Innovation in the Circular Economy in the Water Sector: A Case Study on Wabag Water Services Romania

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Abstract

In Romania, only 12% of urban wastewater meets EU treatment standards, with over 50% originating from commercial and industrial activities containing pollutants like heavy metals, highlighting the urgent need for improved wastewater treatment infrastructure. Literature about best practices of wastewater treatment in Romania to positively impact the circular economy are lacking. The paper's objective is to be informed by observations about the resource recovery model in the wastewater management sector. Drawing from the insights gathered in the literature review, this paper aims to explore the following research questions: "What are the best practices in wastewater treatment in Romania that can positively influence the circular economy?", "What obstacles hinder the transition of wastewater treatment businesses to a circular model?", "What opportunities exist for rethinking the operations of wastewater treatment businesses to align with a circular model?". The research employs qualitative research methods, specifically a descriptive case study. To ensure a thorough, accurate, and impartial analysis of the phenomenon under investigation, multiple data collection techniques were utilized, including an in-depth interview in two stages and the examination of public documents about the company's activities.The global emphasis on ESG criteria highlights wastewater reuse and biogas generation as key to achieving SDG 6, promoting circular economies, sustainable urban planning, and SMART city development through multi-stakeholder collaboration. Addressing the challenges posed by this topic requires a multi-stakeholder approach involving government and regulatory bodies, water utility companies, industry, environmental organizations, researchers, technology providers, consumers and residents, urban planners and policy makers. In the near future, wastewater treatment plants are anticipated to transform into ecologically sustainable technological systems and become essential components of SMART cities.

Keywords: circular economy, the water sector, the resource recovery model, wastewater treatment, innovative business model.

JEL classification: L62, O13, Q01, Q53, Q56.

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1. Introduction

Aligned with the principles of the circular economy (CE), products, materials, and raw resources should be kept in use for as long as possible, with waste being treated as secondary raw materials that can be recycled and reused (Kirchherr et al., 2023; Vecchio et al., 2022), in contrast with the current linear process, where waste is the final stage of a product's life cycle (Shi et al., 2024). Consequently, reducing the amount of waste generated and repurposing it as secondary raw material is closely aligned with the sustainable management of materials and energy (Lingaitiene and Burinskiene, 2024; Prieto-Sandoval et al., 2018). Efficient waste collection and recovery enable its conversion into resources that can be reintegrated into the economic cycle as secondary raw materials, generating both environmental and economic benefits (Strat et al., 2024).

Europe needs CE to success on large scale in European countries because of limited availability of raw materials, European economy dependance on import of raw materials and technologies (figure 1) affected by policrises such as the geopolitical shifts (Brexit in 2018), sanitary crises (COVID 19 pandemia starting 2020), war in Ukraine (starting 2022, drought in Spain (2023, 2024), and decreasing EU competitiveness in global economy (World Economic Forum, 2023; Hartley et al., 2020; Milios, 2021). At the EU level, companies place significant importance on digitalisation and technology, essential for achieving a gradual transition to the CE (Petre et al., 2023).

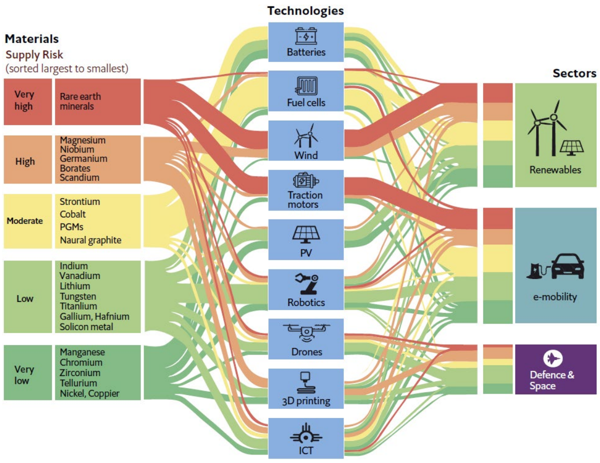

Figure 1. Strategic Minerals and Key Technologies in the Green Transition at Risk for the EU
Source: Gusilov and Staicu (2023).

