SIPA | SUPPORT TO VIET NAM FOR THE IMPLEMENTATION OF THE PARIS AGREEMENT

DCC

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Supported by:
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IKI INTERNATIONAL CLIMATE INITIATIVE

Visionary image of Dong Hoi city with more green walls and green roofs

Guideline to implement green walls and green roofs in Vietnam

Implementation Guideline

Green walls and green roofs: URBAN ECOSYSTEM-BASED ADAPTATION to Climate Change in Viet Nam











Source: © Michael Waibel, Thuy Nguyen

Inspiring green wall and green roof examples from around the world

FOREWORD

Vietnam is a country characterized by stable economic growth that has led to a growing middle class and increased urbanization. At the same time, Vietnam is among those countries most vulnerable to the impacts of climate change. The geographic location and topography of the country, such as its long-stretch of north-south running coastline, make it susceptible to rising sea levels, typhoons, floods and extended periods of drought and heat. This situation requires planned adaptation to the impacts of climate change. The Vietnamese government has acknowledged the issue, and this is expressed in several long-term policies, strategies, and development plans, such as the National Adaptation Plan.

The interrelationship of urban development and growth and the increasing impact of climate change require that adjustments be made to urban planning and development. Public and private investments need to take into consideration intensified rainfall and flooding on the one hand and extended periods of higher temperatures on the other. The integration of elements of Ecosystem-based Adaptation or Nature-based Solutions into urban development is an opportunity for cities to create attractive, green, healthy, and livable urban spaces.

Dong Hoi city in Quang Binh province has developed three Ecosystem-based Adaptation measures as part of a transformative approach to urban development with the support of the International Climate Initiative (IKI) which is an important part of the German government's international climate finance commitment. These measures will serve to showcase the possibilities of green interventions in the urban context. One of the selected measures is a green walls and green roofs pilot model. It will transform a public building into a sustainable urban solution that contributes to flood water absorption, heat stress reduction, and increased biodiversity, as well as contribute a green aesthetic to the city's appearance.

These following guidelines were developed along with the green walls and green roofs measures in Dong Hoi city to provide investors with information regarding technical solutions, project implementation, plant selection, investment costs and so on, in order to facilitate the replication of such projects elsewhere.

We hope that you find this guideline helpful and feasible for the implementation of your green wall and green roof projects. This significantly contributes to climate resilient urban environments and to human health and wellbeing.

Sincerely,

Oemar Idoe
Cluster Coordinator
Environment, Climate Change and Agriculture
GIZ in Vietnam

Pham Van Luong
Deputy Director
Department of Natural Resources and Environment
Quang Binh province

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https://www.international-climate-initiative.com/en/

October 2022

Abbreviation

ADB	Asian Development Bank
CAMaRSEC	Climate-Adapted Research for the Socio-Economic Context of Vietnam
DoC	Department of Construction
EbA	Ecosystem-based Adaptation
EDGE	Excellence in Design for Greater Efficiencies
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Global ABC	Global Alliance for Buildings and Construction
LID	Low Impact Development
NbS	Nature-based Solution
NAMA(s)	Nationally Appropriate Mitigation Action(s)
NDC	Nationally Determined Contribution
TCVN	Tiêu Chuẩn Việt Nam (Vietnamese standards)
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VAT	Value Added Tax
VGBC	Vietnam Green Building Council
VN-SIPA	Support for the implementation of the Paris Agreement in Vietnam
WSUD	Water Sensitive Urban Design

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Source: © Michael Waibel

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Source: © Thuy Nguyen

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Introduction to the **IMPLEMENTATION GUIDELINE**

The project "Support to Vietnam for the Implementation of the Paris Agreement" (VN-SIPA) has been implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Affairs and Climate Action. It supports the Government of Vietnam in establishing a framework for implementing the Paris Agreement.

By integrating the nationally determined contribution (NDC) objectives into a comprehensive national legal framework, VN-SIPA supports Vietnam in setting the foundations for achievable and ambitious mid- to long-term climate change policies. Project activities focus on ecosystem-based mitigation and adaptation measures that provide social and environmental co-benefits and contribute to decarbonizing the national economy. In cooperation with the local authorities of Dong Hoi City and Quang Binh Province, Vietnam, the VN-SIPA project has identified three Ecosystem-based Adaptation (EbA) measures for implementation, one of which is the promotion of green walls and green roofs as a nature-based contribution to climate change adaptation and the resilience of built environments.

These guidelines were developed to enable the implementation of such measures in a variety of other contexts and locations by providing basic technical concepts, details of benefits, and implementation procedures. Practical examples are introduced with brief information. In particular, the green walls and green roofs installations in Dong Hoi City will be described in detail to illustrate the general concepts outlined herein.

This document was developed based on a thorough review of the global scientific literature and accumulated practical knowhow, especially from those countries with similar climate contexts to Vietnam.

These guidelines provide general principles for the effective implementation of green walls and green roofs rather than prescribe any specific technical standards or mandatory regulations. They aim to disseminate information, raise awareness, and promote the installation of green walls and green roofs in the local context.

The target readership is private sector stakeholders (i.e., investors and property owners, development banks, etc.). The guidelines are applicable to both newly built and "to-be-retrofitted" sites of varying scale from single level low-rise houses to multilevel high-rise buildings. The information provided is applicable in Vietnamese urban contexts, especially the rapidly urbanizing mid-sized localities along the Vietnamese coast.

The guidelines are organized into six chapters as follows:
1. Introduction to the guidelines,
2. Context of the guidelines,
3. Technical concepts of green walls and green roofs,
4. Implementation of green walls and green roofs,
5. The green walls and green roofs initiative in Quang Binh,
6. Conclusions and implications.

Source: © Michael Waibel

02

Setting the **CONTEXT**

2.1 GLOBAL CONTEXT

Climate change and rapid urbanization increase the risk of natural disasters and the vulnerability of urban centres to their effects. This is especially the case for coastal areas where growing urban centres are normally located. Increasing urban population and booming construction activities will intensify these hazards in the future. Ecosystem-based Adaptation (EbA) solutions utilize biodiversity and ecosystem services to adapt to climate change and urbanization and can reduce this vulnerability and increase the resilience of people and the environment (UNEP, 2020). These solutions integrate 'green' (ecosystems), 'grey' (engineering) and 'blue' (water) elements for effective climate risk-resilient urban planning and development (GIZ, 2017; UNFCCC, 2020).

Globally, green walls and green roofs have been widely promoted as innovative technologies. They are passive design solutions which enhance the thermal performance of building envelopes, and can impact 20% to 60% of buildings' heating and cooling energy (Pérez et al. 2017; Zhang et al. 2019). In fact, green walls and green roofs have been integrated into nature-based and eco-friendly building design as an important part of worldwide green (sustainable) building certification schemes (Besir at al., 2018). Green walls and green roofs, if well designed, also positively contribute to stormwater and greywater management, thereby forming an integral part of water-sensitive urban design (WSUD) (see ADB, 2019).

Given the multiple environmental, social and economic benefits at both the building and the urban design scales, green walls and green roofs have been strongly promoted. In the European Commission's renewed Strategy on Adaptation to Climate Change (the European Green Deal Initiative), green walls and green roofs have been identified as "no regret" solutions to make infrastructure more climate-proof (Sempergreen, 2021). Countries like the U.S., Canada, Germany, Australia, Singapore and Japan have adopted standards for applying greenery systems in both existing and new buildings (Liberalesso et al. 2020).

[1] The construction sector's share of global final energy-related CO2 emission in 2020 accounts for 36% energy consumption and 37% GHG emission (United Nation Environment Program & Global Alliance for Buildings and Construction, 2021)

[2] Ecosystem service is defined as ecological processes or functions which have value to individuals or society (IPCC, 2018).

2.2 VIETNAM

Fundamental economic reforms since the mid-1980s (Đổi Mới) have resulted in rapid economic growth along with massive urbanization, but at the same time have also created pressing environmental issues (see McGee, 2000). Furthermore, Vietnam is listed as one of the five countries most affected by climate change, given the location of 70% of its population and economic activity in coastal lowlands and deltas (Dasgupta et al., 2007). Urban centers in these areas will be prone to uncertain future precipitation trends, extreme weather events and rising sea levels with serious coastal and fluvial flooding if they don't undertake effective adaptation and mitigation measures (World Bank & ADB, 2020).
Following its consistent climate change commitment, Vietnam adopted the Plan for Implementation of the Paris Agreement (PIPA) in 2016 and updated the country's NDC in 2020 with raised ambitions to promote energy efficiency. In 2020, the Ministry of Construction adopted the action plan to implement the Paris Agreement 2020-2030 (MoC, 2020), emphasizing the reinforcement of sustainable building policies and practices. One of the key actions is to promote passive design solutions such as constructive shading and the natural ventilation of buildings.

In fact, greening the living space has historically been applied in traditional architecture. The planting of palm trees at the front of the house to provide shading in summer and in the case of North Vietnam, bananas at the rear to block the cold north-easterly wind in winter were common practices (Nguyen et al., 2019). In the early 2000s, the sustainable building movement was introduced to Vietnam and has slowly gained momentum contributing to a reduction in the residential construction sector's environmental impacts and improving people's well-being (Nguyen et al., 2017; Pham et al., 2019). In the ensuing period, green walls and green roofs have been incorporated in a number of certified green buildings (e.g. Pouchen Kindergarten in Binh Duong or Dai Lai Flamingo Resort in Vinh Phuc). Among other measures, green walls and green roofs have been promoted through the work of famous Vietnamese architects such as Vo Trong Nghia (VTN Architects), Hoang Thuc Hao (1+1>2 International Architecture Construction, Joint Stock Company), Nguyen Hoang Manh (MIA Design Studio), and in the work of T3 Architects, a French design firm, based in Ho Chi Minh City. However, these projects are primarily located in major cities like Hanoi, Ho Chi Minh City, and Danang. Systematic measures to encourage sustainable construction and bolster the built environment against climate change in small and medium sized coastal cities, remain largely unrealised. (GIZ, 2017).

2.3 QUANG BINH PROVINCE

Quang Binh Province, most widely known for the UNESCO World Heritage-listed Phong Nha Ke Bang National Park, is located in the north of Central Vietnam. It has an area of 7,999km² and a growing population of 901,984 (2020 census figure). The province has a coastline of 116.04km to the east and shares a 201.87km long border with Laos to the west (Quang Binh Province website, 2021). Its climate is divided into two seasons. The rainy season lasts from September to March. The annual average rainfall is 2,000mm to 2,300mm. Heavy falls are concentrated in September, October and November. The dry season lasts from April to August. Quang Binh belongs to the monsoon-tropical zone, with annual average temperatures from 24°C to 26°C, humidity between 83% and 84%, and yearly average rainfall from 2,000 mm to 2,500 mm- peaking in September, October, and November (CAMaRSEC, 2021).

The current urbanization rate of Quang Binh is 30.2%, and the province aims to reach 40% by 2025 (Quang Binh Province website, 2022). Dong Hoi City is the capital of Quang Binh Province, with approximately 118,000 inhabitants, a figure anticipated to grow by 5% each year. In recent years, Quang Binh has successfully attracted significant tourism and hospitality projects. The needs of the growing middle-class population have been catered for by the construction of several new urban residential areas, the development of shop houses and commercial complexes (Quang Binh DoC, 2021).

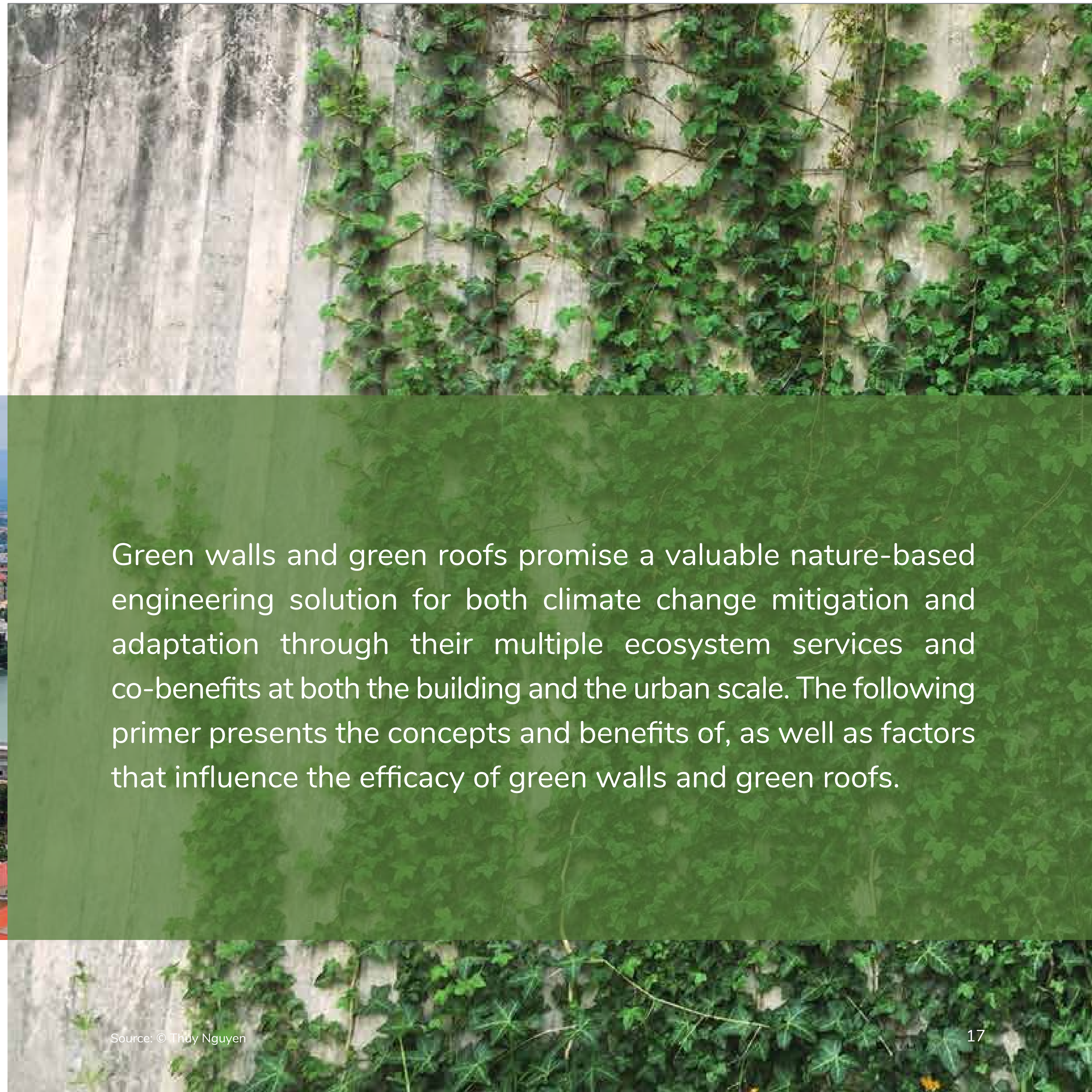
However, due to its geographic location and increasing urbanization, Quang Binh Province is increasingly vulnerable to more frequent and intense climate hazards (i.e. storms, floods, droughts, rising sea level). In the past several years such events have caused substantial damages and losses to the local population and its infrastructure, particularly in Dong Hoi City.

Under the framework of VN-SIPA project, an initiative to promote green walls and green roofs was approved by Quang Binh Province Government as a key nature-based adaptation solution to climate change and rapid urbanization (Quang Binh Province, 2020). An implementation of this initiative took place at the Public Service Management Unit - a public building of Dong Hoi City (see Figure 1). Details of this installation appear in Chapter 5 of this document.

Dong Hoi city
Source: © GIZ/Luong Thanh Trung

03

Understanding GREEN WALLS AND GREEN ROOFS



Green walls and green roofs promise a valuable nature-based engineering solution for both climate change mitigation and adaptation through their multiple ecosystem services and co-benefits at both the building and the urban scale. The following primer presents the concepts and benefits of, as well as factors that influence the efficacy of green walls and green roofs.

Source: © Thuy Nguyen

3.1 CONCEPTS OF GREEN WALLS AND GREEN ROOFS

Green walls and green roofs share a long history dating back to the famous Hanging Gardens of Babylon and Roman architecture featuring the draping of vines over pergolas and city walls (Manso & Castro-Gomes, 2015). Since the 17th century, these concepts have been widely applied in Europe and North America. More recently, they have gained popularity in Southeast Asia, with Singapore being a pioneer (Wong et al., 2021).

Green walls and green roofs are classified by their particular functional elements, including by type of (i) supporting elements, (ii) growing media, (iii) vegetation, (iv) drainage, and (v) irrigation. Each type has its unique features requiring different implementation approaches (Blanco et al., 2018).

