INTEGRATING SUSTAINABILITY IN HIGHER EDUCATION: GREEN CAMPUS PRACTICES FOR ADVANCING THE SUSTAINABLE DEVELOPMENT GOALS

Nur Jannah Azhar, Ariza Sharikin Abu Bakar*
School of Housing, Building and Planning, Universiti Sains Malaysia, MALAYSIA.

*Corresponding author: ariza.bakar@usm.my

Abstract
This study examines the potential of integrating green campus practices to enhance water efficiency within Institution Higher Learning (IHLs), focusing on Universiti Sains Malaysia (USM) as a case study. Using a mixed-method approach involving field measurements, water audits, and scenario-based analyses, the study evaluates the impact of implementing dual-flush toilets and low-flow taps on treated water consumption and operational costs. The findings indicate that the combined adoption of these water-efficient fixtures can substantially reduce water consumption, providing a cost-effective and practical solution for existing campus buildings. Beyond environmental benefits, the initiatives demonstrate financial viability through short payback periods and long-term utility savings, reinforcing the role of IHLs as leaders in practising and promoting sustainability within daily operations. The study also underscores the need for submetering systems and continuous monitoring to quantify performance more accurately. In the context of Penang's growing water scarcity, these interventions support the state's sustainability goals while contributing to the advancement of Sustainable Development Goal 6 (Clean Water and Sanitation) and Goal 12 (Responsible Consumption and Production), with recommendations to further explore integration with rainwater harvesting systems to enhance overall campus water resilience.

Keywords: Green Campus, Higher Education, Sustainability, Sustainable Development Goals, Water Efficiency.

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INTRODUCTION

According to the World Health Organization (WHO), the Sustainable Development Goals (SDGs), also known as the global goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. Ensuring that no individual or community is left behind remains a fundamental principle of sustainable development. The SDGs cover a wide range of complex social, economic, and environmental challenges and addressing them will require transformations in how societies and economies function and how we interact with our planet. Among these goals, SDG 6: Clean Water and Sanitation, emphasises the importance of ensuring availability and sustainable management of water and sanitation for all (Rashed & Shah, 2021).

Education, research, innovation and leadership will be essential in driving the progress of these goals, particularly in creating awareness and developing sustainable solutions for water conservation and management. Universities, with their broad remit around the creation and dissemination of knowledge and their unique position within society, have a critical role to model sustainability through their operations and campus culture. Domingos et al., (2024) highlighted that by integrating green campus practices such as rainwater harvesting, efficient plumbing technologies, and awareness campaigns on water conservation, universities not only reduce their environmental footprint but also demonstrate practical applications of SDG 6.

Therefore, this study focuses on exploring the role of green campus initiatives in promoting SDG 6 specifically within the context of Penang, with Universiti Sains Malaysia (USM) serving as the case study. As one of Malaysia's leading research universities and a recognised eco-campus, USM plays a vital role in demonstrating how higher education institutions can act as living role models for sustainable water management. Given Penang's growing urbanisation and increasing demand for water resources, the adoption of effective water conservation strategies within university campuses is becoming increasingly important. By implementing and strengthening green campus initiatives such as rainwater harvesting systems, water reuse technologies, and awareness programs USM can showcase practical solutions that align with SDG 6 and support the state's broader sustainability goals. Through these efforts, the university not only enhances its own water efficiency but also inspires students, staff, and surrounding communities to adopt sustainable water practices, thereby contributing to the collective agenda of achieving clean water and sanitation for all.

LITERATURE REVIEW

SDG 6 focuses on ensuring the availability and sustainable management of clean water and sanitation for all, recognising water as a critical element for human survival and environmental balance. In recent years, higher education institutions have been increasingly recognized as key players in supporting the SDGs through education, research, and sustainable campus operations.

Water Scarcity

Malaysian Context

According to Maniam (2021) regarding the water scarcity in Southeast Asian; freshwater demand across Southeast Asia continues to increase, driven by rapid population growth, accelerated urbanisation, industrial expansion, and the intensification of irrigated agriculture to support staple food production. The pattern of water withdrawal among Southeast Asian nations varies significantly, reflecting each country's unique socioeconomic structure. Within the household sector, Indonesia being the most populous country in the region records the highest domestic water withdrawal, followed by the Philippines and Malaysia. In many developing nations, population expansion and urban development have amplified stress on available water resources, leading to faster depletion rates and growing competition for supply. Over the past century, global water consumption has risen at more than twice the rate of population growth, underscoring the increasing demand pressures. Although Malaysia benefits from an abundance of rainfall, averaging approximately 3,000 mm annually, it continues to face recurring water shortages and supply interruptions. Scholarly literature suggests that Malaysia's water issues are less a matter of physical scarcity and more a reflection of governance and management challenges, particularly the systemic limitations in recognising water as a finite resource and implementing sustainable management practices.

