Bulletin of Yerevan University: Economics
2025, Vol. 16, No. 2(46), December, 71-79
https://doi.org/10.46991/BYSU.G.2025.16.2.071

APPROACHES TO THE DEVELOPMENT OF A WATER RESOURCE SAFETY SYSTEM IN THE REPUBLIC OF ARMENIA

ARAM KARAPETYAN* **TIGRAN KARAPETYAN****
Yerevan State University

Abstract: The objective of this study is to implement functions—specifically investment measures and legal mechanisms - targeted at reducing Non-Revenue Water (NRW) in the Republic of Armenia (RoA), to address the challenges and issues of enhancing the efficiency of water-resource supply and consumption, including both drinking and irrigation water. The object of the research is the water resources system of RoA and its components. The subject of the research is the principles of water resources supply/management, economic-mathematical methods and models, which are aimed at assessing the increase of the efficiency of water resources supply and consumption with the help of system-wide improvement.

Key words: *water resources management, non-revenue water. water losses, cost-benefit analysis, security of water resources, geographic information systems, Internet of Things (IoT) sensors.*

Introduction

What approaches should be undertaken for developing a comprehensive system for ensuring the Security of the Water Resource Reserves of the RoA, since the safeguarding of water resources is also a key component of the national security of this country.

The purpose of this work is to analyse Armenia's current water reserves, identify the main threats and vulnerabilities, and propose systematic approaches aimed at the sustainable and secure management of water resources. It presents a framework of recommended reforms in the legal, governance, technological, and international cooperation sectors.

Water is one of the fundamental resources of life, and the availability of necessary reserves is of strategic importance both for the livelihood of the population and from the standpoint of state security. In the Republic of Armenia, the uneven territorial distribution of water resources, the reduction of water flows caused by climate change, and the inefficient mechanisms of water use increase the risks of resource depletion and misuse (UNECE, 2022).

* **Aram Karapetyan** – PhD, Associate Professor, Chair of Mathematical Modelling in Economics, Faculty of Economics and Management, YSU
E-mail: akarapetyan@ysu.am ORCID ID: https://orcid.org/0009-0006-5353-6644
** **Tigran Karapetyan** – PhD Student, Chair of Mathematical Modelling in Economics, Faculty of Economics and Management, YSU
E-mail: tigrankarapetyan@ysu.am ORCID ID: https://orcid.org/0009-0008-8945-7264

Received: 19.11.2025
Revised: 01.12.2025
Accepted: 23.12.2025

The main purpose of this work is to present a vision for a comprehensive system to ensure the security of Armenia’s water resources, based on an analysis of current challenges and opportunities.

Characteristics of Water Resources in Armenia

Armenia is rich in rivers and groundwater resources. Within the territory of the Republic, around 9,480 streams, rivers, and rivulets are registered, with a total length of more than 23,000 km. The most water-abundant rivers include the Debed, Hrazdan, Vorotan, and Arpa. Groundwater reserves are mainly concentrated in the Ararat Valley, which is of strategic importance for both drinking water supply and agricultural irrigation (Ministry of Environment RA, 2023).

According to studies, the annual water formation in Armenia amounts to approximately 6.7 billion m³, of which about 4.2 billion m³ is ecologically available for use (FAO, 2020).

The Impact of Water Resources Management on the Economy and Agriculture of RoA

Water resources management is considered one of the most important fields of the country's economy. The solution of problems related to water supply to the population and irrigation of irrigable lands is due to its flexible management. Water is one of the most valuable resources of our country, which should be treated with utmost care and precise targeting. In recent years, numerous projects have been undertaken to develop the irrigation system, with the most significant being those focused on constructing reservoirs. Despite all these, there are many other challenges in the field.

The primary objective in the water resources sector is to substantially enhance the efficiency of water resources management in order to effectively address challenges related to domestic water supply and agricultural development—especially the expansion of irrigated land—while also adapting to rising temperatures and decreasing precipitation caused by climate change.

What is non-revenue water?

