Supplementary material – Literature review

Rainwater Harvesting System (RWHS)

The feasibility of Rainwater Harvesting Systems (RWHS) in commercial and office buildings varies significantly across different geographical locations. The effectiveness of RWHS depends on the local climate, population of the building, infrastructure and cost of construction. Several systematic reviews and meta-analyses support the implementation of RWHS, highlighting its potential for significant water efficiency improvements across various regions. Overall, RWHS offers a promising solution for enhancing water efficiency in commercial and office buildings, though its feasibility is influenced by several factors. The table S1 presents water efficiency improvement in commercial buildings from Europe, Latin America to Asia from selected literature.

Table S1. Feasibility of RWHS in commercial/office buildings.

Geographical location	Improvement in water efficiency	Payback period (yrs)	Reference
UK	87%	6 to 11	[91]
United Kindom	46% to 100% in toilet flushing	NA	[35]
Spain	Significant	NA	[35]
Portugal, Colombo	NA	10	[58]
Irland	94% saving in non-potable water saving		[35]
Turkey	60% along with efficient landscaping	NA	[92]
New Zealand - Auckland, Bay of Plenty, Canterbury, and Wellington	23%	1.6 to 20.9	[93]
Malaysia	17% to 95%	2 to 6	[94]
Malaysia	37% to 90% saving in non-potable water saving	NA	[35]
Malaysia	Approx 43% of the non-potable water required for toilet flushing & irrigation	NA	[84]
Singapore	12.4% in toilet flushing	NA	[35]
Bangladesh - Dhaka	11% to 19%	2.25 to 3.75	[64]
Bangladesh	12.4% to 100% saving in non-potable water saving	NA	[35]
Brazil	69.6%	3.8 to 25<	[30]
Mexico	100% saving in non-potable water saving	NA	[35]

NA – Not available.

Based on the results presented in Table S1, some studies focus solely on using rainwater for toilet flushing, while others include both toilet flushing and irrigation. Consequently, there is significant variation in water consumption efficiency, ranging from 11% to 100%, and the payback period varies from 1.6 years to 25 years. These variations are influenced by the aforementioned factors, as well as additional elements such as climate, building population, infrastructure, and the economic conditions of the region.

Efficient fixtures and fittings

Efficient plumbing fittings are essential for reducing water consumption and promoting sustainability in buildings. As water scarcity and utility costs become increasingly significant concerns, integrating fixtures such as low-flow faucets and dual-flush toilets can substantially decrease water usage. These low-flow fittings include basin mixers, showers, urinals, water closets, and bib taps. They are designed to dispense water at a defined flow rate, tailored to the required amount of water. Table S2 presents the improvements achieved by adopting water-efficient fittings and fixtures in commercial and office buildings across various geographical locations.

The results of the above studies demonstrate that adopting this strategy can achieve water consumption efficiency improvements ranging from 2.7% to 50%. However, the efficiency largely depends on the size of the building and the number of occupants. The payback period varies from 1 to 15 years and largely depends on the cost of water and the fittings.

Table S2. Feasibility of efficient fixtures in commercial/office buildings.

Geographical location	Improvement in water efficiency	Payback period (yrs)	Reference
Malaysia, Central	NA	low in larger building	[31]
Portugal	45%	NA	[69]
Portugal, Colombo	NA	>15	[58]
Turkey	48.4%	NA	[92]
England	Minimum 20%	1.25	[95]
India	Minimize water usage		[96]
Brazil, Florianópolis	2.7 % to 15.4 %	NA	[97]

NA – Not available.

Waterwise landscaping (Native Plants, Trees, and Efficient Irrigation Systems)

Table S3 summarizes the improvements in water efficiency and associated payback periods achieved through waterwise landscaping and related strategies across various geographical locations. In Texas, an office complex reduced outdoor water use by 40%, with a payback period of 1.5 years. In Turkey, a combination of waterwise landscaping and a rainwater harvesting system (RWHS) resulted in a 60% improvement in water efficiency. The table also details the efficiency levels of different strategies within the waterwise landscaping approach. For example, using native plants led to a 78% water savings, while soil moisture sensors improved efficiency by 57%, with a one-year payback period. Additionally, evapotranspiration controllers provided a 29% improvement, with a payback period of less than a year.

Table S3. Feasibility of use of waterwise landscaping in commercial/office buildings.

Geographical location	Improvement in water efficiency	Payback period (yrs)	Reference
Texas	40%	1.5	[44]
Turkey	60% along with RWHS	NA	[90]
Houston, Austin, San Antonio, Dallas, El Paso	Using native plants 78% Using soil moisture sensors, 57% Using ET controllers, 29%	One year Less than a year	[45]

NA – Not available.