Wastewater treatment is a critical environmental challenge of the twenty-first century. Inadequate treatment of wastewater from industries and households before disposal leads to serious environmental and health risks for nearby communities. Improper sludge disposal leads to land and leachate pollution, contaminates groundwater, and contributes to GHG emissions through the release of toxic gases. Consequently, wastewater treatment has far-reaching direct and indirect impacts (Chopra, 2022). Therefore, it is essential to implement cost-effective, high-performance wastewater treatment systems and to raise public awareness on this issue (Choudhary et al., 2020; figure 2).

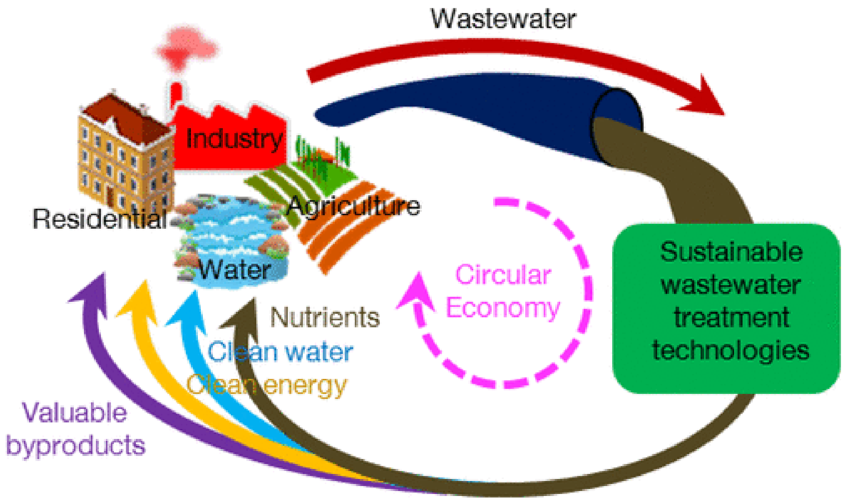

Figure 2. The Role of Wastewater in the Circular Economy
Source: Ghimire et al. (2021).

Recent global discussions on water scarcity, global warming, and the long-term environmental impact of industrial processes have brought the circular economy (figure 3) to the forefront of water sector debates. These discussions tackle the immediate environmental impacts while also contributing to a broader, long-term conversation about conserving natural resources for the future. The answer to this seemingly complex problem is found in the principles of a Circular Economy (figure 3).

This innovative approach focuses on Resource Recovery related to all three components of wastewater: water, sludge, and biogas (figure 4).

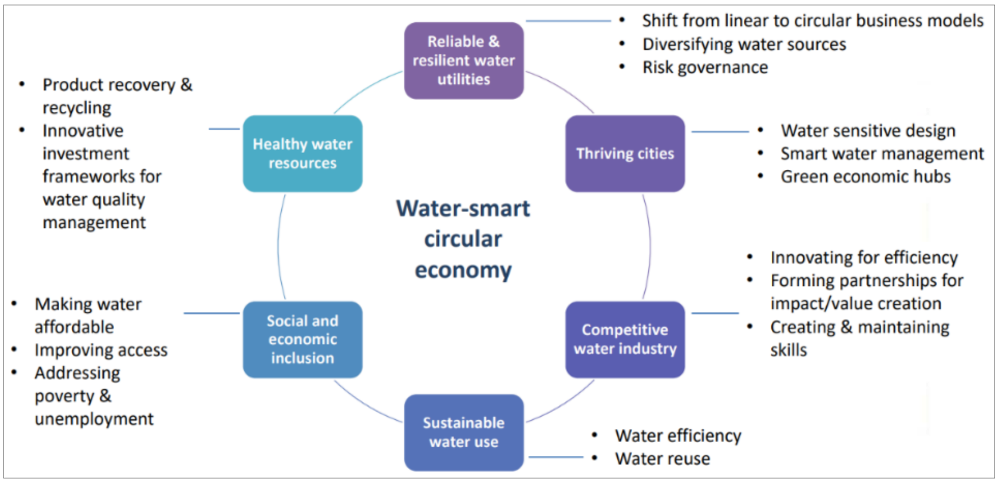

Figure 3. A Circular Perspective on Water Management
Source: Zvimba (2019).

