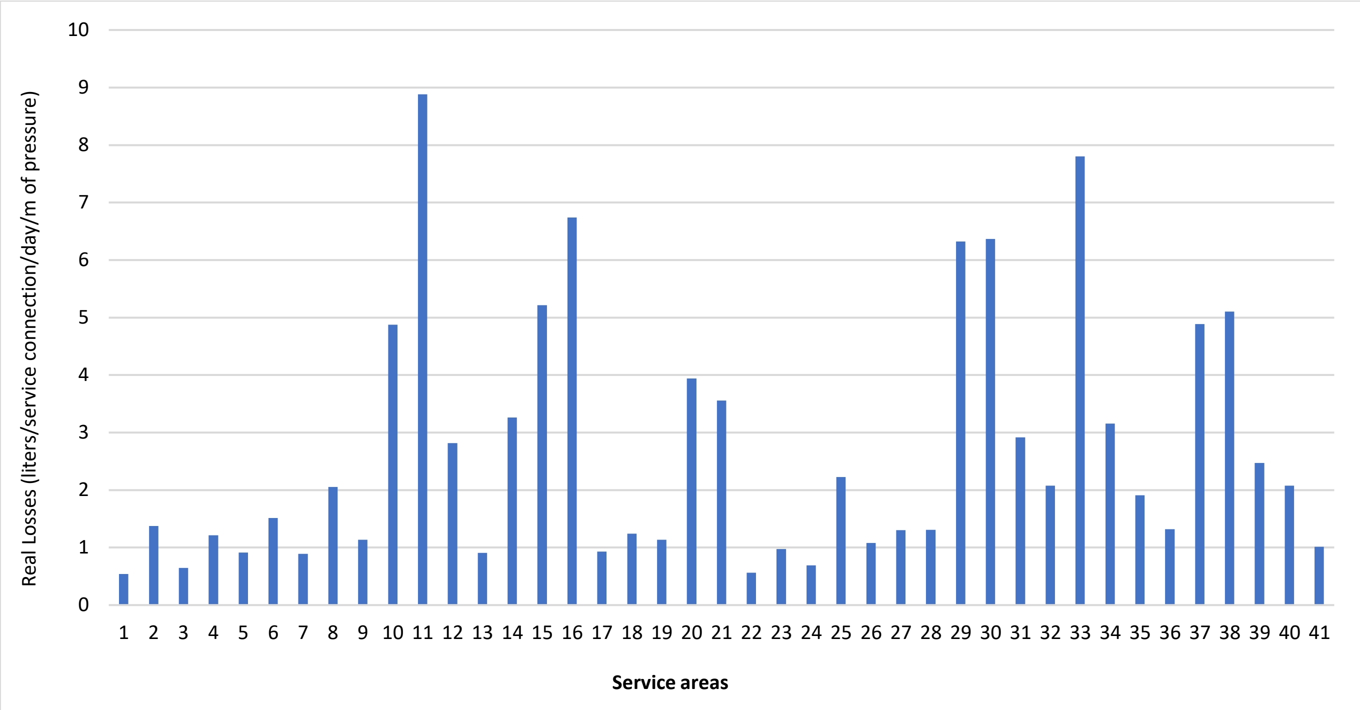


Figure 2.132. Distribution of unit values of Real Losses in liters/service connection/day/m of pressure, by service areas

Table 2.31. Water supply systems in Croatia grouped by the unit values of Real Losses in l/service connection/day/m of pressure

Unit Real Loss range (l/service connection/day/m of pressure)	NUMBER OF PWSPs IN CROATIA ACCORDING TO UNIT REAL LOSS (l/service connection/day/m of pressure)		
< 2	28	Cluster I	0
		Cluster II	2
		Cluster III	7
		Cluster IV	19
2 – 4	38	Cluster I	0
		Cluster II	3
		Cluster III	17
		Cluster IV	18
4 – 16	46	Cluster I	0
		Cluster II	5
		Cluster III	23
		Cluster IV	18
16 or more	15	Cluster I	1
		Cluster II	2
		Cluster III	3
		Cluster IV	9

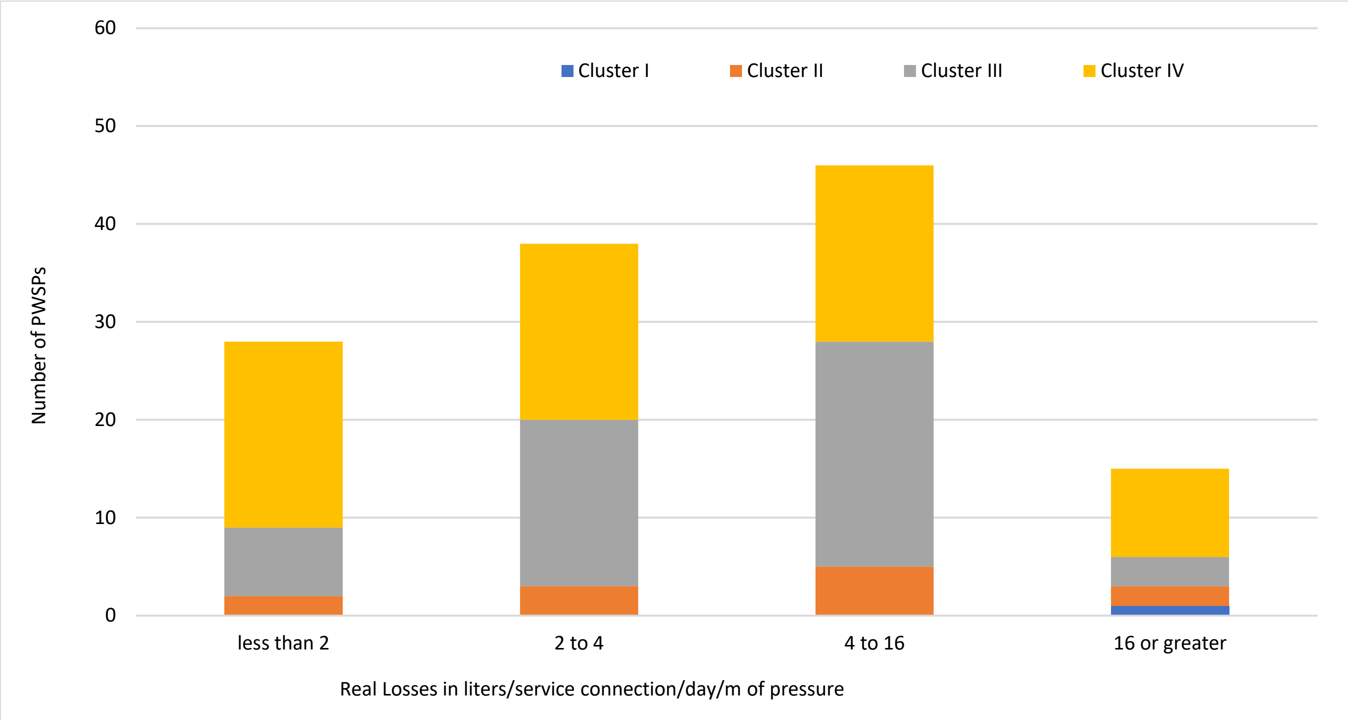


Figure 2.133. Water supply systems in Croatia grouped by the unit values of Real Losses in l/service connection/day/m of pressure

2.6 Review of findings from existing project documentation

The reduction of water losses can be achieved through numerous procedures: psychological; regulation of pressures; improvement and regular maintenance of water meters and other metering equipment (flow and pressure meters), their proper reading; noticing illegal connections; implementation of active leakage control with timely detection and identification of micro-locations of leakages; but first of all through physical procedures which include direct reduction of leakage at bursts or joints on the water supply network, and reconstruction and replacement of mains. In doing so, account needs to be taken of the causes of the occurrence of water losses, the volume of losses, where they are generated, the possibility for their removal or reduction, and the method of monitoring water losses and keeping them within acceptable limits.

Defining quality responses to the above questions for each PWSP, as well as subsequent improvement measures for integrated water supply systems aimed at reducing water losses and keeping them at an acceptable level depends to a large extent on the preparation of quality studies and project documentation.

From the second half of the 1990s all the way until around 2010, the County Water Supply Plans were intensively prepared. Their purpose was to define the needs for system extensions, reconstruction of the existing network in terms of potential need to increase capacities, construction of new structures to provide sufficient water volumes and achieve efficient transport of the required volumes to final consumers. The County Water Supply Plans were only to a small extent focused on water loss reduction measures.

More intensive preparation of studies in Croatia which included detailed surveys of the current status and water loss reduction measures started with the launch of the National Water Loss Reduction Program (NWLRP) by the competent Ministry and Croatian Waters in early 2018 (see Chapter 2.6.2). Recognizing the extent of the issue of water losses in water supply systems in Croatia by the competent state institutions, together with providing certain financial resources and publishing “Call to Co-Finance Reduction of Losses in Water Supply Systems in Croatia”, presents an extremely positive segment in the practice so far, aimed at starting with long-term establishment of sustainable management of water supply systems.

Conceptual solutions

One of the basic measures within the NWLRP (Measure A) is the preparation of conceptual solutions for extension and improvement of water supply systems with the development of mathematical models of the current and planned status and pre-feasibility studies, with a primary focus on water loss reduction. Conceptual solutions were prepared and are currently being prepared for individual PWSPs, i.e., for water supply areas managed by individual PWSPs. 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.

For systems or parts of systems for which data about the current status is missing, all the relevant data (field visits, geodetic surveys, surveying shafts and other installed equipment, identification of technical characteristics of individual elements, etc.) is collected during the preparation of conceptual solutions. The definition of quality measures for improvement of the existing water supply systems largely depends on a meaningful and thorough description of the current status which includes a realistic outline of all relevant factors (characteristics of the mains network – routes, profiles, materials, roughness, age, etc.; and supporting structures – storage tanks, pumping stations, regulation equipment, etc.) and an analysis of water losses within the system in the current status. It is only on the basis of a comprehensive analysis of a system, including water losses, that it is possible to reach quality conclusions which will within the definition of measures for sustainable system management (optimization of operation and extension in terms of improvements) result in economical spending of available financial resources.

During the preparation of conceptual solutions, the prepared detailed analysis of the current status is the basis for the preparation of a preliminary mathematical model of the current status of the complete system the purpose of which is tp identify the basic hydraulic patterns in the system and prepare high-quality plan and program of field measurements (flows, pressures, and water sampling including the identification of residual chlorine). The measurement plan and program divides the system into preliminary DMAs, in which continuous measurement of flows and pressure takes place over a period of 3 to 7 days. The number of flow and pressure measurements in individual conceptual solutions varies significantly, particularly if the conceptual solutions prepared before the year 2018 are compared to those prepared after that within the NWLRP. In the period until 2018 the number of measurements per the length of mains network was lower, sometimes even significantly lower, while in some conceptual solutions flow and pressure measurements weren't done at all. Even in the period after 2018, the number of flow and pressure measurements by individual systems varies and is mostly not correlated with the system size. The number of flow and pressure measurements that the consultants preparing the conceptual solutions were obliged to make was defined in the Terms of Reference (ToR) for the preparation of conceptual solutions. The preparation of ToR most often wasn't preceded by a detailed analysis of the current status with the aim to identify the optimum number of measurements. For some systems, the required number of flow and pressure measurements increased later on during the preparation of conceptual solutions themselves, necessitated by the real needs after the detailed analysis of the current status.

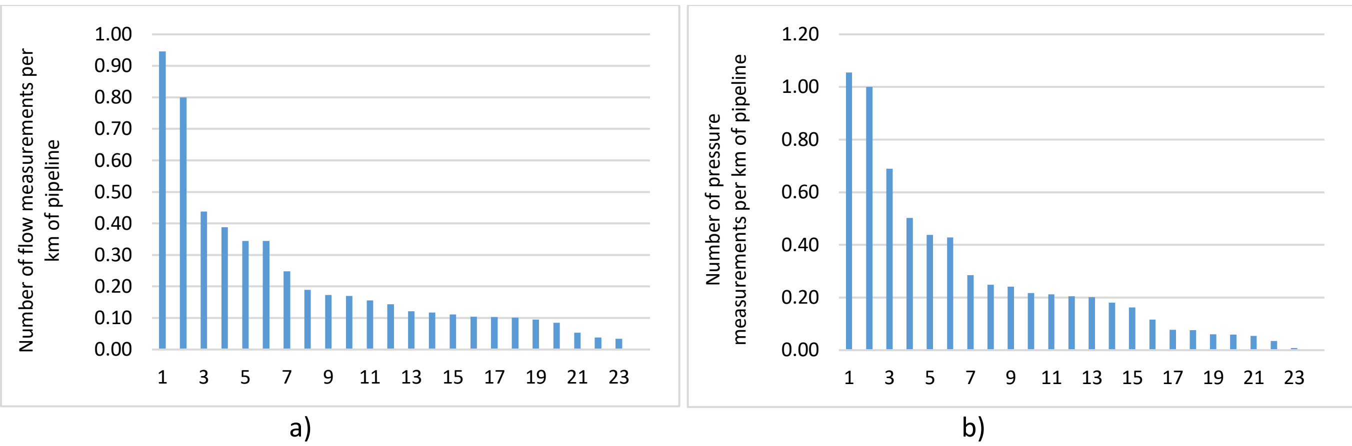


Figure 2.134. Number of flow (a) and pressure (b) measurements per km of mains network in individual PWSPs (within the preparation of conceptual solutions)

In a small number of locations, in the preliminary DMAs where higher volumes of water losses were detected beforehand, pressure measurement with a time log of 0.1 to 1 second is also done, based on which the presence of water hammers is identified. Pressure measurements in seconds are also done at pumping station outlets. The purpose of pressure measurements in seconds is to identify a potential presence of water hammers and, depending on the result, consider the implementation of appropriate mitigation measures or full prevention of water hammers. Pressure measurements in seconds had been rarely done when developing conceptual solutions until the year 2018.

