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Corinne Ong · Cecilia Tortajada · Ojasvee Arora

Urban Water Demand Management

A Guidebook for ASEAN

Lee Kuan Yew School of Public Policy

Institute for Environment and Sustainability

PUB Singapore's National Water Agency

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Foreword by Ridzuan Ismail

PUB, Singapore's National Water Agency, is committed to providing good and clean water. Through the Four National Taps, Singapore has developed a robust and sustainable water supply. However, merely developing the infrastructure to supply water is only one part of the equation. As the population and economy continue to grow, Singapore needs to ensure that the demand for water does not rise at an unsustainable rate.

Water demand in Singapore is currently about 430 million gallons a day. This figure could likely double by 2060 with the non-domestic sector accounting for about 60% of water demand by 2065. As PUB continues to build on water infrastructure and expand water supply capacities, it is also important to manage water demand and achieve a sustainable level of water consumption.

A 2-pronged approach is thus adopted to effectively manage our water demand—through implementing water conservation measures to keep water consumption in check and through efficiently managing the transmission and distribution system from water source to customers' taps to minimise distribution losses.

PUB has implemented a wide range of measures to drive water conservation efforts across households and businesses, such as the Mandatory Water Efficiency Labelling Scheme, the Climate Friendly Household Programme, and the Water-Efficient Building Certification. Last but not least, the ongoing implementation of the Smart Water Meter Programme to install 300,000 smart water meters by 2023 would augment capabilities in early leak detection and empower customers to become more conscious and smarter users of water.

PUB also adopts a holistic approach towards managing the water network. The key components of the approach are broadly categorised as (a) ensuring a good-quality network, (b) active leakage control, (c) full and accurate metering, and (d) strict legislation on illegal draw-offs.

This Urban Water Demand Management guidebook collates best practices of ASEAN countries and other leading cities globally. We hope it will serve as a useful reference for ASEAN countries to adapt to their unique national circumstances.

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Foreword by Vong Sok

Despite the significant progress that ASEAN has achieved in promoting sustainable water resources management over the past twenty years, the region remains challenged with the issue of water security, particularly in cities, among others due to rapid urbanisation, population growth, waste generation, consumption patterns, and climate change. These underpin the need for a comprehensive response and stronger regional collaboration on this subject matter.

Water demand management is among the key priorities under the ASEAN Working Group on Water Resources Management (AWGWRM) Action Plan. Under the leadership of Singapore, the *Urban Water Demand Management: A Guidebook for ASEAN* was thus developed to serve as a significant science-based reference for ASEAN to move towards innovative water demand management in cities. This guidebook comprehensively provides ASEAN with the synthesis of water demand management policies, measures, and practices that are relevant to ASEAN stakeholders. In this light, the guidebook is therefore anticipated to contribute to more effective policymaking on water resources management that considers non-structural approaches to water management as well as conservation and promotion of greater efficiency.

Following the release of the *Urban Water Demand Management: A Guidebook for ASEAN*, enhanced regional cooperation on this subject matter is highly expected, building upon the adaptive recommendations stipulated in the guidebook, namely the need to advance the application of technology for water management and monitoring and strengthen institutional frameworks of national water demand policies and strategies, among others. This guidebook has certainly brought about a higher possibility for ASEAN in its pursuit of achieving the goals of ASEAN Community Vision 2025 and the global development agenda.

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Executive Summary

Southeast Asia as a region, today, faces many socio-economic and environmental challenges, brought on by rapid urbanisation, rising living standards, population growth, and climate change. In ASEAN, countries are faced with increasing challenges in determining how to conserve, allocate, use, and protect water resources for present and future consumption. Globally, cities, in particular, are also facing major water and water-related challenges, such as growing competition between water users, water scarcity and pollution, inefficient water supply systems, increased water demand, and climate change impacts.

In recent decades, greater attention has been paid to the importance of water and local water resource availability. As a response to water scarcity challenges, governments and water service providers are looking to implement water demand management (WDM) measures to provide rapidly growing urban areas with safe, sustainable, and adequate water supplies. Investments in WDM by governments, the private sector, water service providers, and consumers have shown to yield significant environmental, social, and economic benefits for cities, water service providers, and consumers. They depend on the stage of development of the countries and their legal, institutional, human, financial, and technological capacities. WDM also enables countries and cities to achieve greater water security, thus contributing to the attainment of Target 6.4[1] of the United Nations' (UN) Sustainable Development Goal (SDG) 6 (ensuring access to water and sanitation for all) and the UN 2030 Agenda for Sustainable Development.[2]

This guidebook has been developed to document and synthesise knowledge and expertise in urban WDM in ASEAN through comprehensive literature reviews and analysis, as well as stakeholder consultations. It documents urban WDM policies,

[1] By 2030, substantially increase water-use efficiency across all sectors, ensure sustainable withdrawals and supply of freshwater to address water scarcity, and also substantially reduce the number of people suffering from water scarcity (UN-Water, n.d. b).

[2] A blueprint to achieve a better and more sustainable future for all people and the world by 2030, the agenda is made up of 17 Sustainable Development Goals and 169 targets (UN Sustainable Development, n.d.).

measures, and practices that have demonstrated effective implementation outcomes across various contexts and which are expected to be relevant for cities in ASEAN.

A WDM typology developed for this guidebook identifies three key WDM measures, namely *water losses, economic instruments, and non-price mechanisms.* Each of these measures for WDM is described, alongside case illustrations of its effective implementation in different ASEAN cities. Looking to the future, two major potential directions for WDM measures and policies in ASEAN include a review of water tariff levels to improve cost recovery and the adoption of digital technologies for managing water demand more efficiently.

Contents

Abbreviations

ASEAN	Association of Southeast Asian Nations
ATB	Adhya Tirta Batam
AWGWRM	ASEAN Working Group on Water Resources Management
CBA	Cost–benefit Analysis
DMAs	District Metered Areas
DPWH	Department of Public Works and Highways
EBF	European Bathroom Forum
GFA	Gross Floor Area
HDB	Housing and Development Board
IPR	Indirect Potable Use
IWMS	Intelligent Water Management System
KPKT	Ministry of Housing and Local Government in Malaysia
LEED	Leadership in Energy and Environmental Design
LPD or L/P/D	Litres Per Day
MB	Membrane Bioreactors
MWA	Metropolitan Waterworks Authority
NNF	Net night flow
NPNL	Nam Papa Nakhon Luang (Vientiane Capital Water Supply State Enterprise)
NRW	Non-revenue water
NWRB	National Water Resources Board
PBA	Perbadanan Bekalan Air Pulau Pinang
PBAHB	PBA Holdings Bhd
PDAM	State-owned Water Utility in Indonesia
PPWSA	Phnom Penh Water Supply Authority
PT ATB	PT Adhya Tirta Batam
PUB	Public Utilities Board
PV	Present value
RWH	Rainwater harvesting
SAF	Sanitary appliance fee
SAWACO	Saigon Water Corporation

SPAN	Suruhanjaya Perkhidmatan Air Negara (National Water Services Commission in Malaysia)
STP	Sewage Treatment Plants
TGFA	Total Gross Floor Area
UN SDGs	United Nations Sustainable Development Goals
URV	Unit Reference Value
USGBC	United States Green Building Council
USMS	Unified Smart Metering System
UWDM	Urban Water Demand Management
WBF	Waterborne fee
WC	Water closets
WCT	Water Conservation Tax
WDM	Water demand management
WELPS	Water-efficient products labelling scheme
WHO	World Health Organisation
ZCWD	Zamboanga City Water District
ZWAT	Zamboanga Water Audit Team

List of Figures

List of Tables

Chapter 1
Introduction

This guidebook on urban water demand management in ASEAN seeks to document and synthesise good WDM policies, measures, and practices, relevant to ASEAN stakeholders. In particular, the guidebook is expected to be useful to policymakers interested in considering non-structural[1] approaches to water management; to regulators in monitoring and incentivising performance in the water sector; and water service providers in increasing their service efficiency.

The WDM policies, measures, and practices included in this guidebook were drawn from the academic literature and official grey literature from international organisations, governments, and water service providers from the public and private water sectors. Many of these policies, measures, and practices have demonstrated effective outcomes at post-implementation, within and beyond ASEAN contexts. In addition, stakeholder consultations towards the WDM policies, measures, and practices referenced in the guidebook were also sought. Representing these stakeholders were public and private water service providers, policymakers, and public officials from water sectors in ASEAN countries, as well as academics whose expertise lies in water management, policy, and governance. The goal of these consultations was to improve the relevance and accuracy of information presented in the guidebook for use by different stakeholders in ASEAN.

This guidebook is organised into five sections: Section 1 (the present section) introduces readers to the guidebook and its structure. Section 2 defines WDM and the key challenges and potential environmental, economic, and social benefits of its adoption in ASEAN. Section 3 outlines key planning steps for water service providers interested to design, implement, and assess WDM measures. Section 4 presents a typology of key WDM measures that is developed for the purpose of this guidebook. The typology consists of the following measures: (1) water losses; (2) economic

[1] Soft approaches/non-price mechanisms such as public education campaigns and school curricula, water efficiency audits and benchmarking, outreach and communication through utility bills, etc.

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instruments; (3) non-price mechanisms; and (4) alternative water supply systems. The first three themes of the typology are discussed further. They are accompanied by selected case studies of good practice implementation in different ASEAN cities. In conclusion, the final section of this guidebook highlights the top three WDM accomplishments in ASEAN and future directions for ASEAN in its WDM implementation.

Chapter 2
Key Challenges to Urban Water Management in ASEAN

Water is essential for a country's socio-economic development and a key facet of many of the United Nations Sustainable Development Goals (UN SDGs). Access to safe drinking water is vital for healthy societies, biodiversity, and ecosystems (World Bank 2016). Yet, cities worldwide, including ASEAN cities, are facing increasing challenges to their water security. Urban water challenges have escalated due to multiple factors, in particular, rapid urbanisation and urban population expansion; increase in standard of living that results in higher per capita water consumption; increasing industrialisation; ageing infrastructure and a lack of new infrastructure given the requirements; significant non-revenue water losses; and the impacts of climate change on water supply and availability (Boretti and Rosa 2019; Gain and Wada 2014; Lorenzo and Kinzig 2019; Trias 2021; Wang et al. 2020). Some of these challenges are discussed in more detail below.

2.1 Rapid Urbanisation in Developing Countries

In the ASEAN region, 49.5% of the population or 326.8 million people lived in urban areas in 2019 (World Bank 2020). This number is projected to increase by another 70 million by 2025 (ASEAN 2018). Evidently, most cities in ASEAN are witnessing an explosive growth in their population size (Lorenzo and Kinzig 2019), at an average growth rate of 2.4% between 2010 and 2019 (World Bank 2020).

There is a strong relation among economic activity, population growth, and water resource use. Higher GDP per capita and rapid population growth in ASEAN's

C. Ong et al., *Urban Water Demand Management*, SpringerBriefs on Case Studies of Sustainable Development, https://doi.org/10.1007/978-981-19-8677-2_2

Table 2.1 Percentage of total annual freshwater withdrawal

Country	Domestic (% of total annual freshwater withdrawal)	Industry (% of total annual freshwater withdrawal)	Domestic and industrial (% of total annual freshwater withdrawal)
Brunei Darussalam	45.0	49.2	94.2
Malaysia	34.9	42.8	77.7
Singapore	45.0	51.0	96

Source ASEAN Secretariat (2017)

urban areas in recent decades have been accompanied by a surge in water demand.[1] Studies project that the average water consumption of ASEAN cities, such as Yangon (Myanmar) and Penang (Malaysia), will double by 2040, reaching 2519 million litres/day and 1696 million litres/day, respectively (ADB 2020; PBA n.d.). This rise in water consumption has incontrovertibly increased the stress on water sources in ASEAN countries. As a result of greater pressure being placed on the region's water resource availability, water resource per capita availability has decreased.

High rates of annual freshwater withdrawals in the domestic and industrial sectors for ASEAN countries contribute strongly to the declining trend of water availability in the region (ASEAN Secretariat 2017). The freshwater withdrawal percentage for the domestic and industrial sectors (combined) in Brunei, Malaysia, and Singapore represented 94.2%, 77.7%, and 96% of the total annual freshwater withdrawal, respectively. This is illustrated in Table 2.1. As of 2014, the total annual water withdrawal for ASEAN countries amounted to 385 billion m^3, representing approximately 20% of water withdrawals in Asia (ASEAN Secretariat 2017).

Estimates show that between 2007 and 2017, the total water resources in the region have decreased on average by 12%, from 11,171 m^3/capita/year to 12,721 m^3/capita/year (The World Bank n.d.) (see Table 2.2). For instance, Singapore's annual per capita water sources dipped by 18.3% over this ten-year period and the Philippines by 15%. Despite its abundant water sources of 20,025 m^3/capita/year in 2017,[2] Brunei Darussalam also experienced a significant decline in its per capita water resources by almost 11.6% (The World Bank n.d.).

In addition, a proportion of ASEAN's population is living in informal urban settlements without safe and sufficient access to water and sanitation. In 2018—with the exception of Singapore, Malaysia, and Brunei Darussalam—nearly 15% of the ASEAN population (amounting to 91.7 million people) lived in informal urban settlements without adequate access to water and sanitation (UN-Habitat 2020). In 2017, 91.4% of ASEAN's 647.5 million inhabitants reportedly had access to basic or safely managed water. However, 84.9% of these inhabitants still required further treatment of this water for safe consumption (JMP n.d.a).

[1] Average water consumption for domestic and industrial use increases with an increase in GDP per capita growth (Koontanakulvong et al. 2014).

[2] Mainly due to its much smaller population size than Singapore and Malaysia and its proximity to the rest of forest-rich Borneo.

Table 2.2 Per capita water resource availability (m^3/capita/year)

ASEAN country	2007	2017	% decline in water source availability
Brunei Darussalam	22,669	20,025	11.6
Cambodia	8816	7533	14.5
Indonesia	8689	7629	12.2
Lao PDR	32,028	27,383	14.5
Malaysia	21,707	18,646	14.1
Myanmar	20,213	18,788	7.1
Philippines	5358	4554	15
Singapore	131	107	18.3
Thailand	3393	3244	4.3
Vietnam	4208	3799	9.7

Source Ritchie and Roser (2017), The World Bank (n.d.)

Meeting the water needs of a rapidly growing population becomes even more challenging in the absence of adequate urban planning and critical infrastructural maintenance (Lorenzo and Kinzig 2019; WHO and UNICEF 2019; World Bank 2019b). In ASEAN cities, increases in the operational costs of water treatment, transportation, and distribution, as well as infrastructure rehabilitation, pose further challenges to water service providers in meeting the water needs of a burgeoning urban population. For example, in Singapore, the operating expenses[3] of its water system increased by USD 615 million (SGD 0.84 billion) over a 15-year period, due to a rise in operating costs from USD 410 million (SGD 0.56 billion) in 2005 to USD 1.03 billion (SGD 1.4 billion) in 2020 (PUB 2013, 2021).

2.2 Non-revenue Water

Non-revenue water (NRW) has been a leading concern for ASEAN countries due to the high rates of water losses in water supply networks (ADB 2010). NRW management allows water service providers to expand and improve services while enhancing its financial performance. The NRW in the water distribution system may include real losses (actual water losses in water distribution network), apparent losses (water consumption that is not billed to end-users), or unbilled authorised consumption (Alegre et al. 2016; EU ERDF n.d.).

High NRW loss prevents water utilities from providing full and reliable coverage at affordable prices (Liemberger and Wyatt 2019). It also leads to a significant increase

[3] Operating expenses primarily comprise of depreciation of property, plant and equipment (PPE), manpower, maintenance, electricity, research and development, administrative, and other miscellaneous expenses incurred for the collection, production, distribution, and reclamation of water in Singapore (PUB 2021).

in the capital that water service providers must expend on operational and maintenance (O&M) costs to guarantee undisrupted water supply to users (Araral and Yahua 2013; Jones et al. 2021). Moreover, water consumers in the domestic and non-domestic sectors often have little incentive to reduce their water consumption or use water more efficiently (Damania et al. 2017).

As of 2019, the global average NRW rate stood at 30% or 126 billion m^3, equating to financial losses of an average of USD 39 billion/year. Recent estimates suggest that the volume of NRW in Southeast Asia is 6.7 billion m^3 a year or 18.4 million m^3 per day, with the cost/value of water lost amounting to USD 2 billion annually (Liemberger and Wyatt 2019). In general, NRW represents between 25 and 50% of the total water supply and, in some developing countries, accounts for up to 75% of the total water supply (IWA 2015).

NRW rates also vary considerably between ASEAN countries. For example, in 2018, NRW rates in Singapore, Malaysia, Vietnam, and Indonesia were 5.6%,[4] 36.5%, 21.5%, and 32.75%, respectively (PUB 2020; BPPSPAM 2019; SPAN 2018; World Bank 2019a). NRW rates may also vary widely between cities in a country. In Malaysia, for instance, cities such as Pulao Pinang and Johor had NRW rates of 21.7% and 24.19%, respectively (PBAHB 2018; Ranhill 2018). In comparison, the NRW rates of Pahang, Kelantan, and Perlis were considerably higher at 47.5%, 49.3%, and 63.1%, respectively (Jones et al. 2021).

The primary reason for high NRW rates in ASEAN countries is leakage from ageing water infrastructure and deteriorating pipelines (Araral and Yahua 2013). These pose challenges to water service providers in supplying reliable and safe drinking water to end-users (ADB 2010; Kristvik et al. 2019). In many ASEAN cities, the age of water distribution networks and infrastructure is associated with high rates of NRW. To reduce high NRW rates caused by ageing infrastructure, various ASEAN cities, such as Jakarta (Indonesia), Petaling Jaya (Malaysia), and Vientiane (Lao PDR), are planning to upgrade or are in the process of upgrading their water distribution networks (Lee 2021). ASEAN cities such as Phnom Penh (Cambodia) have also benefited from pipe rehabilitation programmes that have been implemented and maintained since 1993 (PPWSA n.d.). Despite an expansion of the pipeline distribution network from 2009 to 2011, NRW rates remained below 6% for the period (Biswas et al. 2021).

Given the persistence of NRW in ASEAN cities, WDM measures could play a critical role in reducing the volume of water loss in these cities and improve water-use efficiency.

[4] Unaccounted for water (UFW) (PUB representative in AWGWRM. Email interview, 7 March 2022).

2.3 Climate Change

Climate change plays a key role in influencing the availability, patterns, distribution, and quality of water resources (Florke et al. 2018; Wang et al. 2020; World Bank 2017). It is expected to have persistent impacts on renewable freshwater resources due to changes in temperature, precipitation trends, and annual surface evaporation[5] (Collins et al. 2013; Hejazi et al. 2014; IIASA 2018). With increased humidity, higher and mid-latitude land masses are predicted to experience significantly higher amounts of precipitation.

Changes in climate differ from country to country within ASEAN, with spatial variations linked to the hydrologic cycle. Wet tropical regions such as SEA are likely to encounter extreme and more frequent precipitation events, which increase the incidence of flooding and contamination of water sources (UN-Water n.d.). Higher temperatures increase surface evaporation and heighten precipitation frequency. The temperatures of inland water bodies in SEA are also predicted to rise by 0.5 to 2.0 °C by 2100. Rising water temperatures induce the growth of bacteria and algae, which deteriorates water quality (Lorenzo and Kinzig 2019). In contrast, semi-arid regions are likely to experience less precipitation and severe droughts, which can impair the resilience and reliability of water supplies (Collins et al. 2013; Trias 2021). Sea level rise has also been attributed to increased risks of saltwater intrusion and fluctuations in groundwater availability. Climate-related risks thus have profound impacts on the quality and availability of potable water in cities and represent an emerging challenge that ASEAN's cities will need to adapt to.

Climate change is transforming the water landscape. Changing rainfall patterns and droughts and floods that are more intense and last longer are affecting availability and variability of water resources adding to water stress and requiring that water is used more efficiently. Less availability of water resources requires that stringent WDM strategies are implemented in order to ensure that water is conserved and that supply is maintained even during changing conditions. Additionally, given the region economic and population growth, more assets and people will be exposed to water extremes unless adaptation and mitigation actions are taken. WDM is one of the most important adaptation measures (Biswas and Tortajada 2022).

2.4 The Role of Water Demand Management in ASEAN

In recent years, water resource management in ASEAN countries has been identified as an issue of strategic importance by the ASEAN Cooperation on Water Resources Management (2020). Urban water demand management, in particular, constitutes one of the identified critical measures for water resource management. The consensus among ASEAN leaders on the imperative of protecting and sustaining water resources

[5] Higher temperatures lead to greater surface evaporation (Lorenzo and Kinzig 2020).

led to the establishment of a dedicated working group—the ASEAN Working Group on Water Resources Management (AWGWRM), in the early 2000s. The AWGWRM provides a consultative platform for ASEAN member states to advance the objective of promoting sustainability of water resources to ensure equitable accessibility and sufficient water availability of acceptable quality to meet the needs of the people of ASEAN (2019).

WDM refers to 'the implementation of policies or measures which serve to control or influence the amount of water used' (EEA 1996). Ultimately, WDM aims to increase the efficiency of water consumption by providing water users with efficient, cost-effective, and more sustainable water supplies, along with the enhancement or protection of water quality (Bao et al. 2013; Butler and Memon 2006; Kampragou et al. 2011; Kayaga and Smout 2011; Smith et al. 2015). Water efficiency can be achieved by means of technical measures (e.g. water-efficient fittings, leakage detection technology), process and operational modifications (e.g. customer engagement, billing procedures), economic incentives (e.g. metering, tariff schemes), and consumer education (e.g. water conservation campaigns) (Kayaga and Smout 2011).

WDM is vital not only for water-scarce countries, but also for countries seeking to improve their internal water security in the long run (Hoa et al. 2017; UN-Water 2016). Traditionally, governments have turned to water supply expansion or supply augmentation, from sourcing for new water supplies, increasing treatment capacity, to expanding treatment and distribution facilities (Trowsdale et al. 2017). This approach, however, is costly on several fronts. Firstly, infrastructure development is comparatively more capital intensive than the cost of implementing water demand management or efficiency measures. Secondly, the environmental ramifications of infrastructure development have been well-evidenced: changes in hydrological flows arising from impoundments and mass withdrawal activities have affected local ecosystem health and water quality; man-made reservoirs have been attributed to significant evaporative water losses; and aquifer pumping activities reduce water quality, increase risks of land subsidence, saltwater intrusion, and reduce river flows (Abansi et al. 2018; Arfanuzzaman and Rahman 2017; Bao et al. 2013; Hoa et al. 2017). Thirdly, the energy costs associated with water and wastewater supply treatment and distribution are substantial and translate to compounded economic costs for water service providers and municipalities (EPA 2016; Escriva-Bou et al. 2018; Kayaga and Smout 2011; Trowsdale et al. 2017).

In the light of these considerations, managing existing water resources more efficiently is comparatively more cost-effective and ecologically beneficial than supply augmentation. WDM measures also serve as a potential contingency measure for countries in times of water shortages, where supply augmentation measures cannot be feasibly achieved within a short time frame. A summary of environmental, economic, and social benefits accruing from WDM implementations is listed as follows:

Environmental Benefits

- Improved water quality resulting from reductions of pollutants (e.g. through diversion and treatment of wastewater for recycling) through the introduction of water-

quality standards for both potable and non-potable water supplies (e.g. greywater, reclaimed wastewater, and rainwater).
- Reduced greenhouse gas emissions resulting from a decrease in energy consumed by new water infrastructures (e.g. water supply, treatment, and pumping) as well as from the installation of water-saving appliances (e.g. dual-flush toilets, low-flow taps, etc.), which consume less energy and water.
- Decreased quantity of water consumed and greater water availability in future.
- Less impact on ecosystems and environmental conditions due to fewer withdrawals from water sources (e.g. groundwater, aquifers, and streams).
- Improved water body aesthetics (e.g. through increased flow of water into rivers which can improve river health).

