

A Review of RWHS Adoption in Non-Domestic Sectors

Nur Aiza Mohamad ¹, Shue Ling Chong ^{1,2}, Tuck Wai Yeong ¹, Chee Fui Wong ^{3,*} and Fang Yenn Teo ^{1,*}

¹ Faculty of Science and Engineering, University of Nottingham Malaysia, Semenyih 43500, Malaysia; evxnm5@nottingham.edu.my (N.A.M.); shue.ling@nottingham.edu.cn (S.L.C.); tuck-wai.yeong@nottingham.edu.my (T.W.Y.)

² Faculty of Humanities and Social Sciences, University of Nottingham Ningbo China, 199 Taikang East Road, Yinzhou District, Ningbo 315100, China

³ Department of Civil Engineering, Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Kajang 43000, Malaysia

* Correspondence: cfwong@utar.edu.my (C.F.W.); fangyenn.teo@nottingham.edu.my (F.Y.T.)

Abstract

Rainwater harvesting systems (RWHS) are increasingly being adopted globally as part of green infrastructure to complement climate change adaptation and sustainable stormwater management. This study reviews the adoption of RWHS in non-domestic sectors, including commercial, industrial, and institutional settings, situating the topic within the broader challenges of water security in urban areas. This review aims to synthesise existing evidence on the key drivers, barriers, trends, and research gaps shaping RWHS adoption beyond the conventional domestic household scale. Following the PRISMA 2020 guidelines, peer-reviewed manuscripts published since 2000 were systematically identified and screened from the Scopus and Web of Science databases, focusing explicitly on adoption-related outcomes in non-domestic contexts. The findings indicate that RWHS adoption is primarily driven by anticipated water bill savings, sustainability, corporate environmental commitments, and stormwater management benefits, while major barriers include high initial capital costs, regulatory uncertainty, technical and maintenance complexity, and concerns regarding water quality and system reliability. This review also reveals sector-specific trends, such as the integration of RWHS with green building certification schemes and smart water technologies, and the prioritisation of process and utility water uses in non-domestic sectors. Overall, the findings indicate that non-domestic RWHS have substantial potential to contribute to sustainable stormwater management, but wider uptake depends on targeted policy support, economic incentives, clearer regulatory frameworks, and improved technical guidance, alongside further empirical research addressing the identified knowledge gaps.

Keywords: RWHS; non-domestic sectors; commercial and industrial sectors; technology adoption; stormwater management; policy and regulation



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1. Introduction

Global freshwater resources are under increasing pressure as a result of rapid population growth, accelerated urbanisation, economic development, and climate change. Although water is abundant at a planetary scale, its spatial and temporal availability is highly uneven, leading to widespread water stress across regions and sectors. Early global assessments demonstrated that population growth and climate variability have intensified the pressure on river basins worldwide, exposing vulnerabilities in both natural hydrological systems and human water management practices [1]. Subsequent studies

further highlighted that water scarcity is not merely a physical limitation, but a complex socio-environmental challenge driven by cumulative anthropogenic stressors, including water withdrawals, infrastructure development, pollution, and ecosystem degradation [2].

Urban areas are particularly vulnerable to water stress due to concentrated demand from residential, commercial, and industrial users. High-resolution global assessments have shown that approximately four billion people experience severe water scarcity for at least one month each year, underscoring the importance of accounting for temporal variability in water availability rather than relying solely on annual averages [3]. Urbanisation intensifies these pressures by increasing demand while simultaneously reducing natural infiltration and groundwater recharge due to the expansion of impervious surfaces. Climate change further compounds these challenges by altering rainfall patterns and increasing the frequency of droughts and extreme events [1,2]. While global projections vary, some scholars argue that future water scarcity may be underestimated due to optimistic assumptions regarding governance, technological progress, and resource availability [4]. Institutional assessments similarly warn that global land and water systems are approaching critical thresholds, with increasing competition among municipal, industrial, and agricultural sectors [5]. These conditions highlight the urgency of diversifying water supply sources and reducing reliance on conventional centralised systems.

Within this context, RWHS has gained renewed attention as a decentralised and sustainable alternative water source. RWHS involves the collection, storage, and use of rainfall from rooftops or other impervious surfaces for on-site applications, thereby reducing dependence on treated potable water. Contemporary research increasingly frames RWHS as a demand-side intervention that complements supply augmentation while enhancing system resilience [6]. Unlike large-scale supply infrastructure, RWHS can be implemented incrementally and adapted to local climatic and demand conditions, making them particularly attractive for urban environments facing water stress.

A substantial body of literature demonstrates the capacity of RWHS to achieve significant potable water savings, especially for non-potable end uses such as toilet flushing, irrigation, cleaning, and cooling. Ghisi [7] reported that rainwater use could substitute between approximately 48% and nearly 100% of potable water demand, depending on rainfall, roof area, and consumption patterns. These findings indicate that RWHS has considerable potential to alleviate pressure on potable water supplies in urban areas. Beyond water savings, RWHS can also contribute to stormwater management by reducing runoff volumes and peak flows, thereby mitigating flood risks and easing pressure on urban drainage networks [6].

The sustainability potential of RWHS is further strengthened when systems are designed to align with building-scale demand characteristics. Ward et al. showed that appropriately designed RWHS in large buildings could reliably meet a substantial proportion of water demand, with improved economic performance observed in commercial and institutional settings [8]. From a systems perspective, RWHS contributes to the diversification of urban water portfolios and reduces reliance on energy-intensive centralised water and wastewater infrastructure, supporting climate adaptation and long-term sustainability [9]. However, economic outcomes remain context-dependent. A global review by Amos et al. [10] found that while many studies report favourable financial performance, the results vary widely depending on water tariffs, system scale, rainfall variability, and the valuation of environmental benefits.

