An Analytical Approach to Vertical Green Systems in High Rise Buildings

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Submitted to the
Institute of Graduate Studies and Research
In partial fulfilment of the requirements for the degree of

Master of Science
in
Architecture

Eastern Mediterranean University
January 2017
Gazimağusa, North Cyprus

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ABSTRACT

The emerging megacities of the twenty-first century are not only known for the opportunities they provide but also for the destructive impact they have on the environment. The heat island effect caused by the increasing man-made environments and diminishing amount of green spaces in the cities has lately led to novel sustainable solutions such as the integration of vertical green systems in high-rise buildings in order to increase the amount of green spaces in the city and enhance the quality of life specially in cities growing vertically. For that reason, the research gives an in-depth review on existing vertical green systems (i.e. façade-supported green wall and/or living wall plants) as provisions for the integration of vegetation into high-rise buildings are required to be done during the design process. This knowledge is strengthened with a literature survey on important criteria, guidelines and regulations on vertical greenery. Then, the thesis focuses on selected precedents with integrated vertical green systems, mostly residential and office buildings, in need to understand how they are designed, constructed and maintained in practice. Overall, the study attempts to provide a deep insight into the green vertical systems, by looking into their standards, classification, how they are integrated into design, and installed during construction process, as well as how they are maintained during the operation of the building in order to benefit architects and researchers wishing to work in this field.

Keywords: Vertical Green Systems, High-Rise Buildings, Design Process, Construction, Installation, Maintenance.

ÖZ

21. yüzyıla girerken kent ve megakentlerin büyümesi ekonomik fırsatlar yaratırken, öte yandan çevreyi de olumsuz yönde etkilemişlerdir. Hızla yapılaşan çevrelerde azalan yeşilin bir sonucu olarak karşımıza çıkan ısı adası etkisine ilişkin üretilen özgün sürdürülebilir mimari çözümlerin başında kentlerdeki yeşil oranının ve dolayısı ile yaşam kalitesinin yükseltilmesini hedefleyen çok katlı binalara entegre edilen dikey yeşil sistemler gelmektedir. Bu araştırma, bu güne kadar inşa edilmiş çok katlı yeşil binalar çercevesi kapsamında iyi örnek oluşturabilecek konut ve ofis binalarına bakmakta, seçilen örneklem calışmaları ve onu destekleyen yazın taraması da önemli kriterlerin, kılavuz oluşturabilecek bilgi ve yasaların altını çizmektedir. Yazın taraması ve incelenen örneklemler, dikey yeşil sistemlerde cephe destekli yeşil duvar ve/veya tasarım sürecinde entegre edilebilecek canlı duvar bitkilerine dikkat çekmektedir. Yapılan yazın taramasi ile de desteklenen örneklem analizi sonuçları, bu konuda calışacak olan mimar ve benzer disiplinlerdeki profesyonellere dikey yeşil sistemlerin klasifikasyonu, hangi iklimlerde nasil bitki ve sistemlerin kullanılabileceği yanında nasıl monte edilebileceği ve bakılabileceğine ilişkin bazi teknik bilgiler sunmaktadır. Dikey yeşil sistemler ile ilgili henüz kapsamlı araştırma olmaması dolayısı ile bu çalışma önemli bir boşluğu doldurarak; konu ile ilgilenen profesyonellere yol gösterici niteliktedir.

Anahtar Kelimeler: Dikey Yeşil Sistemler, Yüksek Katlı Binalar, Tasarım Süreci, Yapım Aşaması, Montaj, Bakım.

ACKNOWLEDGEMENT

I extend my sincerest appreciation to my supervisor, Asst. Prof. Dr. Pınar Uluçay, who has kindly supported me during the formation of this thesis with her insight and tolerance while allowing me to work in my own pace and particular manner. I trait the level of my Master's degree to her consolation and exertion and without her support, I believe that the completion of this thesis would not have come true. I could not wish for a friendlier supervisor who has always given me encouragement with her sincere remarks.

Moreover, I am highly indebted to Assoc.Prof.Dr Müjdem Vural and Asst.Prof.Dr Nevter Zafer Cömert for accepting to participate in this process; as without their invaluable contributions, I would have never succeeded to finalize this thesis.

Lastly, I want to thank my relatives, my dad, my mum and my little brother for supporting and urging me to follow this challenging route. Without their consolation, I would not be able to gain this degree.

This thesis would not be finalized without the support of my lovely partner, Omid, to whom this thesis is dedicated to. He has been a source of encouragement and inspiration in my life.

To Omid

With my love and appreciation

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INTRODUCTION

Vertical growth in dense urban environments has become a significant solution for cities with expanding populations and very limited lands for building. Yet, spreading vertically rather than horizontally has reduced the possibility of inhabitants having access to green spaces, and based on this fact architects like Ken Yeang has come up with conceptual ideas like "maintainable" high-rise building design. He has additionally related this concept with green plants, neighbourhood atmosphere, and environment as well as the spatial conditions and the elements of the building. The integration of plants into design does not only help towards having more green in the city but also increases the quality of life of residents (Ottelé, Bohemen & Fraaij, 2010). The vertical greenery benefits the building by providing shading, enhancing the air quality and also adds value of the property (Ling and Ghafarian Hosseini, 2012).

At urban scale, more green in the city help towards the heat island effect, enhances urban air quality, decreases the carbon dioxide emission in to the atmosphere, and increases the biodiversity. At building scale, there are similar benefits that make the application of this system worthy. However, vertical green systems require expanded assets (fundamentally water and energy) to be managed well. Moreover, there is a necessity for the architect to consider the prominent weight of the system whilst considering the structural system. (Essentially twist, particularly vortex shedding). When history is reviewed, one comes across with many examples of integrated green systems and understands how this innovative technology came to being (Wong, Tan, Chen, Sekar, Tan, Chan, Wong, 2010). The first idea of vertical green systems, including a wide utilization of green facades and walls, can be traced to hanging greenery enclosures of Babylon, one of the seven antiquated marvels of the world, dating from between 600 to 800 B.C. In Pompeii for example, retailers made use of vine as shading elements where they left them hang from their shop balconies. From the Roman Empire to Scandinavia to Japan, different societies have made use of various sorts of vertical green systems for their building structures. During the Renaissance, for instance, we come across with Louis XIV's Palace greenhouses of Versailles in France where green is used on the facades and walls (Wong, Tan, Tan, Chiang and Wong, 2010).

The custom is still carried on in numerous hot-climate regions where diverse climbing plant species are used along building envelopes or in atria to shade the façade and wall from excessive sun radiation and to cool the air. In medieval Europe, elaborate climbing plants and natural product tree espaliers were used against a wall which in the yards of mansions and castles to give shade and to gather foods grown from the ground. Vegetation was regularly incorporated into the buildings of cold regions usually by the use of turf (a top layer of soil comprising of grass and roots) on rooftops. The Vikings for example constructed rooftops and facades with turf, which gave more noteworthy protection against serious cold climate conditions (Köhler, 2008). This building practice was spread all through the northern mid-west prairies of the United States and Canada, where the primary pioneers assembled houses from turf, stacking layers of prairie top soil on top of each other to from building facades and walls. In spite of the fact that turf gave sufficient protection from extreme weather conditions, it was not a decent basic material because of its defencelessness to water coming from rain and snow (Pérez, Rincón, Vila, González, and Cabeza, 2011).

In the tall building domain, numerous thoughts concerning integration of greenery into the building have been developed. For example, bioclimatic tall structures provided opportunities for vertical cultivation, by introducing a medium for plant and habitat life inside; as well as green social/shared spaces; and an aesthetic appeal at the exterior facade. The vertical greenery classification is thus immensely diverse and includes green facades, green walls and living walls. In recent decades, vertical green systems have turned into a tool for engineers, architects and craftsmen who coordinate to transform existing exteriors into green walls as well as developing new office spaces, residences and other common spaces with integrated green systems (Suklje, Vidrih, Arkar, and Medved, 2013).

Within this perspective, the researcher undertakes a deep literature review to list all applied categories of vertical green systems in chapter two; looks into their advantages and disadvantages in the application of high rise buildings; and highlights important issues to be taken into consideration during the installation and maintenance stages of vertical green systems into high rise buildings. The following chapter puts forth the most essential design criteria to be taken into consideration in need to form a checklist for interested disciplines who are involved in the design and construction of building integrated vertical green systems. Chapter four aims to look at the selected precedents (best building practices) so that the information gathered in chapter two and three can be justified. These are 10 best examples selected from around the world where different types of green walls are applied. Being mostly residential and office blocks, these selected precedents give the reader a better understanding on the topic and helps the researcher to initiate a discussion on the matter. Followed by discussions on the selected precedents, the research is concluded with recommendations for further research.

1.1. Aim and Objectives

The thesis aims to clarify the best possible ways of integrating and installing vertical green systems into high-rise building projects as well as understanding how they should be operated and maintained on longer term. Within this framework; the objectives are:

- Discovering various types of vertical green systems utilized in high-rise buildings
- Understanding how vertical green systems can be integrated into the design of high rise buildings
- Investigating existing standard and requirements for vertical green systems
- Listing important criteria and guidelines to be considered in the design of high-rise buildings with vertical green systems.

1.2. Problem Statement

The literature review on the precedents have proven that there is not many high-rise buildings with integrated vertical green systems, and the ones that exist are usually from cities with innovative technologies. Therefore, we can assume that these systems are still not well known in many parts of the world. Due to diminishing green spaces around the world, people are experiencing physical and mental health problems and it is very likely that vertical green systems will be looked upon as an appropriate sustainable solution for vertical cities in the future. These systems are also considered as an alternative for reintroducing agriculture into cities with no fertile lands. Therefore, there is a need to develop comprehensive criteria for future architects. Due to the existing gap in the literature, this thesis will be beneficial to those wanting to find inclusive information on vertical green systems and how they can be applied to high rise buildings.

1.3. Methodology

This thesis will employ qualitative methodology, based on the existing research from documented analysis, information from websites, books, articles, reports, and comparative case studies. The information for more extensive outcome is taken from different fact sheets. Some of the tables and figures and graphs stated and analysed here are taken from secondary references and sources. The information in chapter two was collected from scientific papers, books and internet sources where the classification and definition of vertical green systems are described and their advantages and disadvantages are discussed. Moreover, the installation technology, standards, and design requirements for green walls and green facades are presented with appropriate table and figures. The precedents selected include certifiable vertical green systems. The study comprises 10 selected buildings from eight cities of the world and attempts to give a perspective on various techniques discussed in the second chapter. These cities are Singapore, Bangkok, Santiago, Makati, Melbourne, Pittsburgh, Sydney and Tokyo. Almost all of these locations enjoy tropical climate which encourage the development of vegetation, lessening watering requirements and managing year-round green coverage. The case studies selected include various functions such as governmental offices, multifamily residential and commercial office buildings. In some cases, the readers may come across with missing information due to the absence of adequate data.

Chapter 2

THE USE OF VERTICAL GREEN SYSTEMS IN HIGH RISE BUILDINGS

Since the beginning of time, in need to maintain their presence on earth, mankind has dependably been in a persistent endeavour to adjust nature for their own particular needs, for example, shelter and nourishment. From the utilization of flame and working of caverns to the development of more modern devices and structures, people have figured out how to get by as well as set up families, tribes and after that social orders and urban areas. The world population has expanded because of the innovations of mankind. The population expansion put more weight on urban communities and urban regions where mankind started feeling segregated from nature. As this gap between mankind and nature developed, humanity's ability to appreciate and resonate with the natural world has shrunk (Sadeghian, 2016). Today, some urban communities appear to be totally separated from nature; and in cities cement and manufacturing plants rule. In any case, regardless of the current separation from the green space, people prefer not to lose contact with nature. All things considered, the world is a place where we meet our mental and physiological needs. In the recent decades, mankind have attempted to keep in contact with nature in cities with park areas in order to give individuals space in the outdoor areas, play, hold parties, and fundamentally escape from the city life (HOONG, 2011). Visual and physical contact with plants have not only visually enhanced mankind but also benefited their physical and mental well-being.

Albeit open parks help towards bringing down temperatures inside their region, they are unequipped for thermally influencing the concentrated structures where individuals live, work and spend the vast majority of their lives. The external surfaces of structures offer a generous space for vegetation in urban areas. Thus, planting on building walls and facades has started being used as a strategy for integrating green into high density urban areas, becoming part of architectural design. The system where the nature is integrated inside the vertical surface of a building is called vertical green system. A green wall is characterized as a vertical component either incorporated within the exterior of a building or as an unsupported structure that hosts vegetation and is every often installed in soil or in an inorganic developing medium (Wong, 2007). This chapter aims to explore these green building elements through a literature review where their types, characteristics, and applications are looked at in more depth.

2.1. The Definition and Typology of Vertical Green Systems

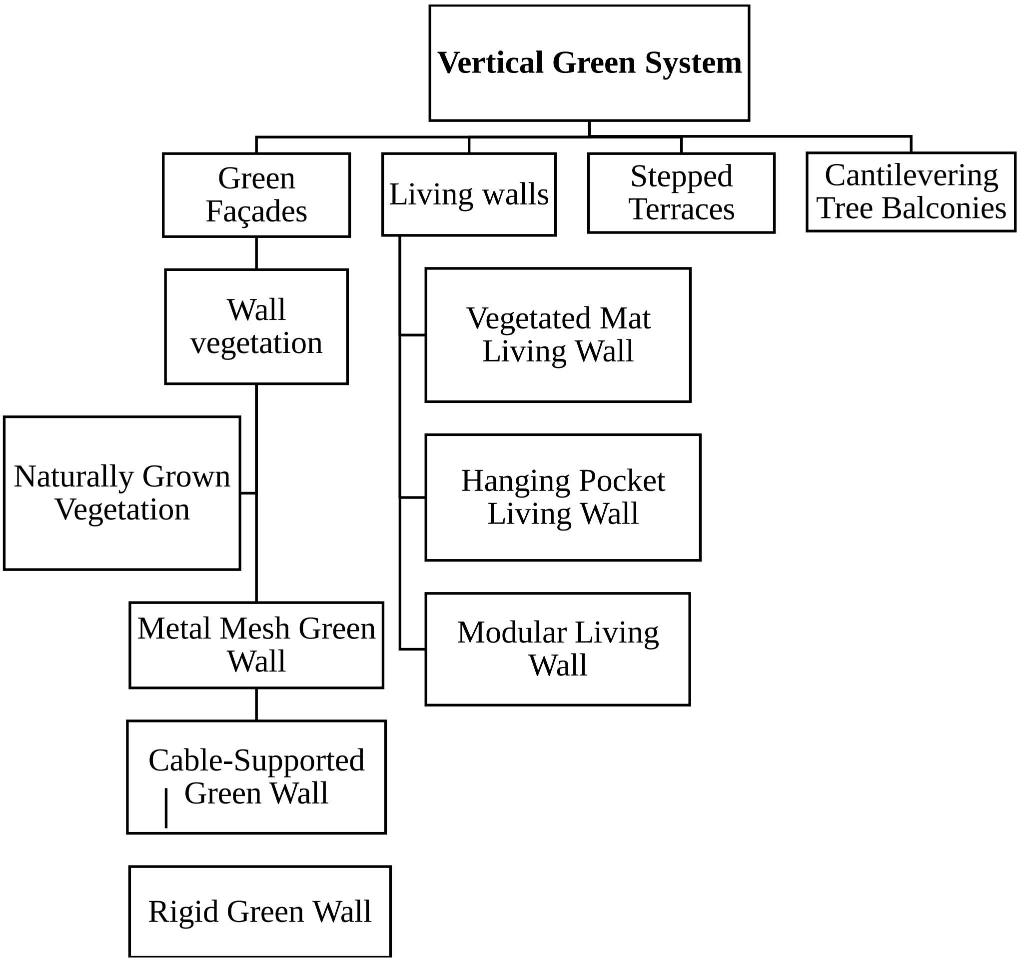
The vertical green system or vegetated walls or facades are characterized as a system in which plants develop on a vertical surface, for example, building exteriors in controlled temperatures with frequent maintenance. Climbing plants are normally seen on building exteriors by appending themselves specifically to vertical surfaces through the assistance of different instruments. Self-sticking climbers and self-supporting woody plants can connect themselves specifically to the façade surface or develop along the façade with no additional support (Köhler, 2008). Other plant species, incorporating climbers with elevated roots, suckers or tendrils, twining climbers, and ramblers, need an extra help, for example, trellises, mesh, or wires connected to the façade surface to advance or maintain vertical development. The main components of vertical green systems are thus:

- Plants
- Planting media
- Structures that support and append plants to the façade
- Irrigation system

Contingent upon the plant species, planting media, and support of structures utilized, one can recognize various sorts of vertical green systems, which, for the motivations behind this proposition, are extensively assembled into two classifications: Façade-Supported Green Walls and Living Walls. Moreover, from the case study analyses realized in the next chapter, more types can be named such as Stepped Terraces and Cantilevering Tree Balconies. After an extensive literature review, vertical green system can be partitioned into these diverse classifications (see graph1):

- Green Façades (Facades-Supported Green Walls)
- Living walls
- Stepped Terraces
- Cantilevering Tree Balconies

Figure 1: Example of façade-supported green wall (left) and living wall (right) (Irina Susorova,2013)



Graph 1: Classification of vertical green systems (krusche et al., 1982; Köhler, 1993; Hermy et al., 2005; Ottele. 2011)

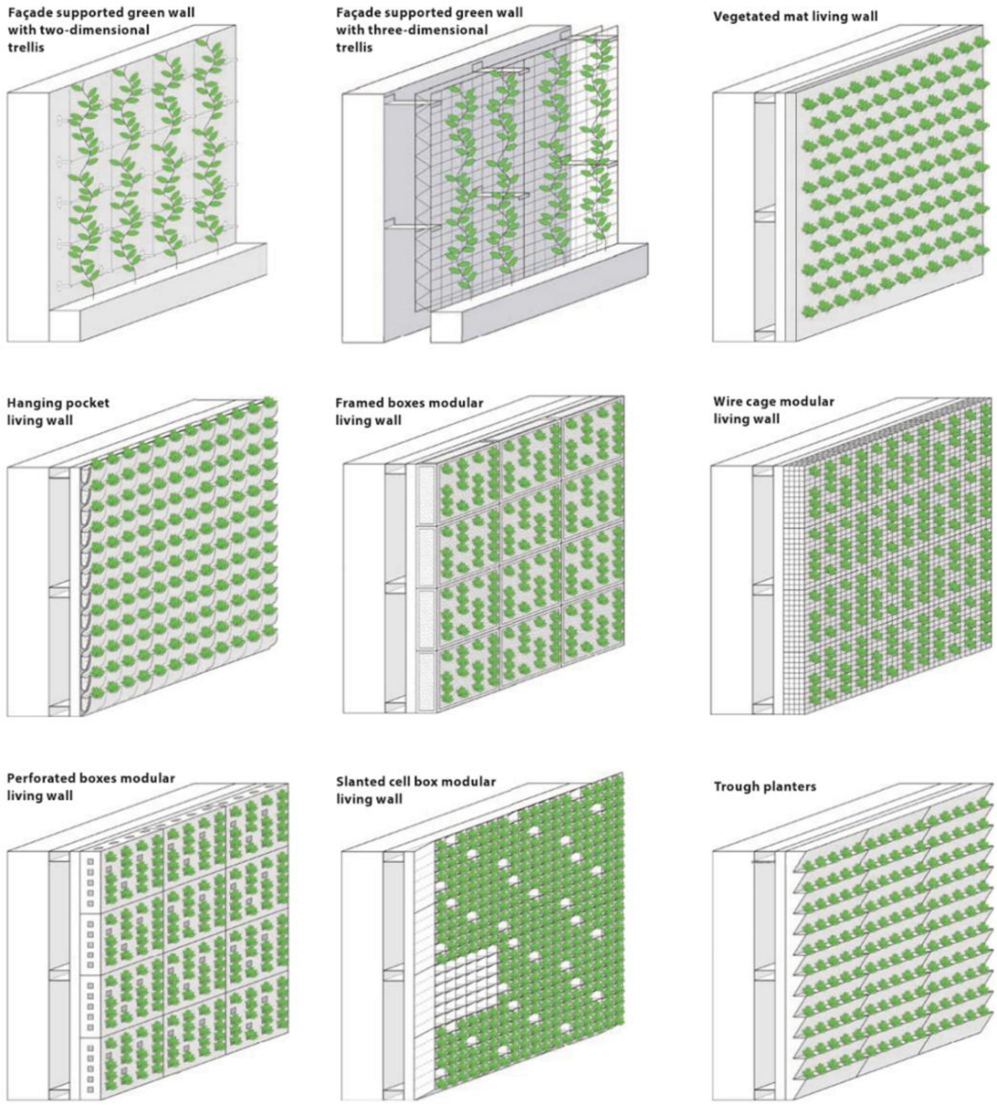
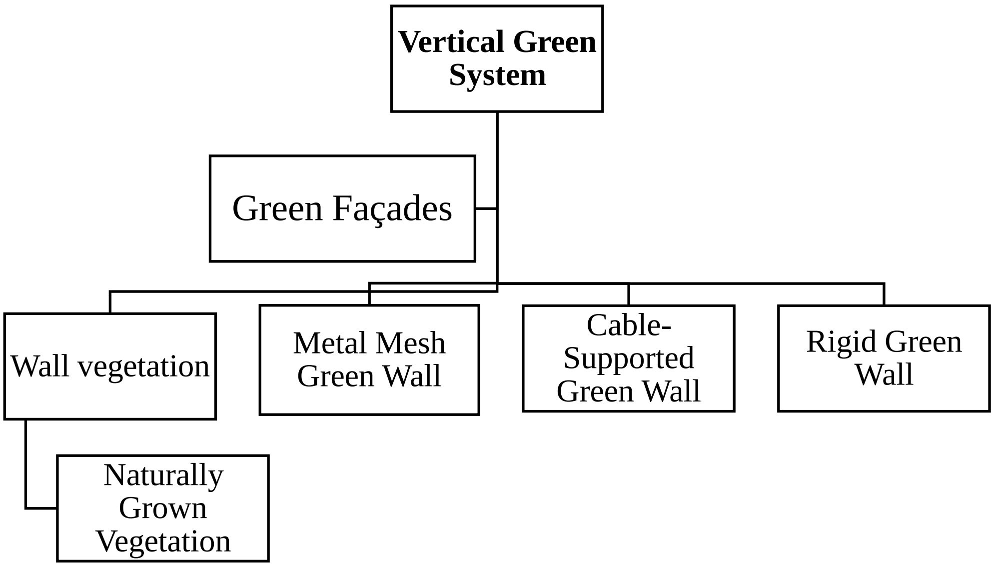


Figure 2: Various types of green wall systems (Author, 2016)

2.1.1. Green Façade (Facade-Supported Green Walls)

A facade-supported green wall is a system supported off by a façade, however where the planting medium is not vital to the façade. Typically the planting medium is conveyed in level grower, which might be situated on the ground or at different interims along the stature of the exterior walls and facades. A façade-supported green wall structural system typically involves steel, wood, or plastic trellises remotely appended to a building façade where climbing plants and vines are bolstered by even, vertical, or corner to corner trellis individuals (Perini, Ottelé, Haas, Raiteri, 2011). Green facades can be two-dimensional, shaped by links, ropes, and networks, or three-dimensional, framed by inflexible casings and confines. For the inspirations driving this postulation, sub orders of façade-upheld green walls are perceived by auxiliary emotionally supportive network, as laid over here (see graph2).



Graph 2: Classification of green façade (façade-supported green wall) in vertical green system (Author, 2016)

- **Wall vegetation**

These plants for the most part develop on wall surfaces like joints and breaks, and also along the highest point of some walls. Wall vegetation can likewise be partitioned in two classes: Naturally developed vegetation and concrete pre-assembled boards with vegetation. (Ling, Ghaffarian, 2012).

- **Naturally Grown Vegetation**

The fundamental norm for this sort of Green Wall is the characteristic development of vegetation on old or abandoned buildings (see figure3). This type of vegetation is also seen on historic walls, recorded landmarks, and other old structures with broke down mortar or building material that empowers plants to root. These plants develop actually in unpredictable and impromptu routes as a result of the non-existent human intervention. Concrete pre-assembled boards with vegetation:

> Green concrete is a pre-assembled board fundamentally made with solid that offers basic quality and also a base for vegetation taking into account fast and unconstrained plant colonization on a wall. One of the solid legitimacies is the porosity; a unique plan utilizing coarse total and adding air to the blend amid the setting makes solid boards with vast pores that can be secured and loaded with a particular soil mixture. To give structure, this layer rests on another layer of self-compacting concrete. Along these lines, vegetation is permitted to develop between the huge solid pores where some dirt has been amassed. All together for these stages to ingest water actually, the boards are tilted marginally vertically keeping in mind the end goal to gather water from outside precipitation. A drawback to this strategy is a consequence of high pH levels in the solid and low levels of water: adaptability. Just a little amount of plants can thrive on these boards.

Figure 3: Section of naturally grown vegetation green façade system (Author, 2016)

- **Metal Mesh Green Wall**

A metal mesh green wall utilizes a firmly interlaced framework of aluminium or lightweight steel, generally joined to the façade by means of sections. Plants normally develop from grower or troughs deliberately situated all through the stature of the wall. Several case studies analysed in this thesis utilize this system: Council House 2, Melbourne; Newton Suites, Singapore; The Met, Bangkok; Pasona Headquarters, Tokyo; Singapore; and IDEO Morph 38 Tower, Bangkok.

- **Cable-Supported Green Wall**

Cable-Supported green walls utilize adaptable links that are utilized to bolster plants in unpredictably formed and wide-traverse establishments. Helios Residences in Singapore is an example to this type.

- **Rigid Green Wall**

This system can use two and three-dimensional trellises that can be joined to a wall substrate, worked around segments, or can be unattached. The Consorico extend in Santiago is an example to this type. (See figure6).

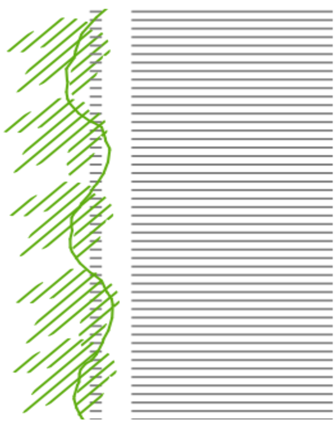
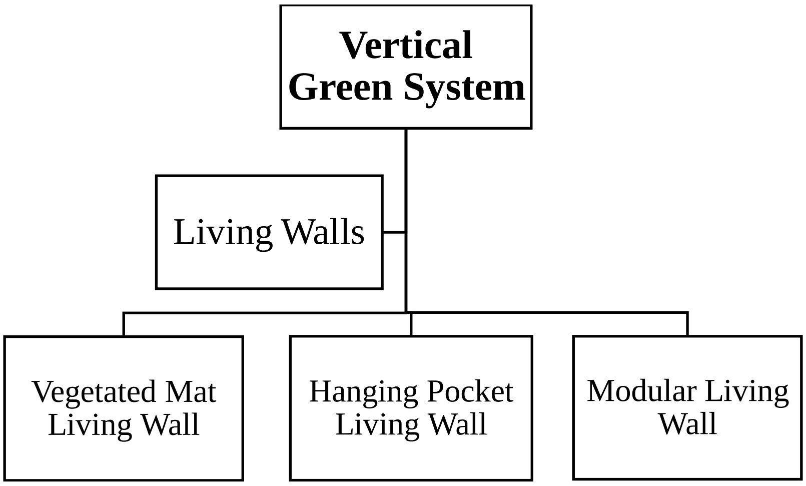


Figure 4: Section of rigid green wall system (Author, 2016)

2.1.2. Living Walls

A living wall is a system in which vegetation is appended to a building facade, as well as being completely coordinated into the facade development in which plants and planting media are both put on the vertical surface of the outside wall (see graph3). Ordinarily, living walls are isolated from the facade surface by a waterproof film layer planned to secure whatever is left of the exterior development from undesirable dampness (Sharp, Sable, Bertram, Mohan, Peck, 2008). Irrigation and water system frameworks can be departed with rain sensors to make the living wall's required irrigation system more proficient and manageable. There are different varieties of living walls, as highlighted below:



Graph 3: Classification of living wall in vertical green system (Author, 2016)

- **Vegetated Mat Living Wall**

This kind of living wall comprises a texture layer joined to an unbending substrate. Pregrown plants are embedded into gaps cut in the texture layer, where they set up their root system in the middle of the layers that serve as the planting medium (see figure 5). Vegetated tangles ordinarily work like water-based hydroponic systems, in light of the fact that no planting medium is utilized and supplements are conveyed to plant roots through water from irrigation system pipes behind texture layers (Jaafar, Said, Reba, Rasidi, 2013). Trio Apartments in Sydney represents this system (see figure 6).

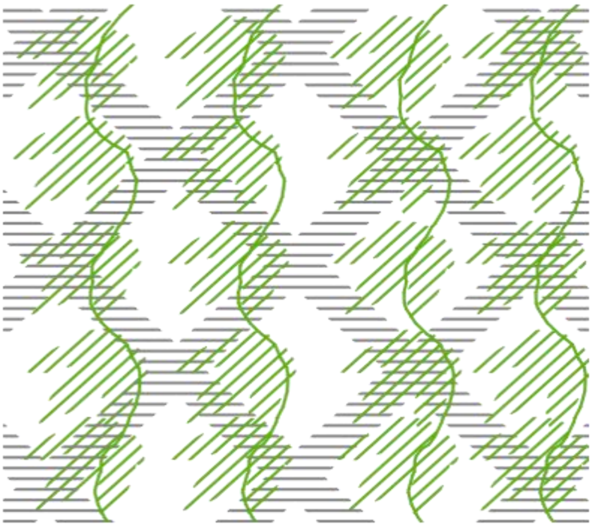


Figure 5: Elevation of vegetated mat living wall system (Author,2016)

Figure 6: An example of a vegetated mat living wall system (Irina Susorova, 2013)

- **Hanging Pocket Living Wall**

Like vegetated mats, this green wall comprises pocket-like texture compartments joined to an unbending substrate layer. Plants are established in these felt or plastic compartments loaded with planting medium (see figure 7 and 8).

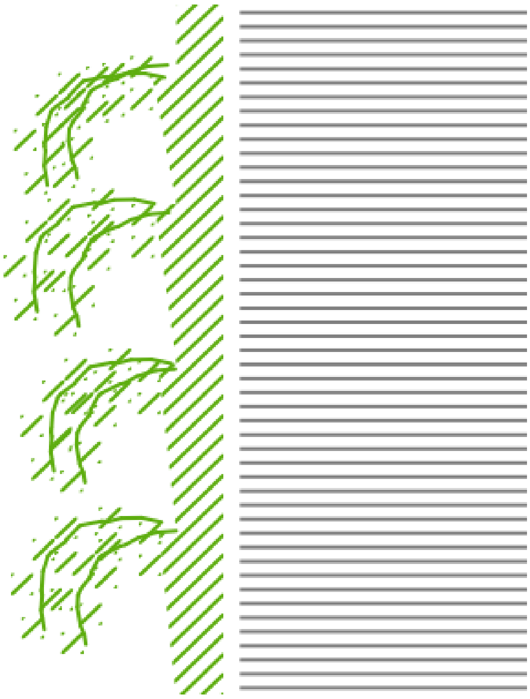


Figure 7: Section of hanging pocket living wall system (Author, 2016)

Figure 8: An example of a hanging pocket living wall system (Irina Susorova, 2013)

- **Modular Living Wall**

Secluded living walls, made of inflexible rectangular compartments that are loaded with planting media, can be joined to an outside wall or be detached (see figure9). The holders are produced out of metal or lightweight basic plastic and can be formed as encircled boxes, wire enclosures, or strong boxes with pre-cut openings. Sometimes, the holders are subdivided into littler individual cells and set opposite or calculated to a compartment's back wall. Measured living walls can likewise be produced using a progression of troughs or flat scaled down grower stacked vertically. Plants are then developed straightforwardly in holders that are loaded with soil, non-natural planting media, or common fiber (Wong & Baldwin, 2016). Cases in this thesis include PNC Plaza, in Pittsburgh and Skypark at Gramercy Residences in Makati.

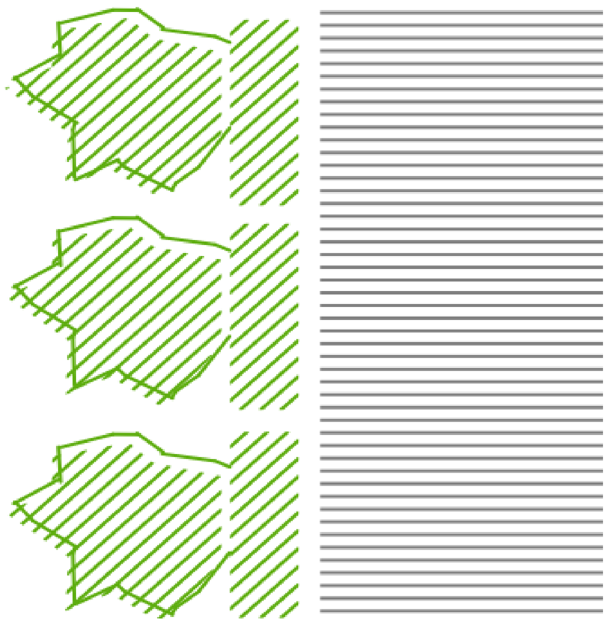


Figure 9: Section of modular living wall system (Author, 2016)

2.1.3. Stepped Terraces

Stepped Terraces commonly comprise solid floors holding planting medium in plate with infill walls, progressing upwards in steps, much like the terraced rural planting fields found on soak slopes in many parts of the world. This approach is frequently utilized when the plants and their related media are fluctuated or require a lot of soil, and a green wall (see figure10).

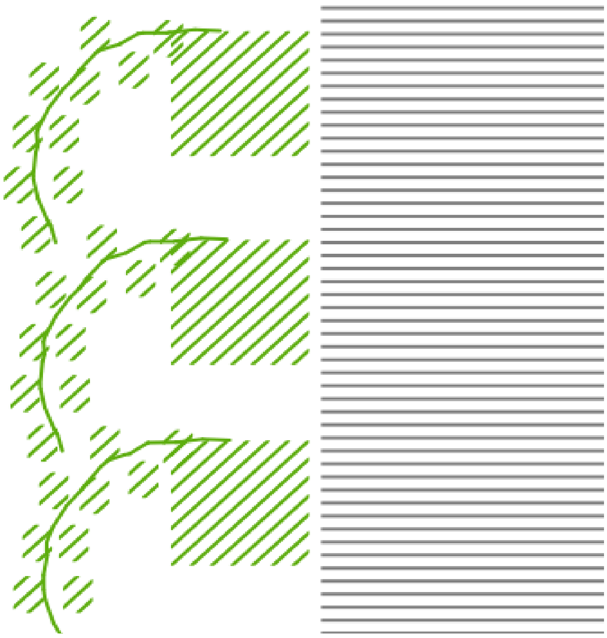


Figure 10: Section of stepped terraces system (Author, 2016)

2.1.4. Cantilevering Tree Balconies

A few structures put considerable trees before their façade utilizing an anticipating balcony. Such stages regularly contain grower of a profundity adequate to support a root structure and the required soil, once in a while up to the level of the security railing. As a result of the heaviness of the tree and soil, the stages have a tendency to be made of strengthened cement and are coordinated into the structure of the building (Djedjig, Bozonnet & Belarbi, 2016).