The following sub-sections present in detail these concepts and examples. The information presented is based on a review of peer-reviewed literature (Cameron et al. 2014; Wong and Baldwin 2016; Besir & Cuce, 2018; Palemo & Turco, 2020; Manso et al., 2021).

3.1.1 GREEN WALLS

Green walls (also called vertical greenery systems or vertical gardens) include green façades and living walls. Each have pros and cons.

GREEN FAÇADES

Green façades consist of three types: (A) Direct/traditional green façades; (B) Indirect/double-skin green façades; (C) Container/perimeter pot/trough-based green façades. They are primarily classified according to the type of plant support structure and the distance between the plant layer and the wall surface (Figure 1).

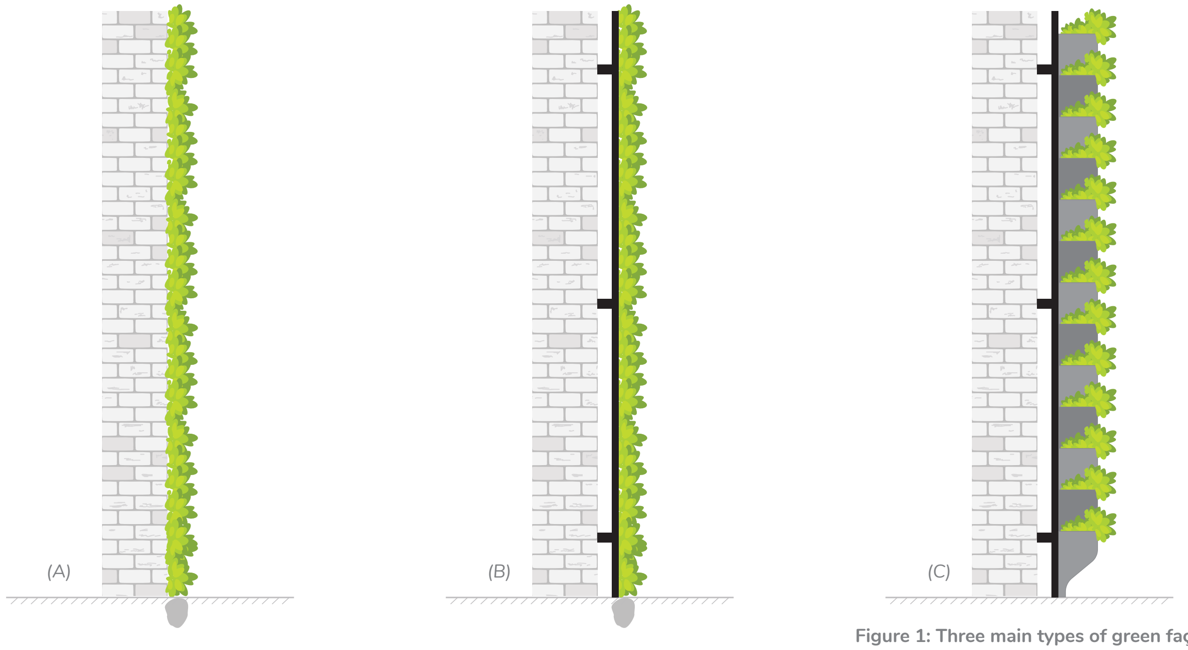


Figure 1: Three main types of green façades
Source: © GIZ/VN-SIPA project

Direct/traditional green façades (A)
are façades in which climbers affix themselves directly to the wall via leaf tendrils, adhesion pads (adhesive suckers, disks) or aerial roots to form a self-supporting vegetation system.

Indirect/double-skin green façades (B)
are façades with a specialized support system (double-skinned framework) on which climbers are trained upward by twining stems or by hooking and clasping tendrils (modified leaf or stem organs). Indirect green façades are separated from the wall by an air space.

Container-based green façades (C)
are façades with plant containers (perimeter pots, boxes or troughs) located at different elevations. Plants for this type of façade can be shrubs, flowering or even edible plants.

Each green façade type has its own pros and cons, which need to be carefully considered to meet expected project outcomes. These are presented in the following table.

Table 1: Pros and Cons of each green façade type

	Direct/traditional green façades	Indirect/double-skin green façade	Container/pot/trough-based green façade
Pros	» No need for additional supporting structures for plant materials » Can use existing soil, if of a high enough quality	» Better thermal insulation due to the air cavity. » Reduced risk of damage to construction materials behind plant layer	» Better plant distribution for very tall buildings where ground level plants cannot grow tall enough.
Cons	» Risk of damage to façade with cracks or porous surfaces (render, timber cladding, mortar). » Damage can be aesthetic in the short-term, but structural in the longer term.	» Require a more complex support system and therefore higher investment cost » For structural reasons, the support system might not be able to cover the whole façade area.	» Limited growing media depth might restrict root growth and limit foliage volumes, although some shallow-rooted species tolerate limited media volume.

Implications:
Each type of green façade presents its own advantages and disadvantages. The selected approach depends on the project goals and specific features of the building. Indirect/double-skin green façades are more likely to return the best thermal performance if they have adequate wall coverage.

Source: Self-summarized from different sources

Source: © Michael Waibel

Examples

In Vietnam, green façades have been well integrated in local buildings.

Figure 2: The Breathing House, Ho Chi Minh city, Vietnam
Source: © Vo Trong Nghia Architects

Project
BREATHING HOUSE

Location

Ho Chi Minh City (Tropical Savannah)

Greenery and building typology

Indirect green façade of a private multistorey house of 69,5 m²

Description

The housing was designed by VTN Architects in February 2019. The open spaces are wrapped in a green veil made of creeper plants that grow on a steel mesh. Micro-voids enable ventilation in each corner of the house.

Benefits

Natural shading; natural ventilation, less direct sunlight, green view, lower energy consumption

Lessons learnt

Creating micro-voids, instead of one large, open space helps to enhance natural ventilation and creates more greenery around the house.

Project
THANG HOUSE

Location

Danang City, Vietnam (coastal area, tropical monsoon climate)

Greenery and building typology

Green walls and green roofs in a private 250 m² area house

Description

The urban housing was designed by VTN Architects in November 2019. For efficient use of space, the building is subdivided into four nested room 'boxes' with a wall shaded by climbing plants alongside with the open living space. The roof offers a fruit garden containing different indigenous crops with nine tree boxes. Irrigation is provided by a water recycling system, sourced from an in-house fishpond.

Benefits

Open, bright spaces; natural ventilation; natural shading, efficient space utilization, reduced direct sunlight, heat-resistant wall, lasting irrigation, solar panels, local materials, improved psychological and physical well-being

Lessons learnt

Efficient use of space by an interleaving of rooms and open space to support natural ventilation. The design reduces energy consumption.

Figure 3: The Thang House, Da Nang city, Vietnam
Source: © Vo Trong Nghia Architects

Figure 4: The City Oasis Apartment, Ho Chi Minh city, Vietnam
Source: © KA Architects

Project
CITY OASIS APARTMENT

Location
Ho Chi Minh City, District Saigon (Tropical Savannah)

Greenery and building typology
Private sector: redesigned apartment from existing one on 300 sqm site.

Description
The 27 apartments were rebuilt from an old apartment in 2020 by K.A. Studio. For preservation of the current plants and daylight, a large void was retained. The natural-curved balconies contain a green layer with various tropical trees and climbing plants

Benefits
Air filtration, green space, utilisation of local materials, lightweight concrete, reduced direct sunlight, natural shade, uses regenerating materials, improved livability.

Lessons learnt
Older buildings have the potential to be rejuvenated by regreening and redesigning according to local conditions.

Project
COCONUT GARDEN

Location
Phnom Penh, Cambodia (tropical, monsoon climate)

Greenery and building typology
Direct and container-based green façades in a bioclimatic-consciously designed hospitality building within a recreational park offering various on-site family activities.

Description
The project was completed in 2021 by T3 Architects. The building follows bioclimatic principles such as providing an open space for natural ventilation and hanging plants, vertical gardens for interior heat reduction. The use of tropical plant species minimises long-lasting maintenance. These plants grow mainly in the natural soil around the building to avoid additional construction costs and allow them to grow freely.

Benefits
Natural ventilation, improved occupant well-being, natural interior, reduced direct sunlight, energy saving, sun protection, maintained with low-tech solutions.

Lessons learnt
A long-lasting, cost-efficient maintenance plan is essential regarding sustainability guidelines, by for example, using indigenous plants and other low-tech solutions.

Figure 5: The Coconut Garden, Phnompenh, Cambodia
Source: © T3 Architects, Michael Waibel

LIVING WALLS

Living walls are modern types of green walls, formed by plants that either set roots into the wall or in purpose-designed cells of substrate embedded in or on the wall. Plants are often supplied with nutrients and water through artificial irrigation or fertigation systems.

Living walls are primarily classified by their design and type of growing medium into A) continuous living walls and B) modular living walls.

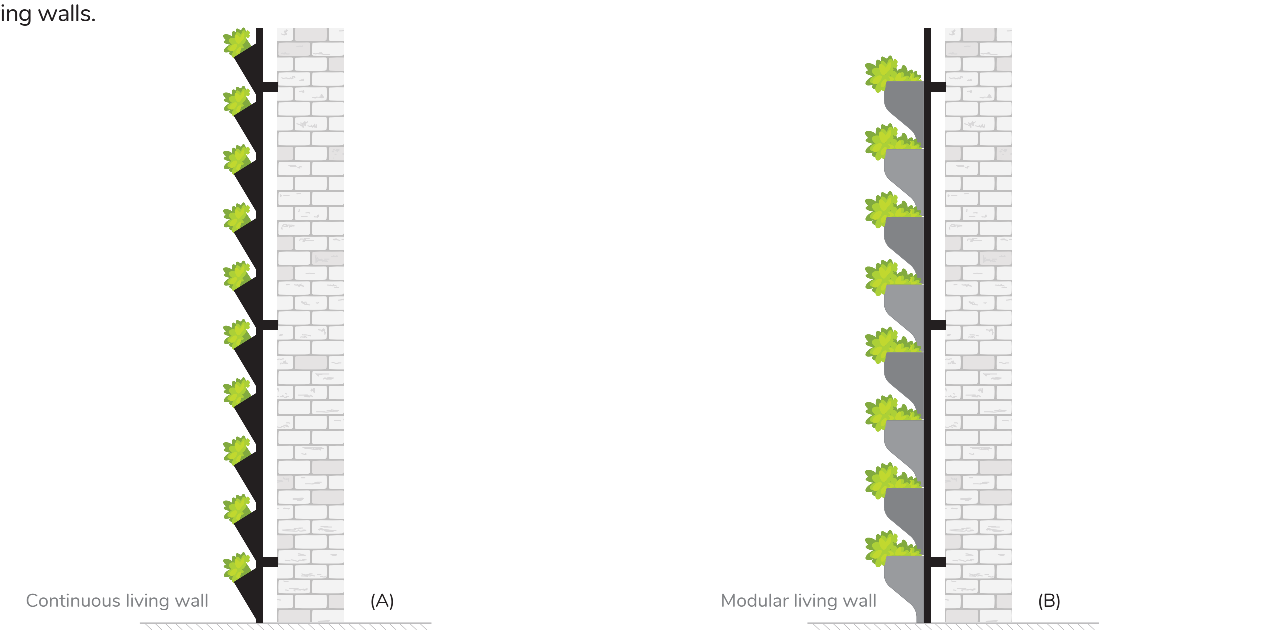


Figure 6: Two main types of living walls
Source: © GIZ/VN-SIPA project

Continuous systems
mainly follow the hydroponic approach of the French biologist Patrick Blanc, which utilise a geotextile membrane - normally covered by hydroponic panels, instead of growing media.

Modular systems *can be both hydroponic and substrate based. Hydroponic systems use the irrigation system to provide nutrients in liquid form directly to plant roots contained in modular planters, trays or bags. Substrate-based systems also employ planters, vessels, trays or bags. Plants are grown in these planters with engineered substrate, which is normally lighter than ground soil.*

The advantages and downsides of both systems are presented in the table below.

Table 2: Pros and Cons of living wall types

	Modular Living Wall	Continuous Living Wall
Pros	» More adaptable to available space and location, therefore having more design and brand options in the market » Easier to remove individual containers » Likely better plant health and higher thermal mass due to thicker growing medium and thicker leaf layer (for media-based modular living wall)	» Lighter weight » No structural decay of the growing medium » No salt build-up from fertilisers » Precise and controlled irrigation and fertilisation » Lower costs
Cons	» Heavier weight due to the container system » Reduced growing media quality overtime and salt build-up from fertilizers for media-based modular system » Imprecise irrigation and fertilization for manual system » Higher costs	» High humidity in the felt rooting substrate surface, thereby affecting plant health and indoor environment due to mold and disease » Likely nutrient deficiency for plants » Lower thermal mass » Difficult to replace unhealthy plants

Implications:
Pros and cons exist for both types of living wall. Both require a well-designed irrigation system that suits the selected plant species and considers the micro-climate of the installation.
Growing media-based modular living walls are in general considerably less complicated and require less maintenance than hydroponic systems.

Source: Self-summarised from various sources.

Source: freepik.com

Examples

A continuous living wall was installed at the Rex Hotel in Ho Chi Minh City. It was awarded the title of largest living wall in Vietnam in 2013. The vertical greenery system currently functions well as shown the pictures below.

Project
REX HOTEL

Location
Ho Chi Minh City, District Saigon (Tropical Savannah)

Greenery and building typology
Hospitality Sector: Luxury Hotel with a green wall of 600m² in area.

Description
The vertical green garden was installed in 2013. In addition to planting pots in the inner courtyard, one side of the hotel complex was planted with various vegetation. Twenty-eight different species (i.e. Plum, Thanh Xuan) grow on braces along the cement wall.

Benefits
Air filtration, green space, natural feeling, lower energy consumption, reduced direct sunlight, improved well-being for occupants, natural oasis in an urban setting.

Lessons learnt
An option worth considering is the greening of a pre-existing building for example for reduced cost.

Figure 7: The Rex hotel, Ho Chi Minh city, Vietnam
Source: © Tran Mai Tram

Figure 8: The Quai Branly, Paris, France
Source: © Michael Waibel

Project
QUAI BRANLY

Location
Paris, France (temperate climate)

Greenery and building typology
Public gallery: a green wall of 650 ft. long and 40 ft. high.

Description
The living wall was designed by Patrick Blanc in 2013. The walls are covered with climbing plants and flowers grown on a metallic structure from the roof to the sidewalk.

Benefits
Natural shading, thermal regulation, urban greenery, reduced direct sunlight.

Lessons learnt
A green façade within a densely settled urban area brings back nature and supports the urban ecosystem.

INTERIM SUMMARY

The preceding text provided the basic the concepts and categories of green façades and living walls, along with the particular pros and cons of each type, which are summarized in the table below.

Table 3: Pros and Cons of green façade and living walls in general

	Green façade	Living walls
Pros	» Lower weight load » Less complicated support system » Lower irrigation and maintenance demand especially for ground plants » Lower total costs	» Quicker results after installation with pre-cultivated plants
Cons	» Plants take time to grow » Limited growing conditions for climbing plants in urban contexts due to compacted soil and sealed surfaces (e.g. concrete footpaths)	» Higher weight load » Requires a more complicated support system » Higher irrigation and maintenance demand » Higher total costs

Implications:
The decision to choose either a green façade or living wall depends on the site conditions, project purpose, level of investment and maintenance capacity.
In the long-term, green façades usually perform better than living walls due to there being better conditions for plant growth, simpler irrigation techniques and lower maintenance demand.

Source: Self-summarized from different sources.

