

REVIEW ARTICLE

DESIGNING SUSTAINABLE BUSINESS MODELS FOR DECENTRALIZED WASTEWATER TREATMENT SYSTEMS (DEWATS)

Mohammad A. Tabieh^a, Tala H Qtaishat^a, Khaleda M. Al Ghazawi^b, Ahmad Jamrah^c, Tharaa Al-Zghoul^c, Emad K. Al-Karablieh^a

^aDepartment of Agricultural Economics and Agribusiness, School of Agriculture, The University of Jordan, Amman 11942, Jordan

^bFree Lancer Consultant, Amman, Jordan

^cDepartment of Civil Engineering, School of Engineering, The University of Jordan, Amman 11942, Jordan

*Corresponding author Email: m.tabieh@ju.edu.jo; jamrah@ju.edu.jo; tharaaalzghoul@gmail.com.

This is an open access journal distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited

ABSTRACT

Article History:

Received 12 March 2025

Revised 14 April 2025

Accepted 25 April 2025

Available online 08 May 2025

Expanding centralized wastewater services to all regions in Jordan is constrained by economic, topographical, and engineering challenges. As a result, decentralized wastewater treatment systems (DEWATS) are increasingly recognized as a complementary solution, particularly for rural and peri-urban areas where centralized connectivity is unfeasible. This study aims to design a sustainable and scalable business model for DEWATS in Jordan, with a focus on overcoming the institutional, financial, and regulatory barriers that have historically hindered their adoption. The research integrates spatial diagnostics, stakeholder consultations, institutional analysis, and a comprehensive financial and economic evaluation of three nature-based DEWATS configurations designed for settlements of up to 5,000 population equivalent (PE). Indicators such as average incremental cost (AIC), net present value (NPV), internal rate of return (IRR), and benefit-cost (B/C) ratios were used to evaluate technical and operational viability under both private and public investment scenarios. While all configurations demonstrated strong economic performance (IRRs > 27%, B/C > 3.7), financial feasibility remains weak without public capital support due to high per capita costs and limited revenue collection in small communities. The study identifies critical challenges, including undefined institutional mandates, lack of certified operators and regulators, insufficient cost-recovery mechanisms, and underdeveloped markets for private sector participation in O&M. Furthermore, existing tariff structures and bylaws do not adequately support capital investment or full operational cost recovery by private service providers. To address these gaps, the paper proposes a hybrid public-private-community business model incorporating performance-based service contracts, revised regulatory standards, and blended financing instruments. The model emphasizes the integration of DEWATS into spatial water safety planning, climate-resilient system design, and resource recovery to enhance environmental, social, and financial sustainability.

KEYWORDS

Barriers and Challenges; Business Model; Decentralized Wastewater Treatment System; Economic and Financial Indicators.

1. INTRODUCTION

Decentralized wastewater treatment systems (DEWATS) present a strategic solution for extending wastewater services to areas beyond the reach of centralized infrastructure. They are particularly suited for regions where topographical challenges, low population density, or high infrastructure costs render centralized sewer networks impractical or economically unfeasible (Ventura et al., 2024). DEWATS enable the onsite treatment of wastewater, producing effluents that can be safely reused for agricultural irrigation and other non-potable applications, contributing to both environmental protection and water resource efficiency. These systems are especially beneficial for remote rural areas, hilly terrains, and rapidly expanding semi-urban communities, offering modular, adaptable, and cost-effective solutions that align with local development needs and climatic conditions. By addressing both sanitation and water reuse, DEWATS support integrated resource management and enhance resilience in underserved regions (Ulrich et al., 2009; MWI, 2016).

Decentralized wastewater treatment refers to a range of localized approaches for the collection, treatment, and reuse of wastewater generated from households, industries, institutional clusters, and entire communities. These systems are designed based on site-specific evaluations, ensuring that the selected treatment method is appropriate for the local hydrological, environmental, and socio-economic context (Ventura et al., 2024; Rahman et al., 2024). Functioning either as standalone units or in coordination with centralized networks (semi-centralized configurations), DEWATS constitute permanent infrastructure tailored to the needs of areas typically located within 3–5 kilometers of the wastewater source and lacking access to conventional sewerage systems. Treatment technologies vary from simple natural systems such as septic tanks and soak pits to more engineered solutions like anaerobic baffled reactors, constructed wetlands, or modular mechanical systems. These systems discharge treated effluent either to the soil, surface water bodies, or reuse pathways, most commonly for agricultural irrigation, and are particularly effective in rural, peri-urban, and topographically constrained locations (Capodaglio, 2017).

Quick Response Code



Access this article online

Website:

www.watconman.org

DOI:

10.26480/wcm.02.2025.316.327

Wastewater treatment enterprises generate a wide array of public and private benefits that extend beyond direct service delivery. By reducing the volume of untreated effluent discharged into the environment, they play a critical role in mitigating health risks, curbing waterborne disease transmission, and preserving ecosystem integrity (Abu-Allaban et al., 2015; Al-Adamat et al., 2003). Effective wastewater treatment also minimizes the loss of freshwater resources caused by pollution, thereby enhancing water security. On a macroeconomic level, it reduces the need for costly environmental restoration and pollution mitigation interventions. At the household level, decentralized wastewater systems enable the safe recycling and reuse of treated water—particularly for non-potable applications such as irrigation—thus supporting sustainable water management and reducing pressure on freshwater supplies (Al Hadidi and Al Hadidi, 2021).

The implementation of private sector operations in wastewater management is consistent with Jordan's national policy framework promoting public-private partnerships (PPPs) in utility service provision (MoF, 2016). While the government supports commercializing water and sanitation services to improve efficiency and sustainability, it remains committed to its social responsibilities, particularly ensuring equitable access for vulnerable populations. In line with this, the Ministry of Water and Irrigation (MWI) sets tariffs that include a lifeline block, which applies a subsidized, fixed rate for limited volumes of consumption to protect low-income households. However, the current tariff structure falls well below the actual cost of wastewater treatment and service delivery, creating a persistent financial gap that challenges long-term cost recovery and discourages private sector engagement unless balanced by targeted subsidies or financial incentives (MWI, 2016; MWI, 2015; MWI, 2023).

The primary objective of this study is to design a sustainable and context-specific business model for DEWATS in rural areas of Jordan. This includes evaluating the financial and economic viability of different DEWATS configurations, analyzing the institutional, regulatory, and operational frameworks that influence their implementation, and identifying key barriers to private sector engagement and long-term sustainability. Through a combined technical, financial, and institutional assessment, the study aims to propose an integrated business model that supports scalable, climate-resilient, and economically feasible DEWATS solutions tailored to Jordan's rural and peri-urban contexts. By addressing these research gaps and advancing these specific objectives, the study seeks to contribute meaningfully to the evolving field of decentralized wastewater management. It offers insights that can inform evidence-based policy development, support strategic planning and institutional reform, and guide practical implementation efforts aimed at enhancing the sustainability, resilience, and inclusiveness of water resource management systems across Jordan and similar arid regions.

2. REVIEW OF LITERATURE

The current body of research on DEWATS reveals significant gaps that hinder the development and scaling of sustainable frameworks. A key shortfall lies in the limited understanding of the multi-dimensional enabling conditions that underpin the long-term viability of DEWATS. In particular, there is a lack of comprehensive analysis of the institutional and legal arrangements—including clearly defined roles, responsibilities, and coordination mechanisms—necessary for effective governance (Zhang et al., 2025). Additionally, there has been insufficient focus on identifying and addressing the specific structural and policy weaknesses that limit the feasibility and adoption of DEWATS in diverse contexts (Chivenge et al., 2024).

Centralized wastewater treatment systems are built on the principle of rapidly transporting sewage away from residential areas to remote treatment facilities, thereby minimizing public health risks and environmental exposure. In urban contexts, such systems have proven effective in managing sanitation challenges at scale and maintaining hygienic living conditions (Zhang et al., 2014). However, centralized approaches are often associated with high capital investment requirements, complex operational demands, and dependence on advanced technologies that are financially and logistically unfeasible in rural or low-density settings. These limitations hinder their applicability in areas with scattered settlements or challenging topographies, where the cost per household connection becomes prohibitively high (Zhang et al., 2014).

In Egypt, DEWATS are promoted as a cost-effective and sustainable alternative to centralized systems, particularly in rural and peri-urban areas constrained by land availability, infrastructure costs, and limited public budgets. The DEWATS approach focuses on low-maintenance,

locally constructed technologies—such as anaerobic baffled reactors, constructed wetlands, and waste stabilization ponds—that are adaptable to Egypt's diverse geographies and community scales. These systems enhance resilience, support wastewater reuse, reduce pollution, and are suited for areas with limited technical capacity. Community participation, capacity building, and policy support are identified as critical for scaling DEWATS sustainably in Egypt (Attia et al., 2024).

