

## Water Distribution and Non-Revenue Water Management Scenario in Asian countries: Malaysian Perspective

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### ABSTRACT

It is being estimated by the World Bank that the operations and maintenance cost for the basic water and sanitation services (WASH) is expected to increase from 4 to 30 Billion USD per year by 2030 which substantially surpass the capital cost of basic WASH services. Still the local and global funding prioritize the capital investment in the current water infrastructure resulting in the lack or no funding for the operation and maintenance mandates especially in the developing countries of Asia due to insufficient revenue generated from consumers to cover the operational and maintenance costs. This has subsequently caused an adverse impact on the financial utility and services rendered to consumers. Many water utilities are facing difficulties with high amount of Non-Revenue Water (NRW) for the past few years. Water utilities are being forced to consider implementing an efficient NRW reduction strategy due to the rapid population growth and industrialization raise the water demand and put pressure on the water resources. Public water utilities are expected to apprehend the demand by increasing the capacity. On the other hand, to solve the increasing water demand it is not enough to just increase the capacity and production. Combine both Non-Revenue Water and the increasing of capacity is more efficient rather than a single approach plan. In Malaysia, there is 35% of non-revenue water loss and mostly are caused by pipe leakages and breakage. This paper aims to assess the NRW reduction strategies by analysing the factors affecting, and challenges faced by Malaysian water utilities in reducing NRW rates. This paper also evaluates the public perception on Non-Revenue water management to establish a way to develop public participation in Non-Revenue Water reduction program. Finding shows that public participation in Non-Revenue Water reduction management in Malaysia remains lacking as many respondents indicate a lack of knowledge and awareness in non-revenue water. Participation from the community to achieve a sustainable water source management is important to enhance Malaysia's water safety. The paper will provide an insight to the water distribution in the Southeast Asian countries and will especially emphasize on the crisis of non-revenue water its implications and possible measures and strategies to improve the situation.

#### **Keywords:**

Water life cycle cost, water distribution, non-revenue water crisis, cost recovery

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### 1. Introduction

Water is one of mankind most valuable resources. Water, not only used for drinking purposes but also served as key resource for economic, environmental, social and cultural activities [1]. Population growth, rapid urban expansion and economic expansion are the reasons behind the rapidly growing water demand in Asia posing challenges to water security in many developing countries.

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Malaysia, which is blessed with plenty of water resources with an average annual rainfall of around 2,000 mm, is considered a water-rich country [2]. However, there is no exception for Malaysia from frequent water supply issues and shortages. Over the past decades, the water situation for many countries have changed from a relatively abundant one to a relatively scarce one. Millions of liters of water are being drawn out every single day to ensure. One of the main issues affecting water utilities in the developing world is the significant difference amount between those from water distribution water system and the water invoiced to customers or also known as non-revenue water (NRW). More than 16 billion m<sup>3</sup> of water are delivered but not being invoiced to customers and 32 billion m<sup>3</sup> of water are lost through leaks from the distribution networks every year.

Non-Revenue Water rates in Malaysia range from 30 to 50 %, and it is considerably high amongst the other developing countries in Asia. The average proportion of non-revenue water in Malaysia was approximately around 38 %. This is regarded as high compared with other developing countries in Southeast Asia, such as Bangkok, Thailand with 25 percent and East Manila, and the Philippines with 11 %. Not many countries in Asia can establish an operational mechanism or have the infrastructure in the attempt to reduce the NRW. Many countries struggle to ensure that customers receive a sufficient amount of water supply to support their health and lives. This is mainly because of the rapid urbanization and population growth that impose rapidly growing demands and pressure on water resources.

High levels of non-revenue water can severely affect the water utilities financial survival due to lost income and higher operational costs. A high NRW rate occurs due to a poorly operated water provider that lacks governance autonomy, responsibility, and the specialized skill needed to develop an acceptable service to the community. The manager or directors of water utilities appointed are comes from various backgrounds unrelated to the water sector. Thus, these managers have limited knowledge of the technical and water supply operations needed to establish a program that effectively manages the NRW and water losses.

## **2. Water Distributions**

Malaysia's common issues and challenges in securing the country's water security.