The key drivers of water scarcity and disruption come from a combination of interconnected factors as stated by Abdul Rahman (2021). The combination of interconnected factors is:

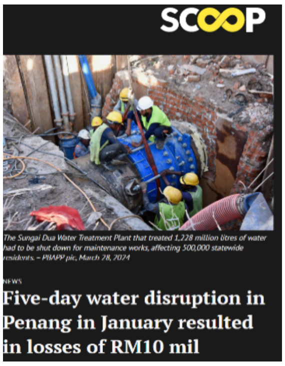
1. Water pollution and quality degradation: This is mentioned as a primary cause of supply disruption, particularly in industrialised states like Selangor. Rivers, which are the main source of water supply, are increasingly contaminated by industrial effluent, untreated sewage, and agricultural runoff. This pollution forces the shutdown of water treatment plants, leading directly to widespread supply interruptions for domestic and industrial users. Land-use changes, such as logging and urbanisation, also contribute to the degradation of water catchment areas.
2. Governance and infrastructure weaknesses: Management deficiencies significantly exacerbate the problem:
   - Non-revenue water (NRW): Malaysia faces a major challenge with high NRW rates, losing treated water due to pipe leaks, inaccuracies in customer meters, and unauthorised use. The national average for NRW is approximately 35%.
   - Outdated infrastructure and mismanagement: Aging infrastructure and a lack of maintenance contribute to frequent technical failures. Critiques point to a lack of a coherent national water policy and ineffective enforcement of existing laws as underlying governance issues.
3. Demand pressure and misallocation: The rapid pace of population growth, urbanisation, and industrialisation is imposing rapidly increasing demands on water resources.
4. Climate change impacts: Changes in weather patterns intensify the problem. The El Niño phenomenon has caused severe droughts in major economic areas, such as the Klang Valley, resulting in extended periods of water rationing. Climate change is predicted to increase the frequency and intensity of extreme weather events, further straining the already fragile water supply-demand balance

The consequences of water scarcity and disruption are severe, particularly for fast-growing states. Frequent water supply disruptions have a massive economic impact, estimated to have amounted to RM461,094 million (34% of Malaysia's GDP) in 2020, through property value at risk and business losses. Furthermore, the water quality and disruption issues have direct social consequences on the safety of drinking water and public health.

Penang Context

Due to the lack of security in our water supply, an action must be taken to overcome the issue. Additionally, with the projected increase in Penang's water demand from 1,208 million litres per day (MLD) in 2024 to 1,532 MLD by 2030, as stated by YAB Tuan Chow Kon Yeow, the Chief Minister of Penang and Chairman of PBAPP (FMT news, 2025) concerns regarding the state's water security have become more critical. The anticipated rise in demand, coupled with existing challenges in water resource management, could further strain Penang's water supply in the coming years.

Several incidents in recent years as shown in Figure 1 have already highlighted the vulnerability of the state's water system. For instance, in May 2023, a sudden drop in water levels at Sungai Muda (Lahar Tiang) reduced inflows to the Sungai Dua Water Treatment Plant (WTP**)**, leading to water disruptions across several areas from 14 to 17 May 2023 (Bernama, 2023). Similarly, in January 2024, the Sungai Dua WTP was temporarily shut down to replace two leaking 1,200mm valves in its main treated water pipelines, causing a four-day water supply interruption from 10 to 14 January 2024 (PBAPP, 2023). More recently, a planned water supply disruption from 25 to 28 April 2025 affected approximately 341,708 users across all five districts of Penang to facilitate the installation of 23 new waterworks projects and a RM8.7 million Sungai Perai River-Crossing Pipeline (Mok, 2025). These incidents collectively underline the pressing need for sustainable water management initiatives in Penang, reinforcing the importance of exploring strategies such as green campus practices to support SDG 6.



(i) Source: (Mok, 2025) (ii) Source: (Malaymail, 2023)

(iii) Source: (Bernama, 2025)

Figure 1: Water incidents in Penang

Role of Stakeholders

Stakeholder engagement is one of the twelve key principles of water governance, serving as a driving force in promoting best practices and initiating reforms for effective water management at any level of government or within a country. Collaboration and cooperation among all sectors are essential, as each plays a complementary role in achieving shared goals. Gathering diverse perspectives from stakeholders is crucial to ensure balanced and inclusive decision-making (Lim et al., 2022).

In Malaysia, the national regulatory and policy framework shapes the scope and instruments available for water-efficiency interventions such as the Department of Environment (DOE) under the Ministry of Natural Resources and Environmental Sustainability has introduced the National Water Resources Policy (Figure 2). According to the policy, ensuring the safety and sustainability of water resources is a national priority, with an emphasis on maintaining adequate and safe water for all. This is to be achieved through sustainable utilisation, conservation, and efficient management of water resources, supported by shared responsibilities among all stakeholders.

Figure 2: National Water Resources Policy 2012
(source: Ministry of Natural Resources and Environmental Sustainability (2012)

Furthermore, to monitor and address the ongoing issue of water pollution in Malaysian rivers, which has affected the nation's water supply for many years, the DOE has published the Malaysian Environmental Quality report. The report highlights a concerning trend, showing a decline in the percentage of clean rivers since 2015, accompanied by an increase in polluted rivers, as shown in Figure 3. In February 2019, the Minister of Science, Climate Change, Energy, Environment, and Technology, Yeo Bee Yin, disclosed that there were 25 'dead' rivers across Malaysia. Of these, sixteen were in Johor, five in Selangor, three in Penang, and one in Melaka. These rivers were classified under Classes IV and V, indicating severe pollution levels where aquatic life can no longer survive (Abdul Rahman, 2021).