Recognizing these constraints, several European countries—such as Germany and the Netherlands—have begun implementing decentralized treatment solutions even within urban areas, using small-scale systems designed to serve populations of up to 1,000 people (OECD, 2013). These demonstrative projects illustrate the growing recognition of decentralized wastewater systems as viable, adaptable, and often more sustainable alternatives, particularly where centralized infrastructure is impractical or cost-prohibitive.

As urban populations expand rapidly, the extension of centralized sewerage infrastructure often fails to keep pace with growth, necessitating the adoption of alternative and complementary sanitation solutions to achieve citywide inclusive sanitation. In this context, DEWATS offers flexible and context-specific alternatives that are especially valuable in areas underserved by centralized networks.

Definitions of decentralized systems vary across institutions. The European Committee for Standardization defines small wastewater treatment plants (WWTPs) as those serving fewer than 50 population equivalents (PE). Meanwhile, the European Commission considers decentralized systems to include plants with capacities of less than 5,000 PE, and other sources define the threshold at 1,000 m³/day or 10,000 PE, depending on the treatment volume and load (Ulrich et al., 2009; Berland and Cooper, 2001). These systems are typically designed for wastewater flows ranging from 1 m³ to 1,000 m³ per day, especially where influent characteristics show COD/BOD ratios typical of domestic sources (Ulrich et al., 2009; Rahman et al., 2024).

In the Jordanian context, the term DEWATS generally refers to treatment plants with capacities below 5,000 PE, located at or near the point of wastewater generation. These may range from onsite treatment systems for individual households to units serving small or medium-sized clusters or even entire communities, depending on settlement patterns and infrastructure design.

Importantly, the classification of systems under the 5,000 PE threshold is not solely determined by the size of the population but also by plant capacity, connection density, and topographical considerations. For instance, a community of 9,000 residents split between two treatment facilities of 4,500 PE each—due to geographical constraints—would be considered as having two decentralized treatment systems. This highlights the need for flexible definitions and function-based classifications, rather than rigid thresholds, when designing and regulating decentralized sanitation infrastructure.

Private sector participation in wastewater services has been widely recognized for its potential to deliver multiple advantages. These include reductions in both capital and operational expenditures, improved compliance with environmental regulations, and enhanced capacity for risk management. Moreover, privatization tends to minimize bureaucratic inefficiencies and political interference, thereby facilitating more agile procurement processes and better adherence to project timelines. Private operators often bring technical know-how and managerial acumen that may not be readily available within the public sector, contributing to more effective service delivery.

Additionally, privatization can yield fiscal benefits for local governments. These include improved cash flow, favorable tax treatment, enhanced debt capacity, and access to private capital markets, which collectively reduce the financial burden on public budgets. When appropriately designed and regulated, privatization arrangements can support the development of resilient, financially sustainable wastewater treatment systems, particularly in decentralized contexts where public sector capacity is limited. However, the success of such arrangements depends on clearly defined contractual frameworks, regulatory oversight, and mechanisms for accountability and performance monitoring (Sansom and Franceys, 2003).

The findings of the study conducted indicate that a broad spectrum of activities and business processes within the water and sanitation sector are increasingly being outsourced across a diverse range of countries by (Sansom et al., 2003). Notably, even in contexts where there is strong

political resistance to large-scale or complex forms of private sector participation (PSP), contracting out specific services—often referred to as micro-PSP—is perceived as a more politically and socially acceptable approach. This form of engagement typically involves short- to medium-term service contracts with small-scale private operators, allowing governments to maintain ownership while leveraging private sector efficiency.

Empirical evidence from previous studies suggests that micro-PSP arrangements tend to deliver higher service quality at lower operational costs. One of the key factors contributing to this improved performance is the presence of competition for the market, which drives efficiency, cost control, and innovation among service providers. By fostering a competitive environment and introducing performance-based contracts, micro-PSP models can contribute significantly to improving service delivery, particularly in settings where public sector capacity is constrained or underperforming (van Afferden et al., 2015)

3. METHODOLOGY

This study employed a multi-method approach that integrates literature review, spatial analysis, stakeholder engagement, and financial modeling to develop a tailored business model for decentralized wastewater treatment systems (DEWATS) in rural Jordan. The selected study pilot site, Rasoon village in Ajloun Governorate, serves as a representative case due to its environmental sensitivity, limited sewer connectivity, and proximity to vulnerable groundwater resources (Lienhoop et al., 2012; Alfarrar et al., 2011; van Afferden et al., 2010; Lienhoop et al., 2014).

An extensive review of existing literature and regulatory frameworks was undertaken to establish the conceptual and contextual foundation for the study. This included peer-reviewed academic articles, national policy documents, technical reports, and case studies related to wastewater management, environmental regulation, and climate adaptation strategies. Particular attention was given to the Jordanian regulatory landscape, including standards such as JS 893/2006 and JS 893/2021 and the Decentralized Wastewater Management Policy (2016), to elucidate the opportunities and constraints associated with DEWATS implementation in Jordan (MWI, 2016; JSMO, 2006; JSMO, 2015; JSMO, 2021; Al-Karablieh et al., 2019; MWI and NICE, 2015).

The village of Rasoon was selected based on its strategic location within the Ajloun Governorate and prior assessments conducted under the SMART project in collaboration with the Ministry of Water and Irrigation (MWI). Criteria for selection included topographical suitability, land use patterns, soil characteristics, depth to groundwater, water consumption rates, and demographic indicators. Rasoon is situated in a critical groundwater recharge area that partially supplies potable water to three governorates, rendering effective wastewater management imperative from both environmental and public health perspectives (Al Hadidi and Al Hadidi, 2021; van Afferden et al., 2015).

To capture multi-sectoral perspectives on the viability and implementation of DEWATS, key stakeholder engagement was conducted through structured focus group discussions (FGDs) and semi-structured interviews. Participants included representatives from central government ministries (e.g., MWI, MoEnv), local municipal authorities, civil society organizations, private sector firms involved in wastewater infrastructure, and academic institutions.

FGDs were designed to elicit stakeholder perceptions, experiential knowledge, and concerns regarding the legal, financial, and operational dimensions of decentralized systems. Discussions also explored the barriers to widespread DEWATS adoption, such as social acceptance, regulatory fragmentation, capacity gaps, and cost-recovery limitations. Thematic analysis was applied to qualitative data to identify recurring patterns and actionable insights (MoEnv and UNDP, 2023; MoEnv and UNDP, 2022; MoEnv, 2021).

This study develops a comprehensive analytical framework to evaluate the financial and economic viability of DEWATS as sustainable sanitation solutions for small and medium-sized communities in northern Jordan. The methodology integrates technical configuration analysis, cost estimation, financial modeling, economic evaluation, and stakeholder-informed willingness-to-pay assessments, providing a robust decision-support tool for policy and investment planning.

The technical assessment was informed by stakeholder consultations, site-specific constraints, and national policy objectives. DEWATS configurations were evaluated based on treatment performance,

environmental compatibility, scalability, and operational sustainability. For each viable design option, capital expenditures (CAPEX), operational expenditures (OPEX), and infrastructure requirements were estimated using standardized engineering cost estimation methods. These parameters were derived from empirical data collected in the Jordanian context and adjusted to 2024 constant prices.

A financial modeling framework was subsequently developed to assess project viability under multiple operational and financing scenarios. The model incorporated detailed cost streams alongside projected revenues from user tariffs, treated effluent sales, septic tank emptying services, and potential public or donor co-financing. The design of the financial model was conceptually aligned with probabilistic risk assessment methodologies. This ensured a realistic treatment of uncertainty in both cost and revenue projections, particularly in scenarios involving variable uptake, energy pricing, or tariff collection efficiency (Ginbo et al., 2021).

Key financial performance indicators—including Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Average Incremental Cost (AIC)—were calculated over a 20-year project horizon. Revenue generation was assumed to commence in year one, following initial capital investment in year zero. A financial discount rate of 10% was applied to reflect the cost of capital and opportunity cost of funds under Jordanian infrastructure investment conditions. The social discount rate measures the rate at which a society is willing to trade present for future consumption. As such, it is one of the most critical inputs used in cost-benefit analysis of public projects (and more generally public policies), and it is especially relevant when considering projects whose benefits are only apparent over the very long run (Lopez, 2008). A discount rate of 5% is chosen to take different credit terms into consideration. Discount rates were selected in accordance with interest rates of KfW investment credits for communal infrastructure projects in Jordan. This financial discount rate is similar to general loan-financed projects in Jordan. It has been found that soft loans are available for the implementation of these basic social infrastructure projects, and accordingly, this borrowing condition is assumed in this case. However, the DWATS policy in 2016 suggests a discount rate ranging from 3% to 5% and a 25- to 30-year project period. This period is assumed in order to determine the total financial scope of each solution for different macroeconomic conditions (FAO/IFAD, 2016; Bank, 2023).

Beyond the project-level financial appraisal, an economic evaluation was conducted to capture broader societal benefits and opportunity costs. Financial costs were converted into economic values using shadow pricing techniques. A social conversion factor of 0.875 was applied to account for distortions in exchange rates and domestic subsidies, particularly for traded goods and energy. Labor costs were adjusted to 50% of financial values and energy inputs to 75%, in line with shadow pricing practices for non-traded goods and subsidized utilities in Jordan (FAO/IFAD, 2016).