Non-revenue water includes all water supplied by a utility that does not generate revenue. This consists of both actual losses, such as leaks and physical damage to the distribution system, and apparent losses resulting from theft, illegal connections, or inaccuracies in metering devices. The goal of water utilities is to minimize NRW to ensure that a greater percentage of supplied water reaches the paying customers. ([7], [8], [9])

The GoA strategy for improving the financial sustainability of the irrigation sector states:

• increase in the efficiency of irrigation services, assurance in the continuity of service provision and the maintenance of accessibility;

• improvement of the financial viability and sustainability of irrigation water system companies (water user companies and water receiving companies) by strengthening the prerequisites for a transition to current cost recovery;

• maintaining and upgrading irrigation systems and infrastructure;

• increase in the effectiveness of the investment of state financial support provided to the irrigation system;

Threats and Vulnerabilities

The main factors threatening the security of the water resources of the Republic of Armenia are:

- **Climate Change**

Over the past decades, a decrease in precipitation, an increase in air temperature, and seasonal changes in water flows have been observed. Years of water scarcity are becoming more frequent, especially in the rivers of the Sevan Basin (UNDP, 2021).

- **Pollution and Inefficient Use**

Agricultural and industrial activities contribute to the pollution of aquatic environments. In the Ararat Valley, a decline in groundwater levels has been noted as a result of the operation of illegal wells (Sargsyan, 2021).

- **Shortcomings in the Management System**

Water resource management in Armenia is a multi-agency system, involving various governmental bodies, including the ministries of environment, territorial administration, emergencies, and others. Fragmented regulations and limited monitoring data hinder the implementation of a unified policy (UNECE, 2022).

Approaches to Developing a Water Security Assurance System

- **Institutional Reforms**

A National Water Security Council should be established to oversee strategic planning, risk assessment, and coordinated intersectoral activities. The distribution of powers among state institutions must also be clarified.

- **Monitoring and Data Management**

The creation of a unified data platform with real-time monitoring systems will make it possible to forecast risks and manage water use more efficiently. These systems should be connected with regional centers.

- **Legal Reforms**

The Water Code must be revised, and the mechanisms of responsibility for illegal water use and pollution must be strengthened. In addition, it is necessary to clarify water-use quotas by sectors.

- **International Cooperation**

Armenia should intensify bilateral and regional cooperation within the framework of joint management of the Araks, Debed, and Akhuryan water flows. This will improve the processes of mutual use of water resources and data exchange (FAO, 2020).

Materials and Methods

The methodological basis for the research was the principles of water resources supply, the results of economic research, publications, and monographs related to commercial, investment, and financial optimal management and modelling, as well as RoA laws, government decisions, and RoA economic development trends and processes.

The Cost–Benefit Analysis (CBA) is a critical tool to evaluate the economic viability of the proposed water governance interventions in Armenia. This analysis helps policymakers understand the long-term economic returns of various strategies to address water scarcity, climate change impacts, and regional water cooperation. The CBA uses the Net Present Value (NPV) approach and Benefit-Cost Ratio (BCR) to compare the costs of implementation with the expected benefits derived from each intervention.

Areas of application are irrigation, provision of drinking water and wastewater services, aiming at increasing the efficiency of operations and reducing losses.

Technologies like Internet of Things (IoT) enabled sensors, a Geographic Information Systems (GIS) based SCADA (Supervisory Control and Data Acquisition) systems can enhance the efficiency of the management of water systems by providing real-time monitoring and improving resource allocation.

Together, they allow operators to see **where** events are happening and **how** the system is performing in real time. Key functions are the following:

- Real-time visualization of water networks on maps
- Monitoring of reservoirs, canals, pumping stations, and irrigation systems
- Leak detection and pressure management
- Remote control of gates, valves, and pumps
- Alarm management with geographic context
- Historical data analysis and performance reporting

Predictive analytics can aid in anticipating system inefficiencies and enabling proactive maintenance, ensuring a reduction in NRW and improved service delivery.

During the research, several scientific results were obtained from which the following provisions will be distinguished as scientific innovations:

- New methods and models, and tools, and steps for their application;
- Implementation in educational processes;

A cost-benefit analysis of transitioning to smart water infrastructure will highlight the long-term savings achieved through reduced inefficiencies and better resource utilization.

Below is presented a comparison of water loss levels with electricity transmission & distribution and natural-gas sector losses' levels.

