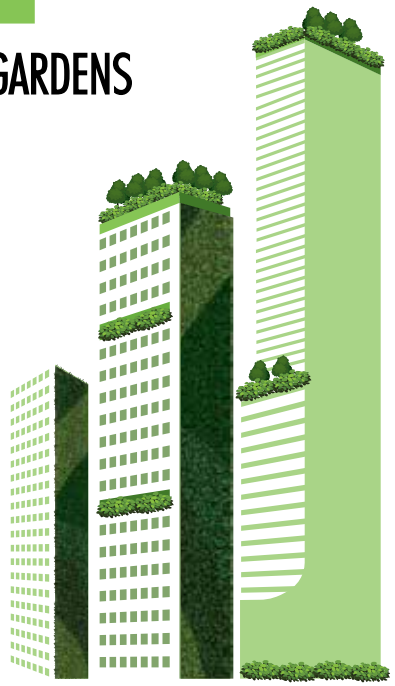
A HANDBOOK ON DEVELOPING SUSTAINABLE SKYRISE GARDENS

BRINGING GREENERY SKYWARDS



CONTENTS

1. THE JOURNEY OF SKYRISE GREENING 01

2. WHAT IS SKYRISE GREENERY 03

3. WHY SKYRISE GREENERY 05

4. BENEATH ALL THAT 07

5. PROJECT SHOWCASE 12

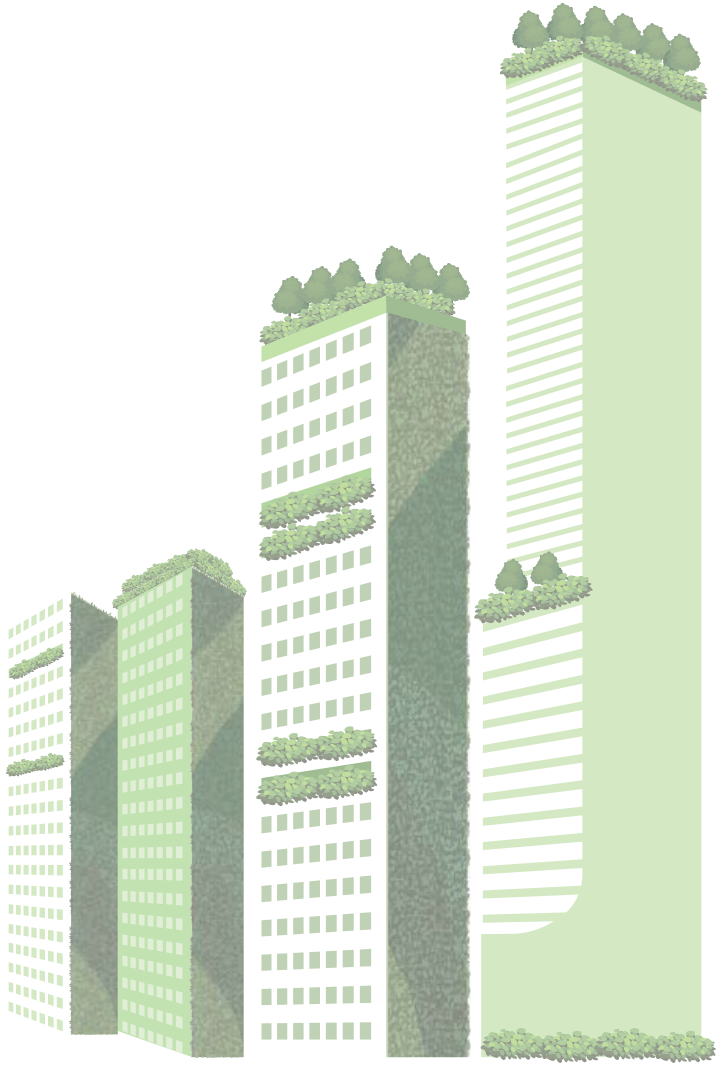
6. STARTING YOUR PROJECT 16

- Building Owner's Responsibilities
- Planting Considerations
- Structural Considerations
- Safety Considerations
- Maintenance Considerations

7. SKYRISE GREENERY INITIATIVES IN SINGAPORE 30

8. RESOURCES 35

- List of Suggested Plants
- References
- Useful Resources



Green is soothing to the eyes. The more greenery you have, the more people are soothed and the cooler it is. So I said look, try to build it up every wall and every building—greenery, creepers, like the creeping ivy or put the framework over it.

Lee Kuan Yew

Kampung Admiralty

THE JOURNEY OF SKYRISE GREENING

Before 1990s

Greening our Garden City

The earliest form of greenery on structure can be found on our transport infrastructure. Concrete columns of flyovers covered with climbing plants such as *Ficus pumila*, overhead bridges were planted with flowering species like *Bougainvillea*. These elements of landscaping became the precursors of what we now term skyrise greenery.

1990s to 2000

Integrating Greenery with Architecture

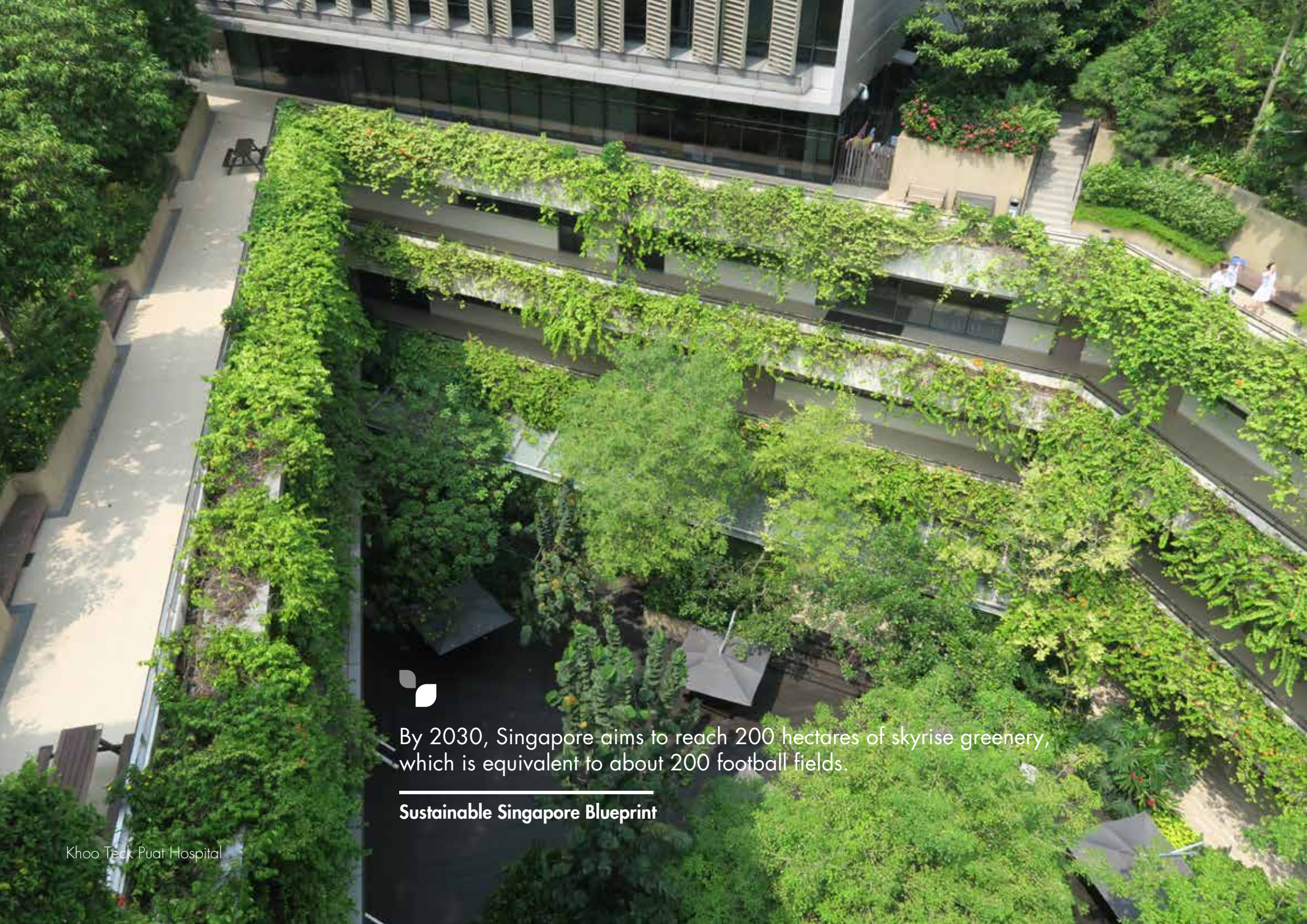
During the early 1990s, architectural innovation led to the upwards shift of green spaces. Green areas on ground level were elevated aboveground and incorporated in buildings such as sky terraces, landscaped balconies, and green roofs. As a driving force initiated by the architecture community, these spaces were developed with a heavy emphasis on its aesthetic appeal.

2000s till present

The Shift Towards Biophilia

In the 21st century, there was a notable shift in focus from aesthetics to biophilia in the integration of greenery in architectural design. A clearer understanding of the impact of urban development on the natural environment led to greater appreciation of our green spaces.

As a result, skyrise greenery was increasingly recognised and adapted as a sustainable means to enhance the built environment, reduce energy usage, and attract biodiversity back into the city. Up till today, skyrise greenery continues to evolve into various innovative forms to meet the needs of the community.



By 2030, Singapore aims to reach 200 hectares of skyrise greenery, which is equivalent to about 200 football fields.

Sustainable Singapore Blueprint

Khoo Teck Puat Hospital

WHAT IS SKYRISE GREENERY

Skyrise Greenery is a term coined in Singapore and refers to both rooftop and vertical greenery. Skyrise greening is a strategy aimed at extending greening skywards in the built environment through the greening of facades, balconies, mid-level and topmost roof spaces.