Economic benefits assessed included avoided environmental damage (e.g., groundwater contamination from cesspits), reductions in public health risks, and the value of agricultural productivity enabled by the reuse of treated wastewater. The residual imputation method was applied to estimate the economic value of supplementary irrigation in olive and forage crop systems, with per-cubic-meter value added ranging from 0.5 USD/m³ for olives to 1.0 USD/m³ for clover and alfalfa. These figures were derived from yield differentials between rain-fed and irrigated plots, supported by production statistics and market prices reported by the Department of Statistics (2022–2023).

Willingness-to-pay (WTP) estimates were incorporated to validate pricing assumptions and assess the revenue potential from beneficiaries. Farmers expressed a WTP of up to 0.7 USD/m³ for treated effluent, driven by perceptions of improved reliability and nutrient content. For households, tariff affordability was benchmarked at 0.17 USD/m³, corresponding to approximately 1–1.5% of disposable income—a standard affordability threshold endorsed by international development finance institutions.

The integrated model enabled a comparative assessment of both financial and economic performance across six DWATS configurations, capturing not only investor-oriented returns but also societal net benefits. This holistic methodology supports decision-making on technology choice, financing structures, tariff policies, and potential public-private partnership (PPP) models. It also informs strategic planning under Jordan's National Water Strategy and Decentralized Wastewater Management Policy by providing insights into the cost-effectiveness and economic sustainability of small-scale wastewater reuse systems.

The final stage involved synthesizing the insights from literature,

stakeholder engagement, and financial assessment into a context-sensitive business model. This model articulates the DEWATS value proposition, delineates cost-sharing arrangements, and proposes governance structures conducive to decentralized implementation. The business model further identifies pathways for public-private collaboration, emphasizes the importance of adaptive regulatory frameworks, and highlights mechanisms for performance monitoring and long-term sustainability (OECD, 2019).

This integrative approach ensures that the proposed model is technically viable, economically sustainable, and institutionally grounded—offering a replicable blueprint for decentralized wastewater management in similarly constrained contexts.

4. RESULTS AND DISCUSSION

4.1 The Business Model Concept

Business models for Decentralized Wastewater Treatment Systems (DEWATS) are fundamentally structured around two interlinked dimensions: “who does what” and “who pays for what.” These dimensions determine the institutional responsibilities, financial mechanisms, and operational strategies that collectively shape the long-term viability and sustainability of DEWATS interventions (Chang et al., 2011).

The first dimension—“who does what”—pertains to the institutional and functional arrangements governing the system. This includes the definition of roles among public authorities, private operators, non-governmental organizations, and community-based institutions. It also addresses ownership structures (public, private, community-based, or hybrid), legal and regulatory frameworks, selection of context-appropriate treatment technologies (e.g., nature-based vs. compact automated systems), and mechanisms for operation, maintenance (O&M), and revenue collection. Clarifying these roles is critical for ensuring accountability, performance monitoring, and equitable service delivery (Gebrezgabher et al., 2015).

The second dimension—“who pays for what”—focuses on the system’s financial architecture. It defines the user groups (e.g., households, commercial entities, public institutions) responsible for covering capital expenditures (CAPEX) and O&M costs through tariffs, service charges, connection or emptying fees, and contributions. This dimension also considers whether systems are managed at the individual, clustered, or community scale and explores cost-sharing arrangements, targeted subsidies, or public-private partnerships (PPP) to ensure affordability, cost recovery, and financial sustainability (OECD, 2013; OECD, 2019; OECD, 2014; OECD, 2014).

A comprehensive DEWATS business model describes the core elements of service delivery and financial viability. These include:

- Purpose: Sanitation coverage, wastewater treatment, resource recovery, and environmental protection.
- Target Customers: Smallholder farmers, rural and peri-urban populations, public institutions, and industrial facilities.
- Implementation Strategies: Public service provision, private sector participation, PPP models.
- Infrastructure: Sewer networks, decentralized treatment units, reuse distribution systems.
- Organizational Structures: National utilities, municipal bodies, private firms, cooperatives, or hybrid models.
- Ownership Models: Sole public/private, shared ownership, or community-managed systems.
- Capital Investment (CAPEX): Sourced from public budgets, private capital (DBO/BOT), municipal funds, or donor support.
- O&M Financing (OPEX): Recovered via user fees, government subsidies, reuse revenue, or cooperative contributions.
- Technology Options: High-tech automated systems vs. low-energy, nature-based solutions (e.g., wetlands, lagoons).
- Trading and Revenue Practices: Tariff structures, by-product sales (biogas, sludge), connection and emptying fees.

- Operational Processes: Wastewater collection, transport, treatment, and safe reuse.
- Policy and Regulatory Frameworks: (e.g., DEWATS policy, national water strategy, investment plans),
- Cultural and Social Factors: Willingness to pay, affordability, trust in service providers, and gender/social inclusion.

A key advantage of DEWATS lies in its double value proposition: providing both environmental and health benefits while enabling financial sustainability through resource recovery. The reuse of treated wastewater for irrigation, along with the recovery of biogas, nutrients, and biosolids, contributes to a circular economy model that enhances the overall return on investment. When appropriately regulated and managed, these revenue streams can support full or partial O&M cost recovery, reduce the pressure on government budgets, and attract private sector investment (Rao et al., 2015).

Moreover, the expansion of DEWATS can significantly reduce reliance on non-engineered cesspits and leaky septic tanks, which pose serious risks to groundwater quality and public health. Improving decentralized sanitation coverage therefore contributes not only to environmental protection but also to the reduction of waterborne diseases such as diarrhea, typhoid, and cholera, particularly in vulnerable rural and semi-urban areas.

4.2 Population Context and Demand for DEWATS

Jordan’s rapidly growing population continues to exert mounting pressure on critical resources, including land, water, and food. This trend has had a cascading effect on the country’s already constrained water and sanitation systems, particularly in water-scarce regions, where increased demand leads to resource depletion, environmental degradation, and declining water quality. As of 2022, national sewerage system coverage reached approximately 67%, reflecting a modest increase from 64% in 2015 (MWI, WAJ, and JVA, 2024). However, regional disparities remain significant. For instance, while sewer coverage exceeds 80% in Amman and Zarqa, it is only 49.4% in Irbid and as low as 23.7% in Mafraq (MWI, WAJ, and JVA, 2024). These gaps are particularly acute in rural and peri-urban communities, where reliance on informal or inadequate sanitation systems remains widespread (MWI, 2018).

The financing structure for wastewater infrastructure in Jordan involves a mix of domestic and international sources. Capital investment is predominantly supported by the national treasury and international grants and loans, while operational costs are partially recovered through user tariffs. Households connected to the formal water network contribute approximately 55% of wastewater service costs via their utility bills. In contrast, those relying solely on private water tankers are excluded from these charges, creating equity and sustainability concerns in cost recovery (Albakkar, 2014).

Jordan currently operates 33 public and 7 private centralized wastewater treatment plants (WWTPs), along with over 85 decentralized facilities. These systems collectively treated an estimated 196 million cubic meters (mcm) of wastewater in 2022 (MWI, WAJ, and JVA, 2024). Approximately 90% of this treated effluent was reused in agriculture—80% of which was blended with surface water for use in the Jordan Valley (JV), while the remaining 20% was used locally near WWTPs. Despite these efforts, treated wastewater represented about 15% of the total national water budget, highlighting the need for scaling up non-conventional water sources to enhance water security (MWI, WAJ, and JVA, 2024; MWI, 2024).

Notwithstanding this reuse potential, many WWTPs operate beyond capacity or use outdated technologies. In 2022, about 66% of generated wastewater was safely treated. However, effluents from 9 out of 33 plants failed to meet the standards established under JS 893/2021 for safe discharge into surface water bodies (MWI, 2023; MoEnv and UNDP, 2023). These findings underscore the urgent need for infrastructure rehabilitation and regulatory enforcement to safeguard environmental and public health outcomes.

In unsewered areas, households primarily rely on on-site sanitation systems, including septic tanks and cesspools. It is estimated that nearly one-third of Jordan’s population depends on these systems (Al-Karablieh et al., 2019). Due to financial limitations, many households resort to cesspools instead of properly designed septic tanks. Unlike septic tanks, which allow for primary treatment and regular sludge removal, cesspools consist of unlined pits that accumulate raw sewage. Over time, the solid

waste seals the surrounding porous soil, diminishing the system's ability to leach liquids and increasing the risk of overflow (Al Hadidi and Al Hadidi, 2021; van Afferden et al., 2015; Al-Karablieh et al., 2019; Al-Karablieh et al., 2024). Furthermore, since cesspools discharge effluent below the aerobic zone of the soil—where nitrifying bacteria are most active—natural purification processes are largely bypassed. This elevates the risk of groundwater contamination and poses serious threats to human health and the environment (Al-Karablieh, 2019).

