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Sustainable wastewater management as a pillar for the sustainable reconstruction of Ukraine

TECHNICAL REPORT

UNEP-DHI CENTRE

UNEP-DHI
Centre on Water and Environment

Acknowledgements

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Join the Global Wastewater Initiative: The Global Wastewater Initiative (GWWI) is a multi-stakeholder partnership whose Secretariat is hosted by the United Nations Environment. Launched in 2013, its purpose is to address wastewater-related issues, prompt coordinated action and encourage new investments for sustainable wastewater management. The GWWI intends to bring about a paradigm shift in the way wastewater is seen, from waste to a resource, and prevent further pollution and degradation of our environment. For more information contact: unep-gwwi@un.org.

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Executive Summary - why wastewater matters

This report underlines the importance of investing in sustainable wastewater management, changing the paradigm of viewing wastewater as a burden or luxury to treating it like a valuable resource, integral to solving the most pressing issues facing the Ukrainian Government in the recovery and reconstruction effort. With an estimated wastewater infrastructure reinvestment need of approximately US$ 3.35 billion (**Table 7**), it is of paramount importance that these investments are made on an underlying principle of sustainable wastewater management and integrated with other sectors.

Sustainable wastewater management has always played a fundamental role in stable societies as a basis for quality of life and economic activity. The paradigm of wastewater management has changed during the past decade, where the sustainable development goals (SDGs) and climate change have moved up on the global agenda. Thus, the contribution of sustainable wastewater management to the SDGs and the sustainable recovery and reconstruction of Ukraine is fourfold; **energy security, quality of life, climate change mitigation, and combating resource scarcity.**

Energy security is one of the main challenges facing Ukraine in the ongoing war and in reconstruction efforts. The potential of using wastewater as an energy resource has been proven to be significant, diversifying the local energy portfolio and reducing the vulnerability of long-range transmission lines. Using benchmark performance data from Europe, it is estimated that excess heat in wastewater can cover 20% of urban heating demand while operating energy positive wastewater treatment plants. Furthermore, on a global scale the potential for energy savings can be estimated to 350 TWh/y, equal to Europe's electricity production from coal in 2021 [1].

Quality of life has always been closely linked to proper wastewater management, which is an essential public health component to prevent the spread of infectious diseases and pandemics. A lack of clean water, adequate sanitation and healthy environment will pose a direct risk to Ukraine in stabilizing their demographic decline resulting from the ongoing war. Offering healthy quality of life by investing in sustainable wastewater management will be crucial to ensure that Ukrainians families return home after the war.

Combating resource scarcity through harvesting valuable nutrients and reusing water contributes to a more circular economy. Several regions in Ukraine are under or close to Water Stress, where treated wastewater can be leveraged to meet local water demands. Reestablishing Ukraine's position as a global breadbasket with fertilizers from nutrients recovered from wastewater has the potential to alleviate local availability issues. It has been estimated that 25% of the global phosphorus and nitrogen demand in agriculture can be met by recycling urine-derived nutrients from wastewater [2], while reducing its environmental impact on receiving water bodies.

Climate change mitigation is an often-neglected potential of sustainable wastewater management, whose operations contribute to the emission of greenhouse gases (GHG), including nitrous oxide (N_2O) and methane (CH_4), which are much more potent than CO_2. Estimates indicate that globally 373-509 Mt CO_2/y can be avoided by retrofitting and optimizing wastewater treatment facilities [3]. A recent Danish study estimates that N_2O emissions from wastewater treatment plants with nutrient removal account for 42% of their total GHG footprint [1]. Case studies have shown that simple changes to process controls can reduce wastewater treatment plant emissions by 50%. Meanwhile, methane leakages are estimated to constitute 10% of the greenhouse gas emissions from wastewater treatment [1].

Climate positive wastewater management in Copenhagen, Denmark

In Copenhagen, the wastewater company, BIOFOS, has managed to avoid more GHG emissions than they emit. This has been achieved through energy savings, reduced N2O emissions, energy recovery of gas and heat, and sector coupling with gas and district heating [4].

Vienna utilizes excess heat to warm up homes, Austria

Europe's largest heat pumps, installed at the Vienna wastewater treatment plant, provide heat to 25,000 households (40 MW), with plans to increase capacity to serve 110,000 households by 2027. The utility, Wien Energie, utilizes the carbon-neutral energy stored in wastewater to supplement other heat sources [5].

Billund Biorefinery implements resource recovery, Denmark

Billund wastewater treatment plant served approximately 70,000 people. Public-private-partnership investments were made to achieve recovery of phosphorus and nitrogen from the wastewater, resulting in an annual revenue of US$ 200,000 [6].

Summary of Call to Actions

As an outcome of this report, several recommendations are identified for leading the transition to sustainable wastewater management as part of the recovery and reconstruction effort and building back better approach. Six calls to action items are listed below with expanded explanations presented in the section entitled "Call to Actions: A sustainable wastewater management plan for Ukraine."

Calls to Action for national **policy makers**:

1. Prioritize wastewater management, reuse, and resource recovery in the political agenda. Nothing can be achieved without political will.
2. Strengthen the institutions responsible for implementing, monitoring, compliance and enforcement of relevant policies. Their role is critical in Ukraine's building back better effort.
3. Attract and sustain investments and financing to support development and innovations in the wastewater sector. The investments pay off.
4. Foster opportunities for capacity building and learning across sectors and borders. Sharing local knowledge will favor the adoption of appropriate solutions.

For partners (including **donors, IGOs, IFIs and NGOs)**, the main Calls to Action are:

1. Finance across sectors. Sector coupling increases resiliency and sustainability.
2. Support capacity building. Know-how promotes local ownership and sustains impact.
3. Create of a database of current and planned projects and activities by international organizations, like MDBs and UN, to support sustainable wastewater management and capacity-building, facilitating collaboration between partners and distribution of support.

Consultative Process

This report is the result of a consultative process. Although the UNEP-DHI Centre led the authorship of this report, the assessment of the current state and future of the wastewater sector in Ukraine would not have been possible without the participation and engagement of stakeholders, in particular the organizations and agencies in Ukraine. The UNEP-DHI Centre is grateful for the numerous comments, suggestions and support received from stakeholders during the production of this report. The final version of this report reflects the input received during stakeholder presentations, through bilateral meetings, and as written commentary. Endorsement by the Ministry of Development of Communities and Territories demonstrates the Ukrainian government's commitment to implement sustainable wastewater management as part of the green recovery of Ukraine. It is our hope that the strong collaboration behind this report will continue in the realization of sustainable wastewater management and systems for Ukraine.

Current Wastewater Landscape

Ukraine is a large country in transition since gaining independence from the Soviet Union. As the country's human development index has risen for the past 3 decades, the population is increasingly urbanized. The country has significant infrastructure for drinking water distribution and wastewater collection and treatment, particularly in urban areas, though these systems are outdated and major improvements are **required to align with EU standards**. However, the ongoing war has thwarted further efforts to modernized utilities [7].

Due to the volatility of the situation in the country, it is considered appropriate to provide an overview of the situation of the urban wastewater sector prior to the war, followed by a description of how war has impacted Ukraine's plans. Ukrainian utilities in particular have been the **target of attacks**, escalating the immediate need for investments in capital reconstruction projects. Hence, reconstruction of the wastewater infrastructure presents an opportunity to improve wastewater management systems and **build back better** when the war ends. There is a critical need for getting the investments right to achieve the Sustainable Development Goals (**SDGs**) and support Ukraine's EU Accession.

Performance Indicators in a Pre-invasion context

Prior to the Russian invasion of 2022, Ukraine was navigating a transition similar to the one which Eastern Germany, Poland and Romania underwent more than 30 years ago. When comparing Ukraine to these countries in terms of overall water availability, water use efficiency, and domestic wastewater production, several insights can be drawn (**Table 1**).

Ukraine has an adequate amount of renewable water resources to support the activities of a developed country and ranks well on overall water availability per capita compared to other more developed countries in the region [8]. However, the country significantly trails behind in terms of water use efficiency. Germany, with more advanced technology and water management practices, ranks highest in efficiency, while Poland and Romania also outperform Ukraine, indicating that Ukraine needs substantial improvements in **optimizing water use and allocation by increasing its value, minimizing losses, and improving its efficient use and reuse**. Energy use efficiency is also intimately related to the efficiency of the water sector, and Ukraine lags in this area.

Regarding domestic wastewater production, Ukraine produces more than Romania or Poland but less than Germany, reflecting its population size and urbanization level. However, Ukraine's wastewater **treatment infrastructure is generally more outdated** and less developed. Germany and Poland treat the majority of their wastewater (99% and 77%, respectively), whereas Ukraine safely treats just 50% of its wastewater, according to WHO 2023 country files [9]. Access to centralized sanitation services is also significantly lower in Ukraine. Thus, there is a critical need for Ukraine to invest, maintain, and upgrade its wastewater management practices, improving sanitation and environmental outcomes. This development will probably be synched with Romania, which has a similar degree of development of their wastewater management systems and faces similar challenges in the upgrade of their sanitation services [10].

Water and wastewater services are managed and provided by water utilities distributed across Ukraine. The major utilities and populations served are presented by oblast in **Table 2.**

Table 1: *Benchmark of key socioeconomic and water use indicators references cited in table*

Indicator		Ukraine	Romania	Poland	Germany	Year	Source
Sociopolitical	Population	41,745,385	19,659,300	37,747,000	83,196,000	2020	[11]
	% Urban population	70%	53%	59%	79%	2020	[11]
	Application to become EU member	2014	1993	1990	-	-	-
	EU member	-	2007	2004	1951/1990	-	-
Water Abstraction	Internal renewable water resources (km^3/y)	55.1	42.4	53.6	107	2020	[8]
	Internal renewable water resources (m3/person/y)	1,320	2,157	1,286	1,420	2020	[8]
	Water withdrawals (km^3/y)	9.9	7.4	9.2	25.8	2020	[8]
	Water withdrawals (m^3/person/y)	225	380	240	310	2020	[8]**Error! Reference source not found.**
	Water stress	12%	7%	30%	35%	2020	[8]
Economy	Water use services	28%	15 %	21 %	42 %	2020	[8]
	Water use agriculture	31%	31 %	15 %	4 %	2020	[8]
	Water use industry	41%	54%	64 %	54 %	2020	[8]
	Water use efficiency (US$/m3)	8	25	52	121	2020	[8]
Human	Drinking water access	96%	100%	88%	100%	2020	[8]
	Water withdrawal domestic (km^3/y)	2.8	1.1	1.96	10.71	2020	[8]
	Water consumed in households (km^3/y)	1.79	0.73	1.25	3.7	2022	[9]
	Non-Revenue Water	12-50%	40%	25%	5%	2021	[12-14]
Wastewater	Domestic wastewater produced (km^3/y)	1.47	0.59	1.00	5.12	2022	[9]
	Domestic wastewater produced (L/person/d)	96	82	73	97 (169)	2022	[9]
	Population with safe sanitation access	72%	85%	98%	97%	2022	[9]
	Domestic wastewater treated	50%	30%	77%	99%	2022	[9]
Tariff	Water utility tariff (US$/$m^3$)	0.9	1.5	3	4	2021	[14]**Error! Reference source not found.**

Water availability

The regional reality of Ukraine's water resource situation deviates significantly from the overall water availability. The situation in different oblasts (regions) is very diverse and complex, reflecting the country's considerable size (>603,000 km^2, nearly double the area of Germany), the varied geographies and climates (e.g., it rains 3 times more in the west than in the south), and different water use intensities.

Surface waters

More than **85% of the available water resources** in the country are concentrated in surface waters [15], hence maintaining good water quality is essential for Ukraine's water supply. Rivers primarily flow from north to south, draining into the Black Sea and the Sea of Azov. A few rivers in the northwestern regions (comprising ca. 10% of the Ukrainian territory) are tributaries to the Vistula and Pripyat rivers, which ultimately reach the Baltic Sea. The Carpathian regions in the west and the forest regions in the north bordering with Belarus (with the exception of Kyiv) are the richest in terms of surface water resources. Surface water availability declines through Roztochia, Podolia, and the Donetsk Ridge to reach minimum numbers in the plains in the central, southern and eastern regions [16, 17]. Seasonal snowmelt plays a vital role in sustaining water reserves in rivers throughout the year. In Ukraine, the Dnipro River basin is the largest and most significant basin, providing approximately 60% of the country's water abstraction needs (see **Figure 1** and **Table 2**). The health of these river basins is threatened by the intensification of soil erosion, which leads to the siltation of water bodies; insufficient forest cover; and various activities within floodplain lands, such as illegal logging, damage to trees and shrubs, and the burning of vegetation.