Based on the results of implemented measurements, the model of the current status is calibrated against the measured flows, pressures, and residual chlorine. The calibrated model presents a quality basis for making conclusions about the current status of system operation (hydraulic operating conditions of flow in different regimes, etc.) and its deficiencies, providing a quality basis for preparing and supplementing the analysis of current status according to the IWA methodology. The calibrated model also gives a quality basis to define spatial and qualitative distribution of water losses in the current status. The calibrated model eventually presents the basis to define high quality measures for extension and improvement of a system or its parts. The calibrated model is used to make an additional analysis of the current status in different hydraulic conditions such as minimum consumption and maximum consumption of water in characteristic winter and summer periods, and at a time of the average annual system load. The purpose of analyses made is to present high-quality conclusions about the way in which a system functions in different hydraulic and operating conditions, and to identify problems and deficiencies in the system, as well as to become aware of potentials for certain improvements, which are later manifest through more efficient definition of specific improvement measures by the order of their priority.

The analysis of the current status of the water supply system is within the conceptual solutions supplemented with an analysis based on the IWA methodology, as part of which the following activities are implemented:

- Preparation of an extended water balance (according to the latest template defined by the IWA), calculating individual performance indicators (ILI; real losses/km of mains/h; real losses/service connection/day; real losses/network length unit/day/m, real losses/service connection/day/m, etc.). In that process, the “Top-Down” and “Bottom-Up” methods are used, and the comparison of results obtained using both methods is presented.
- Definition of reliable inputs for the calculation of the ILI (length of the water supply network, total number of service connections, average system pressure, water balance, real losses, unavoidable water losses, etc.). In that process, the “Top-Down” and “Bottom-Up” methods are used.
- Definition of the average pressure for the whole system, as well as individual DMAs based on the results of the calibrated mathematical model, given in the simulation given the average annual water consumption, taking into consideration all system elements.

All the relevant indicators according to the IWA methodology for the identification of the status of losses in the water supply system are calculated using the guidelines for high certainty (95% certainty for data and possible precision tolerances).

Furthermore, in the majority of cases public water supply systems are built as combined systems (pressure and gravity), with all water losses directly manifest through economic losses, due to unnecessary consumption of energy in the pumping stations (the source and the mains network). In other words, the energy manifest as a loss is consumed by the pumping stations to pump the water volumes leaking within the system. For that reason, the loss of energy in the operation of pumping stations represents a direct economic loss of the PWSP that operates the system. The above-mentioned amount of economic losses from the consumption of energy is joined with other direct economic losses that are part of the costs of water supplied (drinking water treatment, etc.). Direct economic losses generated from water losses are also joined with indirect economic losses generated as the result of the removal of leaks on the mains network and service connections, which are first of all the result of inadequate hydraulic operating conditions of flow (e.g., increased pressures or water hammers) and the occurrence of observed real losses.

The economic analysis of losses is carried out in order to express the total annual economic loss on the level of the system as a whole, as well as of each characteristic DMA separately. In the end, the results of the economic analysis of losses are, among other things, used to identify priorities in addressing the issue of water losses in individual system zones, as well as to justify the application of particular technical solutions.

More intensive implementation of the economic analysis of water losses began with the preparation of conceptual solutions. Before that, that segment had been relatively neglected.

In addition to the calibration of the model of the current status 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 on the mathematical model of the planned status. The analysis covers a design period of 30 years during which the water demand analysis is supplemented. In other words, the entire system and each measure have to satisfy the demand of normal supply of final consumers with water for the next 30 years. As part of the analysis of the future status 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, proposal is given for priority measures and projects of construction, rehabilitation and optimization of the current and future status 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 addition to the above, the preparation of conceptual solutions under NWLRP Measure A for some PWSPs also implies the development of a GIS of the complete system with the creation of a GIS database on mains, water supply structures, and installed equipment with the spatial definition and presentation of:

- The configuration of the DMAs, i.e., register of the monitored water supply network;
- The spatial register of flow meters, pressure meters, closed valves, and other equipment isolating the zones;
- The locations of main consumers, consumption;
- The record of failures in the water supply network mains and equipment;
- Navigation during field inspection of the network, i.e., when locating leakages;
- The locations of noise loggers which can be used when locating leakages;
- Etc.

Almost all the prepared conceptual solutions were actively reviewed by the leading experts in this field in Croatia, thus raising the quality of the preparation of conceptual solutions to a higher level, i.e., the resulting solutions are assessed as more reliable.

Successful completion of the preparation of such studies has resulted in the creation of a high-quality digitized database about the current status of the systems, which is particularly important for the systems for which there are only paper layout plans, without digitized data. As a rule, GIS databases have been prepared which, in addition to the basic information about the technical characteristics of the systems, also contain numerous supporting technical information, data about consumers, system failures, photos, copies of work orders, etc.

Calibrated mathematical models have been prepared which present the basic tool for understanding the operating conditions of the systems, recognition of problems, implementation of advanced analyses (consumption of electric energy, monitoring of water quality parameters), definition of technical measures for improvement by priority phases, and testing the impacts of the foreseen loss reduction activities.

In the conceptual solutions, systems are divided into regulation and metering zones (DMAs) in which after their establishment water losses can be more easily be located and controlled in the future. In addition, the implementation of the monitoring and control systems proposed in the conceptual solutions will enable real-time monitoring of consumption and water losses in the zones.

Not rarely, the conclusions of the prepared conceptual solutions have resulted in the redefinition of the course of further system development in relation to the studies and designs prepared earlier. With the implementation of financial and economic analyses, the analyses of different variants of system improvement and development have been revised and, usually by taking into consideration a larger number of criteria, new objectives and guidelines have been defined.

The statistics related to the preparation of conceptual solutions in Croatia were presented in Chapter 2.4.2. Figure 2.79. gives an overview by clusters with the shares of the PWSPs that have or don't have conceptual solutions prepared. One can notice that there is still a large number of PWSPs, even larger ones (e.g., in Clusters II and III), that don't have conceptual solutions prepared, with their preparation expected in the future. Likewise, Figure 2.80. shows that the largest number of conceptual solutions was prepared after the year 2017, i.e., after the launch of the NWLRP. 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 status, mathematical models at a lower level of detail, a lower level of calibration of the model of the current status as the result of a significantly smaller number of flow and pressure measurements, lack of analysis of the current status 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.

Measure A, i.e., preparation of conceptual solutions, is the basic measure within the NWLRP, and a PWSP is not able to participate (receive co-financing) in the other measures (B and C) if it hasn't fully implemented Measure A, with the exception of the GIS development.

2.6.1 Optimization of water supply systems

Efficient water loss management should start with the optimization of water supply systems in hydraulic terms. The preceding chapters have described the problems of the creation, development, and expansion of water supply systems because of which the water supply layout is not optimally set, it is more difficult to make the system hydraulically balanced, the result of all that being that operating conditions in parts of the systems remain unfavorable. By becoming familiar in detail with all the characteristics of the systems, with the use of calibrated hydraulic mathematical models, it is possible to foresee optimization and plan further extensions of water supply systems for future needs.

The first step is an analysis of possibilities to modify the water supply layout by adding new pressure zones through the construction of new storage tanks, valve regulation shafts (with valves to regulate downstream pressure and/or valves to retain upstream pressure), installation of new pumping stations (with frequency regulation for parts of the system oriented at final consumers), or new main supply routes. Due to the availability of modern technical solutions (regulation valves, air release/intake valves, frequency converters, SCADA, etc.), major reconstruction activities are possible with the aim of modifying operating conditions, as well as energy conditions related to the supply of water, and eventually optimization of pressures in the systems. If conceived from the beginning, almost every built system would have a different water supply layout.

The problem is related to the fact that the impacts of these measures, which in addition to the reduction of water losses and increase of energy efficiency also refer to the environmental aspect of the protection of water resources, are often not sufficient to cover the investment costs which can be significant. A positive example should be a modification of the water supply layout of VIO Zagreb by establishing the so called "Zone 0" (see Chapter 2.2.2.1). It had significant impacts with regard to the reduction of water losses by reducing pressures in in the largest part of the system in terms of supply, having an impact not only on the reduced leakages, but also on fewer occurrences of bursts. It also had an impact with regard to the reduction in the consumption of energy needed to ensure water supply for around 50% of the consumers, and with regard to the protection of the water intakes sites already at potential risk due to many years of decreasing levels of groundwater, on which the supply of the entire system is based.

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. There is already plenty of positive experience in Croatia related to the establishment of DMAs and PMAs.

DMAs

The establishment of DMAs is an unavoidable measure of efficient management of water losses in water supply systems.

The establishment of DMAs is related exclusively to the installation of flow meters that monitor the water balance in smaller, separated distribution areas (parts of systems, or zones), making it possible to better monitor the system status and timely identify new bursts, and thus also to do the repairs faster, thus reducing the total volumes of real losses.

During the establishment of DMAs, flow meters can be installed into the existing valve shafts if conditions exist (sufficient space to install the meters and supporting fittings according to manufacturers' instructions) or into new valve and meter shafts planned during the preparation of a conceptual solution for the establishment of DMAs for a particular PWSP.

During the establishment of DMAs so far, the following things were respected in all water supply systems:

- Further development of the SCADA system;
- Spatial arrangement of the water supply network;
- Existing regulation equipment;
- Existing hydrant network;
- Collected data on flows and pressures and the method of regulation of the existing facilities;
- Plan of future extension of the water supply system;
- Possibility to build shafts with regard to the existing infrastructure;
- Possibility for phased establishment of DMAs.

So far, a certain number of DMAs has been established in the majority of bigger PWSPs in Croatia. The PWSP classified into Cluster I has implemented the first phase with the establishment of 13 DMAs, while 83% of the Cluster II PWSPs have established a certain number of PWSPs. The establishment of DMAs to date reduces in the lower clusters (52% and 20% in Clusters III and IV, respectively). On the national level, 39% of the PWSPs have established a certain number of DMAs (Figure 2.135).

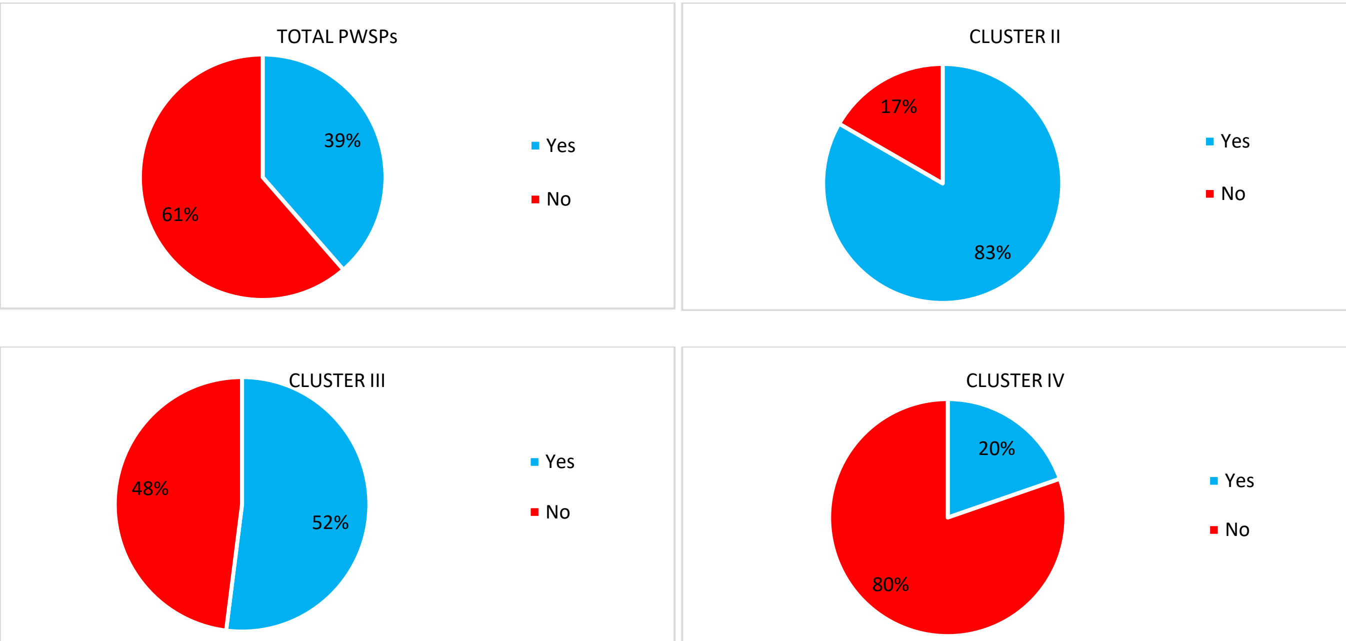


Figure 2.135. Establishment of DMAs on the national level and by PWSP clusters

The number of established DMAs by PWSPs varies significantly in all the clusters, save Cluster I which includes only one PWSP (Figure 2.136). In Cluster II, the number of DMAs by PWSPs varies from 4 to 177, with an average of 68. In Cluster III, the number of DMAs by PWSPs varies from 1 to 110, with an average of 24. In Cluster IV, the number of DMAs by PWSPs varies from 1 to 20, with an average of 4.

