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LEGAL FRAMEWORKS AND ENFORCEMENT STRATEGIES FOR REDUCING NON-REVENUE WATER IN MALAYSIA AND INSIGHTS FROM SINGAPORE'S REGULATORY PRACTICES

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ABSTRACT

Non-Revenue Water (NRW) poses a significant challenge to water utilities worldwide, particularly in developing countries where infrastructure and regulatory systems are often inadequate. Malaysia continues to face high levels of NRW compared to its regional neighbours. This paper examines the effectiveness of Malaysia's legal frameworks and enforcement strategies in addressing NRW, focusing on the Water Services Industry Act 2006 (WSIA 2006) and related regulations. Through a detailed legal analysis, the study evaluates the strengths and weaknesses of Malaysia's current regulatory environment and enforcement mechanisms. It also compares these strategies with Singapore's highly successful regulatory practices to provide insights into how Malaysia can improve its NRW management. The findings indicate that while Malaysia has established a comprehensive legal framework for NRW reduction, inconsistent implementation and limited enforcement capacity significantly undermine its effectiveness. Drawing on Singapore's proactive approach, this paper recommends strengthening regulatory oversight, improving financial and technical support for water operators, and leveraging advanced technologies to enhance NRW management. These measures are essential to achieving sustainable water management and ensuring the financial viability of Malaysia's water utilities.

Keywords: Non-revenue water, water services, water regulation, legal framework, Malaysia.

INTRODUCTION

Non-Revenue Water (NRW) remains a persistent challenge in the global water sector. It refers to water that is produced and distributed but does not generate revenue for utilities (Liemberger & Wyatt, 2019). NRW typically arises from three main factors: physical losses such as leakages in the distribution network, commercial losses including theft or inaccurate metering, and unbilled authorised consumption such as water used for firefighting or other public purposes (Kingdom et al., 2006). This classification provides a practical framework for understanding the multifaceted nature of water loss. In developing countries, the challenge of reducing NRW is not only outdated infrastructure but intensified by weak monitoring systems and limited maintenance capacity, which together hinder consistent control (Mutikanga et al., 2011). Addressing NRW therefore extends beyond technical measures—it also requires efforts to build public trust, as people expect the water supplied to their homes to be properly managed. The effectiveness of a country's NRW management reflects how it values water as a vital resource for both daily life and long-term sustainability.

Liemberger and Wyatt (2019) estimate that NRW accounts for approximately 30% of the world's treated water, while the Asian Development Bank (ADB) reports that levels in many Asian cities often range between 30% and 35%. The ADB further characterises NRW not merely as a technical issue but as "a massive governance and institutional failure" (Frauendorfer & Liemberger, 2010). While leak repairs and metering interventions are necessary, they alone cannot resolve the issue without strong regulatory enforcement and greater accountability within utilities. This perspective highlights the importance of examining legal and institutional contexts that underpin NRW management, alongside the technical solutions commonly promoted in practice.

The growing urgency of global water scarcity has intensified attention on NRW in recent years. High levels of water loss erode the financial stability of utilities by shrinking revenue and reducing their capacity to reinvest in infrastructure (Sturm et al., 2009). When a significant portion of treated water is lost, utilities face revenue shortfalls that constrain operational budgets, delay maintenance. and perpetuate a cycle of deterioration (Rouse, 2013). Consequently, NRW is not merely a technical inefficiency but a financial burden that undermines the ability of utilities to fulfil their core mandate. Communities bear the consequences when utilities are unable to deliver reliable services. Households experience the frustration of intermittent supply while facing rising tariffs, and policymakers face mounting pressure when the public questions the failure of water systems despite substantial investments.

NRW also carries a significant environmental cost. Every cubic metre of water lost or unaccounted for has already consumed energy in abstraction, treatment, and distribution—processes that contribute to unnecessary greenhouse gas emissions (Rothausen & Conway, 2011). These environmental impacts are magnified in regions where water must be transported over long distances or undergo energy-intensive treatment (Arregui et al., 2006). Studies show that reducing NRW can directly lower the carbon footprint of urban water systems. For example, NRW reduction efforts in Antalya, Turkey, not only reduced water losses but also lowered greenhouse gas emissions by 27.65% and energy consumption by 16.48% (Muhammetoglu et al., 2022).

The regulatory dimension of NRW management is therefore crucial. Scholars such as Van den Berg (2014) and Arregui et al. (2006) emphasise that effective regulation should integrate accurate metering, systematic auditing, and enforceable penalties for illegal connections. These measures not only reduce losses but also strengthen institutional accountability and transparency. As Farouk et al. (2021)

highlights, utilities that successfully lower NRW can save considerable volumes of water and energy, with direct financial benefits that can be reinvested into service expansion. In the context of climate change, such savings also contribute to the resilience and sustainability of water supply systems (Thornton & Lambert, 2007).

However, the literature indicates that no single strategy can address NRW effectively. A credible and lasting response requires a combination of technological innovation, capacity development, and community engagement (Alegre et al., 2016). Technologies such as advanced metering infrastructure and pressure management have shown success in reducing physical losses (Moore & Hughes, 2008), yet public awareness and consumer cooperation are equally important for tackling commercial losses (Thornton & Lambert, 2007). Persistent barriers, remain, particularly in developing contexts. Many utilities continue to lack accurate baseline data on water losses, undermining their ability to plan and prioritise interventions effectively (Mutikanga et al., 2011). In developing contexts, institutional limitations, such as inadequate regulatory enforcement and insufficient financing for infrastructure, remains limited, leaving NRW levels stubbornly high (Kingdom et al., 2006; Sturm et al., 2009).

Malaysia exemplifies many of the broader challenges associated with NRW. According to SPAN's Water and Sewerage Industry Factbook 2023, the average NRW across Peninsular Malaysia and Labuan stood at 34.6% in 2023, with Perlis (64.5%), Kelantan (54.5%), and Kedah (50.7%) recording the highest losses (SPAN, 2024). Infrastructure delays have exacerbated the issue. The Auditor-General's 2022 Report revealed that 145 water-related projects were delayed by an average of 361 days, while four states failed to maintain the minimum 10% treated-water reserve margin (Bernama, 2024). Governance fragmentation adds another layer of complexity. Although the Water Services Industry Act (WSIA) 2006 was introduced to establish a uniform licensing and corporatisation framework, recent scholarship observes that major challenges persist in aligning regulatory frameworks with both efficiency goals and public service obligations across states (Abd Rani et al., 2024). The federal government has repeatedly raised concern over this issue. Deputy Prime Minister Fadillah Yusof, for instance, identified ageing and leaking pipes as the main reason for Malaysia's persistently high NRW levels, and called for more funding to enable the replacement of critical infrastructure ("DPM Fadillah: Govt focusing on efforts to solve nationwide non-revenue water issue," 2024). These developments underscore that Malaysia's NRW problem extends beyond technical inefficiencies—it is deeply rooted in governance structures, legal implementation, and financing constraints.

Addressing these challenges requires more than engineering interventions. Strengthening regulatory capacity, improving data management systems, and ensuring stable financing mechanisms are all essential components of a sustainable solution (Rouse, 2013). International actors, including development banks and donor agencies, also continue to play an important role by providing technical assistance and supporting infrastructure programs (Sturm et al., 2009). Against this backdrop, this paper examines the effectiveness of Malaysia's legal frameworks for reducing NRW, drawing comparative insights from Singapore, where regulatory practices have been widely acknowledged for their effectiveness and efficiency in water governance.