In line with the National Parks Board's (NParks) City in a Garden vision, this multi-tiered greening aids in the optimisation of urban spaces for greenery and recreation. Urban dwellers would now be able to reap the benefits of greenery not only at ground level but also at elevated spaces. This enhances their quality of life through their work and living environment.

Rooftop Greenery

Rooftop Greenery comprises of two forms of greening—Green roofs and Roof Gardens. Green roofs are considered extensive in nature and are generally not designed for active recreational use. They are developed mainly for aesthetic and ecological benefits. Generally, these type of roofs are low in installation costs, lightweight (90 - 150 kg/m2) and require minimal maintenance.

Roof Gardens, on the other hand, are considered intensive in nature and are designed to be accessible. Often used as recreation and social spaces, these roof gardens have higher capital costs, associated with added weight and have higher maintenance requirements.

Vertical Greenery

Vertical greenery or green walls, as the name suggests, refers to greenery on vertical facades. They are built mainly for aesthetic and ecological benefits. The level of maintenance is often dependent on the design and safe accessibility of these vegetated vertical surfaces.

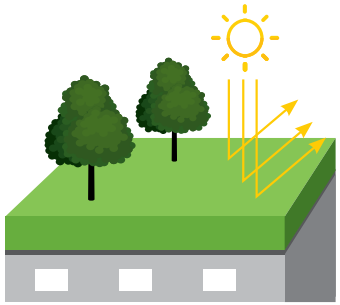
Skyrise greenery can be integrated into buildings in various typologies.

Quality of life is important for investors because you're not talking just about the factory. The machines don't care about fresh air. But the people who come to work, and their families, do worry about the environment. They want clean air; they want pleasant surroundings, and greenery is an important part of living in a happy place.

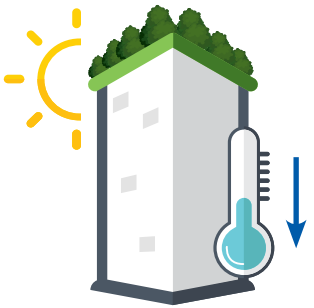
Lee Hsien Loong

Temasek Polytechnic

WHY SKYRISE GREENERY



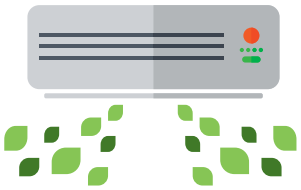
Skyrise greenery contributes to urban greenery which can mitigate the urban heat island effect by up to 4.01°C [1] .



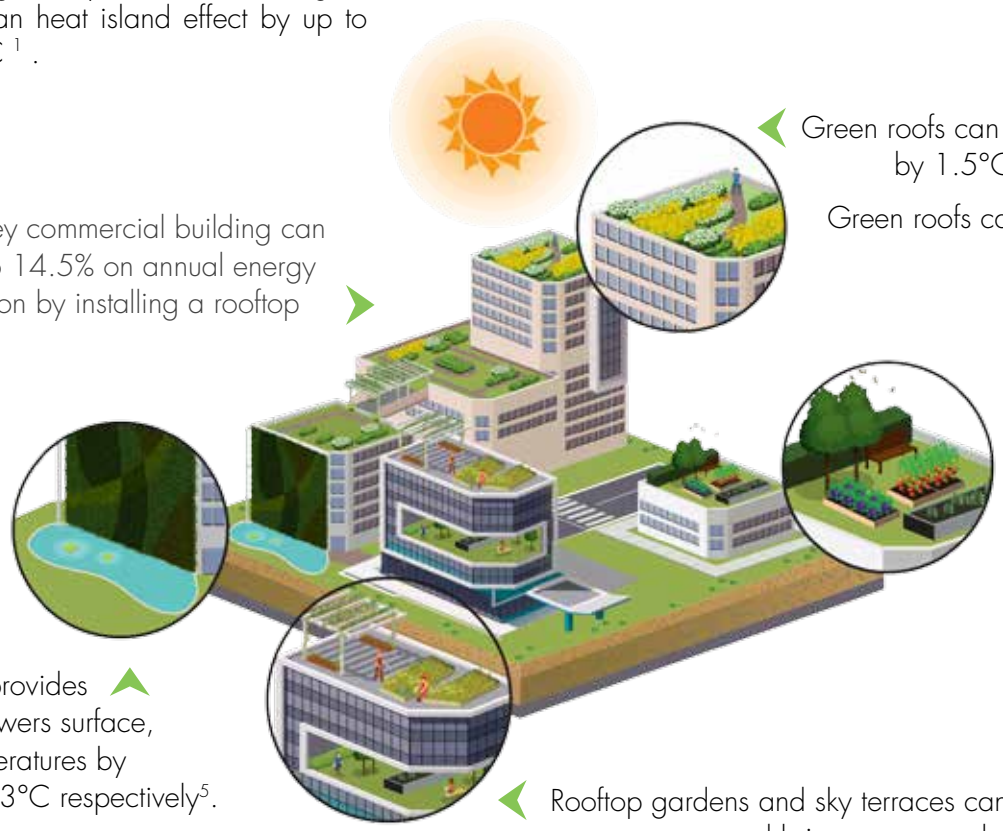
Green roofs can cool the immediate surrounding environment by 1.5°C[2] and surface temperature by up to 18°C[3].

Green roofs can also reduces stormwater runoff so that less water is directed into storm drains.

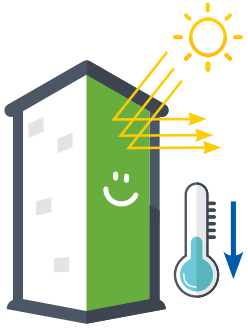
It also extends the lifespan of the roof.



A five-storey commercial building can save up to 14.5% on annual energy consumption by installing a rooftop garden [4] .



Rooftop vegetation improves the air quality, biodiversity of the built environment.



Vertical greenery provides cover shielding, lowers surface, and ambient temperatures by 11.58°C and 3.33°C respectively[5].

It can reduce noise level by up to 10dB by acting as a 'padding'[6].

Rooftop gardens and sky terraces can beautify a space and bring greenery closer to the community by creating more communal space for social interactions, and a way to stay connected with nature.

Saving our environment is the most vital issue that humankind must address today; thus designing ecologically is crucial. Within this context it is clear that the building of green and ecological buildings is just one part of the entire environmental equation that we must address. We must ultimately change our cities into green eco-cities. In making these green we must integrate them seamlessly with the natural environment.

Dato' Dr. Ar. Ken Yeang

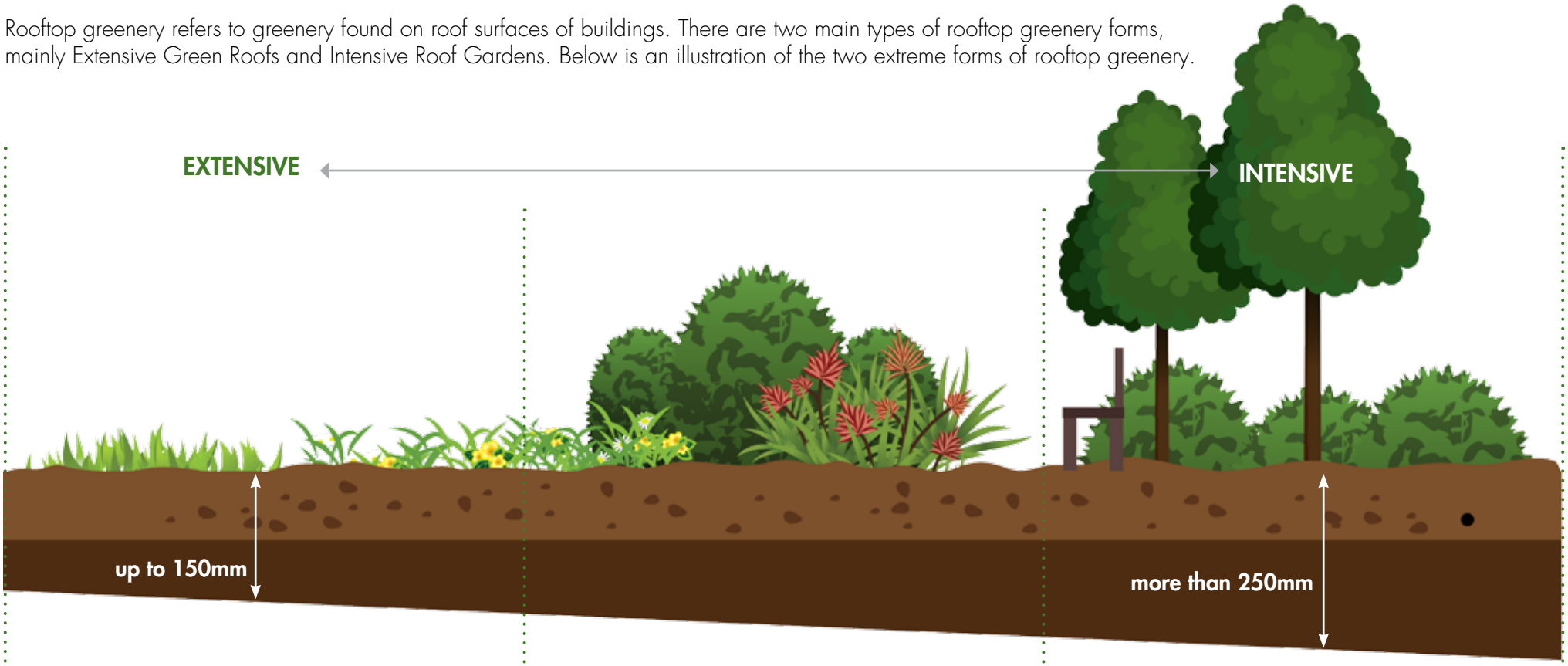
Skyville @ Dawson

BENEATH ALL THAT

Rooftop and Vertical Greenery installations may look similar in terms of lushness on the surface but beneath it all lies a variety of systems configurations.