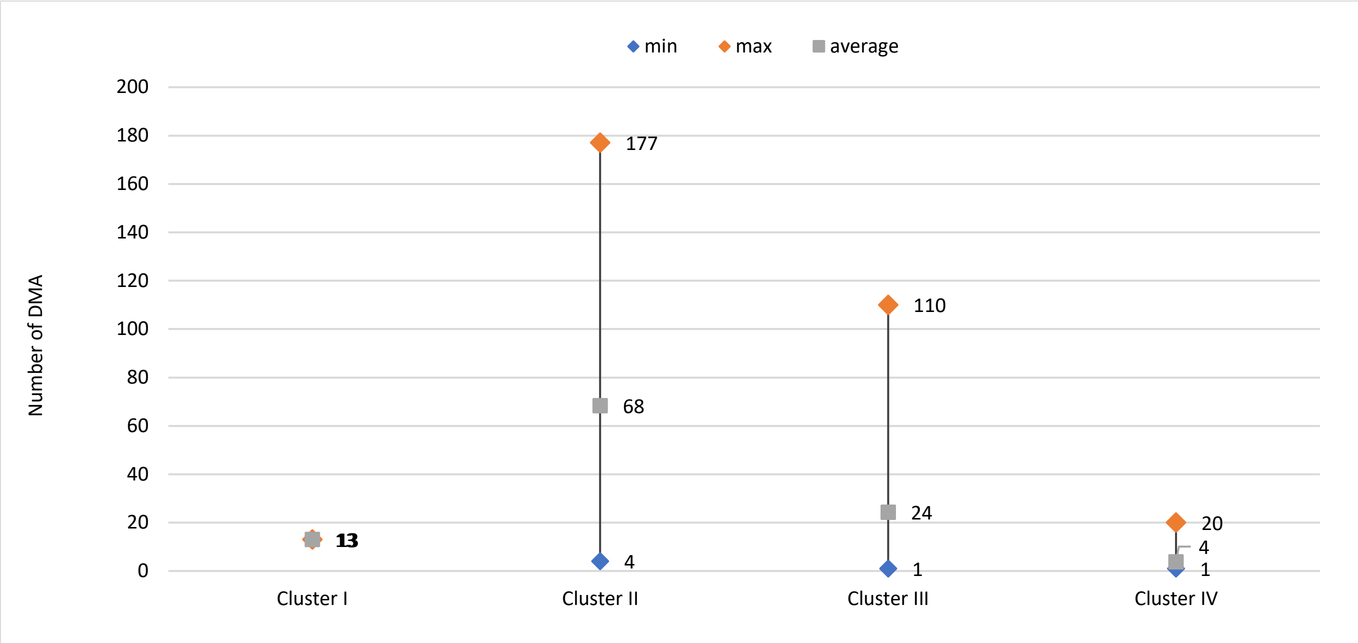


Figure 2.136. Number of DMAs in individual water supply systems by PWSP clusters

The size of DMAs expressed through network length per DMA also varies significantly in all the PWSPs, save Cluster I which includes only one PWSP (Figure 2.137). In Cluster II, the size DMAs by PWSPs varies from 5 to 418 km/DMA, with an average of 76. In Cluster III, the number of DMAs by PWSPs varies from 3 to 633 km/DMA, with an average of 57. In Cluster IV, the number of DMAs by PWSPs varies from 0.8 to 37 km/DMA, with an average of 28.

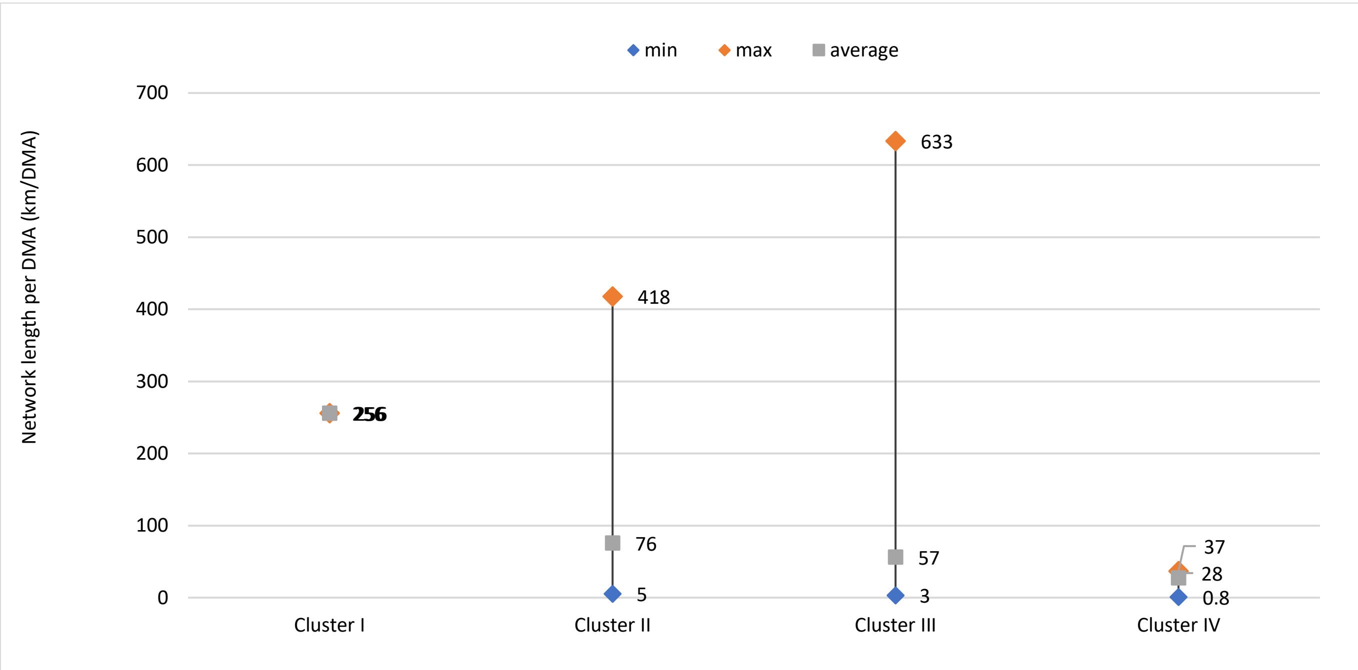


Figure 2.137. Size of DMAs by PWSP clusters

From the above analysis of the current status, it follows that the establishment of DMAs in Croatia is rather uneven, even within individual clusters. The reasons for that are many:

- Level of development of PWSPs' awareness and knowledge about the importance of establishing DMAs;
- Financial capacities of PWSPs;
- Period of preparation of conceptual solutions for individual PWSPs;
- Inclusion of PWSPs in the implementation of Measure B within the NWLRP;
- Inclusion of PWSPs in other forms of co-financing (EU projects, etc.);
- PWSPs' experience with the DMAs established earlier.

PWSPs have different experience with the DMAs established so far. In terms of water loss reduction, all the PWSPs with established DMAs, particularly those with a larger number of DMAs, have achieved positive results in the reduction of losses. For some PWSPs those positive results are expressed to a bigger, and for some to a lesser extent. Some PWSPs have relatively soon after the establishment of DMAs started to achieve positive results in the reduction of water losses, some started achieving positive results only later on, while for some PWSPs after the initial achievement of positive results water losses have increased.

This was caused by numerous facts which can be summarized in several main aspects:

- Personnel organization within the PWSPs, where the people in charge of monitoring the status in DMAs also do many other jobs of higher priority and have no time to monitor DMAs and notice new leakages;
- Insufficient number of trained people to properly monitor the status in DMAs;
- Insufficient technical staff to perform regular and emergency repairs of metering equipment and replacement with new meters;
- Insufficient financial resources to cover the servicing costs for the existing metering equipment and procurement of new metering equipment, with part of the metering equipment either not working or working with faults and inaccurate measurements, and operating staff not being able to monitor the status in individual DMAs.

Almost all the PWSPs with a larger number of established DMAs have had problems with maintaining a large number of flow meters. Those problems have to do with the fact that maintaining a large number of flow meters is highly demanding in financial terms, with PWSPs unwilling to accept further investment in their maintenance. It also requires a large number of working hours by the maintenance staff for metering equipment, since the meters have to be serviced regularly and in emergencies as well as replaced with new ones.

The establishment of DMAs is also one of the short-term measures for improvement of water supply systems for which conceptual solutions have been prepared. In order to establish DMAs in an economically and operationally efficient way and reduce water losses, based on the above-described PWSPs' experience so far as well as based on the prepared conceptual solutions, it is proposed that the planned development is based on phased establishment of DMAs, so that individual final DMAs in the initial phases are merged into bigger zones. This helps avoid a high financial expenditure in the initial phases of establishment and maintenance of DMAs, and PWSPs are better familiarized with the establishment, management, and maintenance of DMAs. The 72 PWSPs that filled in the questionary responded about whether the phased establishment of DMAs is planned. The only PWSP in Cluster I responded positively, as well as 75% of the Cluster II PWSPs, 36% of the Cluster III PWSPs, and 42% of the Cluster IV PWSPs. Based on that it can be concluded that the development of conceptual solutions for a large number of PWSPs needs to be revised in terms of analyzing the possibilities and justification of phased establishment of DMAs (Figure 2.138).

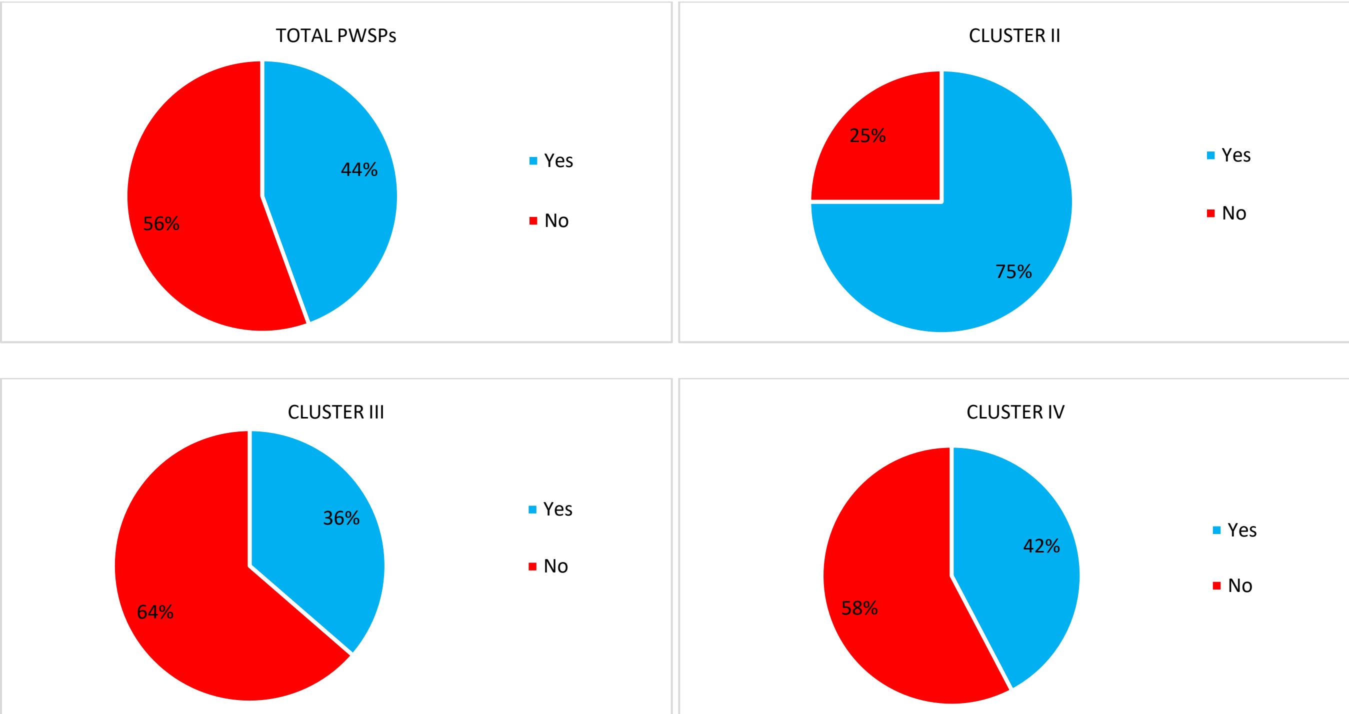


Figure 2.138. Planned phased establishment of DMAs on the national level and by PWSP clusters

The number of planned DMAs by PWSPs is significantly higher than at present, which makes sense, and significantly varies in all the clusters, save Cluster I which includes only one PWSP (Figure 2.139). In Cluster II, the number of planned DMAs by PWSPs varies from 10 to 350 with an average of 105 (average increase by 37 DMAs in relation to the current state). In Cluster III, the number of planned DMAs by PWSPs varies from 4 to 75 with an average of 29 (average increase by 4 DMAs in relation to the current state, although in PWSPs with the largest number of DMAs in the current state the number of planned DMAs is reduced). In Cluster IV, the number of planned DMAs by PWSPs varies from 2 to 31 with an average of 13 (average increase by 9 DMAs in relation to the current state).

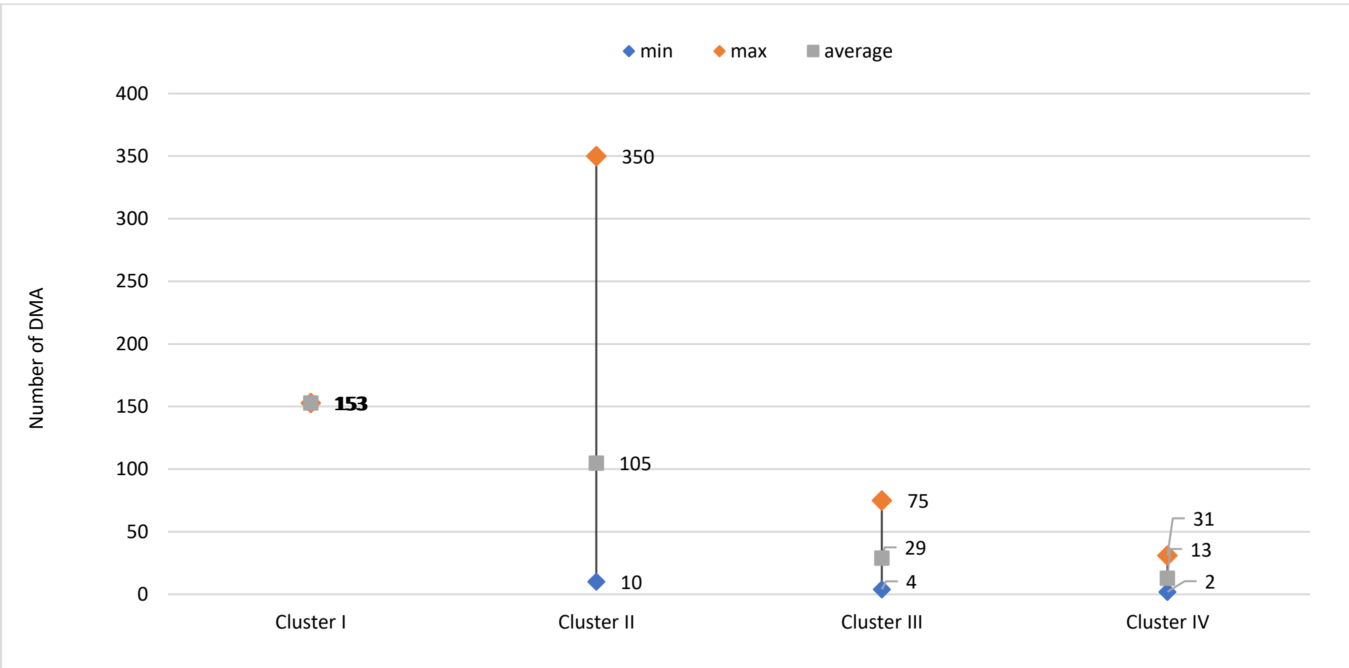


Figure 2.139. Number of planned DMAs in individual water supply systems by PWSP clusters

The size of the planned DMAs expressed through the network length per one DMA is reduced in relation to the current status, which also make sense with the planned increase in the number of DMAs and also varies significantly in all the clusters, save Cluster I which includes only one PWSP (Figure 2.140). In Cluster II, the size of DMAs by PWSPs varies from 4 to 102 km/DMA with an average of 38 (average reduction by 38 km/DMA in relation to the current state). In Cluster III, the size of DMAs by PWSPs varies from 4 to 133 km/DMA with an average of 26 (average reduction by 21 km/DMA in relation to the current state). In Cluster IV, the size of DMAs by PWSPs varies from 2 to 31 km/DMA with an average of 15 (average reduction by 13 km/DMA in relation to the current state).