2.2. The Advantages of Vertical Green Systems

Depending on favourable circumstances relating to factors such as geographic range and climate, building geometry, presentation and plant species, green wall, or green façade systems, there may be various advantages of vertical green systems (see table1). These advantages can be arranged from urban scale to building scale.

Table 1: Comparison of Living wall and façade supported green wall (Manso & Castro-Gomes 2015)

Parameter	Façade – supported green wall	Living wall
Cost	**Less expensive**	**More expensive**
Lifespan	Up to 100 years and longer in some verifiable structures secured by climbing plants	10-15 years life expectancy, which is generally shorter than the structures life expectancy
Maintenance	Few maintenance system required; visual inspections and plant pruning	High maintenance system required; plant pruning, regular inspection of façade structural integrity, and irrigation and watering system required
Irrigation	Natural watering by rain, with manual and automatic watering and irrigation systems	Automatic watering system
Structural Support	Light-weight structural support off the façade (cables, mesh, trellises)	More professional structural supported system; additional dead loads on high-rise buildings structural system need to be calculated
Thermal performance/ insulation	Thermal advantages	Better thermal advantages
Best climate zones	All climate zones	Hot climate zone

- **Benefits: Urban Scale**

Urban heat island effect reduction

Air quality improvement

Reduction in Carbon Emission

Aesthetic appeal

Psychological impact on urban occupants

Adding to natural surroundings and increasing biodiversity

Reduction of noise

- **Benefits: Building Scale**

Building energy efficiency advancement

Improvement in the air quality of internal spaces, oxygenation and air filtration

Health benefits

Envelope protection

Reduction of interior and exterior noise

Agricultural production

Expanding property value

Yet, there is also the other side of the medallion: Green Wall systems can have a few drawbacks. However, with mechanical upgrades, some of these weaknesses may diminish or basically vanish. Green Walls likewise have outcomes like falling leaves, the additional underlying expense, and support costs (Manso & Castro-Gomes, 2015). The multiplication of creepy crawlies is a constructive reaction from an environmental view yet for the most part is thought to disturbing for individuals, particularly for indoor living wall. There is a presumption that Green Walls can harm dividers yet actually plants work to secure and keep up the trustworthiness of walls.

2.2.1. Vertical Green Systems Urban-Scale Benefits

- **Reduction of the Urban Heat Island Effect**

The Urban Heat Island (UHI) effect is brought about by the temperature increase in downtown areas where dense urban structures exist. Temperatures in less dense areas are much less as there is usually less built up areas and more green. According to the US Environmental Protection Agency, the yearly mean air temperature of a city with one million individuals or more can be 1°C to 3°C hotter than its surrounding environment. At night, the distinction can be as high as 12°C. Among different outcomes, the UHI impact expands the utilization of mechanical aerating and cooling to cool buildings, adding to energy utilization, air contamination and gas releases to the climate (Ottelé, Bohemen & Fraaij, 2010). The UHI impact can be improved by bringing more vegetation into urban areas, through urban parks, living walls, and green facades. Plants make a milder microclimate by engrossing warmth to lessen open air temperatures, expanding moistness levels, and protecting buildings and settings from direct sun and wind.

- **Improvement in Air Quality**

During procedures of photosynthesis, plants change carbon dioxide, water, and sun based radiation into oxygen and glucose. Plants accordingly create oxygen, and are thusly fundamental for life on this planet. In urban contexts where land is mostly covered by man-made structures and plants are rare, there is less oxygen generation. Furthermore, various urban sources discharge carbon dioxide and other gasses into the climate. In this circumstance, more gasses are delivered than can be dealt with by plants, prompting to a lower quality of urban air. It has been accounted that the yearly oxygen necessity for one individual can be delivered by a tree with a five meter distance across shelter or by 40 square meters of a vegetated wall and facade secured with thick planting (Minke &Witter, 1985).

- **Reduction in Carbon Emission**

Every single living plant have the capacity to store, or "Emit" carbon that would somehow be discharged into the environment through carbon dioxide, a gas that adds to climate change. Numerous urban areas have initiated tree-planting projects to reduce carbon-emission activity; be that as it may, in numerous urban regions there is a constrained supply of land that can bolster trees and their root frameworks. Vine-based green facades and living walls can give a fabulous, space-and water-sparing option. Vines do not only develop on the dividers of existing structures and require less planting media but they also help in the reduction of carbon dioxide emission. The vast majority of the energy of a tree goes toward developing its trunk, which gives supplements and elevation to the leaves, yet does not make oxygen. Vines are totally made out of leaves, and hence can help the eradication of CO2 more than a tree of comparable mass (Vaingsbo, 2014).

- **Aesthetic Appeal**

The most noticeable advantage of green-wall systems is their aesthetic appeal. Different plants, with their one of a kind hues and surfaces, can be skilfully utilized as a live craftsmanship medium that progresses its shade as per the season. Green walls can enliven a building exterior by covering up unattractive surfaces, (for example, auto parks) or by supplementing existing building highlights. Such green walls can be absolutely elaborate, or can have different advantages. For example, when set close to the ground, green dividers can add aesthetic value to parks or streetscapes used for recreational purposes. The visual impact of green walls is more observable than that of green rooftops, as they are effectively observed from the road level (Arefi & Keivanizadeh, 2015).

- **Psychological Impact on Urban Dwellers**

Vertical green systems enhance the nature of human life in the constructed environment. In many parts of the world, urban regions are especially unattractive for people on foot, with their hard surfaces and auto driven planning organization. Vertical green systems do not give just tasteful alleviation from the repetitiveness of cement and steel; they additionally give substantial help from the heat that transmits from the surfaces of structures and roads and have a quieting impact on urban societies (Afrin, 2009).

- **Providing Biodiversity and Creating Natural Animal Habitats**

A British review that broke down the biodiversity of vertical urban surfaces found that building walls and exteriors provide great conditions to specific types of plants and creatures (Darlington, 1981). As indicated by this review, the most well-known life forms found on outside vertical green facades and walls are green growth and lichens, which can develop in miniscule fissure and opening, other trademark facade tenants are greeneries greenery, liverworts, sedums, herbaceous plants, vines, grasses, and even some coniferous plants. These plant varieties adjust well to vertical life in the light of their capacity to stay in cleft and splits, utilize building surfaces for support, and maintain themselves on little measures of supplements and water (Milana, Gkoumas & Bontempi, 2014). A thick layer of vegetation on building exteriors likewise makes alluring natural surroundings for creepy crawlies, winged animals, and little creatures (see table2).

Table 2: Providing biodiversity and creating natural animal habitats (Darlington 1981)

Common Name	Scientific Name	Green Facade	Living Wall
Pigeon	Columba Livia	•	
Collared Dove	Streptopelia Decaoto	•	
Jackdaw	Corvus Monedula		•
Rook	Corvus Frugilegus	•	
Magpie	Pica Pica		•
Robin	Erithaus Rubecula	•	•
House Sparrow	Passer Domesticus	•	•
Starling	Sturnus Vulgaris		•
Blachbird	Turdus Merula	•	•

- **Decrease of Sound**

Hard surfaces help sounds be bobbed, opened up and diverted. The commotion of activity, sirens, horns are all synonymous with urban life. Thickly vegetated green walls can have an effect on the urban commotions, while giving both a visual and sound-related indication of nature in generally exceptional and mad situations (Sheweka & Magdy, 2011).

2.2.2. Vertical Green Systems Building-Scale Benefits

- **Improvement in Buildings' Energy Efficiency**

Exterior plants have different constructive outcomes on building heat execution, which incorporate expanded wall protection (particularly on account of living dividers in colder atmospheres), facade shading (particularly and roads and have a quieting impact on urban societies in more humid atmospheres), air cooling through evapotranspiration, and lessening of twist close to the facade. Shading with plants prompts to a lessening in the temperature slope of a building's outside dividers and in heat conduction through the building envelope. Evapotranspiration cools and humidifies the air around the plant layer while the permeable structure of the plant layer, shaped by foliage and branches, brings down air temperature close to the exterior. Decreased exterior surface temperatures and diminished small scale atmosphere outside air temperatures close to the facade considerably bring down heat conduction through building envelopes and for lower air invasion into structures, which infers better building energy execution and less energy use (Croeser, 2014).

- **Internal Air Quality, Air Filtration and Oxygenation**

Numerous urban communities experience the ill effects of air contamination that can lead to various human infections and can possibly quicken the weakening of building materials. It has been demonstrated that air quality can be enhanced through the presentation of vegetation. Plants are known to trap airborne particles in their foliage and assimilate vaporous toxins from the environment. Plant leaves likewise can retain particles of substantial metals from the environment, including cadmium, copper, lead, and zinc. A German review exhibited that the air pollution check in a road without trees was 10,000-20,000 earth particles for every litre, instead of 3,000 soil particles for every litre in a tree-lined road (Minke &Witter, 1985). Air pollutions are available in the climate, as well as inside structures where different building materials (cements, rugs, electronic gear, and cleaning liquids) radiate unpredictable natural mixes (VOCs), substance exacerbates that can contrarily influence human wellbeing. As of late, some building designers have begun utilizing the air sifting capacity of plants in green facades and walls for better indoor air quality. Green walls are a characteristic contrasting option to vitality expending simulated filtration, serving as inside Biofilter to expel contaminations from the air. One such Biofilter is the NEDLAW Living Wall, a restrictive Biofilter living wall comprising of toxin debasing (Specht, Siebert, Hartmann, Freisinger, Sawicka, and Werner & Dierich, 2014). A solitary go of the air through the five-centimetre-thick living wall can expel up to 80% of the formaldehyde, half of the toluene, and 10% of the trichloroethylene. For each 100 square meters of floor space, one square meter of living wall ought to be utilized to channel the air viably.

- **Health Benefits**

Plants are known to have an impact on the mental and physiological well-being of individuals. Results of numerous reviews showed that when inside buildings, individuals want to have a visual association with outside vegetation which creates positive feelings (White and Gatersleben, 2011). Also, the air sifting and oxygenating capacities of plants can significantly profit individuals experiencing breathing sicknesses brought about by urban pollution, for example, asthma or sensitivities (see table3).

Table 3: Recorded health improvements after the integration of plants (Croeser 2014)

Ailment	% Reduction
Fatigue	20%
Headache	30%
Sore/dry throats	30%
Coughs	40%
Dry facial skin	25%

In some of the case studies selected including the Consorcio building in Santiago, perceptible upgrades in efficiency and a decrease in sickness related work has been recorded owing to proximity to greenery. Green walls' capacity to channel light, enroll changes in season, and, develop nourishment for inhabitants, cultivates a level of engagement with environment and nature that are not accessible in vigorously built office structures.

- **Envelope Protection**

Exterior vegetation secures wall development behind the plant layer from bright radiation that can bring about material disintegration. By lessening every day temperature variances, plants decrease inside concerns in building materials, which can prompt to material splitting and untimely maturing. On extraordinary days, the uncovered exterior temperature can differ between - 10°C and 60°C while the temperature of a plant-secured veneer varies just somewhere around 5°C and 30°C

(Minke &Witter, 1985) (Wiser, 2011). An outer plant layer on a building serves as an envelope layer," likewise shielding wall materials from physical harm and shedding pushing precipitation far from the wall development. Furthermore, wall development materials that are shielded from outer elements do not require as much maintenance, have expanded life expectancy, and subsequently, have brought down life-cycle costs and expanded heat protection. It ought to be noted, in any case, that some climbing plants particularly can bring about issues with intrusion into building joints if not chosen legitimately, and can even bring about basic harm if not eased.

- **Interior Noise Reduction**

Greenery has solid sound constriction qualities that can be used by giving a layer of vegetation in living walls and green facades to decrease turmoil transmitted to indoor spaces. (Renterghem, 2013).

- **Agricultural Benefits**

Green walls can be utilized for developing agrarian plants, for example, tomatoes, eggplants, zucchinis, squash, cucumbers, beans, and grape vines. Along these lines, in a few atmospheres, vertical surfaces in urban communities can possibly get to be distinctly smaller scale ranches, where neighbourhood inhabitants have the chance to develop new delivery for their own particular use. Nearby delivery developed in urban homesteads is new, occasional, and promptly accessible at the purpose of need to city inhabitants. Such ranches can likewise turn into a focal point of nearby group life. Right now, a few makers are creating business living wall items which can be utilized for developing sustenance vertically, for instance, the Green Living wall system by Green Living Technologies LLC (Green Living Technologies) and the Reviwall system (Reviplant, 2008). A model of such an eatable wall was introduced in Gladys Park, a low-income neighbourhood in Los Angeles, by Green Living Technologies LLC (Irwin, 2008).

- **Increasing Property Value**

A few reviews have exhibited that vegetation found in buildings, for example, green rooftops or green facades, can expand the property value by up to 20% (Pitts &Jackson, 2008), (Fuerst and McAllister, 2009), (Miller, 2008), (Eichholtz, 2010). Free research led by the UK-based Royal Institute of Chartered Surveyors (RICS) explored green structures in Canada, the United States, and the United Kingdom. According to the examination, which depended on the blend of various case study analyses, it was presumed that "the economical elements of green structures can increase the value of land. The developer reasoned that structures with considerable green components do not just positively affect nature and wellbeing of people but additionally give profitable spots to life and work, secure higher leases and costs, pull in occupants more rapidly, lessen inhabitant turnover, and cost less to work and keep up (Corp, 2005).

2.3.3. Green Rating System Credits

Buildings using vertical greenery can frequently get credits in Sustainability Programs, for example, the administration in energy and ecological plan program, the deliberate green building rating system by the US Green Building Council. Green walls can contribute straightforwardly or with other maintainability building components to a structures authority in energy and natural plan affirmation in all classes including Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation in Operation as sketched out underneath.

- **Sustainable Sites Development**

Green walls can accomplish credits in Storm Water Design and Heat Island Effect classifications by averting excessive storm water release and by evacuating suspended particles and different contaminations from the storm water. The dull foliage of green façade and living walls diminishes sun powered reflectance from structures, in this manner decreasing the urban heat island effect (Gobster, 1998).

- **Water Efficiency**

Buildings can utilize a storm water gathering system, including rain water collection, ventilation and cooling condensation, and establishment of drainage for water system of green walls and other scene highlights and help diminish waste water. The potential credits incorporate the Water-Efficient Landscaping and Innovative Wastewater Technologies.

- **Energy and Atmosphere**

Green walls give an extra layer of protection and characteristic cooling through evapotranspiration. These impacts can offer significant energy and cost reserve funds, which change contingent upon an area's atmosphere zone. The potential credit incorporates the classification: Optimize Energy Efficiency Performance.

- **Materials and Resource**

Vertical green systems can be considered in two classifications

Recycled Content

Regional Material

- **Indoor Environmental Quality**

The potential credits incorporate Best Management Practice: Reduce Particulates in Air quality; Occupant Comfort: Occupant Use; and Green Cleaning: Indoor Integrated Pest Management.

- **Innovation in Operation and Design**

Green wall configuration can add to the mental and physical medical advantages of people. The potential credits Include Innovative Wastewater or Ventilation systems.

- **Cost Effectiveness**

Vertical green systems are thought to be practical. The heat costs, protection and soundproofing equivalents diminish energy use. Particular warm seclusion of any surface outcomes in incredible vitality sparing while the heat produced from the Sun light will be consumed by the green wall. It additionally advances assimilation of contaminations and commotion, which enormously enhance acoustics. The significant main wall of warmth developed in many urban communities is measured as the ingestion of sun oriented radiation by hard surfaces, for example, solid structures and the sun oriented impression of glass surface structures. Having vertical green systems, the plant surfaces temperature nonetheless, do not rise more than 4-5°C over the surrounding and are now and again cooler (Göktürk, 2013). This means energy sparing. In addition, the cost of working cooling system is diminished altogether. Neighbourhoods with all around composed and maintained green wall systems can increase the property estimations from 7% to 15% giving a positive impression to the property buyer. It frequently mollifies the recently created private and business area. It also diminishes cooling costs (Veisten, Smyrnova, Klæboe, Hornikx, Mosslemi & Kang, 2012).

2.3. Negative Aspects of Vertical Green Systems

In spite of the fact that there are many advantages in reintroducing vegetation to the surfaces of urban elevated structures and their related spaces, some specialized issues are confronted during usage (Johnston, 1993). Living wall systems are relatively new innovations and infrequently explored yet (Ottele, 2011). There are no genuine drawbacks known for living wall systems. For both green façades and living walls, climbing plants should be chosen which do not prove to be fruitful or give a nourishment source. Additionally, property supervisors lean toward firmly trimmed vegetation to dishearten protect or settling destinations for flying creatures. Any over the top development or dead wood ought to be expelled and standing water ought to be kept away from. A persistent rock strip at the base of the building is prescribed by Prades (Villanova, 2013).

- Damage on vertical green systems such as the green façade directly installed to the façade and wall
- Vertical greenery maintenance
- Vertical green systems costs
- Watering or Irrigation systems

2.3.1. Construction

- **Installation of Vertical Green Systems**

The majority of problems on the walls and facades can be influenced by climbing's plants, for example, Hedera helix plants. The issue can be separated in two: Roots which are entering through the establishment and sewerage pipes if there should an occurrence of green façade specifically to the wall (Hermy, 2005) Adhesive structures sucker root structure of plants straightforwardly to the wall and facade (Hermy, 2005; Kohler, 1993). On the off chance that the divider is extremely smooth, than the cement (sucker) roots would isolate natural acids and respond with limestone materials and structures crystalline mixes. With this compound response the sucker roots can infiltrate a couple of micrometres inside the wall (Kohler, 1993). This demonstrates plants with sucker roots can suck the wall solidly which is really a decent normal for these plants for developing on façades. In view of the thin stems and the footrope character, the plants develop effectively to the dull openings and by removing the plants from the wall, the sucker roots stay on the wall, which is hard to evacuate (Hermy, 2005). By removing the plants additionally some free layers from the wall structure can expel, and cause pressures in the divider, which frames the principle harm.

- **Installation of Vertical Green System**

- **Construction costs**

Vertical greening systems are a costly cladding procedure (Ottele, 2011). The living wall systems are significantly more costly than green façades with climbing plants, as a result of irrigation and water system framework, more materials included, more plant species, and so on. Contrasted with the climbing plants, the living wall systems can satisfy different capacities and increment the assortment of plants that can be utilized. The living wall systems have a mind boggling plan and they can likewise give tasteful pleasure, seeing structures from a separation and a fast develop of the greened surface. The irrigation and water system framework which is required for the living wall systems and the particular supporting structures as indicated by every framework shape likewise a part of the higher expenses (Othman & Sahidin, 2016).

- **Maintenance costs**

As indicated by Middelie (2009) and Perini et al (2011) the following procedures involve the most expensive items in green wall systems.

Management system of the irrigation

Using of boom lifts during pruning phase costs

Replacing of plants

Replacing of panels

Costs of human labour

Fallen leaves disposal and collection

2.3.2. Operation

- **Maintenance of vertical greening systems**

All vertical greening systems require some level of maintenance since they are living walls. The measure of support a client will give is an essential benchmark in the determination of the kind of system and plant species to be introduced.

- **Facades-supported green wall**

Green façades by and large utilize Hedera or/and vines that may develop from ground soil or from grower boxes and every area will have diverse water system and supplement necessities. Site area and conditions may require that a typically vigorous or non-subordinate vine species be given extra water system and supplements. Some plant species will be deciduous and some may give organic products or blooms that may require extra care and support. (Pérez-Urrestarazu, Fernández-Cañero, and Franco-Salas & Egea, 2015).

- **Living wall systems**

Because of the assorted qualities and thickness of vegetation, living wall systems ordinarily require more escalated maintenance (e.g. a supply of supplements to treat the plants) than façades-bolstered green wall. The level of support may likewise be impacted by the client desires of the stylish characteristics of a living wall system establishment and at what level prospering vegetation should be kept up (Perini, 2011). A couple of maintenance necessities are depicted below. Vegetation with high supplement necessities will for the most part require a more noteworthy level of care than those that have advanced from poor supplement situations (Yu-Peng yeh, 2010). Living wall systems require normal pruning (long haul support) and the exact degree to which maintenance will be required will rely on upon the kind of living wall system and the vegetation utilized, substitution of plant species when they are passed on, and selecting of the correct plant species (Ottele, 2011).

- **Irrigation of Vertical Green Systems**

The principal aim of irrigation system is to guarantee that ideal water administrations are kept up inside the root zone of plant species. The functional issue that all water system planning techniques need to battle with is to set up how much water and supplements ought to be added to the dirt and when this ought to be finished. A nonstop evaluation of exactly what plant species requires is in this way vital to the usage of any proficient water administration system. Building up proper levels of watering and suitable levels of supplements are essential living angles which ought to work ceaselessly. Else it can bring about issues by overlooking of administration and working (Yu-Peng yeh, 2010), Irrigation and water system frameworks are vitality devouring which manage a procedure for the ceaseless checking of the dampness administration inside the root zone, and depends on conveying a self-robotized system (Ottele, 2011).

Chapter 3

DESIGN CRITERIA FOR VERTICAL GREEN SYSTEMS

3.1. Vertical Green Systems Design Considerations

There can be various targets and inspirations behind green wall proposals in design considerations which can be summarized as below. One of the primary targets as discussed previously can be the introduction of more green into the city as climate considerations. Design considerations can help us make optimum use of plant selection, structure and materials. Green walls can be introduced on existing structures or new developments (Perini, 2011). Building capacities (business, lodging or private), building size, site analyses and envelope materials will all affect the choice of vertical green system and plants for high rise buildings. Below, important criteria in the design of vertical green systems in high rise buildings are listed and discussed.

3.1.1. Climate Considerations

Local climate characteristics are among the most basic components influencing decisions of vertical green systems in planning. Air temperature, relative humidity, wind speed, sun radiation, overcast cover, and month to month precipitation will all influence the suitability of vertical green systems and plant species. However, as can be seen from the Koppen map showing the location of case studies, green wall systems are usually seen in hot-humid climates where there are necessary humidity levels to support the growth of plants on the vertical green systems. Green walls can grab hold in a choice of atmospheres, given watchful plant choice, exterior temperature, and water system techniques (Renterghem, 2013). When selecting a project area in a specific climate, it is important to decide plant species that can effectively develop in a green wall, in the specified climatic zone. For example, the development time of green wall plants in central, completely humid zones are around a year, however a similar development period is just a couple of months for mainland zones with cold winters. Climatic conditions additionally characterize "plant toughness zones, "geographic ranges grouped by the capacity of plants to withstand the lowest temperatures in that zone. For instance, plants portrayed as "tough to zone 9" can withstand a winter temperature of 19 °F (- 7 °C), the run of the mill least in zone 9. There are 13 strength zones; the least number relates to plants that flourish in greatly cool conditions (Sheweka & Magdy, 2011). Accordingly we can conclude that vertical greenery is achievable in areas with normal temperature varieties, with right plant choice and framework decision. However, relative humidity levels are important; for example in selected case studies, in Singapore the humidity varies between 82% to 86% during the whole year, whereas in Santiago, this difference can be between 58% to 83%. The thesis utilizes the Koppen map order system (see figure 11) to understand in which climatic zone each of the case study is located.

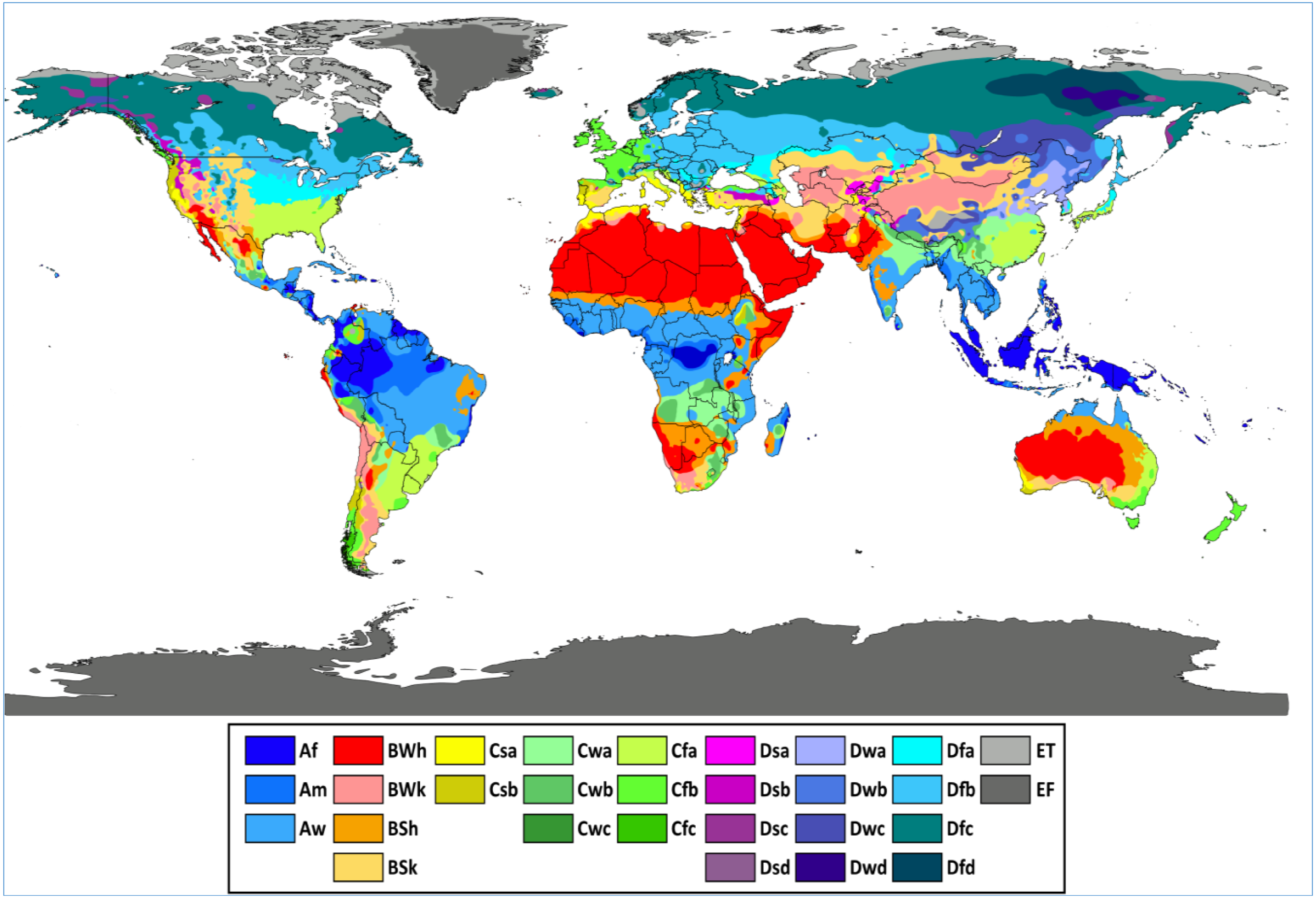


Figure 11: Word map of Koppen-Geiger climate classificatio

The measure of sun radiation will influence plant species decisions and wall introduction. While all plants require light and some daylight, an excess of direct sun radiation for some plants can be ruinous. In the selected case in Santiago, the amount of daylight is 4 hours whereas in Bangkok, Thailand it is 7.2 hours (The measure of sun powered energy that really infiltrates to ground level can likewise be critical, and as a component of height and overcast cover, can at times appear to deny the hours of normal daylight information. As far as day by day daylight and sunlight based energy is concerned, the parts of Bangkok are turned around, while Bangkok, at 1.5 meters above ocean level, gets a most extreme of just 748 WH/m².

The measure of precipitation is another important determinant of how every now and again plants should be watered, and which plant species can be supported in a green wall, extends in this postulation run from a normal month to month precipitation of 30 millimetres (Santiago, Chile) to 201 millimetres (Singapore). Every project has embraced a fitting water system framework to mirror the nearby atmosphere and plant decision (Smith, 2013).

Another vital thought is normal twist speed at the green wall area and the green walls presentation to wind. Plants are by and large powerless to wind and can be at all times harmed by high winds. Eventually, the research in this thesis demonstrate that outer vegetation can be upheld in areas with normal twist velocities of up to 4.4 meters for each second, as shown in the case study in Singapore. Since areas in the tropics additionally encounter infrequent storm winds, it can be assumed that green walls designed for such areas can likewise survive at times much more grounded wind speeds (Solaris, 2012).

- **Temperature and humidity**

When planning living walls and green façade it is vital to comprehend the neighbourhood atmosphere and the particular qualities the climate presents. Taking a look at the month to month normal temperature and relative humidity over various years will not give a genuine photo of the outrageous conditions, while analysing the figures on an individual month to month or even regular schedule will give data that is more valuable to architects. In Adelaide to build up a living wall system appropriate for tall structures the everyday figures inside the month of January 2016 were inspected, where the extraordinary conditions were effectively observed. For example, rather than a month to month mean most extreme temperature of 32°C, the greatest every day temperature of 45.7°C should be considered in outlining appropriate systems. Correspondingly, the least relative humidity perusing was just 4% at 3 p.m. on one specific day, so this exhibits an extraordinary condition contrasted and the month to month mean of 23% (Hopkins, 2010). Not just are the most noteworthy greatest temperatures in Adelaide reliably well more than 40°C, however the relative stickiness scope of between just 4% and 13% implies that, to keep away from drying out, most living things, including plants, creatures and people, require a standard supply of water to adjust for the absence of dampness vapour noticeable all around. A vanishing rate of 36 mm at the stature of summer is put into setting when contrasted and the mean dissipation rate of only 3.3 mm for the winter month of August 2016 (SOLARIS Multiplexes, 2009).

- **Sun exposure**

The other similarly essential component is the length and quality of exposure to the sun: On surfaces where the normal yearly direct daylight is under 3 hours every day, just expressly shade tolerant plants can be planted. Where the exposure is more than 6 hours, plants that require a sunny position will do the best (summer hot-spells may bring about harm). If there should arise an occurrence of exposure somewhere around 3 and 6 hours, plants prescribed for half-shady positions are appropriate; this is the best level for developing and working a vertical green system (Sternberg, Viles & Catherside, 2011).

- **Site Microclimate Conditions**

It has been specified that green walls have an extraordinary potential to direct the microclimate promptly encompassing the expanding on which they are introduced. The siting of the building will along these lines assume a solid part in deciding how viable the green wall will be in changing that microclimate.

- **Building Orientation**

A building's orientation becomes an important consideration in the selection of façade that will have the green wall system. A wall confronting a back street facing shadowed areas for a large portion of the day would be a poor possibility for a green establishment. The face with the best exposure to daylight for the longest time of day (west and south in the northern half of the globe, west and north in the southern side of the equator) will support the largest coverage of plantings and will have more shading and cooling potential (Susorova & Bahrami, 2013). The plant choice may give an ideas on the green wall system in that particular climate (see figure12).

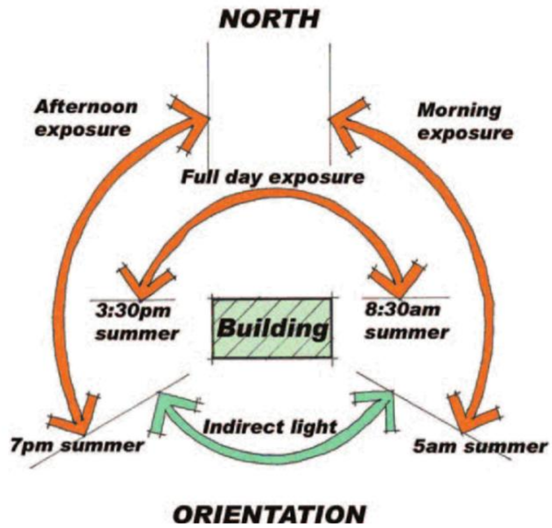


Figure 12: Building orientation diagram (Author, 2016)

- **Exposure to Wind**

While considering vertical green systems in a city, wind streams around tall buildings should be considered. Twist stream on a solitary elevated structure has been all around reported, and a general comprehension is that wind speed increments with tallness and that over 10 stories the speed increments at a higher rate than underneath 10 stories. At the point when wind is opposite to the high-rise structure, the wind is redirected over the rooftop, around the closures of the building and some is occupied down the facade to ground level and some up the exterior to rooftop level. At the point when this wind is redirected around the building, the speeds change as the air is compacted around the building corners. Wind shadows are likewise made on the leeward side of structures (Yeang, 2006). These wind streams are quite compelling when planning living wall systems on the grounds that expanded wind speed affects the developing states of the plants, the auxiliary limit of the plants and the basic limit of the system and how it is settled to the exterior (see figure13). At the point when structures are in groups or in a road situation, there are extra impacts on the wind examples and speeds. Confined wind examples and turbulence, whirlpools and twirls happen, and in addition expanded speeds, in light of the fact that the wind is frequently constrained through littler openings or between structures, so nearby wind appraisal ought to be examined before planning a green facade or living wall (Susorova, Irina, Azimi, Parham, Stephene and Brent, 2014).

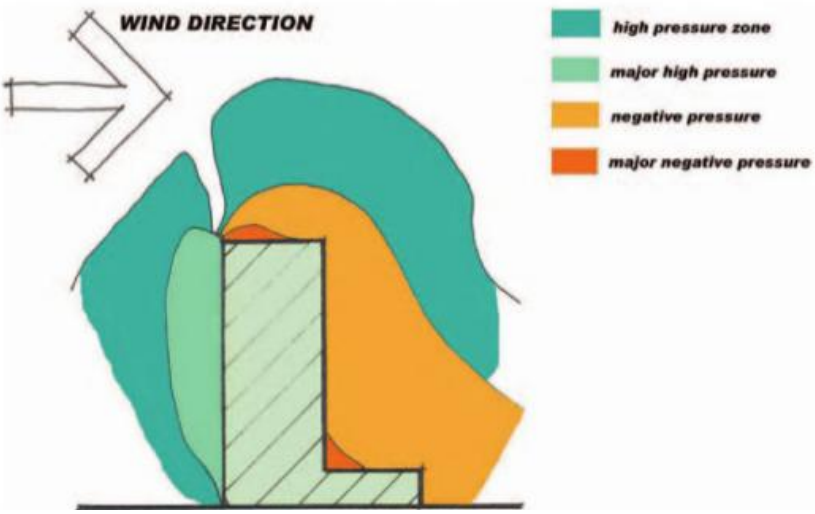


Figure 13: Building elevation wind direction (Author, 2016)

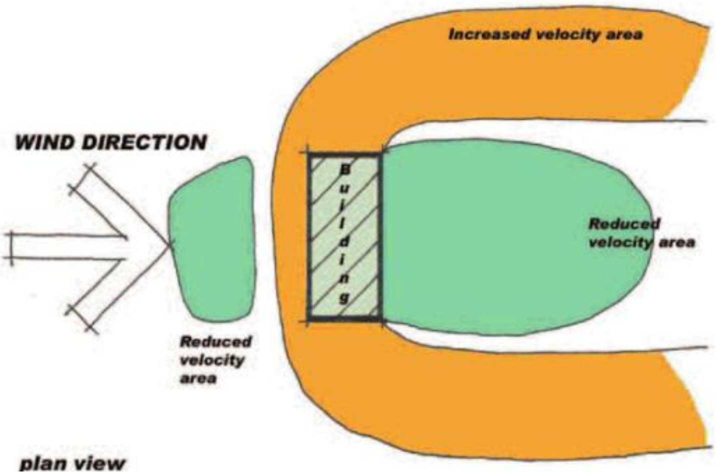


Figure 14: Building plan wind direction (Author, 2016)

Diverse plants have distinctive water prerequisites, so selecting the most proper plants for the specific area is basic, and is talked about in more detail beneath. Twists loadings on the basic casing of the living wall system will turn into an unmistakable calculate the outline of the surrounding, particularly when the living wall is found higher on the tall building façade (see figure14). In particular, the twist stacking on the settling gadget onto the exterior is amazingly basic given the potential pneumatic force differential in the crevice between the facade and back of the confining system. The following basic element is the settling between the plants and planting medium holder and the encircling system (White & Gatersleben, 2011). The greater part of the exclusive frameworks has a huge extent of plastics of some sort, and it is hard to anticipate their auxiliary conduct under outrageous wind loadings. A large portion of these new and reused materials have a low bending level without auxiliary disappointment and, joined with potential long haul UV corruption, these materials may not be appropriate. Ideally, the encircling and compartment systems ought to be of metal so that the basic limit can be effortlessly computed and their weathering life span guaranteed (Webb, 2005).