The recently adopted River Basin Management Plans (RBMPs) aim to ensure sustainable water management and compliance with European legislation [18, 19]. RBMPs for the Don, Dnipro, Dniester, Vistula, Southern Bug, Azov Sea, Black Sea, and Crimea basins were adopted in November 2024, while the Danube RBMP is under approval. The estimated costs of implementing these plans is €7.7 billion, of which 70% is focused on wastewater and sanitation measures [20, 21].

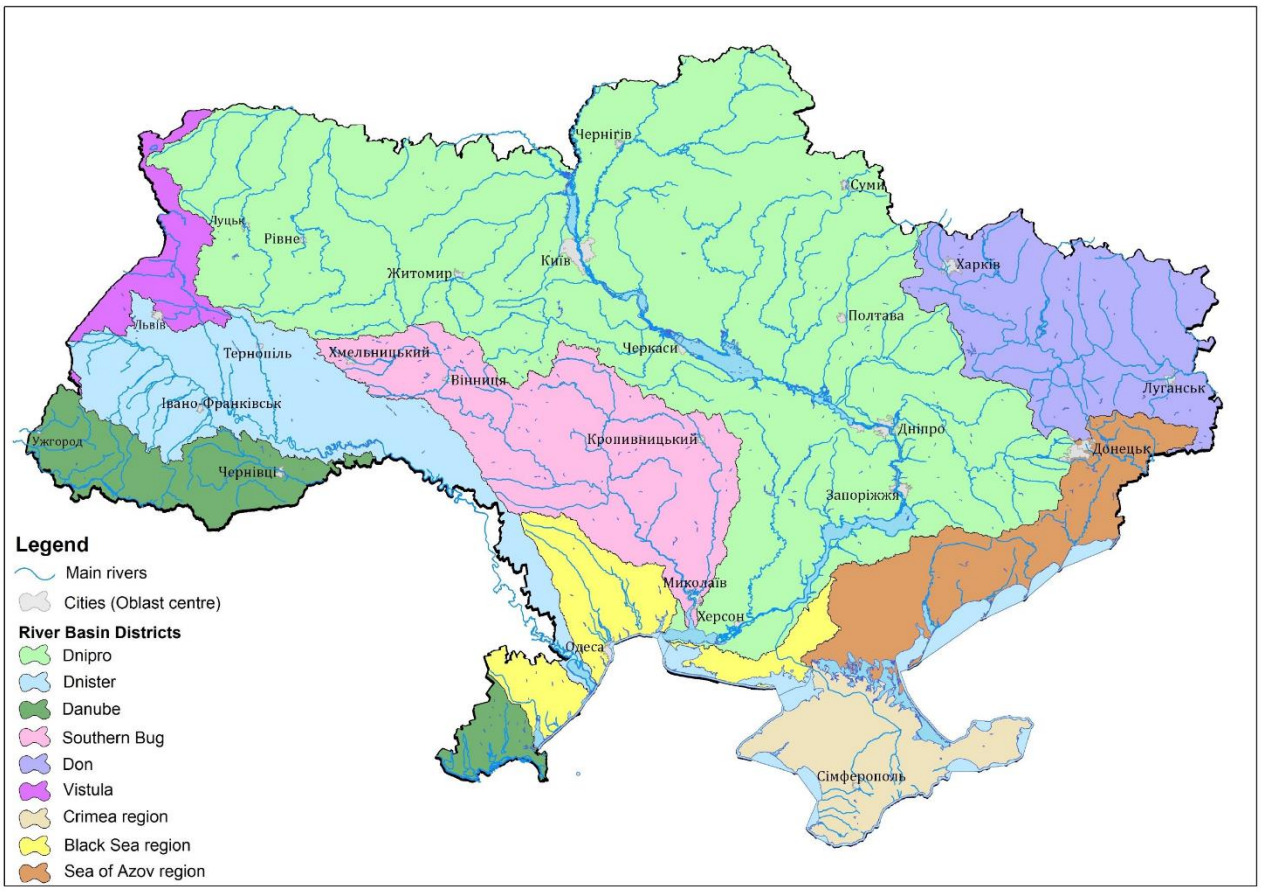


Figure 1: *River basins of Ukraine as designated in the 2016 hydrographic zoning of Ukraine [22]*

Table 2: *River basins in Ukraine with abstraction and wastewater discharges in 2022 [17, 23]*

River Basin	Countries upstream of Ukraine	Discharge basin	Abstraction (km^3/year)	Discharge of polluted WW (km^3/year)
Dnipro River	Russia and Belarus	Black Sea	5.4	0.26
Don River	Russia	Sea of Azov	1.1	0.07
Danube River	Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania	Black Sea	0.79	0.03
Azov Sea	-	Azov Sea	0.63	0.03
Dniester River	Moldova	Black Sea	0.42	0.01
Southern Bug River	-	Black Sea	0.25	0.03
Black Sea	-	Black Sea	0.16	0.01
Vistula River	-	Baltic Sea	0.08	0.11

Groundwater

Ukraine's known groundwater resources (including quarry water from abandoned mines) represent ca. 15% of the total forecasted water resources, but **only 3% can be used** [13]. Nonetheless, groundwater accounts for 14% of the total water consumption and is crucial for domestic and industrial uses. The distribution of groundwater is uneven, with 65% concentrated in the northern and northeastern regions (i.e., Dnipro-Donetsk and Volyn-Podilsk artesian basins). The southern regions have limited access to groundwater resources [13].

Water Stress

The northern and western parts of the country are significantly richer in water resources than the regions in the east, south and center (**Figure 2**). In total, **more than 20 million Ukrainians (50% of the population) lived in water stressed areas** before the war [24]. Consequently, effective management and sustainable use of water resources was essential to sustain national economic activity. Large reservoirs in major rivers (e.g. the Dnipro Reservoir cascade or the Krasno-Oskol, Pechenizke and the Karachunovske Reservoirs) and canals (e.g. North Crimean, Dnieper-Donbas, or Siverskyi Donets-Donbas) ensured water supply to regions with lower water availability. Approximately, 15 km^3 of water were redistributed across Ukraine 2020, equivalent to 2 months of discharge from the Nile River [13, 25].

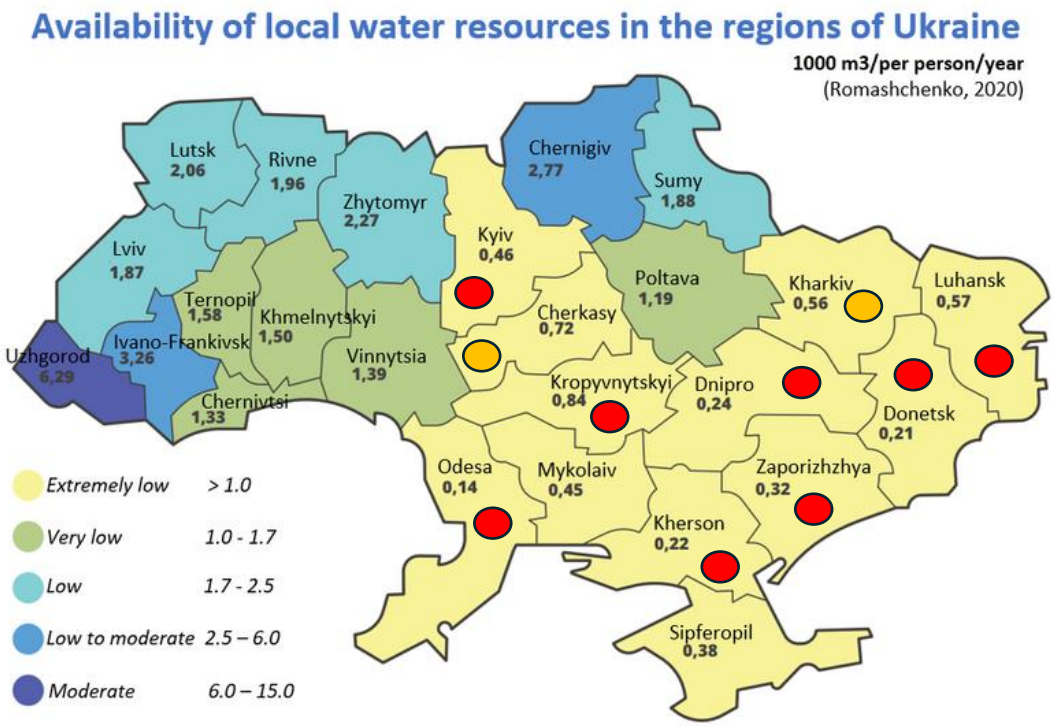


Figure 2: *Resulting distribution of renewable water resources among all the Ukrainian Oblasts. Oblasts with red dots indicate that they are under water stress. Oblasts with orange dots indicate Oblasts close to water stress. Adapted from [13].*

According to Ukraine's Institute of Water Problems and Land Reclamation, the average annual water content of the Dnipro River has decreased by 10% over the past 15 years [26]. Forecasts predict a severe reduction in water resources by 2080, especially in southern Ukraine, with **potential declines of river runoff up to 70%**. The corresponding drop is expected to be around 25% in the Southern Bug River basin. Conversely, the Ukrainian Carpathians (west) might experience increased water

availability. Climate projections predict **increased aridity**, with critical reductions in surface runoff, significantly impacting water supply, irrigation, and water quality [27]. Hence, water reuse from treated wastewater effluent could become an increasingly important resource in the future, especially in regions with significant industrial or agricultural irrigation demands.

The hydrological cycle naturally recharges renewable water resources, both surface and groundwater, unless these sources are overused. **Table 3** summarizes the renewable water resources compared to abstraction levels and presents the degree of water stress by oblast. For example, in Kherson water is abstracted at a higher rate 7.76 times greater than the rate at which water supply can renew itself.

Table 3: *Regional water resources, abstraction and discharges in 2021 (m^3/person/y) [13] with calculated water stress and dilution factor.*

Oblast	Renewable Water resources	Abstraction	Water stress (%)	Wastewater discharge	Estimated dilution factor*
Cherkasy	720	143	20	67	11
Chernihiv	2770	110	4	77	36
Chernivtsi	1330	56	4	46	29
Dnipropetrovsk	240	322	134	190	<1
Donetsk	210	415	197	262	<1
Ivano-Frankivsk	3260	59	2	44	74
Kharkiv	560	118	21	118	5
Kherson	220	1707	776	58	4
Khmelnytskiy	1500	80	5	36	41
Kirovohrad	840	243	29	36	23
Kyiv	460	295	64	261	2
Luhansk	**570**	**37**	**7**	17	33
Lviv	1870	58	3	66	28
Mykolayiv	450	238	53	66	7
Odesa	140	346	247	66	2
Poltava	1190	78	7	56	21
Rivne	1960	101	5	50	39
Sumy	1880	75	4	43	44
Ternopil	1580	38	2	30	53
Vinnytsya	1390	65	5	37	38
Volyn	2060	39	2	28	73
Zakarpattya	6290	38	1	30	207
Zaporizhzhya	320	680	213	512	<1
Zhytomyr	2270	79	3	51	44

** Dilution factor calculated as the renewable water resources for each oblast over the wastewater discharge*

Wastewater Production and treatment

On average, **63% of the water abstracted in was discharged as wastewater** in 2020. An exception is Kherson oblast, where less than 5% of the water abstracted is discharged as wastewater, reflecting the high irrigation demands [12]. Out of 2167 licensed water utilities, approximately half provide centralized sewerage services and wastewater treatment plants (WWTPs). There is not a single registry of these utilities. Instead, utilities are regulated by either the National Energy and Utilities Regulatory Commission (NEURC) or the Regional State Administration (RAS), while services in rural areas may be regulated directly by a village council. This division complicates detailed data collection on utilities' water supply, sewerage facilities, and the condition of WWTPs, if any. The distribution and number of WWTPs by oblast is presented in **Figure 3** and **Table 4.**