- **Water supply losses (NRW)** were by far the largest problem historically — extremely high in the 2000s (reports of **up to ~80–85%** NRW in some systems around 2007–2012), and have been a major focus of World Bank/donor projects since then. Overall, water losses dominate in percentage terms. ieg.worldbankgroup.org+1
- **Electricity transmission & distribution losses** have been **moderate** and **declined** over time: typical combined T&D loss rates in recent years are in the **~6–10%** range (World Bank / IEA series show values near **6–7%** by 2021–2022). World Bank Open Data+1
- **Natural-gas sector losses** (own use + distribution losses) have generally been **low-to-moderate** compared with water — often **~1–5%** as a share of gas throughput in recent years, though occasional spikes and reporting differences exist; 2019 press figures cited ~4.9% for a quarter, while IEA/energy reviews show distribution losses ~1–3% in recent years. In 2023 official energy-balance notes report some increase in gas distribution/transmission losses. Arka+2IEA+2

B — Compact comparison table (2005–2024 summary)

Numbers below show typical ranges or representative values across the period 2005–2024. Use these as comparative indicators rather than precise annual series (see sources & limitations).

Table 1

Compact comparison table (2005–2024 summary)

Sector	Typical range (2005–2024)	Representative recent value (c.2021–2023)	Notes
Water (NRW)	**~40% – 85%** (very high in mid-2000s for some systems; large variation by city/utility)	Still high in many systems; major reduction in some utilities but not uniformly resolved.	World Bank/donor reports document **NRW up to ~85%** in earlier years (Yerevan & other systems improved under projects). ieg.worldbankgroup.org+1
Electricity (T&D losses)	**~6% – 15%** (higher earlier, falling over time)	**~6–7%** combined T&D in 2021–2022 (IEA / World Bank series show ~6.5% by 2022). CEIC Data+1	Combined transmission+distribution loss percentage of output (World Bank indicator EG.ELC.LOSS.ZS). World Bank Open Data
Natural gas (transmission & distribution losses + own use)	**~1% – 6%** (some quarters or years reported near 4–5%)	**~1–3%** typical distribution losses in some official/IEA figures; 2023 energy balance noted increased losses in gas distribution. IEA Blob+1	Reporting differs whether "own use", technical leakage, unaccounted-for gas, or commercial losses are included. Energy Charter

Source: *https://ieg.worldbankgroup.org/sites/default/files/Data/reports/ppar_armeniawater.pdf, https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS https://www.ceicdata.com/en/armenia/environmental-energy-production-and-consumption/am-electric-power-transmission-and-distribution-losses--of-output https://www.energycharter.org/fileadmin/DocumentsMedia/EERR/ARMENIA_IDR_2017_Final_EN.pdf https://iea.blob.core.windows.net/assets/55834e18-f66e-4642-aed2-7ebff9c54c2c/ArmeniaEnergyProfile.pdf*

C — Short interpretation/trends (why these patterns)

1. **Water losses are very large historically** — caused by old/leaking networks, poor metering, weak revenue collection and commercial losses; donor projects and utility reforms (Yerevan and regional projects) reduced losses in some places, but coverage and outcomes vary. The World Bank IEG and project documents explicitly

note NRW as a major operational issue (reported peaks near 80–85% in earlier years). ieg.worldbankgroup.org+1

2. **Electricity losses improved** — investments in metering, network rehab and automation, and modern management reduced distribution losses; IEA notes transmission losses ~1.4% and distribution ~6.0% in 2021. The World Bank/World Development Indicators show an overall falling trend in T&D losses. IEA+1

3. **Gas losses are comparatively low** — the gas grid is metered and operated by a major operator (Gazprom Armenia), and losses are generally kept low; however, some years/quarters showed higher reported "losses & expenses" (e.g., ~4.9% in Q1 2019). Official energy-balance statements flag occasional increases (notably 2023). Differences in how "losses" are defined (own use, system recoveries, theft) complicate exact comparison. Arka+1

D — Key sources and limitations

Primary sources used (representative):

- World Bank / World Development Indicators — *Electric power transmission & distribution losses (% of output).* (time series, country-level). World Bank Open Data
- IEA / Armenia Energy Profile (Energy Policy Review/Armenia 2022) — detailed sector figures (electricity T&D split; gas transmission & distribution losses). IEA Blob+1
- Armenia national energy balance publications (Ministry / Energy Balance PDFs) — 2015–2023 energy balances showing gas loss volumes and notes about 2023 increases. api.mtad.am+1
- World Bank project evaluations and Independent Evaluation Group notes on municipal water projects — document very high NRW (reports citing up to ~85% in some systems around 2007–2012) and project outcomes. ieg.worldbankgroup.org+1
- Local press / Gazprom Armenia statements about quarterly/annual gas loss figures (e.g., 2019 press note about lowest recorded losses in Q1 2019). Arka