Within this new model, wastewater is treated to ensure it is suitable for discharge into water bodies, recharging aquifers, and even for reuse in industrial processes. The by-product is bio-sludge and is digested and dewatered to create nutrient-rich manure, addressing the challenge of land availability for sludge disposal. Additionally, the biogas generated during sludge digestion is used to produce green energy, which powers the plant sustainably (Chopra, 2022).

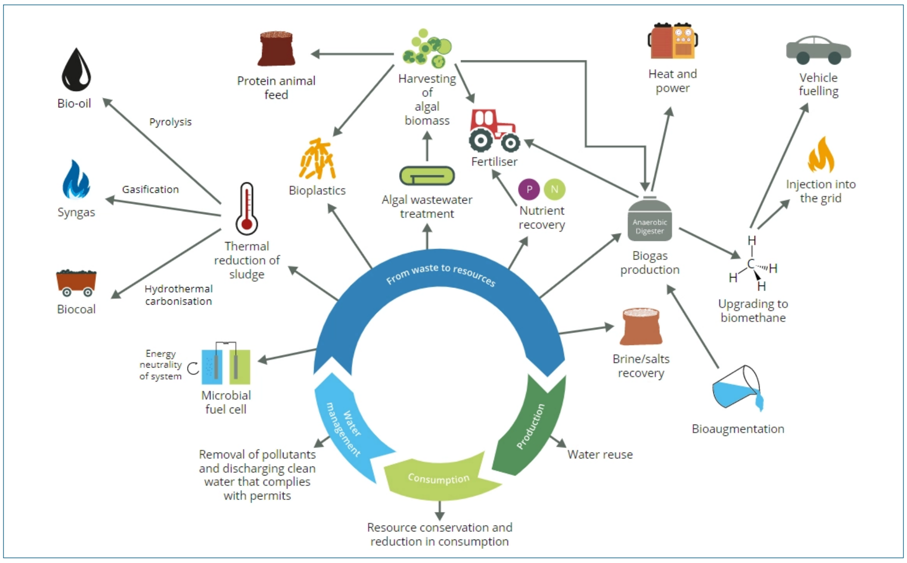

Figure 4. The Wastewater Sector based on the Circular Economy Principles
Source: AMIAD Water Services (2022).

The water recovered and reused can have many functions (Zvimba, 2019): Potable (drinking water, either supplied directly or blended with raw water); Agricultural Industrial non-potable (reuse of treated wastewater or reuse of wastewater onsite); Domestic non-potable (fill swimming pools, toilet flushing, garden watering, car washing); Groundwater recharge (recharge of aquifers); Return to rivers – indirect reuse (figure 5).

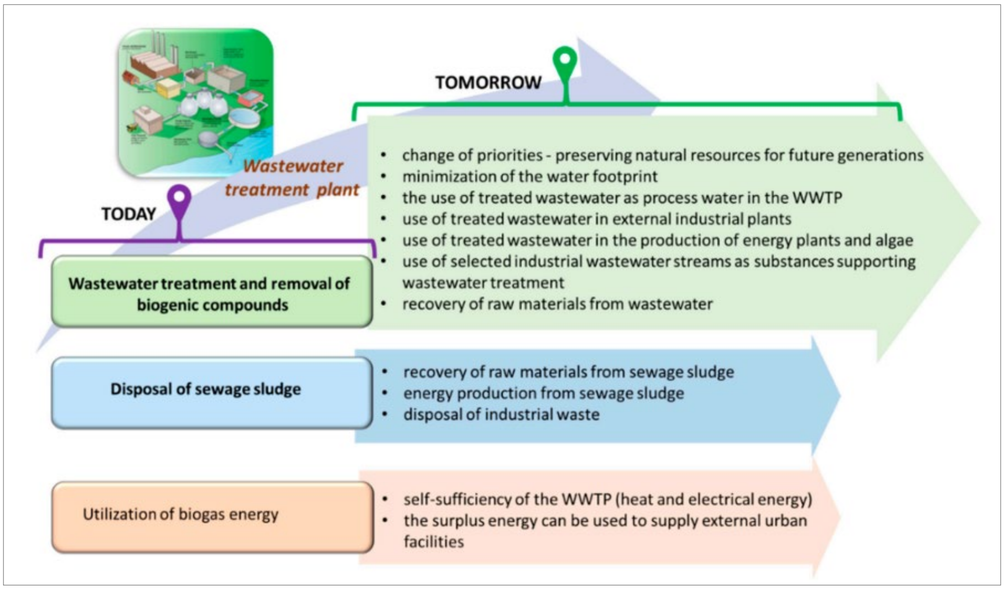

Figure 5. WWTP Today and in the Future
Source: Neczaj & Grosser (2018).