Although early RWHS research focused primarily on residential applications, growing evidence highlights the strategic importance of non-domestic sectors, including commercial, institutional, and industrial sectors. Non-domestic sectors account for a significant share of urban water consumption due to high occupancy rates, intensive operational activities,

and continuous demand. Compared to residential buildings, non-domestic facilities often possess larger roof catchment areas and more predictable water use profiles, which enhance the utilisation efficiency of harvested rainwater. Empirical evidence from petrol stations indicates that RWHS can achieve average potable water savings of approximately 33%, with higher savings under favourable conditions [11]. Such findings suggest that non-domestic buildings offer greater absolute water-saving potential than individual household systems.

Comparative analyses further support the advantages of higher-demand buildings. Domènech and Saurí [12] showed that buildings with higher occupancy density and shared infrastructure achieve more effective utilisation of harvested rainwater, reducing underuse and overflow losses. From an environmental perspective, life cycle assessments indicate that non-domestic RWHS can achieve favourable energy and greenhouse gas emission payback, particularly when integrated at the design stage of new buildings [13]. Concerns regarding energy use and operational complexity have been raised; however, benchmarking studies demonstrate that the operational energy consumption of RWHS represents only a negligible fraction of total building energy use in office buildings [14].

Despite these demonstrated benefits, the literature presents mixed and sometimes conflicting evidence regarding the effectiveness and feasibility of RWHS adoption. One recurring challenge is the so-called “implementation deficit”, whereby policy support does not translate into widespread uptake. In the United Kingdom, Ward et al. [15] showed that fragmented governance arrangements, insufficient incentives, and unclear institutional responsibilities have constrained implementation despite strong policy narratives promoting sustainable buildings. Economic feasibility remains a contentious issue, as upfront capital costs and long payback periods can deter investment, particularly in regions with low water tariffs. Life cycle-based analyses indicate that cost payback periods are highly sensitive to assumptions regarding system sizing, infrastructure costs, and utility prices, leading to divergent conclusions across studies [16,17].

Regional studies illustrate how contextual factors shape adoption outcomes. In Malaysia, despite high annual rainfall and favourable climatic conditions, RWHS implementation remains limited due to long return on investment periods, weak enforcement of guidelines, and low stakeholder awareness [17]. Similar barriers have been reported in New Zealand and Türkiye, where tariff structures, perceived water quality risks, and the absence of targeted incentives influence adoption decisions even when technical performance is favourable [18,19]. Industrial-scale applications further demonstrate both opportunities and limitations. Mendoza et al. [20] showed that RWHS could supply over 50% of daily water demand in granite processing facilities, yet performance was highly dependent on the alignment between rainfall patterns, storage capacity, and process water demand. These findings suggest that conflicting evidence often reflects contextual differences rather than fundamental technical shortcomings.

Despite an expanding body of research, several gaps remain. First, the literature continues to prioritise residential-scale systems, resulting in a fragmented and limited synthesis of evidence specific to non-domestic sectors [6]. Second, empirical operational data remain scarce, constraining the development of robust multi-objective evaluation tools and limiting confidence in scaling RWHS solutions [6,8]. Third, methodological inconsistencies contribute to contested assessments of sustainability performance, particularly with respect to energy use and overall efficiency [16]. Fourth, economic and environmental evaluations are often insufficiently integrated to support decision-making by building owners and facility managers. Finally, governance and policy implementation gaps persist across regions, including Malaysia, where guidelines exist but adoption remains limited in commercial buildings [15,17].

In response to these gaps, this study conducts a systematic literature review (SLR) to synthesise the existing knowledge on RWHS adoption in non-domestic sectors. This review aims to identify the key drivers influencing adoption, examine the barriers and trade-offs underlying conflicting evidence, analyse emerging implementation trends, and highlight future research directions relevant to non-domestic contexts. By explicitly focusing on commercial, institutional, and industrial and integrating technical, economic, environmental, and institutional perspectives, this review addresses a critical imbalance in the literature. The synthesis provides evidence-based insights to support policymakers, practitioners, and researchers in advancing RWHS as a scalable and resilient component of sustainable urban and industrial water management systems.

2. Systematic Review Protocol

This systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [21], which build upon the original PRISMA framework [22]. The review followed a structured procedure comprising identification, screening, eligibility assessment, and study in the conclusion stages. No review protocol was prepared or registered, as this review was conducted as an independent evidence synthesis. The review methodology, including the eligibility criteria, search strategy, study selection process, and data extraction procedures, was defined before the screening process and applied consistently throughout the review.

A comprehensive literature search was performed using two major academic databases namely Scopus and Web of Science (WoS). These databases were selected for their extensive coverage of high-impact, peer-reviewed journals across disciplines relevant to RWHS and non-domestic water management.

The literature search employed a detailed Boolean search string designed to match relevant studies on RWHS adoption in non-domestic sectors: (“rainwater harvesting” OR “rainwater collection” OR “RWH” OR “rainwater harvesting system”) AND (“adoption” OR “implementation” OR “uptake”) AND (“industrial” OR “commercial” OR “institutional” OR “non-domestic”). This approach ensured the retrieval of studies related to RWHS adoption in commercial, industrial, and institutional sectors.