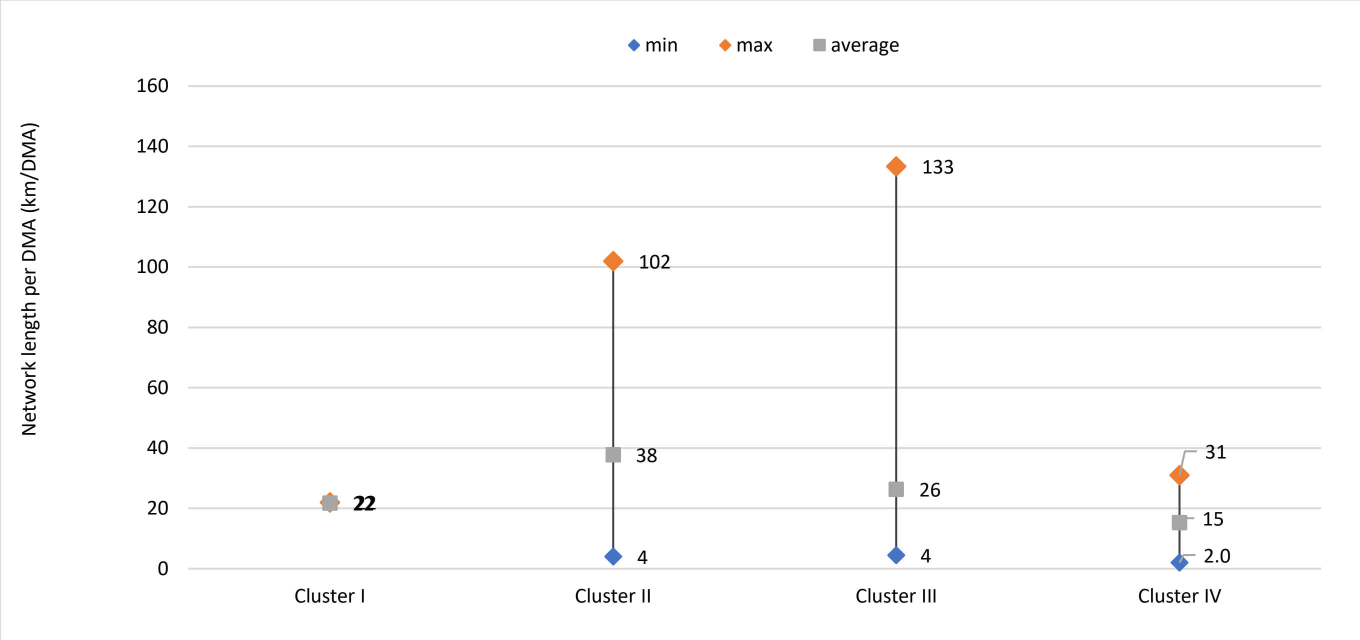


Figure 2.140. Size of the planned DMAs by PWSP clusters

PMAs and pressure regulation

In order to avoid situations in parts of water supply systems when due to unfavorable field conditions there are unwanted hydraulic and operating conditions, which are primarily reflected through the occurrence of high pressures, and consequently of increased water loss volumes, more frequent failures, shortened life of the mains network, etc., pressure regulation valves are most frequently installed. With the installation of pressure regulation valves, the pressure management (regulation) areas (PMAs) are formed. The establishment of PMAs is also one of the short-term measures for improvement of water supply systems for which conceptual solutions have been prepared.

The establishment of PMAs is related exclusively to the management of pressures within individual PMAs, by means of which in parts of the system downstream of the implemented management pressures are reduced to the minimum level that ensures normal supply of water to final consumers. The positive impact of the reduction of pressures in the water supply network was described earlier in the text, and the dependence of leakage on pressure change is mathematically described by the FAVAD equation (see Chapter 2.1.1). Through the establishment of PMAs, pressures are most often reduced with the installation of pressure regulation valves which reduce the pressure downstream of the valve to a certain fixed value or values which can vary in time (night/day) or to values which can vary in proportion to changes in flow (higher pressure is released downstream at higher flows, while at lower flows the pressure released downstream is lower).

The production and development of pressure regulation valves has led to a significant change in the views about how to design, build, reconstruct, and improve water supply systems. The installation of pressure regulation valves enables much better control of the operation of water supply systems in their entirety or parts and ensures higher quality supply of water to final consumers, but also increases the efficiency of water loss management. Pressure regulation valves make it possible to continuously keep the minimum required pressures in the downstream parts of the systems, ensure higher quality service of water supply, reduce the volumes of water losses, and prolong the life of the mains network. Two basic types of pressure regulation valves are in use in Croatia today – spring and hydraulic valves. A large number of spring valves (Chapter 2.2.1,

Figure 2.17) are in function in water supply systems in Croatia, although in the last 10 years or so, and particularly after the launch of the NWLRP in 2018, the installation of hydraulic valves has become a standard. Based on the analyses of a large number of water supply systems in Croatia, numerous deficiencies in the operation of spring valves have been noticed. The main advantage of spring valves is their relatively low price, which is the main reason for their frequent application in water supply systems in Croatia.

Today's technological development makes it possible to, based on measurements of flows and pressures and hydraulic analyses and using sophisticated mathematical models, describe in detail the operating methods and effects of spring and hydraulic valves for pressure regulation. It was exactly such analyses that were made by some PWSPs. The results of such analyses indicate the following:

- Spring valves for pressure regulation don't enable controlled operating conditions, and certain problems occur downstream which can interrupt the supply of consumers with water (significant uncontrolled drop of downstream pressure), but also occasionally cause unwanted increases of pressure (and thus also of water losses) in conditions of minimum consumption when minimum pressures are sufficient for uninterrupted water supply.
- Hydraulic valves with controlled and finer pressure regulation enable economic savings (compared with spring valves), particularly in systems with higher volumes of water losses and with higher unit prices of water supplied.
- Replacing spring valves with hydraulic valves is assessed as economical and justified.

At this moment, it is not known how many PMAs have been established by individual PWSPs or on the national level. However, there are many positive impacts of the establishment of PMAs by all the PWSPs that have established them so far. In line with that, one of the main concepts of improvement of water supply systems in Croatia, both from the aspect of hydraulic optimization of systems and from the aspect of water loss management, will be the formation of a large number of new PMAs. While some PWSPs which have for many years properly invested in their own systems there is a larger number of PMAs established and there is almost no space for the introduction of new ones, some PWSPs haven't established a single PMA, not even those with average pressures of more than 5.0 bar.

2.6.2 Water losses reduction

The reduction of water losses is an essential activity for almost all the PWSPs in Croatia. Few PWSPs already in the current state achieve satisfactory results in reducing water losses and keeping them at an acceptable level. In some PWSPs the situation is pretty bad, and in some even alarming with regard to an extremely high NRW share. For the majority of the PWSPs it is essential to as soon as possible start with a water loss reduction program or become included in the existing programs or continue more intensively with the already initiated programs. There are few PWSPs in Croatia that have so far managed to efficiently implement water loss reduction programs on their own, while the majority of other PWSPs have achieved positive results through financial assistance from the National Water Loss Reduction Program (NWLRP) launched in 2018, EU projects, and (co-)financing by the line Ministry and Croatian Waters.

2.6.2.1 National Water Loss Reduction Program (NWLRP)

2.6.2.1.1 NWLRP in general

The objectives of launching the NWLRP were the following:

- Significantly reduce the total volume of abstracted water from the then (the year 2017) around 480,000,000 to around 320,000,000 m^3/year on the national level through significant reduction of NRW volumes and their share from 49% to 25% of the abstracted volumes;
- Reduce the unit value of real losses from the then (the year 2017) average 0.4 to 0.2 m^3/km of mains/hour;
- Reduce the ILI on the national level from the then (the year 2017) around 5.0 to 3.8 (moving from Group C to Group B);

- Bring all individual PWSPs (in particularly the poorer ones) to an adequate technological level successively with the implementation of the program and implementation of the reform and consolidation of the PWSPs into new service areas;
- Return of financial investment over maximum 10 years.

The line Ministry has since 2018 until today provided certain funds for the NWLRP implementation, as presented in Table 2.32, and these funds were spent to co-finance activities within 4 main groups of activities or measures (Measure M, Measure A, Measure B, and Measure C), with the Ministry covering 80% of the costs of implementing all the activities, while the PWSPs cover 20% of the remaining costs.

Table 2.32. Co-financing of NWLRP activities

Year	Co-financing amount (EUR)
2018	4,115,000
2019	9,291,000
2020	13,140,000
2021	10,220,000
Plan for 2022	13,273,000

Measure M

Measure M implies the installation of flow meters at all the water intake sites in Croatia with a system of technical protection by individual water intake sites, The reasons for implementing this activity are several, e,g,, the water intake sites are not sufficiently covered with flow meters, which gives highly deficient inputs for realistic and precise detailed water balance in water supply systems, and there’s a lack of better-quality control of the main input in the water balance – abstracted volumes, In that context, Measure M in addition to the installation of flow meters also implies the introduction of a double system of managing the metered data, so that they are sent both to the PWSP and the Ministry/Croatian Waters,

Measure A

Measure A implies the preparation of conceptual solutions which include a detailed analysis of the current status of an individual water supply system and the preparation of conceptual solutions of further development and improvement of water supply systems, 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, The contents and methods in which such conceptual solutions were prepared are described above in Chapter 2.6 (introduction),

Measure B

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 of pressures

This measure implies the implementation (design and installation) of a pressure regulation system with a possibility to install pressure regulation valves in several locations in the existing shafts and in several locations in new shafts, The reason for implementing this activity are uneconomically high pressures in the majority of water supply systems or in individual zones in different regimes: night/day - season/off-season - lowland/upland zones,

Implementation of a remote SCADA system

This measure implies upgrading the existing system or establishing a new system, It encompasses the preparation of a preliminary design for the establishment of a SCADA system and a design for the implementation of the full SCADA system with software implementation in several locations with a system of technical control and technical protection (where applicable), This measure also implies the design and construction of control and measurement and regulation shafts for flow measurement with metering equipment in several locations, i,e,, the establishment of DMAs,

The reason for implementing this measure is insufficient coverage with instruments for remote control and management in the majority of the existing systems,

Active leakage control

This measure includes a number of sub-measures:

- Organizational training of the staff to operate leakage detection equipment – education by authorized training companies, In terms of methodology, training has to be theoretical (water losses, IWA methodology, measurement theory, analysis and processing of measurement results, preparation of an operational plan, method of preparing and submitting monthly reports, managing individual system elements) and practical (field work, laboratory work, using metering equipment, managing individual system elements),
- Procurement of leakage testing and detection instruments: correlators, geophones, noise loggers, portable flow meters, portable pressure meters, metal detectors, etc, In order for a PWSP to have equipment financed, it needs to prove the establishment of a technical team including training certificates, In Croatian practice so far, there have been cases when a PWSP had its equipment financed, but part of the equipment was never used or was used very little,
- Organizational measures of monitoring and control of losses and identification of locations of leaks in the system, It is necessary to establish a certain number of technical teams within a PWSP for active leakage control per each 500 km of the system length,
- Detection and repair of leaks,

Measure B is the second basic measure, and a PWSP cannot participate in Measure C if the entire Measure B hasn't been implemented, because there is a high probability that the completed repair/replacement/reconstruction of entire sections will not achieve the required effect due to inadequate status of pressures and flows,

Measure C

This measure cannot be implemented if the preceding measures (M, A, B) haven't been implemented, It implies the preparation of project documentation,

The reason for implementing the measure are the analyses, measurements and other activities implemented before, based on which the missing documents are prepared and the required permits and administrative acts are issued,

The measure implies the repair/replacement/reconstruction of entire sections of the mains network and bigger structures in the system with frequent bursts, It is pointed out that what is mostly done is the repair of leakage locations only, while the reconstruction and construction of individual sections of the transmission mains or parts of the distribution network is done only exceptionally and in individual cases,

2.6.2.1.2 Implementation of the NWLRP

There is plenty of experience and practice so far related to the NWLRP, regardless of the fact that it has been in implementation since early 2018 and that the majority of the implemented and time-consuming activities so far has been related to Measure A, which presents the initial measure through the preparation of studies (conceptual solutions), However, a considerable number of PWSPs have started with the implementation of Measure B as well,

Since the launch of the NWLRP, as the result of implementation of numerous activities, so far some PWSPs have achieved a positive result through the reduction of certain volumes of water losses, Figure 2,141, presents changes in the NRW in the period from the launch of the NWLRP to the beginning of the current year, One can notice that a pretty large number of PWSPs have achieved a certain reduction of NRW, while some have even reduced significant volumes, The reduction of water losses was achieved primarily as the result of the PWSPs' inclusion in the NWLRP and implementation of the Measure B activities,