Limitations

- **Different definitions**: "Losses" for each sector may be reported differently (electricity: percentage of output; water: Non-Revenue Water as % of produced water; gas: % of imported volume or % of throughput including own use). That complicates direct apples-to-apples percentage comparisons. ONE MP
- **Data gaps & heterogeneity**: Water sector figures vary greatly across utilities (Yerevan vs regional systems) and by year; some mid-2000s values are extreme for some utilities but not nationwide averages.
- **Time coverage**: World Bank / WDI and IEA have consistent series for electricity and gas losses up to ~2021–2023; water NRW series are typically found in project reports and are less consistently published year-by-year nationally. World Bank Open Data+1

Armenian Water and Wastewater Supply Company "Veolia Jur" Closed Joint Stock Company (CJSC) mostly does not control the whole water supply network from water intake to end-user customers in the multi-apartment buildings. Inside the multi-apartment buildings, Condominiums are responsible for the maintenance and operation of the water and wastewater supply networks. Due to insufficient funding, Condominiums, in most cases, are not able to control technical and commercial losses of water. In contrast to electricity transmission & and distribution, gas supply networks are fully controlled by those utilities. Therefore, the level of water losses is very high in comparison with electricity and gas supply losses.

How to reduce NRW in drinking and irrigation water supply systems?

Drinking water supply system

Calculation of the Reduction of Non-Revenue Water (NRW) in Water Supplies on the example of one multi-apartment building.

The average cost of internal network reconstruction of drinking water in one apartment is 30,000 AMD.

For 12 apartments in one entrance of a multi-apartment building, the cost is 360,000 AMD /12*30,000 AMD/.

For one entrance, the average cost of installation of the inter-floor water pipe and insulation and the connection to the main water pipe in front of the entrance is 300,000 AMD.

The total is 660,000 AMD or 55,000 AMD per customer.

Yearly Average Non-Collected Revenue Calculation from the population of all multi-apartment buildings

Actual yearly figures for 2023 (www.psrc.am)

- Water input to the centralized water supply system of Veolia Jur CJSC (utility) - 528.7 mln m^3.
- Sold water - 161.9 mln m^3.
- Water losses - 366.8 mln m^3 / 69.4%.
- Revenue & Collected amount - 31,334.1/29,907.1 mln. AMD.
- R&C amount (population)-20,924.9/20,114.5 mln. AMD.
- Actual Technical losses - 12.4 %.
- Non-Revenue water from population (multi app bld) - 57*0.67*20,924.9*0.6/(100-69.4)=15,670 mln. AMD.
- Average yearly non-collected revenue is 15,670*0.96 = 15,043 mln. AMD.

Cost-Benefit analysis

- 350,000 (domestic customers) *55,000 AMD = 19,250 mln. AMD;
- 19,250 mln AMD/15,043 mln. AMD = 1.3 years;
- Within 10 years, by investing yearly 1,925 mln. AMD: the utility can receive 1,504 mln AMD per year, plus the accumulated benefit.

Table 2

Cost-Benefit analysis of reconstruction of drinking water internal network

Name	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Total Benefits	0	3,008,600	4,512,900	6,017,200	7,521,500	9,025,800	10,530,100	12,034,400	13,538,700	15,043,000
Total Costs	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250	19,250
Net Cash Flow	-19,250	2,989,350	4,493,650	5,997,950	7,502,250	9,006,550	10,510,850	12,015,150	13,519,450	15,023,750
R = 12%	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
NPV	-19,250	2,669,063	3,582,310	4,269,222	4,767,816	5,110,558	5,325,124	5,435,044	5,460,279	5,417,715

Source: *Calculated by authors.*

Irrigation water supply system

• Implementation of contemporary technologies to decrease the amount of non-revenue water in community distribution networks.

• Implementation of legal, financial, and commercial reforms to decrease NRW.

• Evaluation of necessary financial investments and redemption calculation.

• Financial calculations and comparisons between different service companies.

• Other steps.

Installation of a new internal network from PVC for an irrigation system for 1 hectare (ha):

• Pipes (with installation) for 1 ha – 500 meter*$10 = $5,000 or 2 mln. AMD. Plus, the cost of pumping is 10% and the water meter installation. In total 2.2 mln. AMD.