Sources Abansi et al. (2018), Arfanuzzaman and Rahman (2017), Bao et al. (2013), Hoa et al. (2017), Sauri (2013), Zapana-Churata et al. (2021).

Economic Benefits

- Creation of financially sustainable water systems due to reductions in energy demands (e.g. water extraction, treatment, and distribution).
- Cost savings on water bills of water users due to decreased water consumption.
- Reduction and control of water losses in the distribution system (e.g. leakage from distribution pipes) by reducing non-revenue water (e.g. leakage detection programmes), generating additional revenue for the water service providers to achieve long-term financial sustainability.
- Fewer operational, clean-up, and maintenance costs due to reductions in water treatments and water supply charges.
- Reduction in total water demand by curtailing water waste and misuse. Savings in capital expenditure due to avoiding, downsizing, and postponing expensive infrastructure developments and amendments (e.g. treatment capacities, pumping and delivery networks, and new sources of water supply).

Sources EPA (2016), Escriva-Bou et al. (2018), Russell and Fielding (2010), Kayaga and Smout (2011), Mehan and Kline (2012), Smith et al. (2015), Trowsdale et al. (2017).

Social Benefits

- Improved water service coverage and access to water.
- Improved equity of water supply due to reductions in the quantity of water lost in distribution systems.
- Optimising water use and cross-sectoral efficiency by providing water users with a reasonable allocation of water.
- Encouragement of water efficiency and citizen welfare due to more equitable redistribution of wasted water.
- Strengthening of effective public participation and government openness due to greater public awareness of the importance of water through public outreach efforts (public campaigns, school curriculum, detailed billing information, etc.).

- Reduced present and future water scarcity concerns due to greater efficiency in water consumption.
- Job creation and sustainability of services in water-related sectors (e.g. staff for leak repairs and monitoring, pipe replacements, and public campaign creation).

Sources Arfanuzzaman and Rahman (2017), EBA (2018), UNEP (2015), World Bank (2017).

Despite the many benefits of WDM, participation can be limited by a series of barriers that result from expected negative outcomes, disapproving social pressure, and missed opportunities at the personal, societal, and institutional levels. It is these aspects that can hinder water conservation and thus result in water insecurity in several countries of the region (Wehn and Almomani 2019).

2.5 Key Takeaways

1. ASEAN cities face emerging challenges to their water security. These include rapid urbanisation and urban population expansion; higher per capita water consumption amid improvements in living standards in cities; increasing industrialisation; ageing water infrastructures and a lack of new infrastructure to meet increased water demand, significant non-revenue water losses; and climate change risks to water supply and availability.
2. WDM offers an alternative to governments and water service providers for addressing the emerging threats to urban water security in ASEAN.
3. WDM refers to the implementation of policies or measures which serve to control or influence the amount of water used. WDM aims to increase the efficiency of water consumption and can be achieved through technical measures, process and operational modifications, economic incentives, and consumer education.
4. Compared to supply augmentation strategies, WDM is comparatively more cost-effective and less environmentally invasive in implementation and facilitates both energy and water resource conservation. WDM strategies can also be more readily mobilised in times of unexpected water scarcity.
5. Investments in WDM have been found to yield multiple environmental, economic, and social benefits to governments, water service providers, and end-users.

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Chapter 3
Developing a Water Demand Management Plan

3.1 Introduction to a Water Demand Management Plan

WDM policies and interventions are proposed, legislated, regulated, and implemented by various stakeholders,[1] depending on a country, province, or city's context. Although federal and/or local authorities often propose WDM interventions in the form of strategies, master plans, and legislations, measures are often implemented by the water service providers, particularly in urban contexts (Barsugli et al. 2012; Liner and DeMonsabert 2011).

WDM plan formats may vary from one city to another, depending on the governance system, water service providers, and existing water supply provisions. Developing a fit-to-context WDM plan can help inform water service providers how to achieve efficient water use and encourage water conservation, optimising existing resources before considering the creation of additional resources and infrastructure (Maples et al. 2014; US EERE n.d.; Wang et al. 2020).

It is recommended that water service providers have a clear and well-structured WDM plan that succinctly outlines the design response to managing water demand with clarity. The plan may give consideration to analyses, programmes, policies, and also measures of WDM, along with clear definitions of the following: (1) objectives/targets (short, medium, and long term); (2) approach/process; (3) budget; and (4) time frames of implementation (IUCN 2016; Hoffman and Plessis n.d.).

1. Objectives/Targets: Measurable objectives/targets should be set based on the existing water situation in a given context (i.e. supply–demand) and realistic estimates of what can be achieved through the proposed measures, while avoiding conflicting objectives (China Water 2010; IUCN 2016; Mohammad-Azari et al. 2021; Xiao et al. 2018).

[1] Stakeholders are organisations, individuals, groups of individuals, and political entities with an interest in the outcome of a decision (Victoria State Government 2021). In this context, stakeholders are federal and local authorities, commercial sector, and residential water users.

C. Ong et al., *Urban Water Demand Management*, SpringerBriefs on Case Studies of Sustainable Development, https://doi.org/10.1007/978-981-19-8677-2_3

2. Approach/Process: The WDM plan may include suggestions on the planning approach through a detailed and transparent decision-making process, with clear roles and responsibilities, which can be adapted to varying conditions (EPA 2016).
3. Budget: Adopters may identify the financing arrangement for WDM measures with associated costs on a time frame consistent with the available budget. WDM measures can be evaluated on a cost-effectiveness basis and prioritised based on the greatest potential benefit for the least capital investment (Hoffman and Plessis n.d.; Pacific Water n.d.) or measures that secure significant water savings (refer to Sect. 3.4 of this report).
4. Time Frames of Implementation: Measurable targets may be determined based on established time frames of implementation that are realistic (Hoffman and Plessis n.d.) and that prioritise relevant measures, address immediate needs, and track the progress of implementations (CSE 2017).

3.2 Notable Example of a Water Demand Management Plan: PUB, National Water Agency of Singapore

Singapore's water supply, water catchment, and used water are managed by the Public Utilities Board (PUB), its national water agency (PUB 2021a, b). Presently, Singapore is internationally recognised as a model city for integrated water management, with expertise in water management technologies (PUB n.d.). Forward planning has played a key role in developing Singapore's water infrastructure, where planning instruments such as the 1971 Concept Plan[2] and the 1972 Water Master Plan[3] have set the foundation for long-term water strategies (Tortajada et al. 2013). Through the years, PUB has formulated long-term plans, implemented them promptly, and embarked on an integrated approach to water management, focusing on three key strategies:

- Collect every drop of water.
- Reuse water endlessly.
- Desalinate seawater (PUB n.d.).

Over the years, PUB has directed attention to the growing water demand to ensure that water demand does not rise at an unsustainable rate. Thus, planning has incorporated WDM measures with clearly defined targets, outcomes, and timelines for implementation. This is illustrated in Table 3.1.

To achieve the above, PUB has adopted a multi-pronged approach with several predetermined WDM measures. A summary can be seen in Table 3.2.

[2] Guide to the physical development of Singapore that aimed to ensure the optimal use of limited land resources to meet the residential, economic, and recreational needs of a population that was projected to reach 4 million by 1992 (URA n.d.).

[3] Guide to Singapore's long-term water resource planning that proposed innovations in terms of policies, management, and technology (Tortajada et al. 2013).

Table 3.1 PUB water demand management planning

Focus area	Target	Present outcome	Timeline for implementation
Water consumption	To reduce household water consumption to 130 L/capita/day[4]	In 2019, water consumption/capita/day was 141 L[5]	From 1 January 2022, MWELS[6] was extended to include WC flush valves, and all WC flush valves for sale and supply to be labelled with 2-tick or 3-tick ratings From January 2022, minimum water efficiency requirements for the sale and supply of new commercial equipment (i.e. washer extractors, commercial dishwashers, and high- pressure washers) to be introduced
Water losses	To reduce and minimise water loss in the distribution network	1. As of 2020, PUB has installed 300 permanent leak detection monitoring sensors 2. In 2020, water loss in distribution networks was 8.0%	1. By the end of FY21, install 900 additional leak detection sensors to monitor 500 km (40%) of the transmission pipelines 2. By the end of FY21, review the Digital Master Plan[7] to develop smart technologies 2. 1. Development of a smart water grid for the monitoring of network pressure and leak detection and to improve demand forecasting 3. In the early 2022, commence installation of the first 300,000 smart water meters. This task will be completed by 2023

(continued)

[4] As per the Singapore Green Plan 2030.

[5] Year 2019 was chosen as water consumption in 2020 was affected by COVID-19 and lockdowns (e.g. people spent longer hours at home).

[6] Mandatory Water Efficiency Labelling Scheme. Since July 2009, suppliers have been required to label the water efficiency of their water appliances on all displays, packaging, and advertisements under the MWELS. It follows a grading system with a '0/1/2/3/4'-tick rating to denote water efficiency (PUB representative in the ASEAN Working Group on Water Resources Management. Email interview, 7 March, 2022).

[7] Refer the PUB Sustainability Report FY20/21, page 55. https://www.pub.gov.sg/Documents/Publications/PUB_SustainabilityReport.pdf.

Table 3.1 (continued)

Focus area	Target	Present outcome	Timeline for implementation
Water conservation	Continue to educate and engage various stakeholders through different platforms and modalities to create greater awareness and encourage personal action towards water saving	1. Engage with consumers through various social media platforms: 1. 1. Water conservation campaigns such as, the 'the climate is changing', Singapore world water day (SWWD), #GoBlue4SG movement (FY20) 1. 2. Introduce water-related topics in the school curriculum to deepen knowledge of water sustainability, conservation, and water-saving habits (ongoing) 2. Develop benchmarks and setting standards: launched the Singapore green labelling scheme (SGLS) for commercial water-use appliances (FY20)	Continues engagement and education of various stakeholders on the importance of using water wisely
Alternative water supply systems	To continue to ensure there will be enough water for all for present and future uses	1. 100% population served by tap water supply (FY21) 2. The Keppel Marina East desalination plant opened on 4 February 2021 (capable of producing 137,000 m^3 of fresh drinking water per day) 3. Supply and distribution of NEWater, a highly treated reclaimed water for both potable and non-potable purposes 4. Encourage innovative water recycling solutions through funding schemes, e.g. industrial water solutions demonstration fund (IWSDF) (part of the water efficiency fund) and the national research foundation's (NRF) living laboratory (water) fund	Ongoing works for the Changi NEWater Factory 3 and deep tunnel sewerage system phase 2. The projects are set to be completed by 2023 and 2025, respectively

Source PUB (2021a, b, n.d.), PUB and Keppel Corporation (n.d.)

Table 3.2 Summary of water demand management measures in Singapore

Measure	Implementation
Water loss	• Rigorous and preemptive leak detection programme • Pressure monitoring • Pipe replacements • Smart technologies for leak detection • Metering
Economic instruments	• Increasing block tariff (IBT) mechanism including water tariff, Water Conservation Tax, and waterborne fee
Non-price mechanisms	• Public education campaigns, for example: – 'Let's not waste precious water', 'use water wisely', 'turn it off. Don't use water like there's no tomorrow', 'SAVE water', 'make every drop count', 'clean water begins with you', #GoBlue4SG • Educational programmes in schools: inclusion of water-related topics in the curricula • Water efficiency measures and awards – Singapore green labelling scheme (SGLS), water closet replacement programme, water efficiency awards, water efficiency management practices (WEMP), Mandatory Water Efficiency Labelling Scheme (MWELS)

Source PUB (2021a, b, n.d.)

Singapore's success in water management is grounded in its comprehensive planning systems, where water has been integrated into the city-state's overall development plans, including urban development (Lafforgue and Lenouvel 2015; Tortajada et al. 2013). Through the years, PUB has formulated long-term plans, with clearly defined targets that have been implemented on a timely basis. Quantifiable targets have been set based on the existing water situation and realistic estimates of what can be achieved through the proposed measures (Chen et al. 2011; Lafforgue and Lenouvel 2015).

3.3 Steps to Developing a Water Demand Management Plan

By developing a strategic and comprehensive WDM plan, water service providers can set out specific water-use reduction targets to achieve water conservation goals and seek greater water efficiency through defined targets (CDWR n.d.; EPA 2015; Kiefer and Krentz 2018; US EERE n.d.).

In general, developing a WDM plan involves the following steps:

- Situation analysis. Reviewing existing policies, regulations, water trends, flows, and demands through data collection and analysis.
- Identifying water management constraints and opportunities. Evaluating the implementation of existing WDM measures and identifying applicable WDM

measures where options may be prioritised based on costs, water-saving potential, social acceptance levels, and impact on the water supply–demand balance.

- Undertaking economic analyses of WDM options through various methods, such as cost–benefit analysis[8] and multi-criteria analysis.[9]
- Setting WDM objectives/targets: clear quantitative indicators to measure performance and progress. Possible indicators may include
  - Rate of non-revenue water (NRW).
  - Levels of metering.
  - Unit operations and maintenance costs.
  - Total water consumption.
  - Trends in leakage reduction.
  - Percentage of cost recovery.
- Selecting and prioritising WDM options: screening measures for applicability, feasibility, and acceptability.
- Developing the WDM plan.

Sources CSE (2017), IUCN (2016), Pacific Water (n.d.), US EERE (n.d.).

As discussed, WDM plan formats may differ from one city to another, depending on the governance system, water service providers, and existing water supply provisions. Thus, the steps to developing a WDM plan may also vary based on the governance and water provision context. Table 3.3 provides an overview of selected guidelines to develop a WDM plan for implementation in countries, such as India, France, South Africa, and the USA.

3.4 Notable Example of Water Demand Management Planning

Figure 3.1 highlights a phased, nine-stage approach for a WDM strategy, starting with the collection and verification of data and culminating in the implementation and evaluation of the effectiveness of strategies in place (Pacific Water n.d.).

The guideline is developed by the Pacific Community, an international development organisation that generates research on topics such as water, sanitation, and fisheries science (Pacific Water n.d.). It serves as a support tool for local water service providers, practitioners, and consultants involved in developing and implementing WDM plans. The nine-stage approach demonstrates how water service providers can develop and implement a feasible WDM plan to achieve WDM targets through a step-by-step method. It provides a comprehensive and integrated approach to WDM planning that has been developed for implementation in water-scarce countries

[8] Process to assess monetary values (all costs and benefits) associated with certain measures, decisions, or projects (FAO n.d.; Smart Water Fund 2011).

[9] Process to assess certain decisions, measures, or projects based on multiple objectives and criteria (or attributes) (Dean 2020).

Table 3.3 Overview of selected guidelines to water demand management planning

Source	Description	Developed for the context of	Summary of steps/phases to developing a WDM plan
International Union for the Conservation of Nature (IUCN) (n.d.) IUCN is a membership union composed of both government and civil society organisations. It produces a range of publications, databases, and guidelines for conservation and sustainable development-related topics	The guideline serves as a decision-making support tool for local authorities and water service providers. It provides a detailed stepwise approach to developing a WDM plan	South Africa	1. Situational analysis • Collect and verify water trends, flows, and demand • Identify main water user groups 2. Identify critical water use, supply, management concerns, constraints, and potential opportunities 3. Identify various integrated water resource management options including opportunities to increase non-conventional supplies (i.e. desalination and rainwater harvesting) 4. Formulate detailed and time-bound WDM targets appropriate to the local situation 5. Analysis of WDM options using multi-criteria analysis or cost–benefit analysis 6. Select and prioritise WDM options based on preliminary analysis 7. Determine budget allocation for implementing measures and to identify potential funding opportunities 8. Develop the WDM plan, including targets, measures to be implemented, financial requirements, and a monitoring and evaluation component Key guideline recommendations: • Periodic evaluation and continuous assessment of measures after implementation that would allow for regular modification of the WDM plan, if necessary • Clear quantitative indicators to measure progress and ensure targets are being met (e.g. rate of non-revenue water [NRW], levels of metering, total water consumption). This is crucial as different stakeholders involved in WDM implementation in urban contexts may interpret performance differently

(continued)

Table 3.3 (continued)

Source	Description	Developed for the context of	Summary of steps/phases to developing a WDM plan
Centre for Science and Environment (CSE) (2017) CSE is a public interest research and advocacy organisation. Its research focuses on environmental issues relating to air, water, waste, and energy	The water efficiency and conservation guideline incorporates measures for developing a WDM plan. The guideline is targeted to stakeholders of urban local bodies, municipal corporations, NGOs, higher learning institutes, and private organisations with an interest in water efficiency planning	India	1. Situational analysis. Collect and verify water trends, flows, and demand data. Review existing policies and regulations related to water conservation and management 2. Set measurable and time-bound goals based on the situational analysis 3. Develop a plan by identifying various water conservation measures, determining feasibility level, and estimating cost and benefits of measures 4. Prioritise measures and develop a strategy for implementing the WDM plan. Involve all relevant stakeholders through the planning process 5. Evaluate and modify the plan based on regular assessments after implementation Key guideline recommendations: • 'Situation-driven' approach to planning and consideration of the local context. This may include a review of current policies and regulations and estimation of water trends through data and analysis • The broad involvement/participation of stakeholders in developing the plan ensures that alternative solutions serving a diverse range of interests are considered through a multi-perspective approach to planning

(continued)

Table 3.3 (continued)

Source	Description	Developed for the context of	Summary of steps/phases to developing a WDM plan
Tampa Bay Water (2018) Tampa Bay Water is a regional water service provider. It supplies drinking water to water users in Tampa Bay, Florida	The guide is aimed at local urban households, industries, authorities, and other water service providers interested in implementing a water demand management programme	USA	1. Formulate WDM objectives and targets 2. Economic analysis of WDM options to determine cost–benefit ratios 3. Screen and rank the most appropriate WDM options in accordance with WDM objectives (e.g. by water-saving potential, costeffectiveness, public acceptability, administrative feasibility, etc.) 4. Undertake water demand forecast scenarios to assess future demand scenarios 5. Select the most appropriate WDM measures for implementation Key guideline recommendations: • Regular monitoring and evaluation of WDM plans and measures to support long-term water supply plans • Work with local government authorities to develop WDM implementation strategies consistent with the local requirements. Strategies may have a specific focus on water users or in areas where there is an opportunity to increase conservation efficiency

(continued)

Table 3.3 (continued)

Source	Description	Developed for the context of	Summary of steps/phases to developing a WDM plan
Dutreix et al. (2014) This guideline was developed on behalf of Plan-bleu, one of the Regional Activity Centres of the United Nations Environment/Mediterranean Action Plan and put in place by France since 1977	This guideline is for decision-makers and managers, local authorities, and water service providers. It is a decision-making support tool that analyses various WDM measures through a methodology which characterises, assesses and ranks WDM measures	France	1. Establish an inventory based in the local context • Define the area's geographical and hydraulic conditions • Identify local WDM policies and measures 2. Identify the short, medium, and long-term objectives and prioritise the needs of all user categories and the natural environment (e.g. increased demand, seasonal variation, etc.) 3. Identify the WDM measures already in place and preselect appropriate WDM measures through various analyses, e.g. multi-criteria analysis, SWOT analysis,[10] etc. 4. Assess each preselected WDM measure through a cost–benefit analysis 5. Use indicators to determine which WDM measures to implement (e.g. performance indicators or results indicators) Key guideline recommendations: • Establish a monitoring and assessment system to regularly evaluate the WDM measures implemented • The frequency of data analysis should not be too high (processes may have restrictive time limits or high costs) nor should it be too low (data must be able to reflect potential seasonal factors, such as variation in climate conditions or peaks of activity in some sectors)

Source IUCN (n.d.), CSE (2017), Tampa Bay Water (2018), Dutreix et al. (2014)

[10] Tool for assessing strengths, weaknesses, opportunities, and threats of a particular measure, decision, or project (Gürel 2017).

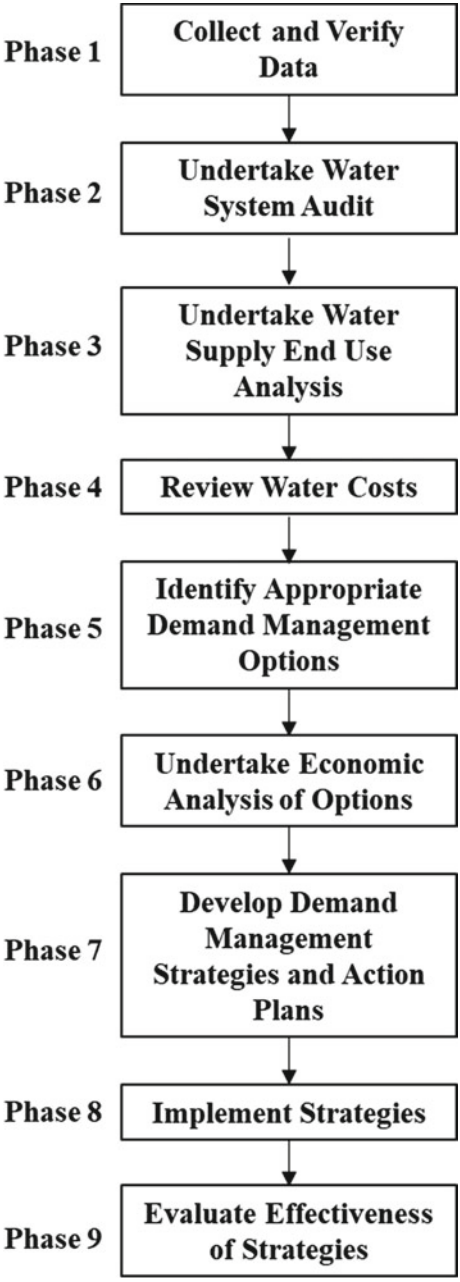

Fig. 3.1 Water demand management process. *Source* Pacific Water (n.d.)

such as Australia[11] (Pacific Water n.d.). In addition, this considers several aspects of relevance to water service providers for WDM planning and implementation, such as system audits, end-use analyses, and economic assessments. This example also acknowledges the valuable role of broad stakeholder participation in providing feedback to water service providers in the WDM planning and implementation process.

The water demand management process involves the following:

Phase 1: Collect and verify data to identify critical constraints and opportunities. This can include collating information related to

(a) Bulk meter readings within the water network.
(b) Wastewater flows and assessments.
(c) Rainfall estimates.
(d) Prior information on leakages within the network.
(e) Daily flow trends of the water system.
(f) Existing information gaps.

Phase 2: Undertake a water system audit. This would help assess all water flows within the system. As a water audit can track water loss by identifying and quantifying potential leaks, it may be followed by a meter testing and calibration programme. Water service providers may also undertake customer and operational investigations for potential leaks or unauthorised consumption (theft) to prevent (further) loss of revenue (EPA 2015; Pacific Water n.d.;Van Arsdel 2021). A preliminary top-down[12] water audit may be conducted as follows:

(a) Identify the amount of water added to the system (typically for one year).
(b) Identify authorised water consumption (billed + unbilled water).
(c) Calculate water losses (water losses = system input − authorised consumption) (CSE 2017; EPA 2015).