To address these systemic challenges, DEWATS are increasingly recognized as viable alternatives. DEWATS offer flexible, modular, and cost-effective treatment solutions that are well-suited for rural and peri-urban communities. Beyond treating wastewater locally, DEWATS contribute to climate resilience by enabling resource recovery, including nutrient reuse in agriculture and potential biogas generation.

4.3 Institutional and Regulatory Framework for DEWATS

The recently issued National Water Strategy 2023–2040 of Jordan emphasizes the urgent need to expand and upgrade the country's sanitation infrastructure in response to projected increases in service demand and to improve the performance of existing wastewater collection and irrigation networks (MWI, 2023). The strategy recognizes the complementary roles of both centralized and decentralized systems, explicitly supporting the integration of DEWATS where they are contextually appropriate. In doing so, the strategy seeks to address the dual imperatives of public health protection and environmental sustainability, especially in underserved urban peripheries and small towns.

A key component of the strategy is the planned expansion of wastewater treatment capacity to reach an estimated 835 small communities with populations below 5,000 Population Equivalent (PE). Notably, the policy stipulates that for such small localities, the construction of new WW collection and treatment infrastructure is not mandated unless the area lies within the service radius of existing treatment facilities or is subject to exceptional public health or environmental risks. This planning criterion is significant, given that nearly 28% of Jordan's population resides in areas falling within this demographic threshold.

The national DEWATS policy thus presents a valuable opportunity to bridge this service gap by enabling wastewater treatment and effluent reuse in regions not connected to centralized wastewater treatment plants (CWWTPs). Decentralized systems are particularly well-suited to rural, remote, and topographically challenging areas, and they offer scalable, modular solutions that can flexibly respond to population growth in semi-urban communities (MWI, 2016; MWI and NICE, 2015). In alignment with circular economy principles and national water reuse goals, the policy promotes treated effluent reuse as a critical strategy for enhancing water budget viability.

To ensure environmental and health safety, the reuse of treated effluent from DEWATS must comply with specific quality parameters outlined in the regulatory framework entitled "Specifications and Programs for Treated Domestic Wastewater from Treatment Plants with a Capacity of up to 5,000 PE." These guidelines govern effluent reuse applications for systems serving small populations, particularly in agricultural irrigation. Moreover, the policy introduces the concept of a DEWATS cluster, defined as a group of neighboring decentralized plants—each with a design capacity of up to 5,000 PE—that can function collectively to optimize operational efficiencies and resource recovery.

Overall, the strategy reflects a paradigm shift toward integrated, context-responsive wastewater management, wherein decentralized systems are not only seen as interim solutions but also as long-term, viable infrastructure options within Jordan's broader water and sanitation framework.

4.4 Ownership of DEWATS Systems

In Jordan, wastewater treatment plants are exclusively publicly owned and managed through a variety of institutional arrangements. Operations may be conducted directly by the Water Authority of Jordan (WAJ), delegated to corporatized water utilities, or implemented under contractual agreements with third-party operators. Strategic oversight is provided by the MWI, which is responsible for water policy formulation, national strategy development, and water resources planning. Within MWI, the Performance Management Unit (PMU) plays a critical role in supervising corporatized utilities, fostering public-private partnerships (PPPs), and

promoting private sector participation in water service delivery. Despite formal commitments to good governance principles—such as the separation of policy, regulatory, and service delivery functions—Jordan's water sector remains highly centralized and politically influenced. In practice, WAJ retains overlapping roles as operator, supervisor, and de facto regulator. It frequently manages PPP arrangements through detailed contractual mechanisms and internal auditing processes, thereby constraining the functional independence of corporatized utilities. Regulatory oversight is primarily exercised through performance monitoring, relying on key indicators rather than independent regulatory adjudication.

While the institutional framework for decentralized wastewater treatment systems (DEWATS) is still evolving, initial efforts to integrate DEWATS into Jordan's sanitation sector have emerged in response to the needs of small, remote, or peri-urban communities. Notably, several privately operated small-scale WWTPs are already in place, reflecting growing demand for flexible, localized solutions outside the centralized network. For DEWATS facilities serving fewer than 5,000 population equivalents (PE), operation and maintenance (O&M) responsibilities are typically structured through contractual agreements involving WAJ, water utilities, and private operators (MWI, 2013). These agreements are subject to public oversight and fall within the regulatory domain of certification frameworks designed to ensure compliance with O&M standards.

To enhance the sustainability and institutional legitimacy of DEWATS, Jordan has initiated a national certification scheme aimed at professionalizing operation and maintenance (O&M) services. This initiative includes the development of standardized training modules and competency-based licensing mechanisms to ensure that service providers meet defined technical and operational performance criteria. By establishing minimum qualifications and standard operating procedures, the scheme seeks to improve service quality, operational reliability, and regulatory compliance. However, despite these advances, the integration of DEWATS into the broader national wastewater strategy remains limited. A more comprehensive legal and institutional framework is still required to fully mainstream decentralized systems, particularly in alignment with national goals related to treated wastewater reuse, climate adaptation, and equitable service provision in underserved areas.

Ownership and management models for DEWATS in Jordan exhibit a degree of flexibility, reflecting the diverse institutional landscape of the country's sanitation sector. Potential ownership arrangements may include state-owned enterprises, municipal governments, commercial operators, or hybrid models involving public-private partnerships. While municipalities are formally responsible for sanitation services—including sewer networks and local wastewater treatment—urban wastewater services, infrastructure development, and strategic planning fall under the jurisdiction of the Water Authority of Jordan (WAJ). Although WAJ is legally established as an autonomous public entity, its operational autonomy is constrained by prevailing civil service laws, ministerial oversight, and financial audits conducted by public accountability institutions such as the Audit Bureau.

These structural and institutional conditions present both opportunities and challenges for the expansion of DEWATS in Jordan. On one hand, the decentralization of service delivery can foster innovation, enhance responsiveness to local needs, and reduce pressure on centralized infrastructure. On the other hand, overlapping mandates, limited regulatory clarity, and bureaucratic constraints on service providers may hinder the scalability and long-term viability of decentralized approaches. Therefore, effective DEWATS governance in Jordan will require coordinated reforms in regulatory policy, institutional roles, and interagency collaboration to establish a more enabling environment for decentralized wastewater management (Abu-Shams and Rabadi, 2003). Advantages and disadvantages associated with each ownership form are shown in Table 1. The evidence on efficiency differences and other differences between utilities with alternative ownership forms is mixed (Beecher et al., 1995). Some studies indicate that the private sector can provide services more efficiently; others are not so conclusive (van Afferden et al., 2015). Both sectors seem to suffer from a degree of inefficiency. Local officials prefer to retain ownership of utility assets and use partnerships for operational services.

Table 1: Comparative Analysis of Organizational Structures for DWWTPs.

Organizational Structure	Advantages	Disadvantages	Applicability to Jordan
Public Utility (e.g., WAJ, Water Companies)	- Access to public funding for CAPEX and OPEX	- High operational costs and bureaucratic inefficiencies	- Currently dominant in Jordan
	- Institutional alignment with national strategies	- Limited innovation and flexibility	- Applicable to large-scale and urban WWTPs
	- Long-term service continuity	- Blurred regulatory and operational roles	- Less suited for rural DEWATS without reform
Consumer Associations/Community-Based Organizations	- Promotes local ownership and transparency	- Often lacks technical and managerial capacity	- Suitable for small rural clusters or DEWATS
	- Potential to attract donor and NGO support	- Risk of local conflicts or governance breakdowns	- Requires technical backstopping and capacity development
	- Enhanced community participation	- Limited scalability and rural service reach	
Municipal Enterprises (Legally Independent Entities)	- Legally protected from bankruptcy	- Tariff setting subject to political interference	- High potential if legal and financial autonomy are established
	- Access to multiple funding streams	- Weak legislative and institutional framework	- Recommended for pilot implementation in medium-sized municipalities
	- Potential for improved local accountability	- Requires enabling bylaws and capacity building	
Municipality Departments (Direct Local Government Control)	- Flexible staff deployment	- Low technical competence in sanitation	- Feasible in the short term where no alternative exists
	- Administrative simplicity	- Susceptibility to political interference	- Long-term shift to municipal enterprises advised
	- Can leverage municipal service budgets	- Limited financial independence	
Commercial Companies (e.g., Joint Ventures, SPVs)	- Ability to attract private capital and expertise	- Limited access to concessional finance	- Limited precedent in Jordan
	- Incentivized by performance contracts	- Profit-oriented model may compromise affordability	- More viable in high-income or industrial zones with cost recovery potential
	- Clear accountability structures	- High regulatory oversight required	
Small Private Operators (Contracted O&M Service Providers)	- Brings technical efficiency and responsiveness	- Operational scope limited by contract terms	- Increasingly relevant for DEWATS O&M under WAJ or utility supervision
	- Enables outsourcing of specialized services	- Risk of cost-cutting or underperformance	- National O&M certification schemes support this model
	- Scalable for cluster-based DEWATS	- May require bundled contracts to be viable	
Private Sector Ownership (Fully Private WWTPs)	- Fully leverages private capital and operational know-how	- High CAPEX and land acquisition costs	- Exists in Jordan in hotels, gated communities, and industrial estates
	- Market-driven service expansion in niche sectors	- Limited public oversight and low affordability for poor communities	- Not scalable for public service provision without regulation and incentives

The municipality or community ownership of DEWATS is an attractive solution to Jordan, largely because land acquisition is a major barrier. The municipality can choose the appropriate location of the DEWATS and allocate the land ownership to the municipality, even if the land is privately owned, because it is in the public interest as set out in the land expropriation law for public benefits.