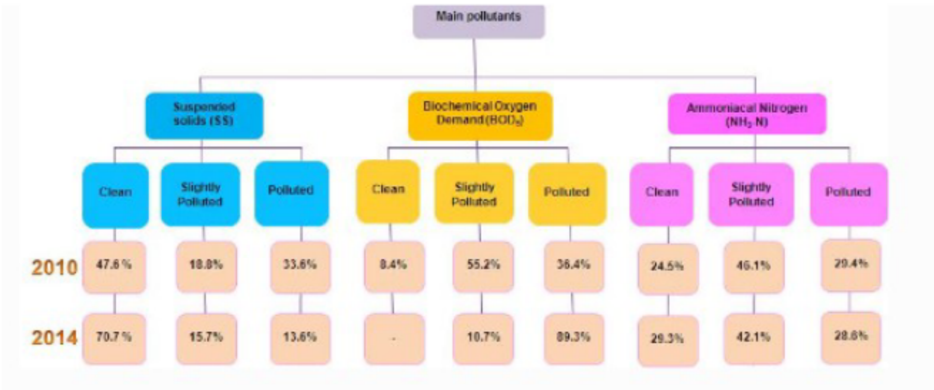


Figure 3: Number of the polluted rivers as reported by DOE Malaysia from 2010-2014
(Afroz & Rahman, 2017)

Suruhanjaya Perkhidmatan Air Negara (SPAN) are one of the national water services commissions with mandates that include regulation, oversight, promoting sustainability and stakeholder engagement. SPAN's guidance documents such as Water Safety Plan Guidelines (WSP) publications (Figure 4) highlight the regulator's role in setting performance targets, requiring service providers to adopt best practice, and facilitating multi-party coordination. These documents position SPAN as a convenor between federal agencies, state water operators, and private service providers (SPAN, 2021).

Figure 4: Water Safety Plan Guidelines
Source: (SPAN, 2021)

Role of Institution of Higher Learning (IHL)

The IHLs are recognised as a critical driver for achieving the SDGs, extending their role beyond merely promoting equal access to tertiary education (SDG 4) to functioning as a key agent for the full set of goals through their essential contributions in human formation, knowledge production, and innovation green Campus Practices in Water Management (Chankseliani & McCowan, 2021)

By implementing and displaying water-efficient technology like rainwater collection, smart meters, and water-efficient fixtures on campus, IHLs can also serve as "living laboratories." This lowers consumption on campus and gives the public or other organisations concrete examples. By actively involving local communities, sharing vital information about water availability, and monitoring water quantity and quality (Figure 5), USM is one of the universities committed to promoting sustainable and integrated water resources management that crosses boundaries (Universiti Sains Malaysia, 2025).

IHLs can conduct applied research on water-efficiency technologies, behavioural drivers of water use, sensor or monitoring systems, non-revenue water (NRW) reduction, and novel reuse systems. Their research outputs support practitioners, regulators, and utilities.

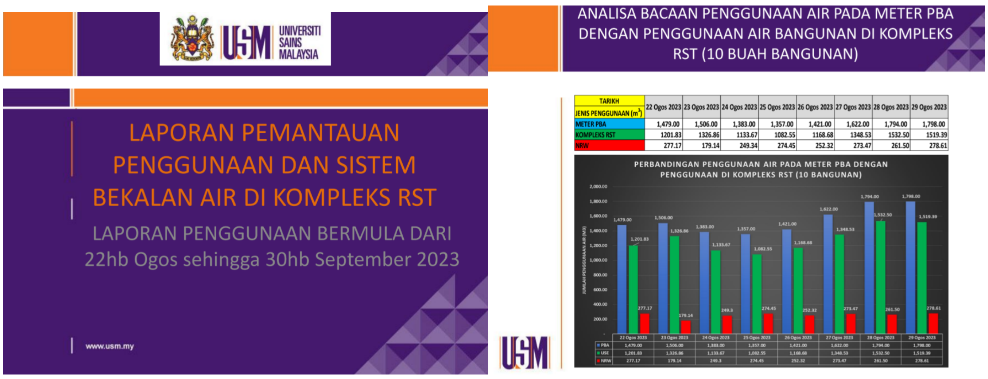


Figure 5: Monitoring report of water utilisation and supply systems at the RST complex
Source: Development & facilities management department,USM

In conclusion, the IHLs play a vital role in advancing Malaysia's water efficiency strategy through their multifaceted functions as educators, innovators, and change agents. As centre of knowledge and research and through education and awareness programs, IHLs foster a culture of water consciousness among students and the wider community, ensuring that future professionals carry sustainability values into their respective industries. Collaborative engagement between IHLs, government bodies such as

SPAN and DOE, and local stakeholders is therefore essential to strengthen policy implementation, improve data sharing, and scale up water-efficient practices nationwide. Ultimately, the leadership of IHLs in research, innovation, and advocacy will continue to shape Malaysia's transition toward a more water-secure and sustainable future.

Highlight Research Gap

Although many studies have discussed sustainability frameworks, policies, and infrastructural initiatives within Institution Higher Learning (IHLs), very few have provided quantified evidence on how simple green appliances such as dual-flush toilets and low-flow taps can effectively reduce water consumption and operational costs. Existing research tends to emphasise awareness programmes or sustainability policies rather than measurable data that demonstrate the tangible impact of these interventions. This lack of empirical assessment limits the ability of campus planners and policymakers to make data-driven decisions on resource efficiency and cost optimisation.