### *2.1 Financial Deficiency of Water Supply Sector*

One of the major threats to Malaysia's water security is the financial issue. Malaysia's water sector can only collect a total revenue that barely covered the total expenditure of the sector from 1990 to 2000. From 2001 to 2010, on the other hand, the water sector has collected a total revenue that was less than the total expenditure. In 2005, over half of Malaysia's states had a financial deficiency in their water supply sector, owing to lost revenue from NRW due to under-meter registration, leaks and water theft, and the water tariff below the recovery cost level. Malaysia also lacked coordination amongst several parties, an inefficient regulatory system with weak enforcement, public expenditure restrictions, and varied privatization performance outcomes [21].

Malaysia's water sector has been running at a loss since 2011, with an average of 567 million MYR per annum. While in 2017, Malaysia's water sector had a loss of 1,819 billion MYR per annum [3]. The main cause of Malaysia's water sector deficit is because low water tariff. Malaysia has the cheapest domestic water tariff in Southeast Asia, with only 0.13 USD per cubic meter for the first 20 cubic meters. For this, the government has begun to revamp its water sector management, and it is believed that following the reform, the issue of low water tariffs would be resolved quickly [4].

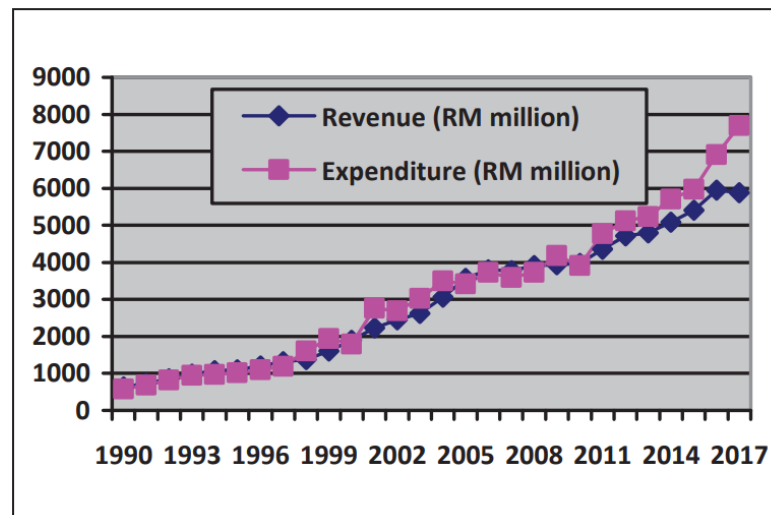


Fig. 1. Malaysia water sector supply Total Revenue vs Total Expenditure, 1990 – 2017 [9]

Improving water supply services requires reforming water pricing policies and tariff mechanisms. In some developing countries, the present urban growth rhythm and difficulties require an urgent assessment and the construction of a more “integrated” management system with an appropriate water tariff policy to enhance water security [16]. To improve water supply services, the reform of water tariff mechanisms and water pricing practices is critical in policy initiatives [17]. Water tariffs are a crucial management tool for ensuring long-term water supply because they provide a possible link between supply and demand that can achieve various goals. On the other hand, water service price looks to be a challenging issue for national and municipal governments [18].

When it comes to water pricing and tariff establishment, determining a tariff structure responsive to both the utility’s and the community’s objectives presents significant problems. Tariff-setting is a contentious political procedure. A poorly constructed water tariff system might lead to overconsumption of scarce water resources or inefficient water distribution, putting the poorest people at a disadvantage [19]. Thus, fees generated from consumers should ideally be sufficient to cover the cost and prevent excessive water usage while yet being low enough to provide affordable access to services [16]. Hence, determining a water tariff is particularly difficult in most developing countries, in which the population’s minimum wages make any rise in water prices undesirable [20].

## 2.2 Aging Water Supply Infrastructure

Malaysia had its independence in 1957; since then, infrastructure development in the water sector has increased in response to the rising domestic and commercial water demand. However, Malaysia’s water supply infrastructure that has been developed over the last 50 years are dealing with degradation resulting in higher maintenance costs, broken water pipes, and a rise in NRW levels [10]. As losses owing to outdated network pipelines were one of the main contributors to the high NRW rate [11]. One approach to minimize the NRW rate is by rehabilitation, which comprises repairing or replacing ageing pipelines.

In 2019, a pipe burst and pipe leakage accounted for 75% of NRW in Malaysia [12]. Malaysia’s existing pipeline system is more than 20 years of age, and at this moment, the existing pipeline is deteriorating and become extremely vulnerable. Old pipes will increase the risk of water leakage and can cause corrosion because of rust. In addition, extensive pipeline leaking can imply that the pipe walls have degraded to the point that the pipes are severely thin [13] [14] [15].