Phase 3: Undertake a water supply end-use analysis. This may include the following:

(a) Identifying customer use profiles and water usage patterns.
(b) Identifying customer water demand trends (i.e. number of connections versus consumption range) (Pacific Water n.d.; US EERE n.d.).

Phase 4: Review operational and maintenance-related costs (Pacific Water n.d.; US EERE n.d.)

Phase 5: Identify appropriate water demand management options by selecting and prioritising options based on measure applicability, feasibility, and acceptability

[11] Australia represents a case study of 'good' WDM practices. Despite the Millennium Drought (1997–2012) that affected most of Southern Australia as well as an increase in the national population, the water consumption levels have declined since 2012 (Government of Australia 2019). This suggests that Australia's WDM plans and measures, implemented in response to the Millennium Drought, had a strongly positive effect on water consumption and habits.

[12] A water audit is initiated at the 'top'. As it is based on existing information and records, additional fieldwork is not required (EPA 2015).

(CSE 2017; McDonald and Mitchell 2019; Rathnayaka et al. 2016; Victoria State Government 2021). The appropriate amount of water demand measures may vary, depending on the governance structure, level of development, and the degree of water scarcity in each city (Global Water Partnership 2012).

Options may be prioritised according to their (a) water-saving potential; (b) social acceptance; and/or (c) impact on the supply–demand balance.

(a) Water-saving potential refers to the total amount of water saved by different water user groups, which may vary considerably in accordance with the WDM measure in question (Pacific Water n.d.; Wang et al. 2020). To determine the water-saving potential of a given WDM measure, a prioritisation analysis of WDM measures can be undertaken by governments and/or water service providers to determine and select the most sustainable WDM options (Bello-Dambatta et al. 2013; Rathnayaka et al. 2016).

(b) Social acceptance refers to a collective consensus of stakeholders and institutional feasibility for the implementation of WDM measures (Butler and Memon 2006). It includes the impacts on society through public perception, politicisation, individual acceptance, and use adaptation (Al-Saidi 2021; Rathnayaka et al. 2016). Despite some WDM measures being more socially acceptable than others, an absolute level of social acceptance for each WDM measure has not been established (CSIRO 2010).

    Effective public education and awareness campaigns, such as public communications through the media (Tortajada and Nambiar 2019), as well as social norms,[13] can influence the social acceptance and public opinion of WDM measures (Lede and Meleady 2018). The social acceptability of WDM measures may also increase when there is a need to reduce water use, such as in times of drought (Bello-Dambatta et al. 2013).

(c) Impact on the supply–demand balance refers to the influence that WDM measures can have on the supply of and demand for water. The current supply and demand of water is influenced by the availability of freshwater and impacts of climate change (Gosling and Arnell 2016; Lede and Meleady 2018). This includes extreme hydrologic events such as droughts, floods, typhoons, and cyclones that create uncertainties about traditional sources of water supply (e.g. freshwater), (Bello-Dambatta et al. 2013; Bloetscher et al. 2014; Xiao et al. 2016).

    At the same time, urbanisation, rapid population growth, and competing water uses (domestic, commercial, and industrial) also affect water demand (Chen and Trias 2020; Cousin et al. 2019; Hartley et al. 2019; Subramanian 2019). Identifying and assessing the potential impact of these influences over the existing supply–demand balance can enhance the decision-making process (Smart Water Fund 2011).

[13] Social norms are signals that can help people make sense of social situations, particularly in terms of the expectations of people's behaviour, by guiding or constraining human behaviour. This social influence approach is increasingly being used by water service providers and related organisations to encourage 'green' behaviour (Lede and Meleady 2018).

To maintain the water supply–demand balance and safeguard the security of future water supply, an array of WDM measures can be implemented. As different WDM measures will have different impacts on the supply–demand balance, governments and water service providers can assess and determine which WDM measures are appropriate for certain areas as well as which WDM measures will improve the water supply–demand balance (Rathnayaka et al. 2016; Victoria State Government 2021). If it is deemed that water demand must be reduced, then other factors, such as cost-effectiveness, may need to be adjusted accordingly to facilitate this (Bello-Dambatta et al. 2013).

Phase 6: Undertake an economic analysis of options.

Reliable estimates of water consumption and operational costs are necessary to evaluate this consideration. An economic analysis of options can be undertaken to guide the prioritisation of options. The chosen approach to an analysis of this kind should be bespoke to the initiative being considered (CSE 2017; Pacific Water n.d.; Victoria State Government 2021).

(a) Cost–benefit analysis (CBA). CBA is the most widely recognised economic tool by public and private sector organisations for the evaluation of investments or to appraise the desirability of certain measures, decisions, or projects. It involves identifying the monetary values for all costs and benefits associated with these measures, decisions, or projects (FAO n.d.; Smart Water Fund 2011).
With the objective of maximising the value of benefits received, CBA can help to determine whether benefits outweigh costs over a given period of time[14] (t) and by how much (Hoffman and Plessis n.d.; Malm et al. 2015; Smart Water Fund 2011). This may be supported by a proposed timeline for the implementation of these WDM measures along with the rationale for adopting the measure (Victoria State Government 2021).
(b) Unit Reference Value (URV). As certain costs and benefits associated with WDM measures may be difficult to quantify, an alternative method of assessing economic efficiency is the Unit Reference Value (URV). This measure was specifically developed to evaluate projects/measures in the water sector (Hoffman and Plessis n.d.; Niekerk and du Plessis 2013). The present value (PV) of the water supplied is calculated by projecting the value of water supplied over a stipulated period of time and discounting it at a predetermined rate (r). The same approach is employed to calculate the PV of costs.[15]

According to this approach, costs refer to those directly related to the quantity of water delivered.[16] The URV can then be calculated by dividing the PV of all

[14] To take into account the time value of money.

[15] These costs are determined at constant prices and adjusted to exclude any taxes and subsidies (Niekerk and du Plessis 2013).

[16] E.g. costs due to water pumping, water transportation, water treatments, etc. (Niekerk and du Plessis 2013).

costs incurred by the PV of the quantity of water supplied[17] (Niekerk and du Plessis 2013). The yield can be calculated on an annual basis. As part of the decision-making process, the URVs of different WDM measures may be compared and prioritised based on the lower URV values.

Phase 7: Develop demand management strategies and action plans that describe key stakeholders' roles, responsibilities, and funding sources, consistent with statutory regulations and stakeholder vision (Kiefer and Krentz 2018; Smart Water Fund 2011; US EERE n.d.). Involving stakeholders in WDM planning serves the dual purposes of generating a feedback mechanism between water users and water service providers, while also educating water users on efficient water use (CSE 2017). Where action from external parties may be required, negotiations may be completed by this stage.

Phase 8: Implement strategies against pre-defined targets. The implementation process can include

(a) Short-term strategies for immediate implementation and prompt visible impacts (McDonald and Mitchell 2019; Wang et al. 2020).
(b) Long-term strategies for implementation over a longer stipulated period (China Water 2010).

Phase 9: Evaluate the effectiveness of strategies through regular monitoring and evaluation arrangements. Designate a unit dedicated to monitoring and evaluation. Annual reviews may be undertaken to assess the effectiveness of the implementation of WDM measures. This would allow certain approaches to be brought forward or deferred, based on the evaluation or new information (Pacific Water n.d.; US EERE n.d.; Victoria State Government 2021).

3.5 Key Takeaways

1. Developing a coherent and well-structured WDM plan, that is fit-to-context can help water service providers achieve more efficient water use by optimising existing resources before considering the creation of additional resources.
2. A fundamental aspect of the WDM planning and implementation processes is the inclusion of stakeholders and, in particular, stakeholder feedback. This can help improve communication and coordination between the parties involved in these processes. For water service providers in ASEAN cities, attending to stakeholder opinions (e.g. federal local authorities and residential and non-residential water users) on WDM measures can help better address both the present and future needs of water users through a multi-dimensional approach to planning.
3. For ASEAN cities, a holistic nine-phase approach to WDM planning is recommended. By starting with the collection and verification of data (first step) and

[17] URV = PV of costs/PV of quantity of water supplied (Bester et al. 2020; Niekerk and du Plessis 2013). A graphic illustration of the URV is shown in Appendix A.

culminating in the implementation and evaluation of the WDM measures in place, the method demonstrates how the design objectives can be met.

4. To further support the WDM implementation process, it is recommended that there is monitoring and assessments of the WDM measures once they are in place. Regular evaluations of the WDM ensure that they can adapt to the changing conditions and remain effective. For ASEAN cities, this may take the form of, for instance, annual or 6-month reviews by water service providers or the establishment of a WDM unit within the water ministry/water resources department of the local government to coordinate with water service providers.

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Chapter 4
Key Water Demand Management Measures

The guidebook contains a WDM typology that has been developed by the authors, following a systematic literature review of academic and non-academic literature sources.

The typology comprises 56 indicators, which are classified into four different categories of WDM applications, namely (1) water losses; (2) economic instruments; (3) non-price mechanisms; and (4) alternative water supply systems. Alternative water supply systems do not reduce water demand, and thus, they will not be discussed in detail. However, they alleviate the need for water abstraction and thus strengthen water security. Advances in treatment processes for different types of water supply systems have further expanded the range of alternative supply options for differentiated end uses; improve the effectiveness of systems to treat and reclaim water to attain or exceed public health and environmental standards; and reduce the economic cost of adoption. (Table 4.1).

C. Ong et al., *Urban Water Demand Management*, SpringerBriefs on Case Studies of Sustainable Development, https://doi.org/10.1007/978-981-19-8677-2_4

Table 4.1 Water demand management indicators

WDM typology	WDM indicators
Water losses	Leakage/NRW reduction target and monitoring mechanism
	Leak detection—mains
	Leak detection—secondary network
	Leak detection—DMA creation
	Leak detection using water balance calculations
	Leak detection/commercial loss reduction using customers' input
	Leak detection by survey
	Raw water (quantity and quality)
	Regulations/policies relating to installation of master connections (to informal settlements/private developments)
	Pipe repair and replacement
	Pressure management
	Technology usage for leak detection and repairs
	Programmes to identify, remove, and replace illegal connections
	Leak detection/commercial loss reduction using customers' input
	Suspend supply for non-payment
	Legal/regulatory measures relating to non-payment
	Meter replacement and upgrading programmes
	Meter calibrations
	Meterisation
	By hiring more people in NRW team
	Increase access to meters
	Involvement of local police
	Programmes to reduce meter tampering (education, penalties)
	Customer information management (updating customer databases, bill accuracy, anomaly identification, and rectification)
	Individual household metering (policy)
	Individual household metering (programme, e.g. to replace building/block meters with household-level meters)
	Support for households to reduce internal plumbing leakage
	Tariff reclassification
	Pilot for NRW reduction
	Pilot for NRW reduction (prepaid meters)

(continued)

Table 4.1 (continued)

WDM typology	WDM indicators
Economic instruments	Tariff structure
	Rebates/incentive schemes for consumption reduction through water bill
	Fines for excessive use
Non-price mechanisms	Household water-use cap (e.g. seasonal)
	Cap/ban on water use for particular purposes (e.g. garden irrigation)
	Household consumption guidelines (per cap/household, unit of output, etc.)
	Benchmarking water efficiency of large users (non-residential/industry)
	Public education campaigns on saving water, sources of water, value, cost of water services, rate structure, customer's own water-use patterns, and simple water efficiency solutions
	School curriculum
	Water rationing drills
	Detailed billing information—households
	Detailed billing information—key accounts
	Water efficiency audits—households/offices
	Water efficiency audits—key accounts
	Key account servicing—households
	Key account servicing—key accounts
	Water efficiency labelling
	Water-efficient appliance market interventions
	Competitions/targets (e.g. 10 litre consumption reduction challenge)
Alternative water supply systems	Policies relating to facility/building/household level non-potable recycling—advisory
	Policies relating to facility/building/household level non-potable recycling—regulatory requirement
	Policies relating to facility/building/household level non-potable recycling—economic incentives
	Policies relating to facility/building/household level water harvesting (rainwater/stormwater/greywater)—advisory
	Policies relating to facility/building/household level water harvesting (rainwater/stormwater/greywater)—regulatory requirement
	Policies relating to facility/building/household level water harvesting (rainwater/stormwater/greywater—economic incentives
	Incentives/regulatory requirement for dual piping in new developments

The following sections discuss the key WDM typology measures that are consistent with WDM practices recommended in most available international guidelines. These include those from international organisations such as the World Bank, Asian Development Bank (ADB), Organisation for Economic Co-operation and Development (OECD), European Union Regional Development Fund (EU ERDF), Environmental Protection Agency (EPA), and water associations such as the International Water Association (IWA).

Chapter 5
Water Losses

Water loss is defined as the difference between water pumped into the system and billed water (AIIB 2020; ADB 2010). The volume of water lost depends largely on the quality, maintenance, and approach to active leakage control of the water distribution network (EU ERDF n.d.). The volume of water lost before reaching water users is referred to as non-revenue water (NRW).

High NRW rates result from the loss of large quantities of water through leakages in water distribution networks. The losses comprise real losses (actual water losses in water distribution network) and commercial or apparent losses[1] (water consumption that is not billed to end-users) (Alegre et al. 2016; EU ERDF n.d.). NRW may result from poor management, lack of support from water service providers, untimely replacement of devices, inappropriate selection of pipes, or water theft. Physical factors, such as the distribution network or density of piped connections, and environmental factors, such as soil conditions, also elevate NRW rates (Jones et al. 2021; Lambert et al. 2014; Tabesh et al. 2018).

NRW management can reap several benefits for water service providers, such as greater reliability of supply, lower operational and maintenance costs, and preventing revenue loss (Al-Washali et al. 2019). In some cases, strong NRW management can also delay the development of new water distribution networks, due to the improved productivity of existing infrastructures (Liemberger and Wyatt 2019). As such, studies indicate that reducing global NRW rates by one-third can amount to savings that equate to serving 800 million people[2] and an annual global financial saving of USD 13 billion (Liemberger and Wyatt 2019).

In 2019, it was estimated that the global annual volume of NRW was 126 billion m^3, at the cost of USD 39 billion per year (Liemberger and Wyatt 2019). Although the global average NRW rate is 35%, this water loss can represent up to 60% of

[1] Refer to Sects. 5.7, 5.8, 5.9, and 5.10 of this guidebook for additional information on apparent losses.

[2] Assuming a consumption of 150 L/capita/day (Liemberger and Wyatt 2019).

C. Ong et al., *Urban Water Demand Management*, SpringerBriefs on Case Studies of Sustainable Development, https://doi.org/10.1007/978-981-19-8677-2_5

the water supplied in various low-income nations (Nasara et al. 2021). These hefty numbers underline the importance of effective NRW management.

NRW management for reducing water losses may be achieved in multiple ways, namely

1. Leak detection and pipe replacement: It can be achieved through a combination of active leakage monitoring, control and speedy repairs, targeted pipe replacements, and pipeline rehabilitation measures (Water Services Association 2019; Li et al. 2016). Appropriate leakage management can help recover revenue from water losses and, in some cases, mitigate the need for water source expansion (Bello-Dambatta et al. 2013; EPA 2016).
2. Technology usage for leak detection and repairs: Modern leak detection technologies include both hardware and software-based tools (Li et al. 2015). Such devices can quickly identify problem areas and leakages in the distribution network, better evaluate their impacts on water loss volumes, and improve the ability of service providers to respond rapidly and repair leaks (Elliott and Bartram 2011; Cassidy et al. 2021).
3. District Metered Areas (DMAs): A division of the water distribution network into smaller sections or zones with defined boundaries. It is a systematic approach to operational management that allows water service providers to analyse water-flow[3] profiles, identify potential problem areas with greater ease, and, thus, reduce leakage detection time (Al-Washalli et al. 2019; ADB 2010; Eliades and Polycarpou 2012).
4. Pressure management: Monitoring, regulating, and maintaining adequate pressure in water distribution systems. It contributes to leakage reductions, decreased new burst frequencies, and reduced water use (Vicente et al. 2016).

5.1 Leak Detection and Pipe Replacement

Leakages may be classified as 'background' leaks (small undetected flows), 'unreported' leaks (moderate-flow rates which gradually accumulate), and 'reported' leaks (heavy detectable leaks that require immediate repair) (Eliades and Polycarpou 2012). Common causes of leakages include ageing pipelines, poor condition of distribution network, and damage to exposed/improperly sealed pipelines (Elliott and Bartram 2011). Estimates suggest that leaks and physical pipe breakages lead to the loss of over 32 billion m^3 of treated water every year globally (Jones et al. 2021). Thus, as a large percentage of water supply is lost when distributed, reducing leakages at this stage is essential (EPA 2016). Appropriate leakage management can help recover revenue from water losses and in some cases mitigate the need for water source expansion (Bello-Dambatta et al. 2013; EPA 2016).

Leakage detection and pipe replacement can be achieved through a combination of active leakage monitoring, control and speedy repairs, targeted pipe replacements,

[3] Data of water entering and exiting the DMA.

and pipeline rehabilitations (Water Services Association 2019; Li et al. 2016). Active leakage detection involves identifying existing leakages on a regular basis through both acoustic[4] and non-acoustic[5] leakage tools (Charalambous et al. 2014). Following leakage identification, decisions about repair, replacement, or rehabilitation of the pipeline can be undertaken. These decisions may be influenced by factors such as pipeline conditions, performance, and deterioration rates (Charalambous et al. 2014). Once the target level of leakage has been achieved, regular checks on leakage control can help ensure that leakage levels do not increase over time (Wu and Liu 2017). When network leakages have been identified and repaired, service providers can also better gauge the extent of illegal connections and other forms of water thefts (ADB 2010).

Leak detection and pipe replacement programmes are in wide use across the ASEAN region. For instance, in Thailand, the Metropolitan Waterworks Authority (MWA)[6] has focused on repairs and improvements to the security of its waterworks systems (MWA 2020). It has reduced water losses by replacing damaged pipes and installing new pipes where required, which has resulted in a water loss reduction of 1.92% (between 2017 and 2018), with a water loss rate of 29.83% in 2018 (MWA 2018).

On identifying potential leakages, targeted pipe replacement programmes may be a more cost-effective solution than the extensive large-scale replacement of pipes. However, large-scale replacements can be adopted if piped networks are in poor operational conditions, or if leak repair and targeted pipe replacements do not reduce leakages (Charalambous et al. 2014; Wu and Liu 2017).

In Phnom Penh, Cambodia, Phnom Penh Water Supply Authority (PPWSA)[7] has actively implemented and maintained a large-scale pipe replacement programme since 1993. By 1999, a majority of the older 288 km pipeline network had been replaced. The entire rehabilitation process was completed by 2002 with all of the replacement work performed by the PPWSA staff (PPWSA n.d.-a). Further, a leak repair team was on standby on a 24/7 basis to repair any leakage in the water distribution network. This ensured that repair work could begin within an hour of receiving information about the leak (PPWSA n.d.-c). Such measures[8] helped reduce water leakages and NRW rates, from 72% in 1993 to only 9.78% in 2020. Despite an expansion of the pipeline distribution network from 2009 to 2011, NRW rates were maintained below 6% at all times (Biswas et al. 2021). Estimates suggest that the steep decline in NRW rates between 1993 and 2013 amounted to savings of USD

[4] E.g. mechanical listening sticks and ground microphones (ADB 2010).

[5] E.g. ground-penetrating radar technology, infrared photography, and gas injections.

[6] Agency responsible for the production, transmission, and distribution of water in Bangkok, Samut Prakan, and Nonthaburi.

[7] PPWSA is a state-owned utility, operating under commercial law, and is responsible for supplying drinking water to Phnom Penh.

[8] In combination with other WDM measures such as metering, programmes to identify illegal connections and suspension of supply for non-payment (Biswas et al. 2021).

150 million, due in part to the deferral of investments for water supply expansion (Water Global Practice n.d.).

5.2 Technology Usage for Leak Detection and Repairs

Leak detection and associated monitoring technologies have become increasingly sophisticated over time. Real-time monitoring[9] tools can identify potential problem areas and leakages in the distribution network, better evaluate their impact on water loss volumes, and improve the ability of service providers to respond rapidly and repair leaks (Elliott and Bartram 2011; Cassidy et al. 2021). Such technology can also imbue greater efficiency in ongoing leak detection operations (Al-Washalli et al. 2019) and help provide an estimate of the gradual accumulation of 'background' leaks not visible on the surface, comprising 90% of water lost through leakages (ADB 2010). Such background leaks can remain unidentified for months or years. For example, a minor leak of 4 L/min can result in the water loss of over 2 million litres/year (Elliott and Bartram 2011).

Modern leak detection technologies include both hardware- and software-based tools (Li et al. 2015). Hardware tools include acoustic detection devices (e.g. mechanical listening sticks, ground microphones, and leak noise correlators[10]) (ADB 2010; Elliott and Bartram 2011) and non-acoustic devices (e.g. ground-penetrating radar technology, infrared photography, and gas injections). Given the expensive nature of the equipment and the number of people needed to operate the tools, these methods are often costly. On the other hand, software-based tools such as water monitoring applications through sensors and smart meters[11] are more economical to implement. Such devices offer real-time monitoring and statistical analysis of water flows (on an hourly or daily basis) and thus estimate the volume of real water loss (Li et al. 2015; Loureiro et al. 2016; Wu and Liu 2017). The data derived from these processes can also help assess pipeline conditions to better plan and schedule pipe replacements and rehabilitation programmes (PUB 2020).

Modern technology usage for leak detection and repair has been widely adopted across ASEAN cities, such as in Singapore, Jakarta (Indonesia), Phnom Penh (Cambodia), Metro Manila (the Philippines), Johor (Malaysia), Bangkok, Samut Prakan, and Nonthaburi (Thailand), Vientiane (Laos), and Ho Chi Minh City (Vietnam). In Singapore, PUB, National Water Agency of Singapore, conducts regular inspections and leak detection surveys using advanced software-based technologies to reduce the leakages (CLC 2012). It utilises an Intelligent Water Management System (IWMS) for real-time monitoring of water assets across the network,

[9] Delivery of continuously updated information.

[10] Computerised equipment used to identify the exact leakage points in the distribution network (ADB 2010).

[11] Refer to Sect. 5.7 of this guidebook for further information on water meters (traditional and smart water meters).

thus providing a comprehensive overview of operations for timely action (PUB 2014). As of 2020, PUB has installed 346 water sensor stations across the city-state to monitor and track the water pressure of the distribution network. This has eliminated the need for installing temporary pressure loggers and pre-empted issues such as potential pipe bursts and leakages that influence pressure volatility (PUB 2020).

Similarly, in Jakarta, Indonesia's capital city, water service providers PALYJA and Aetra have installed both hardware and software-based leakage detection systems to provide early-warning alerts for leakages. For instance, AQUADVANCED—a sensory technology—has been used by PALYJA, and the leak noise correlator (underground pipe leakage detector), by Aetra. The AQUADVANCED technology also includes a 'live' hydraulic model of PALYJA's water distribution network to compare the modelled and actual conditions, thus improving water-flow monitoring and supporting decision-making (PALYJA 2016). Since its implementation in 2016, the 450 sensors using AQUADVANCED technology have detected 10–20 anomalies in the water distribution system daily (PALYJA 2016).

5.3 Leakage Detection—District Metered Areas (DMAs)

District Metered Areas (DMAs) are recognised as one of the most cost-effective methods to overcome water losses (Hou 2018; Bui et al. 2020). This involves a division of the water distribution network into smaller sections or zones with defined boundaries. Doing so allows the water service provider to analyse water-flow[12] profiles, identify potential problem areas with greater ease, and, thus, reduce leakage detection time (Al-Washalli et al. 2019; ADB 2010; Eliades and Polycarpou 2012).