Implementing new business models to deliver additional benefits (Zvimba, 2019) can positively impact resources, communities, and economies. These models can optimize the value extracted from water and wastewater resources, reduce unnecessary waste sent to landfills, enhance productivity and efficiency, stimulate the local economy with new products and services, and generate employment opportunities. Additionally, they help minimize environmental impact. However, if we envision WWTPs as vital hubs in the cities of the future, the priorities of wastewater treatment plants must broaden (Neczaj & Grosser, 2018).

2. Problem Statement

In 2019, 1,870 million cubic meters of wastewater were discharged into natural bodies of water, with approximately 34% of it being untreated. The volume of over 1,200 m^3 treated wastewater originated from municipal wastewater treatment (930 million m^3), industrial wastewater treatment plants (290 million m^3), and independent WWTPs (19 million m^3) (Chopra, 2022; Zvimba, 2019).

In Romania, more than 50% of the total wastewater volume comes from commercial and industrial activities and contains pollutants and heavy metals such as Copper, Chromium, Nickel, Lead, and Zinc, which demand proper treatment (Chopra, 2022). Households and certain industries generate 20.0 million p.e. of wastewater every day, which is the equivalent to around 40 million bathtubs or 3.99 million m^3. There is still 631 million m^3 of industrial wastewater that needs to be purified appropriately (Business Review, 2021). In Romania, urban wastewater is treated in 642 plants across the country before it is discharged (figure 6).

Overall, 12% of the urban wastewater in Romania is treated according to the requirements of the Urban Wastewater Treatment Directive (WISE, 2024) or UWWTD which is below the EU average of 76%. However, urban wastewater needs to be treated before discharge, in order to avoid pollution to the environment.

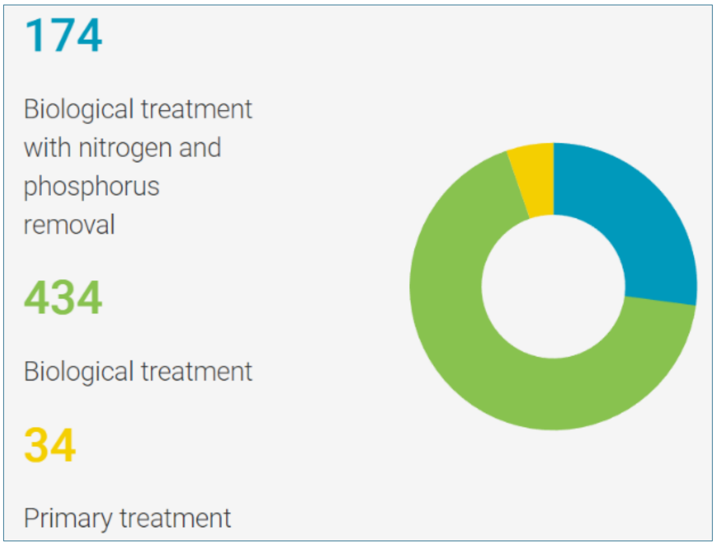

Figure 6. Number of treatment plants by type of treatment
Source: Water.Europa.eu (2022).

Circular economy and supply chain management are two areas that have increasingly captured researchers' attention in recent years (Bunea, 2021). In wastewater treatment, lliterature about best practices of wastewater treatment in Romania and the supply chain to positively impact the circular economy are lacking.

3. Research Question

Research Questions

The business under analysis is Romanian-based company WABAG Water Services Romania (WWS), which specializes in the design, implementation, and operation of drinking water and wastewater treatment plants for both municipal and industrial sectors. The company provides sustainable solutions across a wide range of needs, including drinking water treatment, industrial and process water treatment, seawater desalination, municipal and industrial wastewater treatment, and sludge treatment. By constructing and operating state-of-the-art industrial-scale plants, WWS ensures the protection of water resources and provides efficient water and wastewater treatment solutions for both municipal and industrial applications (WWS website).