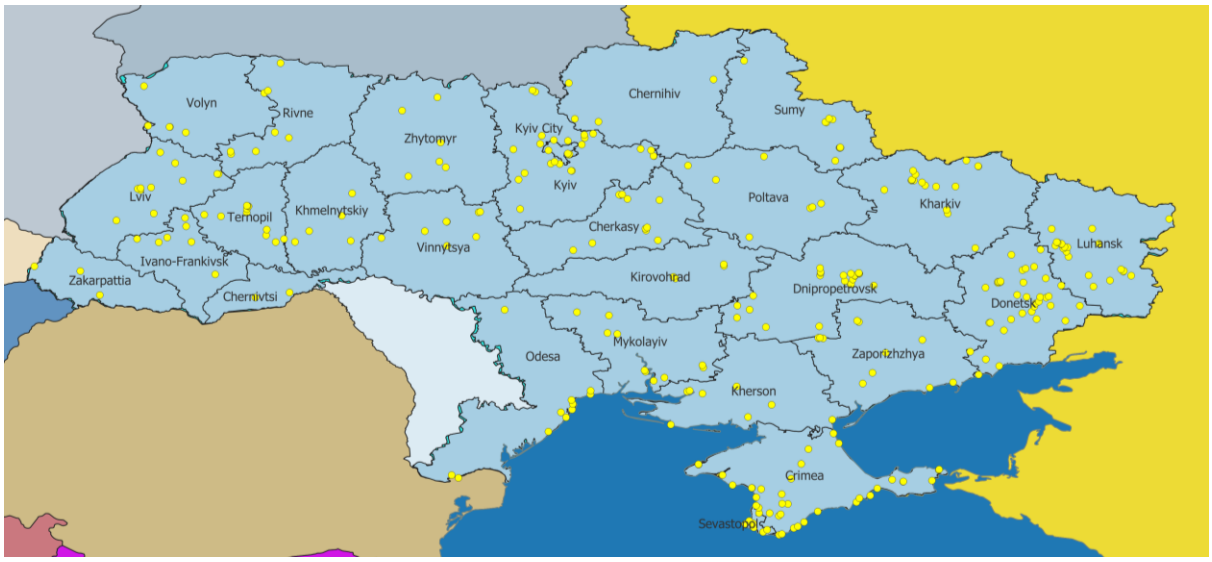


Figure 3: *Distribution of wastewater treatment plants (shown as yellow points) in the HYDROWASTE database, last updated 2023 [28]*

The **sewer infrastructure is also in poor state**. Almost 30% of the 2843 pumping stations and more than 40% of the drainage piping, the total estimated length of which is 14,628 km need to be replaced [29]. The lack of maintenance of the worn sewage lines lead to a high amount of infiltration or leakage into/from the sewer, but the actual contribution remains unclear [30]. It is suspected that wastewater leakages and agriculture are the reason for **nitrate contamination** of drinking water reservoirs.

Urban-rural disparities exist in terms of sewage collection and treatment. While 97% of towns and cities have centralized drainage systems, coverage is sparse in smaller towns (64%) and rural settlements (1,8%), which rely on decentralized systems without any official regulation [31]. Instead, wastewater is released into settling tanks, cesspools, and lagoons that lack waterproofing or sealing, with the risk of seepage into the groundwater and discharge to surface water or adjacent land.

Official statistics indicate that up to 62% of the wastewater is treated, but **only 50% of household wastewater is safely treated** [9]. Yet, independent estimates suggest that figure could be as low as 44% [32]. This uncertainty is also reflected in reported treated wastewater statistics, showing up to 20% variability from one year to another. According to the HYDROWASTE database, Donetsk, Kyviv, Kharkiv, Odesa, Dnipropetrovsk, and Zaporizhzhya oblasts have wastewater treatment service for more than 50% of their population [32].

Table 4: *Wastewater treatment coverage by region in 2022 [24, 28]*

	Total Population	Number of WWTPs	Population served	% of population served
Donetsk oblast	4,131,808	44	3,666,605	89
Kyiv oblast	1,781,044	24	1,011,489	57
Kharkiv oblast	2,658,461	17	1,498,284	56
Odesa oblast	2,377,230	11	1,288,057	54
Dnipropetrovsk oblast	3,176,648	22	1,719,980	54
Zaporizhzhya oblast	1,687,401	12	881,936	52
Luhansk oblast	2,135,913	21	989,573	46
Kherson oblast	1,027,913	10	456,627	44
Sumy oblast	1,068,247	10	440,849	41
Rivne oblast	1,152,961	8	460,350	40
Ivano-Frankivsk oblast	1,368,097	7	541,702	40
Poltava oblast	1,386,978	7	547,293	39
Kirovohrad oblast	933,109	4	349,080	37
Ternopyl oblast	1,038,695	11	377,024	36
Lviv oblast	2,512,084	11	893,898	36
Zhytomyr oblast	1,208,212	6	341,137	28
Mykolayiv oblast	1,119,862	10	286,691	26
Khmelnytskiy oblast	1,254,702	5	242,743	19
Vinnytsya oblast	1,545,416	8	291,334	19
Cherkasy oblast	1,192,137	12	222,616	19
Zakarpattya oblast	1,253,791	3	234,079	19
Chernihiv oblast	991,294	2	73,483	7
Volyn oblast	1,031,421	6	75,941	7
Chernivtsi oblast	901,632	3	28,947	3

As in most European countries, Ukraine has a significant proportion of surface water bodies that suffer from poor environmental quality. Most wastewater treatment plants provide **only basic treatment**, consisting of carbon removal and handling the produced biosolids during treatment via dewatering and stabilization. Nutrient removal is not a common practice, so wastewater discharges content elevated levels of nitrogen and phosphorus, which **contribute to algal blooms and the eutrophication** of receiving water bodies. Furthermore, sludge drying beds are overloaded and pollute groundwater and surface water when improperly managed. In 2023, the total number of centralized wastewater treatment facilities (excluding Luhansk region and the Autonomous Republic of Crimea) was 717, of which half require renovation. Most wastewater treatment plants are small to medium-sized. 90% of the plants (ca. 270 in the HYDROWASTE database) are between 1000 and 150,000 person equivalents (P.E.) [32]; only 30 plants are designed for a load of more than 150,000 P.E. (**Figure 4**).

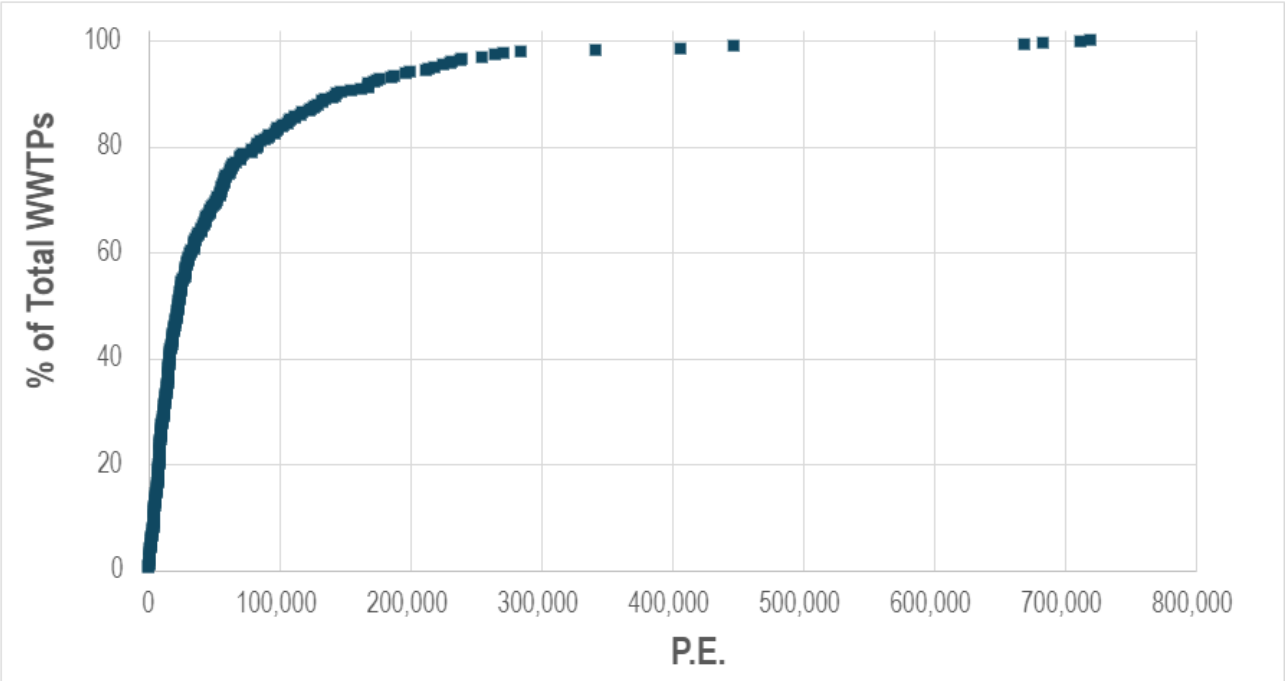


Figure 4: *Cumulative distribution of wastewater treatment plants (WWTPs) in Ukraine over population equivalents (P.E.) served, according to HYDROWASTE database [32]*

The largest contributors to wastewater pollution are cities with populations over 500,000 [33]. Managing stormwater runoff from urban areas is also essential, as most cities in Ukraine have combined drainage systems that bypass municipal treatment plants, discharging harmful substances directly to surface waters during rain events [26].Therefore, **decoupling sewage and stormwater systems** is essential to reduce the discharge of untreated wastewater and improve the treatment capacity and reliable performance of wastewater treatment plants. Separate collection and treatment of rainwater additionally offers its potential use as industrial process water or irrigation, dependent on local conditions.

There is a substantial **lack of publicly available data** on wastewater performance and discharges. However, given the outdated state of wastewater treatment equipment and the lack of treatment for nutrient removal, it is expected that concentrations of nitrogen and phosphorus in treated wastewater **discharges exceed EU environmental standards.** Digitalization of the industry, including online monitoring and modeling of collection systems, treatment facilities, and receiving water bodies would significantly improve process operations and the overall impact on water resources management in addition to increasing transparency and supporting reliable reporting.

The few reports on water quality in Ukrainian rivers also show very elevated concentrations of ammonia, nitrate, and phosphate [34]. For example, environmental ammonium levels are twice as high as measurements in Europe after implementation of the original Urban Wastewater Treatment Directive in 1991 [35]. In the Don River basin, 57% of the river network poses high risk of not achieving good ecological status [36]. Meanwhile, the Dnipro River Basin Management Plan (2025-2030) outlined the establishment or reconstruction of WWTPs for 313 agglomerations with more than 2,000 P.E. in the river basin. In the plan, 186 WWTPs require reconstruction or modernization, including 82 instances where tertiary treatment for **nitrogen and phosphorus removal is required** to comply with European standards [37].

While **WWTPs are major point sources of nutrient pollution** [33], experiences from the Baltic Sea basin indicates that a reduction of the wastewater discharge loads is not enough to ameliorate eutrophication-related issues [38]. Other known sources of nutrient pollution are agricultural runoff, discharges of manure and agricultural waste products, and ineffective management of landfill leachates [39]. Moreover, there is a lack of state incentives for the adoption of phosphorus-free detergents to reduce nutrient loads to municipal sewers.

Hazardous substances, including heavy metals, organochlorine compounds, and pesticides, are being discharged into Ukrainian rivers in addition to organic and biogenic pollutants. Historically, there has been **minimal monitoring of these hazardous contaminants**, which enter water bodies through municipal and industrial wastewater discharges, runoff from polluted sites, and accidental releases. Recent evaluations indicate extension contamination, identifying numerous entities that discharge wastewater containing hazardous pollutants such as heavy metals, petroleum products, and synthetic chemicals, some of which are prohibited in the EU. Elevated concentrations of metals, including copper, zinc, lead, chromium, and nickel, have been found in surface waters and sediments, suggesting ongoing pollution. To address these issues effectively, it is essential to **establish environmental baseline levels** and discharge limits for these pollutants, enhance monitoring and enforcement efforts, and **develop comprehensive classification** schemes to accurately assess the ecological and chemical status of water bodies [36].

Other wastewater sources

Water pollution in Ukraine is significantly influenced by **surface runoff from agricultural** fields, which apply fertilizers and pesticides. Additionally, there are significant issues with the improper handling and storage of agricultural waste. Despite awareness of diffuse pollution, Ukraine is still developing methodologies to assess, manage, and regulate for nitrates and other pollutants. The country is not yet in alignment with EU directives on nitrate pollution.

The **management and control industrial wastewater releases** is crucial and can be achieved by implementing preliminary treatment requirements for industrial wastewater before it is discharged to municipal wastewater systems. Mining industry waste poses a severe risk to water bodies due to groundwater infiltration and the potential of dam failures, which could be exacerbated by climate change and heavier precipitation. The responsibility for **mitigating mining impacts** remains unresolved.