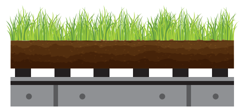
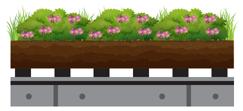
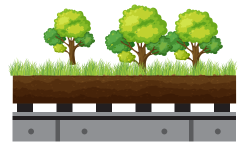
Source: © Michael Waibel

3.1.2 GREEN ROOFS

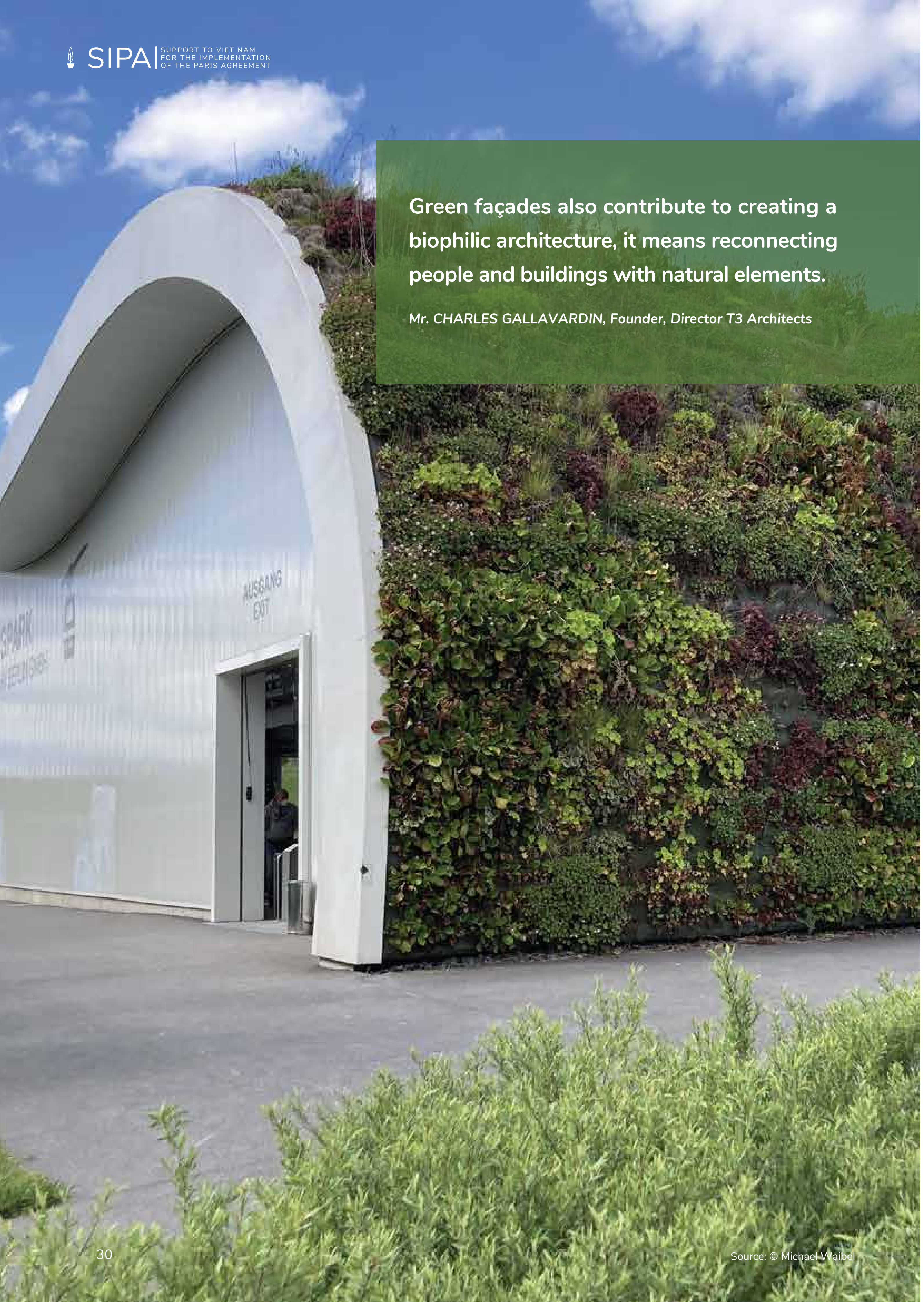
Green roofs consist of a layer of vegetation planted over a waterproof layer. They can effectively convert a rooftop into a multifunctional space. Green roofs can be flat or slightly sloped.

Green roofs basically consist of three categories (extensive, semi-extensive or semi-intensive and intensive roofs) depending on their weight, growing media, plant diversity, maintenance and irrigation, accessibility, use and cost. However, green roofs are increasingly designed and installed with mixed purposes in mind and don't fall into a specific category. The general features of each green roof type are presented in the following table.

Table 4: Characteristics of each green roof type

Characteristics	Extensive green roof	Semi-intensive green roof	Intensive green roof
Roof load	 60-150kg/m²	 120-200kg/m²	 180-500kg/m² (Substantial structural load)
Substrate depth	60mm to 120mm	120mm to 250mm	150mm to 400mm
Plant diversity	Mostly limited to drought tolerant species with short roots and low stems such as mosses, herbs and grasses	Larger range of plant species including grasses, herb and shrubs	Largest range of plant species, including lawn/perennials, shrubs and trees
Maintenance	Low	Periodic	High
Irrigation	Little to no need	Periodic	Regularly
Accessibility	No	Accessible	Mostly accessible
Use	Biodiversity enhancement and aesthetic value (ecological landscape) PV green roof Suitable for retrofitting due to not increasing load on the existing structure	Mixed use between ecological landscape and gardens	Multi-purpose: Water retention, wind barrier, food production, nature-habitat, park and recreation, roof top garden...
Costs	Low	Middle	High

Source: Self-summarized by authors from different sources.



Green façades also contribute to creating a biophilic architecture, it means reconnecting people and buildings with natural elements.

Mr. CHARLES GALLAVARDIN, Founder, Director T3 Architects

Source: © Michael Waibel

Project
POU CHEN KINDERGARDEN

Location

Dong Nai, Vietnam (Tropical Monsoon Climate)

Greenery and building typology

Public educational facility with a green roof, composed of three continuous loops of area 3,800 m²

Description

The kindergarden was planned by VTN-Architects in October 2013. The façade is equipped with climbing plants. The roof is used for urban agriculture with a mix of indigenous vegetables, for example melons, strawberries, green beans (depending on soil depth). The greening of the building is irrigated by treated wastewater from the adjacent factory in order to save limited water.

The project received a LOTUS Silver certification by the Vietnam Green Building Council.

Benefits

Open, bright spaces, natural, cross ventilation, natural shading, rooftop gardening experience for children, solar panels, utilized local materials, reduced direct sunlight, wastewater treatment and recycling and educative benefits of nature for children

Lessons learnt

Green roofs not only serve for agricultural purposes within a densely settled area, but also serve as social venue, for example, as a playground for children.

Figure 9: The Pou Chen Kindergarden, Bien Hoa, Dong Nai, Vietnam
Source: © Vo Trong Nghia Architects

3.2 BENEFITS OF GREEN WALLS AND GREEN ROOFS

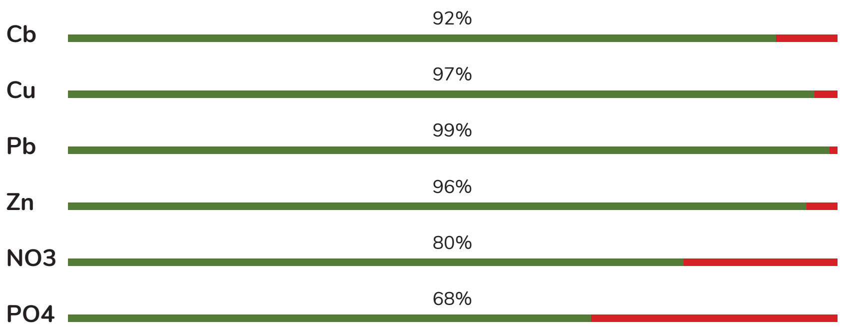
The multiple benefits of green walls and green roofs have been extensively researched in a wide range of climatic regions. Within this report, scientific evidence has been mostly drawn from studies undertaken in tropical contexts including Hong Kong, Singapore, and Malaysia.

AT THE URBAN SCALE, GREEN WALLS AND GREEN ROOFS CONTRIBUTE TO THE FOLLOWING:

Rainwater management

Green walls and green roofs reduce both total rainwater runoff and discharge speed (peak delay) to the sewerage system. This is because water percolates through the growing media and later transpires through the vegetation. Globally, green roofs reduce stormwater runoff from buildings by on average 54% to 62%. In Malaysia, green roofs with Densifolia plants retain up to 41% of stormwater, with Sarboricola plants accounting for 37% (Fang, 2010; Wong and Jim, 2015).

They also mitigate water-borne pollution in runoff. The amount of mitigation achieved is seasonal and is illustrated below (adapted from Seusloff, 1998).



Intensive green roofs, due to their thicker substrate and diversified vegetation, have the highest water retention capacity.

Kew et al. (2014) reported that green walls also retain significant rainfall, especially when the rain is obliquely driven and captured by the gutters integrated into the green wall system (about 60% to 70% of rain events). The same study reported that 50% of rainwater in such events is retained by green walls.

Generally, green walls and green roofs have the attractive potential to store and recycle rainwater and grey water. To achieve this, an underground tank of appropriate capacity is needed to store the collected water for irrigation purposes. Details on the design and installation of such a reticulated irrigation system is presented in detail in sections 4.2 and 4.3.3.

Source: © Thuy Nguyen

Biodiversity enhancement

Green walls and green roofs provide vegetation cover and habitat for insect and bird species in urban areas (Mayrand and Clergeau, 2018). For example, the Oasis Hotel in Singapore introduced 21 creeper and 33 tree species producing flowers that attract birds and insects at different times of the year. This also created habitat for small animals such as squirrels (WIRED, 2022).

Urban cooling and microclimate improvement

Green walls and green roofs reduce urban heat stresses caused by extreme weather events or by urban heat island effects in densely constructed urban areas. Through the high water-retention capacity of the plants and their evapotranspiration, green walls can help mitigate the urban heat island effect by reducing the surrounding ambient temperature by 0.5°C to 2°C (Susca et al., 2011, Nguyen & Waibel, 2021). In this way green walls significantly contribute to improving the microclimate of buildings and their surroundings.

Air quality improvement

Plants produce oxygen by photosynthesis and their aerial parts can trap fine dust, in effect filtering airborne particulate pollutants. Green walls can retain 52% ozone, 14% particulate matter, 12% to 40% nitrogen dioxide (NO_2), 40% ground-level ozone (O_3), 3.5% sulfur dioxide (SO_2), 1.3% carbon monoxide (CO) (Pugh et al., 2012; Jayasooriya et al., 2017).

Wind barrier

Vertical greenery can reduce wind speed along the façade by acting as wind barrier to prevent heating or cooling of the walls (Manso et al., 2021).

Carbon sequestration

Soil and vegetation are known to act as net carbon stores, sequestering carbon as organic matter. For a living wall, carbon can be sequestered by the plants' stem and foliage systems above the substrate (known as above-ground carbon sequestration) (Charoenkit & Yiemwattana, 2017). Carbon accumulated in the substrate is also extracted by plant for root growth (below-ground carbon sequestration) (ibid). Carbon sequestration in a living wall is higher in summer when plants revive, especially by plants that have woody stems, dense foliage and small leaf size. In Thailand for example, Cuphea hyssopifola plant, with high biomass and woody stems, sequester the highest amount of carbon (up to 45% of above-ground carbon and 42% below-ground carbon) (Charoenkit & Yiemwattana, 2017).

Social benefits

Green walls and green roofs enhance quality of life by improving indoor and outdoor thermal comfort, adding utility to public spaces and by enhancing the aesthetic of built environments (Radić et al. 2019). Visual and physical contact with plants has direct health benefits by helping to reduce stress, fear and violent behavior and by increasing illness recovery rate and resistance (Radić et al. 2019). Additionally, green walls and green roofs build place identity and a sense of community (Manso et al., 2021). They can also serve as effective tools for environmental education and for nature observation (ibid). In addition, green walls and green roofs can function as urban farming to produce food. Buildings or houses designed with such a system are considered "edible housing" and contribute to secure / support urban food systems.

Source: elements.envato.com

Source: © Thuy Nguyen

AT THE LEVEL OF THE INDIVIDUAL BUILDING, THERE ARE ALSO NUMEROUS BENEFITS

Thermal comfort

Green walls and green roofs enhance thermal insulation by intercepting solar radiation, screening wind and by evapo-transpiration of the greenery (Wong and Baldwin 2016, p. 35). Green walls can absorb up to three times more solar radiation than conventional walls (Zhang et al. 2019). Additionally, green roofs reduce about 80% of heat transmission and can reduce energy consumption in summertime by 2.2% to 16.7%, depending on type and area covered (Besir and Cuce, 2018).

Energy saving

If well designed and constructed, a building envelope can save from 20% to 60% on heating and cooling costs (Wong and Baldwin 2016, p. 35). green walls and green roofs, with high foliage density and thickness, function as an air insulation vegetation layer. Green roofs can reduce about 80% of heat flow and save 2.2% to 16.7% of energy consumption during summertime (Besir and Cuce 2018, p. 915). An average energy saving of 63% was measured at an extensive green roof of a commercial building in Singapore (tropical climate zone) (Wong and Baldwin 2016, p. 35). Another study in Vietnam showed that green façades reduce the indoor temperature by 1°C and save up to 35% on cooling costs if air-conditioning was used for five consecutive hours during hot days in Hanoi (Nguyen et al. 2019).

Sound insulation

Green walls and green roofs improve the acoustic properties of a building and its surroundings by absorbing, scattering, and reflecting sound (Lacasta et al., 2016). Green walls reduce sound transmission by 10 to 20 dB (Connelly and Hodgson, 2013). An extensive green roof can decrease sound pressure levels by 5dB to 20dB (Manso et al., 2021). This is a significant benefit, particularly in the often-noisy cities of Southeast Asia.

Building protection

Green walls and green roofs add a bio-layer to protect the surfaces and materials of building envelopes from climatic stresses (i.e., UV radiation, fluctuating temperatures), thereby reducing their maintenance cost and prolonging the life of the building (Blanco et al., 2021).

Illustration of a container-based green façade
Source: elements.envato.com

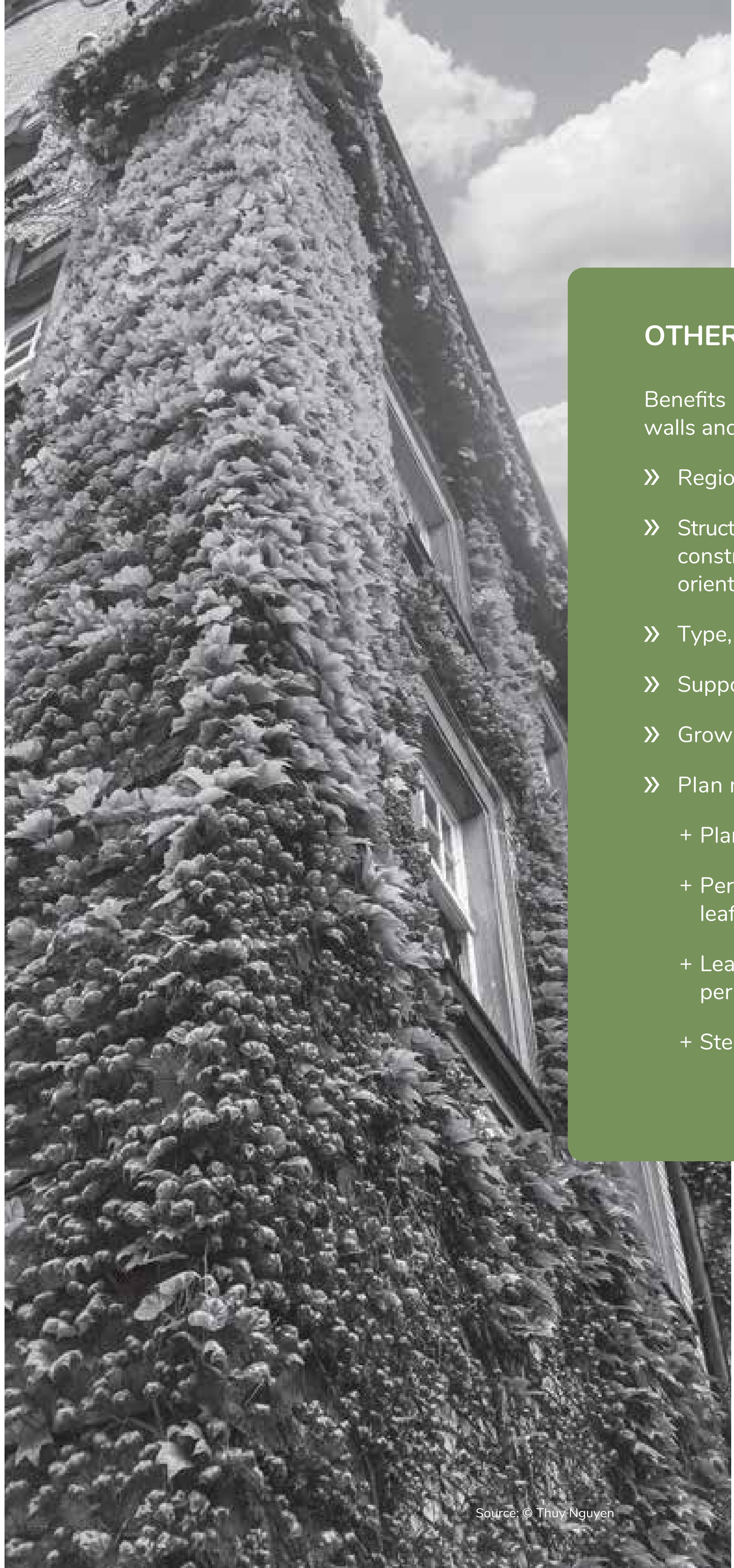
Efficiency of Photovoltaic panels

Photovoltaic (PV) panels are less efficient at converting solar radiation to electricity when cells get warmer (Manso et al. 2021). In this way, green roofs help to reduce the temperature of the panels and thereby increase PV efficiency. Specifically, green roofs can reduce PV operating temperatures by between 1°C and 4°C (Moren et al., 2017; Manso et al., 2021). Higher PV efficiency can thereby be achieved in the case of outdoor temperatures above 20°C.