Studies were included if they clearly focused on the adoption of RWHS in non-domestic sectors (industrial, commercial, institutional), provided empirical data on the drivers, barriers, feasibility, economic, social, or policy aspects influencing RWHS adoption, were published in peer-reviewed journals or conference proceedings from 2000 onwards, and were available in full text in English. Studies were excluded if they focused solely on residential or agricultural systems, were non-English language publications, lacked empirical data or were purely theoretical, or included opinion articles, editorials, non-peer-reviewed literature, or were inaccessible in full text. Table 1 systematically outlines the criteria used to include or exclude studies.

Table 1. Summary of Inclusion and Exclusion Criteria used during systematic review of the literature.

Criterion	Inclusion	Exclusion
Study Type	Peer-reviewed journal articles	Conference papers, grey literature
Language	English	Non-English
Publication Year	2000 onwards	Before 2000
Sector Focus	Commercial, industrial, institutional	Residential, community-based RWHS

Following the PRISMA 2020 flow diagram, the screening began with the identification of 417 records (270 from Scopus and 147 from Web of Science). After removing duplicates

($n = 132$), 285 records underwent title and abstract screening, leading to the exclusion of 222 articles due to various reasons, including unsuitable formats (books, reviews, conference proceedings; $n = 78$), irrelevance to RWHS adoption in non-domestic contexts ($n = 138$), and unavailable full texts ($n = 6$). Ultimately, 63 articles were selected for inclusion in this systematic review. A detailed representation of this screening and selection process is illustrated in Figure 1.

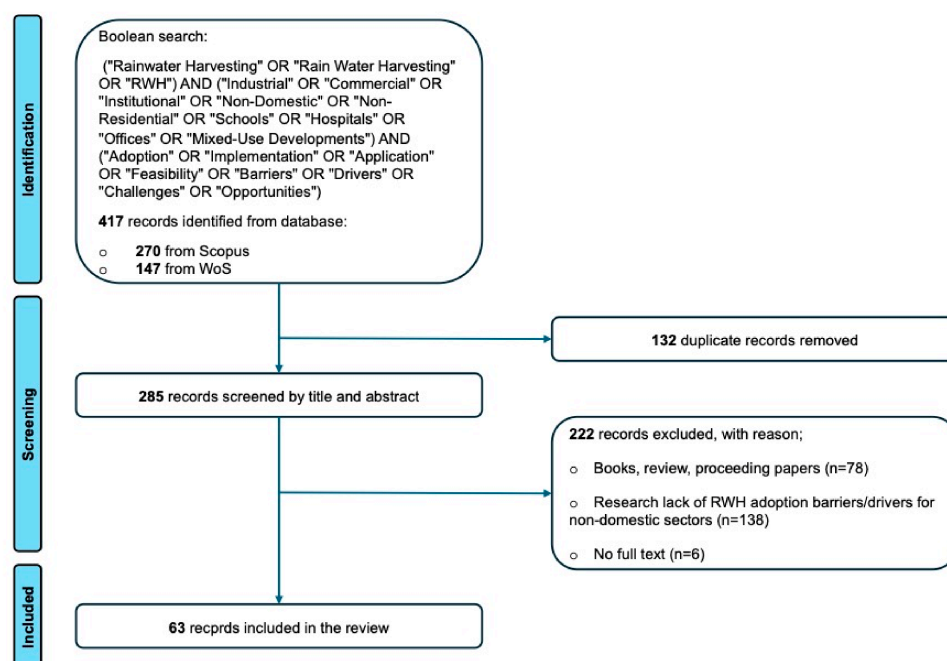


Figure 1. PRISMA 2020 flow diagram illustrating the study identification, screening, eligibility assessment, and inclusion process.

Information extracted from the selected studies included authors, years of publication, study locations, main drivers and barriers to RWHS adoption, methodologies employed, and key findings. The extracted data were then analysed using thematic analysis to uncover consistent themes and relevant patterns.

3. Results

The systematic search and screening process resulted in the inclusion of 63 studies meeting the eligibility criteria (refer to Figure 1). These studies form the evidence base for this review.

3.1. Overview of Included Studies

3.1.1. Temporal Distribution

Analysis of the publication dates revealed a significant increase in research on non-domestic RWHS adoption beginning around 2018, with a notable peak observed in 2023. The distribution, as presented in Figure 2, indicates growing academic and industry interest, particularly within the last five years. This trend suggests heightened global recognition of the importance of addressing drivers and barriers for the successful implementation of RWHS in commercial, industrial, and institutional sectors.

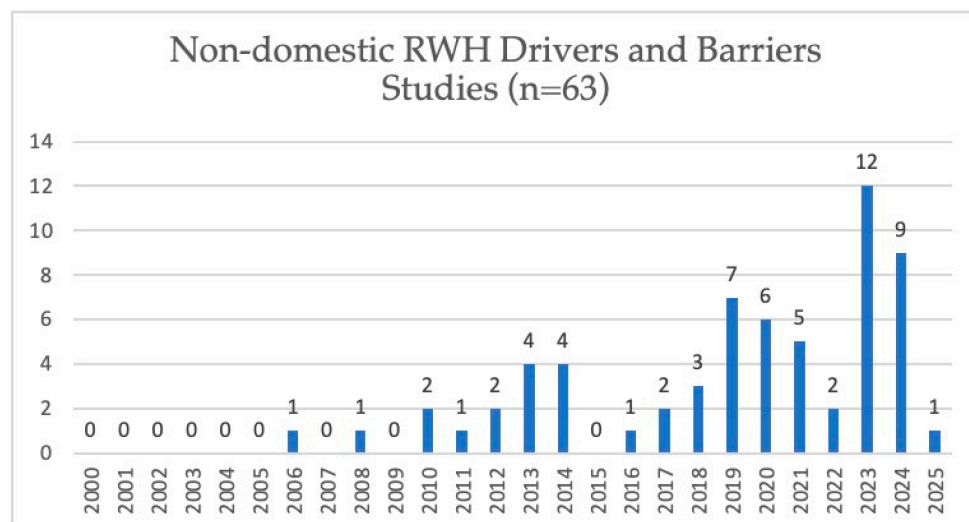


Figure 2. Temporal distribution of studies on non-domestic RWHS drivers and barriers (2000–2025). (X-axis: Year of Publication, Y-axis: Number of Studies).