War impact on Ukraine’s water and wastewater sectors

Since mid-2014, portions of the Don River basin within the Donetsk and Luhansk regions have been outside the control of the Ukrainian government [36, 40]. The escalation of the international armed conflict has intensified all pre-existing challenges, leaving millions of Ukrainians with unreliable or insufficient access to water services. The widespread **destruction of water and wastewater infrastructure**, frequent power outages, difficulties in obtaining spare parts for utility maintenance, and shortages of essential chemical reagents and water treatment supplies have severely hampered service nationwide. Water quality and the associated environment is also suffering from untreated wastewater discharges (urban, industrial, agricultural, and military-related) and the absence of adequate monitoring systems to avert risk situations [40, 41]. **Domestic water tariffs have been frozen** from February 2022 (national average slightly below US$ 1/m^3, **Table 1**), which combined with inflation rates on the order of 13-20% have only worsened the overall situation [11, 42]. Operations and maintenance, administrative responsibilities, and training are allocated to the local level that, with insufficient financial resources, can only rely on the dedication of their water professionals, often on a voluntary basis.

Organizations involved in Ukraine’s recovery and reconstruction planning highlight that the water and wastewater **utilities are not receiving the necessary attention** and support [43]. The financial impact of the damages to the water and sanitation sectors was estimated at nearly US$ 4 billion at end of 2023. Losses for these sectors amount up to US$ 11.6 billion. The most affected oblasts are Kharkivska, Luhanska, Khersonska, Zaporizka, and Donetska. The most significant infrastructure damage has been observed in wastewater treatment plants and wastewater collection networks, each accounting for 26% of the total damage. Additionally, drinking water networks, mostly located underground, have suffered substantial damage, representing 25% of the total damage. Further complicating the needs, **extensive damages are widespread** across both urban and rural areas.

The **total projected cost for water and wastewater utilities** in Ukraine's reconstruction and recovery effort is estimated at US$ 11.1 billion from 2024 to 2033 [43], of which US$ 3.4 billion are marked for wastewater infrastructure rehabilitation. Estimated financing needs specific to the reconstruction and recovery of wastewater collection and treatment systems are presented in **Table 5**. Immediate efforts will focus on restoring service delivery by rebuilding damaged infrastructure and strengthening local technical and operational capacities for water supply and sanitation projects. The plan incorporates inflation adjustments and a **build back better approach**, emphasizing the EU accession criteria and climate friendly solutions. Success will depend on prioritizing investments, informed by local assessments, and ensuring a supportive institutional and legal framework for implementation.

Table 5: *Estimated needs for the recovery and reconstruction of the Ukrainian wastewater collection and treatment facilities, 2024-2033, sourced from World Bank report [43]*

Component	Total Need (US$ million)	Prioritized Need (US$ million)
Wastewater Treatment Plants	1,539.0	20.5
Wastewater collection networks	499.5	37.9
Wastewater pump stations	1,311.4	-
Laboratories	2.2	-
TOTAL	**3,352.1**	**58.4**

The catastrophic flooding from the Kakhovka dam breach represents a single instance of damaged water infrastructure. The breach released hazardous chemicals contaminants (including radioactive sediments from Chernobyl nuclear power plant) and biological contaminants (including untreated sewage and decaying wildlife), posing significant long-term health risks and increasing the threat of waterborne diseases. Despite Ukraine's strong environmental laws, enforcement lags and it is estimated that US$ 665 million is needed to enhance environmental governance and clean-up efforts. However, there is no comparable assessment on the **environmental impact and human health effects of the widespread disruption** of wastewater collection and treatment services [44].

The full extent of the impacts on water resources, including the threat to regional biodiversity, can only be roughly estimated at this time. Reports indicate that 14 Ramsar wetland sites, spanning 400,000 hectares along the coastline and lower reaches of the Dnieper River, are at risk. Additionally, damage to reservoirs during the spring spawning season resulted in mass fish deaths, as confirmed at the Oskil Reservoir [41]. Given these challenges, it is crucial to improve monitoring and establish effective wastewater management strategies to **mitigate the impact of the war on Ukraine's water resources**. Enhanced cross-border cooperation, as previously seen in the Siverskyi Donets Basin, also provides an example framework for managing shared water resources and addressing the environmental risks posed by the ongoing war.

Demographic and socioeconomic considerations

Population decline is expected to decline over the next 50 years (**Figure 8**). The internal water consumption and sewage patterns are also modified due to the **internal relocation** of industries and nearly 4 million people (10% of the pre-war population) from the east to the west [42, 45, 46]. Between 2010 and 2020, water usage and the discharge of return water reduced significantly. This decline was attributed to reduced commercial production and decreased water usage driven by increasing water utility fees, as well as the stop of water flows in the North Crimean Canal to the Crimean Peninsula in 2014. The war has exacerbated this trend, resulting in nearly US$ 5 billion in **lost revenue due to lower water consumption**.

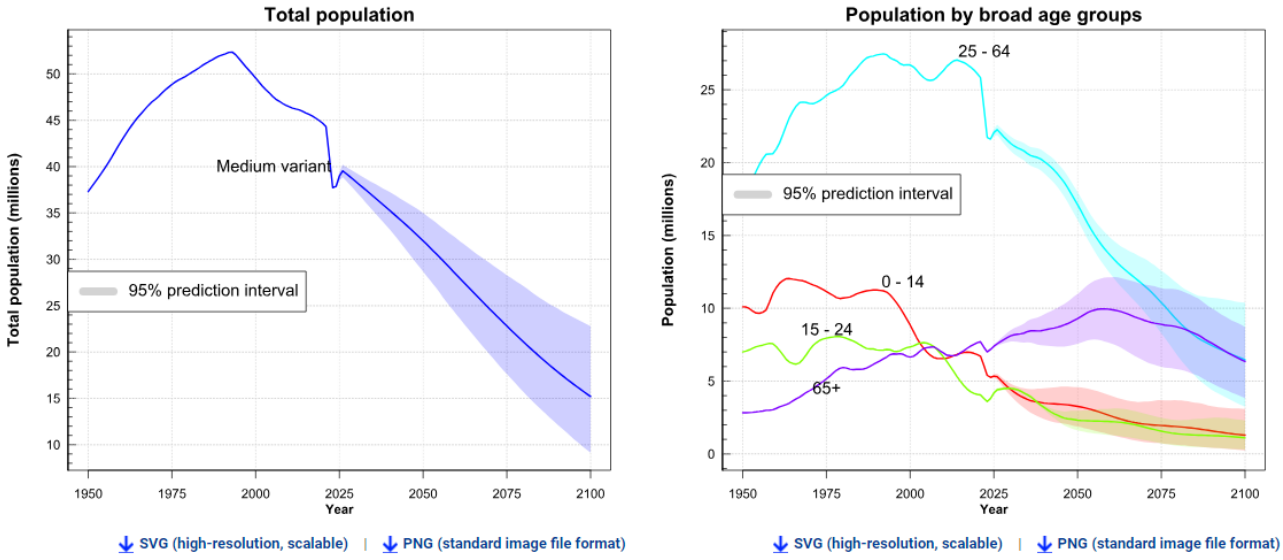


Figure 8: *Population prospects for Ukraine, by the UN Department of Economic and Social Affairs [46]*

Regulatory framework

In 2009, Ukraine joined the Eastern Partnership, which laid the groundwork for establishing closer ties with the European Union. This relationship was formalized in 2014 with the signing of the Association Agreement (AA), which set a deadline for full implementation by 2027. This timeline reflected **Ukraine's commitment to aligning its policies and regulations with EU standards**, aiming for deeper integration into the European political and economic space [20].

The implementation of water laws in Ukraine is **progressing despite the international armed conflict**. River basin management plans and standards for assessing the ecological status of various water bodies have been developed in line with the EU Water Framework Directive and were adopted in 2024. Flood risk management plans were approved in October 2022 to align with the EU Floods Directive. A comprehensive water strategy was adopted in December 2022, addressing water use and resource protection until 2050 [26]. In the strategy, specific actions are provided with achievement deadlines, many of which will need to be revised, such as the designation of nitrate vulnerable zones by December 2023, due to the on-going conflict.

Wastewater legislation

The Law of Ukraine on Wastewater Disposal and Treatment was adopted in January 2023. It regulates drainage systems and sewage treatment processes in Ukraine, in alignment with the principles of the European Wastewater Treatment Directive 91/271/EEC. The law **establishes guidelines** for managing wastewater, protecting water resources, and ensuring compliance with environmental standards and consumer rights. The law **outlines the responsibilities** and powers at different administrative levels as follows:

1. Central Government (Cabinet of Ministers):
    - Formulates national policies for drainage and sewage treatment.
    - Establishes regulations and standards.
    - Oversees the allocation of resources for infrastructure development.
    - Monitors compliance with environmental laws at the national level.

2. Local Administrations (Regional and Municipal Authorities) within their jurisdiction:
    - Implement and enforce national regulations.
    - Manage local drainage systems and sewage treatment facilities.
    - Conduct inspections and ensure compliance with environmental standards.
    - Report on the state of water resources and sewage management.
3. Environmental Authorities:
    - Conduct environmental impact assessments related to drainage and sewage projects.
    - Issue permits for the construction and operation of sewage treatment facilities.
    - Monitor water quality and the ecological impact of drainage systems.
    - Ensure that activities comply with national and EU environmental standards.

Most guidelines are still under development. The ones approved up to date are:

- ***Procedure for the Determination of Maximum Discharge Limits*** dated March 29, 2024, No. 364, focuses on controlling the quality of wastewater discharged to public sewer systems and ensuring compliance with relevant environmental and public health standards. It includes guidelines on how discharge limits should be calculated, monitored, and enforced to protect both the sewer infrastructure and the environment.
- ***Procedure for the Development of Technological Regulations by Enterprises of Centralized Water Supply and Centralized Drainage*** dated April 12, 2024. It establishes uniform requirements for the development, approval, and content of technological regulations for centralized water and wastewater companies. These regulations define the standards and requirements for the technological processes involved in operating centralized water supply and wastewater collection systems and treatment facilities, in order to ensure safe, reliable, and efficient management and operation of water resources and wastewater treatment, complying with the relevant legal and technical standards.
- ***Procedure for Conducting Evaluations of Wastewater Systems and the Quality of Wastewater Treatment*** dated May 14, 2024. The document outlines a procedure for evaluating the technical condition of wastewater systems and the quality of wastewater treatment. It involves a comprehensive assessment of the systems' infrastructure, including the condition of networks, pump stations, and treatment facilities, as well as the technologies and equipment used. The evaluation also covers compliance with safety regulations, the effectiveness of sludge handling processes, and the overall performance of wastewater treatment in meeting environmental standards for carbon and suspended solid removal. Collected data ensures regulatory compliance, supports decision-making for infrastructure maintenance and upgrades, and guides capital improvements. Audits should be performed every 5 years.
- ***Procedure for Purification in Vulnerable Areas***, dated April 2, 2024 outlines several specific requirements for managing wastewater in vulnerable areas, including adherence to stringent purification standards, regular monitoring intervals, and detailed reporting of water quality to responsible authorities. It mandates the development of contingency plans for environmental emergencies and the use of approved purification technologies to effectively remove carbon (i.e., biochemical oxygen demand (BOD), chemical oxygen demand (COD)), nutrients (ammonium-nitrogen, nitrate-nitrogen, phosphorus-phosphates) and solids (total suspended solids (TSS)). Compliance with established discharge limits is required, with ongoing monitoring to ensure that these limits are not exceeded. These measures are intended to

protect sensitive environments from the harmful effects of improper wastewater management.

- ***Procedure for Initial Accounting of the Volumes of Wastewater Sludge Generation, Treatment, Storage and Reuse***, (No. 643), registered on August 27, 2024 with the Ministry of Justice by Ministry of Development of Communities, Territories and Infrastructure.
- ***Amendments to the Rules for Acceptance of Wastewater to Centralized Sewage Systems and the Procedure for Determining the Amount of Fee Charged for Excessive Wastewater Discharges to Centralized Sewage Systems*** (No. 1134), registered on February 2, 2024 with the Ministry of Justice by the Ministry of Development of Communities, Territories and Infrastructure.

While Ukrainian legislation addresses water quality, further efforts are needed to ensure **compliance with EU standards** and facilitate international cooperation efforts, including agreements related to the Black Sea, Danube, and Dniester River basins, as well as **bilateral cooperation** with neighboring countries. With the recent adoption of the revised Urban Wastewater Treatment Directive (2024), Ukraine will need to update its current wastewater legislation to comply with these requirements.

