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ASSESSMENT OF ECONOMIC GREENING EFFICIENCY IN WATER RESOURCE MANAGEMENT

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Introduction. Climate change, water depletion, environmental pollution, and rising economic activities in water use demand greener production. This emphasises the need for efficient methods and the assessment of economic greening in water use for sustainable development by advancing a sustainable blue economy.

Aim and tasks. The study assesses the environmental efficiency of water use in Ukraine by analysing economic and environmental indicators. This study seeks to develop scientifically grounded methodological recommendations for improving enterprises' water use management.

Results. This study conducted an economic and environmental analysis of water use across Ukraine's economic sectors based on statistical data for 2022. The analysis utilised indicators such as water productivity by sector, economic productivity per unit of polluted wastewater, and share of capital investments in wastewater treatment within the total environmental protection investments. The results show that water, sewerage and waste management companies, which are natural monopolies, impact pollution, water abstraction and water resources. These enterprises were responsible for 72% of all the volume of polluted wastewater emitted and 35.28% of all water abstraction. The water productivity (USD 0.29/m³) and economic productivity (USD 1.85/m³) per unit of polluted wastewater were the lowest among all sectors. This indicates that the sector consumes a large volume of water relative to its economic contribution and exerts a significant adverse environmental impact owing to the high level of wastewater pollution. However, the sector's share of capital investments in wastewater treatment within its total environmental protection investments was 59.76%.

Conclusions. Based on the economic and environmental analysis of water use in the sectors of the Ukrainian economy, it is recommended that the level of influence of each enterprise in the sector on the state of water resources be assessed. Methodological recommendations for assessing the level of greening of economic activity in water use have been developed, consisting of four blocks: (i) assessment of water consumption efficiency; (ii) efficiency of wastewater management; (iii) compliance with regulatory requirements and social responsibility; (iv) assessment of innovations in the sphere of water use. Additionally, the calculation of an integrated indicator has been proposed, along with its interpretation according to an evaluation scale.

Keywords: economic greening, sustainable water use, environmental indicators, blue economy, corporate social responsibility.

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1. Introduction.

The water sector is fundamentally linked to the rational use of water resources in the national economy, which requires a review of strategies to balance economic interests and environmental sustainability. This necessitates integrating environmental principles into production processes as key elements of integrated steel development (Burkynskyi et al., 2021; Odeyemi et al., 2024).

A sustainable blue economy is the deterioration of sustainable development that creates economic, social, and environmental benefits. Aquatic ecosystem studies are taking place with the triple planetary loss crisis of pollution, biodiversity, and climate change due to the increasing human population and decreasing resource demand. These are interrelated and threaten the welfare of present and future generations (UNEP, n.d.). The development of a sustainable blue economy and the promotion of the conservation of marine, coastal, and freshwater ecosystems are at the heart of the Paris Agreement on Climate Change (UNFCC, 2015), UN 2030 Agenda for Sustainable Development (United Nations, 2015), UN Decade of Marine Science for Sustainable Development (2021-2030) (IOCU, 2021), and other important global commitments that have significantly accelerated this process.

There are various interpretations of the definition of the "blue economy", reflecting its multifaceted nature and interrelationships with various sectors of the economy, including marine and freshwater resources. A broader understanding of the "blue economy" is not limited to marine resources, but includes freshwater ecosystems and their interconnections in the global water cycle (OECD, 2024).

The importance of water security as a component of the resilience of economic sectors reliant on water resources lies in its ability to ensure business stability, preserve ecosystem services, and maintain living conditions for local communities that depend on water resources. Accordingly, its inclusion in economic strategies is necessary to achieve sustainable development, preserve the environment, and avoid the risks associated with water crises and reduced access to clean water.

Ukraine is one of the countries in Europe with the lowest freshwater supply and is characterised by a high level of water consumption and anthropogenic impacts on water resources. The average annual volume of internal renewable freshwater resources per capita in Ukraine is 1252 m^3 (FAO, 2024), which is a low indicator. According to UN criteria, countries with less than 1500 m^3 per capita water resources are classified as water-scarce (United Nations, 2021). The potential water resources of Ukraine are estimated at 209.8 km^3, and only 30% of this volume is formed in the country, which is its internal reserves (Ministry of Environmental Protection and Natural Resources of Ukraine, 2021).