In 1981, the overall length of water pipelines in Malaysia was 31,090 km; however, the capacities of water treatment plants were only 2,540 million per day (MLD). From then until 2017, the length of pipe and water treatment plant capacity grew significantly with the length of pipes was 152,121 km and the capacity of WTP was 19,706 MLD. However, a significant increase in pipes caused the volume of water leakage to increase. The ageing water infrastructure is responsible for such a significant volume of water loss, and it requires a considerable amount of money to replace these ageing pipes [3].

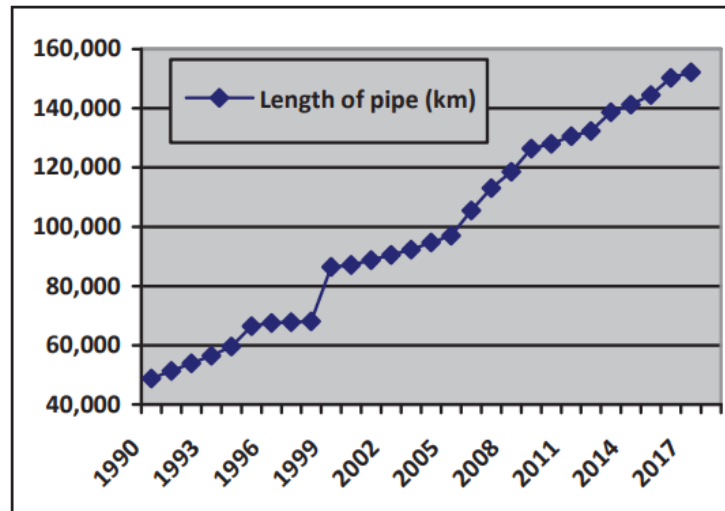


Fig. 2. Length of Pipes (km), 1990-2017 [9]

### 2.3 Public Lack of Knowledge and Participate in NRW Reduction Plan

Lack of public support on a non-revenue water reduction plan is one of the reasons why non-revenue water rates in some regions cannot be significantly reduced, which is frequently caused by a lack of public knowledge of NRW issues. Without effective public participation, water problems cannot be adequately solved [22] [23]. For example, based on the survey conducted in Kuala Lumpur and Selangor, Malaysia in 2021 to determine the level of awareness for the society towards NRW in Malaysia, more than 70% of participants from both Kuala Lumpur and Selangor have never heard of NRW.

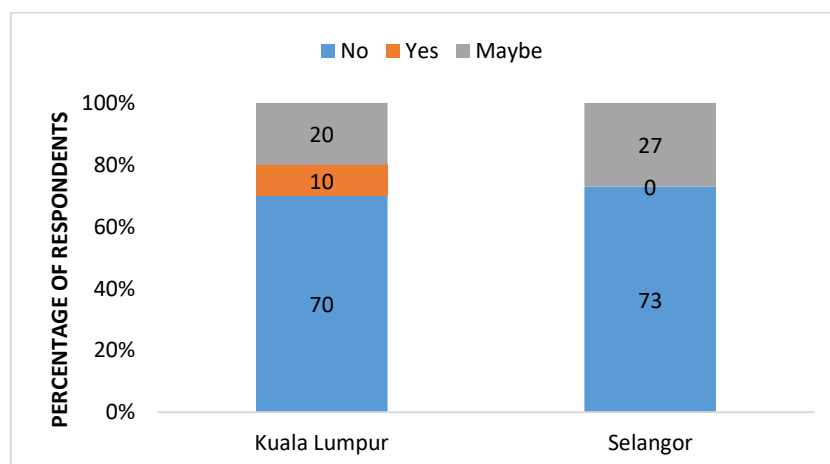


Fig. 3. Public Awareness on NRW in Kuala Lumpur and Selangor

Public participation is proven to contributing a better result in the NRW reduction plan. However, in many developing countries, especially Malaysia, improving public participation in NRW reduction

plan is frequently overlooked. For example, in Phnom Penh, Cambodia, the government successfully reduced their country NRW levels from 72 percent in 1993 to 6.19 percent in 2008. The government encouraged the public to inform the water utilities regarding any illegal activities and offered a reward to those reporting and a punitive measure to those found doing the illegal activities [5]. This effort is effective in reducing the time needed for water utilities to become aware of any NRW issue or incident and repair or replace a damaged meter [6]. Importantly, encouraging public knowledge about the significance of NRW reduction would lessen public opposition to paying a reasonable water tariff that is equitable to both the public and the water service providers.