Furthermore, while IHLs are widely recognised as key agents in supporting the SDGs, their specific contribution to practising and promoting SDG 6 has not been adequately explored from a technical and operational perspective. In the context of Penang, where increasing urbanisation and water scarcity pose challenges to long-term supply security, there is a pressing need for IHLs to act as living laboratories that model water-efficient solutions and sustainable campus management practices. Therefore, this study seeks to bridge these gaps by evaluating the potential of integrating simple green campus technologies within the USM to quantify water and cost savings, assess feasibility, and highlight the leadership role of IHLs in advancing SDG 6 through practical implementation and community engagement.

METHODOLOGY

This study employs a case study approach focusing on selected buildings within USM, Penang. The methodology outlines the procedures used to collect data, analyse scenarios, and estimate potential water savings through the implementation of water-efficient fixtures.

Case Study

Buildings A

The main campus of USM in Gelugor, Penang, the School of Housing, Building and Planning (HBP). Established in 1972, the school was envisioned as a comprehensive institution and comprises three main buildings: E49, a three-storey administrative building; E40, a two-storey resource centre; and Block C, a three-storey studio block designated for students.

Building B

The Convocation Expo (ConvEx) site is also located within the main campus of USM in Gelugor, Penang. It serves as the main venue for the ConvEx event that showcases various student activities and performances.

Data Collection

Water flow rate measurements were conducted at selected toilets, taps, and water-consuming appliances within Campus Building A using a portable flow rate meter. Measurements were taken under normal usage conditions to ensure realistic data on the existing water flow patterns. Each fixture type such as wash basin taps, toilet flush cisterns, and laboratory sinks was tested multiple times to obtain an average flow rate for accuracy and reliability.

In addition to the physical measurements, supplementary information including the number of staff and students occupying the building was collected. This demographic data was obtained from the university's facilities management records and daily occupancy schedules. These figures were essential for estimating total daily water consumption and determining per capita usage rates. The combination of measured flow data and occupancy data provided a comprehensive baseline profile of water demand across the selected building.

Scenario Analysis

A scenario-based analysis was performed to evaluate the potential impact of adopting water-efficient fixtures across the campus. The baseline scenario represented current conditions using existing conventional water fittings, while the alternative scenario simulated the implementation of water-saving devices such as dual-flush toilets, low-flow taps, and aerators.

Each scenario was analysed based on average daily usage patterns, expected water-saving efficiency rates derived from manufacturer specifications and relevant literature, and user behaviour assumptions. The comparative assessment between the baseline and retrofit scenarios enabled the estimation of possible reductions in overall water consumption and identification of the most effective interventions. This analysis also aimed to support decision-making for campus-wide retrofitting initiatives by quantifying achievable water savings and cost benefits.

Estimation of Water Savings

Water consumption was estimated on both a daily and annual basis. For each fixture type, the flow rate (litre per minute) was multiplied by the average usage duration and frequency to calculate total daily consumption. Annual consumption values were then extrapolated by considering typical academic calendar days, excluding weekends and semester breaks to ensure realistic estimates.

Projected savings were determined by comparing baseline and retrofit scenarios. The efficiency percentages of water-saving fixtures (dual-flush toilets reducing water use by approximately 30–40%, low-flow taps by 20–35%) were applied to estimate total volume reduction. The financial implications were evaluated using the current water tariff rates from the local water authority, enabling the calculation of potential annual cost savings.

Assumptions regarding user compliance, maintenance of fixtures, and system performance were integrated into the model to account for real-world variability. Sensitivity analysis was also conducted to observe how changes in behaviour or fixture efficiency would influence total savings.

Limitations

This study focuses primarily on a limited sample of selected buildings within the USM main campus. The measurements and analyses are therefore exploratory in nature and may not represent the full diversity of water use patterns across the entire university. Variations in occupancy, fixture conditions, maintenance practices, and user habits between buildings could influence water consumption and saving potential.

Despite these limitations, the findings provide valuable insight into water-use characteristics and opportunities for efficiency improvements. The results serve as a foundational reference for scaling up future audits, conducting more comprehensive campus-wide assessments, and developing data-driven water management strategies within the university.

System Cost & Payback Period

The financial evaluation of the water efficiency strategy included an analysis of the system cost and the payback period. System cost refers to the total investment required to retrofit existing fixtures with water-efficient devices. This includes the purchase of new appliances (dual-flush cisterns, low-flow taps, aerators), installation labour, and any necessary plumbing modifications.

The payback period represents the amount of time required for the accumulated savings in water bills to offset the initial installation cost. In this study, the payback period was calculated using Equation 1:

$$Payback\ Period = \frac{Installation\ Cost}{Annual\ Benefit} \quad (1)$$

FINDINGS AND DISCUSSION

Table 1: Monthly water consumption and expenditure at USM main campus in 2024

Month	Water usage 2024	
	(m^3)	(RM)
January	163,185	302,156.00
February	96,338	208,990.00
March	107,803	226,396.00
April	126,963	275,371.00
May	151,702	329,109.00

June	368,923	800,395.00
July	143,434	311,189.00
August	290,048	629,236.00
September	174,017	377,512.00
October	197,192	427,823.00
November	158,497	339,120.00
December	180,483	391,564.00
Total	2,158,585	4,618,861.00

Table 1 and Figure 6 illustrate clear monthly variations in water consumption at the USM main campus throughout 2024. The data show that water usage fluctuated significantly across the year, indicating differing operational demands, seasonal influences, and campus activity levels. The highest consumption was recorded in June (368,923 m^3), followed by August (290,048 m^3) and October (197,192 m^3). These peaks may correspond to periods of increased campus activity such as semester preparations, examinations, or facility usage during events. In contrast, February (96,338 m^3) recorded the lowest consumption, likely reflecting shorter operational periods and reduced campus occupancy.