One of the greatest psychological boundaries to actualizing green walls at stature which has a premise as a general rule is introduction to wind, which has a tendency to quicken and whirl as it goes by an obstacle, (for example, an elevated structure), in a marvel referred to physicists as 'vortex shedding' (see Figure15).This ought not keep planners from endeavouring to place green walls at tallness, yet it merits the investigation of particular twist conditions at the level and area of the proposed establishment, as these can change broadly, from floor to floor and side to side of a tall structure (Wong, Hassell & Yeo, 2012).

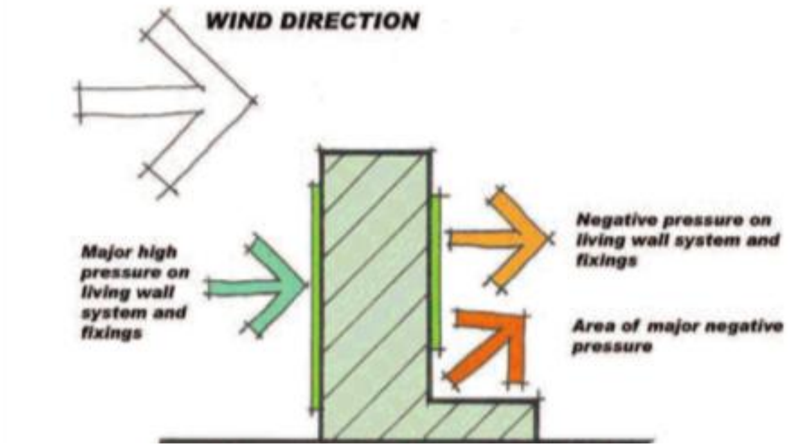


Figure 15: Wind direction pressure on vertical green system and fixings (Author, 2016)

Case studies in this thesis manage twist introduction at stature in a few ways. Newton Suites in Singapore has a metal work supported green facade that runs about the full tallness of the 120-meter building. The overarching wind is from the north, at 4.4 meters for each second (Wong, Hassell, 2011). The greenery is put on a stem wall confronting east, running opposite toward the south facade, toward balconies (which likewise bolster trees) that are tucked behind the projection of the building mass, along these lines setting it in a wind-ensured position (see Figure16).

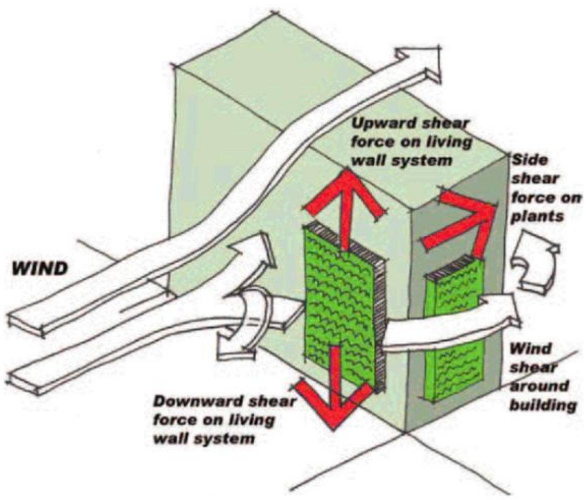


Figure 16: Direction shear force on vertical green systems (Author, 2016)

At the Met, in Bangkok, both private and open balconies are set into indents between vertical balances or under shades, expelling plantings from direct presentation to sun and wind. Then again, there has been some experimentation with arrangement of plantings in ensured zones on this façade (Wong, 2010). The architecture design group was compelled to relinquish plantings in inward centre fire staircases, mostly on the grounds that the plants couldn't manage themselves under the constrained sun introduction. At the Skypark at Gramercy Residences, one of the most noteworthy establishments in this case study, the facade incorporated living wall is conveyed on an inward exterior that is generally open to the components, however ensured by the external bend of the building structure, behind glass and shades (Wong, Nyuk Hien, 2009).

- **Creating Milder Microclimates near Outdoor Areas**

Through shading and envirotranspira-lion, plants can generously decrease the temperatures of the prompt region around them. The Met, in Bangkok, reported a distinction of up to 15 °C between the surface temperatures of greenery region and nearby concrete. This shows one of the bigger scale targets of green dividers generally - to lessen temperatures and enhance the microclimate around the venture, as well as the city general through diminishing the urban warmth island impact. Clearly, various green walls and even greenery areas and parks cooperating will expand the advantage altogether by engrossing bit sunlight based warmth and making MOM oxygen (Almgvist, 2012).

Table 4: Vertical green systems climate considerations

	Vertical green systems Climate Considerations
Wind	Normal wind velocities are more noteworthy at tallness than at ground level. Winds might be solid around the edges of structures, or from the down draft brought on by tall structures. It is important to comprehend the feasible wind stack that a green rooftop, wall or facade will be subjected to, so it can be worked to withstand the strengths. Twist at high rise will likewise impact temperature, and wind has a direct drying out impact on vegetation, in this manner affecting species choice and water system necessities.
Rainfall and irrigation	Precipitation is by and large not adequate to support a green wall or facade consistently. It is essential to build up whether water or another water source can be gathered from different regions on location, and put away to supply a water system framework. This will maintain a strategic distance from or minimize the need to utilize consumable water for water system. It is helpful to do an irrigation system water request examination, to gauge water needs.
Solar radiation	Light power has a tendency to be more noteworthy at stature than at ground level. At tallness there are less structures, no vegetation to assimilate sunlight based radiation and expanded reflection from connecting building and surfaces, (for example, glass and light-hued walls). Then again, there are a small walls and exteriors that may get altogether less sun based radiation, because of extraordinary shading by adjacent structures. Shadowing and shading investigation can be utilized to evaluate zones of light and shade on a site and conceivable changes throughout the year (for instance, at the equinox) and after some time (for instance, bordering new building advancement)
Temperature	In urban situations temperatures tend to increment with height, because of the expanded warm mass of fabricated structures and the comparable warmth pick up. Evaluating the possible temperature go on a site is critical in planting outline, especially in outrageous temperature occasions. While cool temperatures are seldom an issue for, there can be restricted green rooftop circumstances where this could be a calculate

	plant determination.
Microclimate	Encased spaces, for example, urban ravines can make their own particular microclimate where wind turbulence, pooling of contamination, mugginess and temperature can be escalated. The confined atmosphere of these regions will change the developing conditions for plants and should be considered when arranging and outlining green walls.

3.1.2. Structural Considerations

Plants and soil can be substantial, particularly when trees achieve full development and the planting medium is wet. The building structure should be capable to support plantings at their fullest degree, and under extreme wind and seismic load conditions, where relevant. Both exterior upheld green walls and living walls add additional weight to building facades and this needs to be taken into account by architects and structural engineers (Berndtsson, Bengtsson &Jinno, 2009). Plant weight alone can reach to 50 kilograms for every square meters. Extra auxiliary arrangements ought to be made to respond to snow, rain, and wind loads. Putting a green wall on a current building will require an exterior assessment to guarantee the facade's auxiliary weight (Blanc, 2006). When outlining a green wall for new development, its support structure ought to be coordinated with the outside wall development. Suitable strategies need to be utilized to withstand high twist loads on the exterior and to secure grower set up. Basic support for exterior supported green walls incorporate two-and three-dimensional trellises, nets, wires, links, and ropes made from an assortment of materials. These backings can be introduced as unsupported items (wall and segments), regularly propped back to the exterior, or as boards joined to the wall itself. A living wall support structure is normally incorporated into the envelope development and is made of solid stone work, consuming safe metal edge, or wooden casing (Blunden, 2010). The support structure ought to be legitimately waterproofed to avoid water leakage into the outside wall development. Basic materials ought to be precisely chosen to keep away from erosion and antagonistic impacts to plant wellbeing. The greater part of the exterior supported systems are made of light-gage steel or aluminium, and are upheld by systems that separate the planting medium support from the developing structure for the plants themselves, or convey the load more equally over the building facade. Still, the gravity load of a sectioned system, and the limit of a system to be pulled in a solid wind, ought to be assessed before introducing it (Cameron, Taylor & Emmett, 2014).

The load bearing limit of a building must be known before arranging a green wall or facade. For retrofitting a green wall or exterior, it is vital to decide early whether the establishment will meet the current basic limit of the building, or whether this will be altered to support the establishment (D'Alencon, Nobel & Fischer, 2009). It is vital to consider not only the heaviness of plants but rather their weights at development, particularly where bushes and trees are proposed, as these are probably going to be altogether heavier after some time. The heaviness of soaked plants and substrate should likewise be incorporated into the load evaluation. Some case weight loadings of plants are given. Harm to a wall can emerge from wind strengths; plant weight and tie stray. (Derbyshire, 2001).

Table 5: Weight loading of vertical green systems

Dead load	The last developed weight of every single constructed component and all segments connected with the rooftop or wall gathering, including plants, developing substrate and any water held in the system.
Live load	The weight of individuals who will utilize the space, and of any versatile gear that will be utilized intermittently on the site, for instance, maintenance (live load by and large applies to green rooftops, not exteriors or walls, be that as it may it would be proper on a vertical surface if a trafficable support stage was incorporated with the system).
Translent load	Moving, short-term loads, including wind

Table 6: Representative climbing species weight loadings

Façade-Supported Green Wall Species	Weight loading (kg/m2)
Jasminum (Jasmine), Rosa (Rose)	6-12
Clematis (Clematis), Tropaeolum (Flame Nasturtium)	3-12
Vitis (Ornamental Grape), Ampelopsis (Porcelain Vine)	12-26
Lonicera (Honeysuckle), Actinidia (Kolomitka), Wisteria(Wisteria)	10-26

Apart from the free climbing answer for green walls, the foundation system should be basically overviewed. The structure must be safe against meteorological burdens and outside and interior mechanical effects. Besides, the way that the plant may create massive and copious foliage, the weight and range of which is extremely hard to foresee, must also be considered (Holm, 1989). It is prescribed subsequently to significantly oversize the framework or to utilize plants, where the most extreme foliage size is not huge and can be assessed (normally the lasting, yearly and semi-annual herbaceous plants). Consideration ought to be paid to the part of the structure with the biggest weight, which as a rule is the irrigation and water system. The correct amount of water put away in the planting medium in a water-soaked condition fluctuates per system; the sum is more prominent for higher esteem systems than for lower cost setups. In outrageous cases the water-soaked weight might be products of the dry mass (Hoyano, 1988).

There is no perfect size for a green wall, in any case, plainly, the bigger portion of a building's surface it can cover, the greater amount of an impact it will have on sensation, shading potential and microclimate control. Additionally impediments of stature and access have to be considered, as well as the level of staff required, to keep up especially substantial or remote establishments, particularly in the upper spans of a building’s exterior. Still, it has been demonstrated that structures of all sizes can support green walls (Huang, Akbari & Rosendeld, 1987). Amongst the case studies, the largest building in terms of gross floor zone is the Met, Bangkok, at 124,885 square meters. The smallest is the Newton Suits-Singapore, 2007 at 11,835 m^2 square meters. The largest single facade carrying a green wall, and the largest percentage of a wall covered in greenery in this thesis are Ideo Morph 38 Tower Bangkok built in 2013. Although it should be noted that this south facade is actually a series of stepped walls and horizontal terraces, the 1,276m^2 - Ashton east green wall at Asthon covers 66% of the facade, to the degree that the building appears almost completely covered in greenery from the south (Keen, 2009). This should be compared against an average of 66% for the largest single facade coverage across all 10 case studies. The sheer size of the IDEO installation is moderated by relatively easy access via a constantly ascending switchback pathway. The largest percentage coverage of an entire building in this thesis is Ideo Morph 38 Tower Bangkok, 2013 where 23% of the vertical wall surface in the complex (actually composed of two buildings) is covered by significant trees and other plantings on projecting residential balconies.

The Met, Bangkok, which incorporates 7,170 square meters of green wall; covers 14% of the whole facade range; and the IDEO Morph 38 Tower in Bangkok, with 5,850 square meters of green coverage occupies 23% of the whole facade. The smallest coverages are the Skypark at Gramercy Residences, Makati, Philippines, at 189 square meters (just 0.4% of the aggregate surface zone of the building) and Trio Apartments, Sydney, at 139 square meters, (or 0.7% of that building's surface region). Wall mounted green façades can be levelled with walls or set 3-18 crawls from the wall surface utilizing mounting clasps or "standoff" sections. A waterproof layer is not required. The profundity of the trellis modules shields building surfaces by keeping plants from appending specifically to walls to counteract issues that could some way or another trade off a building's respectability (Gonchar, 2009). The structures likewise disseminate the heaviness of climbing plants over the screen structure and wall. In tie and rope wire systems, stops and turnbuckles are introduced toward one side of every tie for fixing and alterations as required by plant development. Climbing plants require a decent supply of dampness and intermittent pruning, contingent upon species, appearance, and natural life control. Supporting structures require insignificant upkeep, with just incidental checking of the pressure and basic associations. Establishment of pre-developed boards for green facades and living walls requires a lead time of 6-12 months before conveyance for plants to proliferate and develop first as attachments and to fill in the boards (Gonchar, 2009). The boards can be developed on a level plane until the date of shipment to the site, when they are then mounted vertically. High-thickness solid dividers might be watertight; be that as it may, a waterproof layer might be required for establishment on metal or wood outline structures

Roughly 500 square feet of living wall boards with edge can be introduced in one day. No less than one month preceding the establishment of the wall, water supply and power supply for a programmed trickle irrigation and water system framework ought to be associated (at the highest point of the wall or for individual boards, contingent upon the system). A standard compost circle is suggested for the infusion of fluid supplements for the plants). The developing medium inside the boards ought to be completely immersed once per day during the week after establishment; from there on, water is given to keep up dampness without over immersion. The particular framework permits boards to be taken out and supplanted if required (Mezzali, 2013).

Negative corners are moderately simple to oversee, however on account of positive corners the development and utilization of a corner-shutting component or uncommon module is suggested. Couple of systems take into consideration unique modules, and as an aftereffect of lessened establishing zones, the vegetation will not be homogenous. The edges possibly better oversaw by covering them with another material that as of now shows up on the facade (Miller & Spivey, 2008). In specific cases, the primary pipelines of irrigation and water system framework likewise should be situated here. Taking after better curved surfaces with substantial modules is not generally appealing; the utilization of a solid framework or smaller module size is less complex and gives a more alluring outcome. Any inclining edge can be totally trailed by the solid frameworks, while if there should be an occurrence of the particular system the arrangement is to make ventures with the units, the size of which varies and relies on upon the system, the bigger the module, the more "pixelated" the last appearance (Newcomb, 2010).

3.1.3. Planning Considerations

One of the primary targets as discussed previously can be the introduction of more green into the city as a sustainable planning strategy. Thick vegetation can help towards envelope protection and shading properties, keeping warm or cool air from moving through the building envelope into the environment (Perez, 2011). Green walls can be introduced on existing structures or new development (Perini, 2011). Climbing plants in façade-supported green wall system can reach as high as 25-30 meters, if established in the ground. Considerably more prominent plant statures can be accomplished with climbing plants, if growers are situated at interims along the vertical face of the exterior (Pitts & Jackson, 2008). Dissimilar to façade-supported green wall, façade coordinated living walls have no stature of size limitations because of the measured way of this system resize and weight of develop vegetation ought to be considered amid the preparatory outline stages to give sufficient space to plant development. The accompanying tables give an idea on design considerations on living wall and green wall type systems.

Table 7: Planning considerations for living walls

Design Criteria	Considerations
A multi-storey green wall	Safe access for maintenance should be provided, hydroponic system should be considered for watering, extra loads coming from plantations should be considered during design
Aesthetic issues	Incorporate an assortment of plant groups with various blossoming times, consider using foliage hues and broadening the planting regionC.
Installation and Maintenance Cost	This system is low cost and easy to install on high rise buildings. However, DIY issues should be considered relating to the maintenance of the system; the span of the framework should be minimized, independent units that recycle water should be considered, systems that can be effortlessly replanted should be provided
Biodiversity	Incorporate an assortment of plant groups with living space elements, for example, organic products or nectar creating blooms.
Internal green wall	Guarantee sufficient light – potentially introduce simulated light
Long lasting wall	Consider nature of plan and life span of parts.

Table 8: Planning considerations for green facades

Design Criteria	Considerations
Installation and Maintenance Cost	Utilize direct joining types of plant, developed from the beginning the base of the wall.
A multi-storey facade	Incorporate compartments at various statures, incorporate cabling or cross section support structures for twining plants, guarantee access for support, give water system, consider auxiliary

greening	assurance of plants against stem harm
Aesthetic Issues	This system helps screening of unpleasant views Utilize evergreen species to guarantee year-round screening, make a structure for the plants to develop on.
Thermal benefits	Utilize deciduous species if sun entry is wanted in winter; guarantee extremely verdant plants, covering the whole wall for giving best shade in summer, especially on north and west-bound walls; give a structure no less than 100 mm off the mass of a working for the plants to develop on, leaving an air crevice between the building and green plants to augment cooling impact.
Production of food	In this system vegetation with edible products can be used
biodiversity	Incorporate an assortment of animal types, with living space components, for example, nectar delivering blooms, natural products, ability to support homes, make ensured or outwardly conspicuous zones.

During the selection of a green wall system, water weight must also be considered as well as how selected water system frameworks are mechanized and computerized; both the pumps and control hardware require solid electric supplies, particularly if watering is to happen self-governing. The accessibility of this choice actually is liable to the recurrence of precipitation in the building area and the retention capability of the planting media (Morison, Hes & Bates, 2006).

3.1.4. Material Considerations

Timber is modest and simple to work with, however in situations where the material is going to contact with water, even with the best additive, it will still face the risk of rot. Mass plastic is another option, however they are touchy to UV, in cold climate they cannot bend, and are combustible. Specialized plastics and composite materials give shifted openings as far as arrangement is concerned, the inconvenience is that most are combustible and the cost regularly surpasses that of stainless steel or aluminium. Aluminium is a sturdy material; nonetheless it is costly and not flame resistant. If there should be an occurrence of powder-covered steel, erosion resistance cannot be ensured, the paint is combustible, Stainless steel has in fact consummate qualities, yet the cost is generally high (Ngan, 2004).

As far as the material for planting is considered, soil is cheap, yet its condition falls apart with time, moreover the quality is somewhat fluctuated and the extensive weight is a detriment when utilized as a part of an exterior framework. Peat substrates at first give better quality; yet it is only usable for one-two years. The structure of stringy mineral substrates (e.g. mineral fleece) after the second year breaks down quickly, and it doesn't wet equitably vertically, bringing about uneven plant advancement. The permeable inorganic grinds (e.g. magma grist, mud grind, perlite, bulbous glass rock) have a steady structure, their pH is normally too high, yet it can be controlled by setting the pH estimation of the medium. These materials, notwithstanding being sturdy, are additionally brilliant in disposing of the abundance water. Because of their microspores they guarantee an even medium-vapour fixation in the full scale pores between the pulverize grains, giving a flawless living space to the foundations of the plants. The structure of froths is satisfactory just for a moderately brief time of 2-3 years. Felt is reasonable and simple to work with, in spite of the fact that the mechanical and hydrostatic attributes are powerless, and there is a propensity for spoiling. The permeable sheets have incredible seepage, yet because of their low microporousity, the root microclimate creating in them is negative (plants dry out effortlessly) (Buchanan, 2005).

It makes sense that covering a facade and wall with planting will shield the façade materials behind from the extremes of atmosphere. In any case, there is obviously an opposite to this, in that the roots and stems of the plants themselves - particularly those climbing plants that connect themselves to surfaces-may prompt to the decay of the exterior materials, and may even prompt to auxiliary harm if not controlled (Osler, Wood, Bahrarmi and Stephens, 2011). The materials utilized for a building envelope is important in terms of green wall system used. A glass blind wall system, for instance, maybe most appropriate to a tie system held far from the wall, for example, found at Consorcio, Santiago, Chile. The feel of such an envelope would be antagonistic to a denser planting system that should have been nearer to the wall for support (Paevere & Brown, 2008). Façade-supported green wall can be consolidated into most envelope sorts, however clearly not before windows; there will be some extraordinary contemplation around weight of the material and waste of the system. The heaviness of completely developed plants and their developing media should likewise be considered, as the settling of the structure can possibly bring about breaks and spalling in mortar, stucco or solid, where the mounting section enters the envelope and binds back to the structure (Radovic, 2006). An especially permeable or layered outside surface is not prescribed for use with climbing vines unless these are all around regulated and prepared; a few climbers and woody plants can enter through building envelopes, bringing about splits and breaks. Additionally, finding vegetation near drains, roof, and operable windows is not exhorted, as plants may obstruct these building components, repressing the building's execution. The sort of windows utilized on the exterior is additionally vital; while vines can't undoubtedly move along smooth surfaces of glass or metal casings, they can connect themselves to wood window edges and trims that are regularly highlighted in more seasoned structures (Sharp, 2008).

3.1.5. Site Considerations

One of the early pioneers of greenery in high-rise projects, Ken Veang, was particularly vocal that a key advantage of vertical greenery was the potential for it to as an eland connect or 'eco passage that could either be an essential home for plant, bug, and natural life, or go about as a vehicle for relocation and cross-pollination of plant, bug and untamed life species (particularly imperative in diminishing plant monocultures). Yeang's own particular project, Solaris in Singapore, encapsulates this standard in a most exacting manner; as the building is circumnavigated by a delicately inclining green slope that stretches out from subgrade level the distance to the rooftop cultivate (Yu, 2006). In spite of the fact that no proof has been given to this impact, one can without much of a stretch envision a venturesome flying creature or ground-based warm blooded animal working its way up the slope, supporting on bugs and nectar (however ideally not very a significant number of the plants) The way to this is the congruity of the scene. At the point when the scene is consistent, airborne seeds and creepy crawlies can cross-fertilize crosswise over species inside a bigger vegetated range (Takenaka, 2001).

The table underneath outlines data that is required in the examination of a site for a potential vertical green system. Some of these components will require pro learning; for example, the load that can be connected to a façade or living wall, will require discussion with an architect and structural engineer. Before planning a vertical green system it is vital to comprehend the attributes of the site (see table 9).

Table 9: Site analysis requirements (Author,2016)

Information to be collected during site analysis	
Seasonal considerations and climate	Expected most noteworthy and slightest temperatures. Expected precipitation volume and scattering reliably. How sun, shade, curve change on the site reliably. How the height of the building may affect some climatic components. Gauges on how the adjacent air may change after some time.
Local environment	Evaluation of shots or threats that near to vegetation will have on the site - discharge hazard, weed or aggravation interruption, biodiversity movement.
Loads	Load bearing limit. Assessed transient burdens, especially wind strengths.
Drainage	Storm water release focuses. Evaluation of whether waste will be satisfactory because of genuine climate
Irrigation	Water collection and limit openings, open entryways for transport of water system, water and for co-discovering set away water with other dull water structures in the building.
Existing structure and size	Size of useable housetop or wall extends. Open space for plants to be produced from ground level upwards. Any slopes or indicates the housetop or wall. Nature of existing housetop and wall materials.
Access	Access to site for cranes and other equipment, and for limit of materials in the midst of improvement. Access for support and visitors (consider prosperity, for instance, a parapet on a housetop and inadequacy get to essentials too). Access to utilities - water, control. Ensure access for passers-by is not blocked.

Green walls convey extraordinary potential to expand the differing qualities of accessible farming sustenance sources and diminish noisy mileage"- the separation that nourishment needs to head out from root to purpose of need, utilizing fossil fuel and adding to gas emissions harmful to the environment. Not many green wall extends right now satisfy this potential. This maybe because of the vast speculation of exertion required to discover plants that will flourish presented to the components in a given domain - particularly when that environment is to a great extent vertical- not to mention create palatable nourishment (Yamada, 2008).

The green wall, notwithstanding extensive indoor hydroponic offices, produces eatable natural products (plums, oranges, peaches), vegetables (pumpkins, tomatoes) and rice, which are collected and arranged at cafeterias inside the building, the level of speculation expected to work out foundation and water system should definitely have been generous, yet as noted over, the advantages to the organization's marking and main concern will probably have been significant too (Wolverton & Wolverton, 1996). Not all activities should be this thoroughgoing in their quest for consumable greenery, obviously; the level of venture giving only one eatable animal categories, alongside available directions for care, would give. Similarly as with any plan, introducing a green wall ought to contemplate the context (Thompson & Sorvig, 2007). History gives no record of residences protesting to a green wall. In any case, it is best to convey green walls where they do not give a burden to residents, and that vines and tree overhangs can be trimmed routinely to anticipate invasions, either by the plants themselves or by their care takers. Green walls have been energized expressly in light of the fact that they would upgrade or enhance the current setting (Hien & Chen, 2009). It is surely known that plants can enhance the micro-climate through the photosynthesis procedure where they take in Co2 and release oxygen. The surface range of leaves can ingest airborne particulates and prevent their intake, where they can be concentrated and recycled. (Wilmers, 1990). In urban environments, the measure of activity and different wellsprings of urban noise, for example, development work, have expanded fundamentally in late decades. The nearness of a thick tangle of vegetation, and its supporting planting medium, can help eliminate noise. (Jonathan, 2003).

Another issue to be considered is the aesthetic advantages they provide. The mental prosperity of people enhance when they are in close proximity to greenery (Kingsbury, 2004). On account of high-rise buildings, for example, Pasona Headquarters in Tokyo, the impact has really been measured through utilization of post-occupancy studies and other methodologies.

3.1.6. Plant Selection Considerations

Suitable plant determination is a fundamental requirement for green wall systems. To guarantee the effective establishment and working of a vertical green system, the accompanying components ought to be considered during plant determination (Crosbie, 1994).

It is prescribed to choose plants that are local to the project area since they are normally tolerant to micro climate conditions and are more resistant to nearby nuisances and maladies. Plants local to a cold climate zone will for the most part require less maintenance than their outlandish partners from tropical climates (Pitts & Jackson, 2008). A wide assortment of plants can be utilized as part of green walls relying upon the site conditions: enduring and yearly, deciduous and evergreen, sun-and shade-adoring, and tropical and leave plants. For instance, at Consorcio, Santiago, Chile, and the architect considered the regular style of four neighbourhood species before selecting them; in order to give leaves a chance assist shading in fall and drop from facade, conceding light and warmth, in winter. On account of deciduous plants, obviously the need to evacuate dead or fallen leaves should be considered (Yamada, 2008).

Facade-supported green walls regularly incorporate climbing vines and bushes, while living walls utilize a more extensive assortment of littler plants that can develop normally on vertical surfaces, for example, ground cover, little bushes, greeneries, wildflowers, and eatable plants (Fuerst & McAllister, 2009). Indoor green walls utilize warm-atmosphere plants, which are appropriate for low light levels and the steady solace states of indoor spaces with commonly 68 °F to 72 °F (20 °C to 22 °C) air temperature and 45% to 65% relative moistness (Dunnett, 2010). The best green wall outlines ought to represent the plant assorted qualities and regularity, and abstain from utilizing plant monocultures (i.e., just a single kind of plant). The preparatory development of plants for green and living walls regularly happens at a neighbourhood nursery or a cultivator's office, where imperative assignments of module get together, planting, developing, and acclimatization occur. Planting modules for custom living dividers ought to start no less than 12 months preceding establishment to consider seed accumulation, engendering in seed plate, and framework testing, particularly if utilizing one of a kind or non-local plants (Hopkins, 2011).The producer or introducing temporary worker transports the completely developed green wall modules to the site, where the contractual worker executes the last establishment. In facade upheld green walls, the grower or individual plants are introduced along the exterior edge. In living walls, the planting modules are typically first hung into place as per the outline drawings and after that the last water system framework is associated (Holm, 1989).

Precisely evaluating the full scope of development for a picked plant is basic to the accomplishment of a green wall extends. Plants that neglect to accomplish the sought thickness of scope will bring about the vitality productivity and shading capability of the building to diminish. Plants that surpass desires of weight as well as strife with desires of development bearing will turn into a steady migraine, needing trimming or expulsion (Yamada, 2008).

Every green wall system incorporates a developing medium that is contained in various ways. In exterior supported green wall systems, a developing medium is commonly set in a trench or grower at the base of the facade, or in grower at vertical interims along the exterior stature (Wolverton & Wolverton, 1996). In a living wall, developing medium is put in individual compartments (pockets, troughs, or module boxes) mounted on a support outline. Hydroponic (i.e., non-soil) systems utilize engineered tangles as a developing medium.

All developing media should be well-depleting and ought to have suitable natural substance, synthetic and physical properties and microbial movement. Some green walls utilize a painstakingly chose inorganic developing medium blend that comprises of calcinated dirt, extended slate, sand, and peruke, vermiculite and comparable minerals (Hopkins, 2010). Natural parts (compost, natural strands, peat, and so on.) ordinarily make up 10 percent of the blend; however give vital supplements to the plants (see tables 10 and 11).

Table 10: Plants suitable for green façade use

Name	Representation	Characteristic	Evergreen/ Deciduous
Five-Leaved Ivy		Develop quick, Good at climbing, Suitable for green spaces	Evergreen
Chinese Trumpet Vine		Simple to engender, sprout, look wonderful	Deciduous
Jasmine Vine		Blossom, blooms smell fragrant, can be utilized as herbs	Evergreen
Fortune's Spindle		Look wonderful, can be use as herbs	Evergreen/ Deciduous

Morning Glory		Bloom ,Look wonderful, can be use as herbs	Deciduous
Cardinal Vine		Bloom, Look wonderful, can be use as herbs	Evergreen
Chinese Wisteria		Bloom, Look wonderful, can be use as herbs	Deciduous
European Ivy		Good at climbing, Look wonderful	Evergreen
Japanese Honeysuckle		Bloom, Look wonderful, can be use as herbs	Deciduous

Table 11: Plants suitable for living wall

Name	Representation	Characteristic	Evergreen / Deciduous	Outdoor / Indoor
Heartleaf Philodendron		Blossom, look delightful, simple to column plant, becomes moderate in shade	Evergreen	Outdoor and Indoor
Dracaena		Blossom early summer to late summer, Low support	Evergreen	Outdoor in summer and indoor in seasons
English Ivy		Develop quick, Good at climbing, Suitable for green eras	Evergreen	Outdoor
Spider Plant		Simple to spread, sprout, look wonderful	Evergreen	Outdoor and Indoor
Golden Pothos		Bloom, Look wonderful, can be use as herbs	Semi evergreen	Outdoor and Indoor

Peace Lily		White blossom, look delightful, can be utilized as a part of herbs	Evergreen	Indoor
Chinese Evergreen		Low developing, strong plant, look excellent	Evergreen	Outdoor

3.2. Vertical Green Systems Technical Requirements

Latest improvements in a façade-supported green wall and living wall are predominantly engaged in systems outline and their components (supporting components, developing media, vegetation, water system and seepage) with a specific end goal to accomplish more productive specialized arrangements and a superior execution in all building stages (establishment, upkeep and substitution) (Villanova, 2013). The versatility to all the more building sorts (e.g., business spaces, tall structures), development strategies (new or existing building walls) and sorts of surfaces (e.g., inclining surfaces, indoor segment walls and unsupported structures) is likewise the worry in the advancement of green wall systems (Kohler, 1993).

3.2.1. Vertical Green Systems Supporting Elements

Customary or coordinate green facades normally have no support structure. They depend on the limit of climbing plants to join themselves to the vertical surface. In any case, when the vegetation satisfies full scope can turn out to be too overwhelming and the danger of falling is expanded. Backhanded green facades work as "twofold skin exteriors", making an air hole between the building surface and vegetation. The use of a bolster structure maintains a strategic distance from vegetation to fall (Othman & Sahidin, 2016). These systems, either secluded or constant, stay and hold the vegetation weight, adding to build the system imperviousness to ecological activities (e.g., wind, rain, snow). Most support structures for aberrant green exteriors incorporate persistent or measured aides, as links, wires or trellis made of aroused or stainless steel. Steel structures and tractable links can be utilized to hold climbing plants with denser foliage and to bolster their weight. Frameworks and wire-nets have littler interims and can be utilized for moderate developing plants bolster (Hopkins and Goodwin, 2011). Some roundabout vertical green systems, for the most part secluded trellises, incorporate pots loaded with substrate and individual support structures, permitting the suspension of the components along the wall and facade at different statures. New types of measured trellises incorporate a bended framework to give the facade mood and three-dimensionality to the wall (Yu-Peng yeh, 2010).

Living walls ordinarily incorporate an edge to hold the components and a support for plants. Persistent vertical green systems depend on the establishment of an edge settled to the wall, shaping a void space between the system and the surface. This edge holds the base board and shields the wall from mugginess. The base board underpins the following layers. It is secured with layers of penetrable, adaptable and root evidence screens, stapled to the base. The outside layer of screen is then sliced to frame pockets for the presentation of plants exclusively (Renterghem, 2013). Secluded living wall system can take a few structures (e.g., plate, vessels, grower tiles or adaptable sacks) requiring an alternate structure. Secluded plates are typically made out of a few interlocked parts, made of lightweight materials as plastic (e.g., polypropylene or polyethylene) or metal sheets (e.g., aluminium, electrifies steel or stainless steel). To guarantee the framework progression, every module typically incorporates an interlocking framework on the sides to interface with each other (Reyes, 2002). These secluded components may likewise contain an intro page shaping a framework to anticipate plants to fall. Plate and vessels are normally settled to a vertical and additionally even casing joined to the surface.

The back surface can incorporate snares or mounting sections and for their suspension in the edge profiles associated with the vertical surface. Particular vessels permit the establishment of a few plants in every component along a similar column. They are generally made with polymeric materials and because of their shape have a critical visual effect on the building surface. Grower tiles are associated with each other by juxtaposition. They regularly incorporate a level back settled to the building surface and a range in which the plants are embedded exclusively (Smit, 2013). These arrangements can be inherent lightweight or permeable materials like plastic or earthenware production. Contingent upon the framework, tiles can be stuck to the vertical surface or be settled with mechanical attaching. Measured living wall system can likewise appear as prolong sacks, loaded with developing media, made of adaptable polymeric materials which are sliced to embed every plant (Solaris, 2012).