#### 2.4 Demand for water in Malaysia

The water industry in Malaysia is divided into two sections: resource management and service supply. The various services provided are water supply for households, hydropower, industrial, ecosystem control, recreational and agricultural use. The water resources needed for these functions are provided by the intertwined natural systems of lakes, wetlands, rivers, coastal reaches and aquifers [29].

More than 98 percent of Malaysia's current water usage comes from surface water resources such as reservoirs and rivers. However, groundwater only contributes to less than 2% of current water use. Agriculture, industry and household needs consume the majority of the country's water supply. Hydropower generation, recreational activities and navigation are the major non-consumptive uses of water. However, as the world's population and urbanization increase, industrialization and irrigation expand, thereby increasing the need for water. As a result, the agricultural sector has the largest water demand in Malaysia [28].

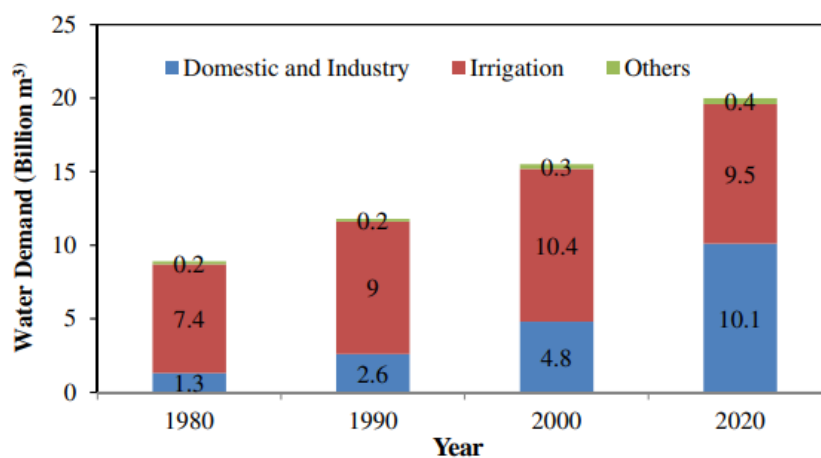
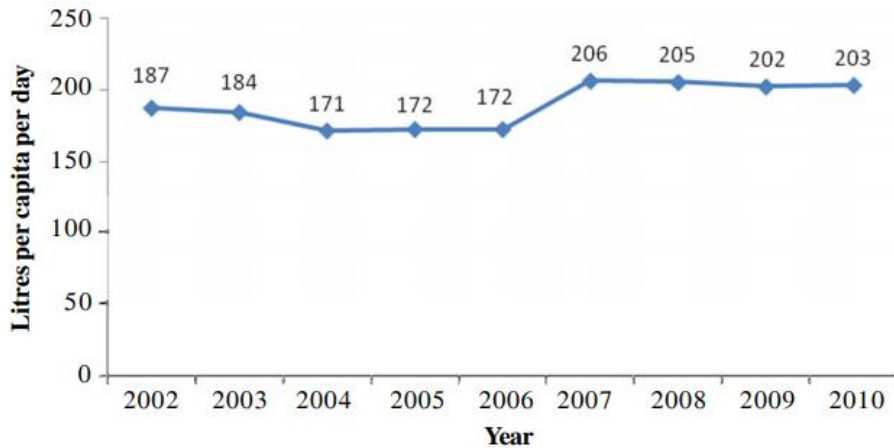


Fig. 4. Water demand in Malaysia from different sectors [27]