Implementation of the revised Urban Wastewater Treatment Directive (UWWTD)

The revised Urban Wastewater Treatment Directive approved in October 2024 establishes comprehensive requirements to enhance urban wastewater management across the EU [47]. These requirements are designed to protect water quality, public health, and align with broader environmental and climate goals. The directive includes specific population equivalent (P.E.) thresholds to ensure appropriate levels of treatment based on the size of the agglomeration.

- **Collection and Secondary Treatment:** The directive mandates secondary treatment for all urban wastewater from agglomerations with 1.000 P.E. or more. Treatment must include the biological removal of biodegradable organic matter, reducing pollution levels before the wastewater is discharged into the environment. Secondary treatment is essential to meet the necessary water quality standards and safeguard aquatic ecosystems.

- **Tertiary treatment**, which focuses on the removal of nutrients like nitrogen and phosphorus, is required for wastewater treatment plants serving:
    - Agglomerations of 150,000 P.E. and above.
    - Agglomerations of 10,000 P.E. and above that discharge into sensitive areas or areas at risk of eutrophication.

- **Quaternary treatment**, which is uses additional treatment techniques to remove micropollutants such as pharmaceuticals and personal care products, is required for wastewater treatment plants serving:
    - Agglomerations of 150,000 P.E. and above.
    - Agglomerations of 10,000 P.E. and above located in sensitive areas identified as at-risk due to micropollutant contamination.

- **Integrated Urban Wastewater Management Plans (UWWMP):** These plans aim to manage urban runoff and stormwater overflows comprehensively, minimizing pollution and promoting sustainable water management practices. Member states are required to develop integrated urban wastewater management plans for:
    - Agglomerations of 100,000 P.E. and above.

- At-risk agglomerations between 10,000 and 100,000 P.E.

- **Extended Producer Responsibility (EPR):** The directive enforces the EPR principle, especially for producers of pharmaceuticals and cosmetics. Producers are required to cover a significant portion of the costs associated with quaternary treatment to manage micropollutant contamination. This ensures that industries contributing to pollution bear the financial responsibility for mitigating their environmental impact.

- **Energy Neutrality:** A key addition to the directive is the requirement for urban wastewater treatment plants to achieve energy neutrality. Treatment plants are expected to produce energy from renewable sources, reducing their carbon footprint and contributing to the EU's climate neutrality objectives. This requirement encourages innovation and promotes sustainable practices within the wastewater treatment sector.

Table 6: *Urban wastewater agglomerations in Ukraine by estimated population equivalents (P.E.) served [24, 28]*

	TOTAL Agglomerations	Tertiary & Quaternary Treatment Requirement	Integrated UWWMP Requirement
1,000-10,000 P.E.	809	No	No
10,000-100,000 P.E.	327	Yes, for sensitive areas	Yes, for sensitive areas
> 100,000 P.E.	40	Yes, for sensitive areas	Yes
> 150,000 P.E.	32	Yes	Yes
TOTAL	1176		
For comparison: TOTAL POLAND	*1678*		
Rural population, not included in agglomerations count	12,763,070 (30%)		
Number in HYDROWASTE database	312		

Table 7: *Requirements and deadlines from aligning with the EU's updated Urban Wastewater Directive [47]*

Requirement	Description	Deadlines
Urban Wastewater Collecting Systems	Obligation to set up separate urban wastewater collecting systems for agglomerations of 1,000 P.E. or more.	2030, with an extension allowed to **2035** due to the large number of small agglomerations and recent EU membership.
Secondary Treatment	Application of secondary treatment (removal of biodegradable organic matter) to urban wastewater from agglomerations of 1,000 P.E. or more.	2030, extended to **2035** for Ukraine due to the need for substantial infrastructure investments.
Tertiary Treatment	Application of tertiary treatment (removal of nitrogen and phosphorus) for plants of 150,000 P.E. and above, and in sensitive areas or areas at risk of eutrophication.	**2039** with intermediate target of 2033. Ukraine must comply by these deadlines, with extensions allowed up to 2045 for areas requiring significant upgrades. For sensitive areas or areas at risk of eutrophication, tertiary treatment is required by 2039.
Quaternary Treatment	Application of quaternary treatment (removal of micropollutants) for plants of 150,000 P.E. and above, and in sensitive areas.	**2045,** with intermediate targets in 2033 and 2039. For sensitive areas, Ukraine must apply quaternary treatment by 2045, with potential extensions if justified by risk assessments and national conditions.
Integrated Urban Wastewater Management Plans	Development of plans for agglomerations over 100,000 P.E. by 2033 and for at-risk agglomerations between 10,000 and 100,000 P.E. by 2039.	**2033** for WWTPs >100,000 P.E. **2039** for WWTPs 10,000-100,000 P.E.. Ukraine must develop these plans within these timeframes, with potential extensions based on specific needs.
Extended Producer Responsibility (EPR)	Producers of pharmaceuticals and cosmetics must cover at least 80% of costs associated with quaternary treatment for micropollutants.	**Upon directive adoption.** Ukraine must implement EPR schemes aligned with national strategies and capabilities.
Energy Neutrality	Urban wastewater treatment plants must achieve energy neutrality by producing energy from renewable sources.	**2045**. Ukraine must comply by this deadline but can plan implementation according to national energy policies.

Vision of the Ukrainian government

Discussions and planning for Ukraine's post-war recovery and reconstruction are already underway, with the National Council presenting the Plan for the Recovery of Ukraine. This plan prioritizes sustainable economic growth as a key priority, emphasizing the **need for strategies to mitigate climate change** impacts on water resources and support future agricultural development.

Water pollution is recognized as one of Ukraine's most pressing environmental issues. To address this, the Ukrainian government is **implementing a comprehensive framework** to protect and manage water resources, enhance environmental resilience, and promote sustainable development as outlined by the **Water Management Strategy of Ukraine for the period up to 2050** (approved in December 2022). The adoption of eight river basin management plans in alignment with this strategy. In the short term, the strategy emphasizes maintaining essential services, containing pollution spills, and enhancing local technical and operational capacities to support future reconstruction efforts. Immediate priorities include **repairing and maintaining critical infrastructure** and developing local strategies for reconstruction and recovery, with plans to repair or replace at least 50% of municipal centralized drainage systems by 2025, increasing to 70% by 2030. Pumping equipment in centralized drainage systems will be replaced at rates of 15% by 2025 and 20% by 2030. Public awareness and engagement are prioritized, with the roll out of water conservation and pollution prevention programs and social advertising targeted for 2025 and posting water quality monitoring data by 2030.

The strategy includes developing legal frameworks to ensure cost coverage for water services and **implementing water supply and sewerage tariffs** that include depreciation charges and profit margins by 2024. **Skill development** is also essential, with plans to train specialists in integrated water resources management by 2025, increase the number of water monitoring stations to meet European standards by 2025, and optimize chemical laboratories for environmental water quality monitoring by 2027.

The implementation of the Water Management Strategy of Ukraine is structured into four stages: The preparatory stage (2022-2024) establishes the legal and organizational framework, updates legislation, approves management plans, and sets up initial action plans. The pilot implementation stage (2025-2030) involves executing initial plans, evaluating their effectiveness, achieving high water quality, reducing health risks, and improving water supply and wastewater treatment. The operational implementation stage (2031-2042) will execute updated management plans, maintain improvements, sustain high water quality, reduce water losses, and mitigate climate change impacts. Finally, the corrective implementation stage (2043-2050) aims to fulfill Ukraine's international obligations, achieve SDGs, stabilize river water content, reduce pollution, and ensure sustainable water resource management.

The government has set **specific numeric targets and deadlines** to ensure its implementation, addressing water consumption, agricultural and industrial pollution reduction, and investments in stormwater management (**Table 8**). The Strategy targets 100% sanitation coverage for urban populations by 2030 and rural sanitation coverage increasing to 95% by 2050. By 2023, less than 5% of total wastewater will be discharged untreated. Nitrogen and phosphorus removal will become compulsory for municipal WWTPs larger than 500,000 P.E. by 2030. However, due to the on-going conflict and operations at survival mode, many targets are no longer realistic and will need to be revised, in coordination with the revised EU Urban Wastewater Treatment Directive.

Table 8: *Overview of relevant targets from the Water Management Strategy of Ukraine for the period up to 2050 [26]*

Category	Goal/Target	Deadline
Water Consumption	Reduce daily water use per person to 150 liters	2030
	Further reduce daily water use per person to 100 liters	2050
Sanitation Coverage	Achieve 80% sanitation coverage for the rural population	2030
	Achieve 100% sanitation coverage for the urban population	2030
	Increase rural sanitation coverage to 95%	2050
	Ensure 2% of rural population has access to centralized sewerage	2025
	Increase to 2.5% of rural population with access to centralized sewerage	2030
	Provide 70% of urban population with appropriate sanitary measures	2025
	Increase to 72% of urban population with appropriate sanitary measures	2030
Infrastructure Upgrades	Repair or replace 50% of municipal centralized drainage systems	2025
	Increase to 70% of municipal centralized drainage systems repaired or replaced	2030
	Replace 25% of pumping equipment in centralized water supply systems	2025
	Increase to 40% of pumping equipment in centralized water supply systems replaced	2030
	Replace 15% of pumping equipment in centralized drainage systems	2025
	Increase to 20% of pumping equipment in centralized drainage systems replaced	2030
Stormwater Management	Install trapping grates on all types of storm sewers not equipped with pre-treatment systems	2025
	Introduce settling of storm sewage effluents before they enter water bodies	2025
	Introduce stormwater management systems in cities with a population over 200,000	2027
	Monitor stormwater quality in cities with a population over 200,000	2027
	Increase the number of settlements with stormwater management systems and stormwater treatment	Ongoing
Financing and Investment	Develop legal frameworks for cost coverage of water services	2024
Pollutant Reduction	Reduce untreated wastewater discharge to no more than 5% of total wastewater	2030
	Introduce tertiary treatment technologies in 15% of municipal wastewater treatment plants for the removal of Nitrogen and Phosphorus	2030
	Reduce untreated sludge from wastewater treatment by 25%	2025
	Introduce state of the art methods for the treatment of wastewater treatment sludge in 70% of the wastewater treatment plants	2030
Reuse of Treated Water	Reuse 0.5% of treated wastewater for irrigation	2025
	Increase reuse of treated wastewater for irrigation to 1%	2030
Skill Development	Train specialists in integrated water resources management and enhance environmental education	2025
	Increase the number of water monitoring stations in line with European standards	2025
	Optimize chemical laboratories for environmental water monitoring	2027

Case Studies

Return of experience: Wastewater management in neighboring countries

Poland case study

As a recent member of the EU, Poland has worked hard to overhaul its infrastructure and align with EU standards. Mobilizing investments and financing has been crucial to initiate major infrastructure projects. The availability of EU funds and public state funds along with borrowing from the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD), and the state-owned development bank (BGK) has ensured funding for long-term capital improvements projects. Generally, the influx of funds has improved infrastructure nationally, leading to more productivity, GDP growth, and attracting more investments.

The Polish government has adopted several long-term national development strategies, along with EU partnership agreements and operational programs, to set the framework for cross-sectoral coordination and harmonize investment strategies across all levels of government. The Ministry of Climate and Environment adopts national environmental policies and oversees several institutions responsible for monitoring, compliance and enforcement as well as funding for environmental investments. Poland also has a National Water Management Authority (NWMA), created in 2006, which manages and protects national water resources in accordance with the SDG's and ensures users' compliance with water permits. Seven regional water management boards are subordinate to the NWMA and set regional agenda for identifying and assessing the status of water resources and their management [48].

As a result of these efforts, Poland has successfully increased sewage collection coverage and now treats over 87% of its wastewater, which is above the European average of 76%. Wastewater is treated in 1678 WWTPs across the country, the large majority of which provide biological treatment. Due to the large number of surface water bodies, Poland regulates the discharge of wastewater from agglomerations greater than 10,000 P.E. for nutrient removal; thus, 570 WWTPs also provide nitrogen and phosphorus removal. Over the past decade, Poland has been closing the gap to achieve requirements of the UWWTD (adopted 1991), with 99.7% of urban wastewater meeting collection requirements and 95.8% meeting treatment requirements. Meanwhile, approximately 38% of wastewater sludge was beneficially applied to agricultural lands in 2018. Improvements to the wastewater treatment sector have also resulted in over 25% reduction in greenhouse gas emissions between 2010 and 2019 [49].