• Water supplied for l ha is10,000 m3/y, out of which only 4,000 m3/y reaches. The cost is 110,000-130,000 AMD. Water losses are 60%. There is no bookkeeping system. The collection rate is below 40%.

• After upgrading the new internal network water losses will be a maximum of 15%, which means 4,706 m3/y will be supplied, and 4,000 m3/y will reach the customers. Around 5,300 m3/y of water will be saved.

• The benefits are the introduction of a reliable bookkeeping system and a high collection rate. Water supply will be scheduled, which will ensure a high yield and extension of irrigable land areas.

• Cost-Benefit Analysis and NPV calculation are presented below:

Table 3

Cost-Benefit analysis *of the irrigation water supply new internal network construction*

Name	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Total Benefits	0	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953
Total Costs	2,200,000	0	0	0	0	0	0	0	0	0
Net Cash Flow	-2,200,000	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953	446,953
R = 12%	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
NPV	-2,200,000	399,065	356,308	318,132	284,047	253,613	226,440	202,179	180,517	161,176

Source: *Calculated by authors.*

Theoretical and applied significance of the research

• Creation of a complete system of RoA water resources management, which will be proposed to be implemented in the Water Committee of the Ministry of the Territorial Administration and Infrastructure of the Republic of Armenia (WC of MTAI of the RoA).

• Ensuring the full use of reliable data in the water supply system based on the use of modern information processing methods for operational, diagnostic, repair, and construction works.

• Representation of spatial data of the main pipelines of the Water and Wastewater (W&W) and Irrigation system by means of maps and technological schemes;

• Visualisation of the interrelationship of W&W and Irrigation system objects through maps and schemes;

• Obtaining information on the problem areas of the water supply system and irrigation system;

• Consumption distribution study and forecasting;

• Water system asset management

The integration of IoT sensors, GIS-based SCADA systems, and advanced data analytics will provide a robust framework for improving the management of water systems by providing real-time monitoring and improving resource allocation.

Benefits for water and irrigation management

- Improved operational efficiency and faster decision-making
- Reduced water losses and energy consumption
- Better response to failures and emergencies
- Optimized irrigation scheduling and water allocation
- Support for climate-change adaptation and drought management

Thus, integrating smart metering systems, combined with automated leak detection technologies, will provide effective tools for reducing non-revenue water in both urban and agricultural sectors.

Conclusion

The water resources security of the Republic of Armenia requires a comprehensive and institutional approach. It is clear that the existing threats—both ecological and governance-related—cannot be overcome through a single sector.

It is necessary to:

• Establish a water security strategy as a component of national security.

• Estimate necessary measurements (investments and legal) for reducing drinking and irrigation water losses.

• Cost-benefit analysis of measurements mentioned above.

• Suggested solutions for securing necessary water resources and reducing water losses to improve the quality of drinking and irrigation water supply systems and services.

• Introduce digital monitoring technologies.

• Build multifunctional reservoirs for water storage and distribution.

• Strengthen public–private cooperation in the water sector. A secure water future requires timely and well-grounded decisions.

References

United Nations Economic Commission for Europe (UNECE). (2022). *Environmental Performance Reviews: Armenia, Third Review*. Geneva.

Ministry of Environment RA. (2023). *Annual Report on Water Resources and Use in Armenia*.

FAO. (2020). *Integrated Water Resources Management in Armenia: Challenges and Solutions*. Food and Agriculture Organization. FAO. (2020). *Integrated Water Resources Management in Armenia: Challenges and Solutions*. Food and Agriculture Organization.

UNDP. (2021). *Water Security in the South Caucasus: Regional Assessment Report*. United Nations Development Programme.

Sargsyan, A. (2021). Integrated water resources management in Armenia. *Water Policy Journal,* 23(4), 451–466.

UNECE. (2022). *Environmental Performance Reviews: Armenia*. United Nations Economic Commission for Europe.

Rudolf Frauendorfer, Roland Liemberger. The Issue and Challenges of Reducing Non-Revenue Water- Asian Development Bank, 2010.- 51 p.

Bill Kingdom, Roland Liemberger, Philippe Marin. The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries How the Private Sector Can Help: A Look at Performance-Based Service Contracting - The World Bank, Washington, DC, 2006 - 52 p.

Using Performance-Based Contracts to Reduce Non-Revenue Water. -The World Bank, 2016 - 28 p.