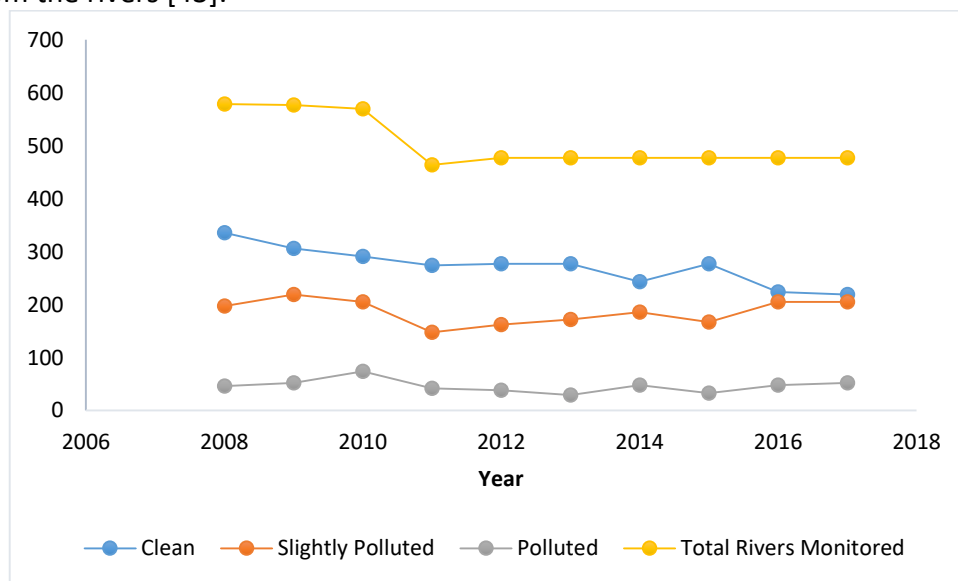
Malaysia has had significant economic growth during the previous few decades. Water consumption is rising in tandem with population growth and the country's development [26]. Water from the industrial and household sectors was primarily used for hydropower generation, navigation, and recreational activities. Water consumption is rising in these parts of the country, which can be attributed to the country's rapidly increasing population and industrialization. The country's water usage is anticipated to increase to 20 billion m<sup>3</sup> by 2020.



**Fig. 5.** Per capita demand for water in Malaysia [30]

### 2.5 Water Pollution in Malaysia

In Malaysia, water pollution is a major problem that significantly impacts the long-term viability of water resources. This is because 95% of the people utilize tap water, while 80% of the tap water is collected from the rivers [43].



**Fig. 6** River Water Quality in Malaysia [3]

Polluted water has an impact on plants and living organisms. The health of the people and the economy of the country are both at stake. It significantly lowers total water availability since cleaning contaminated streams is highly expensive, and polluted waters are often unsuitable for human consumption. The vast water resources available in the watershed are insufficient to feed all consumers due to river pollution [40]. High ammoniacal nitrogen (NH<sub>3</sub>-N), suspended solids (SS) and Biochemical Oxygen Demand (BOD) are primarily contributed to Malaysia’s river pollution. Inadequate sewerage treatment of wastewater produced by industrial enterprises is generally the source of the excessive BOD. The major sources of NH<sub>3</sub>-N were determined to be animal farming and household sewage, whereas the primary sources of SS were determined to be improper earthworks and land clearing activities [41]. Within our river catchments, urbanization has increased population and urban life activities. The quality of run-off within a watershed is usually affected due to urbanization, which has an impact on the water quality of receiving water. Wastewater from



residential, commercial, and industrial sectors has a terrible smell, especially when waste is present, degrades stormwater quality, and pollutes existing river systems [44]. The majority of pollution is anthropogenic, although environmental catastrophes cause some pollution. Water contamination is becoming a more significant concern, with statistics suggesting a decreasing trend year after year [45].