Types of Rooftop Greenery

Rooftop greenery refers to greenery found on roof surfaces of buildings. There are two main types of rooftop greenery forms, mainly Extensive Green Roofs and Intensive Roof Gardens. Below is an illustration of the two extreme forms of rooftop greenery.



Characteristics of a typical extensive green roof:

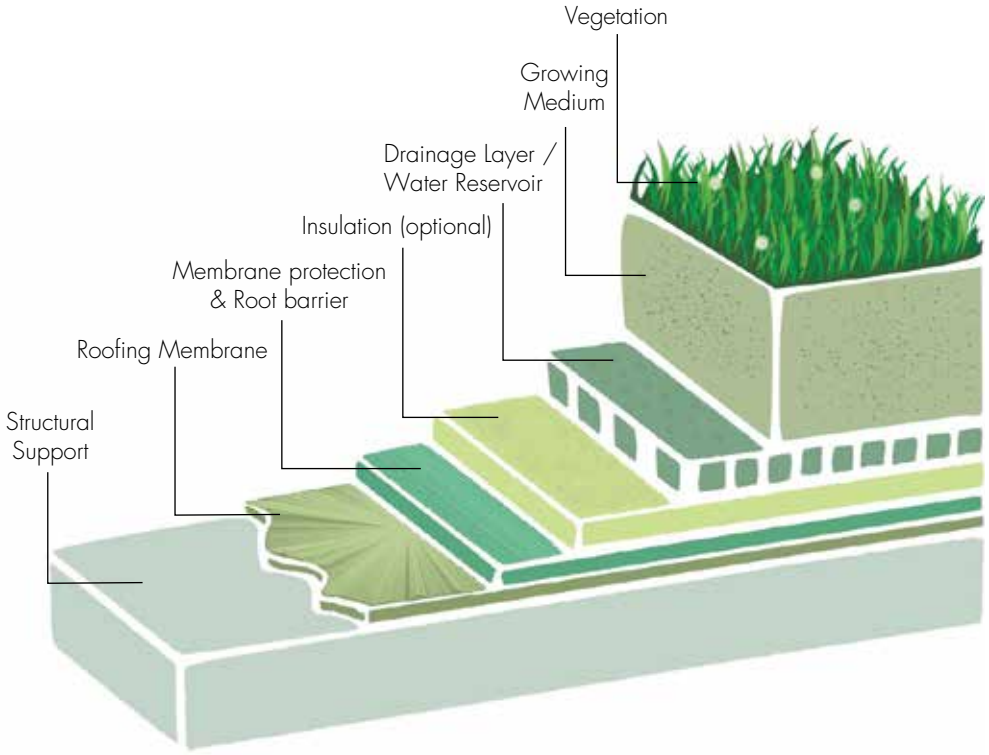
Plant Choice:	Groundcover and low shrubs
System build-up height:	up to 150mm
System build-up weight:	≤ 150kg/m^2
Maintenance:	Low to medium

Hybrid forms of rooftop greenery may exist. This form includes some elements of extensive green roof and intensive roof garden. More intensive planting of taller shrubs and no trees can be found here.

Characteristics of a typical intensive roof garden:

Plant Choice:	Groundcover, shrubs and trees
System build-up height:	up to 1500mm
System build-up weight:	≤ 300kg/m^2
Maintenance:	High

However, while these two forms vary in terms of planting depth, their system components remain largely similar. This includes vegetation, soil or growing medium, drainage cells/ water reservoirs, root barriers and waterproofing membrane



Typical cross-section ot a green root system.

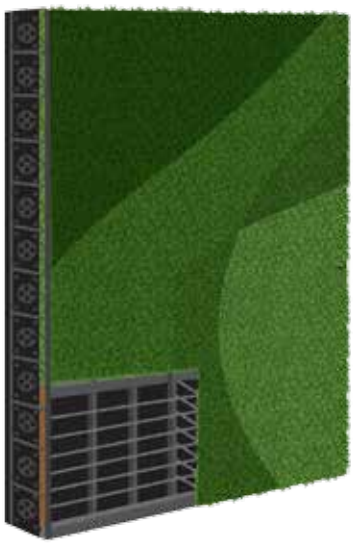
The basic composite layers of rooftop greenery may be implemented in the following ways. While modular systems are mainly used for extensive green roofs, blanket systems can be used for both intensive and extensive forms.

The basic composite layers on rooftop greenery may be implemented in the following ways:

Blanket/ in situ system	Modular system
• Components are assembled on-site, in sheet layers across the roof • Allows lateral migration of water and roots • Has a seamless look • Is customised to fit roof site area	• Components are modularised into small trays that are assembled and planted off-site, then installed later on the roof • Plant growth is confined to individual trays, which are equipped with a filter layer along with drainage and storage cells to hold the substrate in place • Has the appearance of a grid

Vertical Greenery

There are many variations of vertical greenery systems found in the market. However, the basic components remain – vegetation, soil/ growing medium and supporting structure. In this section, we highlight the **four** most common methods of installation.



Cassette System

Planter System

Pocket System

Support System

Cassette System

The cassette system consists of modular units containing growing media that can be easily mounted on framings as standalone systems or attached to wall surfaces.

Planter System

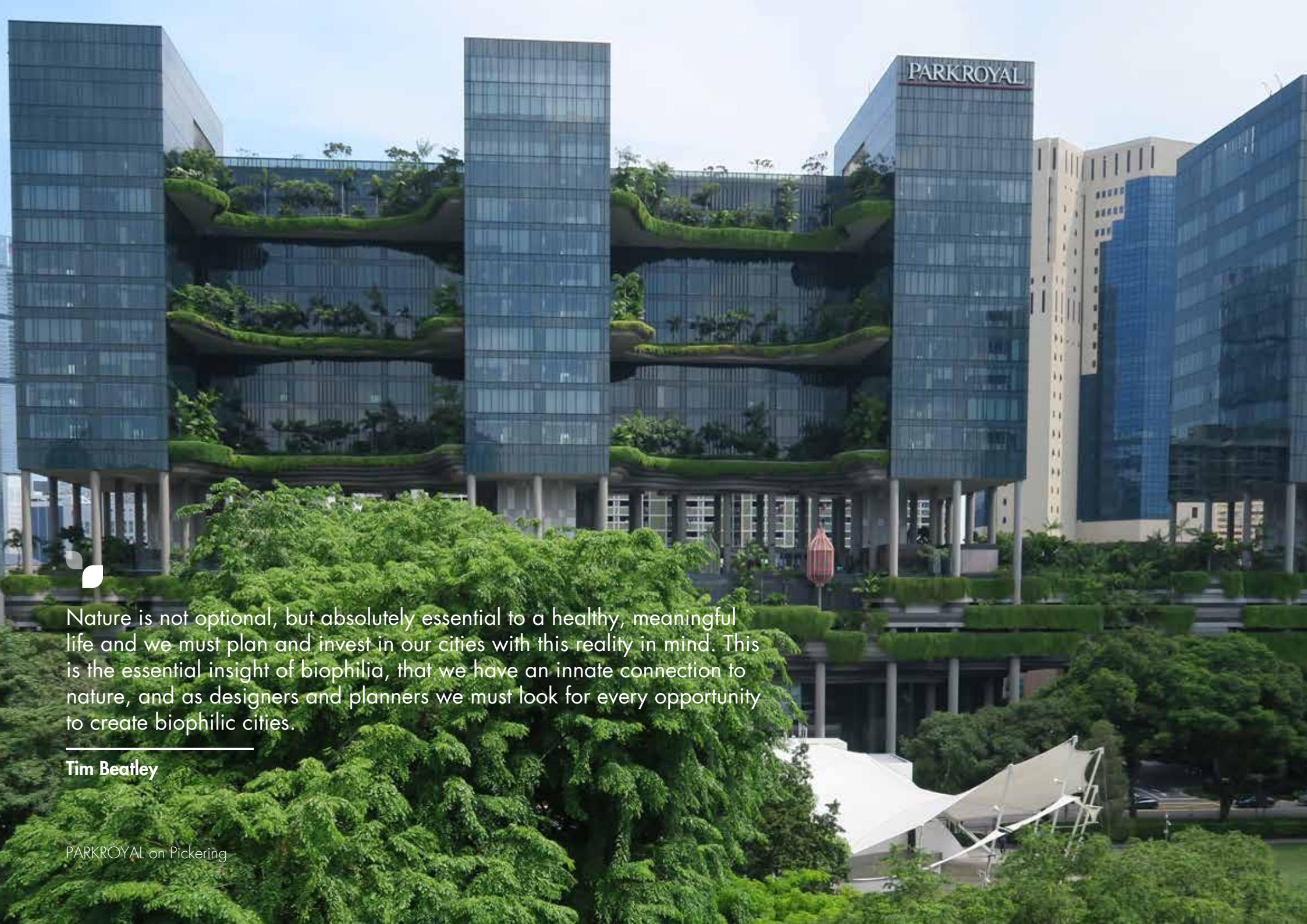
The planter system consists of individual pots mounted at regular intervals onto a structure or frame. When placed closely together, they form a continuous wall of greenery.

Pocket System

The pocket system comprises of moisture retention fabrics that are used to hold the plants in place against a board. These plants are placed in pockets that are cut from this fabric.

Support System

The support system consists of planters placed at regular intervals. Wire mesh and cables attached to them allow plants to climb up creating a green screen.



Nature is not optional, but absolutely essential to a healthy, meaningful life and we must plan and invest in our cities with this reality in mind. This is the essential insight of biophilia, that we have an innate connection to nature, and as designers and planners we must look for every opportunity to create biophilic cities.