3.2.2. Vertical Green Systems Growing Media

With regards to green exterior walls and facades just secluded frameworks require the choice of a developing media, which must be lightweight, considering that every component will be suspended, and adjusted to the chose plant species and natural conditions. In the field of living walls, consistent living wall systems additionally don't have substrate. As specified some time recently, these systems utilize lightweight permeable screens where plants are embedded in pockets. Persistent living wall systems are normally in view of a hydroponic technique, requiring a perpetual supply of water and supplements because of the absence of substrate. Hydroponic frameworks permit the development of plants without soil, utilizing screens continually wet by irrigation and water system framework. The absence of soil is remunerated by giving the essential supplements to plants improvement through water system water (SOLARIS Multiplexes, 2009). Modular living wall systems are generally loaded with a developing media where roots can multiply, made of natural and inorganic mixes or incorporate a layer of inorganic substrate, normally froth, to lessen its weight. Most particular wall systems incorporate a developing media in view of a blend of light substrate with a granular material, extended or permeable (e.g., mineral granules with medium to fine particles, coconut fibbers or reused texture) keeping in mind the end goal to acquire a decent water maintenance capacity]. The substrate might be enhanced with supplements for plants development (e.g., blend of natural and inorganic manures, metal chelates, minerals, supplements and hormones for plants or different added substances). Some secluded living wall systems show the addition of developing media into geotextile sacks to keep its separation (Susorova & Bahrami, 2013). These sacks can possess the whole module and permit the addition of a few plants or cover the developing media of every plant independently. Then again, every plant can incorporate an individual title page to keep away from the developing media to fall.

3.2.2. Vertical Green Systems Drainage

Abundance liquid waste in green walls happens by gravity. Persistent and secluded living wall system utilizes geotextiles that energize waste along the penetrable film while forestalling roots expansion (Ling and Ghafarian Hosseini, 2012). Measured plate exploits the cover of modules and materials to enhance seepage and water overabundance reuse to the modules beneath. For a superior waste the base of a secluded frameworks can be inward, disposed, punctured or be made in a permeable or retentive material. Different cases as vessels specify the utilization of a channel material connected at the base of the module (e.g., immunized sand or other intend to cleanse water, evacuate poisons and substantial metals) or a granular idle filler (e.g., extended dirt, extended slate, rock) which advances the waste and improvement of roots. A few cases of particular systems additionally say the inclusion of furrows or openings on the sides and back face of modules, for a superior air circulation and evacuation of abundance dampness contained in the substrate (Yeang, 2006).

3.2.3. Vertical Green Systems Irrigation

The irrigation system needs rely on upon the sort of system, plants utilized and climatic conditions. Measured façade-upheld green wall and living wall systems require a water system with a specific end goal to give the important water to plants advancement. The water system water can be enhanced with supplements, manures, minerals, phosphates, amino acids or hydroponic materials to enhance the vegetation advancement and vivacity. The water supply of living wall system is made through the establishment of a persistent water system tube situated at the top (Susorova, Irina, Azimi, Parham & Stephene, Brent, 2014). Persistent living wall systems have a water system framework introduced at the structure best associated with the focal irrigation system framework. On account of constant living wall systems the porous screen permits the uniform appropriation of water and supplements along the surface. Some secluded living wall as plate incorporates a break in the top face of the module to embed the water system tube. The plate incorporates a few gaps in the break for watering the developing media by gravity]. Waste openings situated in plate base are utilized to permit abundance water to inundate the modules underneath. The water system tubes and connectors can be delivered in a few materials (e.g., elastic, plastics, channelling thermoplastic, and silicone and water system hose) containing diverse yields (e.g., trickle, sprinkler, openings, and pipe) with conveyance and force adjusted to the plants water system needs. The irrigation and water system framework can likewise incorporate a filtration system to counteract stopping up (Webb, 2005). Some living wall system additionally says techniques for minimizing the utilization of treated water. There are methodologies like water recuperation from the building rooftops, reuse of the liquid gathered in the waste system and observing water supply needs, through the establishment of sensors that control the gathering water tank level, the water system time and climate conditions (e.g., amount of precipitation, stickiness, temperature, air weight) (Loh, 2008). Other living wall system, either measured or persistent, additionally eludes the establishment of a drain in the system base, recouping overabundance water putting away it and reintroducing it into the water system framework. Another procedure comprises in the utilization of sensors in the developing media for supplements needs measurement. This can be essential to minimize supplements utilization and match the plant's needs. Green walls can't be supported without water system (Wong, Hassell, 2011). Intrusions to the water supply are a typical reason for plant disappointment on green walls. Frameworks composed with inbuilt water system ought to relieve plant misfortunes because of conflicting dampness administration, in spite of the fact that mistakes can even now happen. Computerized, remotely controllable water system frameworks are utilized for walls as a part of prominent areas, or in circumstances where get to is testing. Take note of that the quality, plan and expenses will fluctuate between various frameworks. The most modern frameworks empower the maintenance director to monitor the computerized execution of the framework, including the volume of water system conveyed, its recurrence, substrate dampness content, and additionally pH and supplement levels in the water supply.

The settings can be superseded if necessary; for example, the recurrence or span of water system cycles might be expanded on hot days (Wong, 2010). In hydroponic systems, plant nourishment is conveyed by a compost infusion framework that discharges controlled dosages of manure into the water system framework (fertigation). Administration of fertigation systems and rates of conveyance requires authority learning, as it is more mind boggling than treating soil or developing media. Hydroponic frameworks require consistent observing of pH, water hardness and aggregate broke up solids and alteration of these parameters where fundamental. For hydroponic green wall systems, the fertigation framework may apply 0.5-20 litters of water system arrangement per square meter every day. Inside green dividers prerequisites are at the lower end of this range, and outer green walls at the higher end. Water system cycles regularly last a couple of minutes and will be required a few times each day. Keeping water system volumes low minimizes squander and decreases keep running off. Water system keep running off might be caught in a tank at the base of the divider and reused back through the green wall system, green walls that utilization a top notch, water-retentive developing medium, and are not in an uncovered or especially hot area, may flourish with a week by week watering administration(Almgvist, 2012). In most basic, soil-based systems, including DIY systems, controlled discharge compost is blended in with the developing medium, as opposed to utilizing a fertigation framework. Water system must be accessible when the plants are introduced in the wall system. The irrigation and water system framework requires a water meter to screen water system volume, and a weight gage to screen the even use of water. The requirement for progressing consistent water system and the desire that water will be utilized reasonably implies that put away (reaped or reused) water ought to be utilized at whatever point conceivable, so a pump is fundamental(Blanc, 2006).

3.2.4. Vertical Green Systems Maintenance

Green facades, including climbing species, are more financially savvy amid the establishment procedure yet have impediments in plants differences. At the point when there is the need of plants substitution, these systems indicate troubles in guaranteeing vegetation congruity (Mahmudul, 2013). Amid plants development, some climbing plants additionally oblige direction to guarantee that they cover the whole surface. It is additionally critical to allude that some climbing plants can harm structures surface, wrecking it with their underlying foundations and entering in voids or splits. Measured trellises have focal points when contrasted with nonstop aides on the establishment and maintenance forms. The establishment of plants at a few statures diminishes altogether the effect of the scatter development of climbing plants along the surface and empowers the substitution of unsuccessful plants (Cameron, Taylor & Emmett, 2014). A bow number of measured living wall rise in the market to minimize establishment, maintenance and substitution issues, Some particular systems empower to dismantle every module exclusively or incorporate a removable title page for wall maintenance or vegetation substitution. Some secluded components can likewise be settled into each other keeping in mind the end goal to improve the transportation and application forms. At the point when contrasting ceaseless living wall with secluded living wall, constant living wall empower the formation of vegetated surfaces with a more extensive assortment of plant species, and can be lighter, has a thickness of around thirty plants for each square meter and under 30 kg/m^2. Notwithstanding, consistent living wall system are usually hydroponic systems, requiring a changeless supply of water and supplements, which constitute a maintainability detriment and result in higher maintenance costs because of higher water system needs (Blunden, 2010). Truth is told every green wall system has its own qualities, with focal points and disservices relying upon their tasteful potential, cost and support needs. The choice of the most satisfactory system is straightforwardly identified with the building attributes (e.g., introduction, availability, tallness) and climatic conditions (e.g., sun, shade and wind presentation, precipitation). This is the reason it is vital to comprehend their disparities in structure and their principle attributes (Chen & LI, 2013).

- **Maintenance Planning**

A director might be assigned to administer the continuous administration of maintenance exercises, and can give guidance to support staff and evaluate that work has been done palatably (Derbyshire, 2001). Maintenance planning ought to likewise fuse chance administration, with the point of diminishing or wiping out the probability of disappointment that could bring about property harm or individual damage. For huge undertakings, support arranging is frequently in light of 'advantage administration arranging' where the entire existence of the benefit is considered, including outline, development, foundation, operation, upkeep, restoration and annihilation/substitution. Educating different temporary workers who take a shot at the working about the rooftop, wall or facade, with the goal that they don't incidentally harm the advantage (for instance, water benefit contractual workers killing water for a drawn out period) (Eichholtz, Kok, & Quigley, 2010).

- **Plant Nutrition**

A critical component of maintenance is guaranteeing that plants get satisfactory sustenance. This segment gives data on nourishment to rooftops and exteriors. Walls are not tended to here in light of the fact that green wall installers will give particular guidelines to meeting the nourishment necessities of the specific plants in the specific divider. Composts for green walls are conveyed in fluid frame, through the water system framework) (McClenon, 1977). In discussion with the fashioner and customer, set up the least proper application rate for controlled discharge manures. The point is to give adequate nourishment to solid plant execution while minimizing supplement misfortune into water system/storm water keep running off. In that capacity, manure rates are typically essentially lower than those prescribed for garden or compartment plants. Where the plantings are restricted to succulents there may not be any continuous expansion of manure (Otele, 2011). Every rain or water system occasion disintegrates a little measure of the inorganic supplements put away in the dab. On the off chance that the rooftop or holder is being flooded from beneath (a sub-water system framework) then it is imperative to blend the manure well into the substrate. The lifted temperatures on exterior wall can prompt to extreme compost misfortune and harm plant development (Ozyavuz, 2013).

- **Monitoring of Fertilizer Levels**

It is helpful to embrace soil testing of pH and electrical conductivity to build up the conditions under which plants were begun (Vale & Vale, 1991). Progressing, solid plant development and scope is the best sign that developing conditions are appropriate. Extra compost ought to be included if electrical conductivity or aggregate broke up solids comes about propose supplement levels are just running low. In the event that conceivable this ought to be consolidated through the developing substrate to guarantee its even circulation, however this might be hard to accomplish for green exterior compartments introduced at rise (Vale & Doig, 1997).

- **Storage**

Cultivating materials and supplies are required to be put away in a devoted stockpiling. This stockpiling ought to be effortlessly and promptly available to the support staff individuals. Security measure in support on vertical green system should likewise be fundamentally considered. Proper lift system and stepping stool framework is an unquestionable requirement to encourage the maintenance schedule (Vale, 1991)

3.2.5. Vertical Green Systems Lighting and Ventilation

Lighting is frequently required for a façade-supported green wall and living wall situated in low light introduction territories. Many vertical green systems are introduced inside non-lit areas. Lighting green walls is profoundly specific, requiring the administrations of a lighting architect or specialist. Plants require certain lighting amounts and qualities to photosynthesize, develop, bloom and grow suitably (see figure17). Tropical and subtropical green wall establishments can for the most part get by in lower light conditions than Mediterranean, calm plantings.

Broad information of cultivation and outline of green divider frameworks is expected to pick the correct species for the light levels accessible on location.

As in indigenous habitats, diverse plant species flourish in different light levels (Virtudes and Manso, 2012). We can choose plants to oblige the angle and common light power of every venture. In ranges where no common light is available (especially inside) it is basic to misleadingly make the correct light power and shading temperature to bolster solid plant development for your living wall. Light force is measured in foot candles (FC) or lumen's. For reference a reasonable summer day is around 15000 FC. We require at least 250 FC for a durable living wall. Light shading temperature is measured in Kelvin (K). Common daylight gives a full range of shading and indoor living walls will flourish with a comparable light adjust (4500 K to 6000 K). For a solid living wall we require at least 3000 K (Wines, 2000).

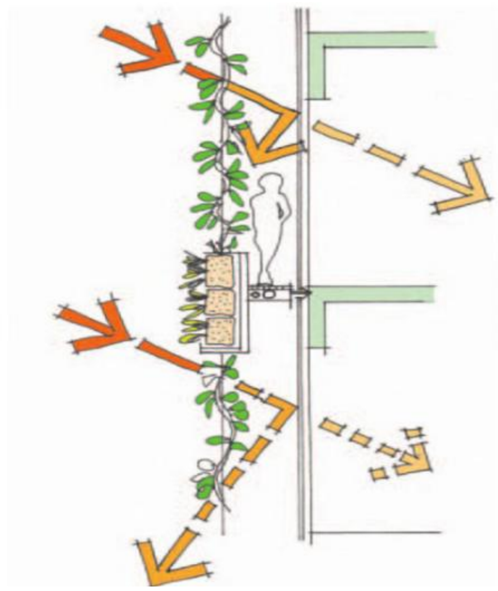


Figure 17: Natural lightening diagram in vertical green system (Author,2016)

- **Ventilation**

Another thought for a façade-upheld green wall and living wall establishments is air development around the foliage. This is essential to avoid parasitic development, and extra ventilation might be expected to guarantee adequate air development and ventilation for indoor walls. Open air walls normally make their own microclimate that makes enough air development, however in exceptionally shielded positions consideration ought to be given to this issue. The procedure of photosynthesis and transpiration cycles is related (see figure18). This procedure requires a fitting ventilation system to scatters the diffused water vapour atoms brought on by transpiration. Keeping in mind the end goal to keep up a typical transpiration rate, a great ventilation system is required (Buchanan, 2005).

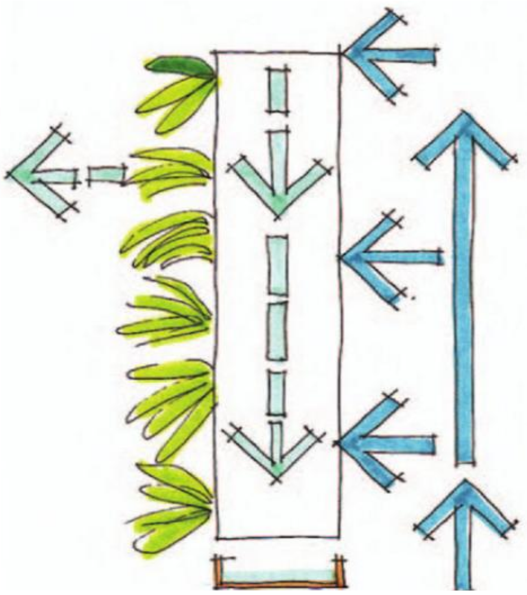


Figure 18: Natural ventilation diagram in vertical green system (Author, 2016)

3.2.6. Sourcing skills, expertise and information

Most undertakings require the inclusion of various distinctive exchanges and abilities, and the more minds boggling the venture, the more components there are to organize. It is essential that a master, experienced, vertical green system planner is locked in amid the outline and meeting stage, instead of toward the end of this procedure. You may need to counsel with different experts, some of them conceivably on a progressing premise, all through both the plan and development periods of vertical green framework extend. For little scale extends, a green wall or exterior supplier will regularly supply a few administrations, from building to water system to building project administration and plan. In different cases, it will be basic that the supplier is working together with whatever remains of the plan and wall administration groups (Sharp, 2008). The accompanying rundown depicts particular ranges of mastery included:

- **Project manager**

Develops a building project program and timeline, Oversees development spending plan and instalments, Guarantees temporary workers have fitting enrolment, authorizing, protection and working at statures preparing. For all of the personnel manages site inductions.

- **Construction manager/Principal contractor**

Outlines the building, working with the customer to choose the most suitable system for the site plan, including thought of how it will be overseen and kept up in the long haul. Arranges arranging and building licenses, either specifically or through a building surveyor, inspects construction and progress reviews. Gives counsel on the establishment with regards to the entire site/landscape design. Note: engineers and scene draftsmen with experience and concentrated information of green facades and living walls will be best ready to give calculated outlines and concentrated outline of support structures and plantings (Radovic, 2006).

- **Structural engineer**

New projects examine the existing building, or the proposed architecture design. Decides the auxiliary components required to accomplish the sought weight stacking.

- **Builder**

Develops the building, or introduces any basic fortification required in a retrofit green wall extend. Introduces any implicit components connected with the wall or facade, frequently in conjunction with the living wall and green facade or exterior supplier.

- **Building surveyor**

Reviews and approves building plans, compliance with the regulations reviews construction and orchestrates Building Permits and Occupancy Permits with urban dwellers.

- **Waterproofing supplier and contractor**

Writes about the state of the current rooftop (retrofit), and prescribes the most reasonable waterproofing for the wall and façade. For installs waterproofing should prepares the wall or façade.

- **Leak detection specialist**

Does spill testing at indicated phases of development, and as a major aspect of customary planned maintenance

- **Horticulturalist**

Growing substrate of provides advice; suitable vegetation's and plants requirements and sources, seeks specialist advice such as, arboriculture advice for tree selection, Arranges conveyance and establishment of plant materials.

- **Living Wall Provider**

Vertical green system installs and planning, gives exhortation on the most proper treatment for the site, including plant determination, water system and progressing administration.

- **Green Facade Provider**

Vertical green system such as green facade installs and planning, gives counsel on the most suitable treatment for the site, including plant choice, water system, cabling, trellising and compartment developing systems, and progressing administration.

- **Irrigation Consultant/Hydraulic Engineer**

Prompts on a reasonable irrigation and water system framework amid the outline procedure in light of the proposed substrate profundity/volume and water-holding properties, informs on utilize concerning reused/collected water, pumps, and capacity tank volumes and setups, encourages on ways to deal with economical and proficient water administration with regards to the entire site (water delicate urban plan), instructs on reconciliation concerning the water system framework with whatever remains of the building's water system (Buchanan, 2005).

- **Landscape Manager/Maintenance Manager**

Regulates support temporary workers, arranges and oversees legally binding game plans, assigns spending plan and assets to maintenance exercises.

3.3. Standards, Policies and Incentives

The advancement of vertical greenery in urban areas is a reaction to numerous natural, social, and financial difficulties of the urban environment. Right now there are no globally acknowledged norms for green wall establishment and execution; however a few arrangements have been produced the world over to empower green divider development. Singapore, advancing itself as an ecologically economical city and a worldwide pioneer in executing green approaches, green structures, and clean-vitality activities, is upheld by different monetary motivating forces presented by the Urban Redevelopment Authority (URA) and National Parks Board (NParks). In 2009, Singapore propelled the Skyrise Greenery Incentive Scheme (SGIS), which funds up to half of the establishment cost of green walls (NParks, 2009). The Landscaping for Urban Spaces dry High-Rises (LUSH) is a Singapore based program that is proposed to combine both new and existing green activities. It incorporates four classes: a scene trade approach for vital ranges, open air refreshment regions on finished rooftop tops, GFA exception for common sky patios, and arranged decks (URA, 2009). Moreover, Singapore's Building and Construction Authority propelled the Green Mark Scheme in 2005 intending to expand maintainability among the development business and building designers (RCA, 2013).

In Australia, the city of Melbourne is right now building up the Growing Green Guide for the development of green rooftops and green walls to make characteristic feel and empower biodiversity (IMAP, 2013). The guide concentrates on green elements and has four fundamental standards" epitomize, ""empowering agent "support :and "draw in which are proposed to exhibit cases of greenery on open structures, to sirnplify the allow and development procedures, to give monetary motivations (concedes and refunds), and to expand group contribution and learning about green walls through media scope, rivalries, and uncommon occasions.

In Germany, the urban areas of Berlin, Munich, Cologne, Munster, Dusseldorf, and Stuttgart have set up directions and motivations keeping in mind the end goal to empower the utilization of green surfaces for tempest water administration. The city of Berlin has spearheaded the "Biotope Area Factor"(BAF) which communicates the proportion between natural viable surface (e.g., green wall, green rooftop, and so forth.) and the aggregate region of site (Ngan, 2004).

In the United States, Seattle has built up the Green Factor Program; a coverage system intended to expand the measure of green urban spaces permitting building proprietors to choose among green elements, for example, road trees, green facades and living walls. The Green Factor program applies to new improvements and requires equal plant scope of 30% in business and scope of half in multi-family private zones. Other American urban communities offer vertical green systems motivators also. The urban communities of San Francisco and Chicago issue assisted licenses for all green wall high-rise buildings, while San Francisco's Green Building Ordinance sets least models for carbon-dioxide outflows, which started in 2008.

In Canada, Vancouver has set up earth capable arranging approach and building local laws, and has advertisement selected necessities for the LEED Gold Certificate which supports green facades. Toronto has additionally settled money related motivating forces for the development of green walls and vertical vegetation (Manso & Castro Gomes, 2015). In Denmark, the city of Copenhagen has built up an approach on supportability, motivators, and manageability targets, concentrating on arranging to accomplish carbon-impartial systems, as a major aspect of the city's desire to be more practical. In the United Kingdom, London has an objective arrangement to build green cover in focal London by 5% by 2030. A specialized guide by the Mayor of London and urban planners has been created for supporting the London Plan strategy. In Japan, Tokyo has arranging approaches and monetary motivating forces set up and the Japanese government is currently applying Tokyo's arrangement the nation over (Grant, 2006).

In China, the city of Beijing has set an arrangement focus of "greening; or adding vegetated elements to 30% of high-rise building projects and 60% of low-ascent structures to enhance air quality and decrease contamination after the 2008 Olympics. Numerous different urban communities are right now building up greenery arrangements and considering motivating forces to support green walls (Villanova, 2013). The coming chapter focuses on the selected case studies in the light of information/criteria gathered above. Although not all of the information provided above is discussed in detail, nonetheless the most important issues detrimental for the design process, construction and maintenance are selected for the comparison of the cases.

Chapter 4

COMPARATIVE ANALYSIS OF SELECTED CASE STUDIES

The bulk of evidentiary material in this thesis is comprised of case studies of real-world green wall and vertical vegetation implementations. There are 10 case studies profiled in detail, reflecting the diversity of implementations around the world. The case studies are presented sequentially based on their completion dates, but it is useful to understand them in several other categories. As a group, case study buildings are sourced from 8 cities in 8 countries, with two in Singapore alone. The other ones are Thailand (2), Chile (1), Philippine (1), USA (1), Australia (2), and Japan (1). The predominance of Singapore is a consequence of several factors. The hot, humid climate of Singapore and other Equatorial cities fosters growth of plant life, reduces watering requirements and affords year-round green coverage.

The region is also home to two of the most prolific and pioneering firms in the relatively young enterprise of green walls in tall buildings. The case study buildings range in function from residential (5), offices (5). They range in height from just 34 meters (Pasona Headquarters – Tokyo, 2010) to 268 meters (Gramercy Residences, Makati, Philippines). Although not all of the selected buildings can be put in the category of universal high rise classification, nonetheless due to the limited number of cases around the world, 34m height has also been taken as high rise in this context. The thesis began the compilation of information fully intending to92 deliver detailed performance data on each case study, which would allow a direct analysis of the effectiveness of each system and strategy employed, for the benefit of those considering such strategies in other buildings. In last decades the practice of installing vegetation and plants into high-rise buildings became popular. This thesis focuses on high-rise building projects, which incorporate greenery and nature into their vertical building elements such as walls and facades. Many case studies have been looked at in order to understand how vertical green systems are classified. In last decades the practice of installing vegetation and plants into high-rise buildings became popular.

- **Building Data**

The first page of each study presents the project data for selected high-rise building, such as year of completion, height, building gross area, building primary function, and structural material.

- **Green Wall Overview**

After that, the vertical green system classification and dimensions are included, such as the location of the vertical greenery on the high-rise building project and the percentage of the total façade or wall area covered by vegetation's or greenery.

- **Climatic Data**

The thesis utilizes the Koppen Climate Classification map, which is predicated on the idea that local vegetation is the most exact articulation of climate. Climate zone limits depend on vegetation appropriation, and characterizations are communicated regarding yearly and month to month temperatures and precipitation, and the regularity of that precipitation. For instance, Bangkok, Thailand is in the tropical climate zone and has dry winter' precipitation condition. The information likewise incorporates measures of sun presentation, for example, geographic position-ing (in order to set up the ideal dividers or plots for shielding veneers from sunlight based radiation), normal day by day daylight, and the most extreme and least direct sun based radiation got by the building. Temperatures are given in three depictions - one as a yearly mean, and the other two show the normal daytime temperatures amid the three coldest and most sizzling months of the year. Precipitation is additionally of impressive significance, similar to the upper and lower extremes of humidity.

- **Background**

Location, program, and general design of the building in a narrative format is describes in the background part.

- **Green Walls Overview**

The category of vertical green systems integrated in the project, such as the location and structural support system for the façade and wall are described in Green Walls Overview part.

- **Plant Species**

Rationale for the selection of the plant species, including climate, maintenance, and desired coverage requirements are described in Plant Species section. Details are then supplied about what sort of the vegetation and plants are used in the high-rise building.

- **Irrigation System**

Some high-rise buildings as well as the ones selected for this thesis use an automated irrigation and watering system.

- **Maintenance**

Maintenance looks into how green façade and living wall in each of the cases are maintained, what is the frequency of maintenance and how access is achieved.

- **Analysis and Conclusions**

Analysis and Conclusions part describe the overall high-rise buildings projects in the context of all of the main information presented, assessing how each project executed its expectation, the degree of the usage in respect to the span of the building, and the appropriateness of the outline procedure picked.

- **Green Coverage Calculations**

This section clarifies the system by which the region of green coverage is resolved. All greenery was surveyed at its foreseen nature/developed. Since vertical green systems by definition fuse plants, which fluctuate incredibly fit as size, and thickness (and change extensively after some time) certain uniform strategies for computation must be executed to decently look at fundamentally changed activities. By and large, the sizes of the secluded trellises or networks were utilized to evaluate the degree of greenery, where planting is contained in sporadic patches of shrubberies and bushes, a5. Vegetation thickness decrease was connected over the consistent diagram containing the planting.

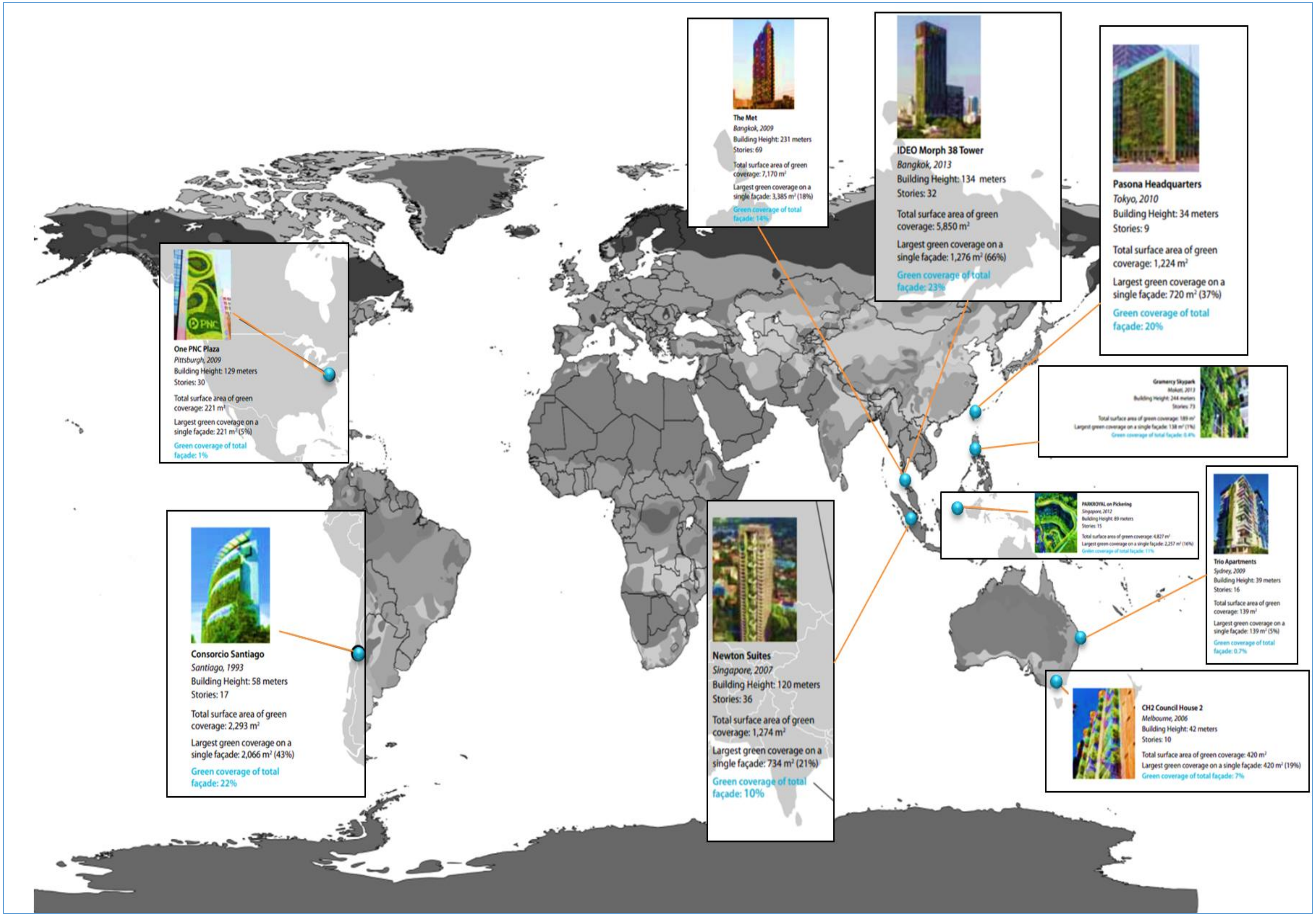


Figure 19: Case studies position on word map of Koppen-Geiger climate classification (Author, 2016)

Table 12: Case study comparative analysis table (Author,2016)

										
Name of Building	**Newton Suits - Singapore, 2007**	**Trio Apartments - Sydney- 2009**	**Gramercy Skypark - Makati, 2013**	**Ideo Morph 38 Tower - Bangkok, 2013**	**The Met - Bangkok, 2009**	**Consorcio Santiago – Santiago, 1993**	**CH² Council House 2 Melbourne - 2006**	**One PNC Plaza – Petersburg, 2009**	**Pasona Headquarters – Tokyo, 2010**	**Parkroyal on Pickering – Singapore 2012**
Climate Classification	Equatorial, fully humid	Warm Temperature with fully humid, warm summer	Equatorial monsoonal	Equatorial, winter dry	Equatorial, winter dry	Warm Temperate, Summer Dry, Warm Summer	Warm Temperature with fully humid, warm summer	Snowy Winter; fully humid, warm summer	Warm Temperature with fully humid, warm summer	Equatorial, fully humid
mean Annual Temperature	27.5°C	18,4°C	27,5°C	28,5°C	28,5°C	14,4°C	15°C	10,5°C	16°C	27.5°C
Annual Average Relative Humidity	82% (hottest months); 86% (coldest months)	71%(hottest months); 67% (coldest months)	75%(hottest months); 75% (coldest months)	72%(hottest months); 65% (coldest months)	72%(hottest months); 65% (coldest months)	58% (hottest month); 83%(coldest month)	64%(hottest months); 73% (coldest months)	67%(hottest months); 70% (coldest months)	86%(hottest months); 70% (coldest months)	82% (hottest months); 86% (coldest months)
Average Monthly Precipitation	201 millimetres	99 millimetres	155 millimetres	116 millimetres	116 millimetres	30 millimetres	83 millimetres	54 millimetres	127 millimetres	201 millimetres
Average Wind Speed	4.4 m/s	3.3 m/s	3.7 m/s	2.9 m/s	2.9 m/s	2.5 m/s	3.9 m/s	3.9 m/s	2.94 m/s	4.4 m/s
Maximum Solar Radiation	837 wh/m² (December 21)	959 wh/m² (December 21)	880wh/m² (February 21)	748wh/m² (December 21)	748wh/m² (December 21)	976 wh/m² (December 21)	985wh/m² (November 21)	893wh/m² (April 21)	839wh/m² (January 21)	837 wh/m² (December 21)
Minimum Solar **Radiation**	737 wh/m² (September)	831 wh/m² (June 21)	798 wh/m² (June 21)	589 wh/m² (Murch21)	589 wh/m² (Murch21)	815 wh/m² (June 21)	805 wh/m² (June21)	795 wh/m² (August21)\	680 wh/m² (May 21)	737 wh/m² (September)
Annual Average Daily Sunshine	5.6 hours	6.6. hours	5.8. hours	7.2. hours	7.2. hours	66 hours	5.5. hours	5.5. hours	5.2. hours	5.6 hours

Building Height	120 meters	39 meters	268 meters	Ashton:134 meters Skyle: 10	231 meters	58 meters	42 meters	129 meters	34 meters	89 meters
Number of Stories	36	16	73	Ashton: 32 Skyle: 10	69	17	10	30	9	15
Gross Floor Area	11,835 m²	37,707 m²	77,000 m²	37,043 m²	124,885 m²	27,720 m²	12,536m²	74,147 m²	20,000 m²	29,277 m²
Building Function	residential	residential	residential	residential	residential	Office	Office	Office	Office	Office
Green Wall Type	Façade-supported green wall (metal mesh); Tree planters on balconies	Façade-integrated living wall(vegetated mat)	Façade-integrated living wall(modular green wall)	Façade-supported green wall (metal mesh); Tree planters on balconies	Façade-supported green wall (metal mesh); Tree planters on balconies	Facade – Supported green wall (Horizontal aluminium slats)	Façade-supported green wall (metal mesh)	Façade-integrated living wall (modular living wall)	Façade-supported green wall (metal mesh);Vertical farm	Stepped terrace garden(some cantilevering)
Surface Area of Total Green Coverage	1,274 m²	139 m²	189 m²	5,850 m²	7,170 m²	2,293 m²	420 m²	221 m²	1,224 m²	4,872m²
Total Percentage of Green Coverage	10%	0.7%	0.4%	23%	14%	22%	7%	1%	20%	11%
largest Green Coverage on a Single Façade	734 m² - north	139m² - north	138m² - south	1,276m² - Ashton east	3,385m² - On both north and south facade	2,066 m²-west	420m² - north	221m² - south	720m² - east	2.257m² - north
largest Percent of Green Coverage on a Single Façade	21%	5%	1%	66%	18%	43 %	19%	18%	37%	16%
	Achieved 130% landscape area (horizontal and vertical) – 110% planted –	36,000 litter underground recycled rainwater tank; 1 irrigation	System consists of 150 mm of substrate weighing	Water Flow Rate: 0.049 m3/h, Water Consumption per day: 5L per	65% of residents confirmed green spaces encourage	Reduced solar radiation by 60% users 48% less energy than 10 comparable	Consumes 85% Less energy, 72% less potable water, than similarly-scaled	Green wall 25% cooler than surrounding surface	12% productivity gains and 23% ailment reduction in employees; provides alternative	Horizontal area of landscaping 215% of site area; saves 30% in operational

In Numbers	of the total plot area	lines at three-meter intervals	25kg/m initially, rising up to 65 kg/m upon vegetation maturity	Dispenser	interaction and a sense of community	building; Green wall floors use 35% less energy than other floors	office buildings (green wall only small contribution to this)		food production method; reduces food mileage	energy use over comparable peers

4.1. Comparative Analysis of Vertical Green Systems in Selected Precedents

This thesis focuses on high-rise building projects, which incorporate greenery and nature into their vertical building elements such as walls and facades. Many case studies have been looked at in order to understand how vertical green systems are classified. Accordingly, below criteria have been used to analyse each of the case studies.