Effective analysis of DMA water-flow data can reduce the duration of water loss significantly as zoning[13] contributes to a systematic approach to operational management (Bui et al. 2020; Kayaga and Smout 2011). Studies demonstrate that the introduction of DMAs can contribute to a leakage reduction benefit range of 26.6% to 59.7% on average, where leakage reduction improves with an increase in the number of DMAs (Ferrari and Savic 2015). The smaller the zonal distribution, the greater the availability of information and efficiency of leak detection. The division of the water distribution network into smaller sections can also protect the rest of the network from potential contamination events (accidental or malicious) (Bui et al. 2020). Moreover, as a by-product, DMA creation entails easier identification of illegal connections when leakages are repaired[14] (ADB 2010).

Although developed and developing countries alike have adopted DMA creation as a best practice for leakage monitoring, there is no universally acknowledged

[12] Data of water entering and exiting the DMA.

[13] Division of the water distribution network into smaller sections.

[14] If water-flow data indicates significant water loss (and unaccounted water) after leakage repair, it can indicate the presence of illegal connections (ADB 2010).

prototype for optimal zoning. Rather, countries often rely on their own local expertise and context (e.g. hydraulic, economic, topographic, and other practical factors) (ADB 2010; Di Nardo et al. 2013; Kayaga and Smout 2011). The water distribution network size has a bearing on the number of DMAs established, with one DMA for every 1000–5000 connections (World Bank 2016). However, where water networks are older, DMAs of approximately 500 service connections have been found to be reasonable (ADB 2010).

Due to its essential role in NRW management, DMA creation has been widely adopted in many ASEAN cities, for instance, in Jakarta and Bogor municipality (Indonesia), Metro Manila (the Philippines), Johor (Malaysia), Vientiane (Laos PDR), Ho Chi Minh City (Vietnam), and Singapore.

Although DMA creation is under the purview of water service providers in ASEAN, in Indonesia, BPPSPAM[15] (PUPR Ministry's Water Service System Improvement Body) has developed a guidebook for DMA creation, which applies to areas with high water loss comprising 500–3000 water connections (BTAMS I n.d.). In Jakarta, the water service providers PALYJA and Aetra have introduced DMAs to improve leakage detection (Aetra 2018; PALYJA 2016). As of 2014, PALYJA had established 95 DMAs and aims to build 52 more DMAs (PALYJA 2015). Similarly, Aetra established 174 DMAs by 2013 (Aetra 2018). As a result of DMA creation and leakage detection systems, 35,916 leakages were detected by PALYJA in 2016. This represented a 28% increase in leakage detection from 2015 (28,067 leakages) (PALYJA 2015, 2016). Meanwhile, Aetra increased leakage detection from 22,932 leaks in 2015 to 25,587 in 2016 (Aetra 2016).

In Johor, Malaysia Ranhill adopted a technology-driven approach and created SMART DMAs with semipermanent noise loggers (Ranhill Holdings 2019a). The implementation of SMART DMAs involved remote correlating noise loggers to detect leakages using GPRS transmission data on net night flow (NNF). The results from the initial installation (SMART DMA trial) of 295 noise loggers in Bandar Putra indicated a 35% reduction in NNF from 30.99 to 20.08 L/s after three months. This contributed to savings amounting to USD 4,000 per month for Ranhill SAJ (Primayer n.d.). By 2019, as many as 1128 DMAs had been created in Johor, with 43 DMAs created in 2019 alone, accounting for 95% of Ranhill's total connections (Ranhill Holdings 2019a).

5.4 Pressure Management

Pressure management is a key element of WDM that seeks to control and manage leakages by monitoring, regulating, and maintaining adequate pressure in water distribution systems. Pressure management can contribute to leakage reductions, decreased new burst frequencies, and reduced water use (Vicente et al. 2016). A reduced leakage rate can help further extend infrastructure life span and obviate

[15] Appointed to develop and implement national water service policies and strategies.

investment in new developments (Wu et al. 2011; Lambert et al. 2014). The volume of leakage has a linear relationship with the pressure system, such that decreasing pressure can reduce leakage (Bui et al. 2020). Estimates indicate that an average pressure reduction of 37% can reduce new pipe breakages by 53% on average (Thornton and Lambert n.d.).

In practice, pressure is regulated through measures of tank regulation, pump control, and pressure-reducing valve (PRV) installed in the water distribution network (Vicente et al. 2016). For greater pressure control over a smaller area, the PRVs are commonly installed at the DMA inlets[16] (Fontana et al. 2018). In addition to water demand, the pressure set by the PRV can depend on factors such as pipe elevation, topology, and building height (Fontana et al. 2018).

As a first step towards leakage management, it is recommended that pressures of the water distribution network be monitored and optimised to remove any excess pressure in the system (Charalambous et al. 2014). Pressure control is effective in preventing leaks by minimising pressure fluctuations and regulating pressures based on demand (Fontana et al. 2018). In particular, pressure monitoring is beneficial in situations of varying demand by providing high pressure during peak-demand periods and reduced pressure during low-demand periods. This contributes to constant and reliable water service to consumers and a reduction in leakage rates and pipe breaks (Elliott and Bartram 2011; Vicente et al. 2016).

As pressure management is commonly achieved through DMAs,[17] most ASEAN cities that have created DMAs also practise pressure management such as in Jakarta and Bogor municipality (Indonesia), Metro Manila (the Philippines), Johor (Malaysia), Vientiane (Laos PDR), Ho Chi Minh City (Vietnam), and Singapore.

5.5 Case Snippet (NRW Reduction): Metro Manila-Maynilad and Manila Water

Metro Manila has introduced and implemented effective WDM measures to reduce and prevent water losses since 2008 (Dimaano 2015). The responsibility for water and wastewater services within Metropolitan Manila lies with the Metropolitan Waterworks and Sewerage System (MWSS), which outsourced its management to two private concessionaires in 1997. Manila Water Company Inc. was awarded the concession for the east zone and Maynilad Water Services Inc. for the west zone. Maynilad Water Services is the Philippines' largest private water concessionaire by customer base and manages the water supply for the west zone, comprising 17 cities of the Metropolitan Manila area. Manila

[16] Entry points.

[17] Typically, pressure-reducing valves (PRVs) are installed on DMA entry points to regulate pressure.

Water is the exclusive water provider for the east zone of Metro Manila and the Rizal Province, consisting of 23 cities and municipalities.

Both concessionaires have reported progress in meeting NRW performance indicators, while expanding distribution lines and increasing the water connections (Abansi et al. 2018). The NRW reduction programme at Manila Water focuses on efforts such as leak detection, pipe replacement, and effective customer service complaint management. This programme has reportedly recovered nearly 750 million/litre/day (MLD). In 2019, the average NRW remained stable at a rate of 10.4%, indicating an improvement of 1% from 11.4% in 2018 (Manila Water 2020)

On the other hand, Maynilad has actively adopted several WDM strategies, including the NRW reduction programme. After privatisation in 2007, it established its non-revenue water reduction programme using a C + 3I strategy, e.g. 'Centralise', 'Isolate', 'Investigate', and 'Innovate'. The programme's key initiatives included the establishment of hydraulic systems and DMAs, leak repairs, selective pipe replacements, pressure management, hydraulic modelling and calibration, and DMA automation. The company assigned a central NRW team to spearhead the programme and partnered with Miya[18] to provide technical advice, training, and assistance

Within the first four years of initiation, approximately 472 MLD volume of water loss was recovered, and a total of 113 hydraulic zones,[19] 798 District Metered Areas, and 247 Pressure Management Areas (PMAs)[20] were established. The number of leak repairs leapt from 18,000 in 2009 to 40,000 in 2010 (Dimaano 2015)

In 2010, Maynilad also acquired the *Sahara*[21] leak detection equipment to detect and isolate leaks below ground level, which helped resolve 1000 leak incidents in an 830-km-long primary pipeline. In 2019, the company acquired a second set of leak detection equipment with an acoustic sensor inserted into a pipe, tethered to a monitoring system on the surface. This allowed the service provider's engineers to conduct audio and visual inspections inside pipes without interrupting water supply to customers (Maynilad 2020; The Manila Times 2021). The system also accurately detected structural defects and pockets of trapped gas within pipelines (Manila Standard 2021)

Since 2007, Maynilad has replaced approximately 2700 km of ageing, leaky pipe infrastructure that accounts for two-thirds of the water distribution network they manage (Maynilad 2020; The Manila Times 2021). Additionally, the utility managed to sustain its leak repair activities despite the enhanced community quarantine period due to COVID-19, repairing over 244 old and leaky pipes (Manila Standard 2021). As of April 2020, Maynilad has fixed 370,000 leaks since the launch of the NRW reduction programme (Maynilad 2020; The Manila Times 2021). These efforts have enabled the company to recover 979 MLD of water since 2008 (Maynilad 2020) and reduce its NRW rate from 67% in 2007 to 25% in 2019 (Fig. 5.1).

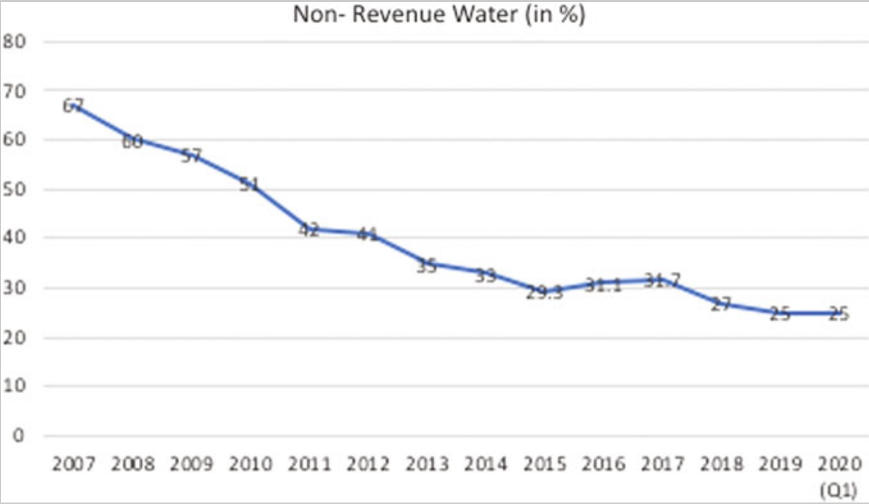

Fig. 5.1 Maynilad's NRW (2007–2020). *Source* Maynilad (2020)

5.6 Key Takeaways

1. The volume of water lost before reaching users is referred to as non-revenue water (NRW). Reducing global NRW rates by one-third can amount to savings which equate to serving 800 million people and annual global financial savings of USD 13 billion.
2. NRW management may be achieved through monitoring and accounting for water flow through leakage detection, pipe replacement, DMA creation, and pressure management.
3. Leakage detection can improve the condition of the distribution network by reducing the flow and frequency of additional leaks.
4. Modern leak detection technologies include hardware tools such as mechanical listening sticks, ground microphones, and leak noise correlators. They also include software-based tools such as ground-penetrating radar technology,

[18] A water operator that provides services to water utilities in commercial management, water treatment, and water efficiency schemes.

[19] Dedicated areas of water distribution network.

[20] DMAs with controlled pressure.

[21] Acoustic sensor inserted into pipe for monitoring (of Sahara brand name).

infrared photography, and gas injections. On average, a pressure reduction of 37% can more than halve the incidences of pipe breakages.
5. DMAs are integral to a systematic approach to operational management for water losses and reduce leakage by 26.6%–59.7% on average.
6. All ASEAN countries implement NRW management through a combination of measures (leak detection, pipe replacement, DMA creation, and pressure management). Several ASEAN countries have also adopted modern leak repair and detection technology, such as Singapore, Indonesia, Cambodia, the Philippines, Malaysia, Thailand, Laos, and Vietnam.

Commercial Losses

Commercial losses, also known as 'apparent losses' (Bao et al. 2013) or 'administration losses', are water losses that occur in the distribution system and which are not paid for by the water consumer (Jones et al. 2021; The World Bank 2016). Commercial losses are the result of customer meter under-registration, data handling and billing errors, unbilled authorised consumption[22] (Jones et al. 2021), and unauthorised use[23] (Al-Washali et al. 2020; AIIB 2020; Marsano and Jannah 2021). However, several different approaches can be taken to reduce commercial losses, including technical measures (e.g. water meter technologies) and non-technical measures (e.g. customer reporting and monetary instruments).

NRW management for reducing commercial losses may be achieved in two ways, namely

1. Water meters: Mechanical and/or smart water meters which monitor customer consumption patterns and reduce unmetered consumption (AWWA n.d.; Koech et al. 2018). Water meters can help reduce commercial losses by tracking the volume of water distributed from the storage locations to the distributor mains and supply service lines (EPA 2016; The World Bank 2016).
2. Customer reporting and monetary instruments: Commercial losses from water theft (e.g. illegal connections and meter tampering) can be reduced through a combination of customer reporting and monetary instruments (e.g. fines) (Jones et al. 2021; Marsano and Jannah 2021). Implementing a customer reporting programme encourages water users to have a greater awareness of their consumption and report illegal connections (ADB 2010).

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[22] This refers to the legitimate consumption of water, which is neither unbilled nor metered. Legitimate consumption includes water usage for street cleaning, fire services, and the flushing of mains and sewers (Jones et al. 2021).

[23] Such as corruption or theft (ADB 2010; Jang 2018; Jang and Choi 2017; Nasara et al. 2021, Water Services Association 2019; Water Services Association 2019).

5.7 Water Meters

Water metering is deployed in many urban areas to address commercial losses and other systemic operational inefficiencies by managing water use and allocation more effectively (Tantoh 2021). Water meters can reduce commercial losses by measuring the amount of water that flows through pipes from the withdrawal area to the distribution and delivery points (ADB 2010; EPA 2016; The World Bank 2016).

The effectiveness of water meters in reducing commercial losses and water demand is recognised worldwide. Research suggests that water service providers can lower unmetered water consumption by between 15 and 30% if smart meters are installed in households, enabling water service providers to accurately bill customers for their water usage (AWE n.d.; Ornaghi and Tonin 2021).

The metering of water consumption may influence consumers' water demand and water-saving habits, with customers gaining a greater awareness of and a significant reduction in water usage (Reynaud et al. 2018; Tanverakul and Lee 2015). For instance, water savings from metering are estimated to be up to 25% of per capita consumption (Abu-Bakar et al. 2021). The reduction in water consumption can also lead to savings in customers' water bills (Harutyunyan 2015).

In general, water service providers charge their customers for water on a per-unit basis, with the price reflecting the quantity of water used. Water service providers should accurately meter all water in their systems and also all water distributed from their systems at the customer's point of service. The meters should be read frequently to support the water service provider's understanding of production quantity, rate structures, and provide data and accurate bills to customers (AWWA n.d.; China Water 2010).

Meters provide accurate data, necessary for customer billing, system performance studies, planning purposes, water system management, and the assessment of water conservation measures. An effective metering programme relies upon choosing and managing metering technology and collecting data that track customer consumption patterns. This includes determining the correct size and type of meter, the installation of meters and regularly evaluating their accuracy, as well as the repair and eventual replacement of all meters. These practices ensure optimum accuracy at a reasonable cost for both the water service provider and the customer (AWWA n.d.; Bello-Dambatta et al. 2013; Koech et al. 2018).

Many cities in ASEAN have installed water meters to reduce commercial losses and monitor water consumption. Water meters are used in Singapore, Jakarta (Indonesia), Zamboanga City Water District (the Philippines), Rayong, Chonburi, and Chachoengsao (Thailand), Vientiane (Laos), Yangon (Myanmar), and Brunei Darussalam. Water meters can also be found in Malaysia, Vietnam, and Cambodia.

For example, in Batam Municipality, Indonesia, water services are currently delivered by PT Adhya Tirta Batam (ATB), a private concessionaire.[24] ATB replaces

[24] As in Jakarta, ATB signed a 25-year concession with Batam Free Trade and Free Port Zone Management Body (BP Batam) through the Build, Operate, and Transfer (BOT) scheme. After

water meters every five years[25] with particular attention paid to meters that have already reached 1500–2000 m^3 of use (ATB 2017b). Replacing old meters ensures the continuity of accurate meter readings while also reducing the risk of commercial losses. Meters that were replaced yet found to be still in good condition were recalibrated, while defective meters were scrapped (ATB 2017b). Since 2009, ATB has established its own ISO/IEC 17025-certified laboratories to ensure the accuracy of its meters (ATB 2017c). ATB has improved efficiency within its operations due to this technology, with fewer staff needed to take manual water meter readings: the staff-to-customer ratio decreased from 7.47 in 1996 to 1.98 in 2019 (ATB 2017a).

Smart Meters

Smart water meters can also be installed to improve urban water demand management and planning and mitigate the limitations of traditional water meters. Smart water meters are devices that digitally measure water consumption and record information related to all aspects of the water cycle in real time. They also monitor when and how the water is used, sending that information to the water service provider. As the smart meters constantly generate and transmit data through solutions provided by Information and Communication Technologies (ICTs) such as wireless sensors, the meters do not need to be manually read by a human meter reader. Accordingly, smart meters engender greater efficiency in water management and facilitate better-informed decisions by providing real-time solutions to challenges faced by water service providers and consumers alike (Greater Western Water n.d.; Koop et al. 2021; Smart Nation n.d.).

Research shows that smart water meters can reduce the incidence of water leakage by 50% through monitoring, resulting in improved operational efficiency and a reduction in economic losses for the water service provider (Fetterman et al. 2020; Li et al. 2020; Marais et al. 2016; Pimenta and Chaves 2021).

Traditional or conventional water meters measure water flow and monitor water consumption to increase billing accuracy. They tend to be low cost and reliable and require little maintenance.[26] However, weather conditions and the age of the water network could affect the longevity of these meters (Fontanazza et al. 2012). Additional costs are incurred when installing and replacing old water meters with new water meters (Bello-Dambatta et al. 2013; Couvelis and van Zyl 2015). Furthermore, as traditional mechanical water meters offer neither real-time data nor automatic water consumption monitoring, water service providers may also employ staff to make periodic visits to water meter installation sites. Staff would be required to manually read the meters at a set time interval; water users are then billed based

completing the concession in November 2020, ATB transferred its water assets, operations, and maintenance services to BP Batam, which provides Batam's water supply.

[25] This practice is in accordance with Law Number 2 of 1981 concerning Legal Metrology and Government Regulation Number 2 of 1985. This concerns the obligation and exemption to be calibrated and/or recalibrated as well as the requirements for measuring and weighing instruments and their equipment (ATB 2017b).

[26] Although there is no agreed time limit to replace mechanical water meters, they tend to have a life of up to 17 years.

on their past consumption levels. While this process may be adequate for the water service provider's billing purposes, it provides limited data on seasonal patterns, leakages, and actual water consumption levels (Koech et al. 2018). In addition, this process may be expensive for water service providers, is labour intensive, is potentially time consuming, and can result in inaccurate water meter readings and bills (Marais et al. 2016; Mudumbe and Abu-Mahfouz 2015; Pimenta and Chaves 2021).

By contrast, the advantages of smart water metering are significant. Smart meters can

1. Increase consumer awareness: Smart water meters can increase consumer awareness of water consumption through near real-time consumption feedback and, thus, lead to a reduction in water consumption (Fetterman et al. 2020; Koech et al. 2018; Liu et al. 2017; Marais et al. 2016; Monks et al. 2019; Pimenta and Chaves 2021). Research suggests that smart meters can reduce water consumption by an average of 12.15% due to near real-time consumption feedback to the consumer (Sønderlund et al. 2016). For instance, a five-year study in Sydney that examined the use of smart water meters in households found that those with in-home display smart meters consumed, on average, 6.4% less water than those without (Davies et al. 2014).
2. Collect and transmit data in real time: As smart water meters show real-time data on water timing and usage patterns, this facilitates water service providers' efforts to accurately detect leaks (Bello-Dambatta et al. 2013; EPA 2016; Kayaga and Smout 2011). The collection of real-time data can better support water conservation policies by forecasting consumption based on the data, which can also help both water service providers and users save water (Beal and Flynn 2014, 2015; Morote and Hernández-Hernández 2018).

   In addition, the wireless sensor network and real-time data also enable water service providers to alert customers to leak more quickly, rather than relying on manual readings of customers' water meters. Water service providers can also use this data to provide customers with more timely information about their water consumption through various mediums which are low in cost (or free) for the water service provider and suit the customer on the go (e.g. text alerts, emails, websites, and mobile phone applications) (Geetha and Gouthami 2016; Liu et al. 2015; Perera et al. 2015). Studies suggest that smart meters and the use of an online portal (for customers to check water consumption) can reduce the duration of leaks, from an average of 29 days to 19 days, equating to a 34% reduction. They may also reduce the probability of recurrence of leaks by 50% (Fuentes and Mauricio 2020; Schultz et al. 2018).
3. Enable water service providers to monitor water flow and consumption: Smart water meters can form part of a bigger wireless sensor network which may have a central hub. A central hub allows water service providers to accurately monitor the flow of water and bill water users based on real data, rather than rely on estimates of water consumption (Beal and Flynn 2014, 2015; Fuentes and Mauricio 2020). Research shows that regularly updated information on the water consumption of users enables water service providers to identify system losses and pinpoint

pipe leaks more quickly and accurately than traditional meters (Joo et al. 2015; Li et al. 2020).

4. Identify meter tampering and water theft: Smart water meters with real-time data and automated technologies that use algorithms can rapidly detect meter tampering and water theft. These smart meters can identify where and when there is a sudden shift in usage (Monks et al. 2019). Research shows that smart meters can significantly increase the detection of water thievery (Monks et al. 2019; Morote and Hernández-Hernández 2018).
5. Reduce staff and labour costs of water service providers: Smart water meters can reduce the number of staff required to perform manual meter readings, thus lowering operational costs. Smart meters can also reduce the amount of estimated readings in those instances where access to the meter is not possible (March et al. 2017). Research suggests that smart meters can produce significant savings and reduce operational costs for water service providers (Monks et al. 2019).
6. Improve cash flow: Smart meters can augment revenue collection via monthly billing of customers, using the automated reading taken at a nominated day and time. As manual meters may be under-read by the water service provider staff (by accident or on purpose), the greater meter reading accuracy that real-time data affords may result in additional revenue for the water service provider. The water service provider may further improve its cash flow by reducing billing and collection costs when monthly billing is coupled with electronic billing and collection. Using an electronic billing system could reduce postal charges and extra mailing costs, such as reminders for payments. Research shows smart water meters coupled with monthly e-billing, and an online payment system can result in improved cash flow and more efficient billing operations (Beal and Flynn 2014, 2015; Monks et al. 2019; WSAA 2019).

Smart Meters in ASEAN

There is growing interest in smart meters in the ASEAN due to their efficiency in reducing commercial losses and improving urban water demand management (Rahim et al. 2020). Several cities across the region have installed, or are in the process of installing, smart meters, to reduce commercial losses. Brunei Darussalam, Singapore, and Kuala Lumpur (Malaysia) have all installed smart meters. In Brunei Darussalam, for instance, the Datastream Digital Network[27] launched the 'Unified Smart Metering System' (USMS), which features meter data management and measurement, and a unified electricity and water billing customer service portal system. This system allows households to monitor their water usage levels, thereby enabling them to better manage their consumption and finances. Starting from March 2020, the new smart prepaid water meters were set to be rolled out to 2000 households in the first phase of testing. Over the next five years, it is intended that this is expanded to over

[27] DST is a telecommunications company in Brunei Darussalam which provides mobile services, broadband, broadcasting, and content.