Tim Beatley

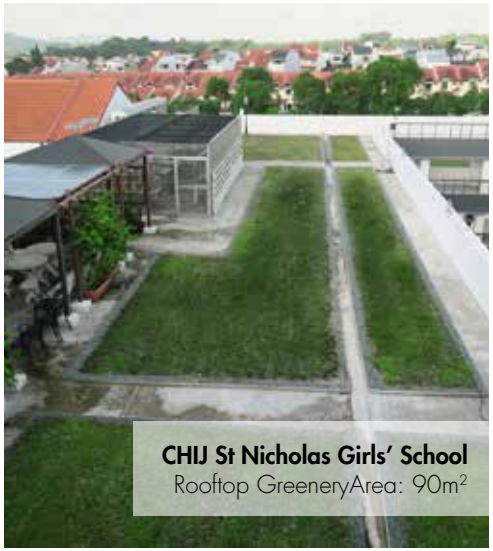
PARKROYAL on Pickering

SKYRISE GREENERY IN SINGAPORE

Extensive Roof Gardens

My First Skool
Rooftop Greenery Area: 796m²

Marina South Pier
Rooftop GreeneryArea: 278m²



CHIJ St Nicholas Girls' School
Rooftop GreeneryArea: 90m²

Temasek Polytechnic
Rooftop Greenery Area: 2,971m²

Singapore Institute of Management
Rooftop Greenery Area: 515m²

Intensive Roof Gardens

SkyVille@Dawson
Rooftop Greenery Area: 5,925m²

Our Tampines Hub
Rooftop Greenery Area: 2,323m²

Sky Garden @ Jurong Central
Rooftop Greenery Area: 200m²

Nanyang Polytechnic
Rooftop Greenery Area: 321m²

Spectra Secondary School
Rooftop Greenery Area: 175m²

Vertical Greenery

Hougang Primary School
Vertical Greenery Area: 171m²

National Gallery Singapore
Vertical Greenery Area: 539m²

Sentosa Express
Vertical Greenery Area: 1,612m²

NUS Ventus
Vertical Greenery Area: 1,232m²

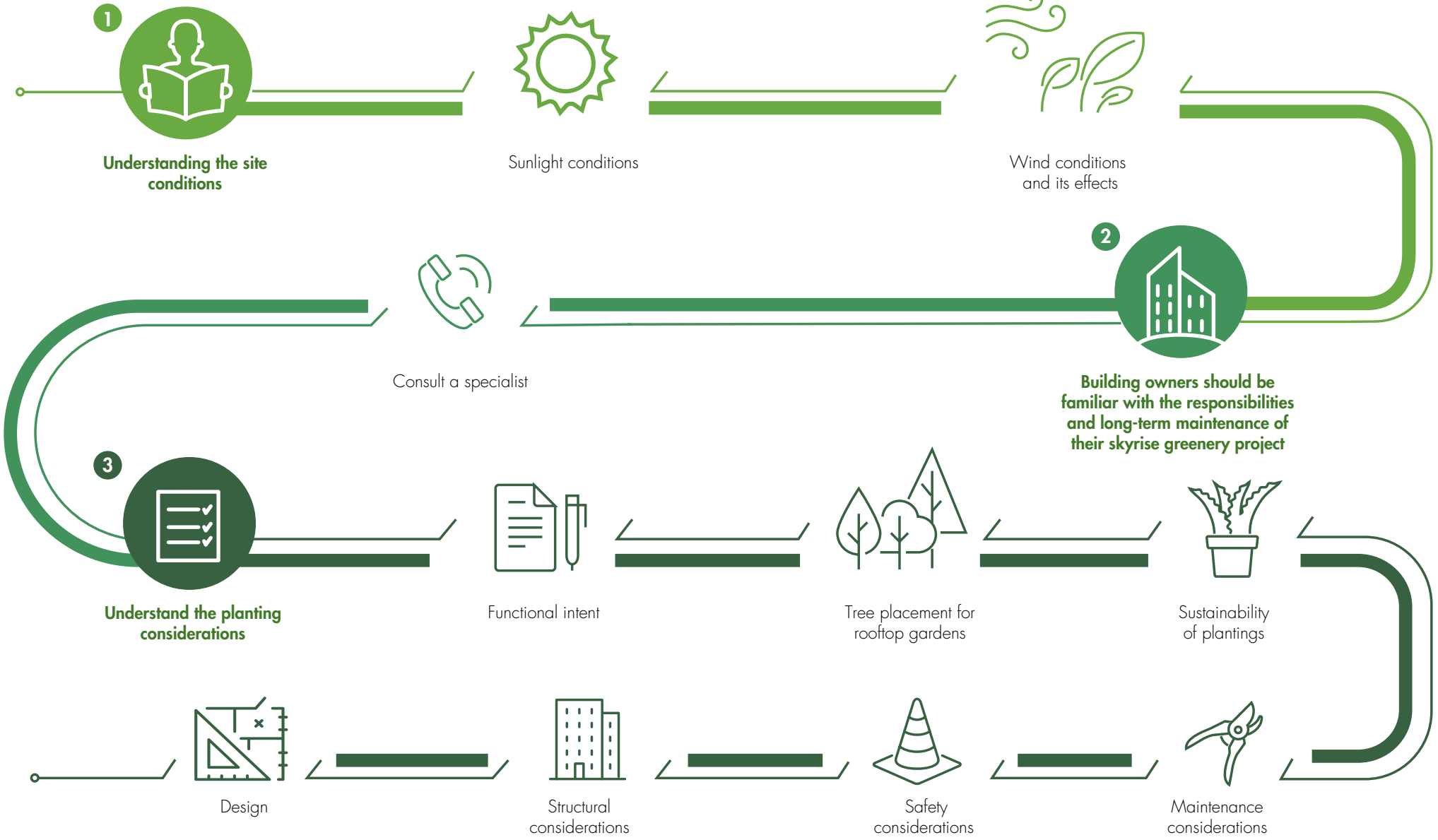
Would you like to view more skyrise greenery projects? Visit our Projects page on our website to view more projects. Want to view a project up close and personal? Download our Skyrise Greenery Trail Maps and embark on your own journey today!

While some countries had been planting trees to convert deserts in fertile land, Singapore was converting what could have been yet another cement jungle into a full-fledged urban garden.

Emilio Ambasz

The Orchard Residences

STARTING YOUR PROJECT



You may wish to approach NParks at any stage if you require further guidance. Drop us an email at skyrisegreenery@nparks.gov.sg

Building Owner's Responsibilities

- Building owners are responsible for the installation, maintenance and safety of their rooftop greenery, unless another stakeholder is officially appointed (e.g. a Qualified Person (QP) during construction, or a managing agent/ occupier after development stage, etc.)
- Safety features (e.g. maintenance access, anchorage points, safety lines, Personal Protective Equipment (PPE), etc.) should be part of the design requirements of future maintenance operations.
- Recognised professionals (e.g. Certified Arborists, Professional Engineers, etc.) should be engaged to perform relevant checks and certifications where necessary
- Building owners should verify that the engaged design, installation and maintenance teams fulfill their responsibilities.

Planting Considerations

Functional intent

At the start of the project, identify the function of the skyrise greenery installation and select a system that best fulfills the objective.

Skyrise greenery may:

- Create more usable space for recreation/social activities
- Reduce the urban heat island effect
- Beautify a space
- Hide unsightly mechanical equipment

Creating recreational spaces on roof gardens

Sustainability of plants

All plants have specific light, water and maintenance requirements for survival and growth. Considerations should be given to these requirements when selecting plant species for placement at each location. Once such requirements are considered, plants can be expected to do well, thereby reducing the cost of maintenance and / or replacement in the long run.

Indoor or outdoor locations

The conditions of an indoor environment differ from an outdoor one. Indoors, a skyrise greenery feature would be protected from the weather and other environmental elements. In such a controlled environment it may be easier to manage irrigation, and more consistent plant growth. In contrast, an outdoor location would be exposed to unpredictable conditions and plant growth. Hence, if placed outdoors, the feature should be constructed of materials that can withstand prolonged exposure to extreme and unpredictable conditions.

Indoor vertical greenery installations have different requirements from outdoor ones, e.g. grow lights and an altered watering schedule.

Lighting requirement

When planting within a built-up environment, the intensity of natural light and duration of exposure may be affected by the surrounding structures. Hence, it is important to understand the local lighting conditions when selecting the species to be planted. Supplementary grow lights specifically designed for plants may be installed for plants that require more light especially in indoor locations.

When planting in shady locations, close attention should be paid to the light requirements of the plants.

Wind effect

Plants tend to dry out more rapidly in strong wind conditions, making them unhealthy and water-stressed. It is recommended to avoid installing skyrise greenery at such areas. Alternatively, selection of hardier plant species or installation of windscreens can reduce the impact.

Watering requirement

The amount of water each species requires differs according to their physiological conditions, the local climatic conditions that they are exposed to, as well as the condition of the substrate in which they are planted.

For skyrise greenery, plants may be planted in areas of high wind and high exposure to the sun (i.e. in roof gardens). This might lead to a higher rate of transpiration in the plants, and may in turn affect the watering requirement. The depth and type of substrates used for rooftop greenery may also affect the water cycles.

Particular attention needs to be given to plants that rely on the natural rainfall cycles instead of irrigation systems for watering. In such cases, species selection and plant placement will determine the sustainability of the planting. For areas that do not receive much rainfall, the use of drought-tolerant plants would be a better choice.

Irrigation

Green roofs are designed to be non-irrigated as the system usually includes a water reservoir. However, irrigated green roofs are not uncommon as they control the growing environment and hence provide a more consistent aesthetically pleasing appearance.