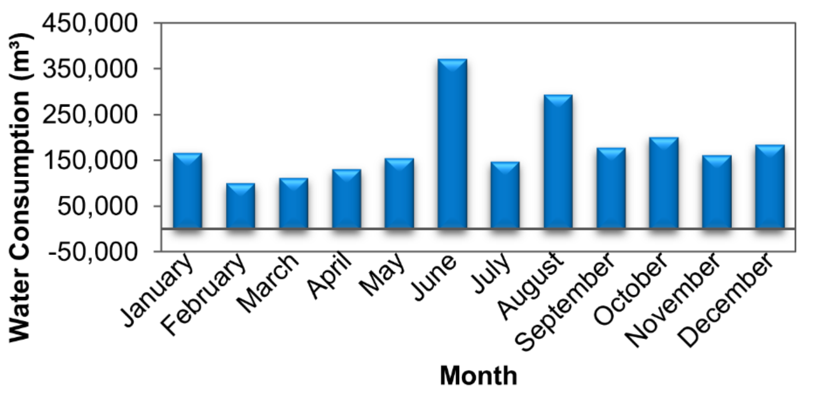


Figure 6: Monthly water consumption at USM main campus in 2024

The substantial increase in water consumption during mid-year months suggests the need for targeted water management strategies during high-demand periods. The pattern also demonstrates the financial implications of campus-wide water use, with June alone incurring RM800,395, the highest monthly expenditure. Overall, the total annual consumption of 2,158,585 m^3 resulted in water spending exceeding RM 4.6 million, underscoring the importance of implementing water-efficient fixtures and conservation practices. By understanding these consumption patterns, higher education institutions can better forecast operational needs, prioritise retrofitting efforts, and strategically plan for water efficiency interventions that support campus sustainability and the broader SDG agenda.

Buildings A (E13) and Building B (Yeap Chor EE)

Table 2: Monthly water consumption and annual expenditure by building at USM main campus in 2024

Location	Jan	Feb	Mac	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total (RM)
Batu Uban	84,966	80,143	80,143	80,143	80,143	191,920	0.00	220,104	107,350	107,415	46,002	105,940	1,184,271
Jln Sg. Dua	8,198	0	10,655	19,028	12,563	9,857	12,222	10,440	10,957	12,985	11,887	14,409	133,204
New Pump House (E13)	16,653	716	1,432	716	11,845	11,845	11,845	113,190	381	0	0	0	168,623
Yeap Chor Ee	88,113	124,255	114,134	91,336	139,087	125,007	127,597	105,527	103,075	135,256	139,206	143,502	1,436,099
RST	105,233	84,019	124,231	164,958	190,544	153,038	171,370	156,284	150,225	172,164	117,629	127,711	1,717,407

Table 2 provides a more detailed breakdown of water consumption across key buildings and operational zones within the USM main campus, offering clearer insight into how water is distributed and utilised at the building level. The data show notable differences in consumption between buildings, with Yeap Chor Ee recording the highest annual expenditure at RM 1,436,099, which is approximately 21% higher than Building A (E13). This disparity may be attributed to variations in building typology, user density, operational hours, and the presence of water-intensive spaces such as laboratories, washrooms, or communal facilities. Such variations highlight the importance of understanding building-specific demand patterns to design targeted water efficiency interventions. Temporal variation is also evident across the dataset, with significant spikes in June and August that mirror the broader campus trends discussed earlier. These peaks may coincide with increased academic activity, maintenance works, or heightened building utilisation during mid-year periods. In contrast, lower consumption in February and November likely reflects semester breaks or reduced operational intensity. These patterns demonstrate how academic calendars and operational cycles shape building-level water demand.

Auxiliary facilities such as “New Pump House E13” and “Jln Sg. Dua” also appear in the dataset. While their overall consumption is relatively modest compared to the main buildings, their inclusion is important for understanding the broader water distribution network within the campus. These facilities may support pumping operations, storage, or maintenance-related activities. However, without detailed sub-metering, it is difficult to attribute water use to specific functions such as flushing systems, irrigation, or laboratory operations. The absence of sub-meter data represents a key methodological limitation of this study. Without more granular instrumentation, disaggregating water consumption by end use is challenging, limiting the university’s ability to pinpoint inefficiencies or identify areas where conservation measures would be most impactful. Elevated consumption during low-activity months, for instance, may indicate leaks, outdated fixtures, or operational inefficiencies. Introducing smart sub-meters and conducting periodic water audits would help detect irregularities earlier and support more effective water management across the campus. Overall, the findings from Table 2 underscore the need for USM to adopt a more data-driven and integrated water management framework. Retrofitting buildings with water-efficient fixtures such as dual-flush toilets and low-flow taps alongside continuous monitoring and user awareness programmes can significantly enhance water efficiency. These initiatives are aligned with national sustainability priorities and contribute directly to SDG 6 through improved resource management and operational resilience.