200,000 homes and commercial buildings, with the aim of replacing existing utility meters used nationwide (The Bruneian 2020).[28]

Smart Meters Outside of ASEAN

Beyond ASEAN, in Loudoun County, Virginia, USA, the local water utility, Loudoun Water,[29] installed Advanced Metering Infrastructure (AMI) in 2017 to monitor water consumption in real time and to also promptly identify leaks in the water distribution network. The AMI solution comprised Sensus iPERL residential and OMNI smart water meters (Water Technology 2018). The installation of the smart meters[30] was a response to the utility's 78,000 customers who complained that it was difficult to read their meters manually. Leaks in the water distribution network also went frequently undetected.

The smart meter solution enabled Loudoun Water to view all of its customers' water consumption levels online and also provided it with data for the proactive repair of leaks through the smart meter's FlexNet Communication Network and alert system.[31] Loudoun implemented a four-step procedure to alert customers to leaks: (1) an automated call or a letter providing initial information of sustained, increased consumption was generated after the first alert by the system within 72–95 h; (2) a follow-up letter to customers indicating that the leak remained unrepaired. After 10–11 days of the first leak alert sent to consumers, Loudoun provided suggestions for leak repairs to the consumer; (3) a visit to the property was made to identify the physical location of the leak within 21 days of the first notification of a leak; and (4) a personal telephone call before the commencement of the next billing cycle. In total, 13,000 telephone calls were made to customers in 2017, 2600 letters were issued to the customers, and 1500 property visits were made to the customer's premises later. Approximately, 80% of the leaks were corrected based on Loudoun Water's first notification outreach to customers. Loudoun's action plan enabled customers to lower both their water usage levels and their water bills (Sensus-3 n.d.).

Another example is the municipality of Terre di Pedemonte, Switzerland. Società Elettrica Sopracenerina (SES), the local water service provider, installed smart meters in May 2015 as part of a pilot programme. The Switzerland pilot-SmartH20 project[32]

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[28] Due to COVID-19, the roll-out of the smart meters has been delayed. As such, 5000 units of DN15 meters and 200 units of DN25 were expected to arrive between April and June 2021. The replacement work of conventional meters with smart meters will be implemented once they are available. As of December 2020, the installation works have not started yet. The meter replacement is to be carried out in stages over five years (Brunei Darussalam representative in AWGWRM. Email interview, 22 December 2020).

[29] Loudoun Water provides waste and wastewater services to over 800,000 households and businesses in Loudoun County. Loudoun Water is a political subdivision of the State of Virginia and is not a department of Loudoun County (Loudoun n.d.).

[30] Sensus iPERL residential and OMNI water meters, all connected by the FlexNet Communication Network.

[31] The smart meter alarm system detects issues such as leaks, reverse flow, empty pipes, and meter tampering (Water Technology 2018).

[32] The SmartH20 is an Information and Communication Technology (ICT) platform for efficient management of water consumption. The EU-funded SmartH20 project is aimed at aiding water

(ETH 2015; Rizzoli et al. 2018) involved the implementation of a gamified portal, where a gamified application was connected to a user's smart meter, serving as a rewards-based marketplace, where target achievement-based collectables like points, badges, and rewards were awarded to users. As part of the project, consumers could set weekly or monthly water-saving targets (5%, 10%, or 15% reduction) and were awarded 'points' based on their target achievements (Novak et al. 2016).

As part of the SmartH20 project campaign, a questionnaire was sent to 70,000 of the canton's 158,647 total households. A total of 462 households responded to the questionnaire, with data extracted from this exercise being used to determine the general profile of users interested in water awareness and efficiency. Some examples of data (per household) extracted include number of bathrooms per home; number of showers per week; number of taps; and duration of showers (Bertocchi et al. 2016).

This pilot project demonstrated the efficiency and accuracy of smart meters, with a 33.4% reduction in water usage with respect to a historical baseline. However, after adjusting for seasonal factors, a water consumption reduction of 3.4%–8.4% was attributed to the use of the portal. The main objective of the pilot was to familiarise the core user group with the ICT-based portal. Based on the experience of the core user group, a larger active user group could be built. The core group consisted of 27 basic and 16 gamified portal users. It was observed that the user activity in the gamified portal version was higher to the user activity in the basic portal, suggesting that the gamified portal prompted more interest among users (Rizzoli et al. 2018).

The water consumption reduction results (based on consumption class) solely attributed to the use of the portal and savings tips (without gamification) are given in Table 5.1. The average reduction is calculated over three months (1 November 2015–6 February 2016) relative to the baseline reading (on 31 October 2015) (Micheel et al. 2015).

Table 5.1 Average reduction in consumption (seasonally non-adjusted) from 1 November 2015 to 6 February 2016, Locarno, Switzerland

Consumption class	Number of users	Average reduction (%)
Low	10	41.2
Medium–Low	22	26.9
Medium–High	10	41.2
High	01	21.2
Overall	43	33.8

Source Micheel et al. (2015)

service providers, municipalities, and citizens with the development of an ICT-based platform to design, develop, and implement better water management practices and policies (EU n.d.). SmartH20 uses the multi-stage behaviour model to influence water consumption demand, and its mechanisms include interactive water consumption visualisations, water-saving tips, water-saving goals, various types of gamified incentives (personal, social, virtual, and physical), and a hybrid physical-virtual card game (Novak et al. 2016; Rizzoli et al. 2018).

5.8 Programmes to Identify, Remove, and Replace Illegal Connections

Commercial losses from water theft are a key concern for water service providers due to the loss of revenue for water service providers. Water theft can take the form of illegal connections,[33] illegal reconnections,[34] meter tampering,[35] and meter reader corruption[36] (ADB 2010; Jones et al. 2021; Marsano and Jannah 2021; Sekyere et al. 2020).

To reduce commercial losses, water service providers can implement programmes to identify, remove, and replace illegal connections. These programmes include imposing fines on customers for excessive water consumption, suspending the accounts of non-paying customers, and implementing verification programmes to monitor inactive accounts (ADB 2010).

Many cities across ASEAN have implemented such programmes to identify, remove, and replace illegal connections to reduce commercial losses. These include the imposition of fines and the suspension of accounts of non-paying customers, for instance, in Brunei Darussalam, Singapore, Phnom Penh (Cambodia), Jakarta and Bogor Municipality (Indonesia), Carmona District (the Philippines), Bangkok (Thailand), Johor (Malaysia), Vientiane (Laos), Yangon (Myanmar), and Ho Chi Minh City (Vietnam).

In Jakarta, Indonesia, both water concessionaires, Aetra and PALYJA, have implemented measures to reduce water theft via illegal connections. In 2018, Aetra introduced a 'master meter programme' to prevent water theft, which involves the installation of a temporary meter to ensure that public water services are delivered to underprivileged areas to deter residents from illegally connecting to Aetra's pipe network. As a result of this programme, Aetra detected 732 illegal connections (Aetra 2018), reducing the number of illegal connections by nearly 50% when compared to 2016 (Aetra 2016). PALYJA has also detected cases of water theft. In 2016, the incidences of water theft that it detected included 2,704 illegal connections and 2,147 illegal uses. Some of the incidents concerning illegal connections were considered criminal offences, warranting police investigations (PALYJA 2014, 2016).

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[33] This is when a consumer is not a customer of the water supply system but has connected himself/herself to the network (Ramos et al. 2020; Water Integrity Network 2015b).

[34] This occurs when a customer reconnects himself/herself to the water distribution network after having been disconnected from the network due to non-payment (Water Integrity Network 2015b).

[35] Meter tampering is 'fraudulent manipulation' where customers falsify their true water consumption readings. It is a concern for water services providers because it represents a loss of income (Monedero et al. 2015; Morote and Hernández-Hernández 2018).

[36] This includes, for example, customers colluding with their water service provider's meter (human) readers to falsify the water meter readings, thus lowering their water bill (Water Integrity Network 2015a).

5.9 Case Snippet (Commercial Losses): Johor and Ranhill SAJ

Johor, Malaysia, has put effective WDM measures in place to reduce and prevent commercial losses. Ranhill SAJ is the sole water operator in the southern Malaysian state (Ching 2017). It is a subsidiary of Ranhill Utilities Berhad, which operates integrated water supply with three core activities: water treatment, water distribution, and billing and collection (Ranhill SAJ n.d.). As noted below, the water utility pays particular attention to upgrading meters and preventing non-payments and meter tampering to avoid commercial losses in Johor.

Although the 25% NRW target set in the Eleventh Malaysia Plan[37] still applies to Johor, SPAN[38] has set itself an ambitious seven-year plan and key performance indicators (KPIs) for Ranhill SAJ,[39] to address commercial losses (Malay Mail 2019). The programme's aim is to achieve a reduction of NRW from 24.12%, to 5% (Global Water Security 2019), and a commercial loss of 1% (Ranhill Holdings 2019a) by 2025 in Johor (The Star Malaysia 2018)

Ranhill SAJ has, in addition, implemented various WDM measures to reduce commercial losses through water theft prevention, non-payment compliance enforcement, and meter replacement programmes. The water theft prevention measures involved appointing 38 additional staff for the newly established Enforcement and Preventive Section within its Customer Service Department. This initiative has resulted in the detection of 9620 cases, of which 9569 have been solved (Ranhill Holdings 2019a). Ranhill SAJ has also imposed a total of RM910,000[40] worth of water loss charges on the offenders and collected RM795,000 thus far (Ranhill Holdings 2019a)

Ranhill SAJ has put in place sanction mechanisms to reduce commercial losses. The water utility will suspend a customer's water connection if their water bill remains unpaid after the timeframe (i.e. 30 days after issuing the water bill). The water utility will also charge the customers their ongoing water bills and additional reconnection fees

Ranhill SAJ also undertakes water meter replacement and upgrading programmes in Johor—schemes that have resulted in positive outcomes. As of 2017, estimates suggest that 92.1% of meters in Johor (i.e. 1.05 million customers) had been in use for less than seven years, a proportion that tops Malaysia's national average of 82.3%. Ranhill SAJ replaces old and poorly functioning water meters with more durable electromagnetic meters (EFM) or R800 metrology mechanical meters. In addition, Ranhill SAJ has set aside an investment of RM 2.04 billion for the period of 2018–2022 to carry out upgrades to infrastructure, including the replacement of old water meters (The Star Malaysia 2020). As of December 2019, R800 metrology mechanical meters had replaced 11,931 water meters in Johor, while EFM had replaced 109 m (Ranhill Holdings 2019a)

5.10 Key Takeaways

1. Commercial losses may result from water theft, incorrect water meter readings, and illegal connections. Technical measures (e.g. water meters) and non-technical measures (e.g. customer reporting) can reduce commercial losses and are usually undertaken by water service providers.
2. Water meters are particularly efficient in reducing commercial losses by measuring the amount of water that flows through pipes from the withdrawal area to the distribution and delivery points. Water metering is an accepted practice in WDM in developing countries to control water consumption based on pricing. By metering water, water service providers can reduce unmetered water consumption by up to 30%.
3. Smart water meters are particularly efficient in reducing commercial losses, by using real-time data and a sensor network, and by increasing consumer awareness of water consumption which reduced water loss by 12.15% on average.
4. The use of real-time data and a sensor network with smart meter technology can also reduce the probability of water leakage by 50% through monitoring; this significantly reduces water theft (up to 80% in some studies) and labour costs for the water service provider. The installation of smart meters can not only save water service providers time and money through accurate real-time data and monitoring but also help support better water conservation practices and improve urban water management planning.
5. All ASEAN countries have installed traditional water meters to reduce commercial losses. However, there is growing interest in smart water meters, due to the efficiency that they offer in terms of providing real-time data on water consumption. Some ASEAN countries, such as Brunei Darussalam, Singapore, and Malaysia, have already installed, or are in the process of installing, smart meters to reduce commercial losses further.
6. Many major cities across ASEAN have implemented programmes to identify, remove, and replace illegal connections to reduce commercial losses. These include the imposition of fines and the suspension of accounts of non-paying customers, for instance, Brunei Darussalam, Singapore, Phnom Penh (Cambodia), Jakarta and Bogor Municipality (Indonesia), Carmona District (the

[37] Malaysia's five-year development plan 2016–2020.

[38] Suruhanjaya Perkhidmatan Air Negara.

[39] Water licensee.

[40] RM 1 = USD 0.24.

Philippines), Bangkok (Thailand), Johor (Malaysia), Vientiane (Laos), Yangon (Myanmar), and Ho Chi Minh City (Vietnam).

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Chapter 6
Economic Instruments

Inefficient water use is often a result of inadequate incentives for users to reduce their water use and consumption (Leflaive and Hjort 2020). To address this, economic instruments can be devised to influence customers' water consumption behaviour. This may be achieved by offering financial rewards (rebates and tax credits) and/or imposing monetary costs (penalties and fines) (Kayaga and Smout 2011). Economic instruments such as tariffs can also help generate revenue which may be used to expand and improve water services (Damkjaer 2020; Leflaive and Hjort 2020). We have identified at least three commonly used types of economic instruments, namely

1. Tariffs refer to the price paid for a given quantity of water service supplied by a water service provider. They serve as the primary means for the service provider to generate revenue and cover all costs associated with the provision of water services.
2. Water rebates are incentives from government bodies/local municipalities to consumers to influence their water consumption levels and promote water-use efficiency. Rebates may be applied as a partial refund on water bills or to encourage the uptake of water efficiency appliances.
3. Fines for excessive use refer to the price paid for water wastage. It is typically imposed in areas where water resources are scarce or depleted due to climatic conditions or over withdrawals.

6.1 Tariffs

Tariffs, the most commonly used economic instrument for WDM, denote the price paid for water supplied through a piped network by a water service provider to households, retailers, industries, etc. (EEA 2017; Kayaga and Smout 2011; Ricato 2019). They are typically determined by the municipal government in line with a particular framework established by higher levels of authority, such as provincial, state, and national governments (ADB 2019). Tariff structures may be influenced

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by various factors, such as operational and maintenance costs, capital availability, consideration of environmental costs,[1] and political factors (EEA 2017). Tariffs serve as the primary means for the service provider to generate revenue and cover costs associated with water treatments and the provision of services (Damkjaer 2020; FAO n.d.; Leflaive and Hjort 2020). Hence, they are the main determinant of the services that a utility provides and the monthly bills of water users (Ricato 2019).

Tariff rates can be determined to reflect the operational and maintenance costs for a water service provider and the value of water resources, to encourage water conservation efforts (EPA 2016; OECD n.d.). Tariff rates are set so as to reflect the costs of these services at different rates (e.g. the greater the water consumption, the higher the cost), which may influence waste and inefficient water use by the end consumer (Bello-Dambatta et al. 2013; EPA 2016). Underpricing may deny utilities the revenue needed to improve service quality and hinder the expansion of coverage (Leflaive and Hjort 2020). As an optimum economic solution, tariff prices can be set to reflect three key elements: (1) supply costs,[2] (2) resource costs[3] (accounting for resource scarcity), and (3) environmental pollution costs[4] (OECD 2013, 2016). The effectiveness of tariffs as instruments for water-use efficiency and conservation depends on end-users' sensitivity to price signals (Leflaive and Hjort 2020; Reynaud and Romano 2018). Although the degree of impact of tariffs on water conservation is uncertain, they still remain the key instruments to ensure cost recovery of water services (EEA 2017). As tariffs and tariff hikes have been shown to have an effective but time-limited impact on changing consumption behaviours, complementary measures such as public information and education campaigns can strengthen WDM measures already in place (FAO n.d; Leflaive and Hjort 2020; Pinto and Marques 2016).

There are several tariff structures in place. The leading tariff structures are as follows:

(a) **Fixed tariffs** refer to a flat charge, regardless of consumption levels. As flat charges are not set according to the consumption levels, a proxy of consumption levels provides the basis for the charge (FAO n.d.). Flat rates are commonly based on pre-assessed factors such as the number of household residents, number of rooms, types of water-using fixtures, and the diameter of the pipe connecting to the water distribution network (EEA 2017; FAO n.d.). Due to the fixed charges, this provides ease of administration and stable cash flow to water service providers. However, as consumers have limited control over their final water bills, this tariff structure may not encourage water-use efficiency (Damkjaer 2020; Leflaive and Hjort 2020; OECD 2010).

(b) **Volumetric tariffs** refer to fixed per-unit consumption charges at a rate that is proportional to the level of water consumption, regardless of total consumption

[1] Charges dedicated to environment protection (EEA 2017).

[2] Supply costs include (1) operation and maintenance costs and (2) capital costs (OECD 2010).

[3] Resource costs refer to the opportunity costs of using water, accounting for resource scarcity (OECD 2010, 2011; Reynaud and Romano 2018).

[4] Pollution costs refer to costs associated with environmental deterioration/externalities through the release of pollutants by urban water systems (OECD 2010, 2011; Reynaud and Romano 2018).

(Ricato 2019). Although this tariff structure encourages efficient water use, it disadvantages low-income households that may not be able to moderate water consumption (Leflaive and Hjort 2020; OECD 2010). Additionally, volumetric tariffs may lead to lower-cost recovery for the water service providers if the variable component represents a large proportion of the water bill and customers drastically reduce their consumption (EEA 2017).

(c) **Increasing block tariff** (IBT) is a type of volumetric tariff and the most common measure used by water service providers worldwide.[5] The IBT is a stratified tariff that is based on a water user's consumption range. The tariff rate includes a base charge for fixed costs that rises when the water consumption increases and reaches a certain threshold (block). The price per unit remains constant for this block, beyond which a higher volumetric price is charged for each additional unit of consumption, until the highest block (EEA 2017). To generate revenue recovery for the water service provider (EPA 2016), IBT also entails a low charge for essential use and a higher charge for less essential (upper blocks) water use (Bello-Dambatta et al. 2013). It follows the concept that higher costs for the upper blocks discourage water wastage and cross-subsidise the water use of low-income households (Fuente et al. 2016; Grafton et al. 2014). However, this measure has been critiqued for disproportionately disadvantaging low-income households, who on average are larger in number (Boland and Whittington 2000; Nauges and Whittington 2017; Meran and Von Hirschhausen 2017) and for whom the minimum consumption charge may be unaffordable (Neto and Camkin 2020). Notwithstanding these perceived shortcomings, IBT has been shown to have contributed to a reduction in overall water consumption (EPA 2016).

(d) **Decreasing block tariffs** (DBT) refer to volumetric tariff rates that decrease with successive consumption blocks (Ricato 2019). DBTs may be appropriate in areas with an abundance of raw water sources, as the average water costs would decrease with an increase in water supply (Damkjaer 2020; EEA 2017). Hence, this tariff structure may disincentivise water conservation and favour big consumers (Leflaive and Hjort 2020; OECD 2010).

Most major cities in the ASEAN region have adopted the IBT system although only a few account for full-cost recovery (FCR) in their tariff structure, such as Singapore and Jakarta (Indonesia). Singapore has, since 1973, implemented IBT tariffs as a pillar of its water demand management (Araral 2010). At present, the tariffs are based on volumetric consumption, covering the full cost of production and supply (PUB n.d.). Additionally, Singapore charges both a Water Conservation Tax (WCT) to encourage water conservation and to reflect the incremental costs of additional water supplies, and a waterborne fee (WBF) to recover the costs of used water treatments and to maintain the used water network (PUB n.d.). However, in the context of developing countries, it is not uncommon for governments to subsidise water tariffs to ensure universal water access.

[5] E.g. Cyprus, Indonesia, Italy, Singapore, Spain, etc. (EEA 2017).

For example, in the Philippines, the private concessionaires Manila Water and Maynilad have implemented a 'socialising' IBT pricing scheme that ensures affordability for households. Maynilad offers a 20% discount on water bills to domestic customers whose water usage is 10 m^3 or less per month (Maynilad 2020). Similarly, Manila Water offers a discounted charge of PHP 83.14[6] to 'lifeline' customers or low-income households with water usage of less than 10 m^3 per month, after which the block pricing applies (Manila Water n.d.). Industries and commercial companies, meanwhile, are charged higher rates to cross-subsidise domestic consumers.

In Copenhagen, Denmark, the water supply is operated by HOFOR, a municipality-owned water service provider. HOFOR's tariffs are set by the city, based on a number of factors, including cost recovery (for expenses for drinking water supply and diversion of water), state green taxes, and VAT (HOFOR n.d.). The cost includes pipe maintenance, groundwater protection, and expansion work for future demand and crises (HOFOR n.d.). Their water prices are among the highest in Europe at DKK 39.85[7] per m^3. All households pay the same price per cubic metre of water used, as there are no block tariffs (HOFOR n.d.). Although HOFOR is a non-profit company, it updates its tariff levels annually to ensure cost recovery.

6.2 Rebates

Incentives for influencing behaviour, such as rebates, represent another economic measure. Local municipalities have been using rebate programmes to incentivise water conservation behaviour, such as a partial refund on water bills (Kayaga and Smout 2011), retrofit residential properties with water-efficient appliances (EPA 2016; Lane et al. 2012; Pérez-Urdiales and Baerenklau 2019), and installing a rainwater harvesting facility as an alternative water source (Lane et al. 2012; Vimont 2017).

Rebates have gained greater public acceptance among water users than other WDM measures such as price hikes and water restrictions[8] (Lee et al. 2011). Targeted rebates can also be implemented in combination with IBTs and assist lower-income households by reducing distributive impacts from high consumption (Hoque and Wichelns 2013; Leflaive and Hjort 2020). For example, in Johor, Malaysia, the water service provider Ranhill has implemented a water rebate programme that provides free water to households in need for the first 25 m^3 of water consumption. In 2019, some 3136 lower-income households benefited from this programme (Ranhill Holdings 2019).

Likewise, in Penang, Malaysia, the water service provider PBAPP[9] implemented a corporate social responsibility programme to ensure that low-income households

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[6] PHP 1 = USD 0.020.

[7] DKK 1 = USD 0.15.

[8] Water restrictions that forbid certain activities may seem arbitrary to the public if the reasoning behind the implementation of water restrictions is not fully explained (Mullin and Rabado 2017).

[9] Perbadanan Bekalan Air Pulau Pinang (Penang Water Utility).

were not disadvantaged by the tariff review in 2015. Introduced in 2017, the 'Projek Perumahan Rakyat Termiskin' (PPRT) scheme provides the lowest income households in Penang with a free water supply of up to 60,000 L over a two-month cycle (Mok 2019). The programme cost PBAPP RM16,482[10] in 2017 and reached 199 families who earned RM790 per month, or less (Mok 2019).

Studies indicate that rebate programmes for both indoor and outdoor water-saving products can encourage user investments in water efficiency appliances (Pérez-Urdiales and Baerenklau 2019). Nevertheless, the use of rebates may be helpful in curbing wasteful indoor water use by incentivising a switch to water efficiency appliances that help lessen water use by restricting water flows (EPA 2016; Tsai et al. 2011).

In Australia, water authorities of all states and territories across the country provided rebates to households that installed water efficiency appliances. This was implemented between 2003 and 2011, where the most commonly subsidised devices included dual-flush toilets and low-flow showerheads. By 2011, the rebate programmes encouraged 46,357 households to replace their showerheads, 40,755 households to instal a dual-flush toilet, and 344,200 households to purchase/replace a water-efficient washing machine (Lane et al. 2012).