4.1.1. Newton Suits –Newton, Singapore

Figure 20: View of Newton Suits – Singapore (Woha, 2012)

- **Background**

Newton Suites is a 36-story high-rise residential building situated in downtown Singapore, neighbouring the business and retail centre of Novena (see figure21). The building site is situated at the edge of a skyscraper zone and faces a stature controlled region, which allows only the perspective of the central natural area. Figure 21 shows the plan and section 0f the building giving references to type of plants/vegetation used in the building.

Table 13: Building and climate data of the Newton Suits – Singapore (Author, 2016)

Building Date			
Year of completion	2007	**Climate data**	
Height	120 meters	**Location**	Singapore
Stories	36	**Geographic Position**	1275 °C
Building Gross Floor Area	11,835 square meters	**Mean Annual Temperature** **Average Daytime Temperature during the Hottest Months (April, May, June)**	Latitude 1o 22 S - Longitude 103' 58'E
Building Function	Residential	**Elevation**	16 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Equatorial, fully humid 1283 °C
Green Wall Type	Facades-supported green wall (metal mesh) Tree planters and gardens on communal cantilevering balconies	**Average Daytime Temperature during the Coldest Months (November, December, January)**	1266 °C
Location on Building	South façade: 6^{th} to 36^{th} floor (green wall); balcony tree/gardens every 4^{th} floor Green walls to car parking podium on south, east and west facades, 1^{st} to 5^{th} floor	**Annual Average Relative Humidity**	182% (hottest months); 86% (coldest months)
Surface Area of Green Coverage	1,274 square meters (approx.)	**Average Monthly Precipitation**	201 millimetres
Owner/Developer	UOL Group Ltd.	**Prevailing Wind Direction**	North
Architect Design	WOHA		
Green Wall Manufacturer	Kajima Overseas Asia Pte Ltd Main Contractor	**Average Wind Speed**	144 meters per second
Green Wall Designer	WOHA	**Solar Radiation**	Maximum: 837 Wh/m² (December 211 Minimum: 737 Wh/m² (September 21)

- **Design strategies**

Trellis-supported green wall runs through the full height of building from the ground floor platform (30 stories) to the upper floors. 30 storey high green walls is separated from single-story green balconies on each floor. These are turning into collective cultivated galleries, where trees, exist on each four storey. Vertical greenery, and trees as well as other site vegetation accomplish 130% of plot in the form of greenery.

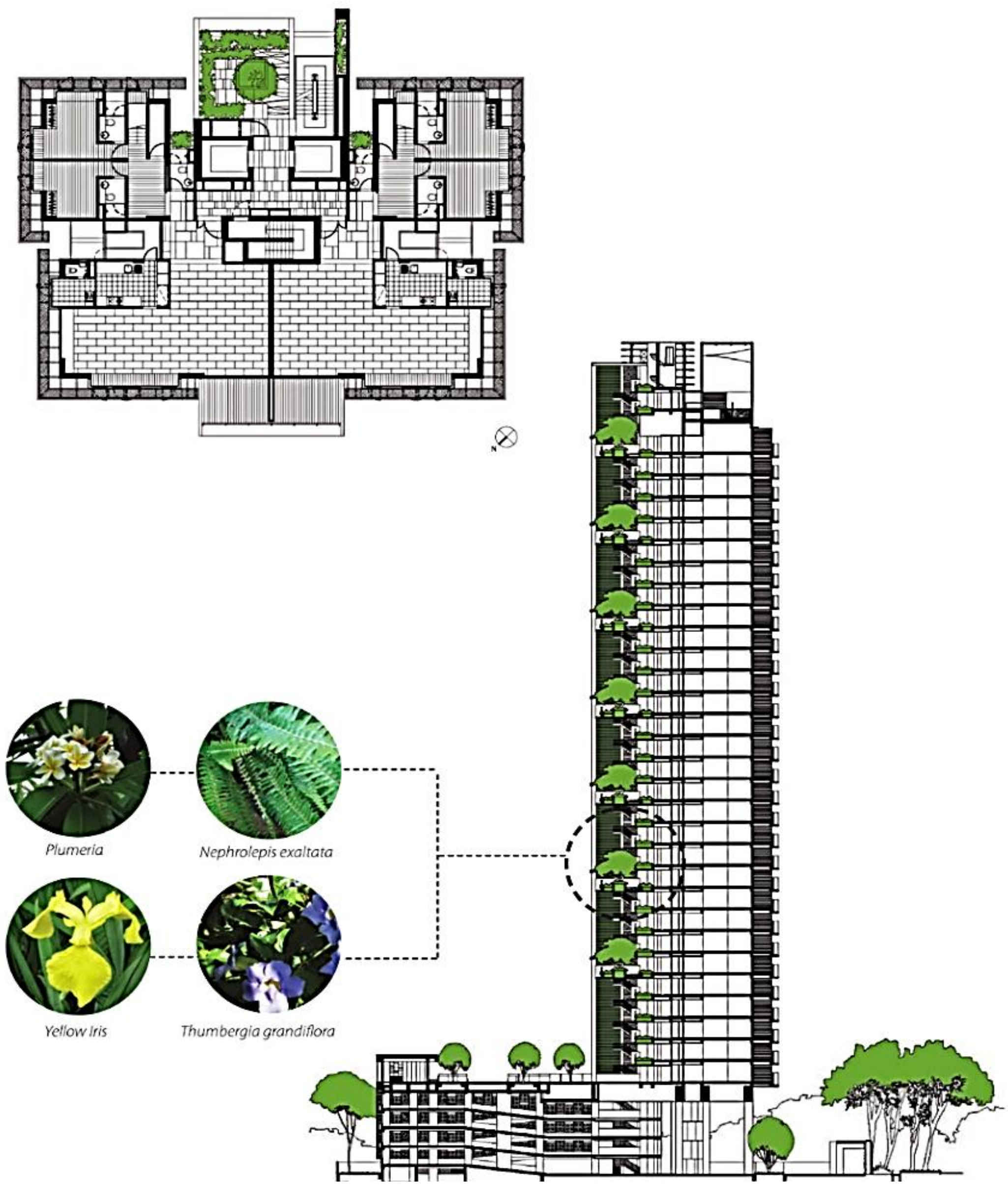


Figure 21: Plan and section showing greenery location (CTBUC, 2014)

- **Green Wall Overview**

As seen in figure 21, landscape has been used as roof planting material, and sky gardens and green wall and facades were united into the system at the beginning of the design process. Creepers screens are associated with clear walls and facades to create visual joy and charm, hold light and carbon and return oxygen back into the environment. The design idea relating to introduction of greenery on most accessible uniform surfaces and some vertical surfaces did not only help accomplish a scenery but also increased planted areas by 110% – of the total project area; huge number for a private tower. The hot and humid atmosphere of Singapore is reasonable for growing common plants and vegetation on vertical surfaces. Consequently, vegetation as trees and plants was broadly consolidated into the building at each level (see figure22).

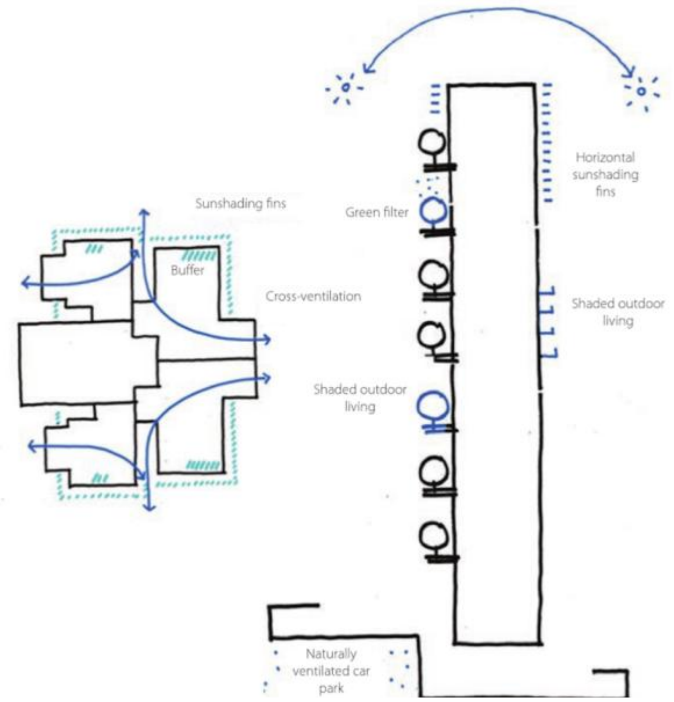


Figure 22: Sketches showing environmental concepts in Newton Suites (Author, 2016)


Figure 23: Section of sky gardens showing green wall beyond (Woha, 2012)

- **Plant Species**

The essential plant utilized on the green wall is Thunbergia grandiflora (see figure 23). Once introduced, the plants grew inside in three months, which permitted the working group to examine all intents and purposes of usage and execution of the entire system. Other plant species used in the building are:

Plumeria, Yellow Iris, Boston fern

- **Irrigation System**

The building utilizes a programmed irrigation system framework on every level, controlled by timing sensors. Green walls normally require waterproofing. Liquid connected elastomeric materials, as utilized here, offer amazing security and simplicity of use. What's more, this specific framework incorporates a water-safe layer and waterproofing of the auxiliary system behind the wall.

- **Maintenance**

Support of the green wall depends on utilizing the outer staircase, adjoining the green wall, which permits the grower and plants to be available from each level behind the metal work. What is more, organizing 30 singular growers vertically, to make the last item out of a clearly adjoining wall, made support simpler and financially more practical.

Figure 24: Detailed and view of the vertical greenery system (Woha, 2012)

- **Analysis and Conclusions**

Newton Suits imaginative utilization of greenery gave back a high green plot proportion, sufficiently critical to be utilized as the model for consequent building-execution enactment in Singapore, which now requires new structures to accomplish no less than 100% plot range greenery. The facade is especially huge in light of the fact that it supplies greenery on no less than three scales. The green walls sheer scale makes it accessible to the wide overall population, i.e., the individuals who are not tenants of the building. It can be delighted in from a separation. The nearness of plantings on the sky gardens makes greenery a collective, sharable resource, without obliging occupants to travel the distance to the rooftop or ground floor of the building. Planted private overhangs additionally hold a feeling of closeness, safer environment and prospect, and close contact with nature. While noteworthy, it ought to be underlined that the green wall that runs the stature of the building is put on a stem mass of maybe one meters thickness, which does not move down to a segment of overhangs. Consequently, the green wall does not give any help to the cooling technique for the inside of the building, which could have been an essential objective for a green plan system at this scope.

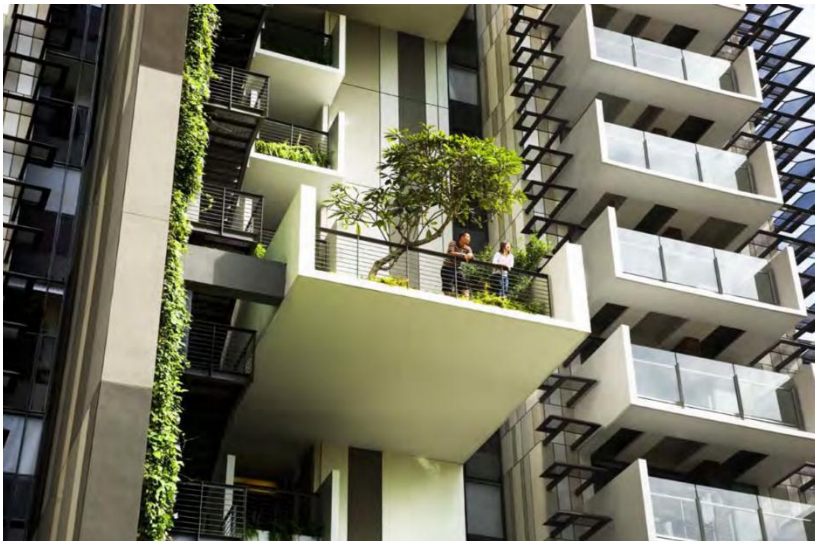


Figure 25 Cantilevered sky garden (Woha, 2012)

- **Green Coverage Calculation**

Newton Suites measurements were dictated by taking the parking structure/platform and tower estimations independently. The towers north height is 120 meters high by 26 meters wide, for a range of 3,120m². The north facade of platform stretches out 11m toward the west of the tower, and is 13m high, giving a further north height region of 143m². Accordingly, there are 3,263 square meters on the north façade.

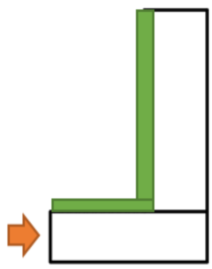
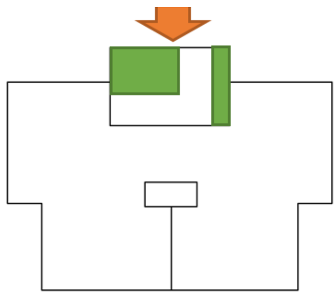
There is no green coverage on this north rise. The east and west raises break the platform and tower into two unmistakable substances.

Figure 26: Elevated communal facilities (Woha, 2012)

Table 14.Calculation of green coverage (Newton Suits – Singapore) (Author, 2016)

Elevation	**Total Wall Area (m^2)**	**Green Wall Coverage (m^2)**	**Tree Coverage on Façade (m^2)**	**Total Coverage (m^2)**	**Percentage of Green Coverage**
Newton Suits					
North	3,263	0	0	0	0%
East	2,910	300	0	300	10%
South	3,541	622	112	734	21%
West	2,910	240	0	240	8%
Total	**12,624**	**1,162**	**112**	**1,274**	**10%**

Table 15: Architectural analysis of building and green coverage (Newton Suits – Singapore) (Author, 2016)

Newton Suits-Singapore, 2007		
Green Wall Type		Façade-supported green wall (metal mesh); Tree planters on balconies
Surface Area of Total Green Coverage		1,274 m²
Total Percentage of Green Coverage		10%
largest Green Coverage on a Single Façade		734 m² - north
largest Percent of Green Coverage on a Single Facade		21%
Massing		
In Numbers	Achieved 130% landscape area (horizontal and vertical) – 110% planted – of the total plot area	
Natural Ventilation	Prevailing Wind Direction is North Average Wind Speed is 144 meters per second	
Maintenance	utilizing the outer staircase, contiguous the green facade, which permits the grower and plants to be open from each level behind the metal mesh	

Landscape Elements	
Irrigation	watering and irrigation automatic system on each level, timing sensors controlled
Interior Spaces	
Plant Species	Plumeria - Yellow Iris - Boston fern

4.1.2. Trio Apartments - Sydney, Australia

Figure 27: View of Trio Apartments - Sydney, Australia (Fender Katsalidis, 2011)

- **Background**

The plan for this long building, which is made out of 397 lofts of fluctuating sizes has more than five levels of storm cellar stopping, which is the consequence of a project competition dispatched by the designers in 2002. Reacting to the expanding requirement for medium and high thickness private settlement in and around downtown areas, this high-rise building was an exercise for scaling, and building structure and site responsiveness. Arranged on the western edge of the City Quarter, the building was proposed to give a noteworthy example inside the rapidly propelling suburb of Camper down. The change was similarly expected to address and supplement distinctive workplaces arranged inside the City Quarter, which all tenants were asked to use. The natural zones inside the site, for instance, the diversion focus and 50 meter outside warmed pool, interconnect through organized spaces to a central sunlit "stop, "an indoor unwinding centre and a bistro/restaurant area that tries to urge a sentimental aggregate.

Table 16: Building and climate date of the Trio Apartments - Sydney, Australia (Author, 2016)

Building Date			
Year of completion	2009	**Climate data**	
Height	39 meters	**Location**	Sydney, Australia
Stories	16	**Geographic Position**	Latitude 33° 57'S – Longitude 151° 10 E
Building Gross Floor Area:	33,707 square meters	**Mean Annual Temperature**	184°C
Building Function	Residential	**Elevation**	3 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Warm Temperate with fully humid, warm summer
Green Wall Type	Facades-integrated living wall (vegetated mat)	**Average Daytime Temperature during the Hottest Months (January, February, March)**	22 °C
Location on Building	North facade	**Average Daytime Temperature during the Coldest Months (June, July, August)**	13 °C
Surface Area of Green Coverage	139 square meters (approx.)	**Annual Average Relative Humidity**	71% (hottest months): 67% (coldest months)
Owner/Developer	Frasers Property Group	**Average Monthly Precipitation**	99 millimetres
Architect Design	Fender Katsalidas	**Prevailing Wind Direction**	Southeast
Green Wall Manufacturer	Patrick Blanc	**Average Wind Speed**	3.3 meters per second
Plant Supplier	Phillip Johnson Landscapes	**Solar Radiation**	Maximum: 959 Wh/m² (December 21) Minimum: 831 Wh/m² (June 21)
Landscape Architect	Oculus	**Annual Average Daily Sunshine**	6.6 hours

- **Design strategies**

This is the largest and tallest green wall of the world existing at the time of completion in 2009. North-façade is vegetated with mat living wall system for aesthetic purpose. Sun-thriving plants located at the top of facade; and more delicate plants are located lower down. 11 irrigation system lines run across the facade at 3 meter intervals in height. Auto watering system runs 6 times each day in a month, and harvested storm water is collected on location of the site (see Figure 28).

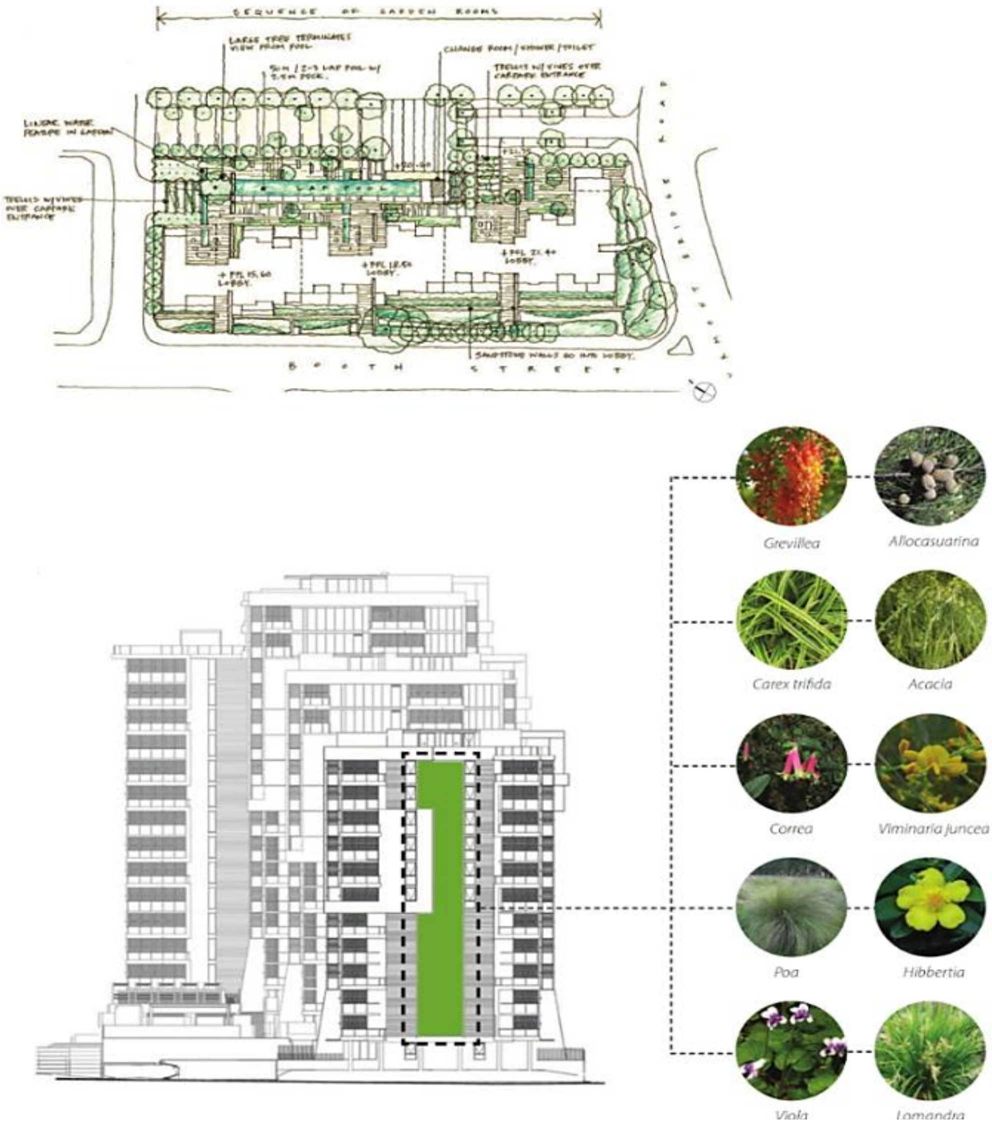


Figure 28: Plan and elevation showing greenery location (CTBUC, 2014)

- **Green Walls Overview**

The tallest vertical garden on the planet at the season of development in 2009, at 33 meters high and 5 meters wide, the vertical green system is comprised of 4,528 local Australian plants (see Figure 28). The essential capability of the green wall is its aesthetic appeal as well as the mission behind its construction: giving greenery to the urban environment. An economical green wall in a urban area goes about as a characteristic air cleansing system, giving a diminishment in contamination, expanded building envelope protection and transference of cooling impacts on the condos. The green wall is given auxiliary support through steel and reused plastic casing which underpins the reused texture takes that the species are planted into. The improvement and foundation of the Trio's green wall took around eight weeks to wrap up. This included evaluating the site and presenting the garden's control room (pumps, filtration, and tanks), wall housings and sheets, water system, felt and plants (see Figure 29).

Figure 29: North view of building, a combination of cladding material, concrete, and green wall (Fender Katsalidis, 2011)

- **Plant Species**

The vertical garden was intended to withstand regular conditions. Plants that flourish in full introduction to daylight, for example, Acacia and Poa, were chosen for the highest point of the divider though fragile plants, requiring more hydration, for example, Goodenia and Viola, were decided for the base.

- **Irrigation System**

All plants are inundated through a dripper-water system from rain water gathered from the site. The material utilized inside the structure is sturdy reused plastic Eleven lines keep running over the divider at three meter interims, in which every line runs six times each day which is controlled by a mechanized dribble irrigation system. Fathered irrigation system gathers water from the site into a devoted, 36,000-liter underground tank that re-utilizes water and compost, accordingly lessening water utilize altogether. The rest of the water unused by the plants and not dissipated in the process is reused back to the tank to be utilized once more (see Figure30).

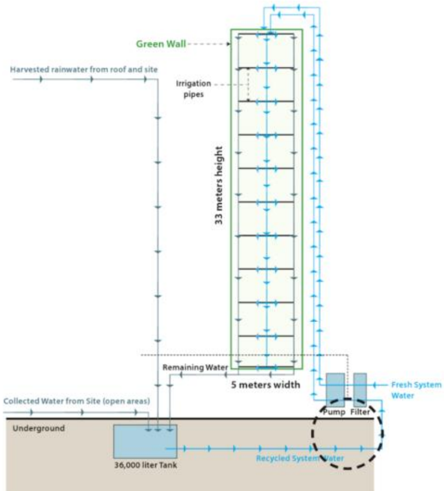


Figure 30: Diagram showing irrigation system (CTBUC, 2014)

- **Maintenance**

In order to overcome the troubles of working with an l6-storey-high vertical garden and guarantee fruitful support, the plant provider was required to design a swing stage that could scale the wall, taking into consideration progressing maintenance. Week by week maintenance is performed by means of visual examination starting from the earliest stage visits to the control space to mind the system's pumps and channels. Month to month support is important to beware of plant wellbeing, treat irritations and infections, and prune plants where required.

- **Analysis and Conclusions**

The Trio residential building extends highlights a particularly verdant living wall, and stands as a demonstration of the legitimacy of Patrick Blanc's plan and irrigation system methodology. Notwithstanding boosting the ecological and water-preservation qualifications of the venture, the water gathering and capacity system is likewise a serious interest later on reasonability of the wall, where procedures in different structures have fizzled. It is trailblazing status as the tallest vertical garden on the planet (when finished) certainly picks up the Trio reasonable presentation as a representation of the typology.

- **Green Coverage Calculation**

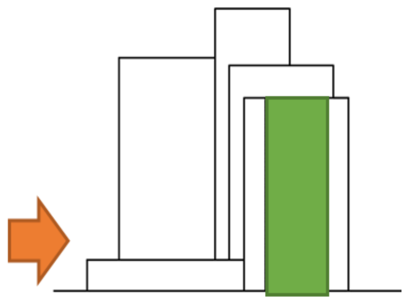
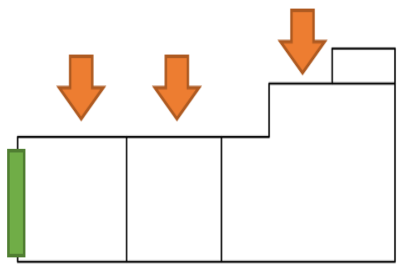
The Trio residential building, as the name suggests, is a long single building massed into three volumes which rise up a slight grade. The motivations behind vertical surface area were the consolidated facades of every one of the three towers and they were taken as solitary, approved height. The north rise has a sporadic however orthogonal diagram that can be converted into a gathering of five rectangles, whose range can be resolved, then included. The area of this littler, framed range (13 m high x 2 m wide = 26 m²) was subtracted from the bigger rectangle's area (33 m high x 5 m wide = 165 m²), bringing about a green wall zone of 139 m² (see Table17).

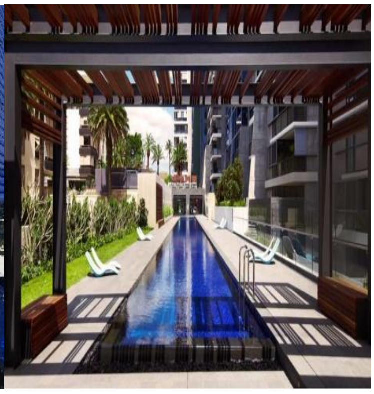
Table 17: Calculation of green coverage (Trio Apartments - Sydney, Australia) (Author, 2016)

Elevation	Total Wall Area (m²)	Green Wall Coverage (m²)	Percentage of Green Coverage
Trio Apartments			
North	2,776	139	5%
East	6,412	0	0%
South	3,322	0	0%
West	6,366	0	0%
Total	**18,876**	**139**	**0.7%**

Figure 31: Exterior view showing landscaping elements(Fender Katsalidis, 2011)

Table 18: Architectural analysis of building and green coverage (Trio Apartments - Sydney, Australia) (Author, 2016)

Trio Apartments-Sydney- 2009	
Green Wall Type	Façade-integrated living wall(vegetated mat)
Surface Area of Total Green Coverage	139 m²
Total Percentage of Green Coverage	0.7%
largest Green Coverage on a Single Façade	139m² - north
largest Percent of Green Coverage on a Single Facade	5%
Massing	 
In Numbers	36,000 litter underground recycled rainwater tank; 11 irrigation lines at three-meter intervals
Natural Light	Solar Radiation is Maximum: 959 Wh/m² (December 21) Minimum: 831 Wh/m² (June 21) Annual Average Daily Sunshine is 6.6 hours
Natural Ventilation	Prevailing wind Direction is Southeast Average Wind Speed is 3.3 meters per second

Landscape Elements	 
Maintenance	Week after maintenance is performed by means of visual examination starting from the earliest stage visits to the control space to keep an eye on the framework's pumps and channels. Month to month support is important to keep an eye on plant wellbeing, treat irritations and sicknesses, and prune plants where required.
Interior Spaces	
Irrigation	dripper- watering and irrigation system from storm and rain water
Plant Species	Acacia, Allocasuarina, Carex trifrda, and Viola

4.1.3. Gramercy Residences – Makati, Philippines

Figure 32: View of Gramercy Residences – Makati, Philippines (Patrice Blanc, 2014)

- **Design Strategies**

Skypark supports at tower midpoint (36th and 37th floors) an exterior coordinated living wall. Affected by New York's Gramercy Park, particularly by assessing a "green plot proportion "and leaf territory list "from Original Park, the green wall of Skypark utilizes a vertical secluded arrangement of grower in "tubs "for instance of support and evacuation and substitution of inadequately performing plants. Extra climbing vines improve style of four-story chamber inside Skypark, between levels 38 and 41, utilizes a concealed directional waste framework to dispense overflow from water system onto the floor.

Table 19: Building and climate date of the Gramercy Residences – Makati, Philippines (Author, 2016)

Building Date			
Year of completion	2013	**Climate data**	
Height	268 meters	**Location**	Makati, Philippines
Stories	73	**Mean Annual Temperature**	27, 5°C
Building Gross Floor Area	77000 square meters	**Elevation**	13 meters above sea level
Building Function	Residential	**Climate Classification**	Equatorial monsoonal
Structural Materials	Concrete	**Average Daytime Temperature during the Hottest Months (January, February, March)**	31 °C
Green Wall Type	Facade-integrated living wall (modular living wall) Facade-supported green wall (metal mesh)	**Average Daytime Temperature during the Coldest Months (June, July, August)**	29 °C
Location on Building	Living wall on "internal Skypark south and west facades between 36th and 37th floors Green wall on Skypark south facade between 38th and 41st floors in central atrium	**Annual Average Relative Humidity**	75 %(hottest months); 75% (coldest months)
Surface Area of Green Coverage	189 square meters (approx.)	**Average Monthly Precipitation**	155 millimetres
Owner/Developer	Dai—Ichttti Mutual Life Insurance Co.	**Prevailing Wind Direction**	North
Architect Design	Emilio Am basz & Associates	**Average Wind Speed**	3.7 m/s
Structural Engineer	Takenaka Corporation	**Solar Radiation**	880wh/m² (February 21) - 798 wh/m² (June 21)
Landscape Architect	Takenaka Corporation	**Annual Average Daily Sunshine**	5.8. Hours

Figure 33: Exterior view showing landscaping elements (Patrice Blanc, 2014)

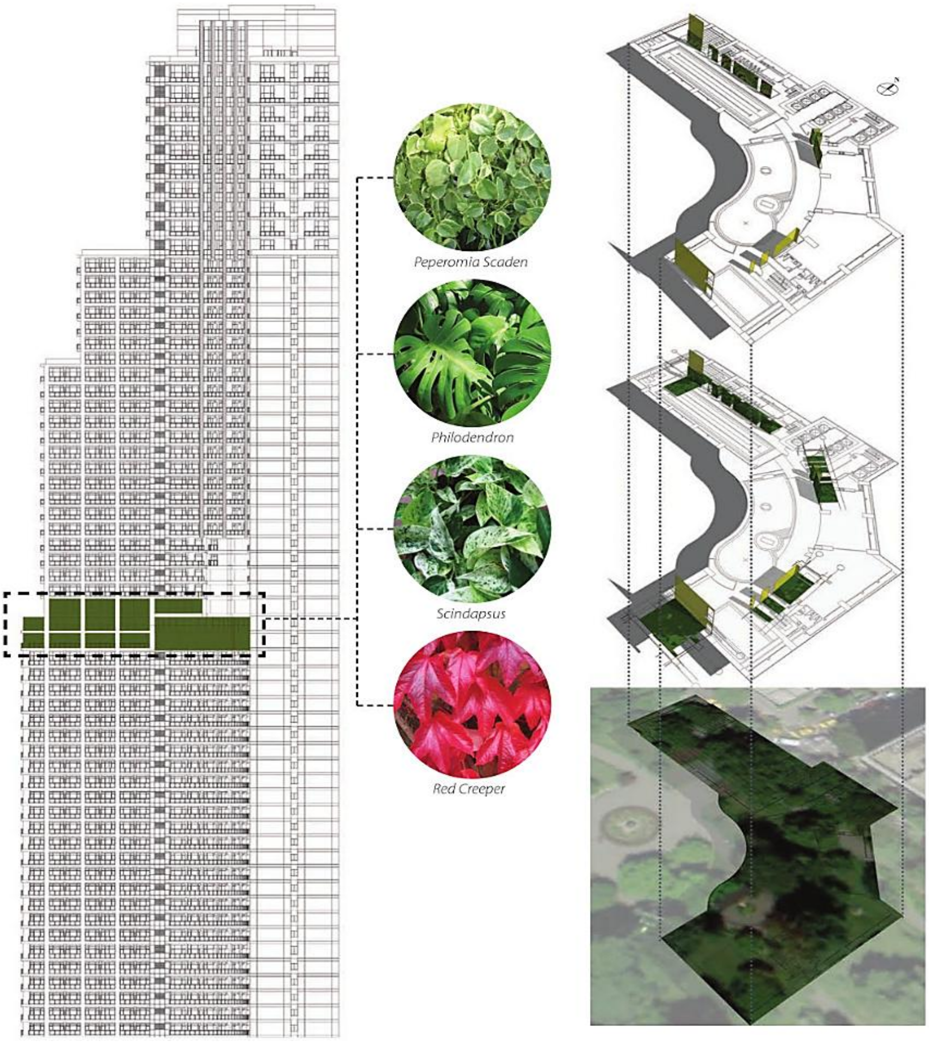


Figure 34: Plan and section showing greenery location and classification (CTBUC, 2014)

- **Green Walls Overview**

The architect/engineer wanted to create a recreational and social space that can likewise offer small scale climate benefits. This space in Manhattan is portrayed by lavish greenery with regards to the city, described by developed trees and wonderful pathways. A sculptural, round wellspring shapes a striking reference point among the expansive shades of the matured trees. In plan, the greenery was then impartially contemplated utilizing the 'green plot proportion" strategy (Pomeroy, 2013) to recognize thick and scanty regions. Foliage, consequently permitting an appraisal of the visual quality and thickness in view of the leaf area record, for the most part, the even greenery of the main Gramercy Park was extrapolated and rotated to effectively make a green wall 'painting "inside the Gramercy Sky Park. Indigenous plant species, set into a suspended and stream overflowed system, were used to clad the walls and to make the green painting, summoning the photo of a 'hanging nursery.

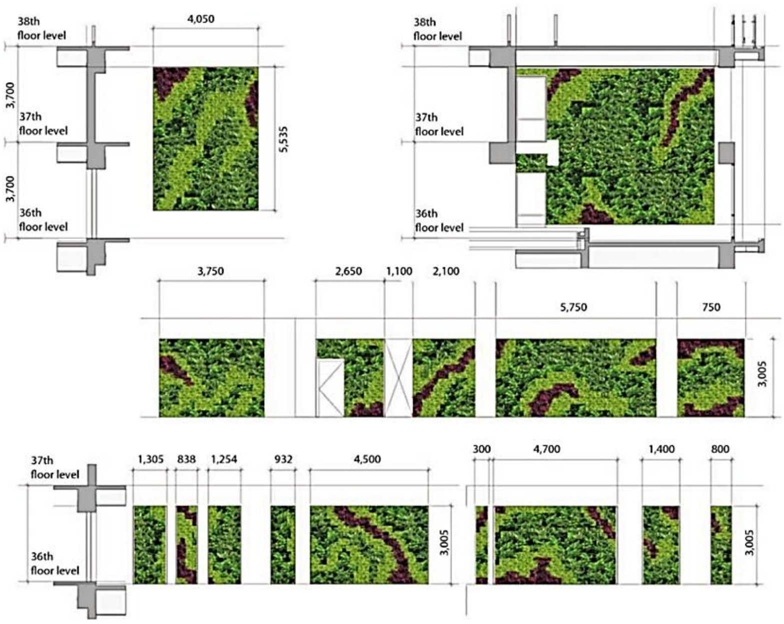


Figure 35: The dimension of modular panels which are used in Gramercy Residences project

- **Plant Species**

Keeping in mind the end goal to make a layering impact in the Skypark that would be illustrative of the thickness and design of the first Gramercy Park, four indigenous species were picked. Philodendron green framed the essential species, with Red creeper, Peperomia scaden"variegate 'and Scindapsus offering the accents of shading. The plants were set up on a substrate made of coco peat, smouldered rice husk, perlite and laca, all of which are effectively sourced In the Philippines In complete, and 8,000 pruned plants involved the vertical greenery in Gramercy Skypark.