Economic Benefits

Green walls and green roofs diversify the property market and increase property value through improving visual and functional amenity. The rental prices of such buildings in New York City have been reported to increase by about 16% (Ichihara & Cohen, 2011). According to another study in Canada, the value of residential and commercial buildings was observed to increase by an average from 7% up to 20% (Rosasco and Perini 2018). Further in-direct economic benefits of green walls and green roofs result from advantages presented above, e.g. in terms of reduction of expenses for artificial cooling due to decreased heat intake of building envelope resulting in higher energy efficiency, better options for food farming, cost reductions for building envelop maintenance, increasing PV system's performance due to induced lower temperatures. Another positive impact of green walls and green roofs is apparently the enhancement of building users' capacity to work better and with higher productivity, as a result of improved living comfort and human wellbeing (Palermo and Turco 2020).

Source: freepik.com



Source: © Thuy Nguyen

OTHER CONSIDERATIONS

Benefits of green walls and green roofs, however, varies across walls and roofs and other factors:

- Regional and local climate conditions and season.
- Structural characteristics of the building (e.g. height, insulation, construction materials, building envelope, glazing area, solar orientation, shading)
- Type, size and location of green walls and green roofs
- Support structure (materials, thickness)
- Growing media used (type, depth and moisture content)
- Plan morphology and geometry
  - Plant types and growth rate
  - Percentage of the wall covered by plant material (PWC) and leaf layer depth
  - Leaf size, leaf area index (the ratio of "single-sided" leaf area per unit area of underlying material)
  - Stem morphology

(see Cameron et al. 2014; Kontoleon and Eumorfopoulou, 2010; Susorova et al., 2013)

04

Implementing GREEN WALLS AND GREEN ROOFS

Apart from investment management and local governmental approval procedures, there are four basic steps in implementing a green wall and/or green roof project:

- STEP 01 PLANNING
- STEP 02 DESIGN
- STEP 03 INSTALLATION
- STEP 04 MAINTENANCE

The following provides general guidelines for each of these steps[4].

4.1 PLANNING GREEN WALLS AND GREEN ROOFS

To plan green walls and green roofs, the project site needs to be thoroughly reviewed, the project goal set and relevant stakeholders engaged.

Source: © Michael Waibel

[4] Information presented is based on the review of publications (including: Leicht-Young et al., 2010; Cameron et al. 2014; Wong and Baldwin 2016, Besir and Cuce 2018; Manso et al., 2021, Blanco et al., 2021; Municipal Guide, 2014).

4.1.1 SITE ASSESSMENT

Site assessment ensures that the project design addresses local conditions. Assessment factors include:

Climatic and geographical conditions: wind, rainfall, temperature, local ecosystem, and other microclimatic issues (air pollution, wind turbulence and humidity).

- Site assessment should account for the most unfavorable climatic and geographical conditions experienced at the project location.
- Knowing the total rainfall and duration of the rainy period at the project location is critical for rainwater retention purposes.
- Wind is normally stronger at the tops and green roof, at the edges, around the perimeter and at corners of roofs. Wind velocity is lowest in the center of the roof.
- The total daytime amount and location of sunlight and shadow are important considerations. For example, living walls should get 10 hours of daylight, or at least 4 hours of midday/morning light. Long hours of afternoon sun should be avoided.
- Temperature is dynamic and tends to increase with elevation in urban areas due to the increased thermal mass of built structures and the commensurate heat gain.
- Ground soil quality is critical for successful green façades. Because urban soils are likely nutrient and moisture poor due to being compacted and concreted, quality soil provision might be needed for green façade projects.

Physical structure: The general structure of the building (height, supporting system, water supply and drainage, irrigation pumping system, etc.), structure and weight loading capacities of the building walls and green roof to bear the extra weight load of the green walls and roof system, issues of accessibility for maintenance (wall height, roof entrance, etc.)

- Green walls and green roofs can be added to existing buildings but require careful structural assessment and potentially reinforcement to accommodate retrofitting.
- The maximum weight load of the anticipated green walls and green roofs will be constrained by the weight load capacity of the existing structure.
- Reinforcement of the walls or roofs can be applied to strategic parts rather than to the whole wall or roof in order to minimize costs.

Source: freepik.com

"Key factors to ensure the success of green walls and green roofs in Vietnam is to consider the microclimatic conditions of the plant system. Even within a city, the areas prone to the coastal wind are different from those not prone to coastal wind..."

Mr. BUI VAN TIEN, Agriculture Engineer,
Expert on green walls and green green roofs

4.1.2 GOAL SETTING AND CONSIDERATIONS

Goals of green walls and green roofs should be identified upfront to guide effective implementation. Below are suggested considerations for each goal of green walls and green roofs.

Rainwater retention

For green walls and green roofs, increase substrate depth and water-holding capacity, use high water uptake plants, design irrigation and drainage systems to store stormwater for recycling.

Wind barrier

For green walls, install a stronger plant support system, use plants with thick foliage.

For green roofs, install adhesive for edge restraints and parapets, and select plants with strong root systems.

Thermal insulation

For green walls, use leafy plants, cover the entire wall to provide best shade in summer, particularly on north and west facing walls.

Provide a structure with at least of 100 mm air gap from the wall for the plants to grow on in order to maximise cooling effect.

For green roofs, increase growing media depth, provide irrigation, select species for leafy plant cover in summer.

Source: © Michael Waibel

Source: elements.envato.com

Nature Habitat/Biodiversity

For green walls, include flowering and fruiting species with capacity to support nests.

For green roofs, include habitat plants (usually native or indigenous spp.), habitat features (water and shelter), small topography changes and substrate variations.

Source: elements.envato.com

Aesthetics /Recreation/Amenity

For both green walls and green roofs, use evergreen species to ensure year-round screening, include a variety of species with different flowering times, textures, foliage colours and consider planting in patterns.

Food production

Increase depth and organic content of the growing media, ensure good access to the site, provide irrigation (see image of Pouchen Kindergarten in section 3.1.2).

4.1.3 STAKEHOLDER ENGAGEMENT

A green wall or green roof project should meet client needs and involve specialists early in the process to achieve effective implementation. Experts include landscape designers or architects, structural engineers, plant biologists, horticulturalists and soil scientists, who will give advice on the most suitable design, planting techniques, the selection and maintenance of plants and growing media, etc. Specialists should also be consulted throughout the project development.

Smaller scale initiatives might be contracted to a service provider as a full package covering site assessment, design and installation. Maintenance can be a separate component but is recommended to be included with the installation contract to ensure that installers take responsibility for their work going forward.

Large-scale projects, however, especially those with public funding, need to follow regulated investment management procedures. These engage a wide range of stakeholders including for example, the project investor, project management agency, project beneficiaries, design consultants, design verification agency, local authorities with approval functions, constructor/installer, independent construction monitoring consultant, and so on.

"The project needs to engage with specialists in each aspect (landscape, irrigation, etc.). If all are well addressed and things are done well from the beginning, the maintenance costs will be significantly reduced"

Mr. QUANG DO, Construction Engineer, Expert of Green Buildings

Source: freepik.com

4.2 DESIGNING GREEN WALLS AND GREEN ROOFS

When designing green walls and green roofs, basic components of the greenery system should cover the vegetation, support system, irrigation, and maintenance. Each system component should be designed in line with the site assessment results, project goals and local regulations where applicable.

VEGETATION

Plant lists should serve the project goals and address the specific conditions of each green wall or green roof type, for example the local climatic conditions, allocated budget, and maintenance capacity. Plant selection is critical for the success of green walls and green roofs and should fulfil the following requirements.

Selected plants should:

- Be local and indigenous or already adapted to the local conditions.
- Grow stably in all seasons and be able to withstand variations in humidity, temperature and weather conditions
- Suit semi-hydroponic farming techniques and the wall/roof space
- Have slow growth and low nutritional needs
- Be more mature with thicker canopies for cooling purposes

"When we select plants we firstly choose plants that don't need a lot of maintenance. So, for the project "The Coconut Park" in Cambodia, we selected Veronica elliptica plants which are very resistant, easy to plant and require low maintenance. Even during the dry season, it remains more or less green and you don't need a lot of soil so you don't overload the structure of the building."

Mr. CHARLES GALLAVARDIN, Founder, Director T3 Architects

Source: freepik.com

Selected plants SHOULD NOT be:

- Prone to pest infestation, disease or being damaged by birds
- An irritant or poisonous variety
- A weed or potentially an invasive species
- An excessively vigorous species such as Common Ivy (Hedera helix) due to its adventitious roots and rambling habit
- Self-clinging climbers if the façade surface is in poor condition (i.e. possessing cracks, holes or loose material)

SUPPORT SYSTEM

The support system consists of structures installed additional to the existing wall or roof which support plant growth, including the containers. An effective support system needs to account for the weight of plant material at full growth, saturated growing media following rain or irrigation, maximum wind speed, and the load bearing capacity of the building.

SUPPORT SYSTEMS FOR GREEN WALLS IN AREAS OF STRONG WIND OR HIGH TEMPERATURES SHOULD CONSIDER THE FOLLOWING:

- To withstand strong wind loads and support a wider variety of plants, the support system should be constructed from metal materials and augmented by "woven" steel nets and mesh, in addition to vertical and horizontal cabling.
- Diagonally oriented cables accommodate both horizontal and vertical plant growth and increase foliage density. These cable braces also add more structural stability than simple vertical and horizontal cables.
- Container volumes should be carefully chosen because they optimize plant growth and affect root development.

Source: © Thuy Nguyen

GROWING MEDIA

Growing media can be soil-based (for green façades or substrate-based modular living walls) or hydroponic-based (for hydroponic modular or continuous living walls).

In general, the growing media for both types need to have the appropriate tilth, chemical properties, and physical qualities to supply water, nutrients, and anchorage for roots.

In particular, while substrate-based living walls provide most nutrients to plants via the growing media, hydroponic living walls deliver dissolved nutrients via irrigation which contains additional supplementary nutrients. The design of each growing medium type, therefore, requires specific considerations to ensure healthy growth.

A substrate-based system should

- Have a suitable balance of porosity, water holding capacity and nutrient supply
- Be able to hold roots and support the aerial plant structures
- Be environmentally friendly and allow beneficial microorganisms to grow
- Be replaced from time to time to ensure adequate nutrient supply. If necessary, liquid fertilizer can be added to the irrigation system

Source: © Michael Waibel

A hydroponic system should

- Be regularly monitored and maintained to ensure the constant provision of water and nutrients
- Provide plants with well-filtered, aerated and clean water to avoid diseases
- Maintain the correct temperatures and pH balance in the nutrient solution

IMPORTANT POINTS

For both soil/substrate-based and hydroponic green walls

The depth of growing medium is determined by

- The goals of green wall or green roof project
- Plant selection
- The load bearing capacity of the supporting structure
- The project budget

The depth of growing medium will determine:

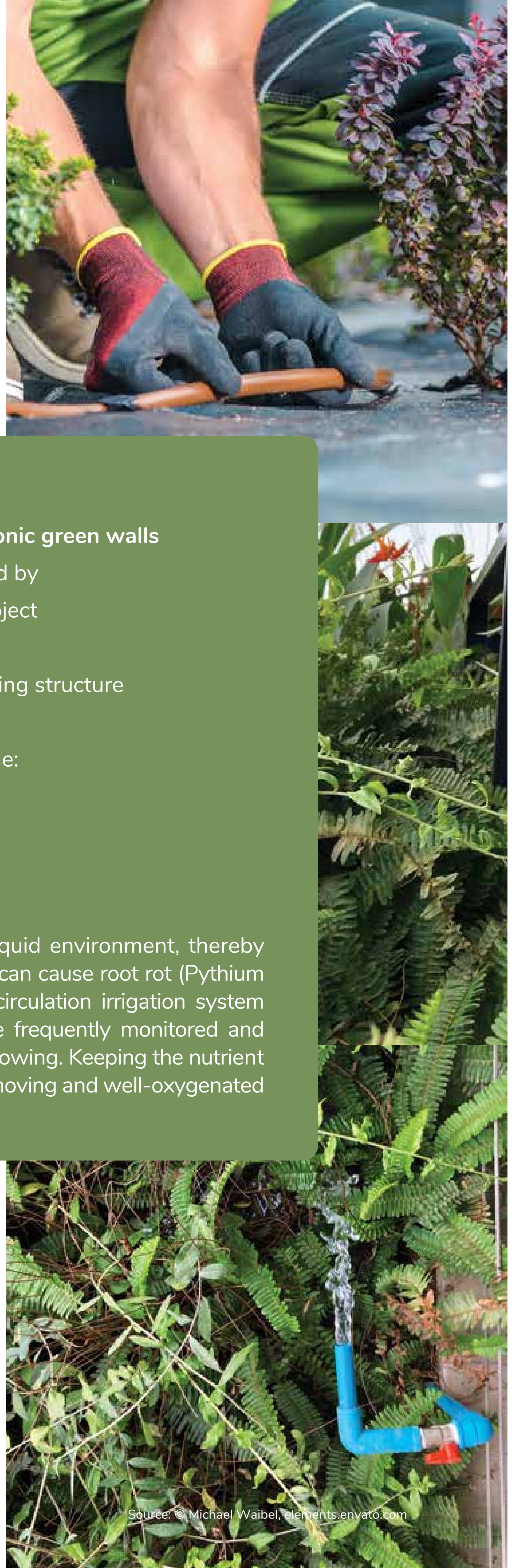
- Plant maximum size
- Water retention capacity and availability
- The required frequency of irrigation

For hydroponic systems

Hydroponic systems expose the roots to liquid environment, thereby having greater risks of plant diseases, which can cause root rot (Pythium spp.) issues. To reduce these risks, the re-circulation irrigation system should have a good filtering system and be frequently monitored and cleaned to prevent algae and bacteria from growing. Keeping the nutrient solution (irrigation/water solution constantly moving and well-oxygenated also prevents a lot of anaerobic disease).

DRAINAGE SYSTEM

Drainage system requirements vary between walls and roofs and between different categories of green walls. In general, drainage systems need to be carefully designed for container-based green façades, living walls (continuous and modular) and all green roof categories.



Source: © Michael Waibel, elements.envato.com

IRRIGATION SYSTEM

Irrigation systems need to be reliable and clean to ensure plant health. The design should adhere to technical standards to avoid water loss, hygiene issues, and rotten roots due to water-logging.

Irrigation frequency depends on

- The type of green walls (green façades or living walls, substrate-based or hydroponic)
- Plant species and growth stage (irrigation is critical during the plants' establishment)
- Climatic conditions (solar radiation, drying winds)
- Type of growing medium used (in-ground soil, hanging planters, substrate-based or hydroponic systems)

To promote effective EbA solutions, irrigation should be designed to recycle rainwater and used (grey) water and require minimum maintenance, according to the water-sensitive urban design approach (WSUD). For recycling irrigation systems, treatment to disinfect and treat run-off water is needed to avoid soil-borne disease and nutrient build-up.

Water-sensitive urban design (WSUD) integrates urban water cycles including stormwater, ground water and wastewater (grey water) in urban design and management to promote water recycling, climate change adaptation and urban aesthetic and recreational purposes. The WSUD term is popular in Australia and the Middle East. The term is close in meaning to the term "Sustainable Drainage System" in the United Kingdom or "Low Impact Development" in the United States (see Roy et al., 2008; Prenner et al., 2021).

The design and installation of recycling/circulation irrigation system is described in detail in section 4.3.3.

MAINTENANCE

Paying due regard to maintenance is a key part of every green wall/green roof project to ensure regular irrigation, fertilization, pruning, system repair or replacement, etc. During the design phase, a maintenance plan and contract arrangement should be drafted and responsibilities, budget, etc. allocated therein. Further details on maintenance appear in in section 4.4.

4.3 INSTALLING GREEN WALLS AND GREEN ROOFS

After the project has been designed and approved[5], and a contractor has been identified, the installation of green walls and green roofs can start. Before and during the installation work, quality management procedures need to be followed to ensure technical and safety standards are met. However, the installation of each type follow different technical procedures.

4.3.1 INSTALLING GREEN WALLS

Installing green walls can be simpler for direct green façades and small-scale living walls. It becomes more complex for double-skin façade, container-based façades or large-scale living walls.

The basic elements of installation include the waterproofing system, plant support system, growing media, plant materials, drainage, and irrigation.

INSTALLING GREEN FAÇADES

Installing green façade is generally simpler than installing living walls. The installation complexity depends on the type, each of which require a different structure. The major components of each green façade type are illustrated in the following figure.