The total volume of internal renewable fresh water resources in an average water year is 52.4 billion m^3, unevenly distributed over the territory: approximately 60% of these resources are concentrated in the north-western regions, while the southern regions remain the least supplied with fresh water (Ministry of Environmental Protection and Natural Resources of Ukraine, 2021). Given the limited availability of water resources, it is important to implement practices that ensure its rational use and conservation, which will promote economic growth without harming the environment (Zhang et al., 2023). In this context, an important aspect is the integration of the principles of sustainable development into business models (Andryeyeva et al., 2021), which allows not only the conservation of water resources (David et al., 2023), but also the optimisation of production processes (Arsawan et al., 2024).

Greening the economy involves systematically implementing environmental principles and approaches to economic activity related to the use of water resources in order to ensure their rational, sustainable, and environmentally safe use (Antonenko et al., 2021; Mikhno et al., 2021). Given the growing importance of integrating environmental indicators in water management (Ben-Daoud et al., 2021), assessing the level of greening of business activities is necessary for achieving sustainable development in the field of water use (Willet et al., 2019; Perez et al., 2019; Navarro-Ramírez et al., 2020).

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Thus, there is an urgent need to develop methodological guidelines that enable a comprehensive assessment of economic greening efficiency in water resource management. These guidelines should account for economic (Aznar-Sánchez et al., 2018), environmental (Schlattmann et al., 2022), and social aspects (Khumarova & Mahats, 2023; Sylva, 2024), as these factors represent a significant step toward improving water resource management and promoting sustainable use. These recommendations can form the foundation for creating a monitoring system to evaluate the environmental efficiency of enterprises in the water use sector and support the integration of environmental standards into business development strategies.

2. Literature review.

Branca et al. (2020) proposed a set of 22 key performance indicators to assess and monitor water resource management's sustainability. These indicators address the water treatment systems' environmental and economic dimensions, efficiency, and viability. Branca et al. (2020) examined the main technical barriers and factors influencing wastewater reuse and recycling, energy consumption, and monitoring system efficiency. Indicators of environmental impact, exploitation, safety, and public safety of waste management are the key indicators by Farouk et al. (2024), who identified and investigated the relationships between the indicators of the effectiveness of water projects. Landa-Cansinho et al. (2020) assessed the performance of integrated urban water supply systems over an extended planning horizon using a set of key performance indicators (KPIs).

Morris (2019) developed indicators based on existing social and economic well-being measures. These indicators consider economic growth within the social and environmental development framework and offer a metric that evaluates how water resources are used efficiently and beneficially for society. Molinos-Senante et al. (2016) proposed a multi-criteria decision analysis that included economic, environmental, and social performance indicators to assess and compare the sustainability of water utilities from an integrated perspective.

D'Inverno et al. (2021) suggested a composite water use performance indicator (WUP-CI) that considers economic profitability, water losses, customer happiness, and financial soundness to assess the performance of Italian water utilities. Falqi et al. (2020) assessed the environmental performance of construction sector companies according to the ISO 14031 standard in three dimensions: planning, use of data and information, and review and improvement of environmental performance assessments.

Rincón-Moreno et al. (2021) developed a set of indicators to measure the different levels of the circular economy (micro, meso, and macro), which will allow progress tracking in implementing environmental circular initiatives. The defined indicators were tested in Spanish companies located in the Basque Country region, confirming that this set of indicators can be adapted to companies, regardless of their economic activity.

Abu-Rayash and Dincer (2021) presented a new model for assessing the smartness of cities, characterised by eight main areas: the economy, environment, society, governance, energy, infrastructure, transport, and pandemic resilience. Each area is assessed using key parameters that reflect the state of a particular city.

All indicators were measurable, thus enhancing the reliability and accuracy of this approach. Latif (2022) proposed the Comprehensive Environmental Performance Index (CEPI), which integrates data from six distinct indicators into a single metric. Unlike other indices, the CEPI avoids complex mathematical procedures and is designed for simplicity, making it accessible to professionals in economics and general users.

3. Methodology.

3.1. Economic and Environmental Analysis of Water Use in Ukraine.

The statistical analysis was based on data from the State Statistics Service of Ukraine (2023a) and the Ministry of Development of Communities, Territories and Infrastructure of Ukraine (2023).

e-ISSN 2786-8958
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Data including indicators such as the volume of water abstraction from natural water bodies, the volume of polluted wastewater discharge, GDP data at current prices, and capital investments in environmental protection and return water treatment were used to assess the economic and environmental efficiency of water resources use in Ukraine in 2022.