- **Irrigation System**

A clock controlled trickle irrigation system framework is utilized that depends on gravity just, and guarantees that the green wall devours the insignificant measure of water, while holding its richness. Water system channels are run on a level plane along the highest point of the grower pots that have little openings that quickly permit the separate pruned plants to be inundated and, if fundamental, evacuated independently for maintenance. The vertical greenery system was finished with a disguised directional waste system. U-formed stainless steel get plate were settled at the base of every board, with the deplete channels associated with an assigned seepage outlet (see figur36).

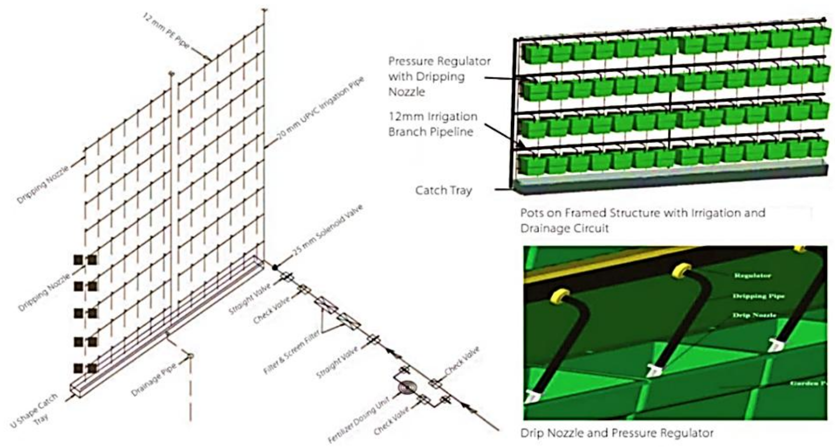


Figure 36: Irrigation system detail of Skypark

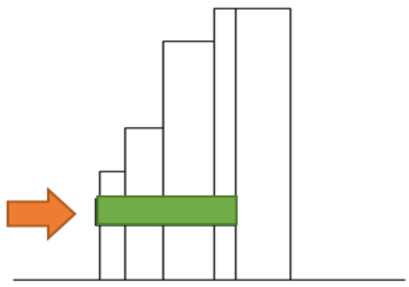
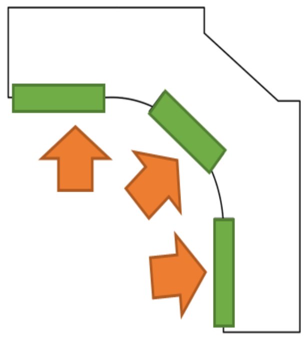
- **Maintenance**

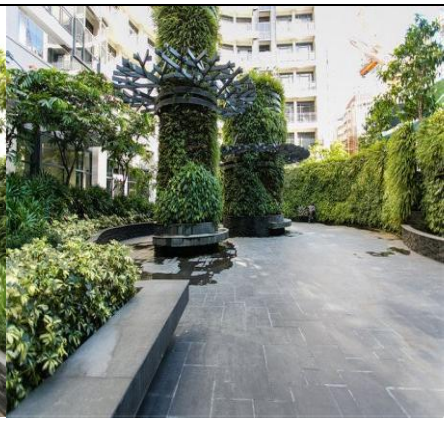
As the larger part of the green walls are close to two stories in tallness, support is effortlessly embraced at the 36th story, or the 37th story mezzanine, in this way keeping away from the requirement for stepping stools and security hardware. There are just two areas that require a gantry: the contemplation region, which houses a twofold sided green wall with a maintenance stage in the middle of, and the vertical hanging garden in the focal void space. In both cases, the scene specialist is securely appended, by bridle, to the gantry when tending the green wall.

- **Analysis and Conclusions**

Despite the fact that actually not altogether a vertical green wall, the Gramercy Skypark was incorporated into this thesis for the interesting characteristics it possesses as a green wall figure, and how it cooperates with the interior spaces of the building. However, Gramercy Skypark's vertical vegetation area is rather small compared to other examples analysed so far.

Table 20: Architectural analysis of building and green coverage (The Gramercy Residences – Makati, Philippines) (Author, 2016)

Gramercy Skypark-Makati, 2013		
Green Wall Type	Façade-integrated living wall(modular green wall)	
Surface Area of Total Green Coverage	189 m²	
Total Percentage of Green Coverage	0.4%	
largest Green Coverage on a Single Façade	138m² - south	
largest Percent of Green Coverage on a Single Facade	1%	
Massing		
In Numbers	System consists of 150 mm of substrate weighing 25kg/m initially, rising up to 65 kg/m upon vegetation maturity	
Natural Light	Solar Radiation is 880wh/m² (February 21) - 798 wh/m² (June 21) Annual Average Daily Sunshine is 5.8. Hours	
Natural Ventilation	Prevailing Wind Direction is North Average Wind Speed is 3.7 m/s	

Landscape Elements	 
Maintenance	As he larger part of the green walls are close to two stories in tallness, support is effortlessly embraced at the 36th story, or the 37th story mezzanine, in this way keeping away from the requirement for stepping stools and security hardware.
Interior Spaces	 
Irrigation	A controlled with timer trickle water system framework is utilized that depends on gravity just, and guarantees that the green façade and living wall expends the negligible measure of water, while holding its richness.
Plant Species	The plants were set up on a substrate made of coco peat, blazed rice husk, perlite and laca, all of which are effortlessly sourced In the Philippines

4.1.4. IDEO Morph 38 Tower – Bangkok, Thailand

Figure 37: View of IDEO Morph 38 Tower – Bangkok

- **Background**

The Ideo Morph 38 improvement is found far from the high thickness and blockage of Sukhumvit Road, in a joyfully green low-ascent neighbourhood. It’s requested, pixelated exteriors give a differentiation to the visual disorder normal for focal Bangkok. The advancement is isolated into two towers to amplify the building plot proportion, with every building focused to various socioeconomics. The lower tower of the two, Skyle provides accommodation for singles or youthful couples, offering the littler impression of the two. Be that as it may, the duplex units are communicated vertically to accomplish a liberal 5.4-meter floor-to-floor stature. Because of impediments on unit size and assortment, the balconies and the air-consolidating units on the outside of the building add to make a "fly up" impact through variety in the façade.

Table 21: Building and climate date of the IDEO Morph 38 Tower – Bangkok (Author, 2016)

Building Date			
Year of completion	2013	**Climate data**	
Height	Ashton:134 meters - Skyle: 10	**Location**	Bangkok - Thailand
Stories	Ashton: 32 - Skyle: 10	**Geographic Position**	Latitude 13°55' N Longitude 100° 35' W
Building Gross Floor Area	37,043 m²	**Mean Annual Temperature**	28,5°C
Building Function	Residential	**Elevation**	12 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Equatorial, winter dry
Green Wall Type	Facade-supported green wall (metal mesh) Tree planters on cantilevering balconies	**Average Daytime Temperature during the Hottest Months (January, February, March)**	33°C
Location on Building	Ashton Tower: green wall on east and west facades from 1st to 32nd floors; green wall on north and south facades from 1st to 8th floors; tree planters on north facade Skyle Tower: green wall on east and west facades from 1st to 10th floors; tree planters on south facade	**Average Daytime Temperature during the Coldest Months (June, July, August)**	31°C
Surface Area of Green Coverage	Surface Area of Green Coverage Ashton Tower: 4,549 square meters (26% of entire facade area) Skyle Tower: 1,301 square meters (17 % of entire facade area)	**Annual Average Relative Humidity**	72 %(hottest months); 65% (coldest months)
Owner/Developer	Ananda Development PCL	**Average Monthly Precipitation**	116 millimetres
Green Wall Designer	Somdoon Architects; Shma Co., Ltd.	**Prevailing Wind Direction**	South
Structural Engineer	Actec Co., Ltd. MEP Engineer: Mect Co.	**Average Wind Speed**	2.9 m/s

- **Design Strategies**

Green wall goes about as persistent "tree rind," wrapping both towers. Trellis structure supporting climbing vines, off-set from exterior by 625 millimetres. Planting media for climbing vines set into grower each floor along length of east and west exteriors of both towers. Trees in grower on galleries at north centreline facade of Ashton Tower and the south centreline of Skyle Tower façade, green walls likewise to 8-storey-high car parking platform, vegetation covers aerating and cooling units behind (see Figures 38 and 39).

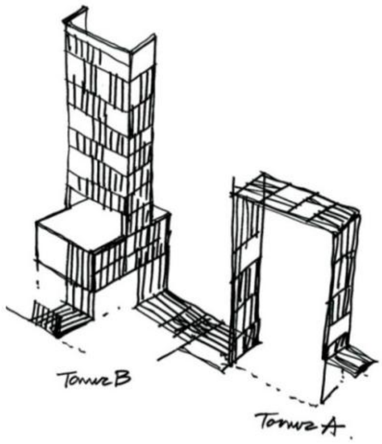


Figure 38: Diagrams showing locations of greenery in external facades

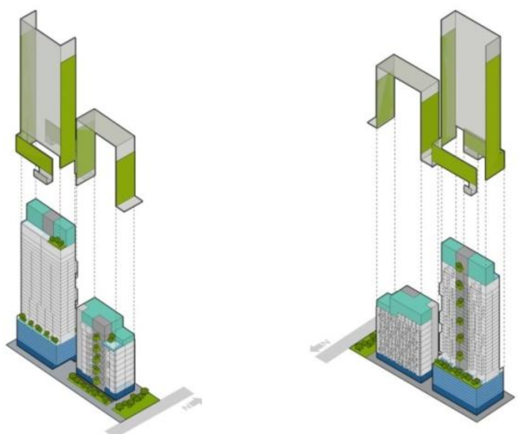


Figure 39: Massing diagrams showing locations of greenery

Figure 40: View of green walls between the buildings

- **Green Walls Overview**

The vertical green wall system is distinguished as the - free Barr envelope, which wraps both structures on the east and west facades and the Asthon platform on the north and south exteriors. In a traditional building exterior treatment, this area would typically turn into a strong solid wall with insignificant openings; subsequently, it would get warm, which would then be transmitted to the private units past. For IDEO Morph 38, the vertical green wall is introduced far from the genuine building exterior, balance by 625 millimetres, which permits normal ventilation and cooling to happen between the skins furthermore, this airspace likewise gives a key administration passage to support get to. The vertical green wall system is distinguished as the - free Barr envelope, which wraps both structures on the east and west facades and the Asthon platform on the north and south exteriors. For IDEO Morph 38, the vertical green wall is introduced far from the genuine building exterior, balance by 625 millimetres, which permits normal ventilation and cooling to happen between the skins furthermore, this airspace likewise gives a key administration passage to support get to (see Figure 40).

- **Plant Species**

One of the difficulties in actualizing this vertical green wall was guaranteeing that the plants can climb and make due at tallness, where quite a bit of Bangkok's solid wind conditions can be found. (See figure41).

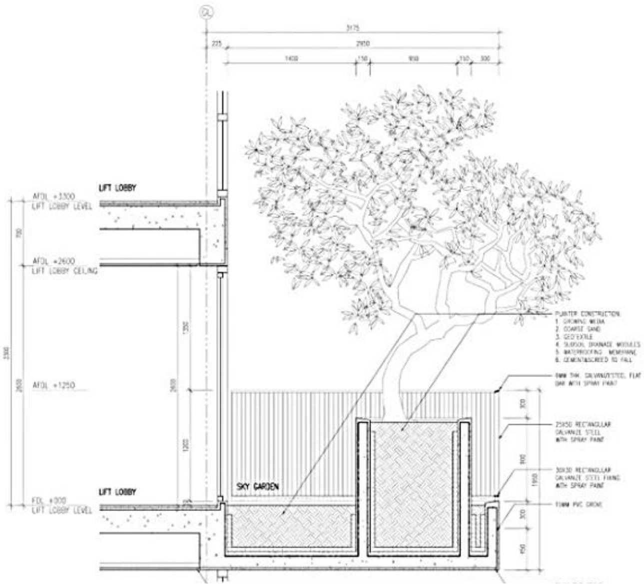


Figure 41: Detailed section showing tree-planted projecting balconies

Figure 42: View of cantilevering balcony and landscape on the podium top of Asthon tower

- **Irrigation System**

The irrigation system of the green exterior comprises of a programmed watering system that keeps running for 15 minutes, 2 times each day, in the morning and evening.

- **Implementation and Maintenance**

The group arranged the establishment by making a planting blend at any rate 450 millimetre profundities. It was important to guarantee that the planting blend included components, for example, topsoil, compost, humus, excrement, coir and sand. Of specific significance was vermiculite, which holds supplements provided through the water, anticipating over-treatment. One month after establishment, the group connected moderate discharge compost, in a light band, over the whole root zone, which can reach out up to a few circumstances the width of the branches. More often than not, the recently introduced plants are under anxiety and ought to get just a light use of compost. Like clockwork, the administration group will apply manure defined with the nitrogen-phosphorous-potassium (NPK) proportion 30-20-10 so as to quicken the development of leaves and shoots.

- **Watering**

At first, support frequently requires a great deal of water and care to advance early development. The planting medium should be refilled at regular intervals so as to keep up the essential supplements for the plant. The dirt ought to stay clammy, yet ought not to be immersed. At IDEO, grower at the base of the exterior systems can be gotten to from entryways at the finishes of the halls opposite to them (see figure43).

Figure 43: View of vertical greenery on the north façade of building

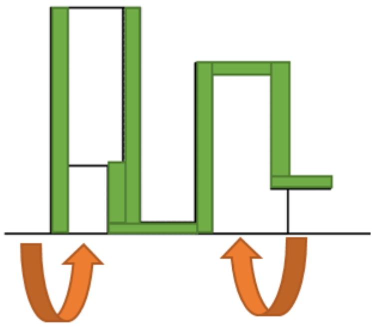
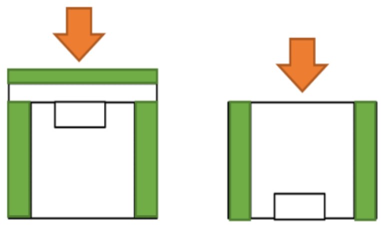
- **Green Coverage Calculation**

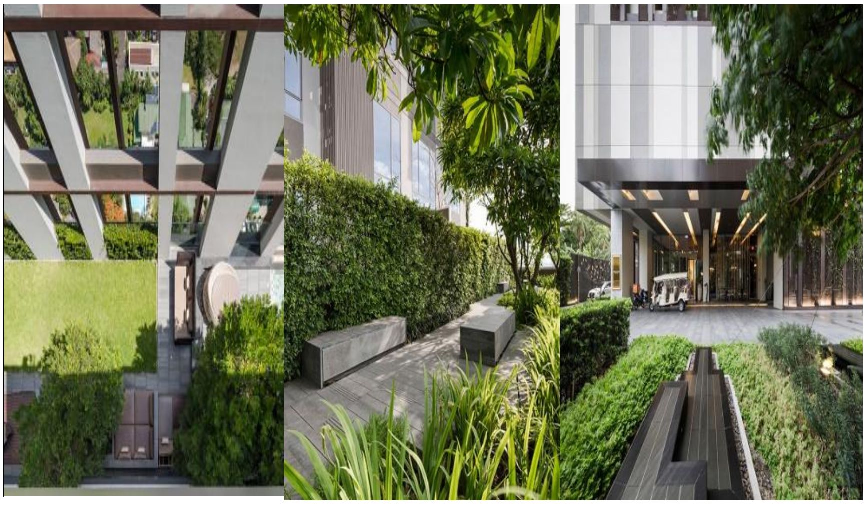
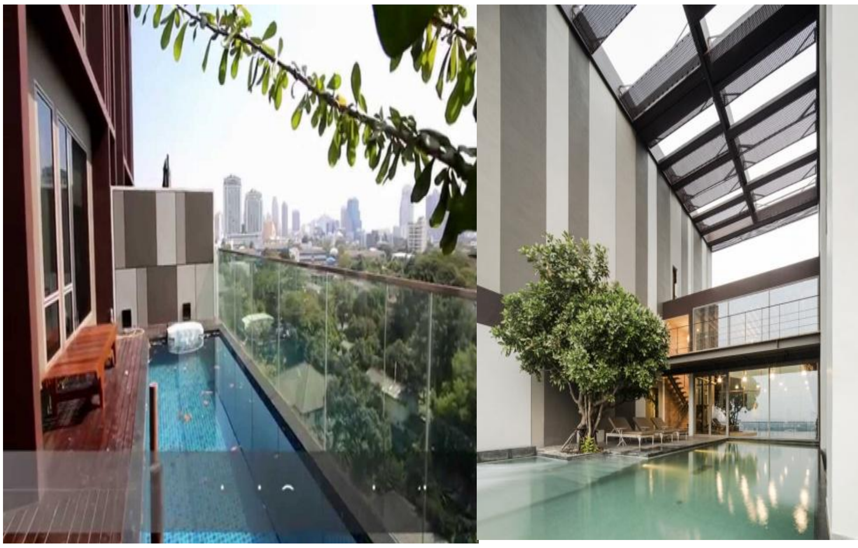
The Ashton Tower is roughly 134 meters tall, by 46 meters in length, by 18 meters wide. It sits on a platform which is flush on the east and west faces, however ventures toward the north and south. The platform is around 24 meters in tallness and 27 meters wide. The Ashton east and west exteriors, including the platform projections, are along these lines figured at 2,628 square meters in all out zone, and the north and south veneers at 6,164 square meters. The Skyle Tower, found straightforwardly toward the east of Ashton, has no platform, and is around 62 meters tall, by 43 meters in length, by 18 meters wide. The Skyle east and west exteriors are subsequently ascertained at 1,116 square meters in all out region, and the north and south veneers at 2,666 square meters. All green coverage figuring are evaluated at the most extreme, completely developed degree of the greenery. The exterior supported green walls cover generous sections of the east and west facades of both towers, and additionally the north and south exteriors of the Ashton platform (to conceal the auto stopping) (see Table 22).

Table 22: Calculation of green coverage (The IDEO Morph 38 Tower – Bangkok) (Author, 2016)

Elevation	**Total Wall Area (m²)**	**Green Wall Coverage (m²)**	**Tree Coverage on Façade (m²)**	**Total Coverage (m²)**	**Percentage of Green Coverage**
Ashton (with podium)					
North	6,164	653	247	900	15%
East	2,628	1,276	0	1,276	49%
South	6,164	994	184	1,178	19%
West	2,628	1,195	0	1,195	45%
Total	**17,585**	**4,118**	**431**	**4,549**	**26%**
Sky (no podium)					
North	2,666	0	80	80	3%
East	1,116	738	0	738	66%
South	2,666	0	0	0	0%
West	1,116	483	0	483	43%
Total	7,564	1,221	80	1,301	17%
Combined Total	**25,148**	**5,339**	**511**	**5,850**	**23%**

Table 23: Architectural analysis of building and green coverage (The IDEO Morph 38 Tower – Bangkok) (Author, 2016)

Ideo Morph 38 Tower-Bangkok, 2013		
Green Wall Type		Façade-supported green wall (metal mesh); Tree planters on balconies
Surface Area of Total Green Coverage		5,850 m²
Total Percentage of Green Coverage		23%
largest Green Coverage on a Single Façade		1,276m² - Ashton east
Largest Percent of Green Coverage on a Single Facade		66%
Massing		
In Numbers	Water Flow Rate: 0.049 m3/h, Water Consumption per day: 5L per Dispenser	
Natural Light	Solar Radiation 748wh/m² (December 21) - 589 wh/m² (Murch21) Annual Average Daily Sunshine 7.2. Hours	
Natural Ventilation	Prevailing Wind Direction is South Average Wind Speed is Average Wind Speed	

Landscape Elements	
Maintenance	Handling Newly Installed Plants: The group arranged the establishment by making a planting blend at any rate 450 millimetre profundity.
Interior Spaces	
Irrigation	The irrigation and water system of the green façade and living wall comprises of a programmed watering framework that keeps running for 15 minutes, 2 times each day, in the morning and evening.
Plant Species	The plants were set up on a substrate made of coco peat, smoldered rice husk, perlite and laca, all of which are effectively sourced In the Philippines

4.1.5. The Met – Bangkok, Thailand

Figure 44: View of the Met – Bangkok, Thailand

- **Background**

The compositional plan of The Met speaks to an imaginative answer for the issues of thickness in tropical Asian urban communities, and offers another model for high-thickness tropical lodging. The model of an actually ventilated, punctured, indoor-open air, green tower is an important other option to the fixed, coated window ornament wall structures being raised crosswise over tropical districts Sun-shading is given by window overhangs and by walls of greenery that likewise change over the daylight into oxygen, hence decreasing the Cheat island" impact of developed metropolitan Bangkok. The building is additionally set back and isolated from the frantic activity of South Sathorn Road by an open passage yard, which highlights a plentiful tropical garden and reflection lakes the building is shaded by shade ing edges, profound vertical balances and punctured metal screens, these shields outside dividers from warmth and daylight.

Table 24: Building and climate date of the Met – Bangkok, Thailand (Author, 2016)

Building Date			
Year of completion	2009	**Climate data**	
Height	231 meters	**Location**	Bangkok - Thailand
Stories	69	**Geographic Position**	Latitude 13°55' N Longitude 100° 35' W
Building Gross Floor Area	124,885 square meters	**Mean Annual Temperature**	28, 5°C
Building Function	Residential	**Elevation**	12 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Equatorial, winter dry
Green Wall Type	Facade-supported green wall to car park podium and tower side wall (metal mesh) Tree planters on balconies Tree planters on sky terraces	**Average Daytime Temperature during the Hottest Months (January, February, March)**	33°C
Location on Building	podium has a green walls, 1st to 8th floors in north and south facades tower has a green walls, 11th to 69th floors in east and west facades balconies and sky terraces have a tree planters on north and south facades	**Average Daytime Temperature during the Coldest Months (June, July, August)**	31 °C
Surface Area of Green Coverage	7,170 square meters (approx.)	**Annual Average Relative Humidity**	72 %(hottest months); 65% (coldest months)
Owner/Developer	Pebble Bay Thailand	**Average Monthly Precipitation**	116 millimetres
Architect Design	WOHA	**Prevailing Wind Direction**	South
Structural Engineer	Worley Pte Ltd.	**Average Wind Speed**	Average Wind Speed

- **Design Strategies**

Green wall on metal work to conceal eight stories of car parking platform, east and west slender tower exteriors highlight a tall and tight segment of green wall developing about full stature of the building, full-measure frangipani trees on private galleries, full-estimate frangipani trees on six-story high sky balcony (see Figure 45).

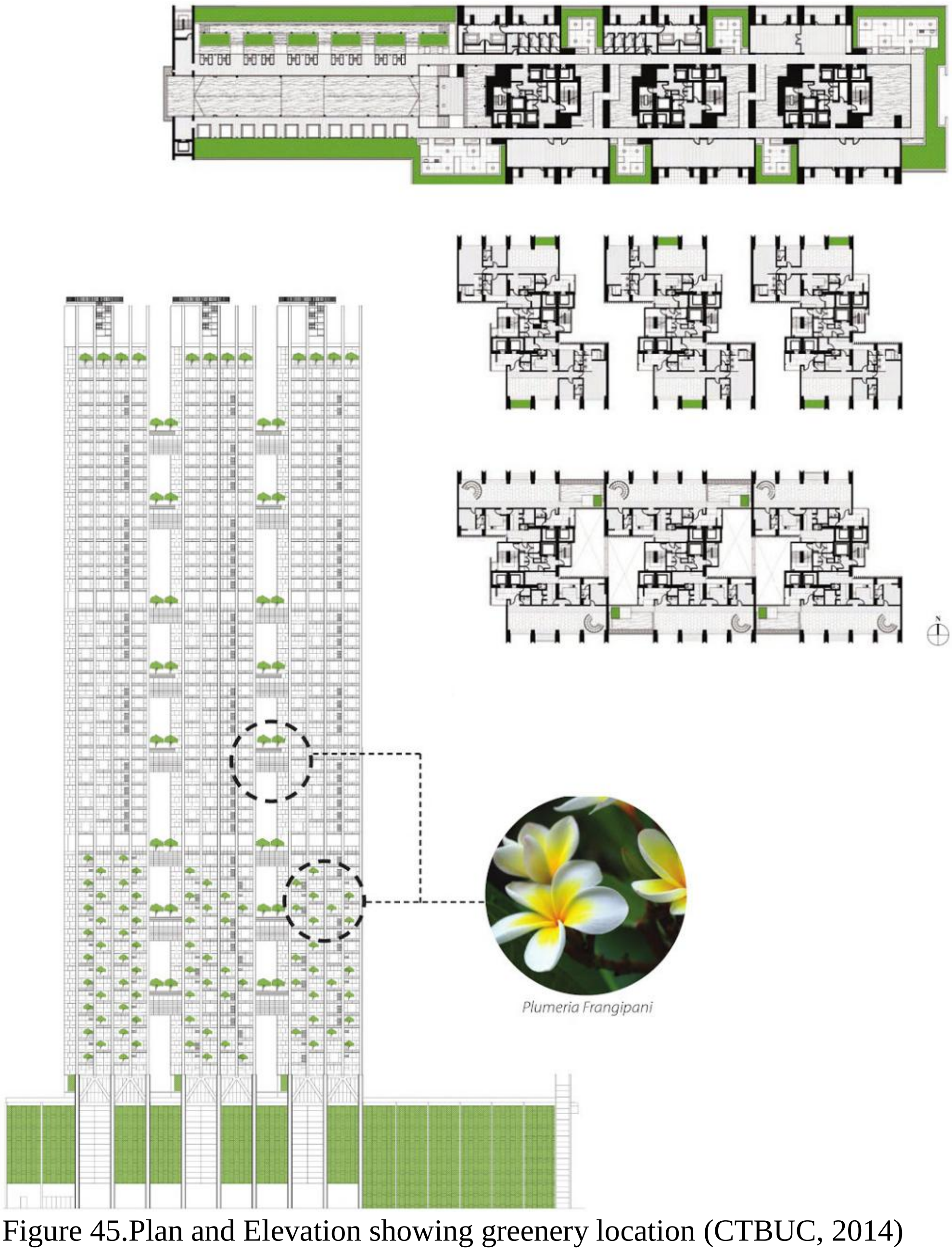


Figure 45.Plan and Elevation showing greenery location (CTBUC, 2014)

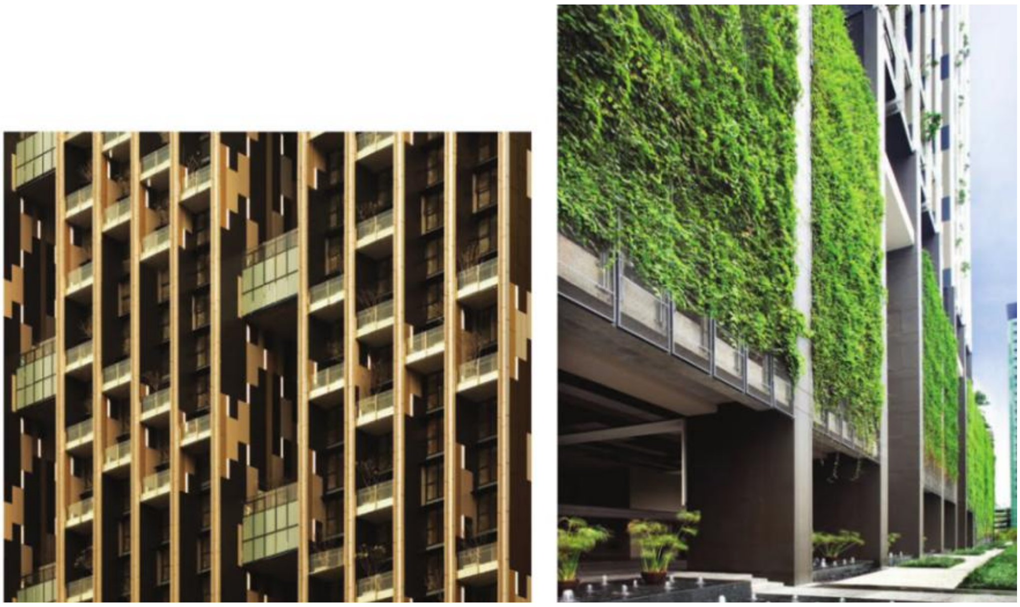


Figure 46. Detail view of façade and climbing plants at exterior of podium car park showing the overhangs and deep vertical fins.

- **Green Walls Overview**

The green wall is included vertical metal work shrouded in climbing plants, scattered along the facade of the auto stop platform, which involves the initial eight stories of the building (see Figure46), and in tall, one far reaching strips along the tower's thin east and west rises. The lofts highlight full-stature coating and galleries with grower containing full-sized frangipani trees (see Figure47).These trees are planted on private. The flats include overhangs with grower containing full-sized frangipani trees. These trees are planted on private overhangs, on each floor from the eleventh through the 28th floor.


Figure 47.View looking to showing greenery

- **Plant Spices**

There is negligible variety in plant species decided for the building. The vertical greenery on the car parking zones and the east and west facades contain Tristellateia Australasia, Jasminurn laurifolium, Thunbergia laurifolia, and Thunbergia grandiflora. Frangipani trees are utilized on the private balconies and sky gardens.

- **Irrigation System**

A programmed water system framework is utilized for watering the plants as a part of the normal ranges. Occupants are in charge of watering their planted overhang. What's more, gathered rain water is put away and reused alongside overabundance cultivate waters which are gathered starting from the earliest stage and recreational floors. The capacity to reuse and use this asset adds to lower maintenance costs.

- **Maintenance**

Maintenance regularly happens at regular intervals for the green exterior of the auto stop platform and the vertical greenery of the normal areas. This incorporates weeding, pruning, mulching, and preparation. In specific situations where segments of the plants or trees don't survive, substitution is instituted. Notwithstanding watering, occupants are in charge of the maintenance of the trees on their balcony.

- **Performance Data**

Post-occupation analysis demonstrates that 65% of occupants indicate that the green spaces do, indeed, energize neighbourly associations. The review additionally found that there are three essential contemplations that influence which deck is favoured by the tenants: twist, perspectives of the horizon and clamour from the road. In general, 60% of those studied said that the greenery coordinated into the improvement was palatable (Kishnani 2012).

- **Analysis and Conclusions**

The Met takes full preferred standpoint of the soothing climate of Bangkok, and there is post-occupation confirmation to reinforce the idea that it’s sending of greenery has positively affected the feeling of group in the building. The Met veils its parking structure in a thick vertical scope of vegetation. In spite of the fact that no quantitative information strengthens this, it can coherently be expected that the plants have some impact on the visual scenery (See Table25).

Figure 48: Diagram showing greenery coverage

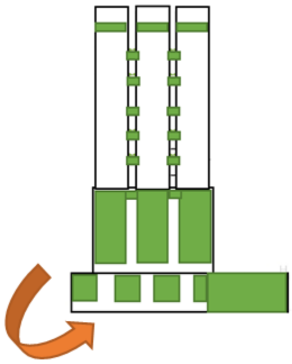
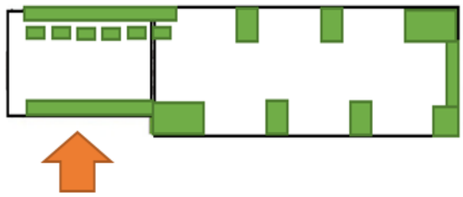
Table 25: Calculation of green coverage (The Met – Bangkok, Thailand) (Author, 2016)

Elevation	Total Wall Area (m^2)	Green Wall Coverage (m^2)	Tree Coverage on Façade (m^2)	Total Green Coverage (m^2)	Percentage of Green Coverage
The Met					
North	18,960	2,400	985	3,385	18%
East	6,952	200	0	200	3%
South	18,960	2,400	985	3,385	18%
West	6,952	200	0	200	3%
Total	**51,824**	**5,200**	**1,970**	**7,170**	**14%**


Figure 49: View of exterior garden at 9th floor podium rooftop

Table 26: Architectural analysis of building and green coverage (The Met– Bangkok, Thailand) (Author, 2016)

The Met -Bangkok, 2009	
Green Wall Type	Façade-supported green wall (metal mesh); Tree planters on balconies and sky terraces
Surface Area of Total Green Coverage	7,170 m²
Total Percentage of Green Coverage	14%
largest Green Coverage on a Single Façade	3,385m² - On both north and south facade
largest Percent of Green Coverage on a Single Facade	18%

Massing		
In Numbers	65% of residents confirmed green spaces encourage interaction and a sense of community	
Natural Light	Solar radiation: 748wh/m² (December 21) - 589 wh/m² (Murch21)	
Natural Ventilation	Prevailing Wind Direction is South Average Wind Speed is 2.9 m/3	
Landscape Elements		
Maintenance	Maintenance ordinarily occurs like clockwork for the green exterior of the auto stop platform and the vertical green system of the basic areas	

Interior Spaces	
Irrigation	A programmed irrigation and water system framework is utilized for watering the plants as a part of the regular areas. Reaped rain water is put away and reused alongside overabundance cultivate waters which are gathered starting from the earliest stage and recreational floors
Plant Species	The vertical greenery on the auto stop ranges and the east and west exterior facades are included Tristellateia Australasia, Jasminurn laurifolium, Thunbergia laurifolia, and Thunbergia grandiflora. Frangipani trees are utilized on the private overhangs and sky gardens. On the first-and ninth-floor amusement ranges, there are add

4.1.6. Consorcio Santiago Building – Santiago, Chile

Figure 50: View of Consorcio Santiago Building - Santiago, Chile (Pastorelli, 2009)

- **Background**

The workplace building is situated in the las Condes Neighbourhood, in Santiago, Chile. The floor plan of the building has the type of a pontoon, looking south with the arrangement of the primary exteriors created by the principle road hub that encompasses the building (Sheweka & Magdy, 2011). At first, the arrangement was that the floor space would be separated into two segments, with the initial three stories possessed by Consorcio, while the higher floors would be leased; nonetheless, the Consorcio Company in the end involved the greater part of the floors in the building. These typically denote the start of the workplace region of the area. The west facade was bended to outwardly get the people on foot originating from the close-by metro and down the road. These bends additionally give a portion of the building space back to the encompassing neighbourhood, delivering two little outside squares in every corner (Sheweka & Magdy, 2011).