LITERATURE REVIEW

Global Overview of NRW Management

As previously discussed, NRW remains one of the most pressing challenges in the global water sector. The problem is severe in developing countries and in water-scarce regions, where old infrastructure, weak governance, financial limitations and urban rapid growth often combine to make matters worse (Appiah et al., 2017; Nasara et al., 2021). Put simply, NRW refers to water that has been produced but not billed to consumers, typically due to leakages, theft, or inaccuracies in metering systems (Lai et al., 2013; Jabari, 2017). The World Bank has repeatedly underlined that reducing NRW extends beyond operational efficiency. It is also essential for maintaining the financial sustainability of utilities and enabling cities to meet rising water demand without resorting to costly new infrastructure investments (Liemberger & Wyatt, 2019).

Global data highlights the magnitude of the problem. In 2019, worldwide NRW was estimated at approximately 346 million cubic meters per day, equivalent to 125 billion cubic meters annually. In monetary terms, these losses are estimated at around USD 39 billion annually (Liemberger & Wyatt, 2019; Pathirane et al., 2024). These figures are not only staggering in scale but also carry significant social consequences. High levels of NRW reduce the funds available to utilities, constraining their ability to extend services, particularly to poorer or marginalised communities (Nasara et al., 2021).

Solving NRW issue is rarely straightforward and requires a multifaced management approach. Many utilities in developing countries, particularly in the Global South, often lack sufficient funding, trained personnel, and incentive structures to prioritise loss reduction (Perera et al., 2018; Van den Berg, 2014). Instead, they tend to focus on expanding supply—such as producing more treated water—rather than addressing the root causes of water loss. These measures are often politically more visible and institutionally easier to justify. This tendency reflects broader weaknesses in governance and regulatory enforcement, which make systematic NRW management difficult to sustain (Kingdom et al., 2006; Lai et al., 2020). In contrast, Europe presents a markedly different story. Some countries have successful reduced NRW levels to around 25%, while Denmark stands out as a global reference point, having achieved levels below 10% and in some areas, even below 1%. These achievements were made possible through compulsory metering, the establishment of district metering areas, pressure management, and active leakage detection. Crucially, these reforms were legally mandated and strictly enforced beginning in 1989, ensuring their long-term effectiveness (EurEau, 2021; Hvilshoj, 2015).

Legal and regulatory measures therefore emerge as essential tools for addressing NRW. Research indicates that performance-based contracts (PBCs)—which link payments to specific NRW reduction targets—have proven effective in improving efficiency, particularly in developing countries (Kingdom et al., 2006; Liemberger & Wyatt, 2019). Such contracts provide financial incentives for utilities or contractors to actively reduce losses rather than maintain existing inefficiencies. In some cases, governments have also engaged private operators, whose participation brings technical expertise and access to capital that public utilities may lack (Wyatt & Alshafey, 2012). However, this approach carries inherent risks. The experience of England's water sector illustrates how inadequate regulatory oversight of private companies can lead to chronic underinvestment, recurring pollution incidents, and declining service quality (Environment Agency, 2024). This example underscores an important lesson: private sector participation can support NRW reduction, but only when it is accompanied by strong legal safeguards, transparent accountability mechanisms, and consistent enforcement. Without such oversight, efficiency gains may be short-lived, and long-term service quality may be compromised.

In many contexts, laws exist but enforcement lags behind. Monitoring mechanisms are often inconsistent, and political pressure or vested interests can quietly undermine what is clearly stated in legislation (Steyn, 2022; Nasara et al., 2021; Liemberger & Wyatt, 2019). Corruption further aggravates the situation, as does the lack of skilled staff and financial resources within utilities. As a result, old pipes remain unrepaired, meters go unchecked, and even when technical standards are well-defined, utilities often lack the capacity to comply with them (Appiah et al., 2017; Jabari, 2017). The persistently high levels of NRW across much of the developing world therefore reflect not an absence of regulations, but rather the ongoing struggle to make rules actually work in daily operations.

For this reason, many scholars emphasise that legal reform alone is insufficient. While robust laws and regulations are necessary, they must be accompanied by adequate funding, capacity, and technical expertise if they are to yield tangible results (Van den Berg, 2014; Lai et al., 2020). Different countries adopt varying strategies: some countries lean heavily on technological solutions, others on financial incentives, and a few involve private operators under strict regulatory supervision. In certain cases, community participation has also proven valuable—whether by assisting in the detection of illegal connections or by raising awareness about water wastage. None of these approaches, however, constitutes a universal solution. The evidence suggests that success comes when legal frameworks, technical interventions, and financial reforms are integrated in ways that reflect local contexts, rather than imposed as one-size-fits-all solutions.

Importance of Legal Frameworks in Water Services Governance

Water services cannot function effectively without a legal foundation. While good governance is often described through ideals such as fairness, sustainability, or efficiency, these principles only acquire practical meaning when legal frameworks establish the underlying rules. Such frameworks define responsibilities, specify operational standards, and delineate how regulators and utilities are expected to act. Rights to water, tariff structures, and service standards are not merely policy aspirations, they are codified in statutes and regulations (OECD, 2015; Bakker, 2014). These legal instruments enable governments to hold service providers accountable while safeguarding the interests of the public (Rogers & Hall, 2003).

The role of law is extensive, often broader than generally acknowledged. One critical area is resource allocation. Legislation provides order in how water resources are distributed, defines usage rights, and embeds conservation obligations (Akhmouch & Correia, 2016). In regions where water scarcity is acute, the importance of law becomes even more pronounced, as multiple stakeholders, such as farmers, industries, households, compete for the same limited supply (Schmidt & Matthews, 2017). Legal mechanisms also establish procedures for resolving conflicts, ensuring that disputes over water rights or distribution are addressed within predictable and transparent frameworks (Biswas & Tortajada, 2011).

Another key domain is utility regulation. where law governs how providers are monitored, what performance aspects are reviewed, and under what conditions penalties are applied (Eliassen et al., 2018). Most regulatory systems include audits and compliance checks, although the level of rigour often varies in practice (Castro & Heller, 2009). Tariff setting is also a legal process that requires balancing two competing imperatives: ensuring water remains affordable for consumers while allowing utilities to cover costs and maintain financial viability (Rouse, 2013). This tension is reflected in Sustainable Development Goal 6.1, which calls for universal access to affordable drinking water by 2030 (United Nations, 2015).

Another key role of legal frameworks is the protection of public health and the environment. Laws set minimum standards for water quality and effluent discharge, ensuring that communities understand the level of safety and service they are entitled to expect (Gleicket al., 2018). The stakes are especially high in urban areas, where pollution and poor sanitation can quickly endanger people and surrounding ecosystems (Grigg, 2016). However, the strength of regulations on paper often exceeds their enforcement in practice. Weak monitoring systems and political obstacles frequently prevent full compliance, leading to suboptimal outcomes. The challenges of climate change and rapid urbanisation further complicate these efforts, underscoring the need for regulatory frameworks that are adaptive rather than static. NRW offers a clear example of this dynamic. Although still relatively underexplored in legal scholarship, the need for clear legal mandates is increasingly recognised. Utilities are often reluctant to invest in leak detection or control illegal connections unless such actions are explicitly required by law (Farley & Trow, 2003).

Nevertheless, the existing literature leans heavily toward technological and economics approaches. Smart meters, pressure management, and performance-based contracts are frequently highlighted as key solutions (Thornton & Lambert, 2005; Marin, 2009; Kingdom et al., 2006). While these tools are undoubtedly useful, their success ultimately depends on a strong legal foundation.