Scenario 1 – Dual Flush Toilets
Building B

A relevant case study conducted at Universitas Diponegoro (UNDIP), Indonesia, provides a practical example of how higher education institutions can successfully implement dual-flush toilet systems as part of campus-wide water conservation initiatives. According to Chang et al., (2023), approximately 75 percent of the university's campus facilities have been retrofitted with dual-flush toilets and other water-saving devices such as sensor-activated urinals and nano-coated non-flush urinals. The study reported that the integration of these technologies achieved an estimated water-use reduction of about 68 percent compared to traditional single-flush toilets. This finding demonstrates that significant water savings can be attained when institutional management prioritises the replacement of inefficient fixtures and complements the initiative with awareness programmes among users. The UNDIP case also highlights the importance of adopting a holistic approach that combines technical solutions with behavioural change strategies, enabling sustainable reductions in both water consumption and operational costs across campus facilities. Such evidence strongly supports the feasibility of introducing dual-flush systems in other higher education institutions seeking to enhance water efficiency and align with SDG 6 on clean water and sanitation.

Similarly, USM has begun to adopt dual-flush toilet systems (Figure 7) in selected campus buildings B as part of its ongoing sustainability initiatives under the USM's SDG framework. However, unlike the UNDIP case where performance outcomes were quantified, USM currently lacks dedicated submeters to accurately measure and monitor water consumption specifically for toilet facilities. As a result, the precise reduction in water usage attributed to the dual-flush installations remains unverified. The absence of submetering data poses a limitation for assessing the real impact of these water-saving interventions and hinders the ability to compare actual consumption trends before and after retrofitting. To strengthen the effectiveness of water management on campus, it is recommended that USM install submetering systems at key facilities to record detailed usage data, which would enable data-driven evaluation and facilitate further optimisation of water efficiency strategies. This approach would align with global best practices in sustainable campus management and support continuous improvement in achieving water conservation targets.

Figure 7: Dual flush use at building B

Scenario 2 –Conventional Taps vs. Low-Flow Taps
Scenario 2 focuses on comparing conventional tap fixtures with low-flow alternatives to assess potential water savings in higher education settings. Water use audits were conducted in Building A, comprising three blocks: E49, E40, and E08 (Block C) using a portable water meter. All blocks are equipped with conventional taps, with E49 and E40 operating daily from 0900 to 1730 hours, while Block C operates 24 hours a day. Water utility bills for 2024 were also reviewed to provide contextual insight into overall consumption patterns.

Table 3 presents the flow rate measurements recorded during the field audit, while Figure 8 summarises the average flow rates for each building. The results show considerable variation across blocks, with Building E49 recording the lowest average flow rate (0.996 L/min), followed by E40 (1.938 L/min), and

Block C (2.275 L/min), which recorded the highest. These differences may reflect variations in fixture age, water pressure, or usage patterns.

Table 3: Water flow rates of conventional wash basin tap across selected buildings at USM main campus

Building No.	Item	Water Flow Rate (L/min)	Average (L/min)
E49	Wash basin (1st floor male toilet)	1.2	0.996
	Wash basin (1st floor female toilet)	0.95	
	Wash basin (2nd floor male toilet)	1	
	wash basin (2nd floor female toilet)	1	
	Wash basin 3rd floor male toilet)	0.83	
E40	Wash basin (1st floor male toilet)	2	1.9375
	Wash basin (1st floor female toilet)	2.14	
	Wash basin (2nd floor male toilet)	1.88	
	Wash basin (2nd floor female toilet)	1.73	
E08 (Block C)	Wash basin (1st floor male/female toilet)	2.22	2.275
	Wash basin (2nd floor male/female toilet)	broken	
	Wash basin (3rd floor male/female toilet)	2.33	

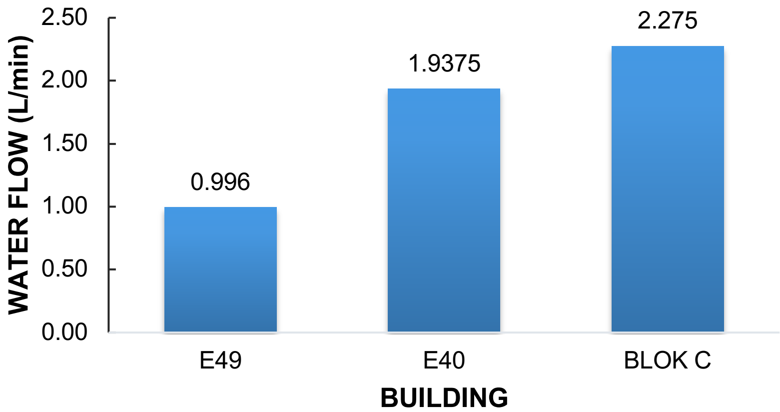


Figure 8: Average water flow rates of conventional wash basin tap across selected buildings

The flow rate values were calculated using Equation 2 as presented below:

$$Flow\left(\frac{L}{min}\right) = [volume\ collected\ (L) \div Time\ (s)] \times 60 \qquad (2)$$

To benchmark the performance of conventional taps against water-efficient alternatives, a desktop case study was referenced from a university building in mainland Portugal, referred to as Building B. This study, which evaluated the water–energy nexus in higher education facilities, demonstrated the effectiveness of retrofitting with low-flow technologies. Self-closing tap initially delivered an average flow of 7.6 L/min but were reduced to 4.0 L/min through the installation of a calibrated flow reducer (Serafini et al., 2022). Table 4 further illustrates the estimated reductions in water consumption by fixture type, with the overall intervention achieving approximately 27% savings in total water use.