3.1.2. Geographical Distribution

The geographical distribution analysis of the reviewed studies ($n = 63$) reveals clear regional research emphases, as illustrated in Figure 3. Asia accounted for the highest proportion of studies (30%), indicating strong regional research interest in RWHS, particularly in Malaysia [17,23,24], India [25,26], and China [27]. Europe also exhibited substantial research activity (27%), notably from the United Kingdom [15], Portugal [28,29], and Germany [30].

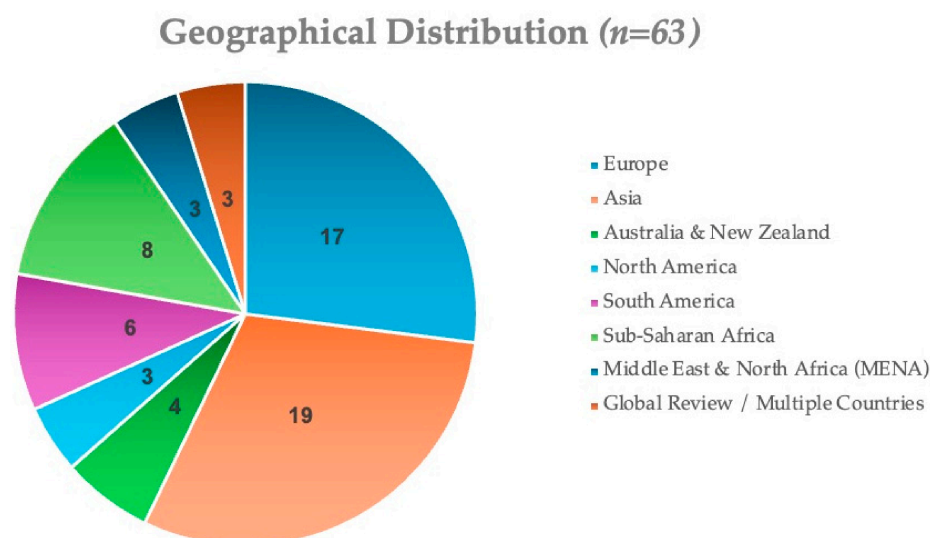


Figure 3. Geographical distribution of studies on non-domestic RWHS adoption ($n = 63$).

South America, driven largely by studies from Brazil [31,32] and Chile [33], contributed approximately 13% of the reviewed literature, while Sub-Saharan Africa accounted for about 9%, highlighting studies from South Africa [34] and Ethiopia [35].

Australia and New Zealand collectively represented around 6%, reflecting focused research primarily from Australia [36,37]. Studies from North America constituted approximately 5%, with contributions mainly from the United States and Canada. The Middle East and North Africa (MENA) region represented a relatively minor proportion (about 5%), predominantly from Egypt [38].

3.1.3. Methodologies

The methodologies employed in the selected 63 studies were diverse, incorporating qualitative, quantitative, and mixed-methods approaches. A substantial proportion of studies adopted quantitative methodologies, predominantly utilising case studies, simulation modelling, and economic feasibility analyses. Simulation modelling frequently involved daily water balance simulations to assess system effectiveness and economic feasibility, such as the Discounted Payback Period (DPP) and Net Present Value (NPV) calculations [39,40]. Economic evaluations were particularly prevalent, often supported by technical performance assessments involving historical climate and demand data analysis [29,41].

Qualitative and mixed-method approaches were also widely adopted, incorporating surveys, structured interviews, stakeholder consultations, and systematic literature reviews. These methods facilitated comprehensive insights into the social and institutional barriers influencing RWHS adoption. Interdisciplinary methodologies integrating social science approaches such as grounded theory and socio-technical frameworks were notable, providing a nuanced understanding of stakeholder perceptions and regulatory influences [15,42]. Additionally, GIS-based Multi-Criteria Decision Analysis (MCDA) was effectively utilised to spatially identify optimal RWHS sites and assess adoption potential based on socio-economic and physical parameters [43,44]. Overall, the methodological diversity underscores the multifaceted nature of research into non-domestic RWHS adoption.

3.2. Drivers and Barriers to RWHS Adoption

The literature consistently identifies a range of factors that either promote (drivers) or impede (barriers) the adoption of RWHS in non-domestic settings.

3.2.1. Key Drivers

The adoption of RWHS in commercial, industrial, and institutional sectors is influenced by diverse and interrelated factors categorised as economic, environmental, technological, policy-related, and social dimensions.

1. Economic Drivers

Economic factors significantly drive adoption, primarily through reductions in potable water costs, lower dependence on municipal water bills, and favourable economic performance indicators such as net present value (NPV) and discounted payback period (DPP), particularly in water-scarce regions with high water tariffs [18,29–31,34,36,39,41,45,46]. Financial incentives and subsidies further enhance the economic feasibility of RWHS reducing initial investment barriers and improving long-term affordability [32,47].