6.3 Fines

Fines for excessive water use have also been imposed in several places as a deterrent to water wastage, typically in areas where water resources are scarce or have become depleted due to climatic conditions or over withdrawals. Such measures have been put in place in ASEAN countries such as Thailand and Indonesia. For example, in Thailand, the Water Resources Act (2018) imposes fines for excessive water use during water rationing to avoid a situation where droughts could result in severe national socio-economic and hydrologic consequences. In such circumstances, individuals who do not comply may be imprisoned for up to a year or receive a fine not exceeding one hundred thousand Baht (THB)[11] or both (The Government of Thailand 2018).

In Indonesia, the national government enforces penalties for non-payment, including fines, and may suspend supply under Government Regulation No. 122/2015 on Water System Provision. In line with the tariff decision mechanism, local governments and state-owned water service providers (PDAMs)[12] can determine the severity of fines for non-payments. In addition, these bodies can suspend the water supply in situations of non-compliance. For this period, water bill payment rates increased slightly from 93.28% in 2018 to 93.67% in 2019 (BPPSPAM 2019). The water concessionaires in Jakarta, PALYJA, and Aetra have also sanctioned those who do

[10] RM 1 = USD 0.24.

[11] THB 1 = USD 0.030.

[12] Perusahaan Daerah Air Minum.

not pay their water bills on time by temporarily disconnecting their water services and imposing fines (PAM Jaya 2014).

6.4 Case Snippet: Singapore

Singapore has implemented an integrated and cost-effective solution to water management through economic instruments and societal engagements (Tortajada et al. 2013). Regarding economic instruments, water is priced to include full-cost recovery of supply and production and to incorporate the incremental costs of alternate water supplies (specifically NEWater[13] and desalinated water) (PUB n.d.). However, targeted rebate programmes can mean affordable water supply for lower-income households by separating unequal distributive tariff impacts from high consumption (Hoo 2019; Hoque and Wichelns 2013).

Singapore adjusted its water tariffs in 1973[14] with an increasing block tariff (IBT) structure being introduced to reduce the nation's longstanding dependence on Malaysia for water supply and to also discourage domestic water wastage (Tortajada et al. 2013). To reflect the market cost of wastewater treatments, the tariff schedules were further revised in 1975, 1981, 1983, 1986, 1992, 1993, and 1997, respectively (Tortajada et al. 2013). In 1997, the revised structure espoused a uniform tariff for domestic and non-domestic users alike; prior to 1997, domestic users were exempted from the Water Conservation Tax (WCT)[15] and paid lower tariffs than non-domestic users. The revision of water tariffs aimed to deliver the message that water is an important resource that should be conserved.

The most recent water tariff scheme came about by way of a revision in 2017 and was implemented in two phases: in July 2017 (Phase 1) and in July 2018 (Phase 2). The revision entailed a 30% increase in water prices over the two phases (The Straits Times 2017). The WCT was imposed as a percentage of the water tariff, to both encourage water conservation, and to reflect the incremental costs of additional water supplies. The sanitary appliance fee (SAF), which was applicable before 1 July 2017, was rescinded and subsumed into the waterborne fee (WBF). The WBF aims to recover the costs for used water treatment and maintain the used water network (PUB n.d.).

[13] Highly treated reclaimed wastewater produced by PUB, Singapore National Water Agency.

[14] Between 1965 and 2000, the water price (water tariffs and related water taxes) was revised 12 times. Initial price modifications were introduced for cost recovery purposes rather than to improve water conservation (Tortajada et al. 2013).

[15] The WCT was introduced in 1991, and tier 1 domestic users (consuming below 20 m^3 per month) were exempted from payment (PUB representative in AWGWRM. Email interview, 7 March 2022).

As indicated in Table 6.1, after the implementation of the tariff regime (Phase 2), the total volumetric price for water has increased from SGD1.80/m^3 to SGD2.74/m^3 and SGD2.31/m^3 to SGD3.69/m^3 for monthly domestic usage of less than 40 m^3 and of more than 40 m^3, respectively (PUB 2020). Singapore's per capita household water consumption decreased by 7 L/day on average, from 148 L/day in 2016 to 141 L/day in 2019[16] (PUB 2020) (Fig. 6.1). Although it is difficult to isolate the impact of water tariffs on water consumption rates, it is likely that the declining trend in per capita household water consumption was influenced by the tariff hike in 2017. During the 2020/2021 period, household water consumption increased to 154 L/capita/day due to the extraordinary conditions imposed by COVID-19, including working and studying from homes (PUB 2021).

Table 6.1 Tariff rates in Singapore

Monthly water usage	Units (SGD[17])	2000–1 July 2017		Phase 1—from 1 July 2017		Phase 2—from 1 July 2018	
		0–40 m^3	> 40 m^3	0–40 m^3	> 40 m^3	0–40 m^3	> 40 m^3
Tariff	SGD/m^3	1.17	1.40	1.19	1.46	1.21	1.52
WCT	% of Tariff	30%	45%	35%	50%	50%	65%
WCT	SGD	0.35	0.63	0.42	0.73	0.61	0.99
Waterborne fee (WBF)	SGD/m^3	0.2800	0.2800	0.78	1.02	0.92	1.18
Sanitary appliance fee (SAF)	SGD/per Sanitary Fitting	2.8037	2.8037	0	0	0	0
Total volumetric price	SGD/m^3	1.80	2.31	2.39	3.21	2.74	3.69

Source PUB (2017, 2020, n.d.); PUB representative in AWGWRM. Email interview, 7 March 2022

[16] 2019 was chosen as water consumption in 2020 was affected by COVID-19 and lockdowns (e.g. people spent longer hours at home).

[17] SGD 1 = USD 0.74.

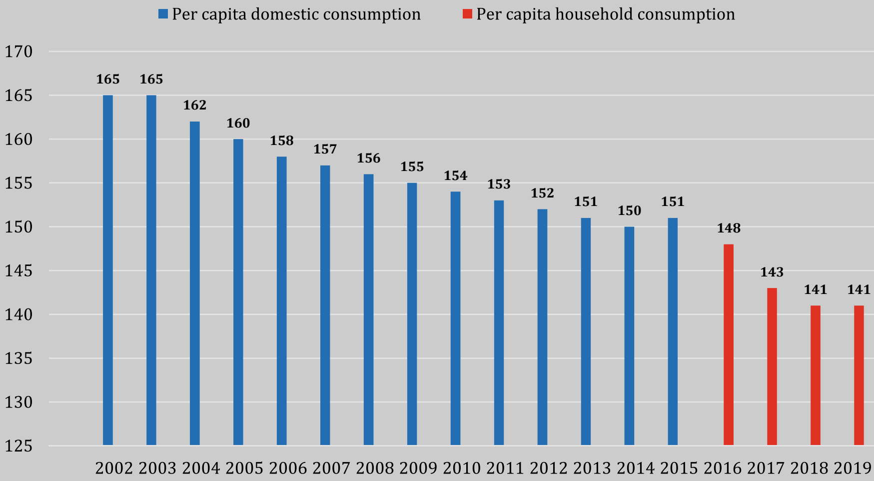

Fig. 6.1 Household water consumption in Singapore.[18] *Source* PUB (2020)

In 2017, the government increased the annual GST Voucher—U-Save rebate[19] for eligible Housing and Development Board (HDB) flats to help households cope with the tariff price changes. The rebate amount ranged from SGD40 to SGD120 per year, based on the type of flat (PUB n.d.). On average, eligible HDB households receive between SGD220 and SGD380 in U-Save rebates per year, which are credited to their respective utility accounts (PUB n.d.). Instead of implementing a low unit charge for the initial blocks of IBTs, which impact all consumers irrespective of their income levels, the targeted rebates approach provides assistance to lower-income groups while collecting revenue for those who can afford to pay (Hoque and Wichelns 2013).

6.5 Key Takeaways

1. Economic instruments are aimed at influencing customers' water consumption behaviour via economic means such as tariff structuring, water rebates, and fines for excessive use.

[18] From 2016, the indicator has been revised to measure water consumption within household premises only (PUB representative in AWGWRM. Email interview, 7 March 2022).

[19] Rebate voucher for eligible households.

2. Tariff mechanisms are the most commonly used economic instrument for WDM in ASEAN. For an optimal economic solution, tariff rates can be structured to reflect the operational and maintenance costs for the water service provider and the value of the resource to encourage water conservation.
3. Most major cities in the ASEAN region have implemented the increasing block tariff (IBT) system. However, only a few, including Singapore and Jakarta (Indonesia), account for full-cost recovery (FCR) in their tariff structure. In Singapore, these measures partly contributed to a reduction in household water consumption by 2 L/day per capita on average, from 143 L/day in 2017 to 141 L/day in 2019.
4. Rebates incentivise water conservation behaviour through measures such as partial refunds on water bills, retrofitting residential properties with water efficiency appliances, and installing a rainwater harvesting facility as an alternative water source. Such measures have been implemented in Johor and Penang, Malaysia.
5. Fines for excessive water use have also been implemented as a deterrent to water wastage, typically in areas where water resources are scarce or have become depleted due to climatic conditions or over withdrawals. Such measures are in place in Thailand and Indonesia.

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Chapter 7
Non-price Mechanisms

Non-price mechanisms denote non-economic tools implemented by water service providers and governments to influence the water consumption of users by reducing their water usage and/or shaping water-use practices and habits, rather than by adjusting the price of water via economic instruments (Matikinca et al. 2020; Reynaud 2013). Non-price mechanisms include, but are not limited to, education and awareness-raising campaigns, water restrictions, installation of water-saving devices that limit consumption, and water audits (Joubert and Ziervogel, 2019; Matikinca et al. 2020; Stavenhagen et al. 2018). These measures are further defined as follows:

1. Restrictions for specific water use refer to the control of water consumption in terms of quantity, water consumption time, and/or specific water uses. Such measures are applied temporarily during periods of acute water shortage to reduce peak consumption.
2. Water-saving devices refer to the uptake of water technologies that use less water for the same level of performance by reducing or restricting water flows. Commonly used water-saving devices include low-flow/dual-flush toilets, vacuum toilets, shower timers, low-flow taps and mixer faucets, water-efficient washing machines, and water-efficient dishwashers. Water-saving labelling schemes that assess the amount of water used by certain products by providing a label or rating to reflect their water efficiency levels may also be implemented to provide consumers with information on the water efficiency of labelled appliances. This aims to encourage consumers to purchase water-saving appliances.
3. Public campaigns and school curricula provide information through various media channels, including billboard advertising and social media, to promote water-efficient behaviour among target audiences. Public education programmes on water conservation are widely practised in schools globally, to impart the importance of water conservation to children and youths.
4. Water auditing is a method of identifying and accounting for all water flows within the water distribution system (EPA 2015). Water audits provide water service

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providers with important information about potential leaks, storage overflows, and unauthorised consumption.

5. Outreach and communication through utility bills include summarised data on water usage and a detailed breakdown of charges in a utility bill received by consumers.

There is increasing support in research that non-price mechanisms can result in positive behavioural changes in consumers' water usage, thereby reducing water consumption. Hence, water service providers are gradually incorporating these as part of their WDM strategies (Brick and Visser 2017; Brick et al. 2017; Matikinca et al. 2020; Tortajada et al. 2019).

7.1 Restrictions for Specific Water Uses

Water-use restrictions refer to the rationing or limiting of water availability by quantity, time of consumption, and/or for designated uses (EEA 2017). In general, restrictions are first officially mandated at the government level before being implemented by water service providers to reduce peak consumption during times of acute water distress (e.g. droughts) (EEA 2017). They are often preferred over economic instruments[1] as an immediate or temporary response when water supply is critically limited (Climate Adapt 2020). Research suggests that formal restrictions can be effective and are now commonplace (Haque et al. 2014).

There are a wide range of water restrictions that can be implemented by governments (local, regional, national) and water service providers, to reduce water consumption (Cooper et al. 2019; Robinson and Conley 2017). Water restrictions aim to encourage individuals to lower their water usage on a daily, weekly, or monthly basis. In addition, water restrictions may be temporary or permanent (Manouseli et al. 2018). However, water demand and water consumption could revert to their earlier, higher levels after water restrictions are lifted. Where recurrent or persistent water scarcity is encountered in a given context, other WDM measures may be implemented alongside water restrictions (Climate Adapt 2020; EEA 2017).

Compulsory water restrictions, in particular, can lead to significant water savings—up to 55%—for residential water consumers in a short span. They are also associated with penalties (e.g. fines) for non-compliance (Manouseli et al. 2018). During times of water scarcity or crises, compulsory water restrictions on specific

[1] The imposition of economic instruments may result in some households being advantaged over others. Although higher prices can lead to a reduction in water use, the lack of concessions for poor or large households may enable wealthy households to simply 'buy' their way out of water shortages. In addition, pricing changes may be slow to implement and politically unpalatable to governments if deemed unpopular with voters (Ehret et al. 2021).

uses of water may be implemented to prevent water shortages[2] and ensure immediate reductions in water usage to conserve scarce water supplies (Mullin and Rubado 2017). For compulsory water restrictions, households may be allowed to undertake certain activities, such as watering gardens but not lawns, at certain times of the day or week (Climate Adapt 2020; Cooper et al. 2019; Robinson and Conley 2017). For example, a 2014 study in Sydney, Australia, found that Level 1,[3] Level 2,[4] and Level 3[5] water restrictions between 2003 and 2009 resulted in water savings of 9%, 18%, and 20%, respectively, for the single-dwelling residential sector, and 4%, 8%, and 9%, respectively, for the multiple-dwelling residential sector (Haque et al. 2014).

However, the implementation of water restrictions may be limited by political will and public resistance (Stoutenborough and Vedlitz 2014). Water restrictions that limit outdoor watering to particular days or forbid certain activities may seem arbitrary to the public if the reasoning behind the implementation of water restrictions is not clearly communicated (Mullin and Rubado 2017). In some cases, individuals may ignore or bypass water restrictions, which creates difficulties for enforcement (Ehret et al. 2021; Sisser et al. 2016; Wilson et al. 2021), and result in heavy fines or temporary suspension of water supply.

7.2 Water-Saving Devices and Labelling Schemes

Non-price mechanisms that encourage water-efficient behaviour can be supported by appropriate infrastructure, such as water-saving devices, retrofits, and labelling schemes (Bello-Dambatta et al. 2013; Moglia et al. 2018). Water-saving devices are technologies that reduce water flows and improve water-use efficiency. Commonly used water-saving devices include low-flow/dual-flush toilets, vacuum toilets, shower timers, low-flow taps and mixer faucets, water-efficient washing machines, and water-efficient dishwashers (Bello-Dambatta et al. 2013; EU EURDF n.d.; Sheth 2017). Examples of water-saving devices are given in Table 7.1.

The use of water-saving devices has resulted in significant water savings for users (Manouseli et al. 2018; Stavenhagen et al. 2018). For instance, low-flow faucets can reduce the amount of water flow independent of water pressure, resulting in water

[2] Aside from creating water security concerns, water shortages can result in inconvenience and economic costs for the community and a loss of producer surplus for the water service provider (March et al. 2012; Wilson et al. 2021).

[3] No use of sprinklers or other watering systems.

[4] In addition to Level 1 restrictions, no hosing of hard surfaces and vehicles, nor of lawns and gardens, the only exception being handheld hosing (of lawns and gardens) before 10 am and after 4 pm on Wednesdays, Fridays, and Sundays; no filling of new or renovated pools over 10,000 L except with a permit from Sydney Water (water service provider).

[5] In addition to Levels 1 and 2, the number of days on which handheld hosing of laws and gardens was reduced to two days (Wednesday and Sunday); no hoses or taps to be left running unattended except when filling pools or containers; fire hoses used only for firefighting purpose and not for cleaning.

Table 7.1 Water-saving devices

Device type	Device image	Device description
Low-flow faucets	 *Source* WaterMark (n.d.)	Takes a trickle of water, shaping it into a paper-thin sheet of water as wide as an average hand. This results in a more efficient distribution of the water from handwashing taps
	 *Source* EU ERDF (n.d.)	Aerated nozzles produce a fine mist rather than a solid flow of water
Mixer faucet	 *Source* EU ERDF (n.d.)	Taps with built-in water brakes (click-stop technology) and thermo-regulating valves achieve savings in both water and energy consumption
Showerguard timer	 *Source* WaterMark (n.d.)	Halts the flow of hot water in the shower after a pre-set shower time (e.g. between 2 and 20 min)

(continued)

Table 7.1 (continued)

Device type	Device image	Device description
Dual-flush toilet	 EU ERDF (n.d.)	Dual-flush cisterns accommodate different flushing requirements
Waterless no-flush urinals	 *Source* WaterMark (n.d.)	Use gravity to drain the urine down into a recyclable trap insert. The sealing liquid floats on top of the urine contained in the trap, building up an effective odour barrier

Source EU ERDF (n.d.), WaterMark (n.d.)

savings of 50–80% (Sheth 2017). Water-efficient washing machines and dishwashers can reduce water use by 33% (Sheth 2017), and replacing a standard 3.5-gallon toilet with a low-flow toilet can reduce toilet water use by 54% (MWRA n.d.). Similarly, waterless no-flush urinals can produce cost savings of up to USD 0.72 per 1000 uses[6] (WaterMark n.d.). The installation of water-saving devices may be complemented by public awareness campaigns and water efficiency labelling schemes to promote more efficient water consumption and behaviours (Manouseli et al. 2018).

Retrofitting may require careful planning and significant costs for installation to consumers. Despite the potential long-term cost-effectiveness of water-saving devices, households/businesses may be reluctant to pay the upfront costs for installation. However, authorities may promote the uptake of water-saving devices through various measures, such as

(a) Low-cost availability of device.
(b) Direct distribution of devices among the population.

[6] Estimate based on water-efficient WaterMark products in Australia.

(c) Outreach campaigns.
(d) Regulations, quality standards, and labelling schemes.

Source EEA (2017).

Water-saving labelling schemes are programmes that assess the amount of water used by certain products by providing a label or rating to indicate their water efficiency levels (IWA 2019). The aim is to provide consumers with information about the water efficiency of a labelled appliance and to encourage consumers to purchase and use these water-efficient appliances. A variety of water efficiency labelling schemes have been developed internationally and have demonstrated effective outcomes in countries where they have been implemented (IWA 2019). Table 7.2 presents some examples of internationally implemented labelling schemes and their outcomes.

Internationally, the use of water-saving schemes has been acknowledged as a 'high-impact' option. In ASEAN, water-saving schemes have been implemented, such as in Malaysia and Singapore. In Singapore, the Water Efficiency Labelling Scheme (WELS)[7] was introduced in 2006 and made mandatory in 2009. Under the scheme, to date, products are labelled according to their efficiency rating, ranging from 1-tick to 4-ticks. It applies to products such as taps and mixers (basin, sink/bib, shower), household washing machines and dishwashers, urinal flush valves/waterless urinals, and water closet (WC) flush valves. From 1 January 2022, the mandatory scheme was extended to WC flush valves and commercial appliances such as commercial dishwashers, washer extractors, and high-pressure washers. The water efficiency ratings and requirements by PUB (Singapore) are indicated in Table 7.3a–c. The scheme contributed to a significant reduction[8] in water consumption across 10 years—from 155 L/day in 2009 to 141 L/day in 2019 (PUB 2012, 2020).

Malaysia introduced a similar scheme in 2013. Its voluntary water-efficient products labelling scheme (WEPLS) allows product suppliers to register and label their water-efficient products with reference to guidelines provided by SPAN.[9] WEPLS uses three levels of water efficiency ratings for all the specified product types with three product ratings: *efficient, highly efficient,* and *most efficient.* Ratings are assigned according to specified thresholds for each product category (Table 7.4). As of 2018, WEPLS has covered five products: water closets, clothes washing machines, showerheads, water taps, and urinals sold by 25 suppliers, comprising 37 brands and 288 models (SPAN 2016; 2018).

Upon meeting the thresholds indicated in the table above, each product receives a label according to the rating issued to a particular product brand and type. The label indicates the water efficiency rating as shown by the star (✰) signs, with detailed information about the product's water efficiency. Figure 7.1 illustrates the WEPLS labels in Malaysia, which must be affixed to each model and its packaging, to allow

[7] As a follow-up to the Voluntary Water Efficiency Labelling Scheme (Voluntary WELS), first introduced in 2006, the Mandatory Water Efficiency Labelling (Mandatory WELS) was introduced in 2009 (PUB 2012).

[8] In combination with several other WDM measures such as metering, tariffs, leak detection, pipe replacements, DMA creation, etc. (CLC 2012; PUB 2020).

[9] Suruhanjaya Perkhidmatan Air Negara (National Water Regulator).

Table 7.2 International water efficiency labels

Country/area	Name of scheme	Mandatory/voluntary	Reported outcomes
Australia	Water-efficient labelling scheme (indoor)	Mandatory	31,500 products registered Estimated annual water savings of 70 billion litres in 2013 Household utility bills reduced by AUD520 million in 2013[10]
	Smart approved watermark	Voluntary	Received over 500 applications, of which 350 have been deemed water efficient
Canada and USA	WaterSense	Voluntary	Over 27,000 products registered. The scheme reported savings of more than 4.5 million megalitres of water, 284 billion kWh, and USD 46.3 billion in savings in consumer water and energy bills by 2017
China	Water conservation certificate	Voluntary	Issued nearly 7000 certificates and certified more than 400 enterprises Conserved 5.28 million m^3 of water in 2017 through certification of water closets, water faucets, and showers
Europe (including the UK)	European water label	Voluntary	Almost 10,000 products registered through 120 major brands with a collective market coverage of 68.7%
Hong Kong	WSD Water Efficiency Labelling Scheme	Voluntary	Around 650 products registered

(continued)

[10] AUD 1 = 0.72 USD.

Table 7.2 (continued)

Country/area	Name of scheme	Mandatory/voluntary	Reported outcomes
India	Water-efficient products India (WEP-I)	Voluntary	Not yet in force
New Zealand	Water Efficiency Labelling Scheme	Mandatory	The scheme found a significant shift towards improved water efficiency across all product categories, but not a significant reduction in household water consumption
Portugal	ANQUIP	Voluntary	110 toilets were awarded the label representing 75% of the national market
UAE	United Arab Emirates ESMA water efficiency label	Mandatory	N/A

Source IWA (2019)

consumers to see and recognise them clearly. Any modifications made to the products must be communicated to SPAN, after which an assessment is made on need for rating adjustments (SPAN 2018).

7.3 Public Campaigns and School Curricula

Low public awareness of water use and its importance is seen as an impediment to achieving sustainable water efficiency. Changes in public behaviours may be influenced through incentives and other means of persuasion (Bello-Dambatta et al. 2013). Hence, water service providers and governments may implement 'soft interventions' such as public campaigns and education programmes to promote water conservation practices (Baalousha and Ouda 2017; Moglia et al. 2018; Stavenhagen et al. 2018). 'Soft interventions' largely target residential water users with the purpose of modifying personal water-use behaviours through information dissemination and education (Bello-Dambatta et al. 2013; Kayaga and Smout 2011). The most commonly used strategy in a campaign is to disseminate information about changes in water usage and habits to citizens in layman terms through various forms of media, including billboard advertising and social media (March et al. 2012; Sauri 2020). Awareness campaigns targeted at households have been implemented in all ASEAN countries.