The paper's objective is to analyze to what extent WWT implements practices from the resource recovery model as informed by the observations of Neczaj and Grosser (2018). Aligned with the stated objective, and building on the insights from the literature review, this paper seeks to address the following research questions:

R1. "What are the best practices of wastewater treatment in Romania to positively impact the circular economy?"

R2. "Which are barriers to rethinking operations of WWT business to adapt to a circular model?"

R3. "What are the opportunities to rethink operations of WWT business to adapt to a circular model?"

4. Research Methods

To achieve the objective, the author employed qualitative research methods, specifically a descriptive case study (Yin, 2018) which provided the author with the flexibility to employ any data collection method that aligned with the author's objectives for this research (Priya, 2021).

The case study method provides an in-depth and detailed understanding of complex issues, in this case the application of the resource recovery model in the wastewater sector, by allowing researchers to explore real-life contexts and situations. Case studies also offer rich qualitative data, capturing nuanced insights that might be overlooked in quantitative research. In this case, challenges related to energy recovery were identified. Additionally, the case study method allowed flexibility in research design, accommodating various data collection methods such as interview, observation, and company public document analysis.

Furthermore, in this research, the case study method enhanced practical understanding about the circular economic practices as understood by a company in the wastewater sector, by offering real-world applications, making them beneficial for decision-makers, in this case policy makers. However, the case study method has several limitations. One major drawback is its limited generalizability, as findings from one company may not apply to broader contexts. The method is also time-consuming and resource-intensive, requiring extensive data collection, in several stages.

To ensure a thorough, accurate, and impartial analysis of the phenomenon under investigation, multiple data collection techniques were utilized, including an in-depth interview in two stages and the examination of public documents about the company's activities.

Moreover, the case study entails an in-depth examination of the specific unit of analysis – one business focused on both manufacturing and distribution, while focusing on the local context. The data was gathered as follows:

D1. consultation of public information about the company ranging from 2014 to 2024 as follows in table 3.1 Data collection implied reading over 200 pages of internal and external documents. The documents were provided by the company's marketing manager.

Public Sources Consulted for this Research

Table 1

Source	**Year of publication**	**Link**
The company's website	2024	https://wabag.ro/en-ro/company/
New-Industrial-Orders-for-WABAG-Romania	2020	https://wabag.ro/en-ro/wGlobal/content/elements/news/New-Industrial-Orders-for-WABAG-Romania-_ENG.pdf
Factory of Philip Morris International, Otopeni, Romania	2019	https://wabag.ro/en-ro/references/RefSheet_Philip_Morris_FLUOPUR_R5.pdf
ARPECHIM Refinery ETP, Romania	2019	https://wabag.ro/en-ro/references/RefSheet_Arpechim_Romania_ETP_DBO.pdf
PEPSI CO. - Kashira, Moscow, Russia	2018	https://wabag.ro/en-ro/references/RefSheet_PepsiCO_Kashira_Moscow.pdf
PEPSI CO. - Dragon WWTP, Romania	2017	https://wabag.ro/en-ro/references/RefSheet_PepsiCO_Dragon_Bucharest_R3.pdf
Oilfield Suplacu de Barcau, Romania	2017	https://wabag.ro/en-ro/references/RefSheet_Suplacu_Produced-Water-Treatment.pdf
AIUD WWTP, Romania	2015	https://wabag.ro/en-ro/references/RefSheet_AIUD_WWTP_RO.pdf
Ocna Mures WWTP, Romania	2015	https://wabag.ro/en-ro/references/RefSheet_OcnaMures_WWTP_RO.pdf
Cugir WWTP, Romania	2015	https://wabag.ro/en-ro/references/RefSheet_Cugir_WWTP_RO.pdf

Source	Year of publication	Link
KAR, Erbil Wastewater Treatment Plant	2014	https://wabag.ro/en-ro/references/RefSheet_KAR_Refinery_Erbil_Iraq.pdf
PetroBrazi Refinery ETP, Romania	2014	https://wabag.ro/ro-ro/referinte/PETROBRAZI-ETP-Operations_RO_2019_ENG_WEB-1.pdf

Source: the company's marketing manager and the company's website

D2. An in-depth interview addressed to one of the company's experienced employees' (table 2).