For vertical greenery, a well-designed irrigation system is essential. When paired with a fertiliser-dosing pump, it can deliver nutrients and water to the root zone of the plants, as they cannot be sustained with natural rainfall alone.

Rainwater sensors reduce watering frequency when rain is detected and can be coupled with irrigation systems to help conserve water in outdoor settings.

Maintenance requirement

When planning, it is important to consider the impact of future maintenance. For instance, a manicured rooftop and vertical greenery installation would be more demanding, requiring a more intense maintenance regime. Accessibility to the plants for maintenance also has to be taken into consideration. For planted areas which are not easily accessible, the use of drought-tolerant and slow growing plants would be a better choice.

Design

Understanding the overall intention of the placement of rooftop and vertical greenery within a building footprint can help in the selection of an appropriate skyrise greenery system and plants.

The appearance of the skyrise greenery installation can be naturalistic or manicured. This can be achieved by varying the planting method, plant selection and the maintenance regime.

Be creative with colours and textures and select a wide variety of plants to create patterns and enhance the visual appearance of the façade or rooftop space.

Feature plants can be used to create points of focus or to accentuate either the overall planting scheme or the form of the system itself. Consult a specialist to develop a detailed landscape plan for your skyrise greenery.

Wind conditions

In general, wind speed intensifies with increased altitude. This, however, is dependent on the rooftop's location and its surrounding environment. Neighbouring buildings, taller elements of the same building, as well as structures on the rooftop (such as water tanks and air conditioning units) can create excessive turbulent wind, which can be stressful for rooftop vegetation. The resultant wind speed and wind pressure, in such high rise context, should be computed by a certified structural engineer based on the relevant codes or standards prescribed in the Building Control and Regulations. Where necessary, wind tunnel testing can be carried out to assess the wind conditions.

In general, the denser and larger the tree canopy spread, the larger the 'sail area' exposed to wind loads. Small trees with open canopies allow wind to pass through easily and are more suited for windy rooftops. When wind acts on trees and palms on a roof garden, safety may be compromised by the following:

- Falling plant debris from height might cause human injury and/or damage to property
- Tree uprooting may occur if rooftop trees and/or palms are not adequately cabled, staked and/or root-ball-anchored in place

Tall trees with dense canopy experience higher wind loads and moment of forces.

Periodic canopy thinning through selective removal of branches to improve air movement through the tree canopy can help mitigate excessive wind load on rooftop trees and palms. As a general rule, rooftop trees and palms should be pruned once every three to six months, depending on the species and rate of growth.

Pruning strategies to reduce wind loads include (1) crown reduction to reduce plant height, (2) crown thinning to reduce drag and (3) structure pruning to improve crown form. Please refer to CS E07:2012 – Guidelines on General Maintenance for Rooftop Greenery, section 2.3 on pruning. All pruning works shall conform to the practices and standards specified in the latest ANSI A300 Part 1.

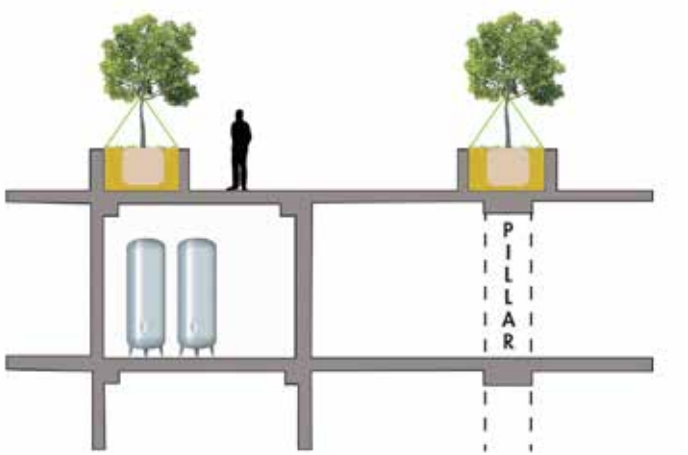
Porous canopy allow wind to pass through, thus reducing wind loads and impacts.

Structural Considerations

Loading capacity and design load of the roof

A Professional Engineer (PE) should be engaged to verify the loading capacity of the roof to certify that it can support the additional loads from the rooftop greenery system, other relevant landscaping materials and wet load of the system during heavy rainfall, and that the structural integrity of the roof/wall structure is not compromised.

The trees' and palms' estimated grown weight must be taken into account when tabulating the total intended load. Bulk vegetation such as trees, palms and big shrubs, should be strategically located and preferably positioned over structural members such as columns. The design should transfer tree loads optimally through the building, and safely to the ground.



Strategic placement of heavy plants over structural elements.

If the existing roof is able to accommodate the additional loads from the rooftop greenery system, a copy of the PE's calculation and certification must be given to the building owner. This document should be submitted to the relevant PE and BCA when the building is due for periodic structural inspection. If structural strengthening is required, the PE should submit the structural plans and calculations to BCA for approval. Loading capacity checks and strengthening proposals should include all loads (such as the soil loading, current and future plants/trees loading and moisture retention during heavy rainfall, etc). In addition, the design imposed loads should be in accordance with Code of Practice BS 6399: Part 1.

Structural integrity of the wall

A Professional Engineer (PE) should be engaged to check and certify the adequacy of structural elements (i.e. beams, columns and Reinforced Concrete walls) in supporting the loads from the vertical greenery systems. The weight of mature and saturated vertical greenery systems should be considered.

If the existing structural elements are able to accommodate the additional loads from the vertical greenery, a copy of the PE's design calculation and certification must be given to the building owner. This document should be submitted to the relevant PE and BCA when the building is due for periodic structural inspection. If strengthening of structural elements is required, the PE should submit the structural plans and design calculations to BCA for approval.

The installed vertical greenery panels must be safely secured. The designed structure, its attachment/ anchorage onto the structural elements and other details must be certified by the PE and submitted to BCA for approval. Structural elements should not be covered by the vertical greenery system; they should be exposed for the purpose of periodic structural inspection.

Where necessary, direct contact of plant roots with the building's structural elements should be avoided. Exceptions can be made where this is intended and appropriately provided for in the design and construction of the building, without the building's future structural integrity being compromised.

For more details, refer to CUGE guideline CS E:10 2014 Guidelines on Design Loads for Skyrise Greenery

Waterproofing of the roof

The integrity of the waterproofing on the roof structure must not be compromised by the introduction of greenery on the roof and their subsequent maintenance.

If the waterproofing membrane contains plastic, it must be used on an unsheltered roof. It must also be laid above the concrete layer and not be embedded within the concrete, as required by the fire safety rules. Please refer to CSE05:2012 – Guidelines on Waterproofing for Rooftop Greenery

Ventilation

For naturally-ventilated buildings, provision of vertical greenery at the facades should not compromise the aggregate area of the openings required. The vertical greenery should also not compromise the performance of any mechanical and electrical systems that may be installed on building facades, such as ventilation outlets and inlets.

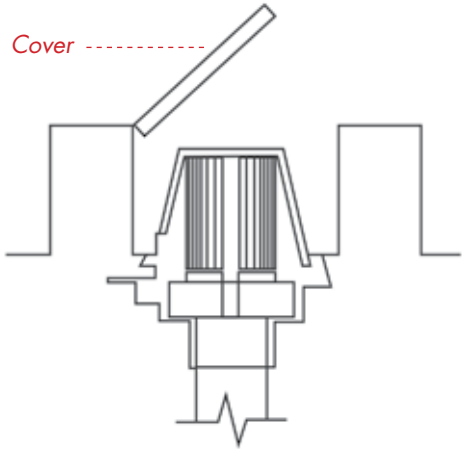
For naturally-ventilated buildings, the vertical greenery should not compromise the aggregate of the openings required.

Drainage

Drainage systems on rooftop greenery should be adequately designed with proper gradients to prevent water stagnation and mosquito breeding, and have adequate drainage capacity (in terms of drainage outlet capacity, number of outlets, placement of outlets, etc.). Light-weighted drain covers, inspection chambers and/or drainage outlets of larger sizes should be used to facilitate maintenance and regular cleansing.

Where the installation of roof gutters is necessary, a Qualified Person (QP) has to apply to NEA for a waiver. There should also be safe and permanent access to the rooftop so that regular inspection and maintenance can be carried out.

The drainage systems should effectively convey water to the stormwater drainage system at ground level. For more details on stormwater drainage system requirements, please refer to PUB's *Code of Practice on Surface Water Drainage*.



A typical inspection chamber at a roof drainage outlet in a vegetated roof area.

Safety Considerations

Trees on rooftop spaces

In Singapore's tropical climate, provision of shade on rooftop spaces, is one of the main driving factors behind the placement of trees on rooftop spaces. Another main driving factor would be for aesthetical purposes, positioning trees close to the edges of rooftop spaces to create a distinctive identity for that development. Some developments have also positioned trees on rooftop spaces to act as a green screen for M&E service areas, while others grow fruit trees as part of their edible roof gardens.

With an increasing number of developments incorporating trees in their roof garden designs, there is a need for stakeholders to address the ease of future maintainability, sustainability/ health of the trees, and safety of users of these elevated spaces. While placing a tree on a rooftop might seem simple enough, building owners and industry practitioners need to understand that the safety of users and pedestrians at street level is paramount.

Safe Design of Trees on Rooftop

While there is no denying the functionalities of trees on rooftop spaces, it is necessary to prioritise the safety of users and pedestrians walking below the roof gardens. The microclimate of rooftop spaces varies from ground level spaces and care must be taken to ensure that the trees planted on rooftops will not endanger the safety of all users within and outside of the space.

To address this, it is crucial for industry practitioners to look at the placement of trees within roof gardens as well as the selection of tree species. As a good safety practice, no trees should be planted within five metres from the edge of a building's periphery. Where possible, small-sized trees should be used. Trees should also be maintained regularly. As a guide, trees should be kept at a height of not more than the horizontal distance between its location and the building edge, while its canopy should not overhang beyond the building's edge.