2. Environmental Drivers

Environmental drivers are underscored by the pressing need to manage water scarcity, mitigate groundwater depletion, and address climate variability impacts. RWHS contribute significantly to water conservation, environmental sustainability, and improved resilience against climate-induced water shortages, notably in drought-prone and water-stressed regions [19,20,25,42,48–55]. Additionally, RWHS support achieving sustainability and environmental certifications such as LEED, enhancing property values and corporate sustainability credentials [56].

3. Technical Drivers

Technological drivers include advancements in reliable, efficient, and proven RWHS infrastructure, ensuring consistent performance and integration with existing water supply systems. Technological innovations, such as improved storage solutions and sustainable

maintenance practices, bolster adoption by demonstrating feasibility and operational reliability [24,27,28,57,58].

4. Policy and Regulatory Drivers

Policy and regulatory frameworks significantly promote RWHS adoption by mandating system installations in public buildings, educational institutions, and certain new buildings above specified roof-area thresholds, while supporting broader sustainable water management policies. For example, the reviewed literature highlights the implementation of RWHS in public university buildings and the regulatory requirements for rainwater harvesting systems in newly proposed buildings exceeding the minimum roof-area criteria. Regulatory incentives, clear governmental mandates, and the integration of RWHS into local and national water management policies encourage stakeholders to incorporate these systems as part of urban water sustainability initiatives [25,30,31,36,37,47,59,60].

5. Social and Informational Drivers

Social and informational drivers, driven by increased stakeholder awareness, educational programmes, and the successful implementation of demonstration projects, enhance community and institutional acceptance. Educational value and the role of RWHS in promoting sustainable water use practices among communities are also important motivators [15,23,28,33,34,42,61–63]. Table 2 summarises the key drivers for non-domestic RWHS adoption identified in the reviewed studies.

Table 2. Summary of key drivers for non-domestic RWHS adoption.

Driver Category	Key Drivers	Supporting Sources
Economic	Cost saving, financial incentives, favourable payback period	[18,29–32,34,36,39,41,45–47]
Environmental	Water scarcity, groundwater depletion mitigation, climate resilience, sustainability certification	[19,20,25,42,48–56]
Technological	Proven system reliability and efficiency, technological innovation	[24,27,28,57,58]
Policy and Regulatory	Government mandates, supportive legislative framework, policy integration	[25,30,31,36,37,47,59,60]
Social and Informational	Stakeholder awareness, educational initiatives, demonstration projects	[15,23,28,33,34,42,61–63]

3.2.2. Key Barriers

Despite compelling drivers, several critical barriers impede the widespread adoption of RWHS in commercial, industrial, and institutional sectors. These barriers are predominantly economic, technical and operational, policy and institutional, informational and perceptual, as well as social and contextual.

1. Economic Barriers

Economic barriers represent a primary concern, particularly due to the high initial capital costs associated with installing RWHS, including storage tanks, pumps, filtration systems, and the necessary infrastructure upgrades [17,18,36,39,64]. Lengthy and uncertain payback periods further exacerbate economic feasibility, especially where water tariffs are low, making investments less attractive [25,27,45,65,66]. Moreover, ongoing maintenance and operational expenses, such as energy for pumping and filter replacements, add to the financial burden [34,36,67]. Recent studies also noted that fluctuating water prices

and a lack of cost-recovery mechanisms further diminish financial predictability [53,61,68]. Financial infeasibility was also observed in contexts where existing free water sources (e.g., wells) reduce the cost justification for RWHS adoption [6,31].

2. Technical and Operational Barriers

Technical and operational barriers significantly affect adoption rates. These include system complexity, the need for specialised design knowledge, and challenges integrating RWHS into existing infrastructure. Failures such as blockages, leaks, microbial contamination, and component degradation were noted as common concerns [38,49,64]. Inadequate storage sizing, high energy intensity associated with water treatment, and the operational requirement of point-of-use treatment systems further reduced system efficiency [20,23,24,27,52,58,69,70]. Maintenance challenges, integration issues in retrofitting older buildings, and the need for continuous monitoring in chlorination-based systems also constrain long-term viability [33,40,51,64,69].

3. Policy and Institutional Barriers

Policy and institutional barriers are noticeable through fragmented and inconsistent policies, the absence of mandates, weak regulatory enforcement, and complex planning frameworks [15,17,19,30]. Barriers include a lack of policy clarity in newer regulations (e.g., Türkiye), an absence of local incentives (e.g., in Brazil and Chile), and limited integration of RWHS into urban planning strategies [31,32,46,47,71]. Institutional rigidity and misaligned policies also contribute to inefficient system implementation and limited adoption [43,72].

4. Informational and Perceptual Barriers

Informational and perceptual barriers are tied to low public awareness, scepticism about system reliability and water quality, and insufficient education. Youth unfamiliarity, misperceptions of risk, and uncertainty over long-term performance have been reported across several case studies [17,18,33,36,38,39,42,64].

5. Social and Contextual Barriers

Social and contextual barriers, such as resistance to change, limited community engagement, insecure land tenure, and socio-economic disparities, were identified as significant. Issues included inequality in informal settlements, a lack of ownership incentives, and cultural taboos [36,38,43,48–50,71].

3.3. Sector-Specific Implementation Trends

While sharing common drivers and barriers, the implementation of RWHS across non-domestic sectors such as commercial, industrial, and institutional reflects unique priorities, applications, and integration strategies. Sector-specific trends highlight how contextual demands, operational needs, and governance structures shape the adoption and functionality of RWHS globally.