Direct green façades

- No water proofing system is needed.
- No plant support system is needed but the wall itself. Walls having similar features to a climbing plant's natural host(s) such as those which mimic natural stems or bark texture can promote rapid growth and canopy cover.
- The growing medium is ground soil. A good quality soil bed needs to be installed to support plant growth in the longer term because soil in urban area is often low in water and oxygen due to being compacted by impervious paved surfaces.
- The plant materials chosen for direct green façades are mostly climbing species
- No extra drainage system is needed apart from the general drainage system of the whole building
- The irrigation requirement for ground-based green façades is not generally high. If irrigation is needed due to dry conditions, it can be an automated surface or sub-surface dripper system or manually managed with a hose.

Direct (traditional) green façade

Figure 10: Direct (traditional) green façade
Source: © GIZ/VN-SIPA Project

[5] The design of green wall/green roof projects must follow national and local regulatory frameworks, including the approval/construction permit procedures. The approval authority is identified based on the scope of the construction on which the green wall/green roof will be installed.

Indirect/double-skin green façades

- No water proofing system is needed.
- The support system is attached to the wall or mounted separately and consists of netting, mesh, horizontal and vertical cables, or modular trellises.
- Growing media installation is the same as for direct green façades (see above).
- Plant choices for indirect green façades are also mainly climbing species.
- No extra drainage system is needed apart from the general drainage system of the whole building.
- The same irrigation considerations for direct green façades apply (see above).

Indirect (double skin) green façade

Figure 11: Indirect (double-skin) green façade
Source: © GIZ/VN-SIPA Project

Container-based façades

- No water proofing system is needed.
- The support structures are designed and installed to hold containers at different heights on the walls.
- The growing medium is designed to support plant growth in a limited substrate depth (nominally 5cm to 10cm) and to minimize the weight load on the wall.
- Mainly vines or shrubs are used for container green façades. Climbing species can be used if an additional support system is incorporated in the design.
- The drainage systems of container-based façades have overflow drainage holes installed on container sides to avoid waterlogging. Drip trays can be installed below each container and connected to a common collection pipe to capture and recycle overflow irrigation or stormwater.
- The irrigation system is generally automated and includes a timer, pump and moisture sensor. It should be designed according to the needs of different species and the microclimate of the supporting wall.

Container based green façade

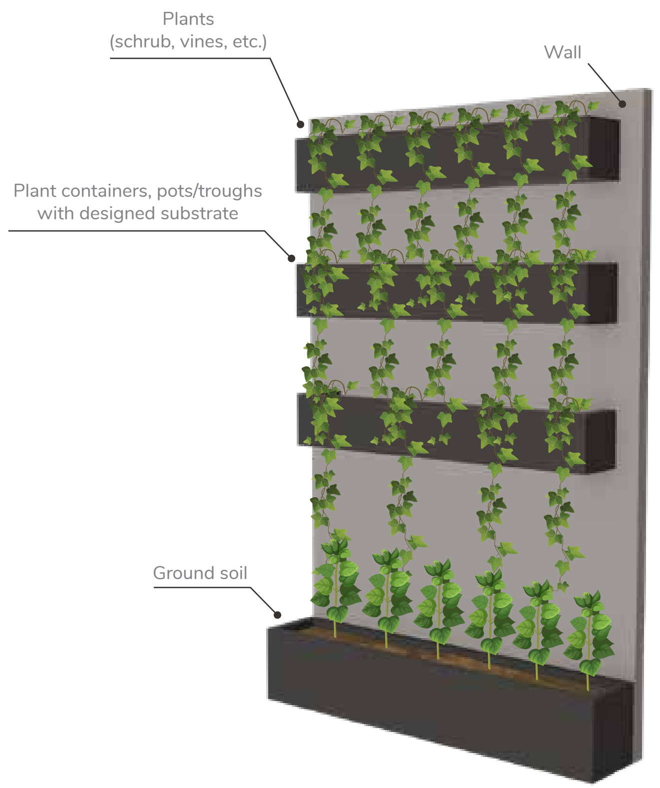


Figure 12: Container-based green façade
Source: © GIZ/VN-SIPA Project


Source: shutterstock.com

INSTALLING LIVING WALLS

Installing living walls is more complex than constructing green façades. The following presents considerations for installing the basic components of each living wall type.

Continuous living walls

- Waterproofing is optional depending on the technology adopted and the air cavity design between the vegetation layer and the wall.
- Continuous living walls require a solid support system to install hydroponic facilities with a separate structure, creating an air gap between the wall and the planter system. Plants are directly placed into small, non-biodegradable fabric pockets.
- Plants in a continuous living wall are anchored in an inert growing medium (i.e. synthetic foam, mineral fiber or a felt mat) allowing roots to penetrate the geotextile. Good quality felt matting will ensure better irrigation and moisture dynamics. This technology is not recommended for indoor environments if the room does not have adequate ventilation and dehumidification systems.
- The vegetation used in continuous living walls can range from ground covers to larger herbaceous species, perennial flowers, low shrubs, ferns, and grasses and even small trees. Cultivars that have been adapted to hydroponic growing conditions are preferable.
- The drainage system of living walls includes drip trays of sufficient size installed at the foot of the greenery system to capture excess irrigation water from the growing medium and stormwater dripping from the foliage. Drip trays are not necessary if the run-off is intended to irrigate the vegetation below. In this case, the run-off water should be managed to avoid creating a slip hazard, damaging the building fabric, or allowing excess moisture or nutrients to flood the area below.
- Automatic irrigation and fertilization are essential for continuous living walls. The irrigation system needs to supply adequate water flow and differential pressure for various elevations because higher elevations tend to be drier and require greater water pressure. There should be power back up to ensure continuous irrigation.

Continuous system

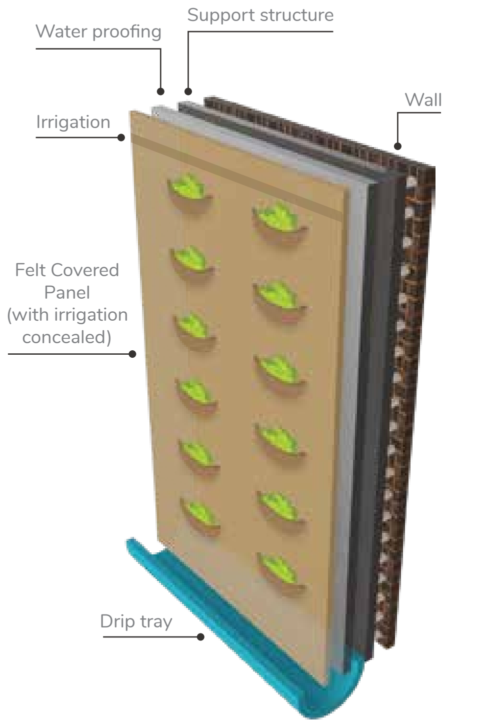


Figure 13: Continuous living wall
Source: © GIZ/VN-SIPA Project

Hydroponic modular living walls

- Water proofing is optional, depending on the selected technology and air cavity created between the vegetation layer and the wall.
- The support structure includes planters and a planter holding frame. The planters can be of different formats and sizes. Materials for the holding frame can be plastic, timber, metal, or stainless-steel cables or cable mesh.
- The growing medium is hydroponic. Dissolved nutrients are provided in liquid form through the irrigation system.
- Suitable plant materials for hydroponic modular walls are similar to those of continuous living walls.
- The drainage and irrigation system of hydroponic modular living walls are essentially the same as for continuous living walls.

Modular system

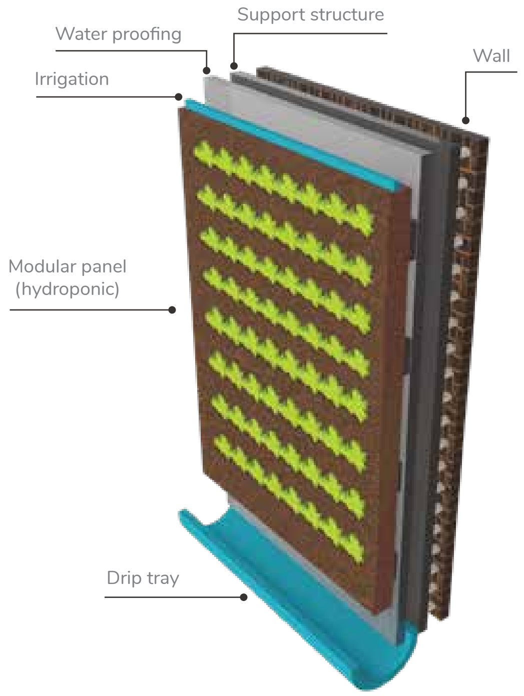


Figure 14: Hxdroponic Modular Living wall
Source: © GIZ/VN-SIPA Project

Substrate-based modular living walls

- Water proofing is optional depending on the selected technology and designed air cavity created between the vegetation layer and the wall.
- Supporting structures of a substrate-based modular living wall include containers and the frame system to hold the planters. For small scale living walls, containers and support frames can be combined in a grid panel that is moveable and can stand against the wall. For large-scale projects, containers and the holding frames are separate. The holding frames need to be primarily constructed from stainless steel and must be installed firmly to support the substrate-based greenery system.
- The growing medium is chosen to support plant growth in a limited substrate depth (of at least 5cm to 10cm) and to minimize weight loading on the wall. Traditional potting mix is not suitable for living walls.
- The range of suitable plants for a substrate modular living wall comparable to that for a continuous living wall. Plants with shallow, fibrous root systems that enable firm anchorage in the limited growing medium are preferable.
- The drainage system is similar to that of a continuous living wall (see above).
- Irrigation and fertilization can be either automatic or manual depending on the project scale. The installation of an automatic irrigation system follows similar requirements of the irrigation system of a continuous living wall (see above).

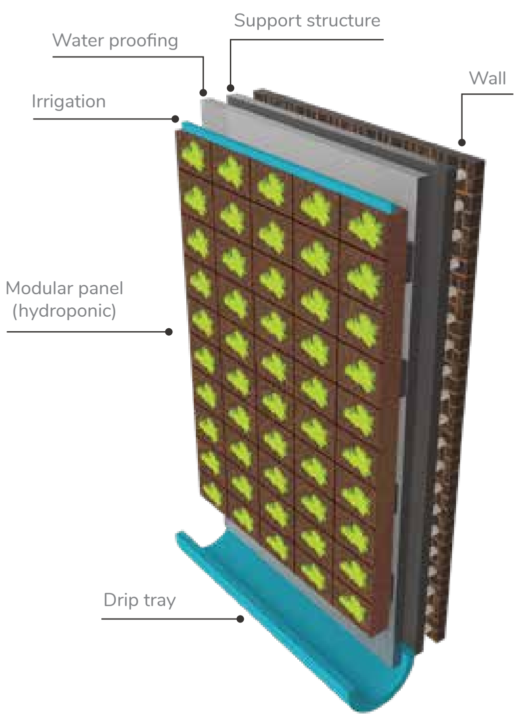


Figure 15: Substrate-based Modular Living wall
Source: © GIZ/VN-SIPA Project

TIPS:

For effective living walls in general, consider the following when choosing plants:

- Shade tolerant plants perform better in low light conditions indoors or for the lowest level of the living wall, while robust plants that are tolerant to direct sun and wind are suitable for highly exposed locations.
- The local ecology of the LWs: Different species should be placed to combine shading and weather protection effects (vigorous plants can protect more sensitive ones in high exposure spaces).
- More mature plants can be installed to provide immediate benefit.
- For visual effect, the support system should be black or green in color so as to visually recede into the background of the greenery.

  Outdoor lighting- either hardwired- or solar-powered can be installed for effect at night.

"So in case we use plants and trees, we always push to plant the trees directly into the real soil as they grow better in this environment and their maintenance is very easy. [...] Indeed, the real soil of the ground floor is full of nutrients, we don't have to add any chemicals and the plants grow really easily, especially in a tropical climate. Then you can bring them up with cables covered by organic material to make sure the plants are strongly fixed."

Mr. CHARLES GALLAVARDIN, Founder, Director T3 Architects

"We need to advise the investors on the tangible and intangible benefits. Let's say: if you install a green roof, it's not only protecting the building from the sun, it's not only reducing the cooling load for the air conditioning system, but it also creates a piece of landscape as a sky park where the end-users or the occupants can spend their time in. It also increase the biodiversity, reduce the CO_2 emissions, and stormwater flow into the environment.

When they see the benefits, they feel that they can attract customers. ... And we also need to advise them to promote PR-Marketing for their project's benefits."

Mr. QUANG DO, Construction Engineer, Expert of Green Buildings

"Our ancestors have taught that the most important factor for a healthy plant is irrigation, second is fertilizer, third is good maintenance, and forth is the plant seed. For green walls and green roofs, our experience shows that the most important factor is irrigation, second is light, third is temperature, then comes the humidity and ventilation."

Mr. BUI VAN TIEN, Agricuture engineer, Expert of green walls and green roofs

Source: freepik.com

4.3.2 INSTALLING GREEN ROOFS

As with green walls, the installation of green roofs needs to follow relevant technical and safety standards and administrative and quality management procedures under national and local regulations before and during the installation. Additional safety measures are indicated for working at elevation.

Green roofs require multiple functional layers for plant cultivation in hostile conditions (elevated temperatures, wind exposure and solar radiation). The following introduces the key components of a green roof. Technical procedures of installing a green roof will be presented in Section 5 using the case study of Quang Binh Project.

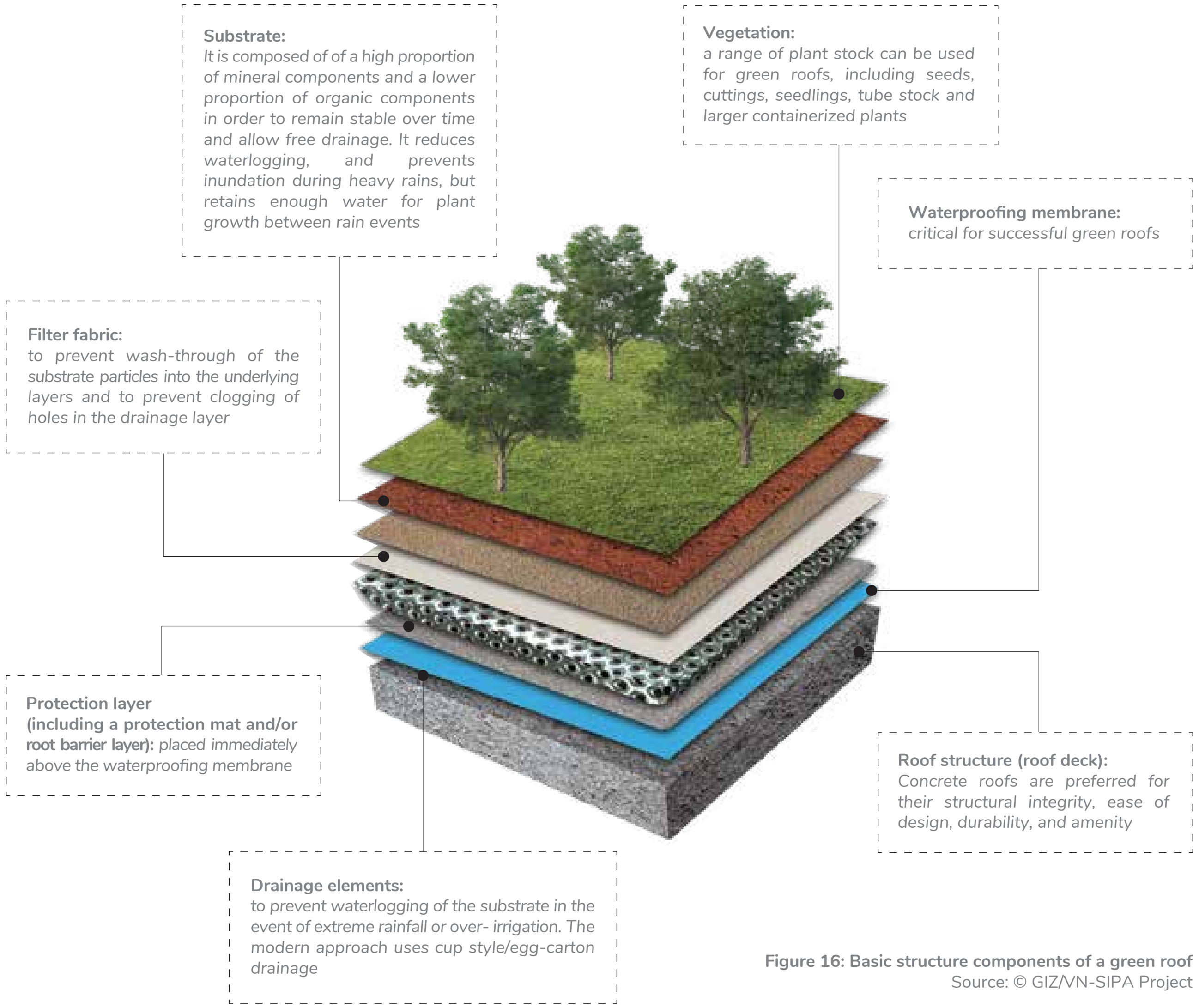


Figure 16: Basic structure components of a green roof
Source: © GIZ/VN-SIPA Project

Notes: See part 3.1.2 for specific characteristics of each layer for each type of green roof

IRRIGATION

The irrigation system for green roofs follow common principles of irrigation for green walls and will be presented in the following section.