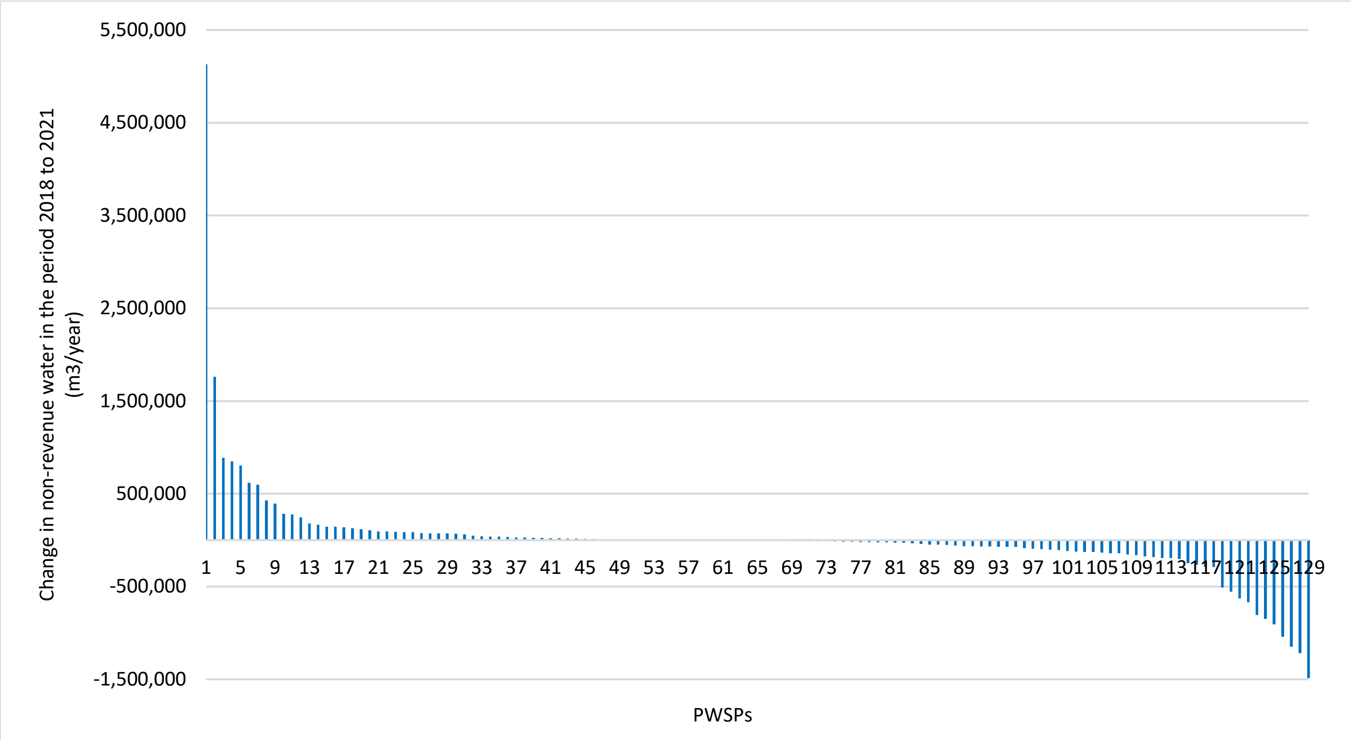


Figure 2,141, Changes in NRW by PWSPs from 2018 to 2021 in m³/year (positive values present NRW reduction, and negative values present NRW increase)

Certain water loss reductions were also achieved during the implementation of Measure A, i,e,, during the preparation of conceptual solutions, At the same time, already during the preparation of conceptual solutions and the implementation of flow and pressure measurement activities and implementation of step and crash tests, but also later on, active leakage control was also implemented by PWSPs in the zones where measurements have identified higher volumes of water losses, In that context, certain PWSPs have already during the preparation of conceptual solutions managed to significantly reduce their water losses, Examples of this are certain larger systems in inland Croatia where in certain zones during the preparation of conceptual solutions water losses were reduced within the range of 10-25 l/s (315,000 – 800,000 m³/year),

Furthermore, continuous implementation of active leakage control within Measure B by individual PWSPs and companies outsourced by individual PWSPs has proved as extremely successful, with excellent results on the annual level, Already in the initial phases of quality implementation of active leakage control significant savings have been achieved in relatively short periods, with additional reductions also achieved later in individual DMAs,

2.6.2.2 Conclusion about the current status of water loss reduction

The National Water Loss Reduction Program (NWLRP) has properly addressed the water loss issue, 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 turned out to be 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 there are preconditions (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 of 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 measures,

It is precisely that reason that calls for the preparation of the 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 RESILIENCE TO CLIMATE CHANGE AND SAVING ENERGY

3.1 Climate change

In the process of upgrading its infrastructure to EU standards, Croatia is likely in the near future to face a period when improvement of water supply will be back in a focus, During this period, the main priority should be to upgrade the reliability of the system, while at the same time embedding resilience into its overall function,

In Croatia, areas of small watersheds in the Black Sea River basin as well as whole Adriatic River basin are particularly sensitive to the impact of climate change, Review of climate trends conducted for the Adriatic River basin within the project (Assessment of the reliability and climate change resilience of water supply in Coastal area of Republic of Croatia, World Bank 2021) indicated possible negative effects on water supply,

As a result of climate change summer rainfall along the coastal areas of Croatia is expected to decrease by 7% in 2040, and 16% in 2070,, and up to 25% in some locations in 2070, At the same time, summer air temperature is expected to increases by 1,3°C in 2040, or 2,4°C in 2070,, with associated negative impacts on the availability of freshwater in these critical areas, With the compounding impacts of saltwater intrusion into groundwater bodies the Adriatic Sea level is expected rise 40 to 65 cm in 2070, - and increasingly frequent periods of climate variability such as floods and droughts, it is likely that water supply systems in Croatia's coastal area are at risk of ensuring reliable system operation due to the compounding impacts of negative water quality trends, reduced quantities available and increasing demand, Building on the strong base of infrastructure that already exists in these coastal areas, ensuring that future planning with regarding expansion of coverage and improvements in service delivery takes into account these uncertainties will allow decision makers such as local public authorities and utilities to build resilience into system operation and should be a priority in the next phase of water supply development in Croatia,

Climate change is found to impact negatively on water availability in the coastal area, resulting in decreased water availability, while increased water demand will further stress water resources, The impact of climate changes is likely to especially endanger coastal karst aquifers and other water bodies in the coastal area (lakes, watercourses, springs) because of the cumulative effect of reduced flows and groundwater levels, and more intensive sea intrusion into the hinterland, In the coastal area of Croatia, interannual distribution of precipitation and temperature is uneven and conflicting with water demand, Summer months (June, July and August) are the focus for the assessment of climate resilience since this is when the conflating temperature, water demand and rainfall are most critical,

Reduction in non-revenue water (NRW) provides, to some extent, water capacity to build system adaptive capacity in the face of near-term climate change impacts on water availability within the current level of water abstracted, Water loss mitigation measures are thus a key measure, with a strong positive effect on the reliability of the system,

Along with necessary investments to improve reliability and safety of water supply systems, it is recommended that an improved climate and future risk assessment is carried out for the coastal area and accompanies the development of a methodology for investment planning that takes into account these uncertainties, The improved risk assessment will provide better information for decision making, including climate change projections and the interaction of these impacts with the hydrological properties of water sources in the region, including karst aquifers, as well as projections of future demand, i,e, better information on elements which vary significantly in quantity, quality and reliability, and identification of areas facing heightened water security issues, Results of this assessment are expected to improve Croatia's risk management approach in line with DWD,

3.1.1 Expected impact

This Assessment of the reliability and climate change resilience of water supply in Coastal area of Republic of Croatia developed a climate change severity indicator, calculated as decrease in summer rainfall (to 2040), Around 42% of water is withdrawn within the area where there is very high or high climate change severity, In the area with moderate climate change severity, around 49% of water is withdrawn, Only 9% of water is withdrawn from the area with low climate change severity, This analysis indicates the high impact that climate change is likely to exert on the water supply system in the face of increasing demand, with, impacts expected on both quantity and quality of water, Regarding the expected impact on availability of drinking water in the mid-term, the following summary conclusions can be made:

- Lower aquifer recharge is expected, not only due to decrease in rainfall but due to increased potential evapotranspiration caused by increasing temperature,
- Additional decrease of capacity of near sea aquifers due to the combined effect of lower recharges with increasing intrusion of sea water,
- Higher air temperatures will lead to increased water demand, not only by population but by agriculture and industry,
- Water quality in reservoirs (and water tanks) may be compromised by increased temperature,

On average, climate change may lead, depending on scenario and time period, to loss of more than 15% of renewable reserves of water, Due to hydrogeological diversity of the Croatian coast, certain water bodies will lose all renewable potential and more strain will be put on others, requiring the establishment of new water supply as adaptation measures, Also, due to significantly decreased water availability, the achievement of good quantitative status of water bodies may be put at risk,

Preliminary risk assessment in coastal area shows very high risk in the PWSP Zadar and PWSP Dubrovnik, and high risk in PWSPs Labin and Krk (northern part of the Adriatic area) and PWSPs Sibenik, Split and Brac (central part of the Adriatic area),

3.1.2 Improved risk assessment

Within project Assessment of the reliability and climate change resilience of water supply in Coastal area of Republic of Croatia, non-structural measures are recognised to be applied:

- Improved climate risk assessment (improved risk assessment is needed which will provide better information for decision making such as climate change projection and hydrological properties of karst aquifers on one side, as well as projections of future demand on the other, i,e, better information on elements which vary significantly in quantity, quality and reliability, and identification of areas with more severe existing water shortage problems),
- Methodology for measure development (national level need to providing framework/methodology for the development of each water supply system, including the balancing of demand with resource status, climate change environmental objectives, technical and O&M capacities of utilities, financial capacities, affordability and willingness to pay, Elaboration of this risk-based approach would support the risk assessment analysis as required by DWD Recast,
- Risk assessment on PWSPs level or source level (according to DWD Recast, which require very elaborated risk assessments of water sources, water bodies, and water distribution systems:

In relation to the current organization of water services, the initiated aggregation process (41 service areas) provides a useful start for optimization, Larger consolidated PWSPs could provide regional or sub-regional approach, where planning and managing of the system bring more favourable results and resilience, for both levels of service and resilience of public water supply systems,

3.2 Saving energy

Since the conservation of water resources creates protection from growing climate change risks, it can be a cost-efficient adaptation measure, When the physical losses are reduced, abstraction (sources and distribution) could be reduced, That would save energy and reduce greenhouse gas emissions if the production of energy includes carbon-based fuels,

The estimated average consumption of energy (weighted with the volume of delivered water in a PWSP area) for a water supply system amounts to 0,78 kWh/m^3 of water produced, For example, a real reduction of losses of 50 million m^3/year would save 39 million kWh/year, which is a value of almost EUR 4.1 million per year.

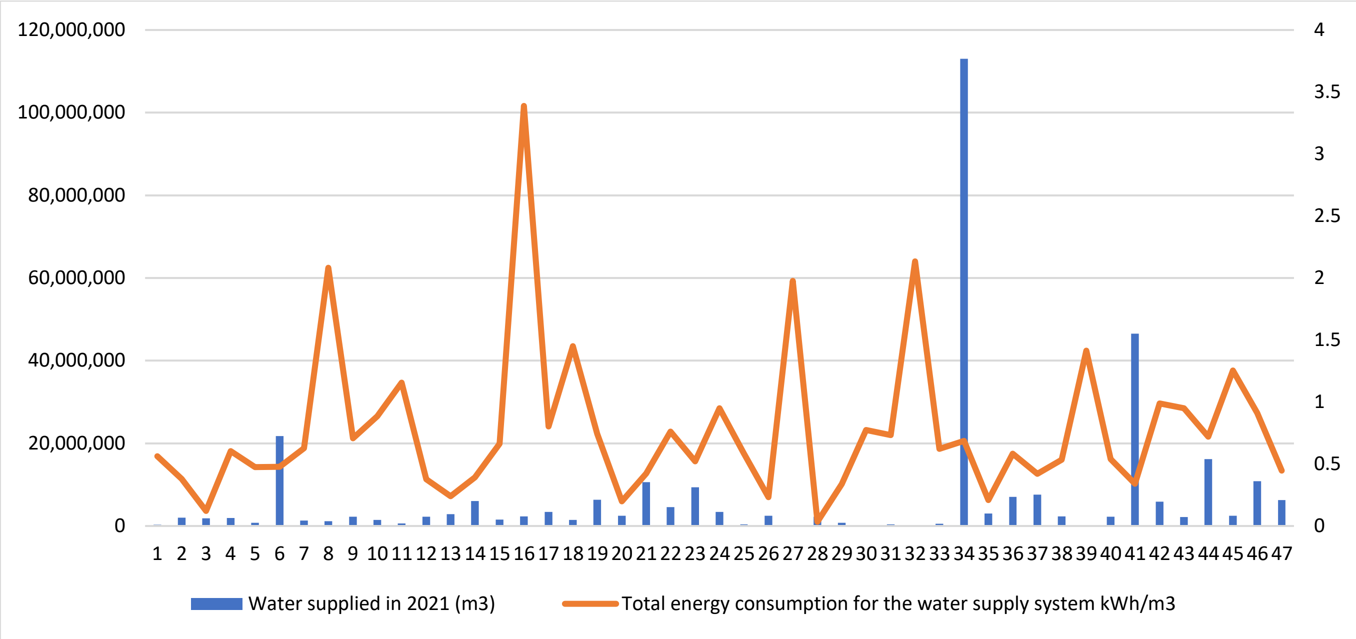


Figure 3,1, Relation between water supplied and total energy consumption (for the 47 PWSPs that submitted data through questionaries)

It is to be expected that the presented unit energy costs (2021) will change (significantly) in the coming years as the result of the impact of growing prices of energy sources on the global and national markets, with a rather significant adverse impact on the water price, Such a state can lead to problems with PWSPs' financial stability (see Chapter 1.2.2), which additionally stresses the need to reduce losses, i,e,, to reduce the consumption of energy for unnecessary water abstraction (systems operating with uneconomical losses),

The country's commitment, i,e,, applications for project financing from the National Recovery and Resilience Plan 2021-2026 indicate a need for more efficient energy use, For projects for which application forms are in preparation it is necessary to ensure/demonstrate that the newly constructed public water supply systems will have average consumption of energy of up to 0,5 kWh per cubic meter or that the ILI is 1,5, and that at activities of reconstruction of public water supply systems the average consumption of energy will reduce by more than 20 % or that the losses will reduce by more than 25%.