Without that foundation, utilities may lack both the authority and obligation to act. It is the law that empowers them to monitor losses, disclose performance data, and invest in system upgrades (Mutikanga et al., 2011). Where this authority is weak or absent—particularly in contexts already constrained by financial or governance limitations—NRW reduction often slips down the list of priorities (González-Gómez et al., 2019). Ultimately, technical and economic measures depend on legal frameworks to provide structure, legitimacy and continuity. Without this legal underpinning, such measures risk becoming short-lived fixes rather than sustainable, long-term solutions.

METHODOLOGY

This study adopts a legal analysis approach, focusing on Malaysia's statutory provisions, enforcement mechanisms, and the effectiveness of these instruments in addressing Non-Revenue Water (NRW). The analysis also incorporates a comparative dimension by examining Singapore's legal framework. This comparison is intended not only to identify the strengths and shortcomings of Malaysia's system but also to draw lessons from a jurisdiction with more advanced water governance practices. Primary sources for analysis include the Water Services Industry Act (WSIA) 2006, its subsidiary legislation—particularly the Water Services Industry (Reticulation and Plumbing) Rules 2014—as well as policy statements, enforcement reports published by the National Water Services Commission (*Suruhanjaya Perkhidmatan Air Negara* [SPAN]). Relevant statutory documents from Singapore are also examined to provide a comparative perspective. Secondary sources consist of scholarly writings, legal commentaries, official reports, and analytical studies that address NRW management and water governance in Malaysia. Collectively, these materials provide a comprehensive foundation for understanding how the current legal system operates and its implications for NRW control. Through this approach, the study not only evaluates the adequacy of Malaysia's legal and regulatory responses but also identifies areas where reform could strengthen the effectiveness of water governance.

ANALYSIS

Non-Revenue Water in Malaysia

According to SPAN, NRW refers to the difference between the total volume of water produced and supplied into the distribution system and the volume that is actually billed to consumers (SPAN, 2024). SPAN identifies three main components contributing to NRW. First, physical losses arise primarily from ageing infrastructure and frequent leaks within the distribution network. Second, commercial losses occur due to unauthorised consumption and metering inaccuracies. Third, SPAN's broader categorisation of NRW may result in comparatively higher reported figures, as it includes components not always captured in international definitions. For instance, public-use water—such as that used for firefighting—is recorded as part of NRW in Malaysia, and it is plausible that water supplied to places of worship is treated similarly, reflecting the country's more inclusive definition of unbilled authorised consumption.

Although WSIA 2006 does not explicitly define "Non-Revenue Water", SPAN's operational definition and classification are broadly aligned with the International Water Association (IWA) standards (International Water Association, 2019; Liemberger & Wyatt, 2019). Internationally, NRW is understood as water that has been produced but is not billed to consumers—that is, water that is lost or unaccounted for. SPAN applies a comparable approach, calculating NRW as the percentage of treated water not delivered to consumers. For example, SPAN's 2023 data for Peninsular Malaysia indicates an NRW level of 34.6%, derived from the difference between system input and billed consumption. This aligns with the IWA/Liemberger standard, which defines NRW as the system input volume minus authorised consumption, encompassing both unbilled use and water losses. Aligning Malaysia's NRW measurement with the IWA standard is crucial, as it enables data to be compared with international benchmarks and facilitates the adoption of best practices in managing and reducing NRW.

Current Status of NRW in Malaysia

As of 2023, Malaysia's national average NRW level stands at approximately 34.6% (SPAN, 2024). Table 1 present NRW levels across different states from 2019 to 2023.

Table 1

NRW Level across Different States in Malaysia, 2019–2023 (SPAN, 2024)

State	2019	2020	2021	2022	2023
Johor	24.9	26.7	25.1	26.3	25
Kedah	48.5	48.4	49.9	51.5	50.7
Kelantan	50.8	51.7	52.6	53.7	54.5
F.T. Labuan	29.8	33.6	37.6	36.8	37.6
Melaka	21.2	30	31.2	33.2	35.1
N. Sembilan	31.9	31.8	32.3	35.1	38.9
Pulau Pinang	22.9	23.5	23.6	26.3	26.8
Pahang	47.4	50.3	49.3	47.7	47.7
Perak	29.5	30.1	29.6	30.3	30.2
Perlis	63.3	64.9	63.3	61.5	64.5
Selangor	29.6	28.5	27.5	27.8	27.8
Terengganu	34.7	35.2	32.8	38.7	40.1
Pen. Malaysia & F.T. Labuan	33.2	33.8	33.4	34.4	34.6

As presented in Table 1, Kelantan, Perlis, and Kedah consistently record the highest NRW levels in the country, each exceeding 50%. In Kelantan, NRW has risen from 50.8% in 2019 to 54.5% in 2023, reflecting persistent management challenges likely linked to ageing infrastructure, leaky pipe networks, and delays in repair and maintenance works. The steady increase underscores the urgent need for targeted policy and infrastructure interventions to reduce losses and improve the reliability of water services in the state.

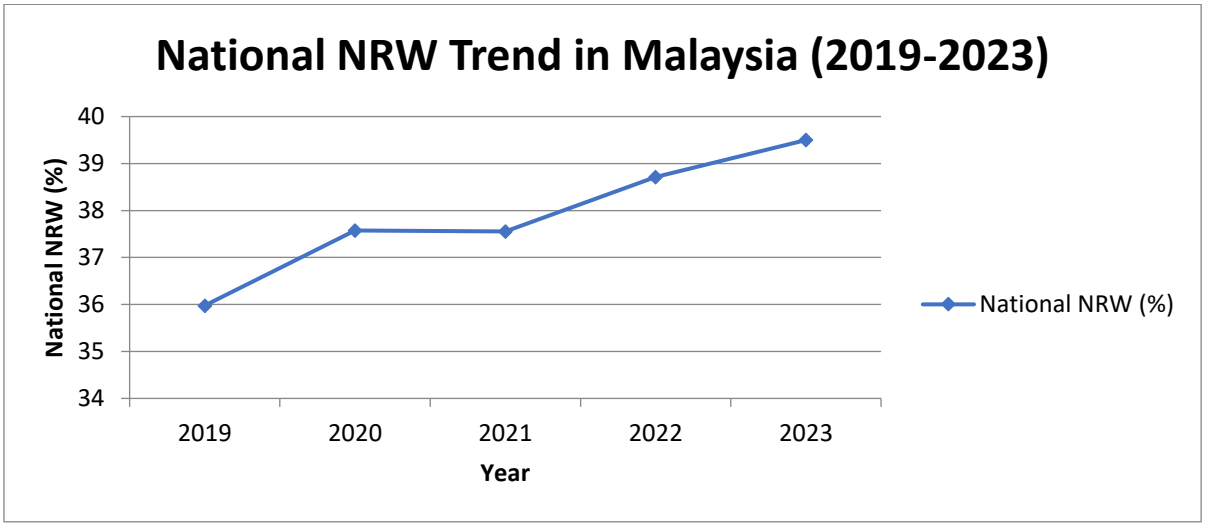
Perlis shows a similarly concerning trend. NRW there increased from 63.3% in 2019 to 64.5% in 2023, ranking among the highest nationwide. This gradual increase is not unexpected, as the state's water supply network has suffered from decades of underinvestment. Large sections of the system have not been significantly upgraded, leaving old pipes and outdated fittings vulnerable to recurrent leakage. Limited financial and technical resources further constrain large-scale rehabilitation efforts, making it difficult to reverse the situation. Unless substantial investments are channelled into comprehensive system renewal, high water losses are likely to persist. The figures for Perlis underscore the need to move beyond incremental repairs toward comprehensive network replacement, supported by stronger regulatory oversight and modern management practices to prevent further decline. In many ways, Perlis exemplifies how chronic underinvestment in infrastructure can trap utilities in a cycle of inefficiency—the older the system becomes, the more difficult and costly it is to manage losses effectively.