4.5 Current Challenges to Business Model in DEWATS

Beyond their financial viability, the success of private sector engagement in DEWATS is critically dependent on a clear, stable, and enabling institutional and regulatory environment. Interviews with stakeholders, combined with practical implementation experiences across Jordan, have

revealed multiple systemic barriers that hinder private investment and operational partnerships. These challenges reflect institutional ambiguity, regulatory gaps, and market disincentives that undermine both investor confidence and service sustainability. Key constraints include (Tabieh et al., 2024):

- **Ambiguity in institutional mandates:** There is insufficient clarity regarding the roles and responsibilities of key actors—particularly the Water Authority of Jordan (WAJ)—in overseeing DEWATS with capacities under 5,000 Population Equivalent (PE). This institutional vacuum impedes accountability and coordinated governance.
- **Undefined ownership and O&M responsibilities:** There is a lack of

structured assignment of responsibilities for operation and maintenance (O&M) in cases of privately managed or hybrid systems. This creates uncertainty for investors and complicates lifecycle planning of DEWATS assets.

- Fragmented and underdeveloped regulatory frameworks: Existing wastewater legislation does not comprehensively address the licensing, monitoring, or compliance mechanisms specific to decentralized systems. The current standard (JS893/2021) primarily targets centralized plants and requires adaptation for DEWATS.
- Lack of certification systems and capacity development mechanisms: There is no institutional framework for the certification of DEWATS operators or service providers. Furthermore, gaps in training, education, and technical capacity building persist, particularly for local O&M service actors.
- Limited private sector involvement: The participation of private firms in the design, construction, and operation of DEWATS remains minimal. This is largely attributed to perceived institutional risks, policy instability, and unclear revenue models.
- Uncertainty around tariff structures and cost recovery: Private investors remain hesitant due to the absence of guaranteed cost recovery mechanisms. Water tariffs are heavily subsidized, and there are no clear provisions ensuring financial viability or profit margins for effluent reuse ventures.
- Perceived unprofitability of effluent reuse: While treated effluent offers potential for freshwater substitution in agriculture, current pricing structures do not reflect the full value of treated water. As a result, expected revenues from effluent reuse are insufficient to cover O&M costs, deterring private investment.

Addressing these constraints will require a concerted policy response—including the revision of legal mandates, establishment of licensing and certification frameworks, and the design of incentive schemes to de-risk private sector participation. Without these measures, the development of sustainable and scalable DEWATS business models in Jordan will remain limited.

4.6 Economic and Financial Viability of Business Model

Rasoon village was chosen as a site for investigation. Located in Ajloun Governorate, it stands as a noteworthy site for detailed investigations owing to available data and its features—826 households with 4090 inhabitants, a rural backdrop, and recognition as a vulnerable groundwater hot spot in Jordan. This setting offers a prime platform to showcase decentralized solutions typical of rural Jordanian conditions. Envisioning that roughly 80% of households would link to a traditional gravity sewer system, the remaining 20% faced elevation challenges necessitating regular emptying of their collection tanks. This assumption was made based on the incapability of about a quarter of houses to connect to street sewers due to elevation constraints, with a total assumed sewer length of 12 km.

The comparison of wastewater treatment frameworks between arid and more water-abundant regions reveals significant disparities in water consumption and treatment requirements. In arid countries like Jordan and GCC countries, where water usage is low and wastewater is highly concentrated, traditional treatment paradigms designed for higher water consumption rates, as seen in Europe, may not be suitable (Capodaglio, 2017; Shareef, 2021; Gómez-Román et al., 2020). This necessitates the adaptation of decentralized wastewater treatment designs to minimize water loss while still meeting treatment objectives. Moreover, the primary goal in arid climates often shifts towards local water reuse, emphasizing the need for wastewater treatment frameworks that facilitate safe and efficient reuse practices. Additionally, the reuse of treated wastewater in GCC countries can yield environmental advantages by combating desertification and preserving biodiversity. To address these challenges, ongoing technological innovation is essential, focusing on the development of new treatment technologies tailored to water-scarce environments and

the integration of renewable energy sources to minimize environmental impact. Ultimately, a nuanced understanding of the unique challenges and requirements of each region is crucial for developing effective and sustainable wastewater treatment solutions in arid climates.

4.6.1 Description of DEWATS Configuration Options

Three DEWATS configurations are proposed, each integrating natural-based treatment by low-energy treatment technologies tailored to varying population equivalents (PE) and effluent quality requirements. The effluent quality met secondary wastewater quality criteria as well as WHO Guide (WHO, 2006).

Option 1: Nature-Based System with ABR, AF, VFCW, and WSTR

This configuration combines anaerobic treatment via an Anaerobic Baffled Reactor (ABR) and Anaerobic Filter (AF) with aerobic polishing through a Vertical Flow Constructed Wetland (VFCW) and final storage in a Wastewater Storage and Treatment Reservoir (WSTR). The system achieves high pathogen removal (>6-log E. coli) and retains nutrients due to the absence of denitrification. It does not meet TN discharge standards for larger capacities.

Option 2: Nature-Based System with ABR, AF, and Aerated HFCW

This setup integrates anaerobic units (ABR, AF) with an aerated Horizontal Flow Constructed Wetland (HFCW-A), enhancing aerobic degradation and nitrogen removal. It delivers improved ammonia and TN reduction (~60%) and reliable pathogen control (<100 MPN/100 mL), meeting reuse standards for systems >500 PE, including open irrigation applications.

Option 3: Nature-Based Pond System with AP, FP, and WSTR

This technology employs sequential Anaerobic and Facultative Ponds (AP, FP) for primary and secondary treatment, followed by effluent storage in a WSTR. It is widely used in arid regions due to its simplicity and robustness. The system achieves 75–85% organic load removal, and with post-treatment or safeguards, it can meet standards for drip irrigation, though it may fall short of open irrigation criteria without additional treatment.

4.6.2 Results of Economic and Financial Evaluation

The results in Table 2 present a detailed comparative assessment of the financial performance, economic returns, and cost-effectiveness of three DEWATS configurations, each evaluated for a standardized capacity of 5,000 population equivalent (PE).

Under the economic analysis, all three-options exhibit strong viability, demonstrated by highly positive Net Present Values (NPVs), elevated Internal Rates of Return (IRRs), and robust Benefit-Cost Ratios (B/C). These results reflect the broader societal benefits generated by DWATS, particularly through treated effluent reuse, environmental protection, and improved public health. Among the alternatives, Option 3—the nature-based pond system—emerges as the most economically attractive, offering the lowest Total Average Incremental Cost (AIC) of 0.75 US\$/m³, the highest IRR of 35.3%, and a B/C ratio of 4.84, indicating excellent economic efficiency and strong return on public investment.

Conversely, the financial analysis, which reflects the perspective of a private investor or utility operator without external subsidies, reveals limited financial feasibility across all options. All three configurations report negative NPVs and low or negative IRRs, suggesting that full cost recovery through tariffs and service charges alone may be unachievable. Still, Option 3 performs best under financial criteria, with the lowest capital and operating costs, a marginally positive IRR (0.1%), and the highest financial B/C ratio (0.427). This indicates that among the options, Option 3 poses the least financial risk and may require the smallest gap-filling subsidy to ensure viability.

Table 2: Financial, economic, and cost-effectiveness of alternative DEWATS options.

Indicators	Unit	Financial Analysis			Economic Analysis		
Options		Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Total Investment	US\$	1,052,755	1,087,847	772,020	921,161	951,866	675,518
Avg. Annual O&M	US\$/Year	9,124	15,791	9,124	7,983	13,817	7,983
AIC- CAPEX	US\$/m3	1.582	1.635	1.160	0.875	0.904	0.642
AIC- OPEX	US\$/m3	0.134	0.232	0.134	0.108	0.188	0.108
Total AIC	US\$/m3	1.716	1.866	1.294	0.984	1.092	0.750
AIB, Benefits US\$/m3	US\$/m3	0.559	0.714	0.552	3.931	4.078	3.631
NPV @10%	US\$	-794,246	-791,297	-509,373	3,274,438	3,317,298	3,200,857
B/C @10%	ratio	0.326	0.383	0.427	3.996	3.734	4.840
IRR	Percent	-2.1%	-1.2%	0.1%	28.4%	27.8%	35.3%
Payback Period	Year	0.0	0.0	0.0	6.0	6.0	4.0
Profitability Index	Ratio	-0.75	-0.73	-0.66	3.55	3.49	4.74

These findings emphasize a fundamental distinction: while DEWATS systems are economically sound and justified for public investment, their financial sustainability—especially under current tariff structures and affordability thresholds—remains a challenge. To bridge this gap, a range of policy and institutional measures is essential, including targeted subsidies, output-based aid, cross-subsidization, and blended finance mechanisms. Additionally, integrating DWATS into regional utility frameworks could leverage scale economies and shared resources to improve cost-efficiency.