To assess the economic and environmental efficiency of water resource use, three indicators were provided: the water productivity of the industry (WP), economic productivity per unit of polluted wastewater (EP), and share of capital investments in return water treatment (KIte). The collected data were analysed to identify trends in water use and pollution in various sectors of the economy.

The assessment was carried out by industry, highlighting the enterprises with the most significant impact on water resources. Special attention was paid to the enterprises of Section E (Water supply, drainage and waste management) (State Statistics Service of Ukraine, 2011), which are components of natural monopolies that play a decisive role in the management of water resources.

3.2. Methodology for Evaluating Economic Greening in Water Use.

The study envisaged the development of methodological recommendations for assessing the level of greening of economic activities in water use. These recommendations are based on the international standard ISO 14031 (2021) (Segnestam, 1999). ISO 14031 (International Organization for Standardization, 2021) guides environmental management and environmental performance assessment in business.

Environmental performance indicators (Segnestam, 1999) are widely used to assess and monitor the environmental aspects of water use. These indicators enable the quantification of the impact of economic activities on natural resources, identify key problem areas, and identify ways to improve them. Four main blocks of indicators are defined: efficiency of water use, wastewater management, compliance with regulatory requirements and social responsibility, and innovativeness in water use to assess the efficiency of water use by enterprises (Ben-Daoud et al., 2021).

1. Assessment of water consumption efficiency.

This set of indicators encompasses metrics such as water productivity (WP), water use profitability (WUP), water reuse ratio (WRR), the ratio of water from alternative sources (RWAR), water savings ratio from alternative sources (WSR), water resource restoration index (WRRI), and water accessibility index (WAI). The selection of these indicators is justified by the need to analyse how enterprises use water resources and whether their actions aim to reduce water consumption and use alternative sources. These criteria assess the economic efficiency of water use and are critical indicators of sustainable water management.

2. Wastewater management efficiency.

These indicators aim to evaluate wastewater management, including its treatment and disposal. Wastewater Quality (WQ), Wastewater Treatment Efficiency (WTE), Wastewater Reuse Rate (WWRR), and Wastewater Compliance Level (WWC) were the metrics used to evaluate a facility's ability to reduce pollutants and re-integrate reclaimed water into the water cycle.

3. Compliance with regulatory requirements and social responsibility.

The enterprise interacts with the social and natural environment. Enterprises affect the environment either through production emissions or as a result of the operation of their products by the end; also, companies cooperate with suppliers, consumers, regulatory and fiscal authorities, and interact with civil society institutions, the local community and society as a whole. Corporate social responsibility involves corporations' responsibility towards the society in which they are located and operate without rejecting that their sphere of influence extends far beyond this (Silva, 2024). The indicators of this block help determine compliance with regulatory requirements (CR), social responsibility in the field of water use (SRWU), and the index of investments in environmental projects (IEP), and also allow us to assess whether enterprises comply with environmental standards and implement socially responsible initiatives.

e-ISSN 2786-8958
ISSN-L 2616-7107

4. Evaluation innovation in water use.

These indicators concentrate on evaluating the degree of water usage innovation. The degree to which businesses have embraced innovative technology to increase water efficiency is measured by indicators like the Innovation Index (II), Water Savings via Innovation (WSDI), and the Research and Development Index for Water (RDIW).

The selection of this block is justified by the need to consider technological progress and innovative approaches that allow enterprises to reduce water consumption and environmental impact. A final integral indicator was proposed, calculated as a weighted average of the integral indicators of each block, to comprehensively assess the economic greening efficiency in water resource management. The proposed assessment scale varies from excellent environmental efficiency of water use to very low environmental efficiency.

4. Aim and tasks.

This study aims to assess the environmental efficiency of water use in Ukraine by analysing economic and environmental indicators and developing methodological recommendations for enterprises that will contribute to increasing greening in water use. The research questions (RQ) were as follows:

RQ1. Analyse water use and pollution by sector of the Ukrainian economy based on statistical data.

RQ2. Determining key indicators of water resource use's economic and environmental efficiency.

RQ3. Analyse monopolisation in Ukraine's water supply and wastewater sector and identify the main factors determining the dominance of natural monopoly in this sector.