Table 4: Water Consumption reduction by type of device, in percentage
Source:(Antão-Geraldes et al., 2024)

Device	Number of devices	Average reduction
Urinal	17	>0%
Shower	2	33%
Toilet (complete discharge)	16	33%
Toilet (double discharge)	3	25%
Washbasin (self-closing tap)	23	40%
Laboratory tap (conventional tap)	11	0%

Although the low-flow fixture data were obtained from an international case study, the results provide a practical benchmark for Institutions of Higher Learning (IHLs) such as USM, where similar retrofitting strategies could yield significant savings. When compared with the baseline flow rates recorded in Building A, the adoption of low flow tap (Figure 9) could substantially reduce daily and annual water consumption, contributing directly to more efficient campus operations and supporting SDG 6.

Figure 9: Self-closing tap (low flow tap)

Scenario 3 – Rainwater Harvesting System (RWHS)

Figure 10: RWHS project at C24 building

The School of Humanities (SOH) at USM has taken a proactive role in reducing water consumption through a demonstration project on water conservation, supported by various stakeholders across the campus. The main objective of this initiative is to monitor, manage, and reduce overall water usage. The project's approach integrates both hardware and software strategies where the hardware component focuses on the physical system and fixtures, while the software component targets user behaviour and awareness.

The hardware interventions include the installation of a rainwater harvesting system (Figure 10) as an alternative water source, the replacement of conventional or outdated water fittings with water-efficient fixtures, and the repair of leaks within the existing plumbing network.

The USM SOH's Water Saving project has achieved notable success, demonstrating a reduction of approximately 50% in total water consumption. Furthermore, with the utilisation of harvested rainwater in Buildings C20 and C24, an even greater amount of water savings is anticipated. Although the rainwater harvesting system initially faced operational challenges, it has shown strong potential as the system's performance improved and more rainwater was successfully collected and reused (Universiti Sains Malaysia, 2018).

Combined Scenario

The combined scenario was developed to assess the total potential water savings when both interventions are implemented simultaneously. Integrating dual-flush toilet systems with low-flow tap fittings presents a comprehensive approach to achieving significant water efficiency gains within higher education institutions. When implemented together, these two water-saving technologies address both high-volume discharge points and frequent-use outlets, contributing to measurable reductions in total campus water demand. Study from (Budihardjo et al., 2022) at Universitas Diponegoro have demonstrated that dual-flush systems alone can reduce toilet water consumption by 60–70 percent compared to conventional single-flush models. Complementing this with the installation of low-flow taps, typically restricting flow to 4–6 litres per minute compared to 9–12 litres for standard taps can yield an additional 30–50 percent reduction in water uses at washbasin points. In the context of institutional buildings, where large populations use sanitary facilities daily, such combined retrofits could collectively lower overall water consumption by up to 40 percent across the campus, depending on fixture density and user behaviour.

For example, in USM, the adoption of dual-flush toilets in several academic buildings and student facilities reflects a growing institutional commitment to sustainable water management under the USM SDG framework. However, without submetering systems dedicated to toilets and taps, it remains challenging to quantify the exact contribution of each intervention to the total water savings achieved. The installation of low-flow taps alongside dual-flush toilets would be expected not only to enhance conservation outcomes but also to provide complementary benefits such as reduced operational costs and lower wastewater discharge volumes. Additionally, behavioural aspects such as user awareness and maintenance practices play a critical role in ensuring the long-term effectiveness of these technologies (Chan et al., 2021). Future implementation should therefore integrate technical retrofitting with monitoring systems and awareness campaigns to promote proper usage and timely maintenance. By combining hardware efficiency with data-driven management, higher education institutions like USM can position themselves as models of sustainable water governance and align closely with SDG 6 and SDG 12.

Practicality and Feasibility of Retrofitting Appliances in IHL

Retrofitting of the water supply network and related infrastructure at USM Main Campus is technically feasible, especially given that previous studies have analysed the campus' water pipeline network. For instance, a study titled "Water Pipeline Network Analysis of USM Engineering Campus Using WaterGEMS" examines the hydraulic behavior, pressure zones, leak detection potential and flow optimisation in USM's own system upgrading old pipes, installing district metering zones (DMAs), pressure management systems, and real-time monitoring sensors could help reduce non-revenue water and improve supply reliability (Salleh, 2022)

Economically, metering systems, telemetry, sensor installation, pump upgrades, and pipe replacement all require an upfront capital investment. However, lifespan cost analysis frequently demonstrates that over time, the initial cost is offset by savings from less leakage, pumping energy, and emergency repairs. Additionally, Malaysia's national water sector transformation plans demonstrate a tendency to prioritise water sector sustainability and finance infrastructure improvements. It is also essential that retrofitting be staged in phases so that disruptions to campus water supply are minimised, ideally during off-peak periods or vacation times.

Integration with campus planning, maintenance capability, and institutional support are critical components of operational viability. Through its institutional arrangements, USM formally commits to managing water resources in a sustainable and coordinated manner. In order for the retrofitted systems to yield the anticipated benefits, the campus must guarantee that facilities personnel are educated to operate new systems, such as Supervisory Control and Data Acquisition (SCADA), leak detection, and pressure control; that sufficient spare parts and monitoring equipment are accessible; and that operations continually assess performance. Many water retrofits do not yield the expected savings if they are not monitored and maintained consistently.