The data highlights the critical role of scale and technology choice. Systems that are modular, simple to operate, and able to serve multiple small communities collectively, such as Option 3, appear more favorable for both economic and financial performance, particularly in rural or peri-urban contexts of Jordan.

4.7 Mobilizing Blended Finance

Blended finance—defined as the strategic use of concessional finance to attract commercial investment—offers a promising approach to mobilize private capital for DEWATS, especially where centralized solutions are unfeasible. Although historically applied to large-scale water infrastructure and creditworthy utilities, its application in off-grid sanitation remains underutilized.

For Jordan, blended finance could help scale DEWATS by combining grants or soft loans with commercial finance under structured risk-sharing models. Instruments such as credit and political risk guarantees can

enhance the risk-return profile for investors, while technical assistance supports project design, capacity building, and tailored financial products for municipalities and banks. Importantly, blended finance must be seen as a transitional tool—not a permanent subsidy—and should align with national strategies like the Jordan Water Strategy and the DEWATS policy. Local capital mobilization is also essential, given the decentralized nature of these systems.

Establishing blended finance funds to pool small-scale sanitation projects can overcome barriers like small ticket sizes and high transaction costs. These funds can attract investors with varying risk appetites through layered structures (e.g., first-loss and senior tranches) and portfolio-level guarantees. Ultimately, to catalyze private investment in Jordan's sanitation sector, blended finance must be accompanied by policy reforms, regulatory clarity, and strong institutional coordination (OECD, 2019).

4.8 Private-Sector Partnerships

To explore viable modalities for private sector participation in DEWATS, several partnership-based business models were discussed in structured stakeholder consultations. These consultations aimed to identify preferences and trade-offs associated with different PPP arrangements, allowing participants to articulate arguments in favor of specific models based on contextual feasibility, risk distribution, and anticipated outcomes. Table 3 presents a typology of commonly applied PPP models in the water and sanitation sector, which were deliberated with stakeholders to assess their applicability to Jordan's decentralized wastewater context.

Table 3: Common Public-Private Partnership Business Models for DEWATS (MWI, 2016; OECD, 2014; Abu-Shams and Rabadi, 2003; UNDP-RBAS, 2013; PPIAF and Bank, 2005; PPIAF and Bank, 2005; Idelovitch, and Ringskog, 1995; Chiu and Bosher, 2005; Rogers, 2003; Cowen and Penelope, 2012; Tilley et al., 2014; MoEnv and RSS, 2022).

Partnership Option	Description
Acquisition/ Divestiture	The public entity sells the wastewater facility to the private partner, who assumes full ownership and operation.
Joint Venture	The public and private sectors share ownership and operational responsibilities of the facility.
Concession / BOT	The private partner finances, builds, and operates the facility; ownership reverts to the public partner after a predefined period.
Turnkey Facility	The private partner is responsible for design, construction, and initial operation; the public sector retains ownership and bears financial risk.
Full-Service Contract	The private partner provides comprehensive operation and maintenance (O&M) services under contract; ownership remains with the public entity.

Table 3 (Cont.) : Common Public-Private Partnership Business Models for DEWATS (MWI, 2016; OECD, 2014; Abu-Shams and Rabadi, 2003; UNDP-RBAS, 2013; PPIAF and Bank, 2005; PPIAF and Bank, 2005; Idelovitch, and Ringskog, 1995; Chiu and Boshier, 2005; Rogers, 2003; Cowen and Penelope, 2012; Tilley et al., 2014; MoEnv and RSS, 2022).

Contract Operations	The private partner operates and maintains an existing publicly owned facility.
Contract Management	The private partner manages and supervises public staff and operations under a service agreement.
Operations Assistance	Short-term technical support by the private sector to enhance the public entity's management capacity during transition or reform phases.

While PPP models offer opportunities to leverage private sector efficiency, technical expertise, and capital, full-scale privatization of wastewater treatment services has been met with skepticism among stakeholders. Concerns include potential prioritization of profit over service equity, limited access for low-income populations, and reduced public accountability.

A balanced approach is therefore recommended—one that integrates private sector participation with strong public oversight. Such hybrid models can optimize operational efficiency while safeguarding affordability, service quality, and environmental compliance. Regulatory frameworks must clearly define performance obligations, risk-sharing arrangements, and tariff mechanisms to ensure the long-term sustainability and inclusivity of DEWATS under PPP schemes.

4.9 Proposed Management of DEWATS

Service contracts cover labor for repair and maintenance of water facilities, requiring the facility owner to purchase equipment. Preventive maintenance and some operations are part of the agreement, but major equipment installation remains the owner's responsibility. A preventive maintenance service contract involves fixed-fee services for scheduled rigorous activities like inspections, equipment overhauls, and calibration. The contractor typically provides necessary materials. Emergency repairs may or may not be included. The aim is to maintain optimal equipment

performance and minimize unexpected failures. While initially cost-effective and focused on quality maintenance, budgeting for emergency repairs becomes challenging. This contract type places most risk on the owner, requiring a clear understanding of requirements for effective setup. An inspection service contract involves fixed annual inspections of wastewater treatment plants (WWTPs) and related installations, focusing on basic checks for issues like blockages or structural integrity. It's the least expensive contract type but may lack effectiveness. Contractors might or might not provide some materials, and emergency repair agreements may or may not be included. While cost-effective, this contract type can carry operational risks, potentially affecting public safety. In Jordan, this contract is used for monitoring wastewater effluents in various private sector DWWTs (MoEnv and RSS, 2022; Tabieh et al., 2025).

Private sector involvement in O&M through management contracts doesn't necessitate capital investment. Funding for infrastructure can come from various sources like the public budget or external financing. The management firm typically covers future reinvestment needs and repairs. Contract operations, maintenance, and management (OM&M) involve privately operated facilities owned by the municipality. The private firm manages operations, ensures compliance, and may handle design, construction, and financing of the facility while the municipality maintains ownership. The advantages and disadvantages related to the WW sector in Jordan are displayed in Table 4.

Table 4: Benefits and drawbacks of management and service contracts in DEWATS in Jordan (Source: Stakeholder consultations).

Options	Benefits	Drawbacks
Management Contracts	- Enhance services and reduce government risks - Improve system efficiency and service quality - Drive organizational reforms - Initial step for private sector involvement	Government finances capital and some operational investments
Service Contracts	- Grant public sector access to private expertise - Lead to efficiency improvements - Widely used and relatively simple	- Limited impact on overall utility management - Cannot solve issues like tariff rate design or cost recovery - Requires careful management and monitoring

4.10 Regulation, Standards, and Institutional Control

The effective governance of decentralized wastewater treatment systems (DEWATS) in Jordan requires an integrated regulatory and institutional framework that ensures technical reliability, financial sustainability, and stakeholder coordination. In addition to institutional gaps, several enabling factors influence the viability of private sector and community participation in decentralized wastewater service delivery.

4.10.1 Conditions for Effective Engagement

Private sector engagement in DEWATS development is contingent on:

- **Regulatory and Financial Predictability:** Investors require assurance of stable tariff frameworks and clear commitments for subsidy support. Uncertainty in these areas discourages infrastructure investment and shifts private sector interest toward short-term operational contracts.
- **Stakeholder Alignment:** Support from sectors such as agriculture (for effluent reuse) and environmental finance (e.g., carbon credits) is critical to secure long-term revenue streams.
- **Consumer Willingness to Pay:** Financial viability depends on public acceptance of wastewater charges and recognition of the system's

health and environmental benefits.

- **Institutional Collaboration:** Effective coordination among regulatory bodies, municipalities, environmental authorities, and service providers ensures coherent policy implementation.
- **Investor Assurance:** Positive cash flow, stable returns, and performance-based contracts are necessary to attract and retain private operators.