RQ4. Proposing the key indicators for assessing the degree of greening of business activities in the field of water use

RQ5. Propose an integral indicator for assessing the greening of businesses in water use using the assessment scale.

5. Results.

Rational water use is one of the key aspects of ensuring sustainable development in Ukraine, as water resources play a decisive role in socioeconomic and environmental processes. The analysis of statistical data (Fig. 1) enables the assessment the level of water use efficiency, identify the main trends and problems, and substantiate areas for improving water policy. Below is a statistical analysis of the current state of water use in Ukraine, covering key indicators for recent years (State Statistics Service of Ukraine, 2016, 2023b).

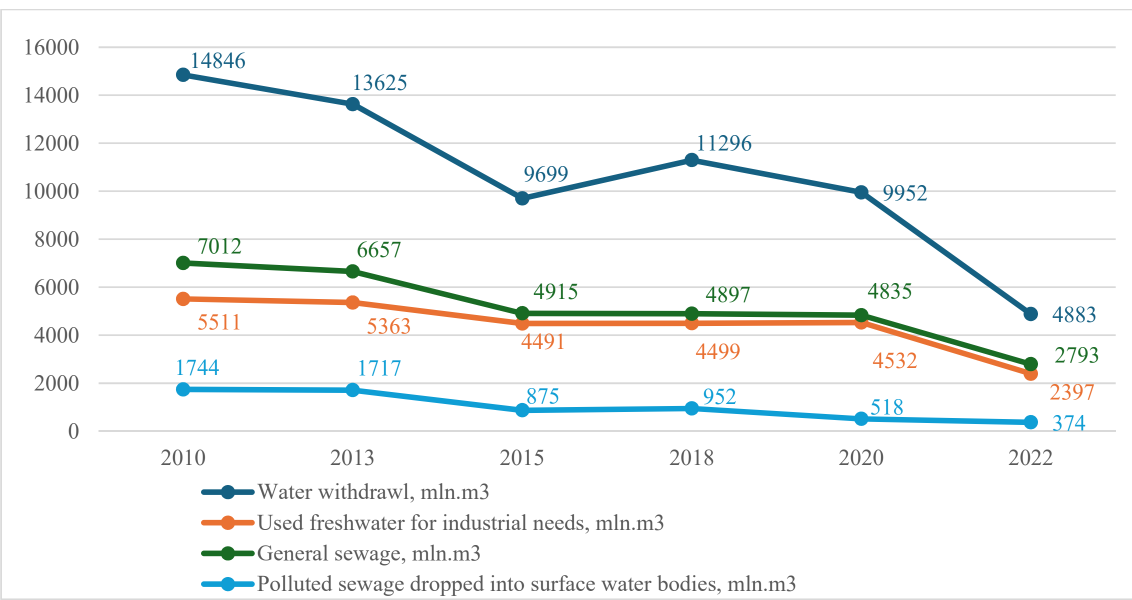

Fig. 1. Statistical analysis of water use sector of Ukraine in the period from 2010 to 2022.
Source: State Statistics Service of Ukraine (2016, 2023b).

The main indicators characterising water use in Ukraine from 2010 to 2022 demonstrated a gradual downward trend owing to several factors. By 2020, the main reasons were decreased industrial production, particularly due to hostilities in eastern Ukraine and economic instability, which limited investments in water-intensive industries. Reducing water withdrawal is associated with socioeconomic changes, including a population decline in certain regions due to migration caused by military operations and a demographic decline. Environmental requirements for enterprises have been strengthened at the level of state regulation, which has contributed to a decrease in unreasonable water intake.

Owing to the full-scale Russian invasion in 2022, which destroyed water infrastructure, stopped industrial enterprises, and caused a large-scale outflow of population, water use in Ukraine has decreased. The economic crisis and loss of authority over individual regions have affected almost twice (by 49%) and reduced water use by industry by more than half (52%).

According to the State Statistics Service of Ukraine (2023a), in 2022, 4,883.45 million m³ of water was withdrawn from natural sources (freshwater 4,860.9 million m³), of which 786.5 million m³ were from underground water sources, including 185.1 million m³ of mine and quarry water. In total, water use in 2022 for various needs (State Statistics Service of Ukraine, 2023a) amounted to 3,401 million m³, of which 2,397 million m³ (70.5%) were for production needs, 753 million m³ (22.1%) were for drinking and sanitary and hygienic needs, 143 million m³ (4.2%) for irrigation, and 108 million m³ (10.8%) were for drinking, sanitary, and hygienic needs. These figures indicate that the industrial sector is the primary consumer of water resources in the Ukraine.