Table 27: Building and climate date of the Consorcio Santiago Building - Santiago, Chile (Author, 2016)

Building Date		**Climate data**	
Year of completion	1993		
Height	58 meters	**Location**	Santiago, Chile
Stories	17	**Geographic Position**	Latitude 33.5° S Longitude 70.7° W
Building Gross Floor Area	27,720 square meters	**Mean Annual Temperature**	14.4 °C
Building Function	Office	**Elevation**	550 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Warm Temperate, summer dry, warm summer
Green Wall Type	Facades-supported green wall (horizontal aluminium slats)	**Average Daytime Temperature during the Hottest Months (January, February, March)**	20.5 °C
Location on Building	On north and west facades, from 4th to 8th , 10th to 12th , and 13th to 14th floor	**Average Daytime Temperature during the Coldest Months (June, July, August)**	8.7 °C
Surface Area of Green Coverage	2293 square meters (approx.)	**Annual Average Relative Humidity**	58% (hottest months); 83% (coldest months)
Owner/Developer	Consorcio Nacional de Seguros	**Average Monthly Precipitation**	30 millimetres
Architect Design	Enrique Browne and Borja Huidobro	**Prevailing Wind Direction**	Southwest
Green Wall Manufacturer	Technical	**Average Wind Speed**	2.5 meters per second
Landscape Architecture	Juan Grimm	**Solar Radiation**	Maximum: 976 Wh/m2 (December 21) Minimum: 815 Wh/m2 (June 21)
Structural Engineer	LBW Consultants	**Annual Average Daily Sunshine**	6.6 hours

- **Design Strategies**

The building comprises even aluminium braces, counterbalance 1.4 meters from facades, reinforced climbing plants more than 2-4 stories in tallness. Green wall split into three separate areas vertically, each with the support of one even grower at green façade and wall base. Deciduous plants give shade from the sun in summer and pre D winter/fall and allow sun in during leafless months (See figure 51).

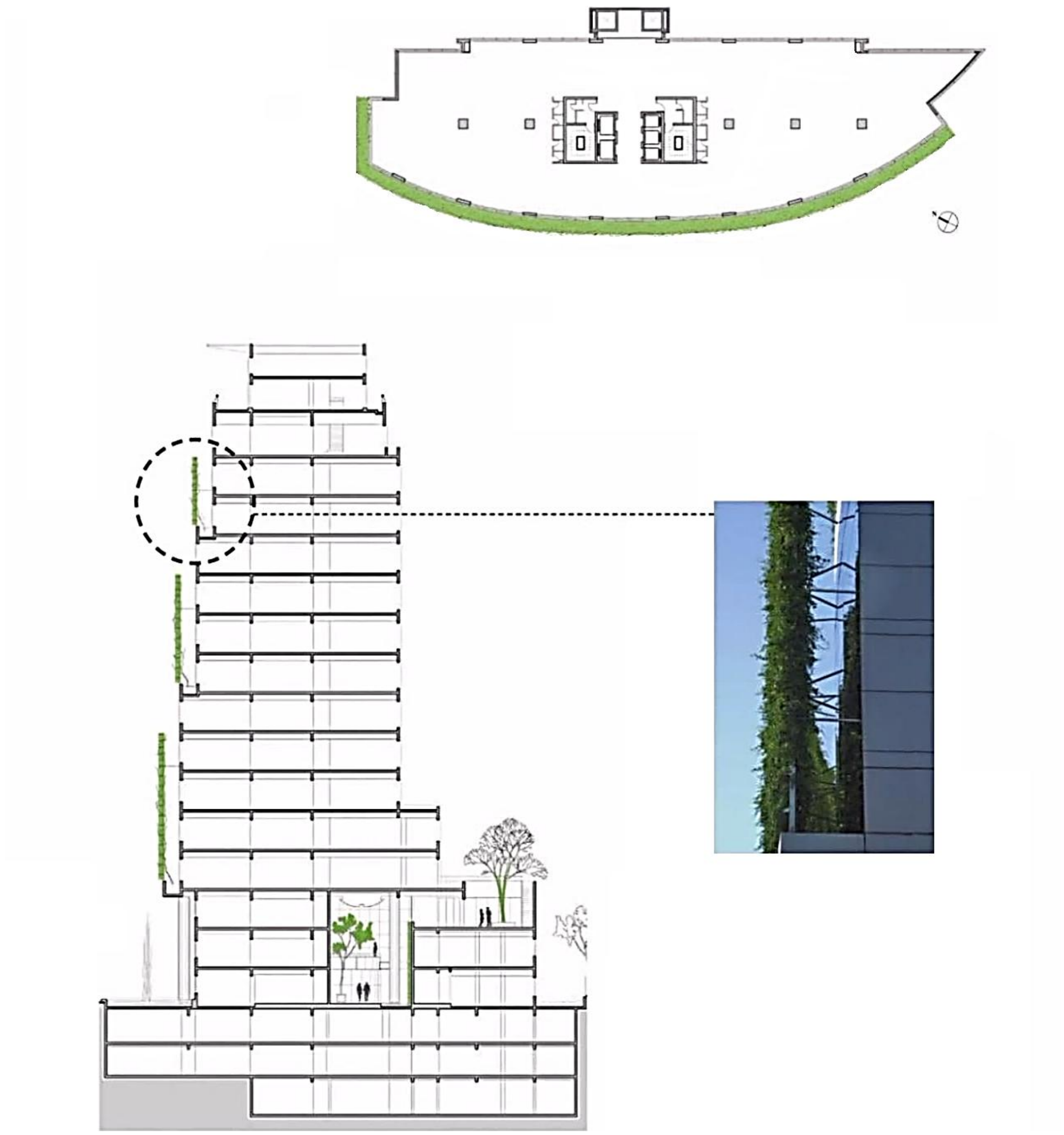


Figure 51: Section showing vertical greenery locations (CTBUC, 2014)

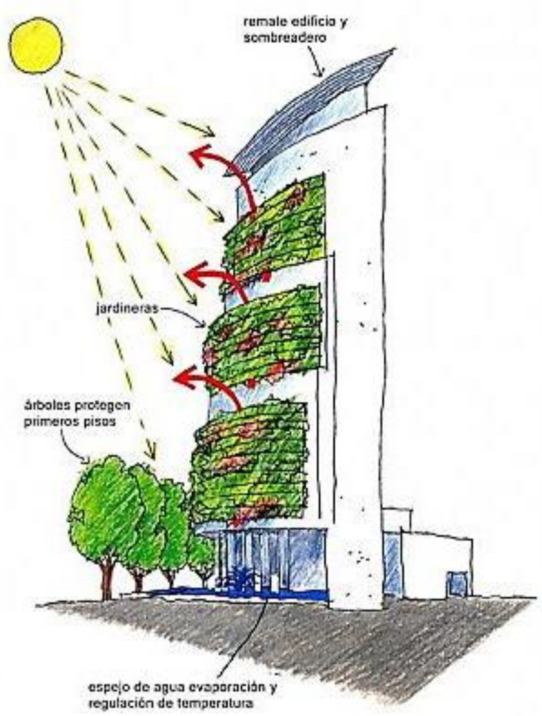


Figure 52: Sketch of the final concept with green elements, using street level trees to shade the first three floors and vertical planting stands for upper floors.

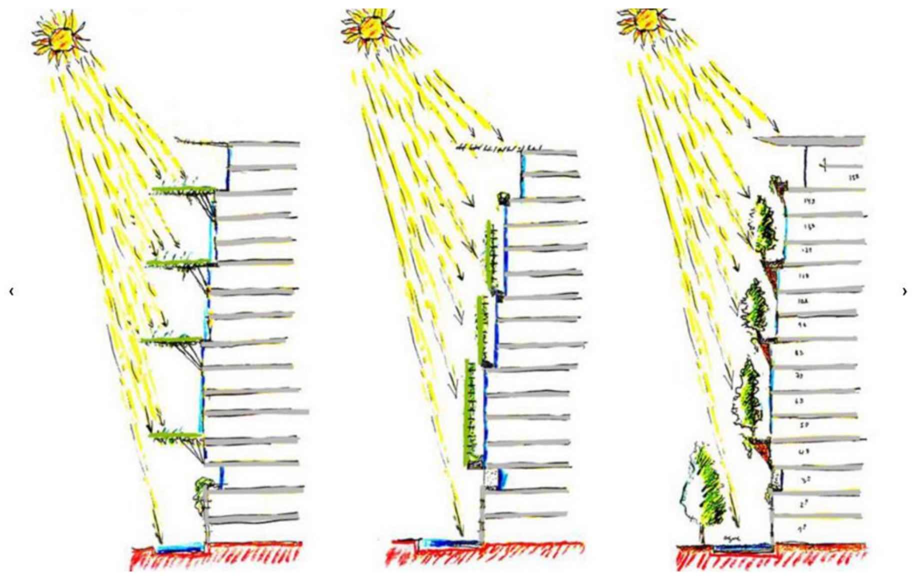


Figure 53: Conceptual analysis diagram of greenery options, the main object was to shade the façade by using vegetation.

- **Green Wall System Overview**

The planner considered working with a twofold vegetated veneers (here delegated a façade-upheld green wall) that would sit 1.4 meters from the skin of the building (see figure52).The mix of the vegetated façade starts over the initial three stories of the building, as these zones are shielded from the sun by road trees. In the meantime, the highest floors are shaded by a metallic cantilever 4.5 meters wide, which serves as a visual crown of the building. Also, to lessen the warmth island impact, the building has a290-square-meter wellspring at the ground level with water distributors delivering evaporative cooling. Trees additionally were planted at road level to shade up to the third floor and to cool the walkway (see figure53). The exteriors upheld green wall was made with deciduous climbing plants, to diminish the take-off increase inside the building. It likewise delivers a stack impact between the outside, directing the warmth way up yonder, into the clouds from the building. Also, I change the façade into a vertical garden that can be seen from the outside of the working and in addition from within (Adria & Allard, 2010).

Figure 54: Detailed view of the planter and grid support system, the left image shows the system in winter, when plants are bare, allowing solar penetration into the building.

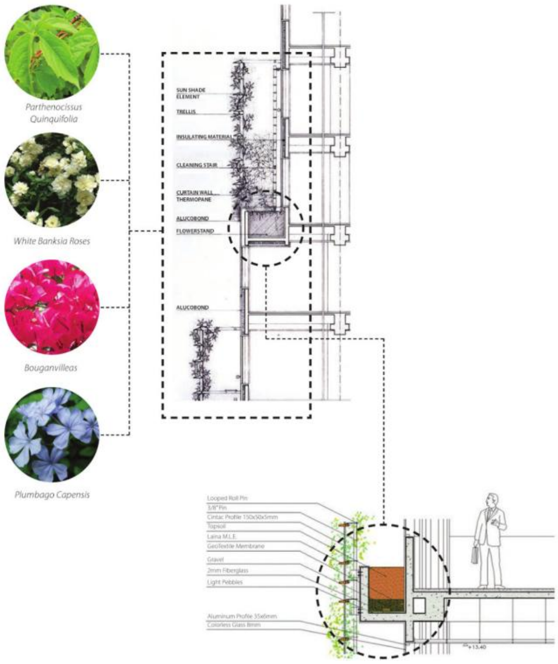


Figure 55: Detail of wall section showing the structural connections between plant stand, planter and building (Pastorelli, 2009)

The architect considered working with a twofold vegetated façade (here delegated a façade-supported green wall) that would sit 1.4 meters from the skin of the building (see figure55).The mix of the vegetated façade starts over the initial three stories of the working, as these zones are shielded from the sun by road trees. In the meantime, the highest floors are shaded by a metallic cantilever 4.5 meters wide, which serves as a visual crown of the building (Adria & Allard, 2010). Also, to lessen the warmth island impact, the building has a290-square-meter wellspring at the ground level with water distributors delivering evaporative cooling. Trees additionally were planted at road level to shade up to the third floor and to cool the walkway (Derbyshire, 2001). The exteriors supported green wall was made with deciduous climbing plants, to diminish the take-off increase inside the building. It likewise delivers a stack impact between the outside, directing the warmth way up yonder, into the clouds from the building (see figure55).

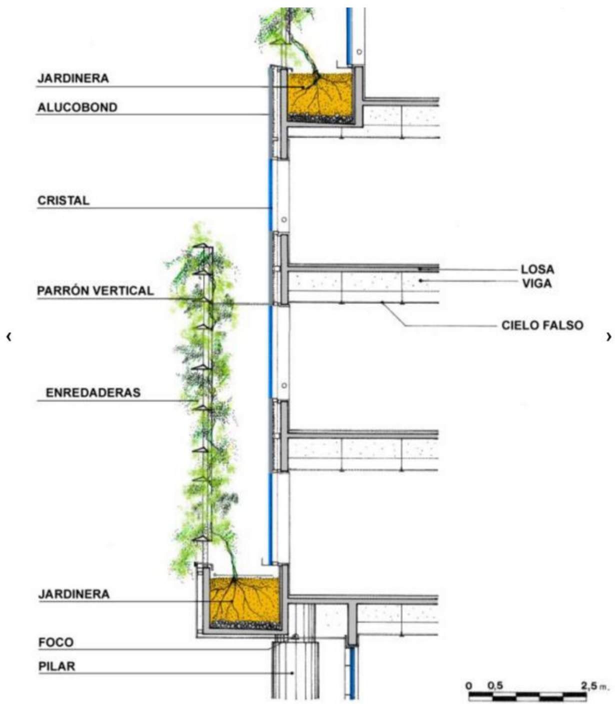


Figure 56: Detail of wall section also showing the structural connections between plant stand, planter and building (Pastorelli, 2009)

The partition of two skin systems additionally permits clients to encounter the changing of the leaf hues consistently, specifically by the building. Notwithstanding the shading and stack impacts, the second skin of the facades supported green wall was decided for proficient maintenance from stages straightforwardly outside the workplace windows. The goal was additionally to expand client connection and control with maintenance staff, in order to modify the measure of light coming into ranges of the working through client coordinated pruning (Mies Van Der Rohe Award for Latin American Architecture 1999) (see figure56).

- **Plant Species**

The landscape architect chose four deciduous climbing plants (see figure57), contemplating their prudent and upkeep focal points and regular stylish. The façade is green in the mid-year and red in fall. The four species utilized are:

Bougainvillea, Parthenocissus quinquefoila, Plumbago capensis, White banksia roses.

- **Irrigation**

The irrigation system framework uses a straightforward plastic hose that discharges drops of water at particular focuses along the framework, a programmed control to manage the water system. Contingent upon the season, water system happens for one time of two minutes in the morning up to three two-minute terms toward the evening.

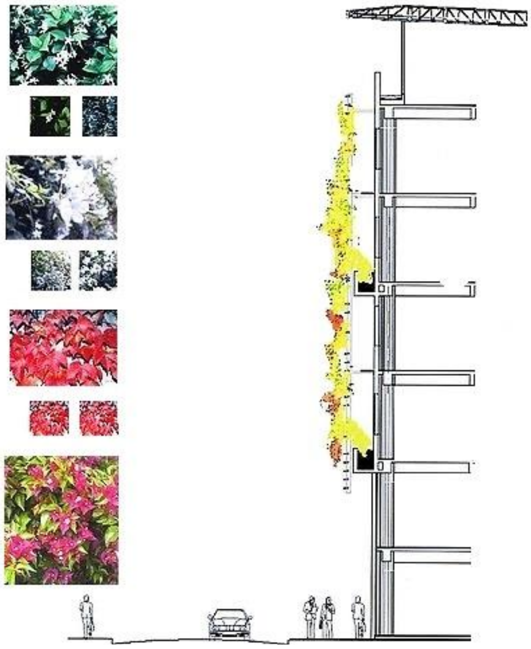


Figure 57: Detail of wall section also showing the structural connections between plant stand, planter and building (Pastorelli, 2009).

- **Maintenance**

There is a noteworthy space between both skins of the facades, which gives the support a chance to staff possess the crevice and go before the windows, taking into consideration simple and proficient access during maintenance. Moreover, the staffs have entry to a nursery worker's lift, which takes into consideration more perplexing maintenance of the framework at its most noteworthy focuses (Cooper, 2001). The cultivator lift is utilized amid yearly pruning as a part of August, and also to control the improvement of the foliage and to sanitize the plants and the emotionally supportive network in spring and summer (D'Alencon, Nobel & Fischer, 2009).

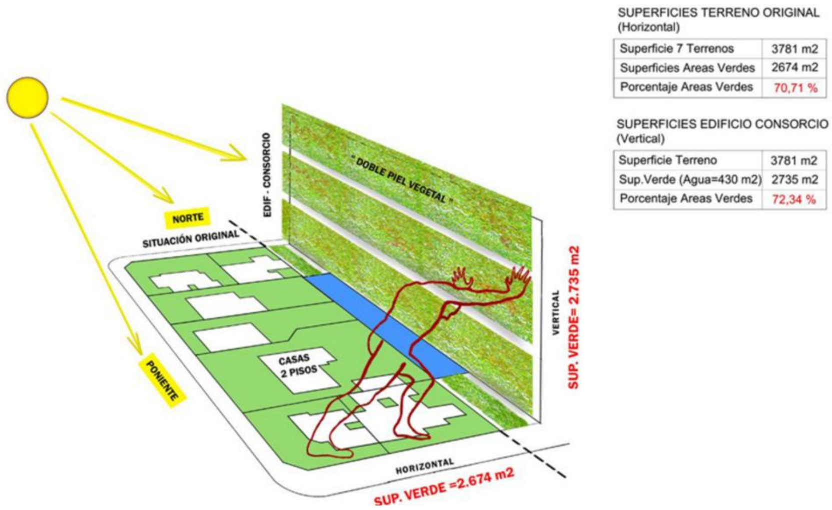


Figure 58: Pre-existing versus new green area comparison (Pastorelli, 2009)

Table 28: pre-existing versus new green area comparison (Consorcio Santiago Building - Santiago, Chile) (Author, 2016)

Percentage of Green Areas - Pre-Existing Homes	
Total Site Area	3,781 m²
Green Areas	2,674 m²
Percentage of Green Areas	70,71 m²
Percentage of Green Areas – New Consorcio	
Total Site Area	3,781 m²
Green Areas	2,735 m²
Percentage of Green Areas	72,34 m²

- **Performance Data**

In 2002, a similar observational investigation of 10 other corporate structures in Santiago was led (Reyes, 2002). The outcomes demonstrated that the Consorcio building utilizes 48% less energy than 10 different conventional buildings (see figure 61). To affirm the outcome, which appeared to be somewhat high on account of incidental variables, a story by-floor correlation was considered inside the Consorico building. The outcomes demonstrated that the green-wall secured floors of the Consorico building utilized 35% less energy and were 25 % less expensive to work against floors without green walls (see table28).

- **Analysis and Conclusion**

The Consorcio building is the most seasoned in this thesis, and is astounding for its spearheading soul, as well as in light of the fact that its outline goal has thusly been approved by precise reviews. The green wall has diminished heat gain by around 60% and brought about huge energy saving. The choice of provincially suitable deciduous plants manages a change of shading that fortifies regularity, even on the high floor of an urban office working, and also conceding northern light when the leaves are off and heat is generally desired.

- **Green Coverage Calculation**

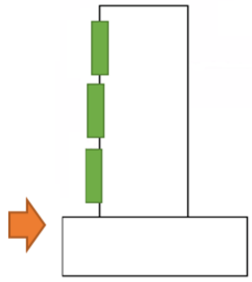
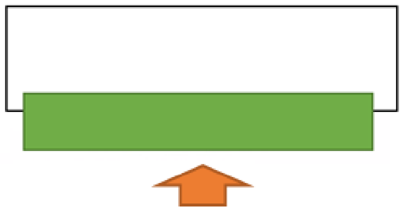
The total vertical wall area of the Consorcio project is 10,498 square meters, by taking the ranges of each of the rises and including them together (see table 29). The slight bend of the west facades was converted into a progression of associated straight – line sections for rearrangements purposes. The north, ventured in plan, façade range (58 m high and 18 m wide) was observed to be 1,044 m². The west, bending façade is 4814 square meters add up to (58 m high × 71 m wide), and the south façade, a range of 522m², (58 m high × 9m wide), don't bolster greenery.

Table 29: Calculation of green coverage (Consorcio Santiago Building - Santiago, Chile) (Author, 2016)

Elevation	Total Wall Area (m²)	Green Wall Coverage (m²)	Percentage of Green Coverage
Consorico			
North	1,044	227	22%
East	4,118	0	0%
South	522	0	0%
West	4,814	2,066	43%
Total	**10,498**	**2,293**	**22%**

Table 30: Architectural analysis of building and green coverage (Consorcio Santiago Building - Santiago, Chile) (Author, 2016)

Consorcio Santiago – Santiago, 1993	
Green Wall Type	Facade – Supported green wall (Horizontal aluminium slats)
Surface Area of Total Green Coverage	2,293 m²
Total Percentage of Green Coverage	22%
largest Green Coverage on a Single Façade	2,066 m²-west
largest Percent of Green Coverage on a Single Facade	43 %

Massing		
In Numbers	Reduced solar radiation by 60% users 48% less energy than 10 comparable building; Green wall floors use 35% less energy than other floors	
Interior Spaces		
Natural Light	Solar Radiation is Maximum: 976 Wh/m2 (December 21) Minimum: 815 Wh/m2 (June 21) Annual Average Daily Sunshine is 6.6 hours	
Natural Ventilation	Prevailing Wind Direction is Southwest Average Wind Speed is 2.5 meters per second	
Maintenance	The plant specialist lift is utilized amid yearly pruning as a part of August, and additionally to control the advancement of the foliage and to sanitize the plants and the emotionally supportive network in spring and summer	
Irrigation	The water system framework uses a simple plastic hose that discharges drops of water at particular focuses along the framework, a programmed control to direct the water system	
Plant Species	Bougainvillea Parthenocissus quinquefoila Plumbago capensis	

4.1.7. CH2 Council House 2 – Melbourne, Australia

Figure 59: View of CH2 Council House 2 Melbourne, Australia (Dianna Snap, 2013)

- **Background**

CH2 Melbourne City Council House 2 was planned to convey a sound working environment for the City of Melbourne's 550-man administrative staff, which would go about as a benchmark for future office headways in the city. This inventive wander has been conceded the underlying 6-star'Green Star° rating by the Green Building Council of Australia, in affirmation of the building's various creative green imaginative components. CH2 is the delayed consequence of joint exertion between the arrangements amasses at Designlnc and the City of Melbourne. The arrangement strategy, driven by client and pro workshops, contemplated wide review of sparing thoughts, with the best comprehensive choices choosing the last layout (Hopkins & Goodwin 2011). Activities fused in the outline incorporate 100% natural air trade all through the building, broad sunlight entrance to all floors and warmth evacuation through warm mass usage (Newton, Hampson & Drogemuller 2009).

Table 31: Building and climate date of CH2 Council House 2 Melbourne, Australia (Author, 2016)

Building Date			
Year of completion	2006	**Climate data**	
Height	12 meters	**Location**	Melbourne, Australia
Stories	10	**Geographic Position**	Latitude 37' 49' 5 - Longitude 144°58'
Building Gross Floor Area:	12.536 square meters	**Mean Annual Temperature**	15 °C
Building Function	Office	**Elevation**	32 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Warm Temperate with fully humid, warm summers
Green Wall Type	Façade-supported green wall (metal mesh)	**Average Daytime Temperature during the Hottest Months (January, February, March)**	10.6 °C
Location on Building	North facade from I st to 9th floor	**Average Daytime Temperature during the Coldest Months (June, July, August)**	8.7 °C
Surface Area of Green Coverage	420 square meters (approx.)	**Annual Average Relative Humidity**	64% (hottest months); 73% (coldest months)
Owner/Developer	Melbourne City Council	**Average Monthly Precipitation**	54 millimetres
Architect Design	Designlnc, in association with Melbourne City Council	**Prevailing Wind Direction**	North
Landscape Design Architect	Melbourne City Council	**Average Wind Speed**	39 meters per second
Structural Design Engineer	Bonacci Group	**Solar Radiation**	Maximum: 985 Whim (November 21) Minimum: 805 Whim' (June 21) Annual
Other Consultants	KPK Group (Construction Management)	**Annual Average Daily Sunshine**	5.5 hours

- **Design Strategies**

Vertical work connected to either side of north-bound overhangs underpins a green wall and facade that screens low edge sun and channels glare. Greenery gives chance to everyday collaboration with nature on either side of galleries. Inside the building, twofold tall winter plants (trees) on northwest corner of the project, at levels 2, 4, 6 and 8, in winter gardens, give glare control, shade and noise control They are secured by timber screens, which additionally encourage vertical air development (Hopkins & Goodwin 2011).

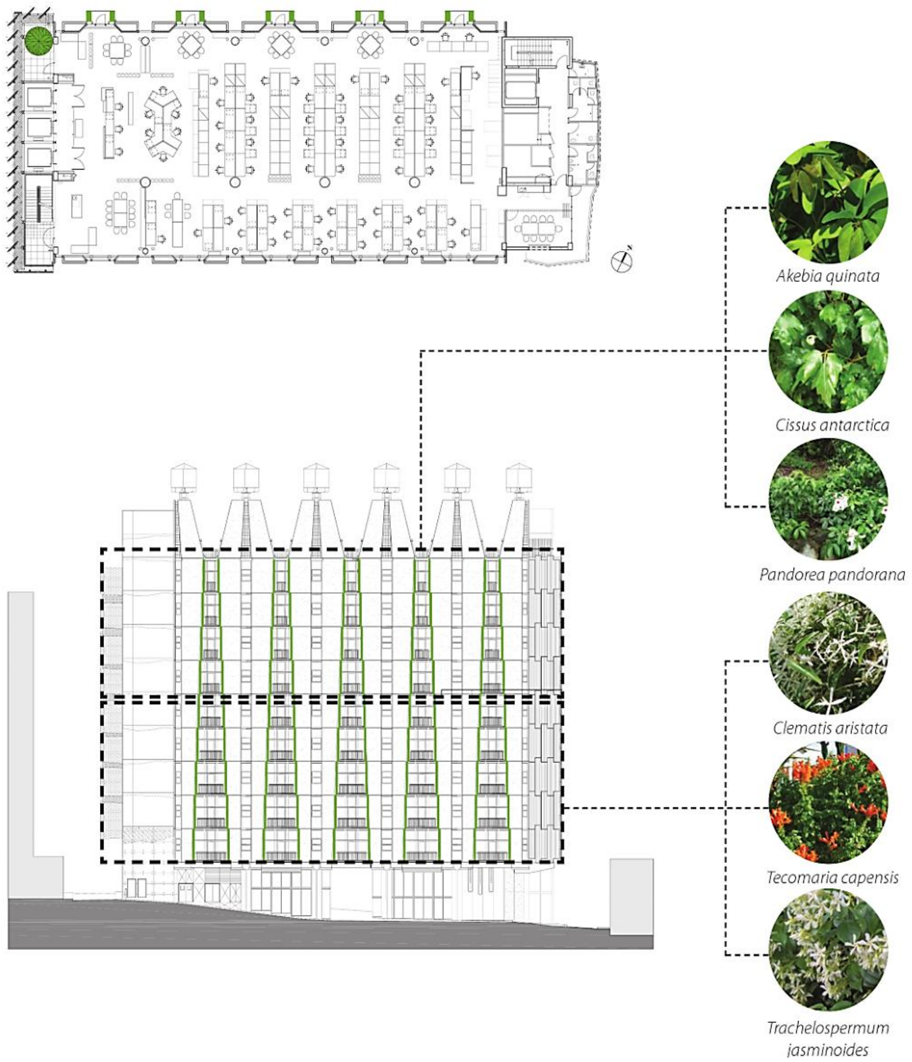


Figure 60: Northern façade elevation showing location of the green wall balcony side(CTBUC, 2014).

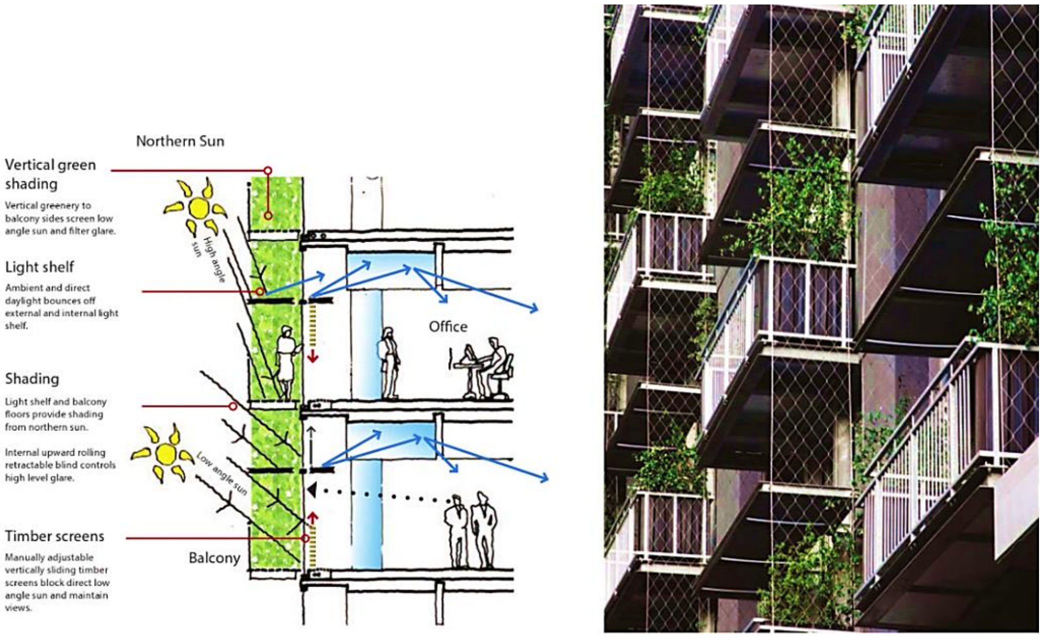


Figure 61: Conceptual diagram highlighting the importance of daylight shading at the north side and climbing plants growing onto metal mesh screens on north façade (Author, 2016)

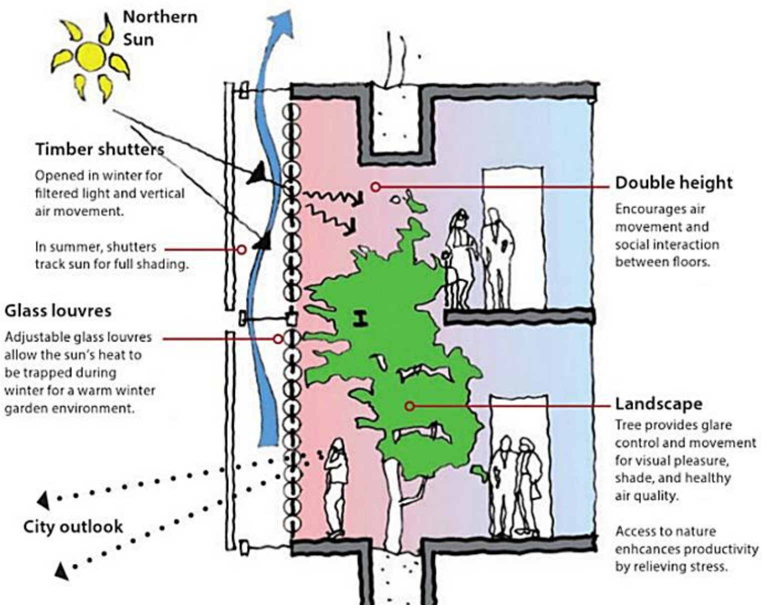


Figure 62: Diagram highlighting benefits of the winter gardens that are implemented on alternate floors in the northwest corner of the building (Author,2016)

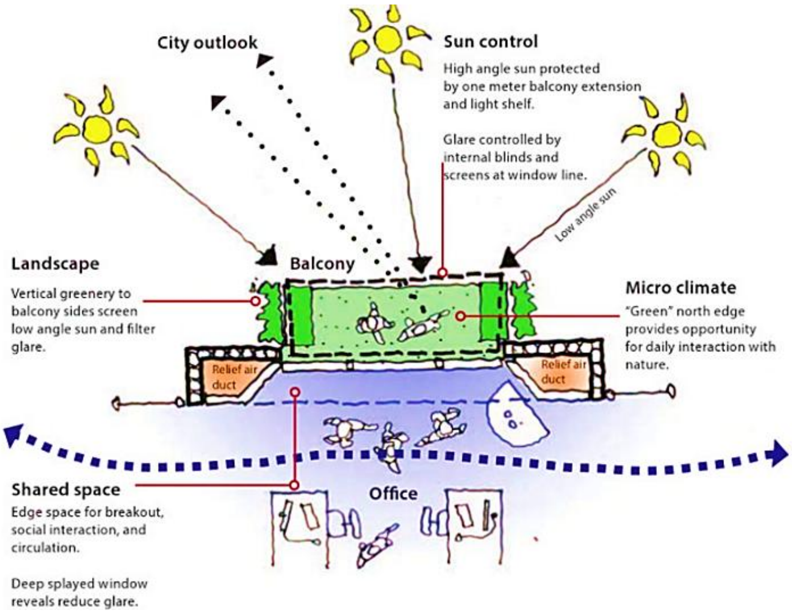


Figure 63: Conceptual plan diagram describing green façade function (Author, 2016)

- **Green Wall System Overview**

The green wall segments on the north exterior assume a critical part in the general supportability plan for the project, through shading and giving a chance to cooperation with nature. The vertical greenery on the balcony side-screens is used impact (see Figure 63) to battle low-edge daylight, giving filtration to counter the glare). The green walls comprise of reused plastic grower boxes, supporting vines that climb a metal work. Two grower boxes involve either side of every balcony, measuring 300 millimetres wide by 1,000 millimetres in length by 750 to 1,000 millimetres profound. The climbing plants develop on 150-millimeter-opening stainless-steel link work screens bolstered on stirred steel outlines, which measure 1,000 by 2,000 millimetres. Window shading is accomplished through the two planting-work screens on either side of the balcony, each reaching out around 1.2 meters from the façade. Notwithstanding the green walls, a progression of little sky gardens, lodging one tree in each, is situated at the northwest corner of the working in twofold stature spaces on floors 2, 4, 6 and 8 (see Figure62).These trees give glare control and in addition tasteful delight, shade and more advantageous air quality (Vassigh, Ozer & Spiegelhalter 2012).

- **Plant Species**

Chosen plant species are as per the following (data by Mary Chapman, City of Melbourne and John Rayner, University of Melbourne):

Northern façade, upper level

Akebia quinata

Cissus Antarctica

Diatictua buccinatoria

Kennedia rubicund

Macfadyena unguis-cat

Pandorea pandorana

Northern façade , lower level

Cissus Antarctica

Clematis aristata

Pandorea pandorana

Tecomaria capensis

Trachelospermum jasminoides

- **Irrigation System**

A self-watering system in view of consumable water in the grower boxes was introduced to give the perfect wet-and-dry cycle required for solid plant development. Every grower box incorporates watering wicks and Hydrocell pieces, expected to help water maintenance (Vassigh, Ozer & Spiegelhalter 2012).

- **Maintenance**

Great preparing and foundation, and additionally the determination of support sort, can cure this issue, yet plants with characteristic 'screening properties," including the maintenance of basal foliage, a high basal shoot thickness and the generation of pendulous parallel shoots, ought to be utilized. Yearly pruning, coordinate from the overhangs, was viewed as a sensible support prerequisite, considering the coverage range of the plants (Morison, Andrew & Bates, 2006).