In Kedah, NRW rose from 48.5% in 2019 to 50.7% in 2023, pushing the state above the 50% threshold. This increase indicates that structural weaknesses in the water supply system remain unresolved. The main contributing factors include ageing distribution networks prone to leaks, limited investment in routine maintenance, and inconsistent enforcement of regulatory standards. While minor repair efforts may have slowed further deterioration, they have not been sufficient to reverse the overall trend. Addressing these challenges demands a more integrated and long-term strategy, combining systematic leak detection, asset rehabilitation, and stronger regulatory compliance. Without such coordinated measures, high NRW levels in Kedah are likely to persist, undermining both operational efficiency and long-term sustainability of the state's water management system.

Figure 1 illustrates the national NRW trend from 2019 to 2023, showing a gradual increase across Malaysia. This trend suggests that, despite ongoing efforts by regulators and utilities, significant challenges remain in achieving efficient water use. The persistently high NRW levels in Kelantan, Perlis, and Kedah highlight the urgent need for targeted investments, improved management practices, and robust regulatory enforcement to ensure sustainable and equitable water management nationwide.

Figure 1

National NRW Trend in Malaysia, 2019–2023 (SPAN, 2024)



Legal Framework for NRW in Malaysia

In Malaysia, WSIA 2006 provides the primary legal framework for regulating water supply and sewerage services including NRW management. This Act was enacted to centralise and strengthen water governance across Peninsular Malaysia and the Federal Territories of Putrajaya and Labuan. Prior to WSIA 2006, the water sector was managed in a fragmented and inconsistent manner, leading to inefficiencies and poor service delivery (Abd Rani et al., 2024). To address these shortcomings, the federal government initiated major reforms in 2005, culminating in the implementation of WSIA 2006. This legislation marked an important shift towards centralised regulation and established a comprehensive legal framework for managing water and sewerage services under a single legislative regime. The WSIA 2006 provides clear regulatory provisions aimed at ensuring the sustainability, efficiency, and safety of water supply systems. It includes specific provisions related to NRW management, such as water metering, leakage control, and penalties for illegal water use. Collectively, these provisions are intended to reduce water loss and improve the overall efficiency of water services in the country.

However, despite its intended benefits, several limitations remain. Centralised regulatory frameworks do not always translate into equitable service delivery, particularly for marginalised urban populations such as low-income households in informal settlements or poorly connected areas. Weak regulatory enforcement and limited recognition of alternative or community-based service providers often prevent these groups from gaining access to essential water services (Gerlach & Franceys, 2010). In addition, centralised wastewater treatment systems are typically costly and require specialised management, which can be impractical or unsustainable in certain urban contexts. Emerging research suggests that more polycentric and community-managed approaches can better address urban sustainability challenges by fostering innovative and locally resilient solutions (Schellenberg et al., 2020). Political influence over water policy also poses a risk, as it can compromise regulatory independence and lead to inefficiencies in service delivery of water and sanitation services—a pattern observed in several developing countries (Berg, 2021). These challenges highlight that strong institutions and capable regulators are crucial for ensuring that legal frameworks translate into equitable, efficient and sustainable water management outcomes.

In the Malaysian context, the federal government established SPAN under the National Water Services Commission Act 2006 (Act 654), commonly known as the SPAN Act, as the primary regulatory body responsible for overseeing the country's water services. SPAN plays a central role in enforcing the provisions of the Water Services Industry Act (WSIA) 2006 and ensuring that water operators comply with established regulatory standards (Abd Rani, 2024). As part of its mandate, SPAN issues license to water operators, sets service performance standards, and monitors compliance with both the WSIA 2006 and its associated regulations. SPAN also actively oversees NRW reduction initiatives and works to ensure that operators adhere to standards for water loss management. Through audits, inspections, and performance evaluation, SPAN assesses the operational efficiency of utilities and enforces corrective measures when necessary. By systematically collecting and analysing data on NRW levels, SPAN is able to identify critical problem areas and implement targeted interventions to address water losses effectively.

Legal Provisions and Enforcement Mechanisms of NRW in Malaysia

Metering Regulations

Effective regulation of water meters within reticulation system is essential to reducing NRW. The Water Services Industry (Water Reticulation and Plumbing) Rules 2014 establish detailed requirements for water metering. For example, Rule 71 stipulates that no water supply may be provided to any consumer unless it passes through a meter, effectively making metering compulsory for all premises. In practice, this ensures that every household and business receiving water services have their consumption accurately measured. The Rules also specify the responsibilities for installing meters and management. Rule 72 places the responsibility of installing meters on water operators, regardless of the meter's physical location. Under rule 73, operators are authorised to determine the placement of meters to ensure secure access and accurate readings. If a meter is located inside a consumer's property, the consumer must ensure its safe custody; however, if the meter is installed outside the property boundary, the operator retains full responsibility. These provisions are reinforced under WSIA 2006, where section 124 makes it an offence to tamper with any meter or sub-meter used to record water consumption. Tampering distorts consumption data and leads to unaccounted-for water losses. Collectively, the Rules and the WSIA establish a comprehensive legal framework that treats metering as a cornerstone of water governance. Accurate metering not only enables the identification and control of physical and commercial losses but also ensures fair billing and discourages unauthorised use.

To strengthen this framework, the federal government, through the Ministry of Energy Transition and Water Transformation (PETRA), has implemented several initiatives to modernise the national water reticulation system (Abd Rani et al., 2024). One key initiative is the NRW Reduction Program (Approach 1), which allocates grants amounting to RM535.4 million to state water operators. The program targets states with NRW levels exceeding 40%—including Kelantan, Pahang, Kedah, Perlis, Sabah, and Sarawak (*Jawapan Parlimen*, 2023). According to PETRA, this program aims to provide critical infrastructure that supports more accurate NRW measurement, particularly through the replacement of old and unreliable meters with new, tamper-proof models. By upgrading metering systems, the program aims to minimise water losses from inaccurate readings and unauthorised consumption, thereby improving the reliability and financial sustainability of the country's water services.

Leakage Control and Infrastructure Maintenance

Under WSIA 2006, SPAN is empowered to enforce standards and guidelines that promote infrastructure maintenance and minimise leakage. Effective leakage control is essential for conserving water resources and reducing the operational costs associated with treating and distributing additional water to compensate for system losses. Specifically, Section 35 of the WSIA mandates that water operators must properly maintain and repair distribution systems to prevent losses caused by leakages. This provision underscores the government's intention to position leak management as a core operational responsibility of operators, rather than a secondary or reactive task. It also underlines that the legal obligations of operators are both preventive and corrective in nature. However, in practice, stronger enforcement of this requirement remains crucial. Weak compliance mechanisms often result in persistent leaks, driving up NRW levels and increasing financial pressure on utilities. Regular monitoring, coupled with clear penalties for non-compliance, can enhance operator accountability and encourage prioritisation of timely repairs and preventive maintenance.