Further steps need to be taken to stay on track with the national plans as EU funding decreases and to support on-going maintenance of infrastructure, for which it is typically more difficult to secure private investments. Furthermore, corruption in infrastructure investments and procurement procedures is still perceived as an issue, despite gains made in the last decade. To overcome these challenges, Poland has several tools available to improve efficient allocation of investments and project quality, such as the adoption of cost-benefit analysis in prioritizing works and the development of public procurement capabilities across all levels of government. In order to finance on-going maintenance and operations, utility capacity development, and future rehabilitations, Poland will need to increase tariffs and/or taxes. While the government has implemented the polluter pays principle with taxes on air and water emissions, the relatively low tax rate generates limited revenue for adopting sustainable upgrades and is insufficient at inciting behavior change [50]. However, revenue creation has been

more successful in the water sector. The adoption of the 2018 Water Act centralized the economic regulation of Polish water utilities under the state regulator, Wody Polskie, tasked to review and approve tariff increases proposed by utilities. As a result, utility revenue accounts for approximately 60% of CAPEX investments, while the remaining 40% is split equally between national funds and EU funds or loans [51].

Romania case study

As another recent EU member state, Romania's efforts to implement sustainable wastewater management have been less successful and the country is less than halfway to meet treatment targets align with the 1991 UWWTD. Currently, only 12% of wastewater is treated in line with EU legislation. There are just 642 WWTPs across the country, a quarter of which have nitrogen and phosphorus removal [52]. Nonetheless, Romania plans to reach compliance with the recast UWWTD (2024) and it could be useful to liaise with other member states to achieve these goals.

Romania faces several significant challenges in improving access to drinking water and sanitation, especially in rural areas [10]. One major issue is the large urban-rural divide. While 94% of the urban population has access to safe water, only 47% of the rural population enjoys the same. Similarly, access to sewerage networks is 87% in urban areas but only 14% in rural regions. This disparity highlights the critical need for focused investment in rural infrastructure. The regionalization policy initially aimed to improve water services by consolidating small, inefficient operators into regional ones. However, this process has stalled, leaving many rural communities underserved. Currently, about one-third of municipalities have not joined Intercommunity Development Associations (IDAs), and only half of those have joined Regional Operating Companies (ROCs), leading to fragmentation and inefficiency in water services.

Another significant challenge is financial. Romania requires an additional €22 billion to meet EU water standards, indicating a substantial funding gap. The current water and sanitation tariffs, though lower than in other EU countries, are expected to rise, posing affordability issues for many rural residents. This financial strain is compounded by the high levels of non-revenue water (NRW), about 50%, which reflects inefficiencies and losses in the system [14].

Institutional coordination and leadership in the water sector are lacking, creating a complex environment with no clear authority driving improvements. Moreover, the impact of climate change, particularly the risks of droughts, has not been adequately addressed, which could further threaten water security and resilience.

To overcome these challenges, Romania needs to enhance the role of civil society, promote technical solutions tailored to local needs, increase professional training for water sector employees, and possibly merge smaller operators to improve investment efficiency and service delivery. Legislative changes may also be necessary to enforce connections to public sewerage systems and to prohibit the discharge of untreated wastewater.

Calls to Action: A sustainable wastewater management plan for Ukraine

UNEP Vision

The GWWI Flagship publication "Wastewater - Turning Problem to Solution" (2023) identified three action areas and six key building blocks to support the adoption of sustainable wastewater management globally [6]. The three key action areas call for the reduction of the volume of wastewater produced; the prevention and reduction of contamination; and the sustainable management of wastewater for resource recovery and reuse. The six building blocks identify the different arenas, in which specific actions need to be taken, including:

1. **Governance and legislation**
2. **Financing**
3. **Capacity Development**
4. **Innovation**
5. **Data**
6. **Awareness and behavior change**

Tailoring these building blocks to the specific action items that fit the Ukrainian context is critical to ensure success. Sustainable wastewater management is particularly important to Ukraine's ability to deliver **quality of life**, provide **energy security**, **combat resource scarcity** and **mitigate climate change**. The involvement of policy makers and donors is essential to initiate a national wastewater management strategy and lay the groundwork for the sustainable collection, treatment, and beneficial recovery and reuse of wastewater resources in Ukraine. To that end, the following calls for action are advocated.

Policy and Decision Maker Actions

Policy and decision makers have the unique ability to set the political agenda and align **legislation and governance** across sectors. Moreover, they play a crucial role in engaging stakeholders, thereby steering the **investment** and **capacity development** in the wastewater sector, as well as creating enabling environments for the adoption of locally **appropriate technologies and innovations**. Specific calls to action for policy makers include:

1. **Prioritize wastewater management, reuse, and resource recovery in the political agenda.**
    - Continue to develop and implement national policies that promote coherence across water-related policies and regulations, aligning the proposed Strategy for Development of the Water Management with the updated EU Urban Wastewater Directive, Water Framework Directive, and Sewage Sludge Directive.
    - Establish multisectoral policy working groups, such as the Water-Energy nexus, and agreements to facilitate coordination across sectors, particularly with participation from water and sanitation, energy, agricultural and industrial sectors to capitalize on renewable resources and opportunities for climate mitigation stemming from wastewater management.

- Set interim goals (3-5 years) for wastewater treatment coverage and resource recovery to maintain momentum in the transformation to sustainable wastewater management.
- Formulate policies that facilitate and encourage the adoption internal gray-water reuse in new and reconstructed buildings.
- Ensure policies encourage and allow for innovations and technologies appropriate to the local context.
- Ensure policies and standards (e.g., water quality standards, water reuse criteria) are clear and transparent, holding appropriate actors accountable, in order to strengthen public trust and confidence.

2. **Strengthen the institutions responsible for implementing, monitoring, compliance and enforcement of relevant policies**
    - Establish commissions to stay current on the latest water, environmental, energy, and resource recovery-related policy developments in the European Union and other regional agencies, such as transboundary management of the Black Sea, Danube, and Dniester River basins.
    - Implement requirements for pre-treatment programs of industrial wastewater discharged to municipal collection systems, or specialized permitting and monitoring requirements for industrial wastewater facilities that charge directly to water bodies.
    - Specify minimum monitoring, data management and reporting standards related to wastewater production, collection, treatment, and resource recovery in order to strengthen indicators and standardize available data.
3. **Attract and sustain investments and financing to support development and innovations in the wastewater sector**
    - Increase public funding allocations for wastewater collection and treatment projects, incentivizing the incorporation of water reuse and resource recovery from wastewater.
    - Regulate appropriate and fair pricing and tariffs for water resources and services, in conjunction with universal water metering, to sustain these systems, promote efficient use and encourage transition to a circular economy.
    - Encourage the adoption of digitalized asset management systems by water and wastewater utilities to accurately valorize and depreciate existing infrastructure.
    - Engage with the private sector to secure investments in capital projects, to co-develop markets for recovered resources (e.g. fertilizers, biogas), and to promote innovations and technical advances.
    - Promote openness and transparency in project funding and competitive bidding processes during design and construction/renovation of facilities.
4. **Foster opportunities for capacity building and learning across sectors and borders**
    - Participate in fact-finding missions and the regional exchange of best practices.

- Facilitate cooperation and knowledge sharing opportunities between cities, regional utilities, and practitioners in and around Ukraine.
- Create national public awareness campaigns educating the public about the potential of wastewater as renewable resource for water, energy, and nutrients.

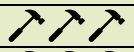
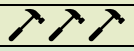
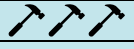
Partner Actions

In addition to supporting the **financing** of wastewater projects, partners (e.g., donors, IGOs, IFIs, and NGOs) can contribute their networks and project experience to support **capacity development** and the other building blocks. Specific calls to action for donors include:

1. **Finance across sectors, coupling sectors for increased resiliency and sustainability**
    - Link wastewater management, energy security, and climate change mitigation to increase impact and return of investments.
    - Allocate funding for wastewater collection and treatment capital improvements projects, demanding circularity as a fundamental design principle.
    - Facilitate cooperation and exchange of best practices between sectors and countries by supporting local workshops and fact-finding tours.
    - Offer blended financial approaches, where appropriate, which allow utilities to pay off debts equitably from collected tariffs and revenues.
2. **Support capacity development for sustained impact and local ownership**
    - Provide grants for multidisciplinary research and development to foster local innovation, ingenuity and technological developments.
    - Develop and support peer-learning and open training platforms, available in Ukrainian, to strengthen capacities, promote innovations, and provide a platform for data and knowledge sharing.
    - Support improved wastewater monitoring through innovative techniques such as sensor technology, computerized telemetry, hydraulic and process modelling, and data analysis tools.
    - Share experience in wastewater management projects to help fill data gaps and support evidence-based policymaking.
    - Capitalize on existing donor networks in Ukraine to promote cross-sectoral coordination, education and awareness locally.
    - Create educational tools and content for public awareness campaigns related to WASH, efficient water use, safe wastewater collection and treatment, and the valorization of recovered resources.
3. Create of a database of current and planned projects and activities by international organizations, like MDBs and UN, to support sustainable wastewater management and capacity-building, facilitating collaboration between partners and distribution of support.

Next Steps…

Based on the discussion of the needs of Ukraine, some examples of the services and products that UNEP can offer are presented in the following table. These activities support the post-conflict recovery through sustainable wastewater management – delivering lasting benefits for people, the environment and the economy of Ukraine. This list is not exhaustive, and the additional inputs by Ukrainian authorities' and partners' is valued.

	Impact	Time	Effort	Cost
1. Advising best practices in wastewater regulations				
i. Guidelines for discharge and monitoring permits	Very high	1 year		€€
ii. Industrial pretreatment program concept and capacity building for regulators and enforcement	High	6-9 months		€€
2. Unlocking financing for sustainable wastewater infrastructure				
i. Master plan for city collection system and WWTP	Very high	1 year		€€€
ii. Asset management plan with digitalized mapping	Very high	2 years		€€€
3. Strengthening Ukraine's capacity for action				
i. Fact-finding tour for officials and operators	High	3-6 months		€€
ii. On-site operator and plant manager trainings - automation and digital process optimization	Medium	3-6 months		€€
iii. Webinar on relevant technical or regulatory topics	Medium	1 month		€
4. Providing technical expertise for appropriate projects				
i. Develop a roadmap for sustainable wastewater management in Ukraine	High	6-9 months		€€
ii. Energy-positive WWTP management	Very high	3-6 months		€€
iii. Implementation roadmap for nutrient recovery	Very high	6-9 months		€€€
iv. Feasibility study for local water re-use system	High	6-9 months		€€
5. Advancing digitalized data collection and mapping				
i. Micropollutants sampling and local environmental assessment	High	6-9 months		€€
ii. Efficiency and benchmarking of local operations	High	3-6 months		€€
iii. Receiving water quality mapping and assessment	High	1 year		€€€
iv. National digital monitoring system	Very high	2 years		€€€€
v. Wastewater solutions digital platform for post-conflict recovery	High	1 year		€€
6. Promoting awareness and behavioral change for long-term prosperity				
∞. Transparency and open communication across activities to build trust, ownership and support	Very high	Continued	Priceless	

Annex

Additional Information

Water Abstraction in Ukraine

The main water consumers are industries, which utilize about 40% of the abstracted water resources. The remaining 60% is consumed equally by the agricultural sector and municipal water utilities. The total water loss from storage, transmission mains, and distribution systems is estimated to be 2.0 km^3 per year, which represents more than 25% of the water withdrawn in the country [13, 29]. The high losses are attributed to the aging infrastructure as well as illegal abstraction by individuals.

Furthermore, there has been a significant lack of legal definitions and clear regulations around water resources protection to meet environmental goals, maintain a good state of groundwater, and balance water usage with natural replenishment is a significant issue. Without these terms being properly defined and consolidated in law, it becomes difficult to ensure that water resources are managed effectively and sustainably within the country [26].