4.10.2 Regulatory and Institutional Strengthening

a) DEWATS-Specific Standards and Monitoring

Existing standards, such as JS 893/2021, cater primarily to centralized wastewater systems and are not well-suited to DEWATS configurations. There is a clear need to develop effluent and design standards tailored to decentralized systems, especially for those below 5,000 PE. Establishing a corresponding monitoring framework—integrated with national sectoral indicators—is also essential.

b) Monitoring and Performance Oversight

To ensure compliance and operational reliability, a national monitoring body should be mandated to oversee DEWATS systems, using remote sensing and automated data collection technologies. These systems enable

centralized control of multiple decentralized units while minimizing the human resource burden.

c) Legislative Reforms

Legislation should support enforcement mechanisms, including

- Penalties for non-compliance with effluent standards,
- Implementation of polluter-pays principles for influent quality,
- Compensation schemes or treatment fee adjustments based on effluent quality and reuse potential.

d) Technology and Operator Certification

A centralized certification body, potentially under the Jordan Standards and Metrology Organization (JSMO), should oversee the accreditation of DEWATS technologies and operational protocols. Certification will ensure quality assurance, promote innovation, and enable risk-based monitoring approaches.

e) Contract-Based Service Models

The creation of a competitive market for decentralized system operation and maintenance (O&M) is essential. Outsourcing O&M services to accredited private providers through performance-based contracts will improve service quality, reduce public sector burdens, and increase accountability. National regulatory oversight remains crucial to safeguard compliance and service continuity.

f) Institutional Roles and Coordination

There remains a significant need for institutional clarity. Although the Ministry of Water and Irrigation (MWI) has nominally assigned DEWATS responsibility to the Water Authority of Jordan (WAJ), formal ownership and implementation mechanisms remain undefined. Strengthening the operational capacity of public agencies and assigning clear mandates for planning, licensing, monitoring, and evaluation are vital steps for institutional coherence.

5. CONCLUSIONS

The current regulatory and institutional framework for DEWATS in Jordan is fragmented and lacks a coherent governance structure. The absence of an empowered central body with a clear legal mandate has hindered effective implementation, oversight, and expansion of decentralized sanitation solutions. Despite these challenges, DEWATS represents a viable solution for wastewater management in rural and peri-urban areas where extending centralized infrastructure is not economically feasible. However, high per capita service costs, particularly in small and dispersed communities, continue to limit affordability and financial sustainability in the absence of public subsidies or blended finance models.

Opportunities for generating revenue—such as effluent reuse in agriculture and participation in carbon markets—are present but remain limited in scale. These streams are insufficient to cover operating costs without public financing of capital investments. As a result, successful DEWATS deployment hinges on public-private coordination, risk-sharing mechanisms, and performance-based service agreements that guarantee demand thresholds and cost recovery. Furthermore, adapting public-private partnership (PPP) models traditionally used for centralized systems—such as BOT, BOOT, and DBO—for the decentralized context is possible but depends on contract flexibility, minimum service obligations, and government support during early stages of deployment.

International experience demonstrates that the successful implementation of DEWATS in arid and resource-constrained environments requires moving beyond traditional engineering paradigms. A shift is needed toward climate-resilient, resource-recovery-oriented, and socially inclusive sanitation systems. Aligning Jordan's regulatory, institutional, and operational frameworks with these principles will be essential to unlocking the potential of decentralized wastewater solutions as part of the country's broader water security and sustainability agenda.

REFERENCES

Abu-Allaban, M., El-Naqa, A., Jaber, M., and Hammouri, N., 2015. Water scarcity impact of climate change in semi-arid regions: a case study in Mujib basin, Jordan *Arabian Journal of Geosciences*, 2015. 8(2): Pp. 951–959.

Abu-Shams, I., and Rabadi, A., 2003. Commercialization and Public-Private Partnership in Jordan. *International Journal of Water Resources Development*. 19(2): Pp. 159-172.

Al Hadidi, N., and Al Hadidi, M., 2021. Suitability of reclaimed wastewater effluent from decentralized wastewater plant for irrigation. *Applied Water Science*, 2021. 11(11).

Al-Adamat, R. A., Foster, I. D., and Baban, S. M., 2003. Groundwater vulnerability and risk mapping for the Basaltic aquifer of the Azraq basin of Jordan using GIS, Remote sensing and DRASTIC. *Applied Geography*, 2003. 23(4): Pp. 303-324.

Albakkar, Y., 2014. An Integrated Approach to Wastewater Management and Reuse in Jordan: A Case Study on the Jordan Valley.

Alfarra, A., Kemp-Benedict, E., Hötzl, H., Sader, N., and Sonneveld, B., 2011. A Framework for Wastewater Reuse in Jordan: Utilizing a Modified Wastewater Reuse Index. *Water Resources Management*, 2011. 25(4): Pp. 1153-1167.

Al-Karablieh, E., 2019. The Reuse of Treated Wastewater for Irrigation in Jordan: Existing Policies and legislations, Current Practices and Future Perspectives. 2022, Improving water productivity and livelihoods in the Jordan Valley by using recycled wastewater and groundwater in agriculture, Valleywater. reference number: 109127 Reference: 2019/143/106477/EWH IHE Delft. Netherland.

Al-Karablieh, E., et al., 2019. Decentralized Wastewater Management in Jordan. 2019, Federal Ministry of Economic Cooperation and Development, Bonn, Germany: Decentralized Wastewater Management for Adaptation to Climate Change in Jordan' (ACC-Project) and the project "Assistance to Jordanian regions in the development of decentralized structures in wastewater management, within the framework of the Bund-Länder-Program (BLP), Amman, Jordan.

Al-Karablieh, N., Al-Shomali, I., Al-Elauimi, L., Tabieh, M., Al-Karablieh, E., Al-Jaghbir, M., and Del Bubba, M., 2024. The impact of treated wastewater irrigation on strawberry development, fruit quality parameters, and microbial and chemical contamination transfer: A health risk assessment. *Scientia Horticulturae*, 2024. 329: p. 113014.

Attia, W.A., A.S.M. Mohamed, and A.A. El-Taweel, 2024. Decentralized wastewater treatment system (DEWATS) as a modern approach for wastewater management in Egypt, Review. *Acta Scientiae et Intellectus*. 1(4): Pp. 59-64.

Bank, E.I., 2023. The economic appraisal of investment projects at the EIB. 2023: European Investment Bank.

Beecher, J. A., Dreese, G. R., and Stanford, J. D., 1995. Stanford, Regulatory Implications of Water and Wastewater Utility Privatization. Vol. 95. CiteSeer.

Berland, J. M., and Cooper, P. F., 2001. Cooper, Luxembourg, Extensive Wastewater Treatment Processes Adapted to Small and Medium Sized Communities (500 to 5000 Population Equivalents). 2001.

Capodaglio, A., 2017. Integrated, Decentralized Wastewater Management for Resource Recovery in Rural and Peri-Urban Areas. *Resources*. 6(2): Pp. 22.

Chang, P. L., Hsu, C. W., Lin, C. Y., and Hsiung, C. M., 2011. Constructing a new business model for fermentative hydrogen production from wastewater treatment. *International Journal of Hydrogen Energy*, 2011. 36(21): Pp. 13914-13921.

Chiu, T. Y. C., and Boshier, C. B., 2005. Risk Sharing in Various Public Private Partnership (PPP) Arrangements for the Provision of Water and Wastewater Services. *Thames Water*.

Chivenge, M., Chirisa, I., and Moyo, T., 2024. Decentralised Wastewater Treatment Plant for University of Zimbabwe Technical Staff Housing, Hatcliffe Harare: A Site Analysis, in *Urban Infrastructure in Zimbabwe: Departures, Divergences and Convergences*, I. Chirisa and A.R. Matamanda, Editors. 2024, Springer Nature Switzerland: Cham. Pp. 161-179.

Cowen, P.J.B., and Penelope, J., 2012. The Private Sector in Water and Sanitation: How to Get Started. World Bank.

FAO/IFAD, 2016. Economic and Financial Analysis of Rural Investment Projects. Basic concepts and rationale. 2016: IFAD's Internal Guidelines. Policy Support and Governance| Food and Agriculture