According to the Ministry of Development of Communities, Territories, and Infrastructure of Ukraine (2023), 2979.4 million m³ of wastewater was discharged into surface water bodies in 2022, including 374.0 million m³ (12.55%) of polluted wastewater, 1054.9 million m³ (35.4%) of wastewater treated to regulatory standards, and 1550.6 million m³ (52.04%) of wastewater meeting regulatory cleanliness without treatment.

On a sectoral basis, the largest polluters of surface water bodies in 2022 were enterprises in Section E (Water supply, sewerage, and waste management) with 269.7 million m³ of polluted wastewater, enterprises in Section B (Mining and quarrying), which discharged 77.4 million m³, enterprises in Section A (Agriculture, forestry, and fishing) with 14.2 million m³, and enterprises in Section C (Manufacturing) with 9.4 million m³ of polluted wastewater (State Statistics Service of Ukraine, 2023a). To evaluate the economic and environmental efficiencies of each type of economic activity, the following indicators were calculated:

- The indicator of water productivity in Sectors assesses how economic production uses water resources. A sector that uses water resources efficiently and produces significant economic value per m³ of water withdrawn is considered to have high water productivity.
- The indicator of the share of capital investment in wastewater treatment in the total environmental investment of the industry shows the percentage of environmental investment explicitly directed to wastewater treatment, which is crucial for understanding the efficiency of production processes from the point of view of their impact on the environment.
- The economic productivity per unit of polluted wastewater was used to calculate the GDP produced per cubic meter of polluted wastewater discharged to the environment.

Analysis of the indicators in Table 1 shows that in Ukraine, the most significant impact on the state of water resources, their intake and pollution is exerted by enterprises of section D (Water supply; water disposal; waste management), which account for 35.28% of the total volume of water intake and 72% of the total volume of discharged polluted wastewater. Water and economic productivity per unit of polluted wastewater are the lowest, which indicates that the industry consumes a large amount of water relative to its economic contribution and has a significant negative impact on the environment due to the high level of wastewater pollution. At the same time, the share of capital investments in wastewater treatment within the sector’s total environmental protection investments was the highest at 59.76%.

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Table 1. Assessment of water efficiency and environmental investments in the water use sector by type of Ukraine's economic activity in 2022.

Name of economic activity	Wd*	WW*	GDP*	Ie*	It*	WP*	EP*	CIte*
Total for the year	**4883,4**	**374,0**	**162001,051**	**199,320**	**22,986**	**33,173**	**433,157**	**11,53%**
[A] Agriculture, Forestry, and Fishing	945,0	14,2	13888,312	2,983	0,500	14,697	978,049	16,78%
[B] Mining and Quarrying	194,3	77,4	7108,194	59,978	0,433	36,583	91,837	0,72%
[C] Manufacturing	274,6	9,3	12317,873	68,884	1,857	44,858	1324,502	2,70%
[D] Electricity, Gas, Steam, and Air Conditioning Supply	1654,3	0,2	7109,060	24,921	0,818	4,295	35545,300	3,28%
[E] Water Supply; Sewerage, and Waste Management	1722,9	269,7	499,784	30,741	18,369	0,290	1,853	59,76%
[F] Construction	2,9	0,5	2142,826	0,069	0,040	738,905	4285,652	57,62%
[G] Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycle	4,2	0,07	19958,411	0,281	0,112	4752,004	285120,152	39,89%
[H] Transportation and Storage; Postal and Courier Activities	8,6	0,46	7010,390	0,843	0,021	815,161	15239,978	2,49%
[I] Accommodation and Food Service Activities	1,0	0,04	929,406	0,007	–	929,406	23235,158	-
[J] Information and Communication	0,07	-	6391,806	0,143	–	91311,512	-	-
[K] Financial and Insurance Activities	0,06	-	4835,034	0,010	–	80583,899	-	-
[L] Real Estate Activities	4,1	0,1	7299,784	0,038	0,019	1780,436	72997,835	49,76%
[M] Professional Scientific and Technical Activities	3,2	0,02	3070,315	1,843	0,013	959,474	153515,770	0,70%
[N] Administrative and Support Service Activities	7,7	0,51	1663,544	1,252	0,033	216,045	3261,849	2,61%
[O] Public Administration and Defence; Compulsory Social Security	52,6	0,62	35155,751	4,230	0,763	668,361	56702,823	18,04%
[P] Education	1,3	0,27	6891,218	0,002	0,001	5300,937	25523,030	24,24%
[Q] Human Health and Social Work Activities	4,3	0,319	4651,515	0,015	0,005	1081,747	14581,552	30,02%
[R] Arts, Entertainment, and Recreation	0,6	0,021	807,452	3,049	0,001	1345,754	38450,099	0,04%
[S] Other Service Activities	1,7	-	1317,934	0,030	0,001	775,257	-	3,26%