In-Depth Interview Held in 2022

Table 2

Section (1 to 4)	**Questions**
1. Company identification data	The company name
	Headquarters
	Website
	Sector of activity
	The company is: - Micro-enterprise (between 1 and 9 employees) - Small size (between 10 and 49 employees) - Medium-sized (between 50 and 249 employees) - More than 250 employees
	Describe your company's business in one sentence.
	Through the activity carried out, the company: − It deals with the production of products − It deals with the distribution of a product − Market a service − It carries out another type of activity
2. Characteristics of the company's activity (Likert scale: 5-point scale)	The company is registered in a platform for sharing goods/ services
	The company buys or takes over goods and reuses them.
	The company refurbishes end-of-life goods.
	The company recycles and/or recovers material.
	The company uses reclaimed material to produce new products.
	The company sells products made from recycled materials.
	The company is considering rethinking operations to incorporate circular economy principles into company operations (design to remove waste and pollution; keep products and materials in use; regenerate natural systems).
3. Barriers to rethinking operations to adapt to a	There is insufficient information on circular economy legislation.
	There are not enough financial resources to implement the activities necessary to adapt the business model to the principles of the circular economy.

Section (1 to 4)	Questions
circular model (Likert scale: 5-point scale)	I did not find a consultant to help the company to adapt to the circular economy.
4. Opportunities in rethinking operations to adapt to a circular model (Likert scale: 5-point scale)	I worked with a consultant to adapt the company's operations.
	Knowledge related to rethinking the business model is from within the company.
	The company received circular economy expertise from the headquarters.

Source: author's own work (2022)

5. Findings

WABAG Water Services Romania: background

Headquartered in Bucharest with 51 employees in 2021, WABAG Water Services (WWS) is specialized in the planning and construction of water treatment plants and industrial wastewater treatment, at both national and international level. Ranked 4th in the Top 50 World Private Water Operators (Global Water Intelligence, 2021), WWS is part of the international VA Tech WABAG Ltd. Group, with a presence in four continents and over 20 countries. The WABAG Group is one of the world 's leading companies for the design, construction, and operational management of complete water and wastewater treatment plants for both the municipal and industrial sectors providing comprehensive and advanced treatment solutions.

Since its inception in 2008, WWS has been serving various industrial sectors in Romania by providing innovative solutions for effluent treatment, both as rehabilitation, modernization, plant extension as well as for greenfield projects for industries such as Oil & Gas, Food & Beverage, Chemical industry or Tobacco production. At the end of 2021, WWS accounted 137.802.566 ron net revenues, and a profit of 30.586.940 ron (Ministry of Finance website, 2021). In the last decade, the company has successfully realized ten industrial projects to ensure environmentally friendly wastewater disposal and water recycling.

WWS aspires to become one of the top three water companies worldwide (Business Review, 2021) by adopting the key circular economy principles. However, to develop such systems was challenging. To overcome the above challenges and rethink its business model for the circular economy, WWS innovated to align to the circular economy principles:

The Resource Recovery Model: Water Reuse

During the design phase of the WWTP, the Engineering department adapt the process so that the waste water is reused for other purposes with the goal to transform it into a "good with value". The reuse of treated wastewater from WWTPs for agriculture, land irrigation, industrial purposes, toilet flushing, and groundwater replenishment is a crucial part of the current strategy aimed at freeing up freshwater for domestic use (Neczaj & Grosser, 2018)

The Refinery ETP at OMV Petrom SA in Brazi, Romania, with a capacity of 30,000 m³/day, has undergone a thorough refurbishment and technological optimization and upgrading program. The challenge to solve was regarding the treatment of wastewater and its reuse in the production flow.

WWS Romania developed for two years a 1.2 million eur project which included also a water recirculation system, with the scope to reuse water and transform it into a "good with value". All these activities were carried out by WWS Romania in two stages, between 2010 and 2014. In addition, a self-washing filtration system was installed for enhanced water reuse in 2014.

Now approximately 60% of the used treated water is recirculated and reused within the unit, in various processing actions. Therefore, in order to improve the quality of the reused water, the effluent is post-treated in three self-washing filtration units with a capacity of 1,000 mc/h. Water purification allowed the reuse of water for other purposes, such as water for the firefighters cars, thus reducing the amount discharged into water bodies or fresh water employed (WWS brochure, 2014; WWS interview).