- Organization of the United Nations.
- FAO/IFAD, 2016. Economic and Financial Analysis of Rural Investment Projects. Case Studies. 2016: IFAD's Internal Guidelines. Policy Support and Governance| Food and Agriculture Organization of the United Nations.
- FAO/IFAD, 2016. Economic and Financial Analysis of Rural Investment Projects. Minimum requirements and practical examples. 2016: IFAD's Internal Guidelines. Policy Support and Governance| Food and Agriculture Organization of the United Nations.
- Gebrezgabher, S., Rao, K., Hanjra, M. A., and Hernández-Sancho, F., 2015. Business models and economic approaches for recovering energy from wastewater and fecal sludge, in *Wastewater*. Springer. Pp. 217-245.
- Ginbo, T., Di Corato, L., and Hoffmann, R., 2021. Investing in climate change adaptation and mitigation: A methodological review of real-options studies. *Ambio*, 50(1): Pp. 229-241.
- Gómez-Román, C., Lima, L., Vila-Tojo, S., Correa-Chica, A., Lema, J., and Sabucedo, J. M., 2020. "Who Cares?": the acceptance of decentralized wastewater systems in regions without water problems. *International Journal of Environmental Research and Public Health*, 17(23), 9060.
- Idelovitch, E., and Ringskog, K., 1995. Private sector participation in water supply and sanitation in Latin America. The World Bank.
- JSMO, 2006. Jordanian Standards 1145/2006: (Sludge – Reuse of treated sludge in agriculture): Technical Regulation. . 2006, Jordan Standards and Metrology Organization: Amman, Jordan.
- JSMO, 2006. Jordanian Standards 893/2006 (Water – Reclaimed Domestic Wastewater): Technical Regulation. Jordan Standards and Metrology Organization, Amman, Jordan.
- JSMO, 2015. Jordanian Standards 286/2015 (Water – Drinking Water: Technical Regulation. . 2015, Jordan Standards and Metrology Organization: Amman, Jordan.
- JSMO, 2021. Jordanian Standards 893/2021 (Water – Reclaimed Domestic Wastewater): Technical Regulation. Jordan Standards and Metrology Organization, Amman, Jordan.
- Lienhoop, N., Al-Karablieh, E. K., Salman, A. Z., and Cardona, J. A., 2014. Environmental cost-benefit analysis of decentralised wastewater treatment and re-use: a case study of rural Jordan. *Water Policy*, 2014. 16(2): Pp. 232-339.
- Lienhoop, N., et al., 2012. Cost Benefit Analysis of decentralised wastewater treatment and re-use in Jordan: An application in Maghareeb and Ma'addi. 2012.
- Lopez, H., 2008. The social discount rate: estimates for nine Latin American countries. World Bank policy research working paper, 2008(4639).
- Ministry of Water and Irrigation, MWI, 2023. National Water Strategy, 2023-2040. Ministry of Water and Irrigation, Amman, Jordan.
- MoEnv and RSS, 2022. The National Project for Monitoring Water Quality in Jordan, Annual Reports (2010-2022). Ministry of Environment, Royal Scientific Society: Amman, Jordan.
- MoEnv and UNDP, 2022. The National Climate Change Policy of the Hashemite Kingdom of Jordan, 2022-2050. 2022, Ministry of Environment, Amman, Jordan. The United Nations Development Programme.
- MoEnv and UNDP, 2023. Jordan's Fourth National Communication on Climate Change. Submitted to The United Nations Framework Convention on Climate Change (UNFCCC), funded by GEF and UNDP. Ministry of Environment, Amman, Jordan.
- MoEnv, 2021. Jordan's updated 1st Nationally Determined Contributions (NDC). Ministry of Environment: Amman, Jordan.
- MoEnv, 2021. The National Climate Change Adaptation Plan of Jordan. 2021: Ministry of Environment, Amman, Jordan.
- MoF, 2016. Public Private Partnership Program: Policy Paper. Ministry of Finance, Public-Private Partnership Unit: Amman, Jordan.
- MWI and NICE, 2015. Effective Decentralized Wastewater Policy: National Framework for Decentralized Wastewater Management. Ministry of Water and Irrigation, Amman, Jordan.
- MWI, 2013. Structural Benchmark-Action plan to reduce water sector losses. 2013, USAID-Jordan: Ministry of Water and Irrigation, Amman, Jordan.
- MWI, 2015. Wastewater Treatment National Plan for Operation and Maintenance. Ministry of Water and Irrigation: Ministry of Water and Irrigation, Amman, Jordan.
- MWI, 2018. Annual Report 2018. Ministry of Water and Irrigation: Ministry of Water and Irrigation, Amman, Jordan.
- MWI, 2024. Annual Water Book for the Water Year 2021-2022. Ministry of Water and Irrigation: Ministry of Water and Irrigation, Amman, Jordan.
- MWI, Decentralized Wastewater Management Policy. 2016, Ministry of Water and Irrigation: Ministry of Water and Irrigation, Amman, Jordan.
- MWI, WAI, and JVA, 2024. Annual Report for the Years 2022-2023. Ministry of Water and Irrigation: Ministry of Water and Irrigation, Amman, Jordan.
- OECD, 2013. Business models for water and sanitation services in Moldova. 2013, Organisation for Economic Co-operation and Development.
- OECD, 2014. Jordan: Overcoming the governance challenges to private sector participation in the water sector in Public Governance and Territorial Development Directorate Regulatory Policy Committee, T.O.C. Centre, Editor. Organisation for Economic Co-operation and Development: Paris, France.
- OECD, 2014. Water Governance in Jordan: Overcoming the Challenges to Private Sector Participation. OECD Studies on Water, OECD Publishing.
- OECD, 2019. Making Blended Finance Work for Water and Sanitation: Unlocking Commercial Finance for SDG 6. 2019, OECD Studies on Water, OECD Publishing, Paris, <https://doi.org/10.1787/5efc8950-en>.
- OECD, 2019. Making Blended Finance Work for Water and Sanitation: Unlocking Commercial Finance for Sdg 6. 2019: OECD Publishing.
- PPIAF and Bank, W., 2005. Approaches to private participation in water services: A toolkit. 2005: The World Bank.
- Rahman, K. Z., Al Saadi, S., Al Rawahi, M., van Afferden, M., Bernhard, K., Friesen, J., and Müller, R. A., 2024. Small Decentralized Technologies for High-Strength Wastewater Treatment and Reuse in Arid and Semi-Arid Regions. *Environments*, 2024. 11(7): Pp. 142.
- Rao, K., Hanjra, M. A., Drechsel, P., and Danso, G., 2015. Business models and economic approaches supporting water reuse, in *Wastewater*. 2015, Springer. Pp. 195-216.
- Rogers, P., 2003. Effective Water Governance. Global Water Partnership Technical Committee (TEC), 2003.
- Sansom, K., and Franceys, R., 2003. Contracting Out Water and Sanitation Services: Volume 2. Case studies and analysis of Service and Management contracts in developing countries. 2003.
- Shareef, N., 2021. Decentralized Wastewater Treatment Using Biofilm Technologies as Cost Effective Applications, in *Agro-Environmental Sustainability in MENA Regions*, M. Abu-hashim, F. Khebour Allouche, and A. Negm, Editors. 2021, Springer International Publishing: Cham. Pp. 49-68.
- Tabieh, M. A., Al-Karablieh, E. K., Qtaishat, T. H., Salman, A. Z., Thaher, N. H., Al-Karablieh, N. K., Al-Jaghbir, M. T., Al-Zghoul, T. M., and Jamrah, A. I., 2025. Assessment of Fresh Water Reallocation by Teated Wastewater for Irrigation. *HighTech and Innovation Journal*. 2025.
- Tabieh, M. A., Al-Karablieh, E. K., Salman, A. Z., Qtaishat, T., Thaher, N., Al-Qinna, M., and Jamrah, A., 2024. Decentralized Wastewater Management in Jordan. 2019, Federal Ministry of Economic Cooperation and Development, Bonn, Germany: Amman, Jordan.
- Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., and Zurbrugg, C., 2014. Compendium of sanitation systems and technologies.
- Ulrich, A., Reuter, S., and Gutterer, B., 2009. Decentralised wastewater treatment systems (DEWATS) and sanitation in developing countries: a practical guide. 2009: WEDC, Loughborough University© BORDA.

- UNDP-RBAS, 2013. Water Governance in the Arab Region: Managing scarcity and securing the future. UNDP-RBAS; <http://arabstates.undp.org/rbas/en/home>.
- van Afferden, M., Cardona, J. A., Lee, M. Y., Subah, A., and Müller, R. A., 2015. A new approach to implementing decentralized wastewater treatment concepts. *Water Science Technology*, 2015. 72(11): p. 1923-1930.
- van Afferden, M., Cardona, J. A., Rahman, K. Z., Daoud, R., Headley, T., Kilani, Z., Mueller, R. A., 2010. A step towards decentralized wastewater management in the Lower Jordan Rift Valley. *J Water Science Technology*. 61(12): p. 3117-3128.
- Ventura, J. R. S., Tulipan, J. U., Banawa, A., Umali, K. D., and Villanueva, J. A. L., 2024. Advancements and challenges in decentralized wastewater treatment: A comprehensive review. *Desalination and Water Treatment*, 2024. 320: Pp. 100830.
- WHO, 2006. Guidelines for the Safe Use of Wastewater, Excreta and Greywater, Volume 1: Policy and Regulatory Aspects. 2006: World Health Organization.
- Zhang, D. Q., Jinadasa, K. B. S. N., Gersberg, R. M., Liu, Y., Ng, W. J., and Tan, S. K., 2014. Application of constructed wetlands for wastewater treatment in developing countries—a review of recent developments (2000–2013). *Journal of environmental management*, 2014. 141: Pp. 116-131.
- Zhang, D. Q., Jinadasa, K. B. S. N., Gersberg, R. M., Liu, Y., Ng, W. J., and Tan, S. K., 2014. Waterborne and foodborne diseases: The peril of expansion of wastewater reuse in Jordan and Lebanon. *Water Practice and Technology*, 2025: Pp. wpt2025018.
- Zhang, R., Wang, Z., Cao, Z., Rousseau, D. P., and Van Hulle, S., 2025. Addressing the rural wastewater treatment dilemma: A techno-environmental-economic analysis. *Chemical Engineering Journal*, 2025. 504: Pp. 158905.