4.3.3 INSTALLING IRRIGATION FOR GREEN WALLS AND GREEN ROOFS

Irrigation for green walls and green roofs is critical and follows similar principles. In general, there are two systems, recirculating and direct irrigation.

The recirculating system follows the water sensitive urban design (WSUD) approach (see section 4.2) and has following features:

- Stormwater and wastewater are collected and stored in an underground reservoir (storage tank), and are filtered to reduce substrate and nutrient accumulation, before being pumped upward to irrigate the plants.
- Water is collected through drainage pipes that connect to the drip trays of green walls or the drainage layer of green roofs. Fascia treatments should be installed to conceal the edges and functional elements of irrigation and drainage systems.
- Plants selected for circulation irrigation must tolerate elevated salt levels and variable pH values which are unavoidable effects of the water recycling process.
- The irrigation and drainage systems need regular checkups to ensure correct functioning and avoid blockages.

The general principle of a recirculation irrigation system is reflected in following figure

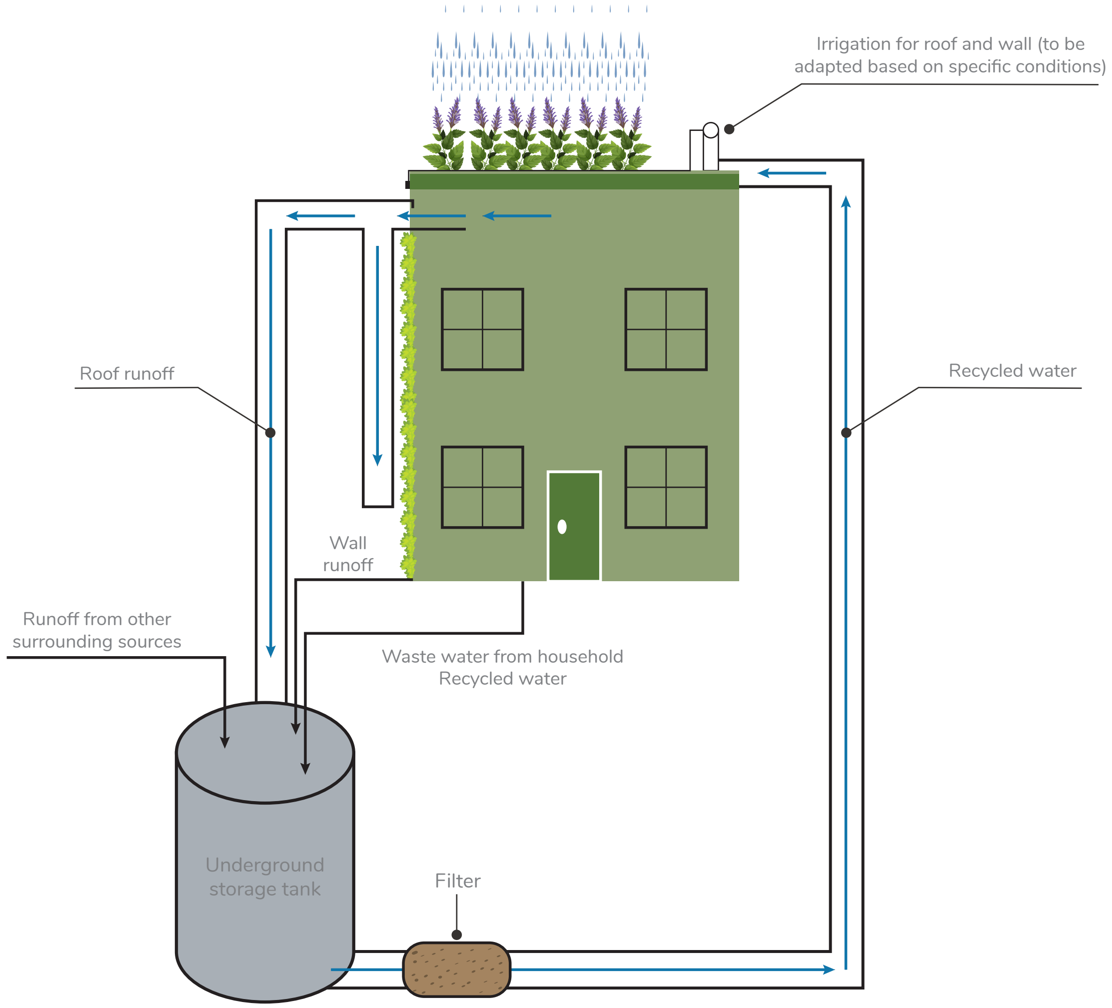


Figure 17: Circular irrigation system for green walls and green roofs
Source: Adapted from Laminack (2014, p.21)

The direct system takes water directly from supply sources. Both systems require pumps and normally include a fertilizer injection. For more effective and efficient irrigation, the systems should be operated automatically by a moisture sensor. Irrigation can be manual for indoor small-scaled or balcony-based living walls.

Source: freepik.com

TIPS:

- Water requirement can be minimized by selecting species that are low water users. This does not apply when the living wall is designed to retain stormwater.
- Longer irrigation periodicity and higher pump pressures are needed for greater elevations because plants at elevation are prone to higher evaporative drying caused by stronger winds and sun. The irrigation pumping system is designed according to the building structure
- Because irrigation becomes easier to achieve toward the lower levels of the wall, species should be selected and positioned on the wall according to their water requirement gradients.

4.4 MAINTAINING GREEN WALLS AND GREEN ROOFS

Maintenance mainly includes pruning, weed control, removal of leaf litter, irrigation and fertilization to ensure vigorous growth, and treatment or replacement of hard landscape structures.

Maintenance schedules serve different purposes: Establishment maintenance takes place one or two years after installation in order to fully realize the design intent. Routine maintenance ensures standard appearance, functionality and safety. Periodic infrastructure maintenance ensures structural integrity of the supporting wall or roof. Reactive or preventative maintenance addresses damage caused by extreme weather events, whilst renovation maintenance enables design changes or reconfiguration.

The maintenance requirement depends on each type of green wall or green roof. Green façade require the least intensive maintenance mainly to prune, trim or train climbers (on a yearly basis for leaves and after five to seven years for stems) and to fertilise once or twice a year. Living walls and intensive green roofs require more frequent maintenance in order to to check the structural integrity, the growing media quality and nutrient supply, irrigation and drainage blockages and plant health.

Irrigation is critical to plant health. The irrigation frequency should be commensurate with the vegetation water-holding capacity and drainage system. More irrigation is needed after planting and during the establishment phase (2-3 times a week) or during high activity phases of the growth cycle (flowering and fruiting). Watering in high daytime temperatures is not recommended due to heat energy transfer from the water to the roof after it drains through the heated growing media. Surface and sub-surface irrigation should not wet the foliage because of fungal disease risks. Spray irrigation for green roofs should be carried out early in the morning to enable foliage to dry off throughout the day, thereby reducing disease risk.

Fire prevention

Green walls and green roofs that receive regular irrigation and maintenance do not pose a fire hazard. To prevent fire risk, dry vegetation and leaves should be removed regularly. Designing breaks in vegetation or using plants of low biomass (for areas with high sun light) will further reduce fire risk.

IMPORTANT:

- Accessibility to green walls and green roofs is critical for maintenance. This factor should be considered early when site assessment is conducted to decide if regular maintenance will be possible after the project installation.

- Access for regular maintenance can be through the building's existing structure (i.e., stairs, windows) or with the support of equipment (ladders, 'cherry-pickers', etc.). If equipment is needed for maintenance work, local availability and hiring fees of such equipment should be factored into the maintenance costs at the planning stage.

4.5 THE COST OF IMPLEMENTING GREEN WALLS AND GREEN ROOFS

Costs for green walls and green roofs are calculated based on life-cycle analysis (from 25 to 50 years, depending on the type of building). These include the cost of installation, operation, maintenance and disposal (Manso et al., 2021). The cost of designing, installing and maintaining green walls and green roofs are usually higher than for most conventional cladding systems (Radić et al. 2019).

The installation cost must include site assessment, design, installation direct costs (component materials, labor, equipment and transportation), as well as indirect costs (e.g. housing for workers and contingencies).

Maintenance costs must cover repair and replacement of degraded or damaged system components (i.e., supporting structure, irrigation pipes), plant pruning and replacement of dead plants (attrition rates of 10% in the first year and 3% each subsequent year). Maintenance costs are likely to be higher in the first years of plant establishment when more irrigation and re-planting are needed. A waterproof membrane (if installed) normally lasts about 10 years.

End of project lifespan disposal costs cover the removal of plant materials and detritus, substrate and supporting systems, transport to landfill and dumping fees.

Source: elements.envato.com

FACTORS INFLUENCING COSTS INCLUDE:

- The specific type of installation
- Climate conditions: A rainy climate might reduce the costs for irrigation while dry climate might increase irrigation costs. These fluctuations can also be seasonal, as in the case of tropical savannah.
- Plant selection: Mature plants with full foliage are more costly, indigenous plant species significantly reduce maintenance needs and associated costs.
- Component materials
- The height and surface area of an installation: Higher green walls are more expensive, projects of greater area might reduce the unit cost at installation (Radić et al. 2019).

Globally, there is high cost variability between countries. The global average costs are presented in the following tables.

Table 5: Examples of green wall installation costs

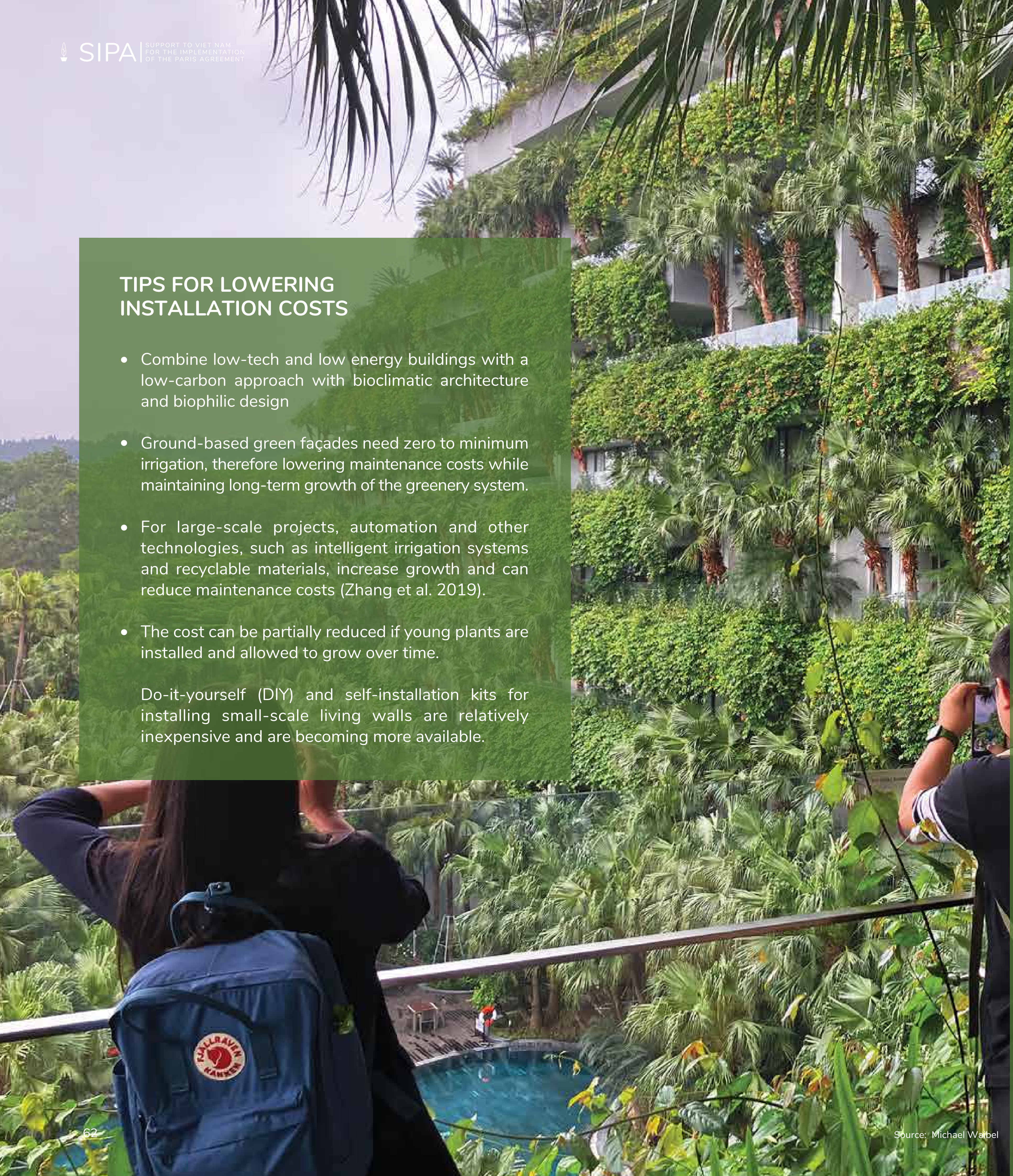
Items	Direct green façade	In-direct green façade	Continuous living walls	Modular living walls
Level of costs	$	$$	$$	$$$
Characteristics	Lower environmental burden, material investment and maintenance requirement		More complex design with nutrients and watering system materials	
Global average installation costs	Average 215 USD/m²		848 USD/m²	
Global average maintenance costs	6.3 USD/m²/year		21.5 USD/m²/ year	
Global average disposal costs	107 USD/m²		270 USD/ m²	

Source: Perini et al., 2011; William et al., 2016; Cruz et al., 2018, Manso et al., 2021

Table 6: Examples of green roof installation costs

Items	Extensive Green Roof	Semi-Extensive	Intensive
Level of costs	$	$$	$$$
Complexity	Lowest	Medium	Highest
Average global installation cost	112 USD/ m²	147 USD/ m²	409 USD/ m²
Average global maintenance cost	4.8 USD/ m² /year	8.8 USD/ m² / year	6.4 USD/m²/year
Average global disposal costs	14 USD/ m²	14.3 USD/ m² (depending on the scope)	29 USD/m²

Source: Perini et al., 2011; William et al., 2016; Cruz et al., 2018, Manso et al., 2021



TIPS FOR LOWERING INSTALLATION COSTS

- Combine low-tech and low energy buildings with a low-carbon approach with bioclimatic architecture and biophilic design
- Ground-based green façades need zero to minimum irrigation, therefore lowering maintenance costs while maintaining long-term growth of the greenery system.
- For large-scale projects, automation and other technologies, such as intelligent irrigation systems and recyclable materials, increase growth and can reduce maintenance costs (Zhang et al. 2019).
- The cost can be partially reduced if young plants are installed and allowed to grow over time.

  Do-it-yourself (DIY) and self-installation kits for installing small-scale living walls are relatively inexpensive and are becoming more available.

Source: Michael Waibel

INCENTIVES

Implementing green walls and green roofs require additional installation and maintenance costs when compared to conventional solutions (Manso et al., 2021). However, given their multiple environmental, economic, and social benefits, they are steadily attracting more interest in both the public and private sectors.

Cost-benefit analyses of green walls and green roofs show they are cost effective in the long-term and on a collective scale (neighbourhood/city) (Rosasco & Perini, 2018; Manso et al., 2021). Globally, governments are reinforcing building codes, drafting construction regulations and permits, adding green building certification and providing more agile administrative processes. They are also providing economic incentives in the form of tax reductions and financial subsidies to those wanting to implement such green projects (Besir and Cuce 2018; Liberalesso et al. 2020). Among 143 studied incentives in 113 cities worldwide, financial subsidies (the government covers a certain percentage of the cost value) and obligations by law are most common (Liberalesso et al. 2020). Most incentives are concentrated in Europe and North America. In Europe financial subsidies account for 85%. In Asia, this figure is 37% and obligations by law also account for 37% (Liberalesso et al., 2020).