Greywater reuse

Greywater reuse have been applied in different regions, yielding varying levels of success and economic feasibility. The results, as presented in Table S4, show diverse outcomes in implementing water efficiency measures. In Baghdad, office buildings achieved a 44% reduction in water use, while a commercial building in Africa saw a modest 6% to 10% improvement but with a 17-year payback period. In Sharjah, UAE, greywater reuse in cooling towers showed significant net present value, highlighting its economic benefits. In Jordan, reusing shower water for toilet flushing reduced water usage by 20.7%, though it was not economically feasible. Melbourne's high-rise buildings achieved a 37.1% efficiency improvement with greywater reuse, while multi-story buildings faced a 22-year payback period. It should be noted, however, that economic feasibility depends on the cost of the common water supply and the additional investment required for the plumbing system.

Table S4. Feasibility of use of greywater in commercial/residence buildings.

Geographical location	Improvement in water efficiency	Payback period (yrs)	Reference
Portugal, Colombo	NA	Over 2	[58]
Iraq, Baghdad, office buildings	44%	NA	[50]
Africa, commercial building	6% to 10%	17	[98]
United Arab Emirates, Sharjah	Highest NPV recorded for greywater reuse in cooling tower	NA	[54]
Jordan, Residential building	Shower to toilet - 20.7%	Not economically feasible	[99]
Melbourne, high-rise residential/retail and commercial buildings	Treated greywater to toilet & outdoor use - 37.1%	NA	[100]
Melbourne, multi-story buildings	Recycled greywater for non-drinking purposes	For a 20-story building 22 yrs	[101]

Supplementary material – Results

Rationale in selecting trees and plants

Table S5 presents tree and plant species selected for their resilience and adaptability to tropical and subtropical environments relevant to the case study project. Each species was chosen for its unique characteristics that make it suitable for harsh environmental conditions, with supporting references provided to validate these selections.

Table S5. Rationale for the Chosen Trees and Plants.

Name of the tree/plant	Reason for selection	Reference
CALOPHYLLUM INOPHYLLUM	It is a hardy tree, native to tropical coastal areas and can survive against wind, salt spray and drought.	[78]
FICUS LYRATA(3PP)	Ficus trees, commonly large evergreen species, are classified as drought-tolerant.	[102, 103]
BARRINGTONIA	Typically situated in the humid lowland tropics where consistently warm temperatures prevail year-round, these mature trees can endure an extended period of drought lasting several months.	[104]
PLUMERIA	Plumeria species are petite evergreen exotic trees with irregular growth patterns that make them ideal as picturesque trees. Although these trees exhibit drought tolerance, they thrive when provided with ample water through regular irrigation cycles.	[103, 105]
DRACAENA TRIFASCIATA	In hot weather and direct sunlight, the leaf tips undergo significant water evaporation, leading to wilting. Nevertheless, there have been recorded high survival rates of up to 80%.	[106]
HYMENOCALLIS	Hymenocallis littoralis is believed to be native to many tropical countries including Sri Lanka. These plants grow in a wide diversity of habitats adapting well to different environments.	[107, 108]
SCAVOLA	*Scaevola Aemula* could grow well under 35/27 °C temperature. The plant shows adaptability to drought by increasing leaf-level water use efficiency.	[109, 110]
IPOMEA PRE-CAPRAE	Ipomoea pes-caprae is a halophytic plant that favorably grows in tropical and subtropical countries in Asia, America, Africa, and Australia	[111]

Name of the tree/plant	Reason for selection	Reference
CLERODENDRUM INERME	Clerodendrum is a genus of flowering plants in the family Lamiaceae. It is native to Sri Lanka and the Andaman Islands. The genus is native to tropical and warm temperate regions of the world, with most of the species occurring in tropical Africa and southern Asia.	[112]

The selected species tabulated in Table S5 are chosen for their ability to thrive in environments that are typically challenging for many plants. For example, Calophyllum inophyllum and Ipomoea pes-caprae are both noted for their tolerance to salt spray and their ability to grow in coastal areas, making them ideal for regions prone to these conditions. This is particularly relevant as the case study building is located just 500 m away from the coast. Ficus lyrata and Barringtonia are selected for their drought tolerance, which is crucial in regions with prolonged dry periods. The resilience of Dracaena trifasciata and Scaevola aemula under high temperatures and water stress further underscores the adaptability of these plants to hot climates. Moreover, species like Plumeria and Hymenocallis littoralis are not only drought-tolerant but also offer aesthetic value, making them suitable for ornamental purposes in addition to their environmental resilience. The inclusion of native species such as Clerodendrum inerme emphasizes the importance of incorporating plants that are naturally adapted to the local conditions, thereby supporting biodiversity and ecological balance.

Landscape layout

The case study building features landscaped areas across multiple levels, including the lower road level, ground floor, parking floors (levels 1 to 7), level 11 recreational floor, and the rooftop. The most extensive green landscapes are concentrated at the ground and lower road levels. Figure S1 shows a site plan of the building (lower road and ground levels), focusing on landscaping and planting design, with various plant species illustrated and labeled across the site, marked with codes such as T1, T2, T3, P1, and P2, each linked to images of specific trees or plants.

The plan includes a mix of greenery that was carefully chosen for both aesthetic and functional purposes, with the layout emphasizing shading and decorative planting. The placement of these species corresponds to the edges, entrances, and key zones of the building, likely enhancing the landscape design while addressing environmental factors such as sunlight and wind direction.