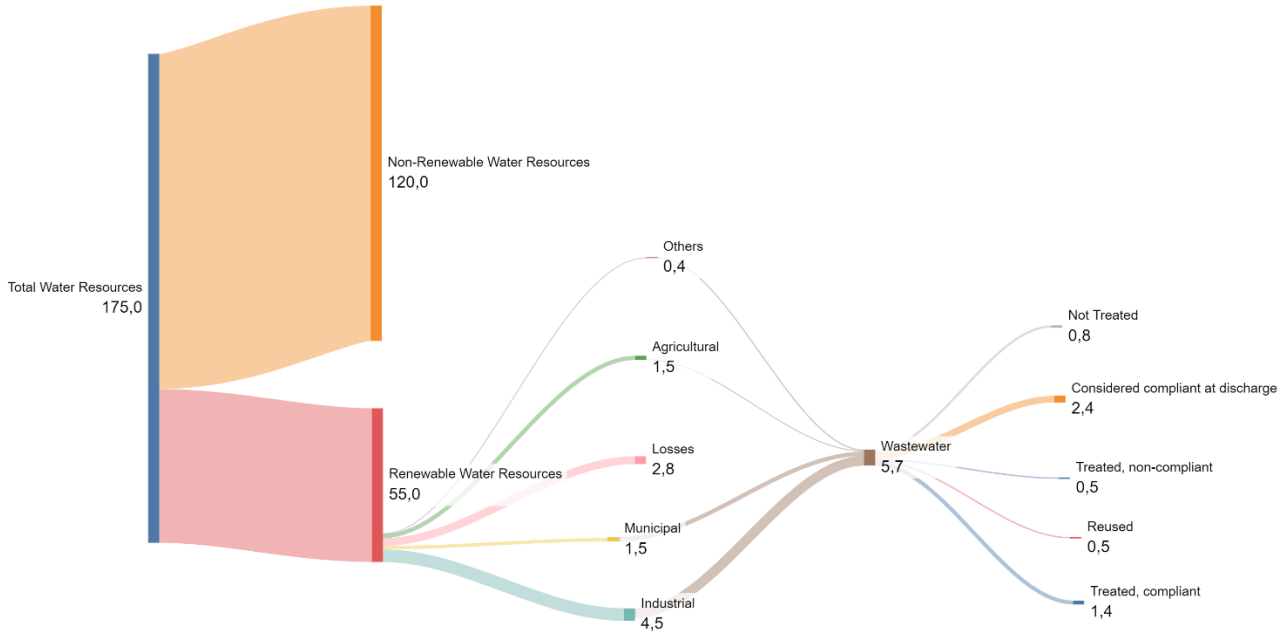


Figure A1: *Distribution of water resources in Ukraine in km^3/y, estimated FAO, WHO and Wise Europa [8, 9]*

Industries

Industries represent slightly less than 20% of Ukraine's GDP and about 40% of abstracted water use. Industrial water use is generally inefficient, primarily due to the use of older equipment. The energy and mining sectors are the primary industrial water consumers. The most industrialized oblasts are in the east (**Figure A2**), where the water resources are less abundant (**Figure 2**) [37, 40]. In the energy sector, water is mainly used for cooling, while in the mining sector it is used for ore and mineral extraction. The water quality required for these activities is not particularly high (**Table A1**), but increased mineralization and high hardness may necessitate chemical pre-treatment.

Intense industrial use of water resources is accompanied by the inefficient operation of old treatment facilities, numerous abandoned hazardous waste storage sites, and unprofitable, aging industrial activities. Addressing these challenges requires coordinated and comprehensive solutions, along with significant investments from the private and public sectors.

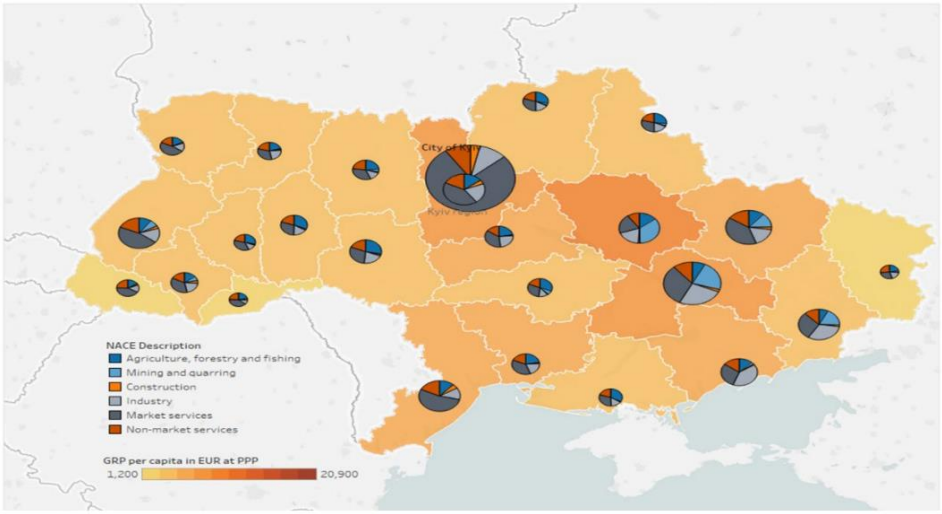


Figure A2: *Gross regional product per capita in Ukraine (2017) [40]*

Table A1: *Water intensity for Ukrainian industries [37]*

Sectors of the economy	NACE Classification	Water abstraction intensity	Water quality required	Wastewater contamination
Ferrous metallurgy	Mining and Quarrying	moderate	low	moderate
Coal industry		moderate	low	low
Energy	Industry	high	low	low
Chemical industry		low	low	moderate
Mechanical engineering and metalworking		low	low	low
Food industry		low	high	low
Housing and communal services	Market services	high	high	high
Transportation		low	low	low
Recreation and healthcare		low	high	low
Fisheries	Agriculture, Forestry, and Fishing	moderate	moderate	moderate
Irrigation		high	moderate	low
Other agriculture (including livestock and crop production)		moderate	moderate	low

Agriculture and irrigation

Agriculture represents about 10% of Ukraine's GDP and about 30% of the abstracted water use. The sector is estimated to feed 400 million people worldwide, according to FAO estimates [53]. The country's main products are wheat, corn, barley, and sunflower seeds. The total arable land covers 55% of the country [11], but only 2% is irrigated from surface waters [54]. Zaporizhzhia (76%),

Kirovohrad (76%), and Mykolaiv (77%) oblasts have the highest share of cultivated land, but rank 20th, 14th, and 19th, respectively, in terms of available renewable water resources [55]. Climate variability is also impacting the agricultural sector. For example, the 2020 drought, the worst in a 40-year period, reduced the winter wheat and barley harvest by nearly 50% compared to the previous year. Oblasts with more irrigation coverage were better at handling this challenge, however, at the expense of the available water resources.

Moreover, agricultural practices are accused of not following regulations of protected water zones and coastal areas. Therefore, proper enforcement is crucial to prevent deterioration of water quality and the environment [26].

Drinking Water Utilities

While the national government is tasked with developing water supply and sanitation policies, local municipalities are responsible for management water resources and providing drinking water treatment and service. A national regulator oversees pricing for larger utilities, but its influence is limited. The water sector suffers from chronic underfunding, relying on tariffs that often fall short of operating costs [43]. The adoption of universal water metering and transparent water use reporting is a prerequisite of robust water management to ensure correct tariff billing as well as to combat water losses.

There are 27,000 settlements in Ukraine, out of which only ca.1,200 have more than 1,000 inhabitants [24], yet cities account for more than 70% of Ukraine's population. While more than 90% of the population has access to piped water in urban areas, that proportion drops to 25-30% in rural areas. In cities, the average water consumption can be as high as 425 L per person per day. Meanwhile, rural areas supplied with decentralized water service consume only 40 L per person per day [13]. However, just 60% of households have water meters, which complicates the estimation of actual drinking water consumption [56].

Overall, 25-35% of the drinking water supply comes from groundwater sources [44, 56]. 15% of Ukrainian cities are supplied exclusively from groundwater sources (e.g. Volyn, Lviv, Rivne, Sumy, Chernihiv). In 35% of urban areas, groundwater abstractions account for over 50% of total water consumption (e.g. Ternopil, Kherson, Khmelnitsky, Zakarpattia, Kyiv, Poltava).

As of the end of 2013, 150 regulated drinking water utilities served 59% of the population. In addition, there are many small cooperative-like entities serving piped water to 6% of the population. The remaining 35% of Ukrainians (mainly in rural regions) relied private wells, small rivers or shallow water reservoirs as their primary water source [56]. The treatment priority for waterworks is to provide disinfected water. Other common water quality issues encountered include high iron, manganese and ammonium concentrations.

Due to decentralization, insufficient treatment capacity, lack of manpower and associated financing, supplying all households with quality drinking water has not been possible. Before the war, it was estimated that more than 35% of the water supply network and 20% of pumping stations required replacement [29]. Water treatment works mainly use technology installed in the 1960-80's, which are outdated in terms of treatment ability and efficiency [31]. Poor water quality, especially from private wells and unregulated sources, motivates many households to either have private treatment systems or complement their drinking water supply with external sources, including tankers, bottled water or

water kiosks. In some regions, scheduled water supply is common, however, this practice favors bacterial growth due to long storage periods.

To overcome these challenges, several governmental initiatives were launched prior to the war to coordinate Ukrainian water law and guarantee universal access to high quality drinking water. For instance, objectives were set to supply 100% of children's educational institutions and healthcare facilities with safe drinking water and to provide universal access to drinking water in Donetsk and Luhansk regions by 2025 [29].

District Heating

District heating in Ukraine is a critical component of energy supply for households, municipalities, and industries, with roots in the Soviet era. Currently, 254 utilities serve 26 million people, relying almost entirely on natural gas. District heating accounted for 18% of Ukraine's total gas consumption in 2018. However, the infrastructure is outdated, leading to significant CO_2 emissions—approximately 11.8 million tons annually. Moreover, district heating infrastructure has been heavily damaged due to the ongoing war. Modernizing and optimizing the sector is essential to address the nation’s energy and climate [57].

Impacts of untreated wastewater and sewage on women and youth

The impacts of conflict situations inevitably affect women and children disproportionately [58]. The past three years of conflict in Ukraine has exposed an entire generation of women to increased gender-based violence, greater domestic burdens, rising unemployment, and, while the exact number of Ukrainians without access to adequate sanitation and wastewater treatment is unknown, it is clear that a significant portion of the population, especially women and children, is facing severe challenges due to the ongoing conflict. These challenges include difficulty in accessing clean water and sanitary products for personal hygiene, over and above the burden of water collection and sanitation for domestic purposes. Additionally, approximately 1.8 million women and girls are internally displaced [59], further straining access to appropriate sanitation provisions and wastewater collection and treatment services.

References

1. DHI, *Analysis of the potential contribution to energy and climate neutrality from Danish technology within the global wastewater sector*, 2022, 45. Available from: https://www.danskindustri.dk/globalassets/politik-og-analyser/di-mener/miljo-og-circular-okonomi/nyheder/vandvisionenergyanalysisreport.pdf.
2. Maria Diamanti, *Infrastructure Solutions: No wastewater to waste*, 2022: European Investment Bank, 6. Available from: https://www.eib.org/en/essays/wastewater-resource-recovery.
3. International Energy Agency, *Emissions Database for Global Atmospheric Research Community GHG Version 7.0*. 2022. Available from: https://www.iea.org/data-and-statistics.
4. BIOFOS, *BIOFOS er blevet klimapositiv*, 2024. Available from: https://biofos.dk/nyheder/biofos-er-blevet-klimapositiv.
5. Bankwatch, *Case Study on large-scale heat pumps in the modernisation of the district heating system of Vienna, Austira*, 2022, CEE Bankwatch Network. 4. Available from: https://bankwatch.org/wp-content/uploads/2022/05/2022-05_Case-study-Vienna_eng.pdf.