As public campaigns and education programmes focus on behavioural changes, their impact is often difficult to quantify (EEA 2017). Nonetheless, they are both

Table 7.3 Water efficiency ratings and requirements by PUB (2022), Singapore

a

Products/fittings	Flow rate/flush capacity requirements	
Water efficiency rating	2-tick ✓✓	3-tick ✓✓✓
Shower taps and mixers (L/min)	> 5 to 7	5 or less
Basin taps and mixers (L/min)	> 2 to 4	2 or less
Sink/bib taps and mixers (L/min)	> 4 to 6	4 or less
Dual-flush flushing cisterns (litres per flush)	> 3.5 to 4.0 (full flush) > 2.5 to 3.0 (reduced flush)	3.5 or less (full flush) 2.5 or less (reduced flush)
Urinal flush valve and waterless urinals (litres per flush)	> 0.5 to 1	0.5 or less or waterless urinals
Water closet (WC) flush valves (litres per flush)	> 3.5 to 4.0	3.5 or less

b

Appliances	Water consumption requirements			
Water efficiency rating	1-tick ✓	2-tick ✓✓	3-tick ✓✓✓	4-tick ✓✓✓✓
Clothes washing machines (per washload)	NA	> 9 to 12 L/kg	> 6 to 9 L/kg	6 L/kg or less
Dishwashers (per place setting)	> 1.2 to 1.5 L	> 0.9 to 1.2 L	> 0.6 to 0.9 L	0.6 L or less

c

Commercial equipment	Types	Water efficiency requirements
Commercial washer extractor	• Front load • Top load	≤ 8.0 L/kg
Commercial dishwasher	• Undercounter • Hood	≤ 2.4 L/rack
High-pressure washer	• For general cleaning except for the following use: – Household – Steam cleaning or hot water pressure washing – Washing of equipment or vehicle	≤ 11.0 L/min

Source PUB (2022)[11]

acknowledged worldwide as useful non-price mechanisms that governments and water service providers could implement (Booysen et al. 2019; Matikinca et al. 2020; Tortajada et al. 2019). They are also considered as an effective means of promoting long-term water conservation (Gilbertson et al. 2011; Kampragou et al. 2011; Ramsey et al. 2017).

[11] PUB representative in AWGWRM. Email interview, 7 March, 2022.

Table 7.4 Water efficiency rating by SPAN

Water consumption	Efficient 1—☆☆☆	Highly efficient 2—☆☆☆	Most efficient 3—☆☆☆
Basin taps and mixers	$6.0 < f \leq 8.0$	$4.0 < f \leq 6.0$	$1.5 < f \leq 4.0$
Sink taps and mixers	$6.0 < f \leq 8.0$	$4.0 < f \leq 6.0$	$2.5 < f \leq 4.0$
Shower taps and mixers	$8.0 < f \leq 10.0$	$6.0 < f \leq 8.0$	$4.5 < f \leq 6.0$
Ablution taps and mixers	$6.0 < f \leq 8.0$	$4.0 < f \leq 6.0$	$1.5 < f \leq 4.0$
Water closets	Full flush $fv \leq 6.0$ Reduced flush $fv \leq 3.5$	Full flush $fv \leq 5.0$ Reduced flush $fv \leq 3.5$	Full flush $fv \leq 4.0$ Reduced flush $fv \leq 3.5$
Urinal equipment	$1.5 < fv \leq 2.5$	$1.0 < fv \leq 1.5$	$fv \leq 1.0$
Showerheads	$8.0 < f \leq 10.0$	$6.0 < f \leq 8.0$	$4.5 < f \leq 6.0$
Clothes washing machines	$12 < v \leq 15$	$9 < v \leq 12$	$v \leq 9$

Source SPAN (n.d.)

Fig. 7.1 Water-efficient product labels in Malaysia. *Source* SPAN (n.d.)

The nature of the messages that policymakers and water service providers strive to communicate through campaigns is crucial (Matikinca et al. 2020; Moglia et al. 2018; Tortajada et al. 2019). For instance, a persistent media focus on droughts, and messages that emphasise the importance of water conservation, can lower water demand by up to 18% in states such as California (Moglia et al. 2018; Quesnel and Ajami 2017). In the Philippines, as a precautionary measure against El Niño, water districts have launched water conservation campaigns featuring conservation

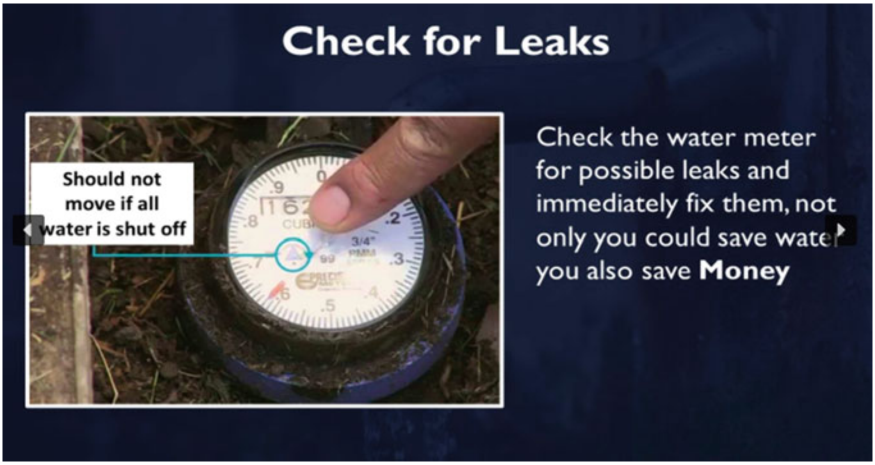

Fig. 7.2 Water conservation tips, LWUA. *Source* LWUA (n.d.)

tips for households (LWUA Memorandum Circular 004-19)[12] (LWUA 2019). These campaigns included specific recommendations to the public, such as adjusting shower habits, checking for pipe leaks, cleaning vehicles with pail and rags (instead of water), and recycling water (LWUA n.d.) (Fig. 7.2).

Likewise, the National Water Resources Board (NWRB) in the Philippines has engaged the public through workshops and conferences. For example, The International Virtual Conference on Water Demand Management, held on 18 March 2021, during the Philippine Water Week 2021 (NWRB n.d.), sought to (1) educate the public about the concept and benefits of WDM, (2) gather insights on WDM from other countries which experienced water supply problems, and (3) learn and recommend hood practices which are applicable to the Philippine setting. Various WDM-related topics were covered in the conference, including (1) WDM in the Philippines; (2) droughts, restrictions, and WDM in Cape Town; (3) end-user WDM strategies in the USA; (4) synergising water utilities and business towards water sustainability in Indonesia; (5) the Singapore Water Story; and (6) a municipal drought plan for WDM (El Dorado irrigation district).

To support existing WDM efforts, the National Water Resources Board also established the Knowledge, Learning, and Research Centre for WDM in partnership with the Western Mindanao State University on 27 January 2022. The knowledge centre aims to (1) monitor and manage knowledge-building and skill development initiatives and data gathering on WDM; (2) develop WDM policies based on national research activities; (3) conduct public awareness, outreach activities, and school educational programmes that will develop and maintain high levels of public awareness on the importance of water efficiency and boost public knowledge and participation in

[12] LWUA Memorandum Circular 004-19 attached in Appendix C.

WDM initiatives by creating tangible demand from stakeholders through proactive information campaigns, policy formulation, regulatory support, and knowledge-sharing activities; and (4) develop a WDM information program that will optimise water allocation and protection of water resources.[13]

Public campaigns may also highlight the environmental and economic benefits of efficient water use (Bello-Dambatta et al. 2013; Kayaga and Smout 2011; Moglia et al. 2018; Sauri 2013). For instance, in the Philippines, the Zamboanga City Water District (ZCWD), and AECOM International Development have set up a water audit and a WDM practices educational toolkit, which aims to educate other water districts as well as corporations and academic institutions interested to improve their water-saving practices. These interventions highlight the economic incentives of water-saving practices, and the toolkit provides information on block tariffs, water-efficient product labelling programmes, water audits, and strategy planning. It also includes comprehensive details on water meters/submeter standards, showerheads, bathroom and kitchen faucet flow rates, toilet flush volumes, and leak detection (ZCWD and AECOM 2016).

Public education programmes on water conservation have also been widely conducted in schools to impart the importance of conservation to children and youth, and in turn, their parents. Education programmes that can positively influence students' attitudes, behaviours, and habits include water conservation lessons, field trips, and educational films (Seyranian et al. 2015). Such programmes are already in place in various ASEAN countries such as Brunei, the Philippines, Thailand, and Singapore. In some cases, as shown below, water savings have been achieved, which also reduce the lack of water access for students, teachers, and other staff (MWA n.d.). We exemplify these cases as follows.

In Thailand, the Metropolitan Waterwork Association[14] (MWA) regularly stages activities to support youth networking to increase awareness about water conservation, water treatment processes, and water-quality standards. The 'Water Conservation Camp' that MWA held in 2016 emphasised water savings and included training in basic pipe repairs. The camp was conducted with 160 students from four schools in the Ratchaburi Province, Mae Klong River area, and received positive feedback (MWA 2016). By 2017, 48 schools from the Mae Khlong and Chao Phraya River basin communities attended the camp, with approximately 40 students in attendance from each school (MWA 2018).

[13] The Philippines, National Water Resources Board representative in AWGWRM. Email interview, 4 May, 2022.

[14] Water supplier for Bangkok, Samut Prakan, and Nonthaburi.

7.4 Water Efficiency Audits and Benchmarking

Water auditing is a method of identifying and accounting for all water flows within a water distribution system (EPA 2015). Water audits present water service providers with important information about potential leaks, storage overflows, and unauthorised consumption (Australian Water Association n.d.; EPA 2015; MDE 2013; ZCWD and AECOM 2016). They also help improve the knowledge and documentation of service providers' system operations, which reduces disruptions to the distribution system, enhances supply efficiency, and improves system integrity by reducing the potential for water contamination (AWWA n.d.; EPA 2016). Identifying potential problem areas also enables maintenance and repair efforts to be prioritised (NRDC 2015). Following an audit, corrective actions to water management techniques can generate ongoing savings for the water service provider to ensure reasonable 'payback periods'[15] (NRDC 2015). Although some water losses within the system may be unavoidable, audits can determine the proportion of water losses that may be 'economically recoverable' before investments in corrective action are made to the water system (NRDC 2015).

A preliminary water audit may be conducted as follows:

(a) Identify the amount of water added to the system (typically for one year).
(b) Identify authorised water consumption (billed and unbilled water).
(c) Calculate water losses (water losses = system input[16]—authorised consumption).
(d) (EPA 2015).

In the Philippines, for example, the Zamboanga City Water District (ZCWD) has established the Zamboanga Water Audit Team (ZWAT), an independent water audit team, to identify anomalies in water use and conduct water audits. The audit team comprises ZCWD employees with expertise in billing and metering, customer care, accounts management, and community relations. The team also compiled a water audit manual for the commercial and residential sectors, consisting of step-wise instructions for conducting audits, sample audit forms, audit reports, and additional reference guides (ZCWD and AECOM 2016).[17] In 2016, ZWAT also conducted four-day on-site water audit training for various commercial establishments (ZCWD and AECOM 2016).

Water audits also allow water service providers to monitor their water losses and compare their experiences with their peers, such as service providers and businesses in the industry, a practice known as benchmarking (EPA 2015). Benchmarking supports healthy competition among water service providers (e.g. public image) and improvements in performance through comparison (EEA 2017). For instance, to improve the water efficiency of the non-domestic sector, Singapore's PUB established the Mandatory Water Efficiency Management Practices (MWEMP) scheme in

[15] Periods to recover the cost of an action/investment.

[16] Volume of water entered into the water distribution system.

[17] Refer to Appendix B for sample audit activity and production reports.

2015. In accordance with MWEMP, large water consumers[18] must declare their water consumption levels, water efficiency plans, business activity indicators, and water recycling rates to PUB annually. Based on this data, PUB establishes water efficiency benchmarks for businesses in selected sectors, such as retail operations, offices, hotels, data centres, commercial laundries, wafer fabrication, semiconductors, and biomedical manufacturing (PUB 2021).

The benefits of water efficiency benchmarking are summarised as follows:

- Measure the performance of a business over time.
- Compare the performance of one business against other similar businesses.
- Identify where water efficiency can be improved.
- Establish realistic water reduction targets.
- Improve confidence in water efficiency.
- Save businesses money and energy by reducing their water consumption.

Sources EEA (2017); PUB (2020); Smart Water Mark (2021); Sydney Water (2021); Water Corporation (2021).

7.5 Outreach and Communication Through Utility Bills

Water consumers may change their consumption levels not only in response to price signals, but it also to more information about their water use (Stavenhagen et al. 2018). Water utility bills on paper or digital platforms constitute an essential outreach tool to educate consumers. Information in bills may include summarised data on consumers' water use as well as a detailed breakdown of charges in that bill (EPA 2016). For example, graphical data on a given consumer's average daily consumption over a period of time enables comparison of water use over time to that of other consumers (City West Water n.d.; EPA 2016, 2019). For relatively high-consumption users, information on their usage compared to that of an 'average' water consumer, and a 'conserving' water consumer, can promote conscious consumption (EPA 2016).

In Indonesia, Adhya Tirta Batam (ATB), a private concessionaire, has launched a mobile application that provides customers with detailed information on their bills, including their monthly water consumption trends (ATB 2019). Likewise, in Vientiane, Laos, the Nam Papa Nakhon Luang (NPNL) launched the 'Nampapa Nakhone Luang App' mobile application in 2017. The app provides customers with detailed information on their monthly bills and consumption trends for the preceding three months. The application also includes a 'water calculation' feature that estimates the monthly water charge that is inclusive of maintenance costs and tax, based on factors such as the year, quantity, and pending charges from previous bills (NPNL n.d.; Apple n.d.). The application interface can be found in Figs. 7.3 and 7.4.

[18] PUB defines large water users as those whose net water consumption exceeded 60,000 m^3 in the previous year.

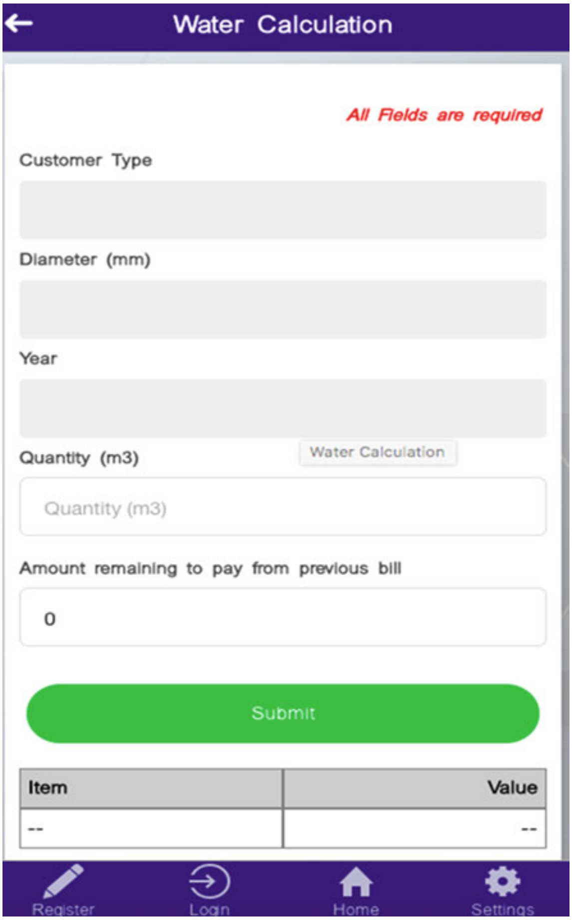

Fig. 7.3 NPNL application interface. *Source* NPNL (n.d.)

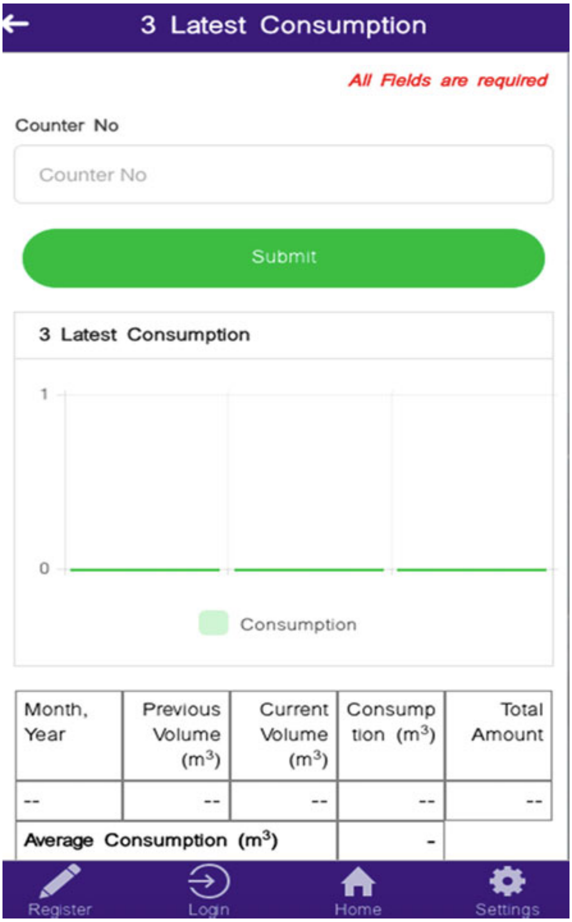

Fig. 7.4 NPNL application interface. *Source* NPNL (n.d.)

7.6 Case Snippet: Jakarta, Indonesia

Water provision in Jakarta is delivered by a unique public–private arrangement. Although a 25-year concession agreement was signed with two private entities, PALYJA and Aetra in 1998, water provision in Jakarta, by law, is still provided by PAM Jaya, Jakarta's state-owned enterprise, as the water assets' owner. Under this concession agreement, PALYJA and Aetra undertake water service operations in Jakarta, ranging from production and distribution to billing and collection (Aerta 2018).

PALYJA and Aetra are acknowledged as having competent customer services, particularly their customers' water bill payment experience. Both companies have utilised a variety of payment channels, ranging from post offices to e-commerce, facilitating the ease with which their customers can settle their water bills. The use of an electronic billing system allows customers to check and pay their monthly water bills online via e-banking platforms without having to visit a physical payment booth (PALYJA n.d.; Aerta 2018). PALYJA has introduced the so-called bill on the spot or BOS mechanism, which allows the PALYJA's metering staff to print the customer's water bills and receive payment when they check the water meter every month (PALYJA n.d.; 2016).

These structures have been put in place partly to address late or non-payments by customers. It was reported that these strategies were effective, evidenced by a 91.9% surge in on-time payments in PALYJA's concession areas[19] in 2016 and a 92.78% improvement in Aetra's concession areas in 2018. Apart from these 'nudge' approaches, PALYJA and Aetra have, at the same time, imposed strict sanctions on those not paying their water bills on time which involved temporarily disconnecting the water services and fines (PAM Jaya 2014).

To ensure that measures are enforced, PALYJA and Aetra have employed identical public outreach strategies on both their online and offline platforms. Offline outreach to customers has been conducted through direct meetings at the district hall or brochures which provide information on connection installation, payment methods, campaigns on the impact from the use of groundwater, and water-saving techniques. Both companies have also used multiple social media platforms to launch public campaigns and to disseminate information on service disruptions. PAM Jaya's social media accounts occasionally publish information on water-saving awareness. In 2016, PALYJA reported a relatively high customer satisfaction rate of 82%, while Aetra attained a comparable customer satisfaction rate of 85.43% for the same year (PALYJA 2016; Aetra 2018).

[19] Areas of operation.

7.7 Case Snippet: Brunei Darussalam

The Department of Water Services (DWS) under the Ministry of Development (MoD) is the Water Authority in Brunei. It has the custody and administration mandate of the country's waterworks and is responsible for the supply management and distribution of water. Several measures related to non-price WDM mechanisms have been implemented in Brunei, including public education campaigns, school curricula, product labelling schemes, and water audits.

The DWS regularly publishes posters and pamphlets to encourage water conservation. These posters and pamphlets contain information relating to typical household water consumption in Brunei Darussalam, the need to save water, and useful water-saving tips (MoD n.d.) (see Figs. 7.5 and 7.6). DWS also distributes water-saving posters and stickers targeting government buildings, building complexes, mosques, and hospitals throughout Brunei Darussalam. As of July 2021, water-saving posters were distributed to the Ministry of Health building and shopping complexes within the Brunei-Muara district. Likewise, water-saving stickers were distributed to RIPAS hospital, mosques and hospitals in the Tutong and Belait district, and government clinics within Brunei-Muara district.

Fig. 7.5 Water-saving tips from the Department of Water Services, Brunei Darussalam. *Source* Ministry of Development (2012a)

Fig. 7.6 Water Facts from the Department of Water Services, Brunei Darussalam. *Source* Ministry of Development (2012b)

Regarding school curriculum, the Ministry of Education plans to establish 'green schools programmes' that focus on activities based on five environmental concerns,[20] which include reducing water consumption and improving water conservation. The guidebook for initiating green schools in Brunei Darussalam also serves as a benchmark for all schools (government and non-government), ranging from primary to pre-university levels (Ministry of Education n.d.). Similarly, the DWS frequently conducts water conservation awareness programmes in primary schools through means of quizzes, jigsaw puzzles and colouring. As of 2021, the programme was implemented in 8 schools (see Fig. 7.7).

[20] Energy, waste management, green school space, water, and health (Ministry of Education n.d.).

Fig. 7.7 Water conservation activities in primary schools, Brunei Darussalam. *Source* Department of Water Services representative in AWGWRM (6 May 2022)

To support public campaigns and water conservation efforts, DWS conducts water audits on government buildings to monitor water losses. In 2020, following a water audit in the DWS building, they replaced several water fittings with water-saving fittings. In 2021, DWS conducted water audits in government buildings such as the Department of Building Services, Department of Water Services, and Public Works Department and submitted recommendations to replace existing water fittings with water-saving fittings.[21] DWS aims to continue conducting water audits on other government buildings and encourage the use of water-saving fittings, particularly those that have been registered with the Brunei Water-Efficient Products Labelling Scheme (BWELS).

[21] Brunei Darussalam, Department of Water Services representative in AWGWRM. Email interview, 6 May 2022.

The BWELS encourages the participation of water fitting vendors to register with BWELS and print water-saving labels on approved products. BWELS uses three levels of water efficiency ratings for all the specified product types with three product ratings: *good, very good*, and *excellent.* Ratings are assigned according to specified thresholds for each product category (see Table 7.5).

Table 7.5 Water efficiency rating by DWS

Water fittings	Flow rate requirements		
	Good	Very good	Excellent
1. Basin taps and mixers 	> 4 to 6 L/min	> 2 to 4 L/min	≤ 2 L/min
2. Sink taps and mixers 	> 6 to 8 L/min	> 4 to 6 L/min	≤ 4 L/min
3. BIB TAP 	> 6 to 8 L/min	> 4 to 6 L/min	≤ 4 L/min
Water fittings	**Flush rate requirements**		
	Good	**Very good**	**Excellent**
4. Water closet (flushing cisterns) 	> 5 to 6 L (full flush) > 3 to 3.5 L (reduced flush)	> 4 to 5 L (full flush) > 2.5 to 3 L (reduced flush)	≤ 4 L (full flush) ≤ 2.5 L (reduced flush)
5. Urinal flushometer 	> 1.5 to 2 L/flush	> 1 to 1.5 L/flush	≤ 1 L/flush

Source Brunei Darussalam Department of Water Services representative in AWGWRM (6 May 2022)

Upon meeting the thresholds indicated in the table above, each product receives a label according to the rating issued to a particular product brand and type. The label indicates the water efficiency rating as shown by the star (✰) signs. As of May 2022, 2 water fittings companies registered with BWELS for three sanitary wares brands. At present, one company has already printed and utilised the labels as approved by DWS. The timeline for implementing the voluntary participation scheme of water fitting companies with BWELS is from 2020 to 2025.[22] The proposed BWELS label is shown in Fig. 7.8.