Additionally, the Water Services Industry (Water Reticulation and Plumbing) Rules 2014 provide detailed technical guidelines for pipe installation and maintenance, which are crucial for leak prevention. For example, rule 36 mandates that service water pipes installed outside buildings must be buried at a minimum depth to protect them from physical damage. Subsection (2) of the Rules, specifies that pipes laid within a road reserve must be buried at least 450 millimetres below the surface, while plastic pipes must be shielded using steel pipe sleeves. These requirements ensure that pipes are installed at safe depths and adequately protected to reduce the risk of leaks caused by external forces. Furthermore, Rule 38 prohibits the installation of service water pipes through sewers, contaminated soil, or corrosive environments that may accelerate pipe deterioration. If installation in such conditions is unavoidable, pipes must be protected with suitable materials to prevent contact with harmful elements.

Besides pipe leakage, another major contributor to high NRW levels in Malaysia is ageing infrastructure. Many water operators continue to rely on asbestos cement (AC) pipes within their distribution networks. According to the Water and Sewerage Factbook 2023, states with the highest NRW levels—such as Kelantan and Kedah—still have a large proportion of AC pipes in use, accounting for 55.4% and 46.6% of their networks, respectively (SPAN, 2024). AC pipes, while once favoured by their affordability and ease of installation are inherently brittle and become increasingly vulnerable to leakage over time, particularly when subjected to fluctuating water pressure or unstable soil conditions (Jones et al., 2021; BERNAMA, 2024). As these pipes deteriorate, they not only contribute to high leakage rates but also escalate maintenance and replacement costs.

Additionally, operational inefficiencies and delayed responses to leak repairs further exacerbate NRW issues. Many states, particularly those with older infrastructure, face difficulties in executing timely repairs due to limited financial resources and technical expertise (National Audit Department of Malaysia, 2011). This results in prolonged water loss and increased operational costs. SPAN (2023) similarly observes that states like Perlis and Kedah, which have yet to adequately upgrade or replace ageing infrastructure, continue to experience increased leakage rates and significant water losses. These findings emphasise the need for a more proactive and preventive approach to water infrastructure management. Key measures include replacing outdated AC pipes with more durable materials such as ductile iron or polyethylene, enhancing leak detection systems, and streamlining repair protocols.

To address persistent leakage issues, the Malaysian government has introduced the NRW Reduction Program Approach 2, which provides financial incentives through matching grants amounting to RM1.37 billion (*Jawapan Parlimen*, 2023). Under this approach, the federal government covers 50% or 75% of the annual expenditure for leak reduction projects when states achieve their NRW reduction targets. This initiative primarily targets states with NRW levels below 40%, including Terengganu, Selangor, Johor, Perak, Pulau Pinang, Negeri Sembilan, and Melaka.

Among these, Selangor and Johor have demonstrated strong commitment to the program by undertaking extensive pipe replacement and maintenance efforts to reduce leaks. In Selangor, *Pengurusan Air Selangor Sdn Bhd* (Air Selangor) has replaced over 600 kilometres of ageing pipes in high-leakage areas, resulting in a significant reduction in water loss (Air Selangor, 2024). Similarly, Ranhill SAJ, the water operator in Johor, has undertaken a comprehensive pipe replacement strategy, replacing approximately 1,000 kilometres of ageing pipelines to enhance the integrity and reliability of its water distribution network (Ahmad, 2023).

Prevention of Unauthorised Water Use

Water theft—encompassing illegal connections and meter tampering—remains a major contributor to NRW in Malaysia. Illegal connections occur when individuals or entities tap into the public water supply without proper authorisation, thereby bypassing official channels and avoiding payment for the water consumed. Meter tampering on the other hand, involves altering meter readings to record lower consumption than the actual amount used, resulting in reduced or unbilled water usage.

The WSIA 2006 specifically addresses water theft through several provisions. Section 123 prohibits unauthorised connections to the public water supply system, making it an offence for anyone other than a licensed water operator to connect to a water main or service pipe without proper authorization. Section 124 further prohibits tampering with any meter or sub-meter used to measure water supplied to premises. Such tampering is treated as a serious offense under the Act, as it compromises the accuracy of water consumption data, leads to unbilled water use, and contributes directly to rising NRW levels. These legal provisions are designed to deter water theft by imposing strict penalties, including fines and imprisonment, for unauthorised connections and meter tampering. Beyond the legal dimension, water theft results in significant revenue losses for water operators and undermines the sustainability of water resources, especially in areas where water supply is already scarce.

For instance, in Selangor, Air Selangor, with the support of SPAN, has taken proactive measures to combat illegal water connections (New Straits Times, 2023a). Through coordinated raids and inspections, the authorities have successfully detected and prosecuted several cases of unauthorised water use. In 2022 alone, SPAN reported 229 cases of water theft, with offenders subjected to fines and legal action, reflecting a robust enforcement of the WSIA's provisions (Shah, 2023).

Challenges in Legal and Regulatory Frameworks for NRW in Malaysia

Despite the comprehensive framework established by the WSIA 2006 and the concerted efforts of SPAN and various state governments, Malaysia continues to face significant challenges in effectively managing NRW. These challenges reveal critical gaps in policy implementation, enforcement consistency, and overall regulatory efficacy.

Inconsistent Implementation across States

The regulatory framework under the WSIA 2006 is legally coherent but structurally rigid. Although the Act centralises water supply regulation under the federal government, its enforcement depends heavily on state-owned water operators. These operators, while licensed under federal law, remain constitutionally bound to their respective state governments, which hold ownership of water resources. This creates a systemic legal tension—a uniform federal mandate is imposed on entities that possess uneven institutional and financial capacities across states.

This is not merely a matter of governance or administrative efficiency but reflects a fundamental regulatory design flaw within the WSIA 2006. For example, Section 36 mandates all licensees to ensure proper maintenance and timely replacement of water supply infrastructure. However, the Act does not differentiate between operators with adequate resources and those lacking them. Nor does it provide mechanisms for SPAN or the Minister to modulate compliance obligations based on fiscal or technical limitations. The WSIA 2006 thus assumes uniform capability where disparities exist, resulting in superficial compliance or technical breaches that are difficult to enforce effectively. This structural rigidity undermines WSIA 2006's overarching goal of ensuring sustainable and efficient water service delivery nationwide.

The consequences of this regulatory rigidity are evident. States such as Selangor and Johor, which possess stronger institutional capacity, financial resources and political commitment, have made significant progress in reducing non-revenue water through sustained infrastructure investments. In contrast, states like Kelantan and Perlis continue to face entrenched structural barriers including ageing infrastructure, chronic funding gaps, and weak governance mechanisms, making full compliance with the WSIA 2006 obligations virtually unattainable. Yet, the WSIA 2006 provides no statutory flexibility or differentiated compliance mechanisms to address these disparities. For instance, despite the Act's uniform obligations, enforcement activities by SPAN in 2022 varied significantly across regions. The Central Region received nearly twice as many inspections on water services as the Northern or Southern Regions (SPAN, 2023). Such uneven regulatory presence exacerbates existing inequalities by reinforcing the structural disadvantages faced by under-resourced states. Consequently, there disparities perpetuate a cycle in which weaker operators remain trapped in non-compliance, while better-resourced states advance, further widening the national gap in NRW performance.