Note: Wd – volume of water abstracted from natural water bodies, million m³; WW – volume of discharged polluted wastewater, million m³; GDP – gross domestic product at current prices, million USD; Ie – capital investments in environmental protection, million USD; It – capital investments in wastewater treatment, million USD; WP – water productivity by the sector, USD/m³; EP – economic productivity of the sector per unit of polluted wastewater, USD/m³; CIte – share of capital investments in wastewater treatment in total sectoral environmental protection investments, %.

* Calculations in USD were conducted based on the official exchange rate of the National Bank of Ukraine.

Source: State Statistics Service of Ukraine (2023a); Ministry of Development of Communities, Territories and Infrastructure of Ukraine (2023); National Bank of Ukraine (2024).

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Enterprises in the water supply and sewerage sectors, according to the Classification of Economic Activities 2010, belong to Section E (Division 36 – Water collection, treatment, and supply; Division 37 – Sewerage, wastewater collection, and treatment). These enterprises are part of Ukraine's housing and utilities sector and, like most of its components, exhibit the characteristics of a natural monopoly. The concept of natural monopoly presents a complex policy dilemma. On one hand, a natural monopoly suggests that production efficiency is higher when a single firm supplies products or services to the entire market.

On the other hand, without any competition, the monopoly owner will desire to use monopoly power to maximise profits (Baumol et al., 1982). According to the National Commission for State Regulation of Energy and Public Utilities, as of 2024, 3,852 enterprises provide centralised water supply and/or centralised wastewater services. Despite the significant number of WSH enterprises operating in this sector in Ukraine, water management is a monopolised industry. In each settlement, a leading enterprise typically provides water and wastewater services. Therefore, competition between the water supply and sewage enterprises is practically absent locally. The main factors in the monopolisation of the water industry are as follows.

1. Technical factors.

1.1. High Capital Infrastructure Intensity:

- The construction and maintenance of water supply and sewage networks requires significant investments.

- The complexity and high cost of creating parallel networks make the existence of several operators in one region economically unprofitable.

1.2. Single network system: Each settlement usually has one water supply and sewage system, which makes it impossible to compete with suppliers at the infrastructure level.

1.3. Technical complexity of management (Beecher, 2020):

- Managing and maintaining the water supply and sewage systems requires specialised knowledge and experience.

- System maintenance includes monitoring, repair, modernisation, and development planning, which require highly qualified personnel and technical resources.

2. Economic factors.

2.1. Economics of Scale (Shchepanskyi, 2021): Large enterprises can achieve economies of scale by reducing costs per unit of product (service) due to large production volumes, making enterprises more efficient than their smaller competitors.

2.2. Financial support and subsidies (Gude, 2021): Utilities often receive financial support from local budgets, providing stability and a competitive advantage over new entrants.

2.3. High barriers to entry (Hanemann, 2006):

- The need for significant financial resources to start and maintain operations;

- A high level of risk associated with long-term return on investment in water supply and wastewater.

3. Regulatory factors.

3.1. State Tariff Regulations. State regulators such as the National Commission for Energy and Utilities Regulation (NECU) set water supply and wastewater tariffs, which limits opportunities for price competition and establishes uniform rules for all market players.

3.2. Licencing and control (Spulber & Sabbaghi, 2012).

- Water supply and wastewater activities require licences and permits, which makes it difficult for new players to enter the market.

3.3. Legislative restrictions (Rouse, 2013):

- Regulations governing the water supply and wastewater sector limit opportunities for the private sector, thereby maintaining the monopoly position of utilities.