3.3.1. Commercial Sector

In the commercial sector, RWHS are primarily implemented to reduce reliance on municipal water supplies, achieve cost savings, and demonstrate corporate environmental responsibility. Common applications include toilet flushing, landscape irrigation, and air-conditioning system support [18,27]. Systems typically range from medium- to large-scale, utilising rooftop catchments integrated with filtration units, storage tanks, and backup municipal connections. In high-rise and green-certified buildings, integration with greywater systems and building management systems (BMSs) has been noted for enhanced water efficiency [16,24,69].

System characteristics are often influenced by space constraints and aesthetic considerations, necessitating innovative designs such as gravity-driven or hybrid configurations [27,56]. The commercial sector shows a growing trend of incorporating RWHS into sustainability and ESG (Environmental, Social, and Governance) reporting frameworks, driven by consumer expectations and environmental certifications [46,73]. However, implementation is often constrained by high upfront costs, long payback periods in regions with low water tariffs, and limited incentives [51,68].

3.3.2. Industrial Sector

In the industrial sector, RWHS adoption is largely driven by resource efficiency mandates, regulatory compliance, and the need for resilient non-potable water sources [20,36]. Applications are typically process-oriented, including equipment washing, cooling systems, and integration into closed-loop water reuse systems [29,60]. Industrial RWHS are often custom-design, large-scale installations tailored to specific operational needs and local hydrogeological conditions.

Integration strategies favour modular and decentralised designs that minimise disruption to existing operations. In several cases, RWHS is embedded within broader environmental management frameworks, particularly in facilities aiming for ISO 14001 certification or circular economy alignment [28,53]. Despite their operational benefits, adoption remains challenged by structural retrofitting limitations, a lack of sector-specific incentives, and the underestimation of long-term economic feasibility [52,55].

3.3.3. Institutional Sector

Institutional RWHS implementations particularly in educational, healthcare, and public buildings prioritise water security, environmental stewardship, and public awareness [34,39]. Systems are commonly used for toilet flushing, cleaning, irrigation, and as part of sustainability education initiatives. They vary in scale depending on building typology and usage patterns, with some facilities incorporating advanced treatment for potable or near-potable reuse [31,58].

Integration is often supported by public sector funding, climate adaptation mandates, and demonstration projects [30,35]. Schools and universities, in particular, have shown leadership in piloting innovative systems that combine RWHS with greywater reuse and solar energy for enhanced sustainability outcomes [45,74]. Nevertheless, barriers such as inconsistent policy support, high initial capital requirements, and limited maintenance capacity remain prevalent [32,33].

3.3.4. Cross-Sector Trends

Across all non-domestic sectors, several cross-cutting trends have emerged. Firstly, the convergence of RWHS with broader sustainability goals—including energy efficiency, green certification, and resilience planning—is increasingly evident [6,63]. Secondly, decentralised and integrated water management approaches are gaining traction, especially in contexts of water scarcity, urbanisation, and climate variability.

Additionally, life-cycle costing and performance monitoring are becoming more critical in evaluating long-term viability and justifying investment decisions [72,75]. Policy instruments such as mandatory RWHS installation for new developments (e.g., in Türkiye and parts of India) and municipal rebates for water-saving measures have proven to accelerate adoption [41,47]. Despite this, persistent issues such as fragmented governance, limited technical capacity, and financial disincentives continue to hamper widespread uptake.

In sum, while the sectoral application of RWHS reflects unique operational and policy dynamics, emerging synergies across sectors underscore the importance of holistic, integrated approaches for sustainable urban water management.

To provide a comparative overview of RWHS implementation across commercial, industrial, and institutional sectors, Table 3 synthesises key trends based on 63 systematically reviewed studies. It outlines sector-specific drivers, common applications, system characteristics, integration strategies, market dynamics, and challenges. This tabulated summary highlights that while the motivations to adopt RWHS, such as cost savings, water security, and sustainability goals, are shared across sectors, the implementation nuances vary considerably. For instance, commercial buildings often integrate RWHS with green certifications and automated control systems, whereas industrial facilities emphasise process-specific reuse and regulatory compliance. Institutional settings, on the other hand, frequently leverage RWHS for educational and public service delivery while facing challenges in maintenance and funding. Table 3 thus serves as a strategic tool to identify sectoral priorities and inform tailored policy and design interventions. Table 4 compares RWHS implementation trends across commercial, industrial, and institutional sectors.

Table 3. Summary of key barriers for non-domestic RWHS adoption.

Driver Category	Key Drivers	Supporting Sources
Economic	High initial cost, lengthy or uncertain payback periods, fluctuating water prices, low cost-recovery incentives, financial infeasibility due to alternative sources, ongoing operational and maintenance costs.	[6,17,18,25,27,31,34,36,39,45,53,61,64–68]
Technical and Operational	System complexity, infrastructure integration, reliability concerns, water quality degradation, sizing and maintenance challenges, energy intensity, long-term monitoring burden	[20,23,24,27,33,38,40,49,51,52,58,64,69,70]
Policy and Institutional	Policy fragmentation, absence of mandates, weak enforcement, planning misalignment, institutional rigidity, limited integration in urban framework	[15,17,19,30,32,37,38,43,46,47,50,59,68,71,72]
Informational and Perceptual	Limited awareness, youth unfamiliarity, misconception about reliability and safety, lack of education programmes	[17,18,33,36,38,39,42,64]
Social and Contextual	Resistance to change, insecure tenure, stakeholder disengagement, inequality, cultural and social barriers	[36,38,43,48–50,71]

Table 4. Comparison of RWHS implementation trends across non-domestic sectors.