The issue, therefore, does not stem from the absence of NRW-related provisions within WSIA 2006, but from the lack of legal instruments that enable the equitable enforcement of those obligations across structurally unequal operators. Addressing this problem does not necessarily require textual amendments to the WSIA 2006. Rather, it calls for a more flexible interpretation and operationalisation of its existing provisions. For instance, Sections 10 (licensing conditions) and 179 (Ministerial power to make regulations) could be strategically utilised to establish tailored, time-bound compliance schedules or phased implementation targets. Such mechanisms would preserve the coherence of the national legal framework while accommodating context-sensitive implementation that recognises differences in state capacity and readiness. Adopting this approach would not only strengthen regulatory legitimacy but also promote progressive realisation of federal water policy objectives, and uphold the principle of differentiated yet fair compliance.

Financial and Technical Capacity of Water Operators

Many water operators in less developed states face significant challenges in complying with SPAN's regulatory standards due to limited financial and technical capacity. Although the WSIA 2006 places the responsibility for operational and maintenance work squarely on the water operators, the federal government continues to provide partial financial assistance for certain projects. Federal funding through programs such as the NRW Reduction Program (Approach 1 and 2) provides initial support to water operators, yet these allocations remain insufficient to cover the substantial costs associated with large-scale infrastructure rehabilitation and the adoption of advanced technologies. For example, matching grants under NRW Reduction Program Approach 2 are designed to assist water operators in implementing NRW reduction measures by allowing them to claim government funds after completing approved activities. However, operators are required to first finance these activities before reimbursement, a condition that poses significant challenges for operators with limited financial resources, resulting in low participation rates and uneven progress across states.

A case in point is Syarikat Air Darul Aman (SADA) in Kedah, which entered into a performance-based contract with a private sector entity to finance its NRW reduction project (Abd Rani, 2024). Despite this collaborative approach, there has been little measurable improvement as of 2024, highlighting the limitations of relying solely on contractual or grant-based mechanisms without addressing the structural financial weaknesses of the operators. This is reflected in Kedah's persistently high NRW levels, which have remained largely unchanged since 2019 (SPAN, 2024).

Insufficient Enforcement and Regulatory Oversight

The enforcement of regulations represents a critical area within Malaysia's water governance framework. Although the WSIA 2006 empowers SPAN with enforcement authority, the actual regulatory oversight of NRW performance remains inconsistent and often ineffective. Mohamad Yazid et al. (2017) observe that many water operators "do not have enough pressure from the authorities to improve performance, especially in NRW," and that monitoring activities "are still limited and often not conducted on a regular basis". The authors further highlight that Malaysia's water service industry lacks a robust and comprehensive enforcement structure to compel operators to meet performance targets, particularly in states where NRW levels have remained persistently high. This regulatory fragility enables some operators to defer essential infrastructure upgrades and efficiency investments, thereby undermining the achievement of national NRW reduction goals. Furthermore, penalties for non-compliance are not consistently applied—particularly in politically sensitive regions where state governments may resist federal oversight.

Empirical evidence from SPAN's 2022 enforcement records illustrates this inconsistency (SPAN, 2023). A total of 168 enforcement activities were conducted that year, but their distribution across regions was far from uniform. The Central region (Selangor, Kuala Lumpur, Putrajaya, Negeri Sembilan) recorded the highest number of water supply-related enforcement actions (46), with a case confirmation rate of 65.4%. In contrast, the Northern region (Kedah, Perlis, Pulau Pinang, Perak) reported only 25 enforcement activities and a 49.1% confirmation rate. The Southern region (Johor, Melaka) inspected 80 premises, resulting in 23 enforcement activities with a 55.7% confirmation rate. Meanwhile, the Eastern region (Kelantan, Terengganu, Pahang) recorded 32 enforcement activities and a 50.5% confirmation rate.

Such disparities weaken the credibility of regulatory oversight and create a permissive environment in which water operators may deprioritise NRW reduction. When enforcement is irregular or perceived as lenient, operators often adopt short-term cost-saving measures rather than investing in long-term strategies such as leak detection, system maintenance, or technological upgrades. This behaviour is particularly prevalent in states with high NRW levels, where the risks and costs of non-compliance are minimal.

Quantitative research supports this pattern. Saad and Anuar (2019), using Data Envelopment Analysis and Tobit regression, found that states with higher NRW levels consistently exhibit lower technical efficiency. These states tend to share structural traits, including weak internal governance, limited autonomy from state political control, and constrained technical and managerial capacity. Consequently, operators in such contexts are less likely to allocate resources—financial, human, or technical—toward NRW reduction unless compelled by strong regulatory enforcement. Without consistent and rigorous application of WSIA standards, these internal institutional weaknesses remain unaddressed, perpetuating inefficiency and obstructing the national NRW reduction agenda.

SINGAPORE EXPERIENCES

Globally, Singapore has consistently maintained one of the lowest levels of NRW, currently around 5% (PUB, 2023). This achievement results from a combination of rigorous legal frameworks, strict enforcement, advanced technological integration, and proactive management strategies implemented by the Public Utilities Board (PUB)—Singapore's national water agency. According to the Ministry of Sustainability and the Environment (2025), Singapore is among the most water-stressed countries in the world due to its limited natural freshwater resources. This scarcity has compelled the government to adopt a comprehensive, long-term wide-ranging strategy to ensure water security and sustainability. Every drop of water is treated as a precious resource, supported by stringent policies to minimise waste. In parallel, public participation plays a crucial role, as citizens actively practice water-saving habits in their daily lives. Together, these efforts illustrate how effective governance, technological innovation and civic responsibility can reinforce one another in safeguarding a vital national resource.

Unlike countries such as Malaysia, which rely primarily on natural water sources like rivers, Singapore's water management framework is guided by the "Four National Taps" policy (Tortajada ET AL., 2013). This integrated model comprises four key water sources: (1) local catchments, (2) imported water, (3) reclaimed water (NEWater), and (4) desalinated water (Tortajada at al., 2013; Irvine et al., 2014). Each of these 'taps' requires strong institutional capacity, technological innovation, and sustained financial investment to remain viable. The Four National Taps approach embodies Singapore's recognition of its geographical and climatic constraints, as no single source can independently meet the country's growing demand for water. For Singapore, effectively managing NRW is crucial to optimizing available water resources, ensuring long-term sustainability, and minimizing environmental impact. This integrated approach shows how Singapore links resource diversification with stringent loss prevention measures to achieve high water security.

Singapore's legal framework for regulating NRW is both comprehensive and robust, primarily governed by the Public Utilities Act 2001 and its subsidiary regulation, Public Utilities (Water Supply) Regulations. This Act confers statutory authority upon PUB to manage and regulate water services across Singapore. It empowers the PUB to implement stringent measures aimed at minimizing water losses and ensuring that water resources are utilised efficiently (Public Utilities Act, 2001). The Act

further mandates the PUB to maintain a consistent, adequate, and sustainable water supply while minimizing losses through efficient management practices.

The Public Utilities (Water Supply) Regulations complement this legislative framework by establishing clear operational standards and procedures for water service management. These regulations govern key aspects such as metering accuracy, leak detection, infrastructure maintenance, and enforcement actions against illegal water use. These regulations do not stand alone but are reinforced by broader national policy directions, particularly those outlined in the Singapore Green Plan 2030. The Green Plan reflects Singapore's commitment to United Nations Sustainable Development Goals (SDGs), emphasising water conservation, resource efficiency, and sustainable infrastructure management (Ministry of Sustainability and the Environment, 2021).