To determine the level of impact of each enterprise in the industry on the state of water resources, the authors, based on the analysed sources, developed and proposed methodological provisions to ensure the assessment of the degree of greening of business activities in the field of water use, which consists of four blocks: assessment of water consumption efficiency, efficiency of wastewater management, regulatory compliance and social responsibility, and assessment of innovation in water use.

 e-ISSN 2786-8958
ISSN-L 2616-7107

1. Assessment of water consumption efficiency (Criterion: Assessment of the total volume and efficiency of water resource use):

1.1. Water productivity *(WP).*

$$WP = \frac{P}{WC} \quad (1)$$

where *P* – volume of produced output,
WC – total volume of water consumed.

1.2. Water use profitability *(WUP)*

$$WUP = \frac{Rtotal}{WC} \quad (2)$$

where *Rtotal* – total revenue of the enterprise.

1.3. Water reuse ratio *(WRR)*

$$WRR = \frac{Wreuse}{WC} \quad (3)$$

where *Wreuse* – volume of water reused.

1.4. Ratio of water from alternative sources *(RWAR).*

$$RWAR = \frac{Walt}{WC} \quad (4)$$

where *Walt* – volume of water sourced from alternative sources (e.g., rainwater).

1.5. Water savings ratio from alternative sources *(WSR).*

$$WSR = \frac{Wsav\_alt}{WC} \quad (5)$$

where *Wsav_alt* – volume of water saved through the use of alternative water sources.

1.6. Water resource restoration index *(WRRI).*

$$WRRI = \frac{Wrepl}{WC} \quad (6)$$

where *Wrepl* – volume of restored water resources (e.g., through natural processes or restoration measures).

1.7. Water accessibility index *(WAI).*

$$WAI = \frac{Wav - WC}{Wr} \quad (7)$$

where *Wav* – volume of available water resources; *Wr* – volume of required water..

1.8. Integral indicator of the water consumption efficiency assessment block. *(EWC)*:

$$EWC = \frac{1}{7} \times (WP + WUP + WRR + RWAR + WSR + WRRI + WAI) \quad (8)$$

2. Wastewater management efficiency (Criterion: Evaluation of wastewater management quality and effectiveness of their treatment).

2.1. Wastewater quality *(WQ)*

$$WQ = \sum_{i=1}^{n} W_I \times \frac{C_i}{S_i} \quad (9)$$

where W_i – weight coefficient for the *i*-th pollutant; C_i – actual concentration of the *i*-th pollutant in the wastewater; S_i – permissible standard or threshold concentration for the *i*-th pollutant.

2.2. Wastewater treatment efficiency *(WTE).*

$$WTE = \frac{WWt}{WWp} \quad (10)$$

where *WWt* – the volume of wastewater that has undergone treatment;

WWp – total volume of produced wastewater.

2.3. Treated wastewater recycling rate *(WWRR).*

$$WWRR = \frac{WWt_{reuse}}{WWp} \quad (11)$$

where WWt_{reuse} – the volume of treated wastewater that is recirculated..

2.4. Wastewater compliance rate *(WWC)*

$$WWC = \frac{Mcompl}{Mtotal} \quad (12)$$

where *Mcompl* – the number of wastewater samples that meet the standards;

Mtotal – the total number of wastewater samples.

2.5. Integral indicator of the effectiveness of wastewater management block *(EWW):*

$$EWW = \frac{1}{4} \times (WQ + WTE + WWRR + WWC) \quad (13)$$

3. Compliance with regulatory requirements and social responsibility (Criterion: Assessment of compliance with regulatory requirements and social responsibility in the field of water use).

3.1. Compliance with regulations *(CR)*

$$CR = \frac{1}{n} \sum_{i=1}^{n} \frac{Ccur_i}{Cst_i} \quad (14)$$

where *n* – the total number of regulatory requirements;

$Ccur_i$ – the actual performance indicator for the *i*-th regulatory requirement;

Cst_i – the standard or regulatory value for the *i*-th requirement.

3.2. Corporate social responsibility in water use (*CSRW).*

$$CSRW = \frac{Ncsrw}{Ntotal} \quad (15)$$

where *Ncsrw* – the number of corporate social responsibility projects related to water use in the current year; *Ntotal* – the total number of corporate social responsibility projects.

e-ISSN 2786-8958
ISSN-L 2616-7107

3.3. Investment index in environmental projects *(IEP)*.

$$IEP = \frac{Ienv\_pr}{Rtotal} \quad (16)$$

where *Ienv_pr* – the amount of investments in environmental projects in the current year.