A second project which has as result water recovery concerned the project entitled "Water Recycling to reduce OPEX for Clean Tech Clean Tech International", a Romanian slaughterhouse and processing company that produces protein foodstuff. At Ciulnita site, wastewater generated during production is treated at the existing effluent treatment plant before being discharged into the Ialomita River. The plant underwent extensive rehabilitation and will be expanded with new process stages to enhance its capabilities. A portion of the treated water is purified in the downstream section and reused as boiler feed water for production operations. WABAG has developed an innovative and sustainable solution that conserves freshwater and reduces operational costs (WWS, 2020).

The Resource Recovery Model: Nutrient Recovery

Nutrient recycling from WWTPs positively impacts the environment by lowering the demand for conventional fossil-based fertilizers, which in turn reduces water and energy consumption. Land application of sewage sludge is widely practiced in Europe and other countries (Kundu et al., 2022). In the future, nutrient recovery processes need to be sustainable by reducing inputs such as water, energy, and chemicals, minimizing "side-waste," and maximizing recovery efficiency (Mehta et al., 2015).

During the interview with WWS responsible, the topic of nutrient recovery was approached. This person mentioned that at this time, the company is not performing nutrient recovery and mentioned a few challenges (table 3).

Challenges related to nutrient recovery

Table 3

Challenge	**Explanation offered**
Regulatory and Policy	The absence of regulations and policies on nutrient recovery and reuse can slow-down progress, especially when there are no incentives or guidelines for implementing recovery technologies.
Quality of Recovered Nutrients	Ensuring the quality and safety of recovered nutrients for agricultural or other uses is difficult. Heavy metals or pathogens may be present, requiring additional treatment stages.
Infrastructure required	Adapting or upgrading existing wastewater treatment plants to incorporate nutrient recovery can be challenging, especially in older facilities where space and resources may be limited.
Energy Requirements	These processes can be energy-intensive, potentially offsetting the environmental benefits if the energy used does not come from renewable sources.
Market Development	Developing a market for recovered nutrients is important because without demand among farmers, and a steady supply and distribution network, the effort is useless.

Source: author's own processing based on interview (2022).

The application of contaminated recycled nutrient products on agricultural land (e.g., those containing heavy metals or organic pollutants) leads to human toxicity and ecotoxicity, which affects human health and the natural environment (Lam et al., 2020).

The Resource Recovery Model: Energy Recovery

Energy recovery at wastewater treatment plants is a significant policy tool for promoting sustainability. This can be achieved through biogas production, the use of heat pumps in treatment plant effluents, and energy recovery from high-temperature streams via heat exchangers. The first installations were established over 20 years ago, and today, heat pumps utilizing wastewater are widely used in Europe, the USA, Japan, South Korea, and China (Neczaj & Grosser, 2018).

During the interview with WWS responsible, the topic of nutrient energy recovery was raised. A few challenges were mentioned (table 4).

Challenges related to energy recovery

Table 4

Challenge	**Explanation offered**
Regulatory and Policy	Romanian regulatory does not fully support or incentivize energy recovery efforts, making it challenging for WWTPs to implement and benefit from these technologies (exception biogas production).
Efficiency of Energy Recovery	Capturing and utilizing energy from wastewater efficiently can be difficult due to the variability in wastewater temperature, flow rates, and composition.
Infrastructure costs and	Implementing energy recovery systems, such as biogas

Challenge	Explanation offered
integration with existing systems	production facilities or heat exchangers, requires significant upfront investment. Retrofitting existing plants can be particularly expensive and complex. Moreover, incorporating energy recovery systems into existing WWTP infrastructure can be technically challenging, especially if the plant was not originally designed with energy recovery in mind.
Market Development	The energy generated may not always align with local energy demands, requiring storage solutions (batteries) or grid integration, which can add to complexity and cost.

Source: author's own processing based on the interview (2023).

Among the opportunities, the current regulatory and policy frameworks for biogas production which cover aspects related to construction, operation, environmental protection, and the use of renewable energy were mentioned (table 5).