Singapore's commitment to water sustainability is further reflected in the implementation of the Water Efficiency Management Plan (WEMP). Under Part IVA of Public Utilities (Water Supply) Regulations 2015, large water users—those consuming at least 60,000 cubic meters annually—are legally required to submit detailed strategies for improving water efficiency, including specific measures to reduce NRW. This statutory requirement ensures that industries and other major consumers play an active and accountable role in managing water resources efficiently, rather than leaving the responsibility solely to government agencies (Public Utilities (Water Supply) Regulations 2002, as amended 2015). The requirement to submit and regularly update water efficiency plans fosters a culture of continuous improvement in water management practices and strengthens Singapore's broader goal of sustainable and integrated resource management.

A cornerstone of Singapore's approach to NRW reduction is its policy of compulsory water metering, which promotes transparency and accountability in water consumption. Regulation 35 of the Public Utilities (Water Supply) Regulations requires all water supplied to consumers to be accurately measured through approved meters. To operationalise this statutory requirement, PUB has implemented Advanced Metering Infrastructure (AMI) and Automated Meter Reading (AMR) technologies, which enable real-time monitoring of water usage. These technologies provide high-resolution consumption data facilitate early leak detection, identify irregular usage patterns, and enable timely interventions to prevent further losses (Kijak, 2021, PUB, 2022). The integration of legal requirements with technological innovation exemplifies Singapore's pragmatic and forward-looking governance model to achieve effective water management.

These smart metering systems enable real-time monitoring of water usage, allowing PUB to quickly detect anomalies that may indicate leaks or unauthorised use (PUB, 2023). Smart meters provide detailed consumption data which helps PUB identify high consumption periods and potential leakages, facilitating timely and targeted interventions to prevent water loss (PUB, 2022). This proactive metering approach aligns with Regulation 36 of the Public Utilities (Water Supply) Regulations, which mandates the use of water meters and stipulates responsibilities for meter maintenance and monitoring. According to PUB reports, nearly 95% of treated water is successfully delivered to consumers, with system losses maintained at approximately 5–6%—among the lowest levels globally (Fu, 2025). In 2024, Singapore recorded only 4.5 pipe leaks per 100 km, a notable improvement from 5.7 in 2014, underscoring the effectiveness of its metering and leak detection infrastructure (PUB, 2025). These measures demonstrate how the integration of technology and regulatory compliance can significantly reduce water losses and enhance water supply efficiency.

Moreover, the AMI and AMR technologies adopted by the Singaporean government align with the nation's broader Smart Nation and smart city initiatives, which aim to improve service delivery and resource management (PUB, 2025; SP Group, 2025; Smart Nation, 2025). Based on AMI and AMR technologies, data collected from smart meters is integrated into Singapore's smart water grid, enabling PUB to optimise water distribution, forecast demand patterns, and implement water-saving measures more effectively. This integration supports the objectives outlined in Regulation 40 of Public Utilities (Water Supply) Regulations, which emphasises water conservation and the installation of water-saving devices. Collectively, these initiatives reflect Singapore's long-term strategy to harness digital technology in promoting water sustainability and building resilience against climate change impacts.

Leakage detection and management form a central component in Singapore's strategy to reduce NRW. The Public Utilities (Water Supply) Regulations authorises PUB to carry out comprehensive leak detection programs and require regular inspections of the water distribution network. Regulation 13 obliges water operators to properly maintain service installations to prevent leaks, while Regulation 14 mandates regular inspection and maintenance of storage tanks to keep them free from contamination and leakage. In addition to these regulatory requirements, PUB employs advanced technologies such as pressure management systems and acoustic sensors to detect and address leaks before they escalate. Singapore's water network is divided into District Metered Areas (DMAs), allowing for close monitoring of water flow and pressure across defined zones. This structure enables PUB to identify abnormalities quickly, locate leaks accurately, and isolate affected areas for prompt repair (PUB, 2022). Through this proactive and data-driven approach, PUB not only reduces water loss but also preserves the structural integrity and reliability of the national water supply system. Collectively, these strategies illustrate Singapore's commitment to preventive maintenance and efficient water management.

Although water theft is relatively rare in Singapore compared to other regions, it remains strictly regulated under the Public Utilities Act and the Public Utilities (Water Supply) Regulations. These laws explicitly prohibit unauthorised connections and tampering with water meters. Such acts are classified as criminal offenses and are punishable by fines and imprisonment under Regulation 12. Additionally, Regulation 31 reinforces these provisions by prohibiting interference with any water service installation used to supply piped drinking water, detailing both the penalties and enforcement procedures for illegal use. PUB complements these legal safeguards with proactive enforcement measures, including regular audits and inspections supported by digital monitoring tools that detect unusual consumption patterns indicative of theft or unauthorised use (PUB, 2022). This combination of strict legal provisions, advanced surveillance and consistent enforcement ensures that water resources are protected and all water consumption is accurately accounted for and billed.

Overall, Singapore's legal framework for regulating NRW is widely regarded as one of the most effective globally. This effectiveness largely stems from its stringent regulations, rigorous enforcement, technological integration and proactive management strategies. PUB has successfully maintained NRW levels at around 5 per cent, significantly lower than global benchmarks which recent estimates place at tens of billions of cubic-metres lost annually worldwide (PUB, 2016; Liemberger & Wyatt, 2018). Singapore's stringent regulatory regime extends beyond utility providers and large consumers to encompass household consumers as well. The Public Utilities (Water Supply) Regulations, particularly Regulations 39 and 40, impose clear restrictions on water consumption to promote conservation. Consumers are prohibited from using hoses or sprinklers for activities such as watering gardens or washing vehicles without written permission from the Board. Furthermore, the regulations mandate the installation of water-saving devices and prohibit fittings that exceed specified flow rates or water

pressures. These measures ensure the efficient use of water in light of Singapore's limited freshwater resources.

Despite its success, Singapore continues to faces challenges in sustaining this level of efficiency and effectiveness. Rapid population growth and industrial expansion require continuous innovation and investment in management infrastructure and technology (PUB, 2023). In addition, climate change poses new threats to water security, necessitating adaptive strategies and resilient infrastructure to manage increased rainfall variability and potential droughts (PUB, 2023). To address these evolving changes, PUB invests heavily in research and development to explore emerging technologies and best practices in water management. Beyond technological advancement, PUB (2023) places strong emphasis on public engagement through educational campaigns that promote water conservation and responsible consumption. Singapore also collaborates with international organisations and participates actively in global water forums, enabling it to stay at the forefront of water management practices, and refine its legal and regulatory frameworks to meet emerging needs (Tortajada, 2018).

COMPARATIVE LEGAL FRAMEWORK ON NRW REGULATION BETWEEN MALAYSIA AND SINGAPORE

Based on the preceding analysis, both Malaysia and Singapore recognise the importance of metering, leakage control, and preventing illegal water use in reducing non-revenue water (NRW). However, their legal frameworks differ significantly in terms of scope, enforcement, and technological integration. To better understand these differences, this subsection examines three main aspects contributing to NRW—metering regulation, anti-theft measures, and leak detection—to identify the strengths and weaknesses of Malaysia's framework in comparison with Singapore's more centralised and technology-driven system.

Metering Regulation

Both jurisdictions legally require metering for all water users. In Malaysia, the legal duty for meter installation is set out in WSIA, but enforcement remains inconsistent. Many water operators continue to depend on conventional mechanical meters, and replacement programs progress slowly. As a result, accurate water accounting is often limited. The problem is particularly critical in high-NRW states such as Kelantan and Perlis, where even the supply of basic meters is inadequate. Financial constraints among water operators further delay replacement work. While federal initiatives—such as NRW reduction programs—have been introduced to address these gaps, the need for such ad hoc interventions reflects weak long-term compliance and enforcement.