Mitigation measures such as guying, staking or root ball anchorage of all trees on roof gardens are also recommended. For more details on the various mitigation measures, please refer to CUGE guidelines CS E09:2012 "Guidelines on Planting of Trees, Palms and Tall Shrubs on Rooftop".

Selection of appropriate tree species is also advisable to ensure the sustainability of the trees. For a list of suggested tree species for rooftop spaces, please refer to Section 8.

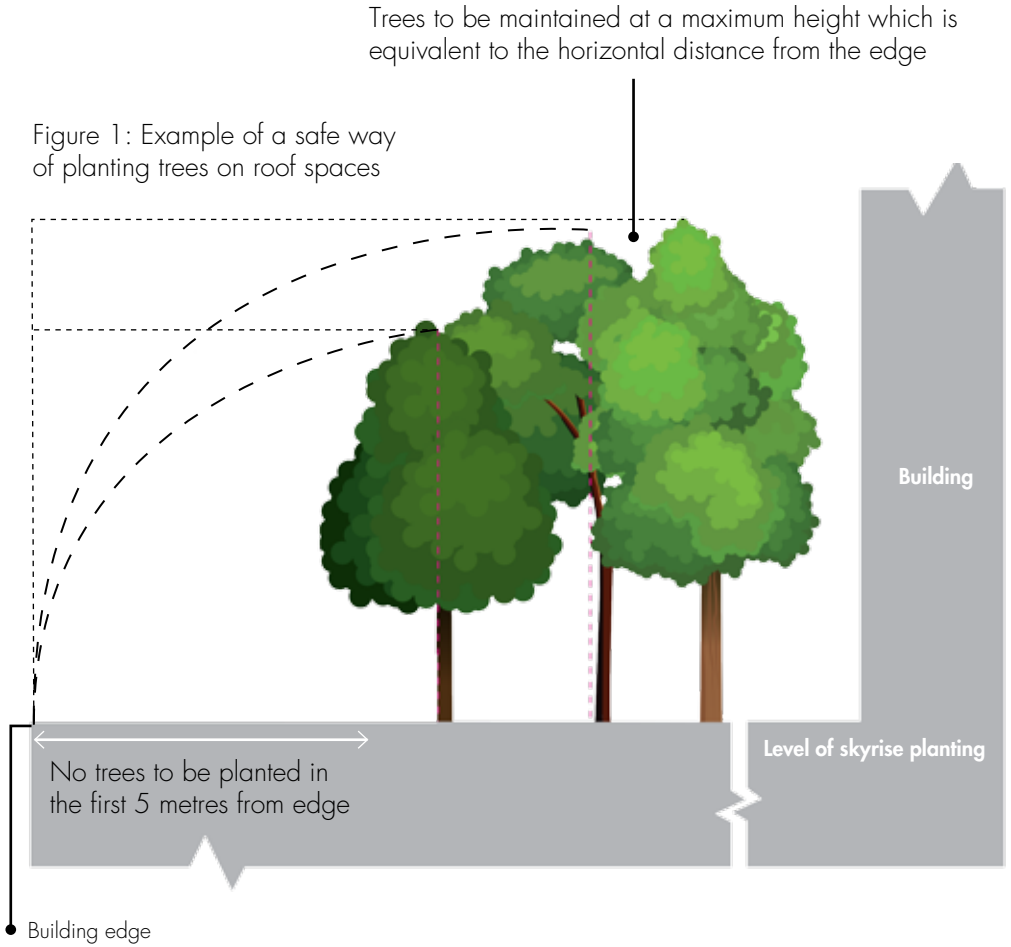


Figure 1: Example of a safe way of planting trees on roof spaces

Users' safety and security

For rooftop gardens that are accessible to the public or residents, safety barriers should be designed and installed to prevent falling. Wheelchair accessibility and lightning protection should also be considered, with proposals submitted to BCA.

Safety barrier along the perimeter of a rooftop garden.

Where necessary, adequate security and monitoring considerations should also be put into place to deter crime, safeguard the property and protect users. A clear escape route to staircases, fire exits or open spaces should be planned, with proposals submitted to and approved by SCDF.

Work safety

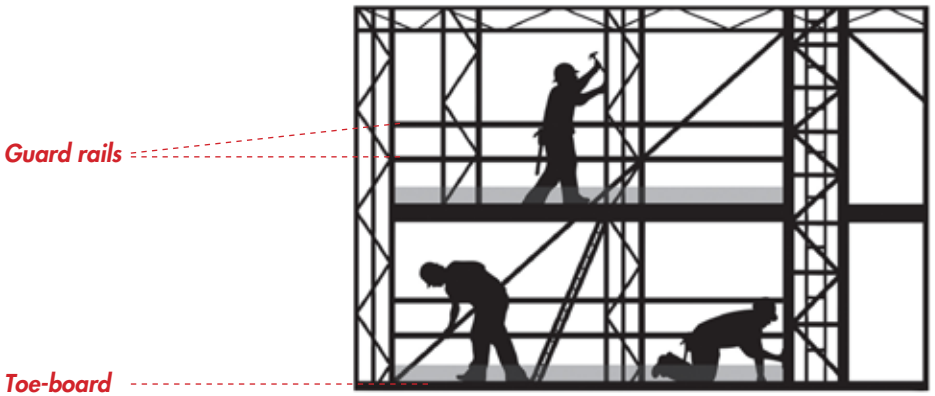
Appropriate and safe work procedures, schedules, equipment and work methods should be adhered to, with adequate site supervision.

Risk assessments should be conducted prior to maintenance work to ascertain any potential risks, hazards and problems; in particular, the risk of falling from heights and falling objects. Respective counter-measures should be devised. Measures to safeguard against falling from height should include, but are not limited to the following:

- Providing safe means of access to or from a work area
- Installing a work platform with adequate barricades and secured anchorages
- Ensuring appropriate full body harness and travel restraint or fall arrestor when working from the bucket of an aerial lift and/or from any elevated work space.

There should be adequate site supervision so that all workers understand and comply with the established safe work procedures, safety rules and work methods, including proper usage of all Personal Protective Equipment (PPE) provided.

For lifting operations involving cranes (including lorry cranes), measures such as the Lifting Plan, Permit-to-Work (PTW) system and Risk Assessment (RA) should be implemented to address lifting-related hazards. These hazards include getting struck by a falling or swinging load, collapse of crane and disruption to nearby vehicular traffic.



Where scaffolding is used, it must be properly erected based on requirements under the Workplace Safety and Health (Scaffolds) Regulations. Workers working on scaffolds should wear the appropriate PPE and be provided with proper anchorage where necessary.

Fire safety requirements

Mandatory fire safety requirements for rooftop gardens that are accessible to the public or residents are stipulated in the *Fire Code of SCDF*. If access is limited to maintenance personnel, SCDF may waive the above fire safety requirements on the merits of each case.

Examples of fire safety requirements include the permitted number of occupants based on occupant load factor, provision of adequate exits, extinguishers, hose reels, etc. One of the considerations is whether there is a possibility of fire and smoke spreading to upper adjacent floors with differing rooftop height.

For vertical greenery, the installation must not impede the building's fire safety provisions, strategies and performances. SCDF will review the requirements for vertical greenery on the merits of each case. For example, SCDF would not allow vertical greenery installations if the proposed designs affect smoke ventilation or cause fire and smoke to spread to upper floors and essential spaces such as naturally ventilated exit staircases, smoke stop or fire-fighting lobbies, etc.

For both rooftop and vertical greenery, should the use of plastic be required, Fire Safety Requirements must be met.

Lightning protection

A Professional Electrical Engineer has to be engaged to ensure that a lightning protection system is fitted to protect people and the building from lightning strike. The lighting protection system should be designed and installed in accordance with the *Approved Document* by BCA.

Lightning protection systems should be present on green roofs and rooftop gardens.

Maintenance Considerations

Design for safe and efficient maintenance

Access for safe and easy maintenance should be provided for early in the design stage. Workers should be able to reach and maneuver around the work area effectively. They should also be able to thoroughly inspect and maintain the vegetation and/or system. In addition, considerations should be given for the tools and equipment that the workers will require for the installation and maintenance of the greenery.

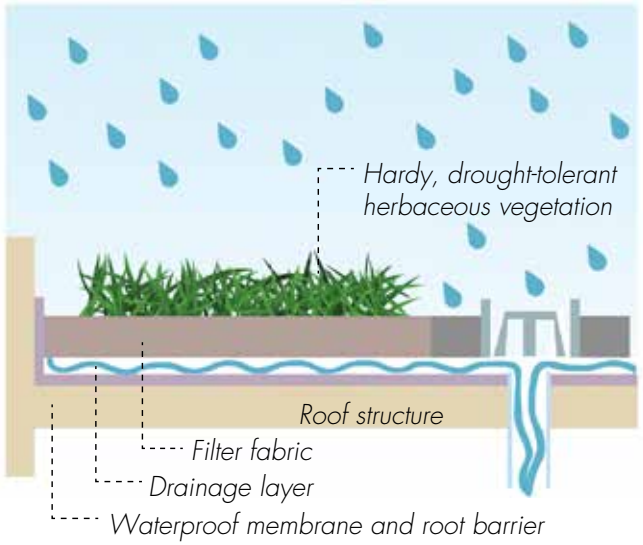
Provision of railings for the attachment of safety hooks allow the planters along a narrow beam to be safely maintained.

Gondola attachment structures allow for the maintenance of vertical greenery that span several levels.

In cases where vertical greenery systems span a few storeys, maintenance access should be provided at every level. Means of access (tower scaffold, ladders etc) must be structurally sound, stable, of adequate strength for the intended purpose and must comply with the Work Safety and Health Council's (WSHC) Work-At-Height (WAH) requirements.