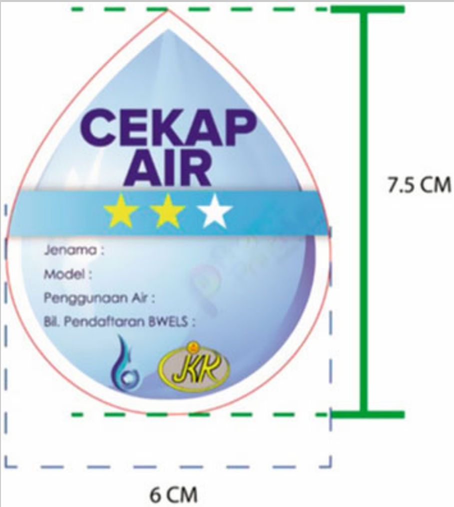

Fig. 7.8 Proposed BWELS Label

Source Brunei Darussalam, Department of Water Services representative in AWGWRM (6 May 2022).

7.8 Key Takeaways

1. Water service providers and governments can implement many non-price mechanisms to encourage water conservation among both residential and non-residential water users. Measures include, but are not limited to, education and awareness-raising campaigns, water restrictions, water-saving devices and labelling schemes, water efficiency audits, and consumer outreach through utility bills.

[22] See Footnote 21.

2. Non-price measures have been widely implemented in various forms and combinations throughout ASEAN, with demonstrated effectiveness in outcomes.
3. In certain contexts, compulsory water restrictions can lead to savings of up to 55% for residential water consumers in a short span of time, but temporary restrictions may not be sustainable in reducing water demand in the long run.
4. Water-saving devices are designed to encourage water conservation by restricting water flows. Appliances such as low-flow faucets and water-efficient washing machines and a low-flow toilet can reduce water use by 50–80% and 33%, respectively. Replacing a standard 3.5-gallon toilet with a low-flow toilet can reduce toilet water use by 54%. Similarly, waterless no-flush urinals such as in Australia (WaterMark products) can provide cost savings of up to USD 0.72 per 1000 uses.
5. Education programmes and public awareness campaigns, e.g. films, advertisements, social and print media, radio, and school curriculums, represent some non-price mechanisms. Regular media attention on droughts and messages that emphasise the importance of water conservation can lower water demand by up to 18% in states such as California.
6. Water audits are an essential step towards identifying water losses by quantifying flows within a distribution system. With the use of smartphones and mobile phones on the rise in ASEAN, water service providers could capitalise on digital platforms to conduct educational outreach on water conservation and enable customers to access their monthly water bills and estimates of their average quantity of water use per day.

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Chapter 8
Concluding Remarks and Water Demand Management Measure Overview

8.1 Concluding Remarks

WDM has a critical role to play in securing future water supplies. The management of water resources in cities globally has changed in recent years, due to rapid population growth, urbanisation, rising living standards, and impacts of climate change. This has resulted in the need to develop more sustainable and efficient urban water systems worldwide, with urgency.

Water management is dependent on the stage of development of the countries, legal and institutional frameworks, and institutional and financial capacities, among others. Given the current level of water consumption in urban areas, it will become increasingly challenging to manage water demand, unless cities are able to address current water challenges. These challenges include but are not limited to, increased water demand, growing competition between water users, water scarcity and pollution, inefficient water supply systems, and climate change impacts (Arfanuzzaman and Rahman 2017). Hence, the roles of water conservation and water demand management (WDM) measures are crucial in all spheres of the water sector (Kayaga and Smout 2011).

This guidebook is based on an extensive documentation review and synthesis of urban WDM policies and practices both in ASEAN, with international examples. It is designed to be an accessible resource for stakeholders, such as policymakers and practitioners, to assess and implement water demand management strategies and initiatives and promote knowledge transfer among ASEAN countries.

The guidebook draws upon notable WDM practices and policies, which have demonstrated effective demand management outcomes. The guidebook follows a WDM typology developed by the authors and comprises 47 indicators, further classified into three different categories of WDM applications, namely (1) water losses; (2) economic instruments; and (3) non-price mechanisms.

The guidebook recognises the efforts of ASEAN countries in initiating several WDM strategies and planning efforts. As large proportions of water loss in distribution networks are one of the main challenges that water service providers face

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in ASEAN, all countries in the region have implemented several NRW management strategies to overcome this concern. Strategies include NRW monitoring, leak detection, and pipe replacements. Within ASEAN, Metro Manilla (the Philippines), Singapore, Jakarta (Indonesia), and Johor (Malaysia), in particular, have been leading protagonists of investment in technologically advanced leak detection equipment and surveillance systems, which have contributed to significant improvements in NRW levels.

As low public awareness of water conservation continues to impede the objective of water-use efficiency, all ASEAN countries have invested in improving public communication and outreach as part of their WDM strategies. Since public campaigns and education programmes focus on behaviour changes, their impacts on water-use efficiency are often difficult to quantify and assess (EEA 2017). Nonetheless, they are both acknowledged as highly useful non-price mechanisms that governments and water service providers adopt (Booysen et al. 2019; Matikinca et al. 2020; Tortajada et al. 2019). In Malaysia and Singapore, campaigns that aim to influence water-efficient behaviours are further bolstered by supportive infrastructure, devices, and initiatives, which include water-saving devices, retrofits, outreach and communication through utility bills, and labelling schemes. Such measures have consistently proven effective in reining in water demand in many countries, including Singapore and Malaysia.

ASEAN countries may strengthen WDM management further by adopting cutting-edge technologies to manage water demand more efficiently, such as smart meters, smart DMAs, and other novel devices for leakage detection and management. They may review their tariff levels and structures to improve cost recovery, which is important as tariffs serve as a primary means for service providers to generate revenue and cover costs for water service provisions (Damkjaer 2020). Underpricing water may also inadvertently contribute to overconsumption and inefficient water usage (Bello-Dambatta et al. 2013; EPA 2016).

Policy and regulatory measures, as well as technical and institutional measures, are necessary components to each country's WDM efforts. A summary of these measures, for consideration by ASEAN leaders who oversee WDM efforts in their respective countries, is as follows:

(i) **Policy and regulatory**

- Water demand management can be made a priority issue at all levels of governance—regional (ASEAN), national, and local (and the priority of the local communities) through the development and implementation of coherent regional, national, and local water demand management policy frameworks.
- Encourage efforts at all levels (regional, national, and local) to promote water demand management through various policies and water demand strategies (e.g. tariffs and non-price mechanisms).
- Establish the importance of effective water demand management and the need to conserve water resources to help implement the plans for each ASEAN country, which could address broader environmental and development goals (e.g. UN Sustainable Development Goals).

- Ensure that legal and institutional frameworks possess the jurisdiction to enforce the implementation of national and local water demand management policies and strategies into actionable plans.
- Ensure that national plans/strategies incorporate achievable water demand management targets, which can be transposed into local water demand management plans and programmes.
- To support such policies and strategies, various regulatory, social, and economic instruments may be implemented, to ensure compliance by all stakeholders.

(ii) **Technical and institutional**

- Efficient and transparent institutional arrangements can be established in countries and city to identify and address limitations in service delivery. This can help improve organisational efficiency and encourage inter-departmental/agency cooperation. For instance, an independent national body such as a department of Water Demand Management with clear roles and responsibilities can be established.
- Decentralisation: Empower mid-level staff of water service providers to plan and implement WDM strategies.
- Smart and 'green' cities that formulate and implement efficient, innovative water demand management measures can be rewarded.
- Establish and maintain national water demand management statistics, which can be shared with all stakeholders so that they benefit from the shared knowledge. To achieve this, assessments and studies of all aspects of water demand management (e.g. residential and non-residential water consumption rates, rate of physical losses, and benefits of greywater recycling) may be conducted.
- Research and share information on the development of innovative and emerging water demand management technologies.

Sources Araral (2010), Rivera (2014).

8.2 Water Demand Management Measure Overview

A brief overview of key WDM measures and notable examples of implementation in ASEAN countries that are explained in greater detail in the guidebook can be found in Table 8.1.

Table 8.1 Key water demand management measures and notable examples

Key WDM measures	Description	WDM indicators	Notable examples in ASEAN	Section
Water losses: NRW management	Water loss is defined as the difference between water pumped into the system and billed water. The volume of water lost depends largely on the quality, maintenance, and approach to active leakage control of the water distribution network. The volume of water lost before reaching water users is referred to as non-revenue water (NRW)	Measures aimed at reducing the treated water loss in the distribution system. E.g – Leakage/NRW reduction target and monitoring mechanism – Leak detection – Pipe repair and replacement – Pressure management – Technology usage for leak detection and repairs	*Cambodia* PPWSA significantly reduced NRW from 72% in 1993 to approximately 9.78% in 2020. It implemented measures such as leakage repair and replacement, metering, and programmes to identify illegal connections and suspension of supply for non-payment *Indonesia* PALYJA and Aetra installed automated leak detection systems in 2016 to provide early warning alerts for potential leakages. In that time, 450 sensors, using AQUADVANCED technology, have detected 10–20 anomalies per day in the water distribution system PALYJA and Aetra also introduced DMAs to improve leakage detection. As of 2014, PALYJA had established 95 DMAs and aimed to build 52 more DMAs. Similarly, Aetra established 174 DMAs by 2013. As a result of DMA creation and leakage detection systems, 35,916 leakages were detected by PALYJA in 2016. This represented a 28% increase in leakage detection from 2015 (28,067 leakages). Meanwhile, Aetra increased leakage detection from 22,932 leaks in 2015 to 25,587 in 2016 (Aetra 2016) *Malaysia* Ranhill created SMART DMAs with semi-permanent noise loggers and correlations technology. The results from the initial installation (SMART DMA trial) of 295 noise loggers in Bandar Putra indicated a 35% reduction in NNF from 30.99 to 20.08 L/s within three months SPAN requires its water operators to meet standards for water pressure in landed and vertical buildings in its uniform technical guidelines for water reticulation and plumbing *The Philippines* Manila Water in Metro Manila: NRW reduction efforts helped reduce the NRW rate from 23.9% in 2007 to 10.4% in 2019 and the recovery of nearly 750 million litres per day MLD Maynilad: NRW reduction efforts helped reduce the NRW rate from 67% in 2007 to 25% in 2019 and helped to recover 979 MLD *Singapore* The PUB conducts regular leak detection tests using advanced technologies. Its intelligent water management system (IWMS) permits real-time monitoring of water assets across the network and provides a comprehensive set of readings for timely action *Thailand* MWA has reduced water losses by replacing damaged pipes and installing new pipes where required, resulting in a water loss reduction of 1.92% (since 2017), with a water loss rate of 29.83% in 2018	5

(continued)

Table 8.1 (continued)

Key WDM measures	Description	WDM indicators	Notable examples in ASEAN	Section
Water losses: commercial losses	Commercial losses, also known as 'apparent losses' or 'administration losses', are the water losses that occur in the distribution system and which are not paid for by the water consumer. Commercial losses can be the result of customer meter under-registration, data handling and billing errors, unauthorised use, or theft	Measures to reduce loss in revenue. E.g.: – Programmes to identify, remove, and replace illegal connections – Suspension and legal measures for non-payment – Meter replacement and upgrading – Programme to reduce meter tampering – Repairing the sites of leakages – Individual household metering	*Malaysia* SPAN's 7-year programme in Malaysia has set a 1% target for commercial losses. In addition, Ranhill SAJ (Johor's water utility) has added 38 staff to its newly established enforcement and preventative section in the customer service department. Ranhill SAJ also undertook an extensive water meter upgrading and replacement programme Ranhill SAJ has also put the following sanction mechanisms in place: – Any outstanding bills must be settled within 30 days, or else a disconnection notice will be issued – The deposit might be deducted to settle outstanding bills – The water licensee has the right to carry out suspensions and deduct deposits *Cambodia* PPWSA runs an internal education programme to educate PPWSA workers to ensure that they do not breach rules (e.g. facilitating the installation of illegal connections). Staff members who are involved in such activities are fined. Water supply suspensions are imposed on customers who do not pay their bills. PPWSA issues a warning and gives the customer a 15-day grace period. If the customer still does not pay, he/she is disconnected from the water supply network. To regain access, customers must pay the outstanding amount, a penalty amount of 1%, and a reconnection fee of 60,000 KHR[1]	5

(continued)

[1] KHR 1 = USD 0.000246.

Table 8.1 (continued)

Key WDM measures	Description	WDM indicators	Notable examples in ASEAN	Section
Economic instruments	Economic instruments are targeted at customers to motivate desired decision-making and directly influence their water consumption behaviour. This may be achieved by offering financial rewards (rebates and tax credits) for desired actions and/or penalties (penalties and fines) to deter undesirable behaviour	Monetary incentives to encourage water-saving behaviour among users. E.g.: – Tariff structure – Rebates/incentive schemes for consumption reduction through water bill – Fines for excessive use	*Singapore* Tariffs are based on volumetric consumption, covering the total cost of production and supply. Additionally, Singapore charges both a Water Conservation Tax (WCT) to encourage water conservation and to reflect the incremental costs of additional water supplies, as well as a waterborne fee (WBF) to recover the costs of used water treatments and to maintain the used water network. eligible HDB households receive between SGD 220 and SGD 380 in U-Save rebates on average per year *Indonesia* The national government imposes sanctions for non-payment, including fines and supply suspensions, under Government regulation No.122/2015 on water system provision Local governments and state-owned water utilities can issue fines imposed for non-payment. These measures may have contributed to a slight increase in water bill payment rates from 93.28% in 2018 to 93.67% in 2019 PALYJA and Aetra have also imposed tough sanctions on those not paying their water bills on time by temporarily disconnecting their water and levying fines *Malaysia* In Penang, the water utility PBAPP has implemented a corporate social responsibility programme to ensure that tariff reviews do not disadvantage low-income households. The programme costed PBAPP RM[2] 16,482 in 2017 and reached 199 families who earned RM790 per month or less In Johor, Ranhill has implemented a water rebate programme that provides free water to needy households for the first 25 m^3 of water consumption. In 2019, 3136 low-income households benefited from this programme *The Philippines* The private concessionaires Manila Water and Maynilad have a 'socialising' pricing scheme in place to ensure affordability for households. Manila Water provides a discounted charge of PHP 83.14[3] to low-income households with water usage of less than 10 m^3 per month *Thailand* The Water Resources Act (2018) imposes fines for excessive water use during periods of water rationing, as droughts could inflict severe national socio-economic and hydrologic damage. Individuals who do not comply may be imprisoned for up to a year or receive a fine of up to ฿100,000,[4] or both	6

(continued)

[2] RM 1 = USD 0.24.

[3] PHP 1 = USD 0.02.

[4] THB 1 = USD 0.030.

Table 8.1 (continued)

Key WDM measures	Description	WDM indicators	Notable examples in ASEAN	Section
Non-price mechanisms	Non-price measures refer to non-economic tools implemented by water utilities and governments that seek to control the water consumption levels by restricting water usage and/or altering water-use practices and habits, rather than by influencing the price of water	Non-price mechanisms that directly affect water consumption. E.g.: – Restrictions for water-specific uses – Water-saving devices and labelling schemes – Public campaigns and school curriculum – Water efficiency audits – Outreach and communication through utility bills – Water efficiency benchmarking (household/residential) – Water efficiency benchmarking (non-residential/industry)	*Brunei Darussalam* Both public campaigns and school education programmes are in place, with green school programmes teaching school children the importance of water conservation. The department of water services also publishes posters and pamphlets on water conservation to educate residents *Indonesia* PALYJA and Aetra have employed public outreach strategies via online and offline platforms. In 2016, PALYJA reported a relatively high customer satisfaction rate of 82%, while Aetra attained a comparable 85.43% in 2018 ATB has launched a mobile phone application that provides customers with detailed bills, which includes their monthly water consumption trends. ATB has also devised a minimum water bill scheme where customers are charged a minimum of 10 m^3 worth of water consumption should their monthly usage level fall below that threshold Aside from public outreach through online and offline platforms, PALYJA and Aetra have utilised various payment channels, ranging from post office to e-commerce platforms that allow customers to pay their water bills *Laos* NPNL launched a mobile application, 'Nampapa Nakhone Luang App', which provides customers with detailed information on their monthly bills and consumption trends of the past three months *Malaysia* Malaysia introduced the water-efficient products labelling scheme (WEPLS) in 2013. As of 2018, WEPLS applied to five products, namely water closets, clothes washing machines, showerheads, water tap, and urinals, sold by 25 suppliers across 37 brands and 288 models *The Philippines* The water district of Zamboanga City has established an independent water audit team to identify anomalies in water usage and conduct water audits. They have also developed water audit manuals and conducted audit training for the commercial sector. In 2016, ZWAT also completed a four-day onsite water audit training for various commercial establishments *Singapore* The WELS introduced in 2006 was made mandatory in 2009. The scheme contributed to significant water reductions in water consumption. Water consumption declined from 155 L/day in 2009 to 143 L/day in 2017 *Thailand* The MWA regularly conducts activities to support youth networking and raise awareness about water conservation, water treatment processes, and water-quality standards. The 2016 'Water Conservation Camp' emphasised water savings and included training in basic pipe repair with local schools. By 2017, 48 schools from the Mae Khlong and Chao Phraya River basin communities attended the camp, with approximately 40 students per school	7

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Appendix A

Additional References

See Fig. A.1.

$$\text{URV} = \text{PV of lifecycle costs/PV of additional yield}$$

PV of additional yield is bounded by a water requirement curve that represents a reduction in future water shortage (due to greater water availability). It is calculated as the thatched area EBCD (Bester et al. 2020). PV of lifecycle costs is inclusive

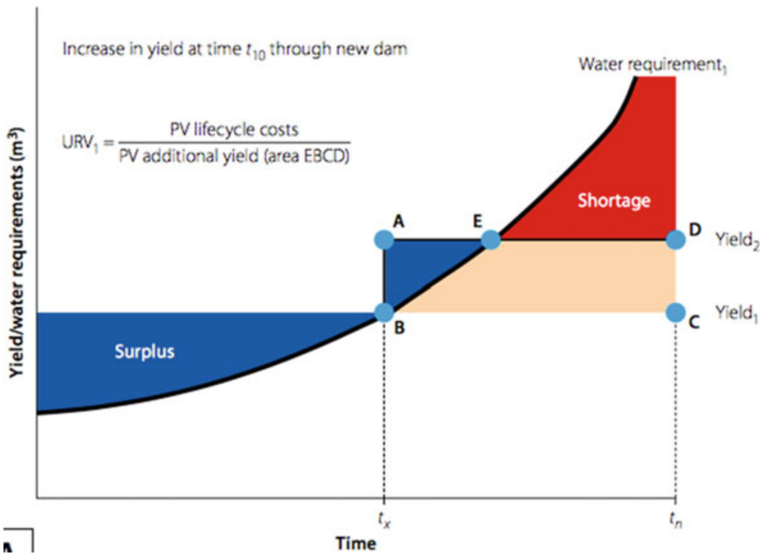

Fig. A.1 URV graphic illustration. *Source* Bester et al. (2020)

C. Ong et al., *Urban Water Demand Management*, SpringerBriefs on Case Studies of Sustainable Development, https://doi.org/10.1007/978-981-19-8677-2

of costs due to water pumping, water transportation, water treatments, etc. (Niekerk and du Plessis 2013).

Table A.1 includes information on measures not included in the typology, but which are relevant to WDM considerations.

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Table A.1 List of water demand management measures not included in the typology

Measure	Description	Sources
Capacity development	• Training and development of staff for effective leakage detection and repair • Ensuring accountability of the staff of the water utility	• Kayaga and Smout (2011) • Ministry of Water and Irrigation, Jordan (2016) • Rivera (2014)
Public–private partnerships	• A public entity entering into a contractual agreement with the private sector to take over some or all of its activities to provide services for the general public • Attempts made in the study (Baroudi et al. 2005) show positive changes in service delivery efficiency, including reducing unaccounted for water	Baroudi et al. (2005)
Energy management	• Energy may be lost from water distribution systems as a result of poor design specification, installation, and/or maintenance of pumps • Energy output can be managed through the replacement or refurbishment of pumps; installation of variable speed drives so that station output is matched to demand and/or ensuring the correct sizing of pumps	Bello-Dambatta et al. (2013)
Life cycle assessment	• Conduct a systematic analysis of the possible environmental impacts of products or services for water reuse and recycle purposes during their entire life cycle	Butler and Memon (2005)
Non-tariff economic instruments to encourage water efficiency	• Examples include taxation of alternative water sources and incentives/financial assistance to encourage water-efficient products adoption and drought surcharges. This involves the imposition of a temporary rate adjustment tied to drought conditions and water storage levels	Ministry of Water and Irrigation, Jordan (2016)

Appendix B

Audit Reports

See Table B.1.

Table B.1 Sample water audit production summary report

Residential			
Number of audits			
Number of toilets	Efficient	Not efficient	# of Leaks
Number of shower heads	Efficient	Not efficient	# of Leaks
Number of basins	Efficient	Not efficient	# of Leaks
Commercial			
Number of audits			
Number of toilets	Efficient	Not efficient	# of Leaks
Number of urinals	Efficient	Not efficient	# of Leaks
Number of shower heads	Efficient	Not efficient	# of Leaks
Number of basins	Efficient	Not efficient	# of Leaks
Summary By Surveyor			
Surveyor	Residential	Commercial	Total

Source ZCWD and AECOM (2016)

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Appendix C

Circulars

See Fig. C.1.

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LOCAL WATER UTILITIES ADMINISTRATION

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March 13, 2019

MEMORANDUM CIRCULAR No. 004-19

TO : LOCAL WATER DISTRICTS

SUBJECT : Water Conservation Campaign

In the El Niño Advisory No. 1 dated 20 February 2019 of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) of the Department of Science and Technology (DOST), all concerned agencies and the general public were advised to take precautionary measures to mitigate the potential adverse impacts of El Niño, which is anticipated to be weak and will likely result to below normal rainfall conditions in different parts of the country in the coming months.

The said office further advised in its El Niño Advisory No. 2 issued on 08 March 2019 that the recent conditions suggest that the El Niño phenomenon will likely continue until the April-May-June 2019 season and that varying impacts are now occurring in most areas of the country.

In the light of the said PAGASA advisories, all local water districts are hereby directed to immediately undertake Water Conservation Campaign in their respective areas as part of their precautionary measures in mitigating the potential adverse impacts of El Niño. The campaign must include water conservation tips, such as:

1. Repair leaking faucets;
2. Turn off the faucet when brushing teeth;
3. Take shorter showers;
4. Don't let the water run unabated while washing dishes;
5. Use dipper and pail when taking a bath;
6. Limit the use of washing machines;
7. Use dipper and pail in washing cars instead of running hose;
8. Collect the water used in rinsing fruits and vegetables for reuse in water plants;
9. Teach children to turn off faucets tightly after each use.

It is further directed that schools and hospitals should be prioritized in water distribution.

Strict compliance is enjoined.

JECI A. LAPUS
Acting Administrator

Fig. C.1 LWUA memorandum circular 004-19. *Source* LWUA (2019)