Feature	Commercial Sector	Industrial Sector	Institutional Sector
Key Sector-Specific Drivers	Cost savings, environmental sustainability, water efficiency, climate resilience, and corporate social responsibility [18,27].	Water scarcity, resource efficiency, regulatory compliance, and sustainable production practices [20,36].	Educational value, environmental consciousness, and operational cost savings were primary motivators in schools and healthcare institutions [34,39].
Common Application	Toilet flushing, irrigation, air-conditioning cooling towers, and general non-potable uses [16,18].	Process water (water used in industrial production, cooling, cleaning, or equipment operation), equipment cleaning, dust suppression, and reuse in production cycles [20].	Toilet flushing, irrigation, and educational demonstration tools [34,39].

Table 4. *Cont.*

Feature	Commercial Sector	Industrial Sector	Institutional Sector
Typical System Scale/Features	Medium to large-scale systems with roof catchments, integrated filters, gravity/pressure tanks, and backup connections to municipal water [27].	Large, site-specific systems designed for integration with existing industrial processes and often requiring bespoke engineering [20,36].	Medium-scale systems tailored for facility-wide use with attention to user behaviour and seasonal variability [34,39].
Integration Trends	Integration with green building certifications, sustainability targets, and facility management systems [16].	Embedded within environmental management systems and broader water conservation hierarchies [36].	Often part of climate adaptation and sustainability programmes in educational institutions and public facilities [19,39].
Market Dynamic/Growth	Growing uptake in response to corporate social responsibility, urban water stress, and increased awareness of cost savings [27].	Growth is driven by regulation and sustainability mandates, particularly in water-intensive industries [20].	Expansion supported by public funding, sustainability education, and local pilot projects [34].
Key Sector-Specific Challenges	High upfront costs, limited incentives, space constraints, and design complexity [18,27].	Resistance to operational change, high retrofitting costs, and need for technical expertise [36].	Funding limitations, lack of skilled maintenance personnel, and reliance on municipal water during dry seasons [34,39].

4. Discussion

4.1. Synthesis of Findings

This systematic literature review (SLR) synthesised critical insights from studies investigating RWHS adoption in non-domestic sectors, encompassing economic, environmental, technological, policy-related, and socio-informational factors. The economic drivers notably included cost savings, financial incentives, and favourable payback periods, identified by numerous studies as pivotal in influencing RWHS adoption [29,34,39]. Environmental motivations such as water scarcity, mitigation of groundwater depletion, and achieving climate resilience were also significant, reflecting broader sustainability aspirations [48,53]. Technological advancements, particularly proven system reliability and innovative solutions, emerged as essential factors for adoption [24,27]. Several reviewed studies also highlighted the importance of technical and economic performance in shaping RWHS adoption decisions. For example, Stec and Zeleňáková [39] demonstrated that RWHS effectiveness varied across locations, with favourable NPV and DPP reported in Slovakia, whereas the payback period exceeded 30 years in Poland under less favourable conditions. The study also reported potable water savings of approximately 29% and 18%, respectively. Similarly, Silva et al. [29] found that the financial feasibility of RWHS in an industrial building was strongly influenced by system configuration and demand characteristics, with a reported payback period of 11.29 years. These findings suggest that economic viability and water-saving performance are important supporting factors influencing adoption alongside environmental, technological, and policy-related considerations. Furthermore, supportive policy frameworks, legislative mandates, and social awareness through educational initiatives significantly contributed to facilitating RWHS integration [25,31].

Conversely, the barriers were primarily economic, including high initial capital costs and uncertain payback periods, alongside fluctuating water prices and financial infeasibility compared to other water sources [17,65]. Technical and operational challenges, such as system complexity, infrastructure integration difficulties, and concerns about water quality, further hindered adoption [24,64]. Policy and institutional limitations, including fragmented policies, weak enforcement, and institutional rigidity, compounded these challenges [19,59]. Finally, informational and perceptual barriers such as limited awareness, misconceptions regarding safety, and social-contextual resistance to change represented additional layers of complexity [42,50].

4.2. Sectoral Differences and Implication

The reviewed studies highlighted distinct sectoral implications regarding RWHS adoption across commercial, industrial, and institutional sectors. Commercial entities prioritised financial incentives, cost savings, environmental sustainability, and corporate responsibility, reflecting a stronger sensitivity to economic viability and reputation management [18,27]. Industrial sectors emphasised technological reliability, resource efficiency, regulatory compliance, and sustainable production practices, aligning RWHS with their broader operational and sustainability strategies [20,36]. Institutional sectors, particularly educational and healthcare institutions, underscored the role of operational cost savings, educational value, and environmental consciousness, leveraging RWHS as a tool for sustainability education and practical demonstration [34,39]. These differences imply a need for tailored policy instruments, technical solutions, and incentives that address sector-specific priorities, applications, system scales, and integration strategies.