Contribution to SDGs

By reducing per-capita and per-use water demand, retrofitting restrooms throughout USM Main Campus with dual-flush cisterns and low-flow taps directly advances SDG 6. When high-density user contexts switch out traditional fixtures with ultra-low-flush or dual-flush toilets, field studies on university campuses demonstrate significant absolute savings. For instance, a campus deployment study found that installing numerous ultra-low-flush units resulted in annual water savings of thousands of cubic meters. These savings ease the strain on the campus storage and potable water supply, allowing treated water to be reallocated for higher-value applications (Melville-Shreeve et al., 2021).

By lowering overall resource consumption and the embedded energy related to water treatment and pumping, lowering fixture flowrates further advances SDG 12. In areas with volumetric water tariffs or high pumping/energy costs, building-scale fixture retrofits yield immediate volumetric reductions and quick payback, making them one of the most economical demand-management strategies in institutional settings, according to recent reviews. Thus, implementing dual-flush and low-flow tap programs in lecture halls, residence halls, and administrative buildings lowers the campus operations' energy and water footprints (Jacque et al., 2024).

Role of stakeholders in adopting and Maintaining Green Practices

Strong leadership from USM plays a crucial role in promoting green practices across the campus. To achieve this, it is important to establish clear water efficiency targets, allocate adequate funding, enforce the use of proven low-impact technologies, and place sustainability at the core of decision-making. For example, university management could implement policies that require the installation of water-efficient fixtures such as dual-flush toilets and low-flow taps in student accommodations, lecture halls, and administrative buildings. Leadership commitment ensures that these sustainability efforts are prioritised and supported over other infrastructure needs.

Facilities and maintenance teams are the hands-on actors in both adoption and long-term sustaining of these green systems. They select specific models of dual-flush valves, calibrate flush cycles, install flow restrictors in taps, and perform preventive maintenance for example repairing leaks, checking aerators to preserve performance. Their ongoing role is critical: ill-maintained fixtures can revert to inefficiency or failure, negating water savings. Evidence from university projects shows that the performance of fixture retrofits is strongly dependent on quality of maintenance and prompt repair of faults (Melville-Shreeve et al., 2021).

Through their actions and comments, students, faculty, and other users affect the effectiveness of green practices. Increased compliance and decreased misuse are achieved through awareness programs, signage that explain proper dual-flush settings, and mechanisms for reporting broken taps or toilets. Academic divisions can assist by keeping an eye on usage, evaluating information, and disseminating results. Research on campus sustainability emphasises that student involvement and initiative increase the adoption and tenacity of green projects (Kansal & Venkatesh, 2020). Technology, money, guidelines, and legitimacy are provided by external players, including vendors, governmental organizations, non-governmental organisation (NGOs), and municipal water authorities. Their assistance facilitates the verification of water savings, incentive programs, and the bulk purchase of energy-efficient fixtures.

Policy Application for Campus

A campus water efficiency policy should be implemented at USM that requires all new construction or renovations to use water-efficient devices, like low-flow taps and dual-flush toilets. In order to ensure that real-world usage matches specifications, the policy should mandate that procurement submissions contain commissioning verification, warranty conditions, and manufacturer performance data. By requiring these requirements during renovation cycles, USM guarantees widespread but gradual improvements throughout the campus. The policy must require metering, auditing, and reporting in order to track and maintain performance. Verification of savings and irregularity identification are made possible by submetering buildings or blocks and comparing usage before and after installation. To ensure accountability and transparency, USM might include yearly water statistics in its sustainability report. Additionally, pilot installations. Before expanding campus-wide, convert one hostel wing first and present data, user comments, and lessons learned.

Lastly, the policy needs to incorporate maintenance governance, stakeholder cooperation, and education. This entails including instruction on water use and fixtures into orientation programs, dual-flush mode signage, recurring campaigns, and academic integration, which includes project-based monitoring. It also entails setting up a governance committee within facilities or sustainability that manages the water policy, communicates with outside parties, examines data once a year, and makes sure maintenance budgets are maintained. Green water practices can be ingrained in campus culture by making sure everyone is aware of their roles, responsibilities, and feedback mechanisms.

CONCLUSIONS

In conclusion, this study highlights the significant potential of implementing green campus practices particularly the adoption of dual-flush toilets and low-flow taps in improving water efficiency within IHLs. The findings indicate that such initiatives can effectively reduce treated water usage and operational costs through the combined impact of efficient fixtures, behavioural awareness, and sustainable management practices. Beyond environmental benefits, the financial implications are also notable, as the reduction in water consumption directly translates into long-term cost savings on utility bills and maintenance expenses. Although the initial investment for retrofitting fixtures may appear substantial, the payback period is often short due to recurring water and cost savings, making it a financially viable strategy for institutions with high daily water usage. These results further emphasise the important role of IHLs as leaders in integrating sustainability within daily campus operations and advancing SDGs particularly SDG 6 and SDG 12. Within the context of Penang, where growing water demand and limited freshwater resources have raised concerns over water scarcity, the implementation of such water-efficient technologies becomes even more critical. Moving forward, it is recommended that future campus water management strategies explore the integration of dual-flush and low-flow systems with rainwater harvesting to further enhance conservation outcomes. Evaluating both environmental and financial effectiveness through continuous monitoring and submetering will enable IHLs to develop evidence-based frameworks for sustainable water governance and strengthen their contribution to long-term water security.

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