6. UNEP, *Wastewater - Turning Problem to Solution. A UNEP Rapid Response Assessment*, 2023, Nairobi, United Nations Environment Programme. Available from: https://doi.org/10.59117/20.500.11822/43142.
7. UN-IOM, *Ukraine & neighboring countries 2022-2024: 2 years of response*, 2024. Available from: https://www.iom.int/sites/g/files/tmzbdl486/files/documents/2024-02/iom_ukraine_neighbouring_countries_2022-2024_2_years_of_response.pdf.
8. FAO *AQUASTAT - Global Information System on Water and Agriculture*. 2024. Available from: https://data.apps.fao.org/aquastat/?lang=en.
9. WHO, *Country files for SDG 6.3.1 Proportion of wastewater safely treated*. 2023. Available from: https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/monitoring-and-evidence/wash-monitoring/2023-country-files-for-sdg-6.3.1.
10. Adriana Pienaru, *The Romanian experience regarding the water and wastewater systems in rural areas*, in *Designing and implementing green public investment programmes: Experience of EU countries with water supply and wastewater treatment in rural and remote areas*. 2022, EU4Environment: Online.
11. World Bank Group, *DataBank. World Development Indicators*. 2024. Available from: https://databank.worldbank.org/reports.aspx?source=world-development-indicators.
12. Olena Vyshnevska and Oleh Prokopenko, *Environment of Ukraine*, 2022, Kyiv: State Statistics Service of Ukraine, 147.
13. С. Сергій, Ш. Ольга, and Д. Юлій, *АНАЛІЗ ВПЛИВУ КЛІМАТИЧНИХ ЗМІН НА ВОДНІ РЕСУРСИ УКРАЇНИ*, 2021, Kyiv, Екодія. Available from: https://ecoaction.org.ua/wp-content/uploads/2021/06/analiz-vplyvu-vodni-resursy-full.pdf.
14. EurEau, *Europe's Water in Figures: An overview of the European drinking water and waste water sectors*, 2021. Available from: https://www.eureau.org/news/566-europe-s-water-in-figures.
15. V. K. Khilchevskyi, *Water resources of Ukraine: assessment based on the FAO AQUASTAT database*. 2021. **2021**(1): p. 1-5 DOI: https://doi.org/10.3997/2214-4609.20215K2005.
16. Y. Gadzalo, M. Romashchenko, and M. Yatsiuk, *Conceptual framework to ensure water security in Ukraine*. Proc. IAHS, 2018. **376**: p. 63-68 DOI: 10.5194/piahs-376-63-2018.
17. V. K. Khilchevskyi, V. V. Grebin, and H. V. Bolbot, *River Basins Districts of Ukraine – Comparison with the Map of Russia's Armed Aggression (Summer 2022)*. 2022. **2022**(1): p. 1-5 DOI: https://doi.org/10.3997/2214-4609.2022580017.
18. Cabinet of Ministers of Ukraine, *On Approval of Management Plans for the Vistula, Dniester and Southern Bug River Basins for 2025-2030*,1078-r. 1 November, 2024. Available from: https://zakon.rada.gov.ua/laws/show/1078-2024-%D1%80#Text.
19. Cabinet of Ministers of Ukraine, *On Approval of Management Plans for the Dnieper and Don River Basins for 2025-2030*,1077-r. 1 November, 2024. Available from: https://zakon.rada.gov.ua/laws/show/1077-2024-%D1%80#Text.
20. European Commission, *Ukraine 2024 Report*, 2024. Available from: https://neighbourhood-enlargement.ec.europa.eu/document/download/1924a044-b30f-48a2-99c1-50edeac14da1_en?filename=Ukraine%20Report%202024.pdf.
21. EU4Environment, *Ukraine adopts eight River Basin Management Plans: a major milestone towards sustainable water management*, 20 November, 2024. Available from: https://www.eu4waterdata.eu/en/blog-news/34-ukraine/400-ukraine-adopts-eight-river-basin-management-plans-a-major-milestone-towards-sustainable-water-management.html.
22. Valentyn Khilchevskyi and V. V. Grebin, *Hydrographic and hydroeconomic zoning of Ukraine's territory, approved in 2016 - implementation of the WFD provisions // Гідрографічне та водогосподарське районування території України, затверджене у 2016 р. – реалізація положень ВРД ЄС / Hidrolohiia, hidrokhimiia i hidroekolohiia. – 2017. – T. 1(44)*. 2017. **1(44)**: p. 8-20.

23. Hennadii Hapich, et al., *Water security consequences of the Russia-Ukraine war and the post-war outlook*. Water Security, 2024. **21**: p. 100167 DOI: https://doi.org/10.1016/j.wasec.2024.100167.
24. State Statistics Services of Ukraine, *Population of Ukraine 2021*. 2022. Available from: http://db.ukrcensus.gov.ua/Pxweb2007/eng/publ_new1/2022/publ2022.asp.
25. Valentyn Khilchevskyi, et al., *Large and small reservoirs of Ukraine.* Journal of Water and Land Development 2021. **52**: p. 101-107 DOI: 10.24425/jwld.2022.140379.
26. Cabinet of Ministers of Ukraine, *Water Strategy of Ukraine for the period up to 2050*,1134-r. 9 December, 2022. Available from: https://zakon.rada.gov.ua/laws/show/1134-2022-%D1%80#Text.
27. Anatoly Shvidenko, et al. *Vulnerability of Ukrainian Forests to Climate Change*. Sustainability, 2017. **9**, DOI: 10.3390/su9071152.
28. HydroWASTE database, *Waste water treatment plants in Ukraine*. 2022. Available from: https://datacatalog.worldbank.org/search/dataset/0061361/Ukraine---Waste-water-treatment-plants.
29. Ministry of Environmental Protection and Natural Resources of Ukraine, *A summary report on the progress of the implementation of the Protocol on water and health in Ukraine in 2019-2021*, 2022. Available from: https://unece.org/sites/default/files/2022-09/Ukraine_5th_reporting_cycle_ENG_01.09.2022.pdf.
30. Y. Vystavna, et al., *Quantification of water and sewage leakages from urban infrastructure into a shallow aquifer in East Ukraine.* Environmental Earth Sciences, 2018. **77**(22): p. 748 DOI: 10.1007/s12665-018-7936-y.
31. Ukrvodokanalekologiya, *The experience of Ukrainian water supply companies during the war.* Водопостачання Водовідведення, 2022, https://ukrvodokanal.in.ua/wp-content/uploads/2023/03/vodopvodovidv_special-issue_december_6_eng.pdf(December). Available from: https://ukrvodokanal.in.ua/wp-content/uploads/2023/03/vodopvodovidv_special-issue_december_6_eng.pdf.
32. H. Ehalt Macedo, et al., *Distribution and characteristics of wastewater treatment plants within the global river network.* Earth Syst. Sci. Data, 2022. **14**(2): p. 559-577 DOI: 10.5194/essd-14-559-2022.
33. State Agency of Water Resources of Ukraine, *Top-100 largest water polluting enterprises in 2018*, 2018. Available from: https://davr.gov.ua/news/top100-najbilshih-pidpriyemstvzabrudnyuvachiv-vod-u-2018-roci.
34. European Environment Agency, *Water availability, surface water quality and water use in the Eastern Partnership countries – An indicator-based assessment*. doi/10.2800/6351702020.
35. European Environment Agency. *Oxygen consuming substances in European rivers*. 2023 [cited 12 December, 2024]; Available from: https://www.eea.europa.eu/en/analysis/indicators/oxygen-consuming-substances-in-european-rivers?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b.
36. OSCE, *The Arteery of Eastern Ukraine. Summary of the Analysis of Water Issues in the Siverskyi Donets River and Programme of Measures to Address Them*, 2021, Kyiv: Organization for Security and Co-operation in Europe, Sate Agency of Water Resources of Ukraine, 102. Available from: https://www.osce.org/files/f/documents/5/b/509501_0.pdf.
37. Oleksii Iaroshevych, et al., *Draft Dnipro River Basin Management Plan for Ukraine Part 1 (2025 - 2030)* 2021. Available from: https://euwipluseast.eu/images/2021/04/PDF/EUWI_UA_Dnipro_RBMP_1_202102_ENG.pdf.
38. Baltic Sea Centre, *Fact Sheet: Effects of the new UWWTD on nutrient inputs to the Baltic Sea*, 2024: Stockholm University, 4. Available from: https://www.su.se/stockholm-university-baltic-sea-centre/policy-analysis/policy-briefs-and-fact-sheets/fact-sheet-effects-of-the-new-uwwtd-on-nutrient-inputs-to-the-baltic-sea-1.745858.

39. C. I. Ludemann, et al., *A global FAOSTAT reference database of cropland nutrient budgets and nutrient use efficiency (1961–2020): nitrogen, phosphorus and potassium*. Earth Syst. Sci. Data, 2024. **16**(1): p. 525-541 DOI: 10.5194/essd-16-525-2024.
40. Peter Havlik, Artem Kochnev, and Olga Pindyuk, *Economic Challenges and Costs of Reintegrating the Donbas Region in Ukraine*. wiiw Research Reports, 2020. **447**: p. 72 DOI: 10.13140/RG.2.2.26825.57443.
41. Oleksandra Shumilova, et al., *Impact of the Russia–Ukraine armed conflict on water resources and water infrastructure*. Nature Sustainability, 2023. **6**(5): p. 578-586 DOI: 10.1038/s41893-023-01068-x.
42. Drazen Rakic, *Two years of war: The state of the Ukrainian economy in 10 charts*, 2024: Economic Governance and EMU Scrutiny Unit, European Parliament. Available from: https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/747858/IPOL_BRI(2024)747858_EN.pdf.
43. World Bank, *Ukraine - Third Rapid Damage and Needs Assessment (RDNA3): February 2022 - December 2023*, 2024, Washington, D.C.: World Bank Group. Available from: http://documents.worldbank.org/curated/en/099021324115085807/P1801741bea12c012189ca16d95d8c2556a.
44. Daniel Hryhorczuk, et al., *The environmental health impacts of Russia's war on Ukraine*. Journal of Occupational Medicine and Toxicology, 2024. **19**(1): p. 1 DOI: 10.1186/s12995-023-00398-y.
45. UNHCR, *Ukraine Situation Report*, 2023. Available from: https://reporting.unhcr.org/operational/situations/ukraine-situation.
46. UN Department of Economic and Social Affairs. *World Population Prospects - Ukraine*. 2024 [cited August 23, 2024]; Available from: https://population.un.org/wpp/Graphs/DemographicProfiles/Line/804.
47. European Parliament, *Directive of the European Parliament and of the Council concerning urban wastewater treatment (recast)*, PE-CONS 85/24, 2024.
48. Water News Europe. *Profile: Polish water sector*. 2022 (Last Update: 31 May 2024) [cited 12 December 2024]; Available from: https://www.waternewseurope.com/profile-polish-water-sector/.
49. EU. *WISE country profile on urban wastewater: Poland*. Freshwater Information System for Europe (WISE) [cited 12 December, 2024]; Available from: https://water.europa.eu/freshwater/countries/uwwt/poland.
50. Antoine Goujard, *Improving transport and energy infrastructure investment in Poland*. 2016. https://doi.org/10.1787/5jlwz8jrf89r-en DOI: https://doi.org/10.1787/5jlwz8jrf89r-en.
51. COWI, *Getting investment planning in water supply and sanitation right*, 2022: Danish Environmental Protection Agency.
52. EU. *WISE country profile on urban wastewater: Romania*. Freshwater Information System for Europe (WISE) [cited 12 December, 2024]; Available from: https://water.europa.eu/freshwater/countries/uwwt/romania.
53. FAO, *Ukraine: FAO surveys impact of war on smallholder farmers*, 30 May, 2023. Available from: https://www.fao.org/countryprofiles/news-archive/detail-news/en/c/1640738/.
54. Lorenzo Rosa, et al., *Regional irrigation expansion can support climate-resilient crop production in post-invasion Ukraine*. Nature Food, 2024. **5**(8): p. 684-692 DOI: 10.1038/s43016-024-01017-7.
55. O. Skydan, et al., *Analysis of rural areas of Ukraine on the basis of ESA WorldCover 2020*. Scientific Horizons, 2022. **25**(5): p. 74-85 DOI: https://doi.org/10.48077/SCIHOR.25(5).2022.74-85.
56. World Bank, *Water and wastewater services in the Danube region: Ukraine country note*, 2015, Washington, D.C.: World Bank Group. Available from:

http://documents.worldbank.org/curated/en/646881467999080997/Water-and-wastewater-services-in-the-Danube-region-Ukraine-country-note.
57. IKI, *Reforming the Ukrainian District Heating Sector*, 18 July 2023, 2023. Available from: https://www.international-climate-initiative.com/NEWS2343-1.
58. UNICEF, *Three years of full-scale war in Ukraine*, 2025, UNICEF. Available from: https://www.unicef.org/ukraine/en/media/51326/file/Three%20years%20of%20full-scale%20war%20in%20Ukraine%20February%202025.pdf.pdf.
59. UNWomen, *Ukraine women at the front lines of resistance and recovery*. 2025. https://www.unwomen.org/en/news-stories/feature-story/2025/06/ukranian-women-at-the-frontlines-of-resistance-and-recovery#%3A~%3Atext%3D1.8%20million%20women%20and%20girls%20remain%20displaced%20within%20Ukraine%20%E2%80%93%20that%27s%2Cmillion%20people%20need%20humanitarian%20assistance.%26text%3DWomen%20are%20spending%2056%20hours%2C49%20hours%20before%20the%20war.