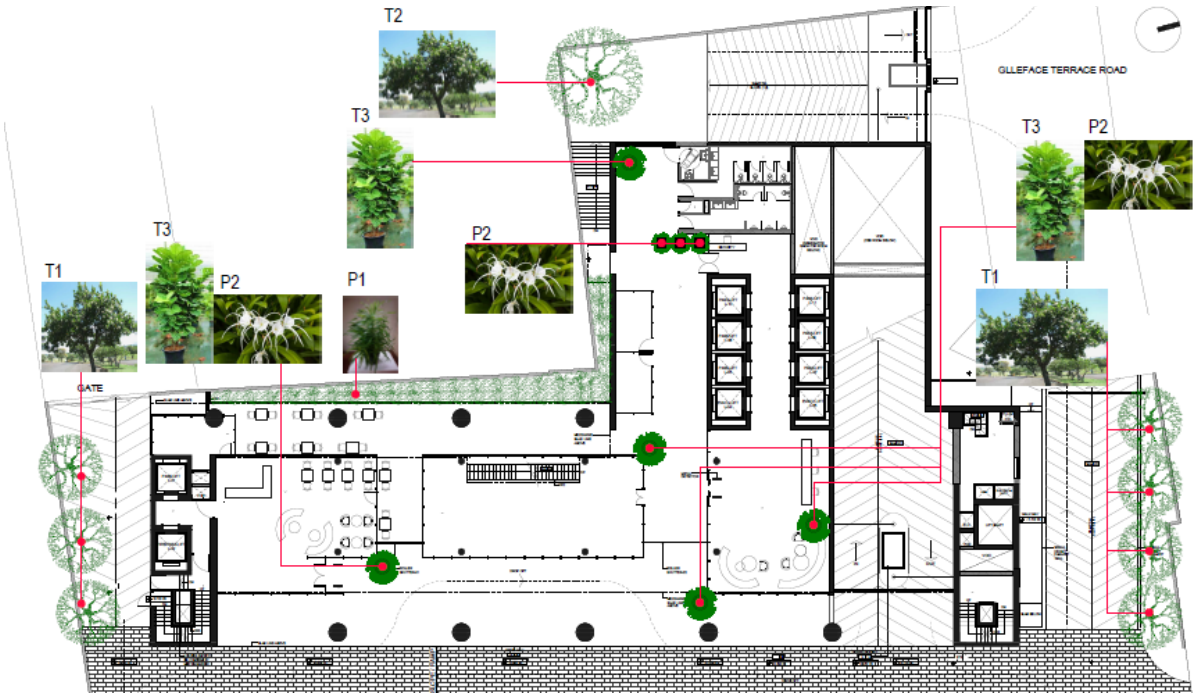


Figure S1. Landscape at ground level.

Calculation of Landscape Water Needs Using LEED Guidelines

Introduction

Accurate water need calculations are essential for sustainable landscaping as they ensure that plants receive the right amount of water, preventing both over-watering and under-watering. This sample calculation is designed to demonstrate how to determine the landscape water needs using LEED guidelines. By providing a clear and detailed example, it aims to enhance the understanding of the methodology and its practical application.

Parameters and Equations

$$\boldsymbol{Landscape\ water\ requirement} = \frac{\boldsymbol{ET_0\ x\ K_L\ x\ A - (P\ x\ F)}}{\boldsymbol{DU_{LQ}}} \qquad \text{Equation 1}$$

Where:

ET_0 = Peak watering month evapotranspiration (mm/month)

$\boldsymbol{K_L}$ = Landscape Coefficient (dimensionless)

A = Landscape Area (m^2)

P = Average Monthly Rainfall for peak watering month (mm/month)

F = Effective Rainfall Factor (0.25 for effective rainfall)

DU_{LQ} = Distribution Uniformity

Sample calculation for Zone ID G1 T3

As per Fig 7, the peak watering month is January.

Evapotranspiration for January is 130 mm/month.

Landscape coefficient factor for low water requirement plants taken as 0.5.

Landscape area for the Zone ID G1-T3 is 15.7 m^2.

Monthly average rainfall for January is 58.2 mm/month.

Not all rainfall contributes to meeting the water needs of plants. Some of it may be lost to runoff, evaporation, or may not penetrate deeply enough into the soil to be useful for plant roots. Hence, to account for the inefficiencies the monthly average rainfall was multiplied by "Effective rainfall factor"; 0.25.

To account for the inefficiencies in the irrigation system and to ensure that even the least watered areas receive adequate water, irrigation need was divided by "Distribution Uniformity" is 70% drip irrigation.

By substituting above values in equation 1, landscape water need for Zone G1-T3 can be obtained as shown below.

$$\text{Landscape water requirement for Zone G1 T3} = \frac{130 \quad \text{x } 0.5 \quad \text{x } 15.7 - (58.2 \text{ x } 0.25)}{0.70}$$

$$\text{Landscape water requirement for Zone G1 T3} = 1{,}134 \text{ L/month}$$