It is to be expected that the same or similar requirements will be defined for the financing of water supply projects in the Operational Programme Competitiveness and Cohesion 2021-2027.

3.3 Connection with loss reduction measures

Climate change will be taken into account when selecting the measures for the National Loss Reduction Action Plan through special evaluation of areas with higher assessed climate change impact (small watersheds in the Black Sea River basin, whole Adriatic River basin) and with smaller availability of sources, limitations in water volumes, or increased water demand in the planning period, when the loss reduction measures will open room for climate change adjustment and increase the reliability of water supply systems,

Saving energy will during the selection of loss reduction measures be analyzed in the financial context of cost reduction, but also through requirements for more efficient energy use, which creates preconditions for the eligibility of financing the loss reduction measures using the financial instruments of the European Union,

4 OTHER COUNTRIES' PRACTICE

The water management authorities on the national level as well as the water service providers themselves are responsible for the rational use of the water resource, In doing so, it is necessary to strike a balance between the efficient use of that resource and other resources (financial, human, etc,), The balance between those two approaches contributes to the achievement of the environmental requirements laid down by the Water Framework Directive, The annual renewable drinking water resources in Europe are relatively rich, with the annual average of around 4,560 m^3 per inhabitant, However, climate change leads to significant differences across Europe, ranging e,g,, between 120 m^3 per inhabitant per year in Malta and 70,000 m^3 per inhabitant per year in Norway, Among the EU countries, Croatia has the highest freshwater resources (with a long-term average of 28,800[37] m^3 per inhabitant), followed by Finland (20,000 m^3) and Sweden (19,300 m^3)[38], Freshwater abstraction by public water supply ranged across the EU from a high of 157 m^3 of water per inhabitant in Greece (2017 data) down to a low of 30 m^3 per inhabitant in Malta, Some of the abstraction patterns reflect specific conditions: for example, in Ireland (127 m^3 per inhabitant, 2017 data) the use of water from the public supply is free of charge for the population, while in Bulgaria (119 m^3 per inhabitant, 2018 data) there are particularly high losses from the public network, Abstraction rates are also high in some non-EU Member States, notably in Norway (155 m^3 per inhabitant) and Switzerland (112 m^3 per inhabitant, both 2018 data), The annual average in Croatia amounts to around 115 m^3 per inhabitant,

In terms of drinking water supply, it is estimated that the losses of drinking water from the distribution system in the majority of countries amount to an average of around 30 per cent, In urban areas, the losses are significantly higher, reaching as much as 70-80 per cent in some cities, Detecting and reducing the losses is costly, but since in the majority of countries the losses aren't calculated through the price of water charged to consumers (except in the part of the increased energy costs), they largely remain unnoticed by the public, Water suppliers are therefore often unwilling to spend their money on resolving this issue, unless when the availability of water is at risk, Still, the majority of developed EU countries pay deserved attention to the reduction of losses, which is reflected in a significantly lower share of losses in the total abstracted quantities, i,e,, in the rationalization of water resource abstraction,

Across Europe today, the structure of the water industry varies significantly from one country to another, Some countries have several thousand water supply organizations (Spain 2,800, Austria 5,500), whilst other countries have relatively few (United Kingdom 25, the Netherlands 10), Some water service providers provide both water and wastewater services, while some provide only the water supply service, According to their size, there are also differences among countries, with some providers providing the service to only several hundred consumers (Austria around 900 inhabitants) to those with a large service area of several million consumers, In terms of system management, there are examples where the water service providers are responsible for the entire water supply system, i,e,, water abstraction and treatment, the water supply network, and the water delivery service, There are also other examples where the water service providers share the management responsibility over the water supply system, e,g,, they manage only the water supply network and the delivery of water service to the service users, In terms of ownership there are examples of public and private ownership of the water service providers, but also examples of public-private ownership, depending on the specific country,

4.1 Leakage management

Nowadays 25-50 % of the total water volume distributed on the global level is lost or never billed due to leakages, incorrect collection systems, incorrect measurements, illegal connections, deteriorating infrastructure, improper pressure management, etc, NRW is the water that was distributed but lost in the context of evaluation because it never brings any revenue to the water service provider, Since NRW is a serious economic issue, just as wasting the scarce drinking water resources on the planet, the intention is to reduce NRW to a reasonable level,

[37] In terms of the total volume of renewable annual reserves, the volume of water abstracted for water supply is currently relatively low. However, the situation differs significantly among regions and sub-regions or locations in terms of hydro-geological diversity and availability of water. The quantity of water abstracted at a source is significantly lower than the average annual yields; however, in the summer and dry months the yields at the sources in the Adriatic River Basin District (karst springs) often become total abstraction volumes due to a significant increase in consumption (tourist water demand).

[38] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Water_statistics

The majority of European countries calculate their water balance using a methodology of the International Water Association (IWA), at the same time respecting their differences (which can be or are significant), Therefore, a simplified IWA water balance for potable water is used to ensure standardized estimates of annual losses,

Each water service provider has unique characteristics and losses, and sets of tools, techniques, and methodologies to manage its system, A failure or inability to quickly repair visible leaks is damaging to a supplier's reputation, High leakage rates in the water distribution system are perceived by the general public and the media (as well as the political structures) as waste and inefficiency on the part of the water service provider, but also as damaging to the environment,

What a "high" or "low" leakage rate is often depends on the choice of leakage indicators, It is therefore little wonder that some water service providers choose indicators which appear to show their performance in the best possible way or use favorable (rather than neutral or unfavorable) options and assumptions leakage calculations,

4.2 Good management practices[39]

Recommendations for all stakeholders (authorities competent for economy/environment, institutions competent for water management and water service providers),

Leakage reduction targets:

- Analyze costs, taking into consideration the economic impact as well (consider the total water balance on the national level, possible resource scarcity in relation to climate change, and current and future status of water bodies);
- Set strategic targets in volumetric terms, total annual leakage volume (in m^3/year) or as an average in (m^3/day);
- For very small and small systems (less than 3,000 and 30,000 service connections, respectively) use the "squeezing the box" principle (as small DMAs as possible) and set the targets accordingly;
- For bigger systems set the targets for the entire water supply system (aggregated for the entire system, then operationally manage/act in smaller DMAs), taking into account the general condition of the system, a short cost recovery period, and a high benefit (cost in relation to the net present value),

Performance indicators:

- Leakage expressed as a % of system input volume (SIV) is simple and easy to calculate, However, interpreting the leakage expressed in that way can lead to a wrong conclusion because of limitations in correct interpretation, which happened for example in Belgium, Bulgaria, Austria, Portugal, Germany when the leakage was expressed in %, after which they turned to expressing it in the form of m^3/km/day (or l/service connection/day, which is the case in the UK), Expressing and monitoring the leakage as a % of SIV ("zero-sum" calculation) is unable to identify actual decreases in either consumption or leakage "volume" over a period, **Therefore, it is clearly recommended to use a volumetric parameter as an indicator;**
- For making comparisons between systems, use ILI, which is always in the function of pressure, So, if all the checks or pressure management by zones have been done, then the use/interpretation of ILI is justified;
- The annual water balance (used to calculate the level of leakage) needs to include volumes of potable water imported into and exported from the system;
- Cost recovery (the water lost through leakage cannot be attributed to consumers (WFD, Art, 9);
- Leakage reduction should always be considered in parallel with reduction of (excess) consumption in relation to demand (such as water efficiency, tariff management – e,g,, Belgium, etc,),

4.3 Examples

Leakages are a particular problem in countries with limited resources of water for human consumption and in areas where drought leads to water scarcity (exacerbated by the impact of climate change), There is an example of a country with scarce resources, (Cyprus), where problems (damage) in the system occurred when continuous supply (a system with continuous lower pressure) was replaced with intermittent supply in order to reduce water consumption during dry periods, This resulted

[39] EU reference document Good Practices on Leakage Management, EC 2015

in heavy damage to the system with consequential high losses due to leakage, It was therefore recommended to standardize the service in such a way for the system to operate with a minimum pressure during water scarcity or drought in order to impact leakage reduction,

Characteristics of the systems and examples of leakage management in EU countries:

- Austria
  - Many small water utilities (about 5,500);
  - IWA methodology adopted;
  - The l/connection/day indicator and the use of ILI as a performance indicator introduced; very low levels of leakage recorded;
  - Approach applied: In small systems (alpine/mountainous) with high levels of leakage recorded (over 50%), leakage management/reduction by small zones through active leakage control and pressure management;
  - The legislation requires the water service providers to regularly maintain the system; development of sustainable management strategies; the use of state-of-the-art monitoring technologies and system management tools;

- Malta
  - Small DMAs;
  - IWA methodology adopted;
  - The presentation of losses as a % of the system input volume not used at all;
  - The l/connection/day indicator introduced, and ILI used as a performance indicator;
  - ILI introduced as a goal in relation to volumetric presentation;
  - Low system leakage levels recorded;

- Italy
  - More than 2,500 water service providers (significant discrepancy in the size of the distribution areas, lack of efficient management);
  - % of the system input volume used as the expression of leakages, not good particularly in bigger towns, gives wrong information and makes leakage management more difficult;
  - A growing number of water service providers are starting to use the IWA methodology and improved management (pressures, system, installation of water meters, etc,);

- Bulgaria
  - High leakage levels recorded (e,g,, town of Razgrad: ILI 41,4); characterized by limited/low water resources and low capital investments;
  - Since there is a tendency of reduced water consumption (thanks to the growing awareness of consumers through campaigns on the need to save water, the result of the closure of industrial production, reduction in the served consumers), the water services sector was faced with a decreased inflow of financial resources which would be directed at the repair of the water supply system and investments, For that reason, new water taxes were introduced, making it possible to take out a loan, thus ensuring significant funds for investment in the systems;
  - Building on the IWA methodological approach, the systematic resolution of the problem was launched; small DMAs were established, active leakage control, pressure measurement and management were introduced; very good results of the systematic approach are recorded;
  - There was a problem with presenting the leakages as a % of the system input volume, leading to wrong conclusions about the actual achievement of leakage reduction (related to reduced consumption), The planning and performance indicators have to be adjusted;

- France
  - DMA-based structure (based on the hydraulic model the flows were regulated; limitations were set on the boundary valves; maintaining/managing pressures is in place);
  - Night consumption and uncontrolled leakages were detected;
  - Active leakage control by zones introduced (acoustic noise loggers were installed);
  - Consumer campaigns were implemented in order to raise consumer awareness about the importance of every drop of water (the obligation to install acoustic noise loggers introduced for consumers as well);
  - Efficiency improved in 5 years;

- IWA methodology applied with very good system control (through zones, pressures, consumption); excellent results were achieved; losses are expressed both in volumetric terms and as a % of system input volume (ILI reduced from 3,2 to 2,5, i,e,, the volume of losses in relation to the system input volume was reduced by 5% - in 5 years from 10,8 Mm^3 to 7,5 Mm^3);
- Activities to improve the management of system assets continue (reconstruction of service connections, etc,);

- Denmark
  - High environmental awareness and particularly high costs of water and wastewater services are the main reason behind the development of system management and a strong drop in water use/consumption;
  - All possibilities to reduce the water loss are analyzed, One meter per property is mandatory, Old buildings with apartments can do with a meter for the entire property, The water loss is calculated as the pumped amount (input into the system) minus the sold amount;
  - The legislation limits the maximum loss – all water companies with water loss above 10% pay penalties, The water loss above 10% leads to an additional tax of 6,13 DKK per m^3;
  - Night consumption and uncontrolled leakages were detected;
  - Active leakage control is in place (introduced back in the 1970s);
  - "Smart" leakage control and detection tools are used; prioritization of trunk main replacement, taking account of the quality of the piping material and in particular the execution of works;
  - Adjusted approaches to leakage reduction:
    - In Aarhus, a smart system management strategy is in use (SMART WATER NETWORK – an advanced method applying innovative technologies and management systems, with special attention paid to data collection, development of advanced realistic models that enable planning and designing optimum technical (smart meters, pumps, valves, etc,) and software solutions for efficient reduction of losses with the best results), Such an approach gives an excellent ground for the prioritization of investments in terms of replacement or reconstruction of the network, equipment, etc, A combination of smart technologies and soft solutions (such as DMAs) has proven very efficient, Nevertheless, new ideas continue to be developed, as well as even bigger system management automation, even robotization in order to obtain maximum system optimization and maximum possible energy savings;
    - In Copenhagen, active leakage control was implemented over a period of 7 years, It had a characteristic noise logging campaign lasting for 2 days that crossed the entire city (with the result being that after 2 days they detected system leaks even where earlier logging had detected none), The repairs were initiated only after the calculation of potential costs and benefits;
    - In Odense, a master plan for the distribution network was prepared by replacing ring systems with network systems, the system was divided into small DMAs, and everything was controlled using a SCADA system, making it possible to precisely detect the leakage, It was only after these measures were implemented that the trunk pipelines were reconstructed or replaced (mainly steel pipes replaced by PE pipes), The aim was to fully renew the system, after which they offered their consumers a subsidy, free pipe and welding, in order for them to be able to keep monitoring the entire system and manage it in the most efficient way, The proposal was accepted by 90% of the population, The effect of the district zoning and system rehabilitation was obvious, and the losses were reduced, Apparent losses in Odense are minimum, so leakage is almost the same as water losses;

Experience related to water losses and reform of the sector of water services

The aggregation of service providers could allow for economies of scale, greater professional capacity and better access to sources of finance in countries with dispersed or fragmented systems. However, aggregation can entail long consultation and negotiation processes. Hungary, Ireland and the Netherlands, for instance, have benefitted from the aggregation of service providers, while Cyprus, Lithuania and Estonia are potential candidates for such a reform.