4.3. Policy Effectiveness and Gaps

The effective policies identified in the literature include mandatory regulations, performance standards, financial subsidies, tax incentives, and the integration of RWHS within broader water management and sustainability policies [15,18,19]. Despite these instruments, significant gaps remain, notably concerning policy fragmentation, partial mandates, a lack of enforcement mechanisms, and limited financial incentives. Technical guidelines often lacked enforceability and were limited to specific sectors or jurisdictions [17,45,66]. Awareness campaigns and local industry support initiatives were effective but typically informal, lacking mainstream policy backing [50,76]. Addressing these gaps requires coherent mandates, improved enforcement, and consistent economic incentives. Based on the reviewed evidence, economic and policy-related barriers appear to be the most pressing challenges to RWHS adoption across commercial, industrial, and institutional sectors. High initial capital costs, uncertain payback periods, fragmented regulatory frameworks, and weak enforcement mechanisms were consistently identified as factors limiting implementation despite the recognised environmental and operational benefits of RWHS. To encourage wider adoption, greater emphasis could be placed on financial incentives, supportive regulatory measures, and practical technical guidance tailored to different building types and user needs. These measures may help strengthen the key drivers identified in the literature while addressing the barriers most frequently reported by stakeholders. Ultimately, such efforts could contribute to more effective urban water management and support broader sustainability and climate resilience goals.

4.4. Connection to Broader Concepts

The findings from this SLR align closely with broader concepts of sustainable urban water management, climate resilience, and circular economy principles. The economic drivers and barriers directly correspond to circular economy concepts advocating cost efficiency and resource optimisation. Technological advancements such as modular scalable systems, advanced filtration, and smart technologies highlight innovations supporting the broader goals of resilience and sustainability in urban infrastructure [16,19,36]. Predictive analytics and integration with green infrastructure further enhance sustainable urban design and climate adaptation strategies [38,44]. Moreover, the policy and informational dimensions emphasise governance, stakeholder engagement, and community awareness, aligning with contemporary sustainability discourses. Addressing identified barriers and leveraging highlighted drivers can significantly enhance RWHS's role within integrated water management frameworks, thus advancing urban sustainability and resilience goals globally.

4.5. Limitation of the Review

This review has several limitations that should be considered. Firstly, the literature selected primarily included peer-reviewed articles, potentially excluding grey literature, government reports, and industry case studies that could provide additional practical insights. Secondly, geographical biases may exist, given that many studies were concentrated in specific regions or countries, limiting the generalisability of the findings globally. Thirdly, despite careful methodology, publication bias might influence reported outcomes, especially where positive results tend to be more frequently published. Finally, variability in study methodologies and reporting standards made direct comparisons challenging, highlighting the need for standardised metrics and clearer definitions of effectiveness across studies. In addition, this review primarily focused on adoption-related factors, including drivers, barriers, trends, and policy influences. Performance indicators such as water-saving efficiency, long-term operational reliability, lifecycle costs, and comparative effectiveness across different non-domestic contexts were beyond the scope of the present review. Future studies should integrate adoption-focused analyses with technical and performance assessments to provide a more comprehensive understanding of RWHS implementation.

4.6. Future Research Direction

Based on the synthesis of the existing literature and the identified limitations, several key areas warrant further research. Future studies should focus on incorporating grey literature and case studies to provide a broader understanding of practical applications and challenges. Expanding the research to underrepresented regions would also help address geographical biases, providing insights into context-specific challenges and opportunities. Standardising evaluation metrics and methodologies would enable better comparative analyses across studies, improving the robustness of findings. Additionally, longitudinal studies assessing the long-term effectiveness and sustainability of RWHS, particularly regarding maintenance and operational viability, would offer valuable insights. Finally, exploring integrated approaches that combine RWHS with other sustainable water management strategies could provide comprehensive solutions to enhance urban resilience and resource efficiency.

5. Conclusions

This systematic literature review aimed to synthesis the current state of knowledge regarding the adoption of RWHS within non-domestic sectors. The analysis reveals a complex landscape where compelling drivers, rooted in economic benefits like cost savings and environmental imperatives such as water conservation and stormwater management, coexist with significant barriers. High initial capital costs, coupled with technical uncertainties, regulatory gaps, and persistent negative perceptions about water quality and reliability, collectively impede widespread uptake beyond niche applications.

Implementation trends exhibit notable variations across sectors: commercial and institutional settings increasingly integrate RWHS with green building initiatives and smart technologies, while industrial adoption is often driven by large-scale water needs for specific processes. Policy instruments and technological advancements serve as critical enablers, yet their full potential is often unrealized due to issues of policy fragmentation, insufficient incentives, lagging regulations, or inadequate consideration of factors like the energy consumption associated with advanced technologies.

Despite these challenges, the potential for non-domestic RWHS to contribute significantly to urban water sustainability, enhance resilience to climate change impacts (both drought and flooding), and alleviate pressure on conventional water resources remains substantial and largely untapped. Realizing this potential necessitates a transition from

viewing RWHS as an isolated measure to integrating it strategically within broader urban water management frameworks.

Moving forward, accelerating the adoption of RWHS in commercial, industrial, and institutional settings requires concerted and integrated efforts. This includes the development of clear, supportive, and context-specific policies; the provision of robust and accessible financial incentives; targeted technical assistance and capacity building; continued innovation focused on cost-effectiveness, reliability, and ease of use; and dedicated research to fill the knowledge gaps identified in this review, particularly concerning long-term performance, policy effectiveness in diverse contexts, and holistic sustainability assessments including the energy–water nexus. By addressing these multifaceted challenges, RWHS can be effectively mainstreamed as a vital component of sustainable water management in non-domestic sectors globally.

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Abbreviations

The following abbreviations are used in this manuscript:

RWH	Rainwater Harvesting
RWHS	Rainwater Harvesting System
DPP	Discounted Payback Period
NPV	Net Present Value
LEED	Leadership in Energy and Environmental Design
GIS	Geographic Information System
MCDA	Multi-Criteria Decision Analysis
CSR	Corporate Social Responsibility

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