Current Regulatory and Policy Frameworks for Biogas Production

Table 5

Regulatory and policy frameworks (Romanian title)	Framework guidelines
Legea nr. 292/2018 privind evaluarea impactului asupra mediului	Any project to build a biogas plant must be subject to an environmental impact assessment (EIA) to identify and mitigate potential negative environmental effects.
Ordinul ANRE nr. 48/2017	sets the regulated tariffs for energy produced from biogas and how they are calculated.
Legea nr. 123/2012 privind energia electrică și gazele naturale	This law establishes the general framework for the production and use of energy from renewable sources, including biogas.
Legea nr. 211/2011 privind regimul deșeurilor	biogas plants using organic waste must comply with waste management regulations, including their collection, transport, treatment and disposal.
Ordinul Ministerului Mediului nr. 662/2006	It regulates the conditions for issuing environmental permits for biogas-producing installations, including technical requirements and environmental protection measures.
Legea nr. 220/2008 privind stabilirea sistemului de promovare a producerii energiei din surse regenerabile de energie	This law and subsequent amendments establish the support mechanisms to produce energy from renewable sources, including biogas; include the green certificate system, which provides financial incentives to producers.
Other laws: Legea nr. 50/1991 privind autorizarea executării lucrărilor de construcții; Legea nr. 107/1996 a apelor	Construction related and biogas plants must comply with discharge and water use regulations.

Source: author's own processing based on interview (2022).

The Resource Recovery Model: Other Resources

Integrating sewage sludge into the construction industry perfectly aligns with the principles of a circular economy. Sewage sludge ash can be used in producing building materials such as bricks and tiles. It also serves as a raw material for manufacturing cement, concrete, mortar, lightweight materials, and more. Additionally, recovering valuable elements like copper, silver, and gold from the ashes left after sewage sludge incineration is both feasible and economically beneficial.

Researchers at the world's top technical universities are also exploring biotechnology for wastewater treatment, focusing on the production of biodegradable plastics, focused on biomass treatment (Bengtsson et al., 2017). Similarly, attempts are made to directly generate electricity during the process of removing contaminants from wastewater.

No such initiative has been mentioned during the interview or in the company's public documents consulted.

More generally, other challenges formulated during the interview concerned the regulations and financial incentives "Permissive environmental legislation and no specific legislative incentives for investment in water reuse solutions". Moreover, the government was not perceived as a partner in the process of adapting design for water reuse though it is a policy maker. In addition, "the financial support guaranteed by the state for this type of investment is either non-existent or difficult to approach."

6. Conclusion

From an industry perspective, the growing global focus on Environmental, Social, and Governance criteria underscores the need to implement technologies that optimize the utilization of every aspect of the precious resource which is water. Implementing a Circular Economy model, particularly through the reuse of wastewater and the generation of green energy via biogas in the municipal sector, plays a crucial role in achieving the United Nations Sustainable Development Goal 6 - "Clean Water and Sanitation for All." (Chopra, 2022). This aligns with the philosophy WWS has always followed: "Water is too precious to be used just once."

This case study highlights the critical role of wastewater treatment in advancing the circular economy within the water sector. By implementing innovative resource recovery models, such as water reuse and energy generation through biogas, WWS demonstrates the potential of wastewater treatment plants to become sustainable, technologically advanced systems that contribute to SMART city development. However, not all the practices of the recovery resource model are attainable at this point and various policy challenges have been raised.

Challenges such as regulatory barriers, financial constraints, and infrastructure limitations remain significant obstacles to a full transition toward circular wastewater management. Addressing these issues requires a collaborative, multi-stakeholder approach involving government bodies, industry leaders, researchers, and policymakers to create supportive frameworks and incentives for sustainable water management practices.

The findings of this study reinforce the importance of continuous innovation, regulatory alignment, awareness about the circular economy as it applies in the wastewater sector, and investment in circular economy principles to maximize the efficiency of wastewater treatment and resource recovery.

Future research could analyze the economic impact of adopting a circular economy model in the water sector, with a particular focus on the resource recovery model, and a cost-benefit analysis that could provide valuable insights into the financial viability and economic incentives of circular wastewater management.

Additionally, further studies should explore the level of engagement, challenges, and collaborative opportunities among different stakeholders, including public bodies, local communities, NGOs, and industry players in implementing circular economy principles, coclusion also supported by Pacesila and Radu (2024).

Comparative research on international best practices and successful case studies from other countries could also provide guidance on effective frameworks, regulatory mechanisms, and financial incentives that drive the adoption of circular economy principles in the water sector.

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