LITHUANIA

The European Union – DG Reform co-financed through a structural reform support program the preparation of a case study for the Lithuanian Government which was conducted by the OECD Environment Directorate through the Activity "Reform of Water Supply and Wastewater Treatment in Lithuania through Consolidation of Utilities" with the aim to support an ambitious national reform directed at the consolidation of the water sector (water services) as a condition for future efficient and sustainable provision of services in the water supply and sanitation sector. The case study gives a good example of the method of implementing the reform. Namely, activities of the water and sanitation sector in Lithuania over the past two decades were directed at implementing a massive investment program to catch up with EU standards.

The current state of the sector is more than satisfactory since more than 90% of the population is connected to the public water supply system, aiming to increase it to 95%, for which around EUR 3.5 billion is still missing. So far, they have mostly used the EU funds, primarily the Cohesion and Structural Funds, from which they used around 70% of resources for the required investment.

However, the existing public water supply systems require new considerable financial investment in operating costs for maintenance and management but based on the full cost recovery principle. The price of the water service is regulated by the State Energy Regulatory Council which, if the water tariffs increase due to new financial investment and cost coverage, requires the water service providers to revise their development plans and investment projections in order to manage the systems in a more efficient way.

In Lithuania, the water utilities are owned by the municipalities and local governments (62 water utilities in 2020). In order to respond to the sustainability requirements in technical and financial terms, they are faced with the problem of (i) the lack of appropriate professional staff to manage the systems, resulting in the increase of costs for that purpose; (ii) low population density, which makes the achievement of the appropriate connection rate more difficult; and (iii) losses in the system (2020 average 26%). Utilities in small (rural) regions cannot provide an appropriate water supply service, which is why investment is much higher. Furthermore, quality maintenance and management of water supply systems require an increase in water tariffs, exceeding the affordability thresholds (above 4% for households with low income).

The Lithuanian Government (they applied the principle on a pilot project in two regions in Lithuania: Kaunas - urban region and Marijampole – rural region) therefore adopted a 5-year program to increase efficiency of the water and sanitation system in terms of reducing operating costs by:

- Consolidating the number of utilities (integration) in order to make them more efficient and thus more eligible to apply for new funds (through loans, grants, aid);
- Introducing the licensing of companies (based on the number of customers, service coverage area, financial indicators, etc.), which will result in better state of “weaker” companies after 3 years of implementation.

The average losses in the system in 2022 were 26%, with economic losses significantly higher, which is reflected on consumers. The level of data on losses available to utilities doesn’t refer to customers’ losses (leakages in households – internal network), but since the Council encourages utilities to implement programs of measures and requires that the prices of water services are regulated after their implementation, it is assumed that utilities will be asked to introduce into their plans activities to encourage the reduction of customers’ leakages.

The reform of the water and sanitation sector in Lithuania presents practical options for the implementation of the national strategy towards consolidation of the water and sanitation services in Lithuania as a tool to encourage operational efficiency and financial sustainability of the sector. In two pilot regions in Lithuania the practicality of the consolidation scenario and supporting measures was tested. Special attention was given to tariff setting as an effect-stimulating tool.

ESTONIA

Estonia can be said to be in a situation similar to that in Lithuania. Namely, a significant progress in the water and sanitation sector over the last 20 years is seen in the increased rate of population connected (87.3% of the population connected to the public water supply system) and in the quality of provision of the public water and sanitation service (mostly using financial resources available through EU funds).

However, today the water sector is also faced with new challenges since new financial resources have to be invested in the renewal of the existing systems as well as in efficient maintenance and management of systems. The fragmentation of the existing water sector is evident in a large number of water service providers (177 in the year 2018, 44 local governments are serviced by more than one water company). It is estimated that only 3 of 4 providers that provide their service in big towns operate efficiently and sustainably.

The Estonian Government has therefore introduced a 3-year national Program (2020-2023) to enhance the efficiency of the water and sanitation sector. The defined objective is to achieve financial stability as well as sustainable and efficient use of the water resource. This should primarily mean that it is necessary to reduce water leakages, i.e., eventually reduce losses in the system. The average system losses amounted up to 23% in 2018. Furthermore, Estonia is also faced with a problem of water shortage in some regions, which makes efficient management of water supply systems and taking action on reducing uncontrolled use of the water resource a necessity.

The Estonian Government first carried out an administrative reform (reduced the number of local government units through consolidation from 213 to 79), after which it legally obliged the service providers (which are owned by local government units) to transparently present the results of their operations. This motivated the providers to more efficient management and application of loss reduction and system improvement measures. A project financed by the European Commission - DG Reform and the OECD provided support for the preparation of a national plan for the water sector reform through the sector's consolidation as a precondition for a sustainable strategy to finance a wider reform of the water sector in Estonia.

The aggregation of water service providers as one of the ways to improve the efficiency of systems in Estonia has been considered for several years, even a decade. Since aggregation can be done on different bases, Estonia started with one model (consolidation based on geographical basis with well-functioning providers aggregating less functional ones). Such a model was faced with difficulties because the "bigger" ones didn't want to merge with a smaller, inefficient provider which they considered a burden, whereas the "smaller" ones resisted it thinking that they would in that way lose their "right to be heard". Since such voluntary aggregation took place at a slow rate, they turned to a different model that enabled flexibility in merging on the principle of functionality of both providers. The integration was supported by the need for financial stability without which they cannot apply for new funds (from the government, EU funds, or IFI loans and/or credits on the market), since for further financial injection they have to increase their revenue (i.e., increase the prices of water services) and ensure the sustainability of costs.

4.4 Main recommendations coming from other countries' experiences

Efficient water loss management cannot be achieved quickly, as each water supply system is specific and unique, The final objectives of the reduction of water losses depend primarily on the current condition of each particular system,

Based on the good practice examples, there are several steps in the development of the loss reduction plan:

- Develop the master loss (or NRW) reduction plan
  - The first step is to analyze the current condition of the system and develop the master loss reduction plan;
  - Calculate the water balance using the IWA methodology (quantify different NRW elements to define priority activities and investments for the reduction of losses);
  - Take into account all water quantities (from the abstraction site to the consumer);
  - Develop awareness among consumers (national-level campaign) that each consumer in the system is important because "each drop of water" matters;
- Register of the water supply system
  - Establish GIS (precise spatial identification of system structures), SCADA and other systems;
  - Locate the main locations of losses (leakages), use for example standard portable acoustic equipment and a systematic approach;
  - Assess and register all the identified leakage locations;
  - Identify priorities and adjust them accordingly, and store the results in a GIS database;
- Pressure optimization and leakage control
  - Use hydraulic modelling, pressure management solutions (smart valves, pumps, etc,);
- Quality repairs
  - Invest into staff (sufficient number of staff, well-trained staff working in a professional atmosphere with access to the proper tools and equipment);
  - Invest in the quality of materials during construction/reconstruction, as well as in the quality of works;
  - Optimize the speed of repairs;
- System replacement

- Countries need to invest in the maintenance and renovation of existing water supply systems (especially the replacement of pipelines), and improve the condition of existing infrastructure as well as services, which primarily means solving problems in the system (leakages or water losses)

Method of DMA establishment:

- According to size in terms of the number of service connections, from 5,000 (Austria, Salzburg) to less than 100 (Bulgaria);
- Why: It is easier to identify leakages (based on continuous night flow measurements);
- Active leakage control without pressure management is often ineffective;
- PMA (pressure managed are, reduction pressure transients and small reductions in maximum pressure over large areas (pressure zones) are likely to be more beneficial in reducing network bursts than large pressure reductions over small areas (pressure zones), An example of the UK, where the focus was put on bigger areas with higher operating costs,
- PMAs can be sub-divided into more rationally sized smaller DMAs, where it is efficient to have a big PMA for pressure management which includes smaller DMAs where only flows are measured, However, in hilly regions the establishment of small PMAs can be very important/beneficial,

ANNEX – QUESTIONNAIRE FORM

QUESTIONARY – Water loss management in Croatia
Name of water service provider:

1. Has a Conceptual Solution been developed for the water supply system you are operating?
   - Your answer:
2. What year was the Conceptual Solution developed?
   - Your answer:
3. Have you got your own active sources/water abstraction sites?
   - Your answer:
4. Number of active sources (different locations of water abstraction):
   - Your answer:
5. Do you take over water from another PWSP?
   - Yes
   - No
6. Do you deliver water to another PWSP?
   - Yes
   - No
7. Is water supply at risk during dry years?
   - Yes
   - No
8. Have you had water use restrictions during the years on the system you are operating?
   - Yes
   - No
9. Have you got a water treatment plant?
   - Yes
   - No
10. If the answer to the question above is Yes, how many constructed water treatment plants have you got?
    - Your answer:
11. Which water quality indicators do you remove?
    - Manganese
    - Iron
    - Arsenic
    - Other
12. Do you plan to construct new water treatment plants?
    - Yes
    - No
13. Length of the pipeline network (km):
    - Your answer:
14. Length of transmission mains (km):
    - Your answer:
15. Length of the distribution mains (km):
    - Your answer:
16. Length of service connections (km):
    - Your answer:
17. Which pipe materials are represented:
    - PEHD
    - PVC
    - ACC
    - DUCTILE
    - Cast iron – grey cast iron
    - Steel
    - Other

18. Is there pipe statistics by material?
- Yes
- No

19. Average age of the pipeline network (years):
- Your answer:

20. Is there pipe statistics by age?
- Yes
- No

21. Is there pipe statistics by profile?
- Yes
- No

22. Average pressure in the pipeline network, on the level of the entire system (bar):
- Your answer:

23. Number of permanent population in the supply area (current state):
- Your answer:

24. Number of temporary population and tourists in the supply area (current state):
- Your answer:

25. Number of connected permanent population (current state):
- Your answer:

26. Number of connected temporary population and tourists in the supply area (current state):
- Your answer:

27. Number of permanent population in the supply area (planned state):
- Your answer:

28. Number of temporary population and tourists in the supply area (planned state):
- Your answer:

29. Number of connected population (planned state):
- Your answer:

30. Number of connected temporary population and tourists in the supply area (planned state):
- Your answer:

31. Number of household connections (current state):
- Your answer:

32. Number of economic operators' connections (current state):
- Your answer:

33. Number of household connections (planned state):
- Your answer:

34. Number of industrial connections (planned state):
- Your answer:

35. Are all the connections equipped with water meters?
- Yes
- No

36. If the above answer is No, how many connections without water meters are there?
- Your answer:

37. Average distance of the water meter from the street main (m):
- Your answer:

38. Is the consumption of water by the permanent population forecast to decrease, increase or stagnate?
- Decrease
- Stagnate
- Increase
- No forecasts have been made

39. Is the consumption of water by the temporary population and tourists forecast to decrease, increase or stagnate?
- Decrease
- Stagnate
- Increase
- No forecasts have been made

40. Is the consumption of water by the industry forecast to decrease, increase or stagnate?
- Decrease
- Stagnate
- Increase
- No forecasts have been made

41. Is the total water consumption forecast to decrease, increase or stagnate?
- Decrease
- Stagnate
- Increase
- No forecasts have been made

42. Has an ILI value been calculated for the current state of the entire system?
- Yes
- No

43. If the above answer is Yes, what is the ILI value for the current state of the entire system?
- Your answer:

44. Has an ILI value been calculated by individual DMAs for the current state of the system?
- Yes
- No

45. Has an economic value of water losses (HRK/m^3 or HRK/year) been calculated for the current state of the system?
- Yes
- No

46. What is the economic value of water losses averaged for the entire system?
- Your answer:

47. What is the water loss reduction potential (m^3/year)?
- Your answer:

48. The best traditional performance indicators, PI (l/connecting main/d)
- Your answer:

49. With which intensity would you rate the theft of water in the system, as a component of apparent losses?
- No theft
- Minor quantities stolen
- Significant quantities stolen
- Enormous quantities stolen

50. Are there any water tanks/water towers in the system?
- Yes
- No

51. How many water tanks/water towers are there in the system?
- Your answer:

52. Out of the total number of water tanks/water towers in the system, how many of them are in operation?
- Your answer:

53. Are the existing water storage capacities sufficient to meet the current needs?
- Yes
- No

54. Are the existing water storage capacities sufficient to meet the planned needs?
- Yes
- No

55. Do you plan to construct new water storage capacities for hydraulic modification of the system, i,e, to establish new pressure zones?
- Yes
- No

56. What kind of protection from water hammer is in place?

- There is no protection from water hammer in the system
- Protection from water hammer exists only at the water abstraction site
- Protection from water hammer exists only at the pumping stations within the system
- Protection from water hammer exists both at the water abstraction site and at the pumping stations within the system
- Protection from water hammer exists both at the water abstraction site and at the pumping stations within the system and along the pipeline network

57. How many air release/intake valves are installed in the network?

- Your answer:

58. How often are the air release/intake valves serviced?

- Every month
- Every 3 months
- Every 6 months
- Once a year
- Once in 2 years
- Once in 5 years
- Less frequent than once in 5 years

59. Have DMAs been established?

- Yes
- No

60. If the answer to the question above is Yes, how many DMAs have you established so far?

- Your answer:

61. How many DMAs are planned to be established?

- Your answer:

62. Is phased establishment of DMAs planned?

- Yes
- No

63. If the answer to the question above is Yes, how many DMA establishment phases are planned?

- Your answer:

64. How many pumping stations have been built in the system?

- Your answer:

65. How many pumping stations have frequency regulation of pump operation?

- Your answer:

66. Are there pumping stations in the system to abstract water from the sources?

- Yes
- No

67. Are there pumping stations in the system to transport the water towards the water tanks?

- Yes
- No

68. Are there pumping stations in the system to directly push the water towards final users?

- Yes
- No

69. Is pressure regulation implemented in the system?

- Yes
- No

70. How many pressure regulation valves in total are installed in the system?

- Your answer:

71. Out of the number specified above, how many hydraulic pressure regulation valves are installed in the system?

- Your answer:

72. How often are the pressure regulation valves serviced?

- Your answer:

73. In what way is the air released from the water distribution mains?

- Air release is not done
- Air release is done with the help of hydrants
- Air release is done with the help of air release and/or air release/intake valves
- Air release is done with the help of hydrants and air release and/or air release/intake valves

74. How many employees in total are employed in your company?
- Your answer:

75. How many employees are employed on system development and maintenance?
- Your answer:

76. How many employees actively (on a daily basis) work on water losses?
- Your answer:

77. Is there a water loss team(s) established?
- Yes
- No

78. How many water loss teams are active?
- Your answer:

79. How many employees are there in each water loss team?
- Your answer:

80. How many engineers are there in each water loss team?
- Your answer:

81. How many low-skilled workers are there in each water loss team?
- Your answer:

82. How many portable flow meters do your water loss teams use?
- Your answer:

83. How many portable pressure meters do your water loss teams use?
- Your answer:

84. What kind of equipment for active leakage control do the water loss teams use?
- Correlator
- Geophone
- Noise loggers
- Pipe detector
- Other

85. What is the total energy consumption at the level of the entire PWSP (kWh / year; kn / year)?
- Your answer:

86. What is the total energy consumption for the water supply system (kWh / year; kn / year)?
- Your answer:

87. What is the total energy consumption for the drainage system (kWh / year; kn / year)?
- Your answer:

88. How much do you estimate the future energy consumption after the implementation of the planned investments, which includes the upgrade of the water supply, drainage and UPOV systems, as well as measures to improve the existing systems (kWh / year; kn / year)?
- Your answer:

89. Do you have your own power plants built and in operation?
- Yes
- No

90. How many power plants have been built and are in operation?
- Your answer:

91. What is the power of all energy sources together (kW)?
- Your answer:

92. What is the total energy production (kWh / year; kn / year)?
- Your answer:

93. Do you sell surplus energy produced?

- Yes
- No

94. Are you planning to build new energy sources?

- Yes
- No

95. Is there a water balance for the 2017-2021 period?

- Yes
- No

96. Is there a register of failures for the period (2017-2021)?

- Yes
- No

97. How do you prepare the water balance (please select one of the options)?

- The water balance is not prepared
- We have tried to prepare the water balance, but we gave up because we don't know how to separate real and apparent water losses
- We prepare the water balance based on our own format of component analysis
- We prepare the annual water balance in accordance with the IWA methodology
- We prepare the annual water balance in accordance with the IWA methodology and we also use an analysis of 95% data reliability in order to understand the accuracy tolerance

98. How is the abstracted water measured?

- Most of the abstracted water is not measured with flow meters
- More than 50% of the abstracted water is measured with flow meters
- The abstracted quantity of water is measured, but we are not sure of the accuracy of measurement (with some meters more than 10 years old)
- The abstracted quantity of water is measured with mechanical and electromagnetic flow meters which are rarely calibrated (checked for accuracy)
- The abstracted quantity of water is measured with electromagnetic flow meters which are regularly calibrated (checked for accuracy)

99. How is the pressure in the system controlled?

- We have no devices in the system to register pressure measurements
- We have several devices to measure and register the pressure values at the pumping and other facilities
- We have several devices to measure and register the pressure values at the pumping and other facilities and we occasionally measure the pressure
- We have several devices to measure and register the pressure values at the pumping and other facilities and we occassionally measure the system pressure with devices to measure and register the pressure values
- We have permanently installed devices to measure and register the pressure values and we continuously control the pressure in the facilities and in the system

100. What is the status of GIS development?

- We haven't got any system maps
- The systems maps that we have got aren't updated
- We have started to regularly update the maps
- The maps are updated, but we don't use the GIS
- We use the GIS and we regularly update the system maps

101. Which GIS modules have you got?

- Your answer:

102. Have you implemented a SCADA system?

- Yes
- No

103. Which structures in the system do you control?

- Your answer:

104. Is collected data stored for many years?

- Yes
- No

105. What is the time increment of the collected data?

- Your answer:

106. Is it possible to remotely change parameters in the structures and valves (flows, pressures)?

- Yes
- No

107. In what way are leakages and repairs recorded?

- We have no records of system leakage repairs
- We can collect leakage data from the register of work orders of the maintenance department or from the register of reports
- We keep records of repaired leakages with the basic information about the type of repair and pipeline diameter
- We make detailed leakage records, recording the leakage location, pipe diameter, material, type of leakage, as well as dates of detection and repair
- We make detailed leakage records, recording the leakage location, pipe diameter, material, type of leakage, dates of detection and repair, entering everything into the GIS

108. How are the performance indicators used?

- We only use the indicator % of NRW for water losses
- We have tried to calculate the performance indicators, but it is still only the % of NRW that is used
- We regularly calculate the indicators for physical (real) water losses which we present in m^3
- We regularly calculate real and apparent water losses according to the IWA methodology and calculate the ILI indicator
- We regularly calculate real and apparent water losses, the ILI indicator according to the IWA methodology, and we publish them in our official annual reports

109. In what way is active leakage control performed?

- It is only visible leakages that are repaired
- We have leakage detection equipment, but we don't use it
- We have leakage detection equipment and we sometimes use it when there is problem in the system
- Leakage detection equipment is frequently used for reported leakages and sometimes to detect unreported leakages
- We perform regular tests and look for unreported leakages (entire system/yearly or according to measurement by zones)

110. In what way are the DMAs established?

- We have no DMAs zones and no plans to establish them
- We have started establishing DMAs in the system
- We have a few DMAs and we already have first results in the reduction of water losses
- We have several DMAs, and flows and pressures are sometimes measured using portable meters
- We have several DMAs, and flow and pressure measurement is monitored through the SCADA system and an analysis of indicators is done

111. How long does the repair of leakage on transmission mains last?

- We have no records and don't know the rate at which the leakages are repaired
- The average repair time is more than 7 days
- The average repair time is from 7 to 3 days
- The average repair time is from 3 to 1,5 days
- The average repair time is up to 1,5 days

112. How long does the repair of leakage on supply pipelines last?

- We have no records and don't know the rate at which the leakages are repaired
- The average repair time is more than 7 days
- The average repair time is from 7 to 3 days
- The average repair time is from 3 to 1,5 days
- The average repair time is up to 1,5 days

113. How long does the repair of leakage on house connections last?

- We have no records and don't know the rate at which the leakages are repaired
- The average repair time is more than 14 days
- The average repair time is from 14 to 7 days
- The average repair time is from 7 to 2 days
- The average repair time is up to 2 days

114. How many pipelines are restored on average per year (m)?

- Your answer:

115. How many house connections (a pipe from the connection to the main pipeline to the water meter) are restored on average per year (m)?

- Your answer:

116. In what way is the consumption by users measured?

- The consumption of water by users is not measured
- Only the big consumers have water meters
- All the big consumers and most of the small consumers (households) have water meters
- All the consumers have water meters except public fountains, public taps, firefighters and other special users
- 100% of water consumers are measured with water meters, with the consumption of water for system maintenance is also measured (controlled)

117. How frequently is the consumption by users measured?

- Once a month
- Once in 3 months

- Once in 6 months
- Once a year

118. What is current practice related to the replacement of water meters and age of water meters?

- We have no reliable data on the age of users' water meters
- Many users' water meters are more than 10 years old and we have no programme of regular water meter replacement
- We replace only those water meters which are clearly defective
- We have a programme of regular water meter replacement, but we don't manage to replace them on time, and there is a considerable number of water meters that are more than 5 years old
- We conduct the water meter replacement programme and all the water meters are regularly replaced (calibrated) within 5 years or less

119. What is the state related to the accuracy of water meters?

- All the users' water meters are of accuracy class A and/or B
- All the users' water meters are of accuracy class B and C
- All the users' water meters are of accuracy class C
- All the users' water meters are of accuracy class C and D
- All the users' water meters are of accuracy class D

120. In what way is the user database operated?

- The user (consumer) database hasn't been updated for a long time
- We occasionally update the user database
- The updating of the user database is being improved
- We regularly update the user database together with network visits and field checks
- We have a regularly updated user database connected with the GIS

121. In what way is the reading of consumers' water meters controlled?

- We have no programme to control the work of staff reading the water meters
- We rotate the staff doing the manual reading only if we suspect inaccuracies
- We regularly rotate the staff doing the manual reading of water meters
- We regularly rotate the staff doing the reading of water meters, we do random checks, we introduce remote water meter reading
- We use manual/remote water meter readers in the entire system and control the work of staff working on readings and data processing

122. In what way are illegal connections controlled?

- We haven't made any assessments and there is no programme to control illegal water consumption
- We occasionally detect illegal connections
- We occasionally detect illegal connections and other forms of illegal water consumption
- We detect and implement the programme to locate illegal connections
- We implement the programme to locate illegal connections and work on identifying bypass pipes and other forms of water theft

123. In what way are analyses of potential for system pressure management made?

- We don't make analyses of system pressure
- We occasionally measure the pressure in certain parts of the system and try to analyse the results
- We occasionally measure the pressure (minutes), we have an estimate of the average system pressure and we make pressure reduction analyses
- We regularly measure the pressure (minutes and seconds), calculate the average pressure in the system and certain zones, make pressure reduction analyses
- We make regular detailed pressure measurements, we use EPANET or similar software, make analyses of potential improvements in pressure regulation, planning of solutions (manholes, equipment, savings)

124. In what way is the system pressure regulated?

- We have no special regulation of the system pressure in order to control water losses
- We have pressure regulation by managing the operation of pumping facilities
- We have a few pressure regulation areas (zones) with valves (spring, hydraulic), without measurements, no special performance analyses are made
- We have several pressure regulation areas (zones) in the system (with the help of pump frequency control or hydraulic valves), measurements are done and performance analyses are made
- The system is divided into macro and micro pressure regulation areas (zones), methods of advance pressure regulation are used, SCADA-controlled measurements, indicators are calculated

125. In what way is the work in the company organized?

- There is no special department (team) to control NRW
- There is a team (person) to locate leakages, but these people also do other work when needed
- We have a team only to locate leakages, but these people don't make special analyses and reports
- We have a department to control NRW (real and apparent water losses), we make analyses and reports, but there is no special unit/department
- We have a department to control NRW, we make analyses and reports, and there is coordination with the Board (CEO) – regular meetings

126. In what way are different departments in the company coordinated?

- There is no coordination among different departments in the company
- There is occasional coordination (with no special rules or procedures)

- Coordination among some departments has been established for the purpose of efficient water leakage control
- There is regular coordination among departments, coordinated activites are planned and implemented
- We have a special team (or a person) responsible for efficient coordination among all the departments in the company; the Board (CEO) is regularly informed about the plans and results

127. In what way is the water leakage control programme planned and implemented?

- We don't make any plans or reports on the implementation of water leakage control activities
- We make implementation plans for annual water leakage control activities, but no special reports on results are prepared
- We make implementation plans for annual water leakage control activities and special reports on results are prepared
- We make implementation plans for annual water leakage control activities, we define objectives, and special reports on results and performance are prepared
- We have a multi-annual strategy of activities with an assessment of objectives, based on which we plan our annual activities, prepare reports on results, and a regular annual external audit is performed

128. In what way is the programme of annual reconstruction of water supply system planned and implemented?

- Your answer:

129. In what way are the staff working on water leakages trained?

- We don't implement targeted staff training
- Occasionally a small number of people attends conferences, fairs, events and lectures
- We occasionally conduct staff training in order to improve their know-how, but without any special plan; we procure expert literature
- A plan and schedule of the regular acquisition of new know-how for all the key jobs has been prepared; effort is made that this is implemented in accordance with the plan
- The company budget has reserved funds for the regular staff training, literature, conferences; a training programme is implemented in accordance with the multi-annual strategies; annual implementation reports are prepared

130. Have short- and long-term improvement measures been defined?

- Short-term measures have been defined
- Both short- and long-term measures have been defined
- Neither short- nor long-term measures have been defined

131. Is the system hydraulically balanced for the planned state with the improvement measures?

- Yes
- No

132. Which of the improvement measures are foreseen?

- Optimizing the use of water abstraction sites
- Establishing new pressure zones with pressure reduction in parts of the system
- Replacing the existing spring valves for pressure regulation with hydraulic valves
- Introducing remote reading of water meters
- Establishing DMAs
- Extending and upgrading the SCADA system
- Digitalizing the water loss management system

133. What is the estimate of costs of system improvement measures aimed at the reduction of water losses (HRK)?

- Your answer:

134. Has the ILI value been calculated for the planned state with the establishment of the DMAs?

- Yes
- No

135. Is water supply expected to be at risk during dry years/months in relation to the development plans?

- Yes
- No

136. Are there limitations in the capacities of the main water supply routes in relation to demand (today)?

- Yes, during summer months
- Yes, unfavourable conditions throughout the year

137. Do you expect limitations in the capacities of the main water supply routes during increased demand?

- Yes, during summer months
- Yes, unfavourable conditions throughout the year

138. Are there limitations in the available water supply quantities in relation to demand (today) and identified capacities of the abstraction site?

- Yes, during summer months
- Yes, unfavourable conditions throughout the year

139. Do you expect limitations in the available water quantities in relation to the expected increase in demand and identified capacities of the abstraction site?

- No
- Yes, during summer months
- Yes, unfavourable conditions throughout the year

140. If there are limitations in available quantities at the abstraction sites (current or planned state), do these refer only to the quantity or to both quantity and quality of water?

- The limitations refer to quantity
- The limitations refer to quality
- The limitations refer to both quantity and quality

141. If there are limitations in available quantities (current or planned state), do you have the possibility to increase the available quantities at the existing or planned abstraction sites?

- Yes, at the existing abstraction sites by expanding the abstraction permit
- Yes, by opening up new identified abstraction sites
- No, there are no identified backup abstraction sites to supplement the capacities

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

ACTIVITY 1:

BASELINE ASSESSMENT ON THE CURRENT STATUS OF WATER SUPPLY SERVICES IN CROATIA, AN ESTIMATION OF LOSSES AND TECHNICAL CAPACITIES OF PWSPS

October 2022