In contrast, Singapore integrates its legal mandate into a highly coordinated and technology-based infrastructure. Under the Public Utilities (Water Supply) Regulations, the PUB is responsible for providing and maintaining meters, which are installed as smart meters using AMI and AMR systems. These meters transmit data in real time to national monitoring platforms, enabling continuous oversight and rapid detection anomalies. This approach removes reliance on water operator discretion and transforms metering into an active tool for loss reduction and billing accuracy. The main difference between the two systems lies not in legal recognition but in implementation and enforcement. Malaysia's law depends heavily on the capacity and commitment of local water operators, whereas Singapore's system achieves compliance through automation, national oversight, and data-driven enforcement.

Regulation on Water Theft and Unauthorised Use

Water theft is a criminal offence in both Malaysia and Singapore, but the degree of enforcement and institutional coordination differs substantially. In Malaysia, SPAN has statutory authority to enforce offences such as illegal connections, meter tampering, and unauthorised water use. However, enforcement practices vary considerably across states. While some water operators carry out regular inspections and enforcement raids, others face challenges such as underreporting, limited prosecution, and weak follow-up actions. The issue, therefore, lies not in the absence of legal provisions but in the fragmented nature of service delivery. State-owned water operators often prioritise service continuity of water supply over enforcement, which constrains SPAN's ability to act decisively and consistently.

Singapore, by contrast, adopts a far more stringent and centralised approach. Under the Public Utilities Act and related Water Supply Regulations, where water theft is treated as a strict liability offence, and PUB holds both investigative and prosecutorial powers. Critically, PUB's real-time metering systems serve not only as billing instruments but also as enforcement tools. Usage anomalies that suggest unauthorised use are automatically detected and flagged, enabling swift intervention before losses accumulate. This approach shifts the legal strategy from reactive enforcement to proactive prevention. Moreover, enforcement efforts are nationally coordinated, ensuring uniform application of regulations without dependence on local discretion.

Comparing with Singapore, the evidence clearly shows that Malaysia's model remains largely reactive. In the absence of automated monitoring systems, enforcement relies heavily on physical inspections and customer complaints. Singapore's strength lies in its capacity for early detection, backed by a nationally coordinated framework. Singapore's regulatory advantage is not solely on imposing stricter penalties but on the systemic design of its water governance model, which enables the law to anticipate and intercept violations in real time.

Leak Detection and Infrastructure Maintenance

Both Malaysia and Singapore legally mandate measures to control leaks within their water distribution networks. In Malaysia, the requirements for leak detection and maintenance are stipulated in both primary and subsidiary legislation. However, their effectiveness is constrained by operational and financial capabilities of state-level water operators. Ageing AC pipes remain prevalent in many states, and their brittle nature increases the likelihood of risk of bursts and water loss. Repair works are often delayed due to funding shortfalls and lack of technical expertise. While leak detection tools and modern monitoring technologies are used in better-resourced states, their use is inconsistent nationwide. Even when federal grants are available, many operators remain hesitant to invest, given the high upfront costs and uncertainty in meeting prescribed reduction targets.

In Singapore, leak detection is not left to the discretion of water operators. The entire distribution network is divided into District Metered Areas (DMAs). Each DMA is fitted with sensors, acoustic monitoring devices, and telemetry systems. These systems are legally required to be maintained and regularly inspected. Any abnormal change in flow or pressure triggers immediate alerts, allowing prompt intervention. Leak detection, therefore, forms an integral part of how the law is applied. Singapore's exceptionally low leakage levels are not merely the product of strict laws but of infrastructure purposefully designed to enforce those laws automatically. While Malaysia's framework aspires to achieve similar outcomes, its implementation remains inconsistent. Weak enforcement, financial constraints, and fragmented governance continue to delay progress and create inconsistent results across states. In contrast, Singapore shows how legal frameworks, technological innovation, and coordinated enforcement can be integrated into a cohesive and self-reinforcing system.

Table 2

Comparative Overview of Legal Frameworks for NRW Control in Malaysia and Singapore (Metering, Water Theft, and Leak Detection)

Element	Malaysia	Singapore
Metering	Legally required under WSIA 2006 and 2014 Rules; implementation varies across states; no legal mandate for smart metering.	Legally mandated under Public Utilities Act; AMI and AMR are required; real-time integration and national oversight.
Water Theft	Criminalised under WSIA 2006 (Sections 123 & 124); inconsistent enforcement; reliant on physical audits.	Criminalised under Water Supply Regulations (Regulations 12 & 31); strict penalties; technology-backed enforcement.
Leak Detection	Obligated under WSIA 2006 (Section 35) and Plumbing Rules; implementation depends on state resources; mostly reactive.	Legally mandated (Regulations 13 & 14); proactive surveillance using sensors and pressure zones; very low leak rates.

This comparative analysis reveals a recurring theme: Malaysia's legal framework for NRW management is structurally sound but functionally uneven, whereas Singapore's framework translates legal provisions into enforceable actions through strong institutional design and digital infrastructure. Singapore exemplifies what an effective legal framework should achieve—it not only establishes obligations but also ensures their consistent implementation without discretion, delay, or disparity. The law operates not merely as a set of prescriptions but as a system with embedded enforcement logic. In Malaysia, the gap between legal intent and practical outcomes reflects deeper systemic weaknesses related to institutional capacity, financing models, and regulatory decentralisation. Consequently, efforts to reduce NRW through law means must extend beyond the drafting of provisions to focus on building enforcement pathways. Each legal requirement should be supported by institutional mechanisms that enables real-time compliance and accountability. For Malaysia to close this implementation gap, it must evolve from a centralised administered, rule-based approach to a more adaptive regulatory model that is data-driven, digitally integrated and capable of continuous monitoring. Only through such transformation can legal reform meaningfully contribute to NRW reduction across all states, regardless of their starting capacity or resource constraints.

CONCLUSION

This article shows that Malaysia has established a legal framework for managing non-revenue water (NRW) through the Water Services Industry Act (WSIA) 2006 and its subsidiary regulations. However, its overall effectiveness remains limited due to inconsistent implementation, financial and technical constraints, and weak enforcement mechanisms. In contrast, Singapore's success in managing exceptionally low NRW levels offers valuable insights and lessons for Malaysia's ongoing efforts. To improve NRW management, Malaysia must address the varying institutional capacities of its states by adopting a more tailored and context-sensitive approach. Policies and regulations should reflect the specific challenges faced by each state, rather than applying a uniform compliance model. Enhancing financial support and providing incentives for technological adoption is also critical. Revising funding mechanisms under the NRW Reduction Program could ensure that water operators have sufficient upfront capital to undertake infrastructure upgrades and adopt advanced technologies. Equally important is the strengthening of enforcement and regulatory oversight to promote compliance and accountability within water utilities. Implementing stricter penalties for non-compliance and enhancing

monitoring—similar to Singapore's proactive enforcement model—would help detect and address NRW issues more effectively and promptly. By embracing these strategies, Malaysia can significantly strengthen its NRW management, reduce water losses, and enhance the overall sustainability of its water supply system. Closer collaboration between state governments, federal authorities, and international partners could further provide the necessary technical expertise, innovation and funding support. Ultimately, such coordinated efforts could contribute to a more efficient, resilient and equitable water management system nationwide.

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