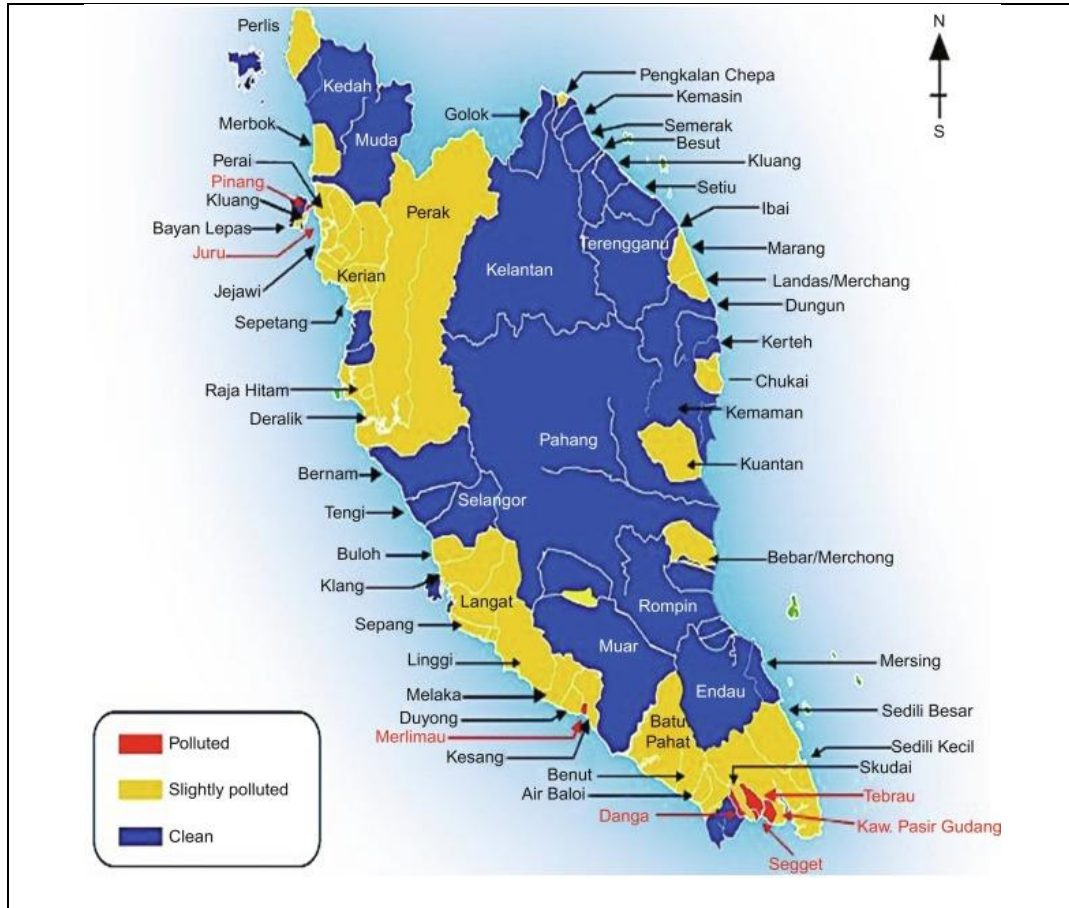


Fig. 7 Polluted rivers map in Malaysia [42] [46]

### 3. Non–Revenue Water

Non-Revenue Water (NRW) can be identified as the difference between the amount of water delivered through the water distribution system and the volume of water invoiced to the consumers. It involved physical water loss, such as leak of pipe and reservoir overflows, water lost commercially through water theft, unrecorded water usage, and other forms of unbilled water consumption or loss. A high rate of non-revenue water raises the risk of water scarcity and negatively impacts people, the environment and the country economic state. On the other hand, a low rate of NRW indicates the water supply system's capability to serve consumers sustainably and profitably while also efficiently generating profit for water utilities.

Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption (Including Water Exported)	Revenue Water
		Billed Unmetered Consumption	
	Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
		Unbilled Unmetered Consumption	
Water Losses	Apparent Losses	Unauthorized Consumption	
		Metering Inaccuracies	
	Physical Losses	Leakage on Transmission And/or Distribution Mains	
		Leakage and Overflows at Utiliti's Storage Tanks	
	Leakage on Service Connection up to Point of Customer Metering		

**Fig. 8** IWA Standard International Water Balance and Terminology [39]

Non-Revenue Water has been threatened Malaysia's water security for decades [31]. The Malaysian government has started handling the NRW issue since Malaysia experienced a severe water crisis in 1997 caused by the El Nino weather phenomenon. According to the 8<sup>th</sup> (2001), 9<sup>th</sup> (2006) and 10<sup>th</sup> Malaysia plan (2010), the government had invested almost USD 750 million from 1996 to 2010 to reduce the country's NRW rate. Unfortunately, Malaysian NRW rates have not decreased as expected. The average NRW rate nationally is around 37% from the year 2000 to 2010 [32]. The amount of NRW losses, according to a study by the Malaysian Association of Water and Energy Research (AWER) from 2008 to 2013, is about RM 10 billion.

Referring to the latest water statistic provided in 2013 by Suruhanjaya Perkhidmatan Air Negara (SPAN), NRW rates of more than 50% were reported by five out of 13 states in the country. This rates proof that all the investments made by the government thus far did not work out. These high rates of NRW have significantly compromised the country's water safety. In addition, agricultural intensification combined with industrial development and population growth has aggravated Malaysia's water issues.