Cat ladders and sufficient space behind vertical greenery structures allow workers to effectively access the system for maintenance.

Irrigation requirements (e.g. manual tap points, storm water storage tank, etc.) should be catered for, along with the effective capture and discharge of excess water, runoff of substrate media and plant materials. Drainage outlets must be designed and installed for easy and effective cleaning and maintenance (e.g. drainage outlets should be large enough to cater for the discharge from the rooftop space and be fitted with raised covers to minimise choking by vegetation).



Cross section example of a drainage system.

Effective rooftop drainage systems should be designed.

Maintenance cost

Design and installation of plants must be carried out with prudence to ensure ease of maintenance. If low maintenance is preferred, proposed plants should require minimal pruning, be slow-growing and hardy. Bear in mind that maintenance cost includes routine maintenance and cyclical plant and component replacement costs. The design of the rooftop and vertical greenery should ideally meet the maintenance expectations of the building owner and/or building operator.


Study nature, love nature, stay close
to nature. It will never fail you.
Frank Lloyd Wright

SKYRISE GREENERY INITIATIVES IN SINGAPORE

Skyrise Greenery Incentive Scheme

To increase greenery provision in Singapore, the National Parks Board has introduced the Skyrise Greenery Incentive Scheme (SGIS) which provides up to 50% of installation costs of rooftop greenery and vertical greenery.

Rooftop Greenery Projects

A grant equal to **50%** of installation costs, capped at **$200** per sqm of planted area[1]

Vertical Greenery Projects

A grant equal to **50%** of installation costs, capped at **$500** per sqm of planted area[1]

Applicable for the following building types

RESIDENTIAL AND NON-RESIDENTIAL BUILDINGS

Residential:
Non-landed, mixed commercial and residential development and others[2]

Non-Residential:
Commercial, business parks, industrial, educational institutions, community buildings[2]

Let's get started!

How to get started?

1. Contact NParks regarding your proposed greening plans at skyrisegreenery@nparks.gov.sg

2. Arrange a site meeting with NParks to:
   - Verify eligibility of the building for SGIS
   - Obtain technical advice and recommendations

3. Engage the help of specialists.
   - Consult a rooftop greenery and/or vertical greenery specialist
   - Ensure loading capacity is sufficient for installation
   - Check on waterproofing membrane on roof
   - Check on condition of existing wall façade
   - Be mindful of water source and drainage

4. Appoint a rooftop greenery/vertical greenery specialist.
   - NParks can provide inputs on suitable plants to use
   - Confirm implementation plans

5. Proceed to apply for funding under the Skyrise Greenery Incentive Scheme.

APPLICATION

To submit application form (R1 and/or V1) before works begin.
A Letter of Offer will be issued upon successful application. Download the forms at our website

▼

ROOFTOP GREENERY / VERTICAL GREENERY INSTALLATION

Funding will be reserved for 6 months as indicated in the Letter of Offer. An official email or letter is required to seek extension before the funding deadline expires.

▼

REIMBURSEMENT

To submit reimbursement form (R2 and/or V2) once project is completed. To arrange for site inspection with NParks to verify job done. Reimbursement will be done if there is sufficient greenery coverage for the funded greenery

[1] Potted plants and hardscape such as footpaths, seating, trellises, water features etc, are not eligible.

[2] Approvals are granted case-by-case.

Landscape Excellence Assessment Framework

Recognising skyrise greenery as an integral component of urban greenery, the Landscape Excellence Assessment Framework (LEAF), is a certification scheme by the National Parks Board to recognise development projects with outstanding greenery. This is the first scheme in Singapore that is solely dedicated to the provision and management of greenery. With LEAF, NParks aims to encourage more greenery in Singapore's urban landscape. All applications which complete the assessment successfully are certified LEAF. Each year, certified projects which demonstrate high quality landscape and biodiversity enhancements above and beyond the norm are recognised as "Outstanding Projects". For more info, please click here

Landscaping for Urban Spaces and Highrises Programme

URA has implemented a consolidated package of incentives and requirements known as the Landscaping for Urban Spaces and High-Rises (LUSH) programme to encourage the provision of pervasive skyrise greenery. LUSH capitalises on developments to green our cityscape and to strengthen Singapore's distinctive image as a City in a Garden. Besides giving gross floor area incentives to encourage developers and architects to provide greenery in communal areas in the form of sky terraces, planter boxes, roof gardens and covered ground gardens, there is also the need to provide Landscape Replacement Areas (LRA). The LRA scheme requires new private and public sector developments to provide greenery and communal areas within the development proportional to the site area it occupies. LUSH is also focused on enhancing the quality of greenery and its contributions to sustainability, through supporting urban greening trends such as quality green walls, extensive green roofs and the growing interest in urban farming. For more info, please click here

Green Mark Certification

The provision of skyrise greenery increases energy efficiency and promotes sustainability in the built environment. Such building sustainability is encouraged by the Building and Construction Authority Green Mark certification which also aims to raise environmental awareness among developers, designers and builders when they start project conceptualisation and design, as well as during construction. For more info, please click here

Active, Beautiful and Clean Waters

Rooftop greenery can slow down rainwater runoff and act as aesthetic improvements to the sky terrace and roofs. Such landscape enhancements contribute to the objectives of PUB's Active, Beautiful and Clean Waters Programme by creating beautiful and clean waterscapes and community spaces for all to enjoy. For more info, please click here

LEAF certified 2017 for existing developments, Outstanding Project

Skyrise Greenery Awards

Launched in 2008, the Skyrise Greenery Awards is the first in the region to recognise and reward skyrise greening efforts in developments. The Awards honour the team effort of building owners, developers, architects, designers, and landscape contract managers who have creatively integrated sky gardens and vertical greenery in their projects.

The Skyrise Greenery Awards is organised by the National Parks Board (NParks), supported by Building and Construction Authority, Landscape Industry Association Singapore, Singapore Green Building Council, Singapore Institute of Architects, Singapore Institute of Landscape Architects and Urban Redevelopment Authority. For more info, please click here

Outstanding Award Winner 2011

Outstanding Award Winner 2013

Oustanding Award Winner 2015

Oustanding Award Winner 2017

RESOURCES

The Heeren

LIST OF SUGGESTED PLANTS

The following are some plants that can be featured in skyrise greenery. This list of plants is not exhaustive, and serves only as examples that can be used. Plants with similar characteristics can also be introduced into the gardens. Plant selection should be made foremost based on site suitability, with considerations primarily on soil, water and light conditions.

For more information on plant choices, growing conditions and unique plant characteristics, please visit florafaunaweb.nparks.gov.sg

Glossary

Plant Care Requirements


Full sun


Semi-shade


Full-shade


Little water


Moderate water


Lots of water


Ocassional

Plant Use/Characteristics


Bird-attracting


Fruit and vegetable


Herb and spice


Butterfly host plant


Butterfly nectar plant


Storage organs

TREES

Ardisia elliptica
Seashore Ardisia

Plumeria pudica
Bridal Bouquet

Calliandra surinamensis
Powder Puff Plant

Calliandra tergemina var. emarginata
Red Powderpuff Plant

Callistemon citrinus
Bottlebrush Tree

Citharexylum spinosum
Fiddlewood

Clusia rosea ' Variegata'
Variegated Autograph Tree

Cordia sebestena
Geiger Tree

Cratoxylum cochinchinense
Yellow Cow Wood

Garcinia subelliptica
Happiness Tree

Gardenia tubifera
Water Gardenia

Leptospermum madidum ssp. sativum
Weeping Tea-Tree

Lophanthera lactescens
Golden Chain Tree

Podocarpus polystachyus
Sea Teak

Tabernaemontana divaricata
Pinwheel Flower

Photo credit: florafaunaweb.nparks.gov.sg

TEXTURED PLANTS

Anthurium veitchii
King Anthurium

Artemisia vulgaris
Common Mugwort

Callisia repens
Creeping Basketplant

Euphorbia tithymaloides ssp. smallii 'Albino' and cultivars
Zigzag Plant

Microsorum musifolium 'Crocodyllus'
Crocodile Fern

Microsorum punctatum 'Grandiceps'
Fish-Tail Fern

Osmoxylon lineare 'Yellow'
Yellow Aralia

Pennisetum x advena 'Rubrum'
Red Fountain Grass

Philodendron bipinnatifidum
Split-Lead Philodendron

Phyllanthus pulcher

Phyllodium longipes
Dragon's Tongue

Scaevola taccada
Sea Lettuce

Sesuvium portulacastrum
Sea Purslance

Vernonia elliptica

Xiphidium caeruleum
Angelhands

Photo credit: florafaunaweb.nparks.gov.sg

PLANTS FOR COLOUR

Arundina graminifolia
Bamboo Orchids

Brunfelsia pauciflora
Yesterday Today and Tomorrow

Catharanthus roseus cultivars
Rose Periwinkle

Codiaeum variegatum cultivars
Croton

Cryptanthus bivittatus 'Pink Starlite' and cultivars
Pink Starlite Starfish Plant