For private developers, on the one hand, benefiting from government subsidies and tax breaks are important incentives, especially in places where these practices are still in an early development stage (Radić et al. 2019). On the other hand, the proven economic value of green walls and green roofs should be considered to regain investment costs. The most appealing benefit of these projects is the reduction in energy costs for heating and cooling a building. Savings can reach 84% in heating seasons and 48% in cooling seasons. green walls and green roofs also increase a building's market value by an average of 8% (Manso et al., 2020). Specifically, rental prices are reported to increase by 16.2% (Ichihara & Cohen, 2011), and the property sale value increases by 2% to 5% (Perini & Rosasco, 2013). Other economic benefits include the protection of building envelopes against the effects of extreme weather, thereby extending the life of the building. Specific benefits of green walls and green roofs with empirical statistics are presented in more detail in section 3.2 of this document.

05

Case study: Implementing
GREEN WALLS AND GREEN ROOFS IN DONG HOI CITY, QUANG BINH PROVINCE

Under the auspices of VN-SIPA, promoting in Quang Binh Province the first green walls and green roofs project was implemented at the Public Service Management Unit building in Dong Hoi city. The project was designed and approved for implementation in 2021, with a total green wall area of 544.96m² and green roof area of 362m². The building is a three-storey modern design with a height of 13.6m. It is located on a large campus and flanked by roads on two sides. This chapter describes in detail the project goals and implementation procedures. The figure below provides an outline[6].

[6] Information presented is based on the project's technical documents.

1 – Project planning
- Brainstorming, discussion and agreement
- Consultant selection
- Site assessment
- Goal setting
- Stakeholder engagement

2 – Project design and approval
- Design and technical document development
- Design auditing
- Approval of the Project Design and other related technical documents

3 – Project construction/ Installation
- Green walls
- Green roof
- Stormwater storage tank and irrigation system

Project monitoring

4 – Project completion and handover
- Construction work quality check and acceptance
- Work operation guideline transfer
- Maintenance responsibility clarification

5 – Project upscaling
- Case study and implementation, guideline development
- Lessons learnt and sharing experience
- Knowledge dissemination

Figure 18: The process of implementing green walls and green roofs in Dong Hoi
Source: Self-developed by authors

An overview of Dong Hoi city landscape
Source: © Nguyen Duc Ngoc Linh

5.1 PLANNING THE GREEN WALLS AND GREEN ROOFS

Following agreement with the Dong Hoi City People's Committee and Dong Hoi City Public Service Management Unit (the beneficiary unit), the project was planned in collaboration with local consultants and experts and the beneficiary unit. Experienced experts in the field were consulted to provide insights into suitable technologies for the local context. The project planning also included site assessment, goal setting and considerations for stakeholder engagement.

5.1.1 SITE ASSESSMENT

To plan the project, site assessment was conducted. Specific climatic and geographical conditions were identified as below:

- High heat in summer
- Southwest monsoons (from Laos to Central Vietnam) negatively impacting vegetation
- Stormy season with wind gusts posing a threat to structural viability of the construction site
- Greenhouse effect in the urban core zone having negative effects on plants
- Atmospheric salinity due to the proximity of the sea- suitable trees should be selected
- Atmospheric salinity causing rapid degradation of the steel structure system
- Ground at the project is saturated with water due to the proximity of the river and its minimal elevation above mean river water level
- The physical building features the following characteristics
- The building walls were built 150mm thick from six-hole tunnel brick, are permeable and have limited sound and heat insulation capacity
- The main façade of the building and one side adjacent to a road receives direct sunlight due to a large area of glass doors and windows, making it hot in summer
- The walls are large making it easy to shape a greenery design
- The maintenance work will not be difficult given the low building elevation

Trees planted at the rooftop garden of the pilot in Dong Hoi city
Source: © Luong Thanh Trung/ GIZ

Figure 19: The original front façade of Dong Hoi Management Unit of Public Services
Source: © Luong Thanh Trung/ GIZ

Figure 20: The original roof of Dong Hoi Management Unit of Public Services
Source: © Luong Thanh Trung/ GIZ

5.1.2 GOAL SETTING

The green wall-green roof measure of Dong Hoi follows the VN-SIPA project overall aim of supporting ecosystem-based solutions for climate change adaptation in the urban areas. Accordingly, the project focuses on climate change adaptation goals. These include improving the building's thermal performance against extreme heat in summer, mitigation of the effects of high winds and improving rainwater retention capacity. In addition, the initiative also aims to improve the natural habitat and create a living space in which to foster creative thinking and quality work.

To serve these goals, hydroponic modular living walls covering the whole building's front and sides and a rooftop garden (semi-intensive green roof) will be installed (see figure below). The greenery system is supported by a solid steel frame. The selected technologies allow for quick estabilshment and receipt of beneficial impacts of the greenery systems, in line with the stated goals.

Figure 21: The front elevation of the green wall and green roof
Source: © Luong Thanh Trung/ GIZ

Figure 22: The left side elevation of the green wall and green roof
Source: © Luong Thanh Trung/ GIZ

5.1.3 STAKEHOLDER ENGAGEMENT

The green wall-green roof project in Dong Hoi was implemented with the engagement of key stakeholders, including GIZ, the project recipient unit (Dong Hoi City's Public Service Management Unit), local authorities (Quang Binh Province Department of Construction, Dong Hoi city People's Committee, Department of Natural Resources and Environment, and the Department of Urban Management), and consultants/contractors (architects, engineers, landscape designers, horticulture experts, etc.). The following figure summarizes key functions and activities carried out by each stakeholder.

THE GREEN WALL-GREEN ROOF PROJECT IN DONG HOI CITY

IMPLEMENTER

- Allocate funding
- Manage the project and organize bidding procedures
- Collaborate with the beneficiary unit and local authorities
- Select consultants

PROJECT RECIPIENT UNIT (Dong Hoi City's Public Service Management Unit)

- Receive project support
- Collaborate with the donor to manage the project
- Provide information for site assessment
- Provide inputs and be involved in the process of planning, design, monitoring implementation
- Receive training and guidance for operation and maintenance
- Receive hand-over and take responsibility for maintaining the work

LOCAL AUTHORITIES

- **Dong Hoi City People's Committee:** Approve the project concept
- **Dong Hoi City Department of Urban management:** Collaborate to provide information for site assessment and project design, monitor the project implementation
- **Quang Binh Province Department of Construction:** Approve the Project Design and issue the project implementation permit

CONSULTANTS/CONTRACTORS

(architects, engineers, landscape designers, horticulture experts, etc.)

- **Design consultants:** Conduct site assessment, develop project design and supporting technical documents
- **Design auditing agency:** Appraise the project design and technical documents
- **Construction/Installation contractor:** Construct the project components
- **Monitoring consultant(s):** Monitor the project implementation

Figure 23: The stakeholder mapping of the measure in Dong Hoi city
Source: Summarized by authors

5.2 DESIGNING THE GREEN WALLS AND GREEN ROOFS

The initiative was then designed according to the site assessment and set goals.

Specifically, the wall vegetation was designed to

- Cover the entire wall of the main façade and a portion of the glass panels (total of at least 95%)
- Divide the green patches into layers according to building blocks
- Reduce weather effects by choosing plants with bright colours
- Follow the principles of plant selection (see above)
- Match colours between plants
- Combine small and large-leaved plants, weeping and upright habits, dark and light colours, etc. to make the green walls durable and visually appealing

The green wall vegetation cover is illustrated in the following pictures

Figure 24: The green wall vegetation cover of the measure
Source: © Luong Thanh Trung, Trinh Ngoc Quynh/ GIZ

Source: freepik.com

The green roof structure was designed to:

- Include a truss for climbing plants in order to enhance the roof's thermal performance and minimize the impact in adverse weather conditions.
- Use a light-weight structural frame with plant load bearing capacity and light growing medium (specified weight of the project: 1.5 tons/m³).
- Avoid water clogging and washout of growing medium onto the roof yard.

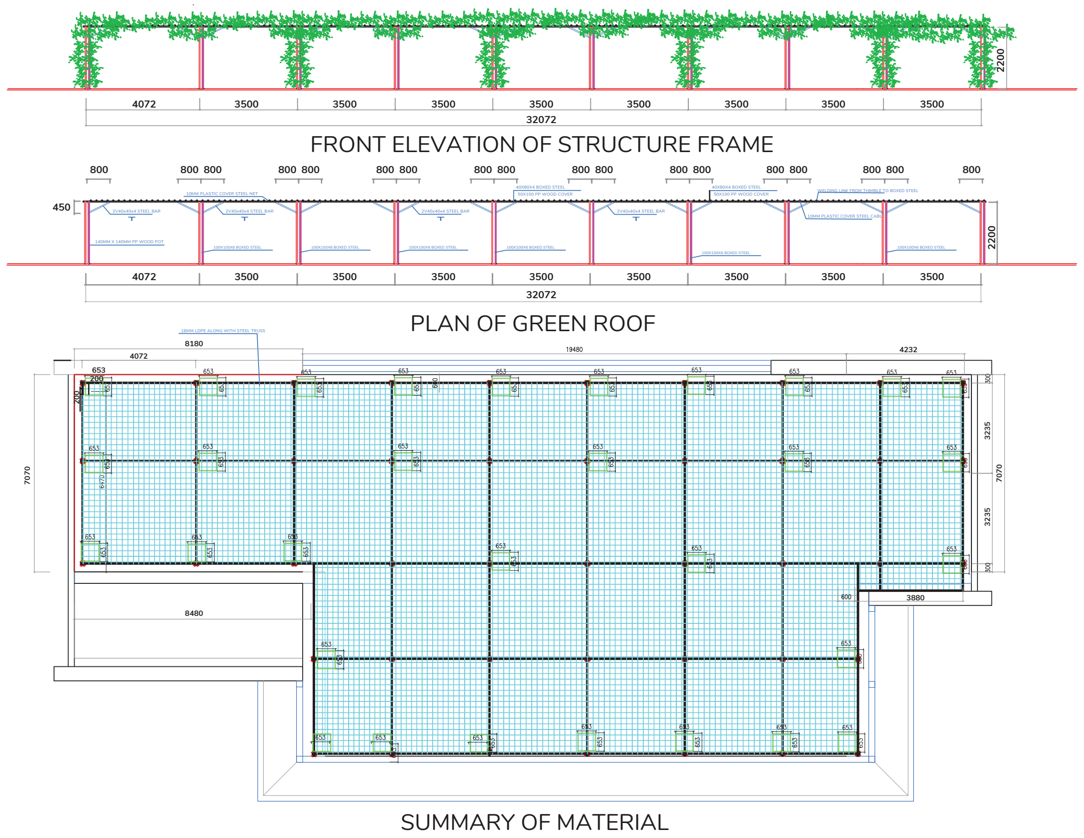


Figure 25: The front elevation of the measure's green roof
Source: © GIZ/VN-SIPA Project

Plant selection

Plants were selected to ensure sustainable growth and low maintenance requirements. For this, all the plants used for the walls and roof of the project are indigenous, locally grown or available in the city's plant nurseries. Below is the list of plants selected for the project.


Paperflower


Moss Rose


Manaca Rain-Tree


Vinca


Blue Daze


Duranca Ecercta


Tradescantia Spathacea


Schefflera Octophylla


Aglaonema Muntifolium


Spider Plant


Fern


Zinnia


Asparagus Cochinchinensis


Spotted Pothos


Yellow Iceton Croton


Petra Croton

Figure 26: The plants used for the measure in Dong Hoi
Source: © GIZ/VN-SIPA Project

Source: pxhere.com

The green wall support system

The wall support structure is 544.96m² in area to cover the whole front façade and two lateral sides of the building. The support system was caculated to bear vegetation and media estimated to be 27.54 tons (50kg/m²) and to cope with wind gusts (equivalent to level 8 at 20m/s). The wind load was calculated based on factors like wind level, region, topography, standard wind pressure, building height from basement, basement depth, building size, number of floors.

As a result, the support system has the following characteristics:

- A welded frame of 20x20x2 stainless steel tubes (CT34 steel with a strength of 2,200kg/cm² or equivalent), coated with anti-rust paint according to TCVN 8790:2011
- The truss frame is linked to the wall or beam by steel plate PL50x100x12 and anchor bolts M12 (grade mark 6.6) with epoxy adhesive (Ramset) (see below diagram)
- The weight of the steel frame is distributed across 17 façade columns
- The total weight of the steel frame and planters will be transmitted to the wall and beam columns by plates and bolt systems

The drawing of the support system is illustrated in the pictures below.

Figure 27: The steel support system and modules of the green wall were being installed
Source: © Luong Thanh Trung/ GIZ

The drainage system

The wall drainage was designed as a stainless-steel trough installed at the base of the wall to collect excess water (see below). The collected water is then piped to the collection tank (as described in the next section). The roof drainage system is designed with cup-style, 'egg carton' drainage to allow unrestricted water drainage and water storage for later irrigation.

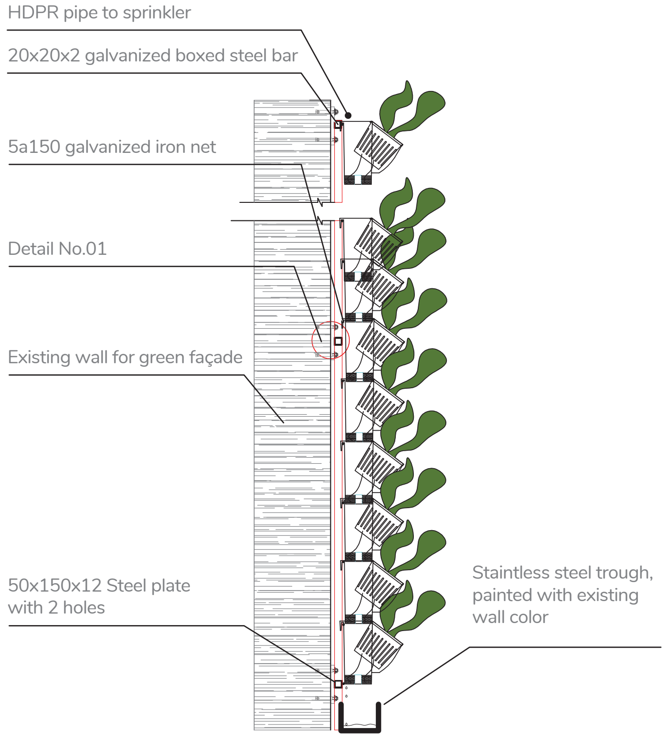


Figure 28: The wall system with stainless drainage drip tray at the bottom drainage layer
Source: © GIZ/VN-SIPA Project

Figure 29: The plastic cup-style drainage layer of the measure's green roof
Source: © GIZ/VN-SIPA Project

Source: elements.envato.com

Irrigation system

Following the EBA and WSUD solutions, an automatic circulation irrigation system was designed with an underground tank to collect and recycle stormwater and overflow from the green system. The rainwater storage tank is designed with:

High storage capacity:

- The tank capacity (50m³) is defined based on calculating the average of 12 months' rainfall and daily sunlight hours in Dong Hoi area, the water collected from the building area of 1500m², and the irrigation need for the greenery system.
- The tank is divided into 5 compartments including 3 filter compartments and 2 settling compartments.
- Three filter compartments are constructed with specialized mat water filters, size 100x100x4cm.

Good location:

- The location should have no underground infrastructure
- Accessibility for maintenance and to the building's technical axis, easy collection of different water sources and low impact to the surrounding during maintenance) should be ensured.

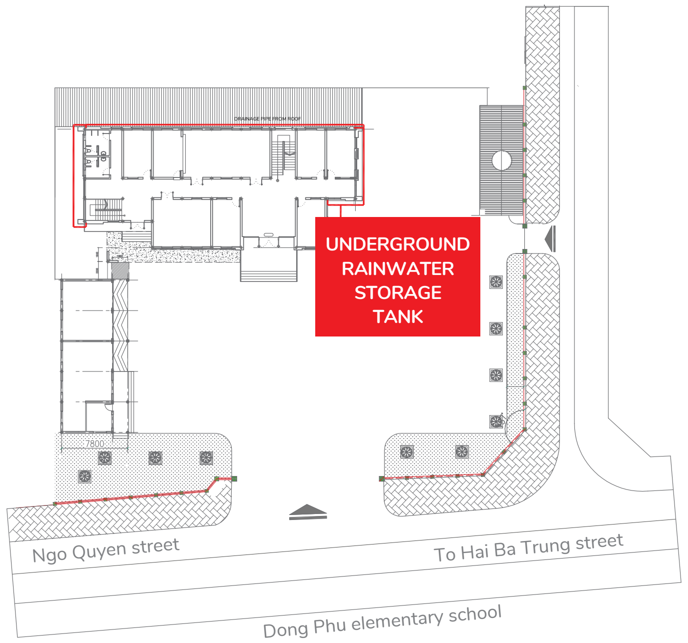


Figure 30: The location of the rainwater storage tank (highlighted)
Source: © GIZ/VN-SIPA Project

Good filter technology and materials to prevent dust particles, dirt from clogging the irrigation dripping heads.