3.4. Integral indicator of the regulatory compliance and social responsibility block *(ECSR)*.

$$ECSR = \frac{1}{3} \times (CR + CSRW + IEP) \quad (17)$$

4. Evaluation innovation in water use (Criterion: Evaluation of the implementation of innovations in water use).

4.1. Innovation index *(II)*.

$$II = \frac{Ninnov}{Ntotal} \quad (18)$$

where *Ninnov* – the number of innovations and technologies implemented in water use in the current year;

Ntotal – the total number of innovations and technologies in the enterprise.

4.2. Water savings due to innovation *(WSDI)*.

$$WSDI = \frac{Wsav\_i}{WC} \quad (19)$$

where *Wsav_i* – the volume of water saved through the implementation of innovations.

4.3. Research and development index in water use *(RDIW)*.

$$RDIW = \frac{Ir\&d}{Rtotal} \quad (20)$$

where *Ir&d* – the total amount of investment in research and development in the current year.

4.4. Integral indicator of the innovation in water use block *(EI):*

$$EI = \frac{1}{3} \times (II + WSDI + RDIW) \quad (21)$$

A final integral indicator is applied to comprehensively assess the level of greening economic activities regarding water use, considering various ecological, economic, social, and technical aspects. The scale of this indicator helps to determine the level of ecological compliance with a business's activities and identify areas for improvement. Below is a scale that details the different levels of greening based on the value of the integral indicator (Table 2). It is necessary to determine the weighting factors to develop the final integral indicator. These coefficients can be established based on the importance of each block for the overall evaluation of business greening in terms of water use. Assuming the following weighting coefficients:

1. Efficiency of Wastewater Management (EWW): 0.25
2. Regulatory Compliance and Social Responsibility (ECSR): 0.20
3. Evaluation of Innovation in Water Use (EI): 0.20
4. Evaluation of Innovation in Water Use (EI): 0.20

The final integral indicator is calculated as the weighted average of the integral indicators of each block:

$$i = 0{,}35EWC+0{,}25EWW+0{,}2ECSR+0{,}2E \quad (22)$$

Table 2. Scale for evaluating the integral indicator of water use.

Integral indicator (i)	**Evaluation**	**Description**
0,9-1	Excellent	Excellent ecological efficiency in water use. The enterprise applies best practices.
0,7-0,89	Good	Good ecological efficiency in water use. Some areas for improvement exist.
0,5-0,69	Satisfactory	Satisfactory ecological efficiency in water use. Additional measures are needed for improvement.
0,3-0,49	Unsatisfactory	Unsatisfactory ecological efficiency in water use. Significant improvements are needed.
0,0-0,29	Very poor	Very low ecological efficiency in water use. The enterprise does not meet basic standards.

6. Conclusions.

The low level of fresh water supply in Ukraine compared to European countries is characterised by high water consumption and a significant anthropogenic load on water resources. It is necessary to take comprehensive measures to improve water resource management, in particular, through greening economic activities in water use.

This sector's water productivity and economic productivity per unit of polluted wastewater were the lowest, indicating that the sector consumes a large amount of water relative to its economic contribution and has a significant adverse environmental impact due to the high level of wastewater pollution.

To determine the level of impact of each enterprise in the sector on the state of water resources, the authors proposed methodological recommendations for assessing the level of greening the economic activities in the field of water use, which ensures a comprehensive and detailed analysis of water use efficiency and water resource pollution levels, as well as impacts on ecosystems and the sustainability of the enterprise. The integration of various indicator blocks, together with their integrated assessment, enables a comprehensive approach to determine the environmental sustainability of an enterprise, which is key to developing effective water resource management strategies.

This approach allows the identification of both weak and strong aspects of water use within an enterprise, determines the main issues, and develops recommendations for their resolution. The presented indicators are universal in their set and can be adapted to water use characteristics in various industries. The indicators can be changed or supplemented by each company's unique requirements.

These include reducing pollutant emissions, optimizing production processes, introducing modern water purification and recycling technologies, and improving interaction with regulatory authorities. This can ensure transparency and accountability in water use, which increases public trust and the social responsibility of businesses.

The principles of the developed methodology can contribute to the methodical assessment of the environmental efficiency of water sector enterprises, increasing their environmental sustainability and ensuring sustainable growth of water resources.

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