**Table 1**  
 Rate and Volume of NRW of Malaysian State, 2017 [9].

State	Volume of NRW (MLD)	NRW Rate (%)
Terengganu	186	30.4
Sarawak	529	37.8
Perlis	152	63.1
Pahang	528	47.5
Negeri Sembilan	245	32.6
Kelantan	234	49.3
Kedah	651	47.5
Johor	433	24.7
Melaka	101	19.6
Penang	231	21.9
Perak	406	30.9
Sabah	679	53.8
Selangor	1,526	31.5
<b>Malaysia</b>	<b>5,929</b>	<b>35.3</b>



There are many benefits in reducing the NRW rate, for instance: customers would have more access to already treated water. More people will have access to water, water sectors will never have to suffer losses or financial deficits, fairness to customers will be promoted through firm action against those who engage in illegal meter-reading practices, and finally, customer service will be improved [7] [8].

### *3.1 Factors Contributing to Water Loses*

A non-Revenue Water reduction program is usually known as the direct factor to determine the NRW rate in a city. The function of this program is to reduce each of NRW's components, which is apparent losses, physical losses, and unbilled authorized consumption. Technically, these programs are the most important factors in determining the NRW rate. Most of these programs support the use of engineering and technology solutions to reduce the non-revenue water rate. Many believe that solving water problems relies upon an engineering solution. As a matter of fact, others factors from other aspect such as governance, human behaviour, and management also play a really significant role in non-revenue water reduction. Additionally, the government, private company, contractor, consultant, and Politian each impact the outcomes of NRW reduction activities [6].

Additionally, the financial resources of water utilities depend on the type and rate of Non-Revenue Water reduction activity in a city. It is associated with the water tariff, the bureaucracy of the water utility, the types of water utilities such as private, public or public-private and the funding that the government provide to reduce the NRW rate [22]. The private company claimed to have a better financial capability than a public water utility as the water tariffs in private water utilities have a higher rate and are more capable of investing in NRW programmes. Policymakers and politicians play a crucial role in establishing a reasonable water tariff and funding the NRW program. They are also held accountable to raise public awareness and concern on NRW, which in circumlocutory can affect the outcome of the NRW reductions program.

An increase in population could affect the NRW rate of a city [22]. Due to the increased water demands from customers, and will also increase the ramification of water infrastructures. Moreover, improving the efficiency of water utilities in decreasing the NRW rate is from the public participation in NRW reduction programs such as reporting any illegal activity in water consumption such as illegal water use and pipe leakage [24]. Furthermore, cooperation between water utilities, contractors, private companies and the government is required to establish an extensive and suitable plan to reduce the NRW rate in a city [22] [25].

### *3.2 Water service strategies in Malaysia*

The federal government made significant policy statements regarding water in the five-year Malaysia plan, in line with the spirit of the Water Vision as shown in Table 2. In an attempt to provide water security, the strategies use a combination of water supply and demand control approaches. The current unusually cheap water rate will be increased to reflect the actual cost of the water supply and services system when the tariff and billing system is reformed. This acts as just a technique for managing water demand, and it has a significant influence on water demand since customers will use less and conserve more. The goal of establishing a water demand management strategy is to decrease the consumption of treated water for non-potable purposes by utilizing alternate sources such as rainwater collecting, storm water recycling, and treated wastewater. [37] [38].

**Table 2**  
 Strategies to improve water service in Malaysia [31-34]

No	Strategy	Program
1	Water and sewerage services are becoming more productive and efficient	Develop a comprehensive NRW reduction plan Renew sewage treatment plants Develop new treatment facilities
2	Infrastructure investment and efficient technologies are being used to expand the network and treatment plant capacity	Increase the amount of clean and treated water available Connect sewerage services in rural regions
3	Strengthening the water services industry's regulatory framework	Design a comprehensive sewage plan Develop a specific strategy for managing water demand
4	Increasing the water service industry's financial viability	Reform the tariff system

#### 4. Conclusions

Non-Revenue Water has been one of the major issues faced by water sectors in Malaysia for so many years. Financial deficiency of the water sector, ageing in the water infrastructure and lack of public participation and knowledge are common issues in reducing NRW rates in Malaysia. Water utilities are expected to be more active and play a critical role in lowering Non-Revenue Water rates. There is still room for improvement in public participation in NRW management in Malaysia. It requires contributions from all parts of the community to help reduce the NRW rates in Malaysia to achieve sustainable water source management.

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