In general, the irrigation system has following characteristics:

- Rainwater on the roof and concrete yard is collected to the tank.
- Water from the tank is then circulated to the greenery system through an automatic control device. Water is supplied to the top modules through pressure compensating water dividers and pass through the overflow pipe to the lower module
- Two systems operate in parallel to ensure smooth irrigation in case one system is out of order (see figure 31)
- Wick fibres absorb water to the plant containers and can sustain for 10 days without irrigation. When the reserve water runs out, the storage compartments will be refilled by the automatic control device (see figure 32)
- The roof irrigation system is connected to the wall irrigation through HDPE pipes attached to the flower truss structure frame and controlled by an independent solenoid valve for water transmission.

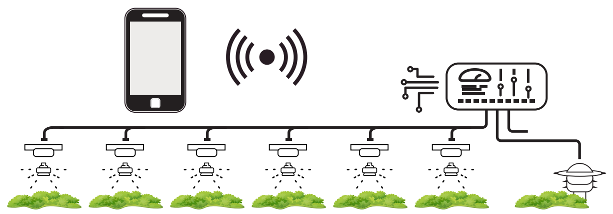


Figure 31: The measure's automatic irrigation control device
Source: © GIZ/VN-SIPA Project

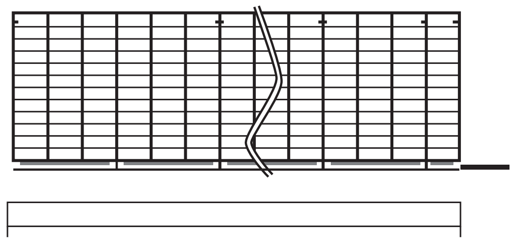


Figure 32: The wick fibres absorbing water from the storage compartment for plant growth
Source: © GIZ/VN-SIPA Project

In general, the irrigation system was designed to ensure:

- Irrigation efficiency of at least 95% with a minimum irrigation cycle of 48 hours
- Adequate water is reserved for plants for 5 days to 10 days under adverse conditions
- A pump is fitted with sufficient head (pressure) to provide water at higher elevations of the wall and roof
- Efficient operation of pipes and sprinklers which are connected to the building's technical system and have easy access for inspection and repair with a minimum maintenance cycle of six months

Figure 33: The irrigation system design of the green walls
Source: © GIZ/VN-SIPA Project

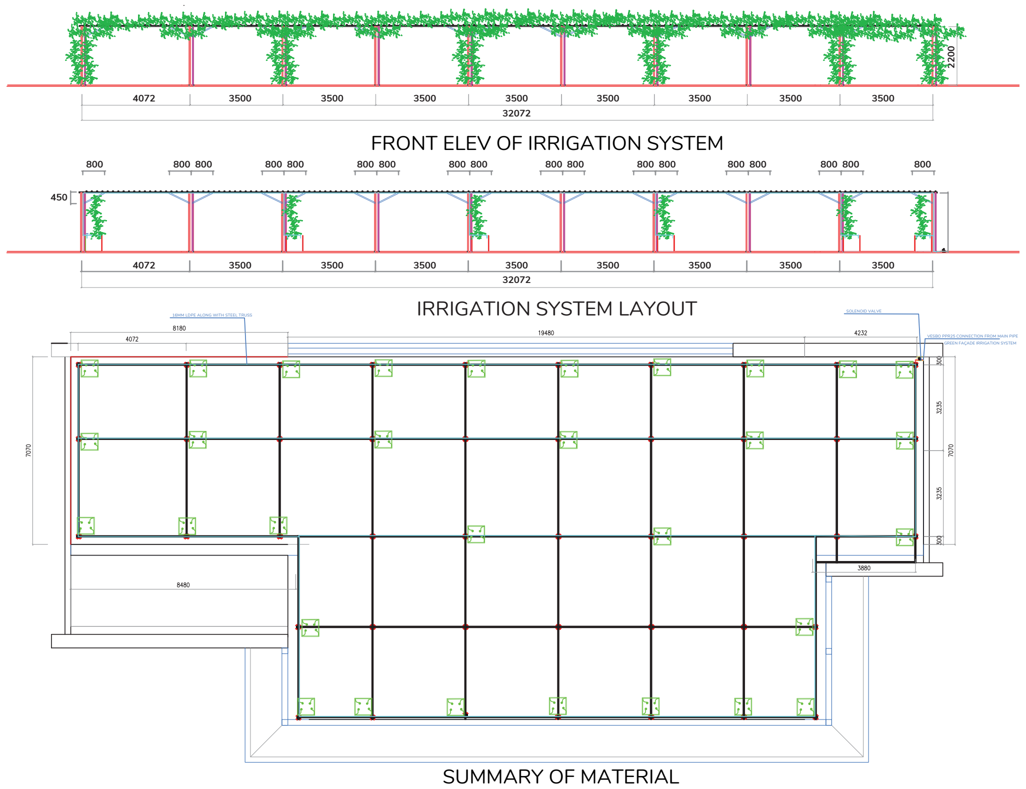


Figure 34: The irrigation system design of the green roof
Source: © GIZ/VN-SIPA Project

5.3 INSTALLING THE GREEN WALLS AND GREEN ROOFS

Installation of the greenery system takes place after completion of the approval and contractor selection procedures. The work starts with preparation (plant selection and gathering construction tools, equipment and materials on site).

The installation of the wall and roof sections takes place in parallel but follows specific technical steps.

To install the green walls, following steps were taken

- Install the structural frame and specialized steel mesh on the building bearing beam system
- Affix the plant modules to the wire mesh frame, set the system into the wire mesh, use the hooks to attach the module from bottom to top, from right to left. (See the diagram for further explanation of the hooks)
- Install the safety wire mesh on the outside of the module
- Install an automatic water supply system with excess water to be piped to the storage tank
- Install the prepared planter basket, set safety latches for each basket
- Check the trial operation, instruct the local operator on how to monitor and detect and rectify abnormal function

To install the green roof, following steps are taken:

- Chisel and remove existing wall ledges, pick up and remove waste, and clean up dust
- Clean the roof surface, make the cracks waterproof by applying a me brane and apply 2-layer waterproofing method on the whole roof surface
- Create water collection points
- Apply a waterproof protection layer on the neck of the water collector
- Apply a waterproof protection layer with mortar mark 75, and create slopes to collect water at the points where the excess water collection pipes are attached
- Construct trusses
- Install chemical bolts by glue method, attach ciphertext plates, weld bearing columns to ciphertexts, installing truss - beams and install decrative wooden boxes, weld and connect cable reinforcement rings and arrange cables plastic wrap in checkered shape with size 200 x 200mm (details in drawing)
- Establish plant pots (details in the drawing)
- Arrange the plant pots in the right position
- Create the drainage layer at the bottom of planters/containers/pots
- Pour growing media into planters/containers/pots
- Install automatic watering system (connect to water source from resevoir via the pump and automatic controller, install water pipes to planters, install drip irrigation equipment in planters)
- Fully test the operation of the system
- Diagnose and rectify any malfunction
- Handover together with the operating manual

Construction of the water storage tank

The water storage tank is constructed underground adjacent to the building foundations.

The tank is 2.1m deep. Given the proximity of the river, the tank wall needs to be 200mm thick, and fabricated from high-grade concrete to withstand flooding.

The construction must adhere to local regulatory standards and be strictly supervised to ensure the technical quality and design requirements.

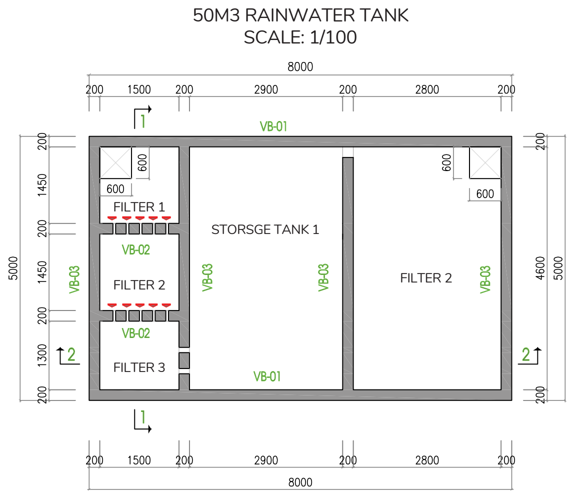


Figure: 35: The rainwater storage tank design
Source: © GIZ/VN-SIPA Project

5.4 HANDING OVER AND MAINTAINING THE GREEN WALLS AND GREEN ROOFS

Maintenance is critical to ensure the success and sustainability of the green walls and green roofs. For the project in Dong Hoi city, the installation contractor is responsible for maintaining the plant system for six months during the warranty period. After six months, maintenance responsibilities will be handed over to the local management unit, namely Dong Hoi City's Public Service Management Unit.

The project maintenance after the warranty period will be self-funded by the project recipient (Dong Hoi City's Public Service Management Unit). The work is sub-contracted out to a local maintenance service provider.

The contractor commits to help the investor to select a capable local maintenance service provider who will be trained and guided by the contractor during the warranty period.

The following table illustrates maintenance schedule anticipated for the project after installation.

Table 7: The project maintenance schedule

NO.	TASKS	FREQUENCY
1	Monitor to ensure the system's smooth operation (power supply, irrigation, plants, etc.)	Daily
2	Conduct pest and disease monitoring	Weekly
3	Add fertilizer	Every two weeks
4	Prune the yellow leaves	Every two months
5	Clean the filter	Monthly
6	Clean the water sump/manholes	Every two months
7	Clean filter compartment No. 1	Every 3 months
8	Clean filter compartment No. 2	Every 6 months
9	Clean filter compartment No. 3	Annually
10	Replace dead plants	If needed

Source: © GIZ/VN-SIPA Project

5.5 COSTS FOR IMPLEMENTING THE GREEN WALLS AND GREEN ROOFS

In Vietnam, the installation costs depend on the project scope and the type of packages (with or without plant supply and maintenance contracts). Installation costs normally include site assessment, consultation fees, system design and construction/installation costs. The total cost will include other related expenses for equipment and contingency costs. The final figure will be subject to a 10% value added tax. Web-searched data shows that the average cost in Vietnamese market range from \$110 to \$135/m² for a continuous green wall with felt mat, andf rom \$80/m² to 160/m² for modular green walls with planter boxes.

The following table illustrates the actual pre-VAT costs of the Dong Hoi city greening project.

Table 8: Total pre-value added tax (VAT) cost for green walls (544.96 m²) and green roofs (362m²)

No.	Cost item	Description	Pre-VAT Cost in VND	Pre-VTA Cost in USD (rounded, VCB exchange rate as of March 10th, 2022)
1		Green walls	1,995,809,063	87,360
2	Construction Works	Green roofs	1,073,031,817	46,968
3		Water storage tank	311,463,594	13,633
4	Equipment	In Equipment Sheet	175,515,600	7,682
5	Contingency cost	5%*(Construction Work Cost)	177,791,004	7,782
6	TOTAL pre VAT		**3,733,611,078**	**163,425**

(Source: © GIZ/VN-SIPA Project)

The maintenance cost of the project is calculated from the expiration of the warranty period, including costs for monthly maintenance and yearly pruning and dead plant replacement (estimated at 5% to 7% of the total plant number). Monthly costs cover labor for site monitoring/supervision, technical checkups and cleaning (irrigation, nutrient supply, filtering, etc.), fertilizer, power supply, anti-mosquito chemicals (for the rainy season). Yearly costs cover the rental of a cherry-picker for maintenance work at elevation, wages and new plant purchases. The overall maintenance costs are estimated to be 30,980,000 VND/year (1,360 USD/year) if all the labor for monthly maintenance and yearly renovation is provided by in-house technicians. If the same maintenance is outsourced, the total cost is calculated to be about 76,408,000 VND/year (3,340 USD/year).

06

Implications for Upscaling

GREEN WALLS AND GREEN ROOFS IN VIETNAM

As reported here, green walls and green roofs have been implemented in Vietnam since the early 2010s. Those projects have, however, mainly taken place in large cities like Hanoi, HCMC and Danang as high-end market investments. In response to the increasing impacts of climate change and rapid urbanization, especially of medium-sized coastal cities, green walls and green roofs promise an effective nature-based solution to improve the resilience of growing built environments in these areas.

The following lists the opportunities, challenges and recommendations for promoting green walls and green roofs in Vietnam. Insights are based on interviews with relevant experts and a review of the relevant literature.

Source: © Michael Waibel

Opportunities

- Greening the living space has been rooted in people's habits and applied in traditional architecture (for example, planting palm trees at the front of the house to provide shading and enable natural ventilation in summer and in the case of Northern Vietnam, banana trees at the rear to block cold north-easterly wind in winter)
- The national government has a commitment to global climate change action and sustainable development initiatives, particularly for the building sector
- There is an emerging green building movement, replete with various certification schemes, consultancy services and financing mechanisms
- Market demand is increasing for green wall and green roof technologies and options of differing scales, including low and medium-rise residential, industrial, commercial, office buildings
- Availability of foreign technical assistance and increasing awareness amongst urban managers, investors and the general public

Challenges

- Lack of uniform governance structures (regulations, standards, etc.) and public policy incentives at both national and local levels
- High cost of installation and maintenance with a long pay-back term
- Lack of financial capacity and bankable funding schemes
- Lack of public awareness and requisite professional skills (especially related to horticulture and soil science)
- Complicated technical issues of the green wall-green roof systems (i.e. moisture risks to the walls and roofs, plant diseases, insects, etc.)
- Lack of a comprehensive database of technologies, products, and local manufacturers

Recommendations in the case of Vietnam

To effectively implement green walls and roofs in Vietnam, the following recommendations should be considered:

Promote public policies (i.e., legal obligations, taxation incentives, financing support, etc.,) and appropriate strategies at national and local level.

Promote technical knowledge and practice trainings, develop a database of technologies, products and service providers for each geographical and climate region, tailor green wall and green roof project design, especially the irrigation system, for each site, given the diverse climatic conditions in Vietnamese cities.

Enhance collaboration between science, the policy level and practice to promote knowledge transfer and implementation, incorporate green infrastructure in public buildings and/or in other public services to set consistent examples ("leading by example") and to motivate private investors.

Develop a comprehensive communication strategy to raise public awareness in order to increase public participation and engagement, report standardized metrics for cost-benefit analyses of green walls and green roofs to promote upscaling, establish an internet inventory of such greening projects at the municipal level where inhabitants can register their own green walls and green roofs.

Enhance multi-stakeholder collaboration to promote cross-cutting research, incorporate green walls and green roofs in public buildings, setting best practices ("leading by example") and motivating private investors, acknowledge and encourage pioneering private sector projects and initiatives of private citizens.

The recommendations are summarized in the following figure.

UPSCALING GREEN WALLS AND GREEN ROOFS IN VIETNAMESE CITIES

Public policy promotion, for example through

- Legal obligations
- Taxation incentives
- Financing support
- National/local strategies and action plans
- Awards
- Organisation of public excursions / events in the context of green wall and roof projects

Technical knowledge and capacity building, for example through

- Database of technologies, products, experts and service providers for each region
- Development of GIS-based urban climate maps with specific guidelines for planting and irrigation techniques
- Internet inventory of green wall and green roof projects on a municipal level

A good communication strategy is required to raise public awareness, for example through

- Documented cost-benefit analysis with measurable standardized benefits
- Implementation guideline development
- Lessons learnt and experience shared
- Dissemination of knowledge, including use of social media

Enhance multi-stakeholder collaboration, for example through

- Cross-cutting research on the topic
- Promoting green walls and green roofs in public buildings to set good practices and to motivate private investors
- Acknowledging pioneering private projects
- Encouraging initiatives of urban citizens

Successful implementation of green walls and green roofs depends on effective multilevel urban governance: Coordination among horizontal sectors and vertical governmental levels, public-private partnerships, international cooperation, engagement with specialists and service providers, construction developers, building owners and end-users, etc.

Figure 36: Recommendations to upscale green walls and green roofs in Vietnamese cities
Source: Own design from various sources.

After all, it is important to point out that everyone can make a difference. There is no need to wait for the state or investors to erect green walls and green roofs because everyone has a chance to plant vegetation around their house. This will significantly contribute to greener and healthier urban environments and improve the urban quality of life. In addition, to achieve mass effects in terms of sustainability, low-tech and low-energy buildings with a low-carbon approach should be augmented by bioclimatic architecture and biophilic design.

Source: freepik.com

The completed green walls and green roofs at the Public Service Management Unit building in Dong Hoi city
Source: © Luong Thanh Trung/ GIZ

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- Mr. Charles Gallavardin, CEO of T3 Architects, Ho Chi Minh City, Vietnam, Interview on 28 February 2022
- Mr. Do Huu Nhat Quang, GREENVIET, Green Building Consultant, Ho Chi Minh City, Vietnam, 09 March 2022

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