Cyanotis cristata
Nabhali

Lantana camara
Tick Berry

Pilea cadierei
Aluminum Plant

Portulaca pilosa ssp. pilosa and species/ cultivars
Pink Purslane

Strophanthus gratus
Climbing Oleander

Tecoma stans
Golden Bells

Tetracera indica
Fireweed

Trachelospermum asiaticum 'Tricolor' and cultivars
Tricolour Star Jasmine

Tradescantia pallida
Purple Heart

Zephyranthes rosea and cultivars
Rain Lily

Photo credit: florafaunaweb.nparks.gov.sg

FRAGRANT PLANTS

Aglaia odorata
Chinese Perfume Plant

Buddleja davidii
Butterfly Bush

Cananga odorata var. fruticosa
Dwarf Ylang-Ylang Tree

Centratherum punctatum
Brazil Button Flower

Cestrum diurnum
Singapore Kopsia

Crinum asiaticum
Seashore Lily

Cymbopogon citratus
Lemon Grass

Gardenia jasminoides
Gardenia

Ixora congesta
Malayan Ixora

Jasminum multifloru 'Variegatum' and cultivars
Variegated Star Jasmine

Jasminum sambac 'Maid of Orleans' and cultivars
Arabian jasmine

Otacanthus caeruleus
Amazon Blue

Polianthes tuberosa 'The Pearl'
Double Pearl Tuberose

Quisqualis indica (double-petaled)
Double Rangoon Creeper

Wrightia religiosa
Water Jasmine

Photo credit: florafaunaweb.nparks.gov.sg

EDIBLE PLANTS

Alternanthera sessilis 'Red'
Red Sessile Joyweed

Averrhoa carambola
Star Fruit

Canavalia rosea
Beach Bean

Carica papaya
Papaya

Citrus hystrix
Kaffir Lime

Clitoria ternatea var. pleniflora and varieties
Butterfly Pea

Coffea arabica
Arabica Coffee

Gynura bicolor
Okinawan Spinach

Helianthus tuberosus
Jerusalem Artichoke

Murraya koenigii
Curry Bush

Plectranthus amboinicus
Indian Borage

Sauropus androgynus
Cekur Manis

Synsepalum dulcificum
Miracle Fruit

Tagetes lucida
Sweetscented Marigold

Talinum paniculatum
Jewels-of-Opar

Photo credit: florafaunaweb.nparks.gov.sg

PLANTS FOR BIODIVERSITY

Antigonon leptopus and cultivars
Coral Vine

Arachnothryx leucophylla
Bush Pentas

Ardisia elliptica
Seashore Ardisia

Asclepia curassavica
Blood Flower

Asystasia gangetica
Chinese Violet

Caesalpinia pulcherrima
Peacock Flower

Callicarpa tomentosa

Calotropis gigantea
Giant Indian Milkweed

Coccoloba rugosa
Red-flowered Sea Grape

Costus productus var. productus

Hamelia patens (variegated)
Variegated Firecracker

Ixora congesta
Malayan Ixora

Kopsia
China Inkberry

Leea rubra
Pucok Merah

Rotheca myricoides 'Ugandense'
Blue Butterfly Bush

Photo credit: florafaunaweb.nparks.gov.sg

EPIPHYTIC PLANTS

Aeschynanthus albidus and species/ cultivars

Aglaomorpha quercifolia
Oak Leaf Fern

Asplenium nidus
Bird's Nest Fern

Bulbophyllum vaginatum
Magrah Batu

Coelogyne rochussenii
--

Cymbidium finlaysonianum
–

Dendrobium crumenatum
Pigeon Orchid

Dischidia ovata
Watermelon Dischidia

Hoya verticillata var. verticillata
Ridley's Hoya

Nephrolepis falcata
Fish-Tail Fern

Ophioglossum pendulum
Adder's Tongue Fern

Phalaenopsis cornu-cervi
Deer Antlered Phalaenopsis

Platycerium bifurcatum
Elkhorn Fern

Platycerium ridleyi
Ridley's Staghorn Fern

Grammatophyllum speciosum
Tiger orchids

Photo credit: florafaunaweb.nparks.gov.sg

Journal/ Publication references

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[1] Sustainable Singapore Blueprint 2015, Ministry of the Environment and Water Resources and Ministry of National Development, Singapore

2. WHY SKYRISE GREENERY

[1] Wong, N H, Y Chen, 2005. Study of green areas and urban heat island in a tropical city. Habitat International, Volume 29, Pages 547-558.

[2] Wong, N H, V L Wong, Y Chen, S E Lee, K W Cheong, G T Lim, C L Ong and A Sia, 2002. The thermal effects of plants on buildings. Architectural Science Review, Volume 45, Pages 1-12.

[3] Wong, N H, P Y Tan, Y Chen, 2007. Study of thermal performance of extensive rooftop greenery systems in the tropical climate, Building and Environment, Volume 42, Issue 1, Pages 25-54.

[4] Wong, N H, D K W Cheong, H Yan, J Soh, C L Ong, A Sia, 2003. The effects of rooftop garden on energy consumption of a commercial building in Singapore, Energy and Buildings, Volume 35, Issue 4, Pages 353-364

[5] Wong, N H, A Y K Tan, Y Chen, K Sekar, P Y Tan, D Chan, K Chiang, N C Wong, 2010. Thermal evaluation of vertical greenery systems for building wall. Building and Environment, Volume 45, Pages 663-672

[6] Wong, N H, A Y K Tan, P Y Tan, K Chiang, N C Wong, 2010. Acoustics evaluation of vertical greenery systems for building walls, Building and Environment, Volume 45, Issue 2, 1st International Symposium on Sustainable Healthy Buildings, Pages 411-420

SUGGESTED READINGS

CUGE STANDARDS

The Centre for Urban Greenery and Ecology (CUGE) standards is a set of written guidelines for voluntary adoption in the landscape and horticulture industry. They are developed through a formal process that involves consultation with relevant bodies and reaching consensus across all interested parties so that they are able to meet the needs of business and industry. All standards take the form of either specifications, methods, vocabularies, codes of practices or guides.

CS E01: 2010 - Guidelines on Design Loads for Rooftop Greenery
This guideline addresses the loading issues of rooftop greenery and provides suggested landscape materials and their appropriate placement on rooftop spaces. Some content has been revised and updated in CS E10:2014
ISBN 978-981-08-5231-3

CS E02:2010 - Guidelines on Design for Safety on Rooftop Greenery
This guideline highlights safety considerations during the design, installation and maintenance phases for rooftop greenery. Some content has been revised and updated in CS E11:2014
ISBN 978-981-08-5232-0

CS E03:2010 - Guidelines on Substrate Layer for Rooftop Greenery
This guideline provides an understanding of the constituting substrate components for rooftop greenery installations.
ISBN 978-981-08-7203-8

CS E04:2010 - Guidelines on Filter, Drainage and Root Penetration Barrier Layers for Rooftop Greenery
This guideline provides an understanding of the filter, drainage and root penetration barrier layers and recommended technical properties for the effective monitoring of the overall performance of the rooftop greenery installation.
ISBN 978-981-08-7206-9

CS E05:2012 - Guidelines on Waterproofing for Rooftop Greenery
This guideline outlines the basic considerations and requirements for the selection, application, protection and testing of the waterproofing layer of rooftop greenery installations.
ISBN 978-981-07-1271-6

CS E06: 2012 - Guidelines on Irrigation For Rooftop Greenery
This guideline sets out the basic technical considerations and requirements for the design, construction and up-keep of the irrigation systems for rooftop greenery.
ISBN 978-981-07-1272-3

CS E07:2012 - Guidelines on General Maintenance for Rooftop Greenery
his guideline addresses the requirements, respective needs and technical components for general maintenance of rooftop greenery.
ISBN 978-981-07-1273-0

CS E08:2012 - Guidelines on Design and Construction of Pitched Green Roof
This guideline identifies the basic design and construction requirements to address pitched green roof stability and feasibility issues.
ISBN 978-981-07-4725-1

CS E09:2012 - Guidelines on Planting of Trees, Palms and Tall Shrubs on Rooftop
This guideline identifies basic horitculture requirements for the planting of trees, palms and tall shrubs on roof gardens, as well as addressing basic architecture issues such as the sizing and design of rooftop planters.
ISBN 978-981-07-4726-8

CS E10:2014 - Guidelines on Design Loads for Skyrise Greenery
This guideline is an updated version of CS E01:2010 and includes basic requirements, considerations and estimates for associated design loads in the design, planning and operation of both rooftop and vertical greenery.
ISBN 978-981-09-1215-4

CS E11:2014 - Guidelines on Design for Safety of Skyrise Greenery
This guideline is an updated version of CS E02:2010. It sets out relevant safety requirements and safe design considerations for both rooftop and vertical greenery.
ISBN 978-981-09-1217-8

CS E12: 2017 - Design Guides to Promote Biodiversity on Roof Gardens
This guideline provides design considerations for the creation of biodiversity habitats in roof gardens.

For more information on safe working conditions at heights and safe lifting operations, please refer to:

- Approved Code of Practice on Working Safely at Heights
- Approved Document (by BCA)
- Circular to Professional Institutes on Amendments to the Fire Code – Review of Occupant Load Factors for Roof Garden/Roof Terrace/Sky Garden/Sky Terrace (by SCDF)
- Circular to Professional Institutes on Planting Beds on Sky Terraces and Rooftop Garden (by URA & SCDF)
- Code of Practice BS 6399: Part 1 (by BCA)
- Code of Practice for Surface Water Drainage (by PUB)
- Code of Practice on Safe Lifting Operations in the Workplaces
- DC Handbook for Residential Developments (by URA)
- Fire Code (by SCDF)
- Ladder Safety Pack
- Lifting Equipment - Technical Advisory
- Workplace Safety and Health (General Provisions) Regulations
- Workplace Safety and Health (Scaffolds) Regulations
- Workplace Safety and Health (Work at Heights) Regulations
- Workplace Safety and Health Guidelines - Anchorage, Lifelines and Temporary Edge Protection Systems
- Workplace Safety and Health Guidelines – Personal Protective Equipment for
- Working at Heights
- Workplace Safety and Health Guidelines - Safeguarding against Falling Objects
- Workplace Safety and Health Guidelines - Working safely on Roofs

THIS DOCUMENT CONSISTS OF INPUTS FROM THE FOLLOWING AGENCIES:

Building and Construction Authority (BCA), Housing and Development Board (HDB), Ministry of Manpower (MOM), National Environment Agency (NEA), National Parks Board (NParks), Public Utilities Board (PUB) and Singapore Civil Defence Force (SCDF).