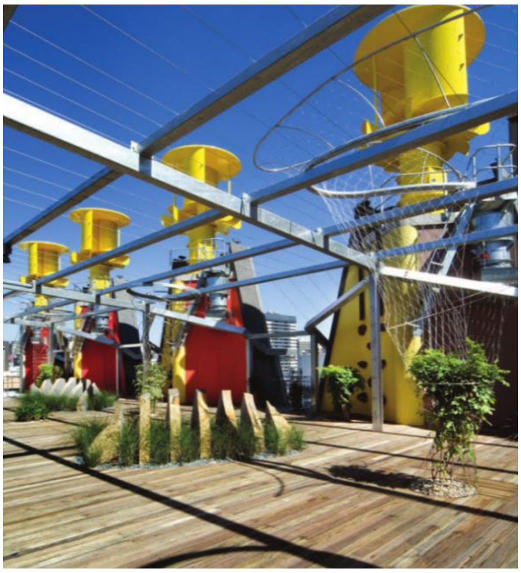


Figure 64:View of initial rooftop greenery (Dianna Snap, 2013)

- **Analysis and Conclusions**

The delayed consequence of the imperativeness examination led by City Council of Melbourne construed that CH2 uses 85% less essentialness and consumes 72% less water than correspondingly scaled office structures. CH2 moreover transmits 60%

less CO2, than practically identical structures. It is, in any case, implausible that any critical piece of these results were inferable from the closeness of green wall system. A social overview was additionally led, demonstrating that CH2 tenants are "profoundly fulfilled "with the building in general (Yudelson & Meyer, 2013).

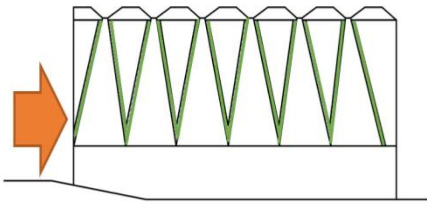
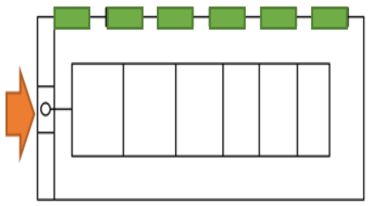
- **Green Coverage Calculation**

The Council House 2 is around 42 meters high and is for the most part rectilinear in shape. Its northern and southern exteriors are roughly 53 meters in length, and its eastern and western veneers are 20 meters wide. The north and south exteriors are roughly 2,226 m^2 in region each, and the east and west facades are 840 m^2 each. In this manner, the aggregate wall facade range is 6,132 m^2 (see Table32). The building highlights outer greenery on its northern exterior as it were.

Table 32: Calculation of green coverage (CH2 Council House 2 Melbourne, Australia) (Author, 2016)

Elevation	**Total Wall Area (m^n)**	**Green Wall Coverage (m^2)**	**Percentage Green Coverage**
Council House 2			
North	2226	420	19 %
East	840	0	0 %
South	2226	0	0 %
West	840	0	0 %
Total	**6.132**	**420**	**7 %**

Table 33: Architectural analysis of building and green coverage (CH2 Council House 2 Melbourne, Australia) (Author, 2016)

CH^2 Council House 2 Melbourne - 2006	
Green Wall Type	Façade-supported green wall (metal mesh)
Surface Area of Total Green Coverage	420 m^2
Total Percentage of Green Coverage	7%
largest Green Coverage on a Single Façade	420m^2 - north
largest Percent of Green Coverage on a Single Facade	19%
Massing	 
In Numbers	Consumes 85% Less energy, 72% less potable water, than similarly-scaled office buildings (green wall only small contribution to this)
Natural Light	Solar Radiation is Maximum: 985 Whim (November 21) Minimum: 805 Whim' (June 21) Annual Average Daily Sunshine is 5.5 hours
Natural Ventilation	Prevailing Wind Direction is North Average Wind Speed is 39 meters per second

Landscape Elements	
Irrigation	A self-watering framework in light of consumable water in the grower boxes was introduced to give the perfect wet-and-dry cycle required for solid plant development
Interior Spaces	
Plant Species	Akebia quinata - Cissus Antarctica Diatictua buccinatoria - Kennedia rubicund - Macfadyena unguis-cat - Pandorea pandorana Cissus Antarctica – Clematis aristata - Pandorea pandorana - Tecomaria capensis - Trachelospermum jasminoides

4.1.8. One PNC Plaza – Pittsburgh, USA

Figure 65: View of One PNC Plaza Pittsburgh, USA (Mingo Design, 2010)

- **Background**

The PNC Financial Services Group realized "greening' around its base camp offices in Pittsburgh in 2009. The PNC Green Wall was hence a first endeavour at connoting the organization's dedication to maintainability. The Green Wall on One PNC Plaza is a living' notice for other manageable activities the organization has embraced. The Tower at PNC Plaza, which is a more considerable activity that is intending to surpass LED Platinum, the US Green Building Council's most astounding accreditation level. Advancements, for example, geothermal wells, sun based fireplaces, and water gathering/reusing frameworks are being utilized in the new tower.

Table 34: Building and climate date of One PNC Plaza Pittsburgh, USA (Author, 2016)

Building Date			
Year of completion	2009	**Climate data**	
Height	129 matters	**Location**	Pittsburgh, USA
Stories	30	**Geographic Position**	Latitude 41B 30'N Longitude 80°13' W
Building Gross Floor Area	74,147 square meters (approx.)	**Mean Annual Temperature**	28,5°C
Building Function	Office	**Elevation**	373 meters above sea level
Structural Materials	Steel	**Climate Classification**	Snowy winters; fully humid, warm summer
Green Wall Type	A Facade-integrated living wall (modular living wall)	**Average Daytime Temperature during the Hottest Months (January, February, March)**	21 °C
Location on Building	South facade of offset core Surface	**Average Daytime Temperature during the Coldest Months (June, July, August)**	I2 °C
Surface Area of Green Coverage	221 square meters (approx.)	**Annual Average Relative Humidity**	67% (hottest months); 70% (coldest months)
Developer	PNC Bank	**Average Monthly Precipitation**	183 millimetres
Green Wall Designer	Mingo Design LLC	**Prevailing Wind Direction**	Southwest
Architect	Welton Beckett Associates	**Average Wind Speed**	139 meters per second
Engineering Associates (Structural)	8D8.8 Strategic Branding and Design (Graphics)	**Solar Radiation**	Maximum: 893 Wh/m² (April 21) Minimum: 795 Wh/m² (August 21)
Plant Supplier	Plant Connection Other ConsultantuCenkner	**Annual Average Daily Sunshine**	15.5 hours

- **Design Strategies**

A Green wall is introduced on a clear solid wall where the plants came from off-site in hot zone, then introduced vertically on location. Different blossoming plants give seasonal varieties. System reconstructed from a stainless-steel board.

- **Green Wall System Overview**

Pre-developed into the modules and all parts that made up the system were spot welded. The first framework was mounted with a stainless steel sectioning and board framework secured specifically into One PNC Plaza's strengthened solid brick work. The green wall had 602 boards, every measuring 610 millimetres high x 610 millimetres wide x 102 millimetres profound, with 24 plants in every (see Figures65 and 66). A thick soil-less planting medium was utilized inside a 102 millimetre high x 152 millimetre wide x 102 millimetre profound aluminium cell, inside every board.

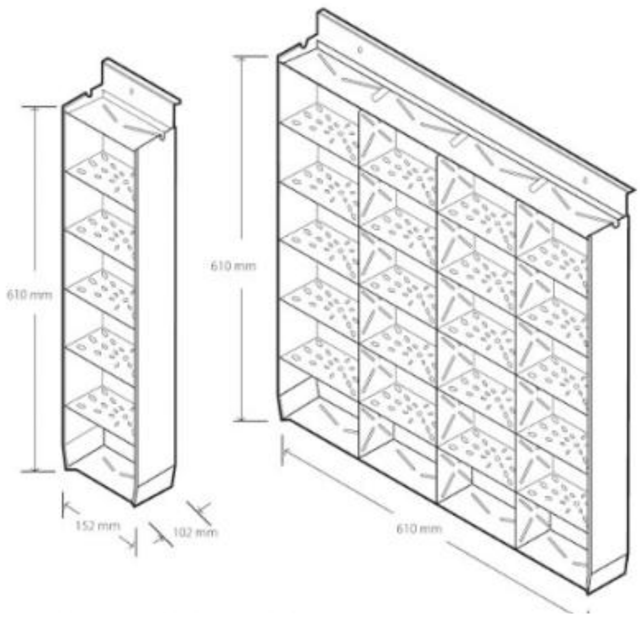


Figure 66: Detail diagram of original panel system (Mingo Design, 2010)


Figure 67: Detailed views of the stainless steel panels before plantings were inserted (Mingo Design, 2010)

- **Plant Species**

Concerns, for example, support of the wall, and in addition style, were entire deciding elements in creating criteria for the plant sorts and also the last appearance of the 11 Living Wall. The plants were chosen for their capacity to flourish in Pittsburgh's atmosphere and to make an outline which fluctuates in surface and shading with the evolving seasons, Approximately 14,448 plants in eight plants Sped, are used in the wall. The plants incorporate Carex variegated, Heuchera Purple Varietle, Ajuga, Brass Button, Lysimachima numm, Euonymus, Sedum, and Fern (See Figure 68).

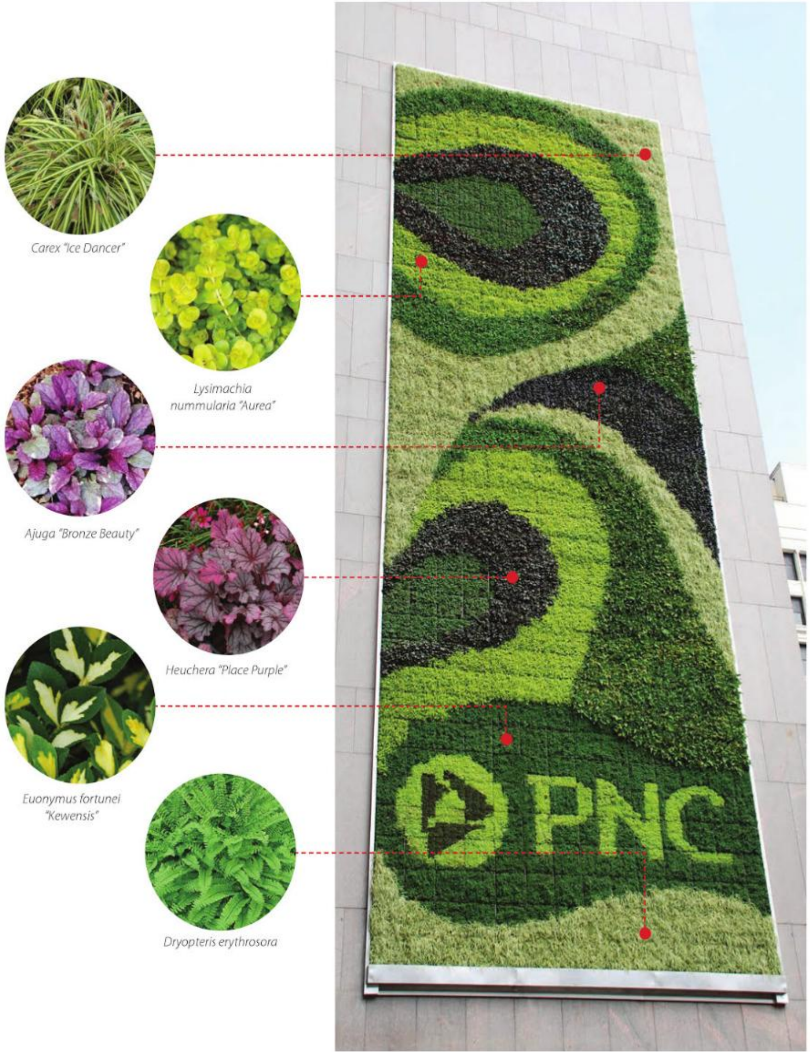


Figure 68: View of vertical green system on the south façade of the off-set core (CTBUC, 2014)

- **Irrigation System**

In the first framework, the watering of the plants on the wall was done through a 6.4 millimetre dribble line separated each 610 millimetre skyline count. Each of these lines is laid on the highest point of each of the 610 by 610 millimetre boards. There was a little bended section at either end at the highest point of every board, where the trickle line was installed. At the point when the framework was initiated, the water dribbled starting with one cell then onto the next, through nine water system zones, and was planned to guarantee that there was insignificant keep running off starting with one board then onto the next; anticipating overwatering of boards that are lower in the design. The wall weighed around 24 tons when completely watered and was managed through an inside controlled framework. Amid a normal week, just IS minutes of watering time were required to keep up the wall.

Figure 69: View of nursery house where plants were cultivated (Mingo Design, 2010)

- **Maintenance**

The first technique of the first system depended on the characteristic development example of the green wall plants. The wall was adjusted once every week until the green wall achieved 90% development and scope. Upon development, administrations were moved to once every other week. After development, administration was considered once every month or as required - endorsed by the arranging administrations. The technique of the new system is to utilize an upkeep checking system which incorporates creative support administration programming to control the water system framework. The new system utilizes remote observing sensors to give more ecological and practical answers for keeping up the green wall.

- **Analysis and Conclusions**

At the time of its establishment, the PNC Green Wall was the biggest in North America, Preparatory reviews demonstrate that the south-bound green wall is cooler than different surfaces on a similar facade. Overall, the green facade surfaces appeared to be 25% cooler than encompassing surface temperatures. Benefits on the ground level incorporate the living facade cooling the court underneath it by retaining as opposed to mirroring the sun's beams.

Figure 70: Since the installation of the green wall at one PNC Plaza Pittsburgh, a similar wall has been installed at the corporate location in Baltimore, Maryland

- **Green Coverage Calculations**

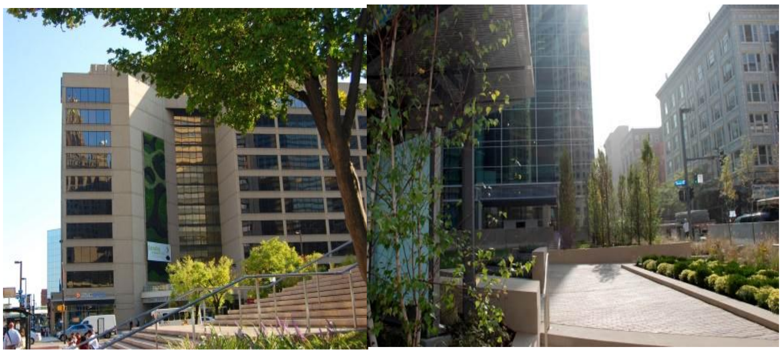
One PNC Plaza is a rectilinear tower with a different balance concrete-clad centre. The consolidated veneers measure roughly 129 meters high x 36 meters wide x 68 meters in length. The north and south raises measure 129.2 m high by 36.4 over, for an aggregate of 4,703 m² each. The east and west raises measure 129.2 m high by 67.9 rn over, for an aggregate of 8,773 m² every (see Table35).

Table 35: Calculation of green coverage) One PNC Plaza Pittsburgh, USA (Author, 2016)

Elevation	Total Wall Area (m^n)	Green Wall Coverage (m^2)	Percentage Green Coverage
PNC			
North	4,703	0	0%
East	8,773	0	0 %
South	4,703	221	5 %
West	8,773	0	0 %
Total	**26.952**	**221**	**1%**

Table 36: Architectural analysis of building and green coverage) One PNC Plaza Pittsburgh, USA (Author, 2016)

One PNC Plaza – Petersburg, 2009	
Green Wall Type	Façade-integrated living wall (modular living wall)
Surface Area of Total Green Coverage	221 m²
Total Percentage of Green Coverage	1%
largest Green Coverage on a Single Façade	221m² - south
largest Percent of Green Coverage on a Single Facade	18%
In Numbers	Green wall 25% cooler than surrounding surface
Natural Light	Solar Radiation is Maximum: 893 Wh/m² (April 21) and

	Minimum: 795 Wh/m² (August 21) Annual Average Daily Sunshine is 15.5 hours
Natural Ventilation	Prevailing Wind Direction is Southwest Average Wind Speed is 139 meters per second
Maintenance	The procedure of the new system is to utilize a maintenance observing system which incorporates inventive support administration programming to control the watering and irrigation system framework. The new system utilizes remote checking sensors to give more natural and economical answers for keeping up the green façade and living wall.
Landscape Elements	
Irrigation	The new G-02 system utilizes remote checking sensors to give key data with respect to the condition of the façade and wall, taking into account educated basic leadership in regards to the maintenance. In this system, plants are pre-developed to guarantee they are completely developed into boards and in the most ideal development environment preceding Installation.
Plant Species	The plants incorporate Carex variegated, Heuchera Purple Varietle, Ajuga, Brass Button, Lysimachima numm, Euonymus, Sedum, and Fern

4.1.9. Pasona Headquarters – Tokyo, Japan

Figure 71: Pasona Headquarters Tokyo, Japan (Emilio Am basz, 2011)

- **Background**

Situated in downtown Tokyo, Pasona Headquarters is a nine-story, 20,000-square-meter. Corporate office working for the Japanese enlistment organization, Pasona Group, Instead of building another structure starting from the earliest stage, a current 50-year-old building was remodelled, with its building envelope and superstructure incorporated into the new plan. The project comprises of a twofold skin green facade, workplaces, a theatre, cafeterias, a housetop cultivate and, most prominently, a urban cultivating office. The inside and outside green space adds up to more than 4,000 square meters with 200 types of plants including organic products, vegetables, and rice that are gathered, arranged and served at the cafeterias inside the building. It is the biggest and most direct ranch to-table operation of its kind ever acknowledged inside an office working in Japan.

Table 37: Building and climate date of Pasona Headquarters Tokyo, Japan (Author, 2016)

Building Date			
Year of completion	2010	**Climate data**	
Height	134 meters	**Location**	Tokyo. Japan
Stories	19	**Geographic Position**	Latitude 35°41'N Longitude 139°46' E
Building Gross Floor Area	120,000 square meters	**Mean Annual Temperature**	16 °C Average
Building Function	Office	**Elevation**	35 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Warm Temperate with fully humid, hot summer
Green Wall Type	Facade-supported green wall (metal mesh) Vertical farm	**Average Daytime Temperature during the Hottest Months (January, February, March)**	26 °C
Location on Building	South and east facades, plus internally integrated into main lobby and offices	**Average Daytime Temperature during the Coldest Months (June, July, August)**	I 7.1°C
Surface Area of Green Coverage	1,224 square meters (approx.)	**Annual Average Relative Humidity**	86% (hottest months); 69% (coldest months)
Developer	Dai-Ichttti Mutual Life Insurance Co.	**Average Monthly Precipitation**	127 millimetres
Green Wall Designer	Emilio Am basz	**Prevailing Wind Direction**	North
Design Architect	Emilio Am basz & Associates	**Average Wind Speed**	12.94 meters per second
Landscape Architect	Takenaka Corporation	**Solar Radiation**	Maximum: 839 VH/m² (January 21) Minimum: 680 Wh/m' (May 21)
Structure engineer	Takenaka Corporation	**Annual Average Daily Sunshine**	152 hours

- **Design Strategies**

Remodels a current 50-year-old building, utilizes a 1.8-meter wide, twofold skin green wall gallery zone as a vertical cultivate; giving palatable nourishment far building tenants, and decreasing certain surge mileage to zero. Utilizes deciduous plantings as part of a few ranges so that more heat gain and light can be conceded in winter months, Uses 'super soil' planting medium inside grower. In the all-inclusive overhang zone at every level - plants are prepared to develop toward outside facade and wall. (See figure 72).

Figure 72: Floor plans of the 1st (left) and 4st (right) floors showing locations of internal and external farming space (CTBUC, 2014)

Figure 73: Side entrance view, south façade (left) and view of east façade across the street (right) (Emilio Am basz, 2011)

- **Green Wall System Overview**

The vertical greenery is situated on the east and south exteriors of the building which confront the primary road crossing point, stretching out from the second floor up to the top ninth floor. The wall and facade covers around 66% of these two essential exteriors, accepting the most sun powered introduction. Randomly, the east and south exteriors additionally are the most noticeable from the overall population and adjust to the primary activity stream, giving the building its solid notorious personality (see figure73). The way to deal with vegetation in the building, including the twofold cleaned green facade, was to utilize the most recent in cultivating innovations. Depending on the characteristic of outside atmosphere, these plants make a living green divider and a dynamic personality for Pasona. The overhangs shade and protect the insides, while giving outside air operable windows.

- **Plant Species**

The vertical greenery commonly includes a 1.8-meter-significant display space encased by an open-louvered lacquer in light of current circumstances, and an operable covering structure inside. Each one of the plants, which involve normal blooms and orange trees, are planted inside this 1.8 meter overhang space at each level, using standard soil.

- **Irrigation System**

The living façade and living wall uses a self-water system prepares that permits plants to develop, without soil, on a vertical surface. The irrigation and water system utilizes weight managing droppers, which comprise of dribble lines, which are controlled by a programmed timing system with the objective of utilizing as meagre water as could reasonably be expected.

- **Maintenance**

Maintenance is kept to a base, for financial reasons as well as to support characteristic natural surroundings for London's untamed life and wildflowers. This procedure has produced positive reactions from people on foot, basically due to the "regular "feel of the façade and wall. The wall gets an intensive review and maintenance regimen around three times each year with the lower levels accepting this treatment around five times each year.

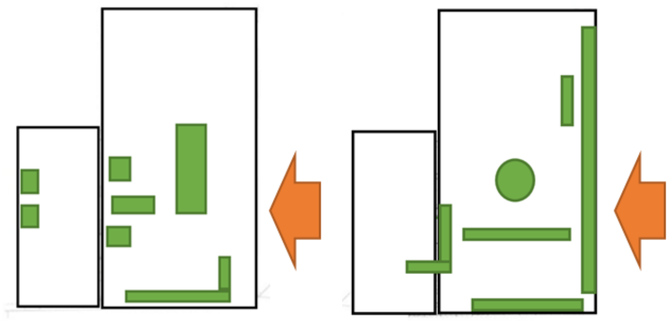
- **Analysis and Conclusions**

The underlying arranging application for the expansion of the living wall to the Athenaeum is very advising with regards to the goals of the facade. The report of the Director of Planning and City Development for the City of Westminster portrayed the current working as "needing visual upgrade ment"and said it "degraded the superb structural surroundings of Piccadilly, specifically, the recorded structures which flank both sides of the site onto Piccadilly. All in all, "The proposition will be a positive expansion to this fair edifice, which, by incompletely clouding its rises, will upgrade its appearance.

- **Green Coverage Calculations**

The living wall and green facade are arranged on the southwest corner, subsequently on the south and west walls. The north and east rises are not considered in this computation since they are associated with neighbouring structures. The south rise measures 47 m high × 24 m wide, for an aggregate region of 1,128 m². The west rise measures 47 m high × 36 m wide, for an aggregate territory of 1,692 m ². The aggregate vertical surface range of the building is in this manner 2,820 m² (see Table). The seven windows measuring 1.5 m high by 1 m wide or 11 square meters are subtracted, for a sum of 159 square meters. The aggregate green scope is along these lines (159 + 97) =256 m², or around 9% green scope of the whole exterior region (see table38).

Table 38: Architectural analysis of building and green coverage) Pasona Headquarters Tokyo, Japan (Author, 2016)

Pasona Headquarters – Tokyo, 2010	
Green Wall Type	Façade-supported green wall (metal mesh);Vertical farm
Surface Area of Total Green Coverage	1,224 m²
Total Percentage of Green Coverage	20%
largest Green Coverage on a Single Façade	720m² - east
largest Percent of Green Coverage on a Single Facade	37%
Interior Spaces	
In Numbers	12% productivity gains and 23% ailment reduction in employees; provides alternative food production method; reduces food mileage
Massing	

Natural Light	Solar Radiation is Maximum: 839 VH/m² (January 21) Minimum: 680 Wh/m' (May 21) Annual Average Daily Sunshine is 152 hours
Natural Ventilation	Prevailing Wind Direction is North Average Wind Speed is 12.94 meters per second
Maintenance	The façade and wall gets an exhaustive assessment and maintenance regimen around three times each year with the lower levels accepting this treatment around five times each year.
Landscape Elements	  
Irrigation	The green façade and living wall uses a self-water and irrigation system prepares that permits plants to develop, without soil, on a vertical surface. The water system framework utilizes weight directing droppers, which comprise of trickle lines, which are controlled by a programmed timing system with the objective of utilizing as meagre water as would be prudent.
Plant Species	The Living Wall is made out of 260 plant species and more than 12,000 plants including uncommon assortments of mild and tropical atmosphere species. About 80% of the plants at the Athenaeum are evergreen, while 20% are classified as occasional.

4.1.10. Parkroyal – Pickering, Singapore

Figure 74: View of Parkroyal on Pickering Singapore (Patrick Bimgham-Hall, 2014)

- **Background**

Parkroyal on Pickering is situated in focal Singapore, at the intersection between the focal business region and the beautiful areas of Chinatown and Clark Quay, confronting Hong Lim Park. The building is an inn comprising of four glass tower squares (three of them connected) on top of a platform. Raised on pili's and ringed with solid grower, the building replaces as well as copies the measure of greenery initially on the site. The moulded platform reacts to the road scale, drawing motivation from a blend of finished bonsai courses of action that are demonstrated, etched oral joined to copy common scenes and mountain shake arrangements, and additionally that of the shaped paddy fields of Asia Four fresh, streamlined tower squares fit with the encompassing skyscraper office structures, and are lessened into an open-sided patio setup, separating the' mass of structures impact.

Table 39: Building and climate date of Parkroyal on Pickering Singapore (Author, 2016)

Building Date			
Year of completion	2012	**Climate data**	
Height	89 meters	**Location**	Singapore
Stories	15	**Geographic Position**	Latitude l°22 N -Longitude 103° E
Building Gross Floor Area	29127 square meters	**Mean Annual Temperature**	27, 5°C average
Building Function	Hotel & Office	**Elevation**	16 meters above sea level
Structural Materials	Concrete	**Climate Classification**	Equatorial, fully humid
Green Wall Type	Stepped terrace garden (some cantilevering)	**Average Daytime Temperature during the Hottest Months (January, February, March)**	28, 3 °C
Location on Building	Numerous levels, predominately on north and south facade	**Average Daytime Temperature during the Coldest Months (June, July, August)**	16.8 °C
Surface Area of Green Coverage	4,872 square meter	**Annual Average Relative Humidity**	82% (honest months) 86% (coldest months)
Developer	Ralph Trustees Ltd.	**Average Monthly Precipitation**	201 millimetres
Green Wall Designer	Patrick Blanc	**Prevailing Wind Direction**	North
Landscape Architect	Daniel Bell	**Average Wind Speed**	4.4 meters per second
Green Wall Manufacturer	Patrick Blanc	**Solar Radiation**	Maximum: 837 Wh/m². (December 21) Minimum: 737 Wh/m² (September 21)
MEP Engineer	WSP Lincolne Scott	**Annual Average Daily Sunshine**	5.6 hours

Figure 75: Cross-section through
the linking elements between towers one and two (CTBUC, 2014)

- **Design Strategies**

Increment the green plot proportion of an urban site by raising greenery onto the border of a substantial platform and tower inn and office complex. Utilize pre-thrown solid structures to make an undulating terraced scene for considerable plantings, changing what may have been an overwhelmingly largo rectilinear venture into a point of interest that appears a naturalistic beginning of close-by parklands. Execute vase like grower on the south facade of tower 4. Raise the greater part of the secure up a few stores above review to make intriguing extras in

She under croft while giving chances to greenery above to develop in numerous measurements. Covers auto stopping zones with grower encompassing the edge of the vehicle slopes, help upkeep by giving level surfaces that can bolster access from the possessed floors (see Figure75).

- **Green Wall Systems Overview**

Parkroyal on Pickering accomplishes a remarkable measure of greenery and arranging in a skyscraper advancement of this size, coordinating these common components in creative ways that address urban outline and maintain capacity issues. In the flat measurement, there are 15,000 square meters of plantings, water highlights, waterfalls, patios and green dividers in the many sky gardens, making a rich withdraw in the heart of the city, with the aggregate in-a-garden "idea, the draftsman brought broad measures of finishing into the building (see Figure76).

Figure 76: North view of complex showing greenery (Patrick Bingham-Hall, 2014)

Figure 77: Cross section detail of integrated vertical vegetation and vertical green systems (Patrick Bingham-Hall, 2014)

Figure 78: Section detail of integrated vertical vegetation (Patrick Bingham-Hall, 2014)

Figure 79: Internal section detail of integrated vertical vegetation in complex (Patrick Bingham-Hall, 2014)

Figure 80: First and second plan detail of integrated vertical vegetation (Patrick Bingham-Hall, 2014

Figure 81: Section detail of integrated vertical vegetation and green systems in complex (Patrick Bingham-Hall, 2014)


Figure 82: View looking down, showing terraces with lush greenery (Patrick Bingham-Hall, 2014)

- **Plant Species**

A portion of the plant species are Plumerias, Tall plumbs, Bucidas buceras, Ficus Lyrata, Monsteras, Alocasias, Calatheas and Lee ow creeper (see figure77).

- **Irrigation System**

The sky-rise scenes are intended to act naturally maintaining and depend negligibly on valuable assets. Rooftops surfaces gather water for water system of the arranging by gravity nourish. Gathering tanks are estimated to hold saves and are supplemented with non-consumable ""Newater"" (Singapore's reused wastewater) just amid expanded spells of dry climate, which is uncommon in Singapore's tropical atmosphere. A trickle water system framework is utilized to improve water utilization. All scene ranges are likewise fitted with rain sensors, which kill water system when a base level of rain is distinguished to counteract squander.

Figure 83: View of podium terrace at the 5th floor (Patrick Bingham-Hall, 2014)

- **Analysis and Conclusions**

On the premise of it sparing 30% in operational energy use over similar companions, PARKPOYAL is an admirable project. It is absolutely a standout amongst the most outwardly striking utilizations of greenery at tall buildings. From a visual point of view, and as far as the net advantages of urban greenery is considered, any reasonable person would agree PARKPOYAUs greenery is a resource for the individuals.

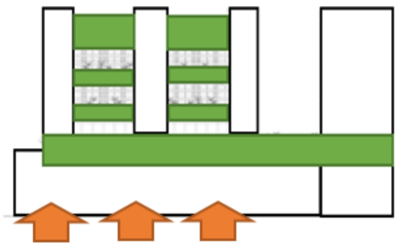
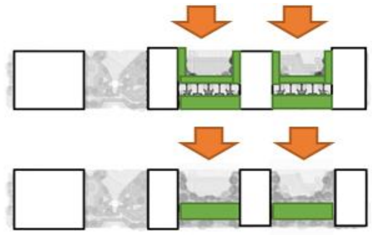
- **Green Coverage Calculations**

PARKROYAL is tied down by a long east-west-arranged platform, mass' identity's differentially lifted on segments above road level to give shading shades and stages to plantings. The platform is bested by four unmistakable towers, which additionally lay on sections around 15 meters over the highest point of the platform. The four towers are arranged oppositely to the longitudinal direction of the platform. Towers 1.2 and 3 are associated by bar volumes running in parallel to the length of the platform. Tower an office (see figure84).

Figure 84: Diagram showing site area greenery with context of adjacent park (Patrick Bingham-Hall, 2014)

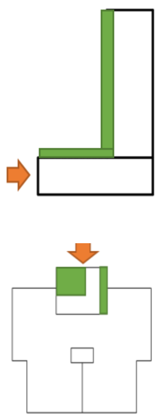
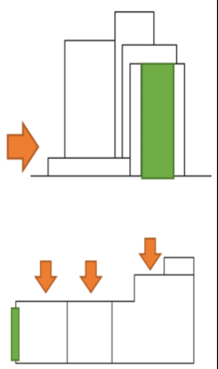
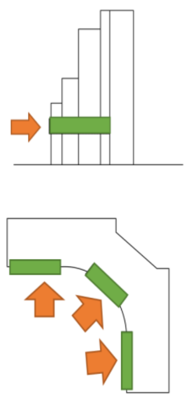
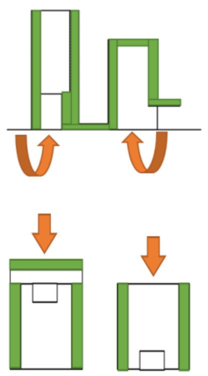
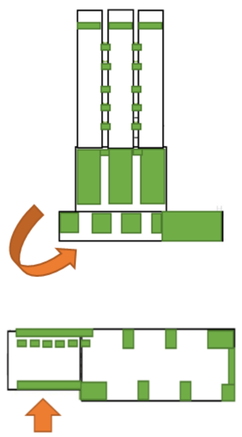
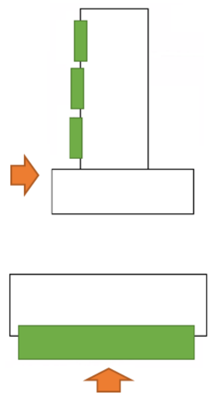
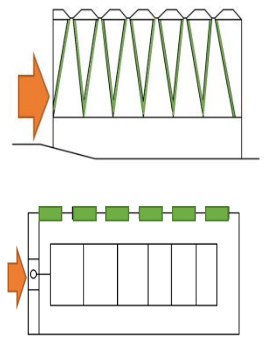
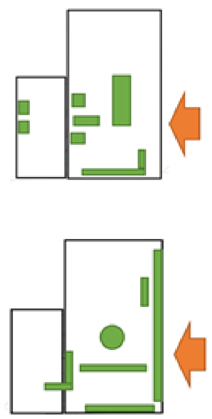
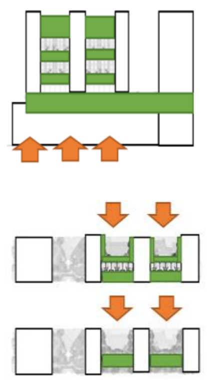

Figure 85: View of south façade of tower for showing the intended vase-like planters

Table 40: Architectural analysis of building and green coverage) Parkroyal on Pickering Singapore (Author, 2016)

<table>
<tr><th colspan="3">Parkroyal on Pickering – Singapore 2012</th></tr>
<tr><td colspan="2">Green Wall Type</td><td>Stepped terrace garden(some cantilevering)</td></tr>
<tr><td colspan="2">Surface Area of Total Green Coverage</td><td>4,872m²</td></tr>
<tr><td colspan="2">Total Percentage of Green Coverage</td><td>11%</td></tr>
<tr><td colspan="2">largest Green Coverage on a Single Façade</td><td>2.257m² - north</td></tr>
<tr><td colspan="2">largest Percent of Green Coverage on a Single Facade</td><td>16%</td></tr>
<tr><td>Massing</td><td></td><td></td></tr>
<tr><td>In Numbers</td><td colspan="2">Horizontal area of landscaping 215% of site area; saves 30% in operational energy use over comparable peers</td></tr>
<tr><td>Natural Light</td><td colspan="2">Solar Radiation is Maximum: 837 Wh/m². (December 21) Minimum: 737 Wh/m² (September 21) Annual Average Daily Sunshine is 5.6 hours</td></tr>
<tr><td>Natural Ventilation</td><td colspan="2">Prevailing Wind Direction is North - Average Wind Speed is 4.4 meters per second</td></tr>
</table>

Interior Spaces	
Irrigation	The sky-rise scenes are intended to act naturally maintaining and depend insignificantly on valuable assets. Rooftop surfaces gather water for water system of the finishing by gravity sustain
Landscape Elements	
Plant Species	Some of the plant species are Plumerias, Tall plumbs, Bucidas buceras, Ficus Lyrata, Monsteras, Alocasias, Calatheas and Lee ow creeper.

Table 41: Compare important stages and information’s of each case study (Author, 2016)

										
Name of Building	**Newton Suits** **Singapore**	**Trio Apartments** **Sydney**	**Gramercy Skypark** **Makati**	**Ideo Morph 38 Tower** **Bangkok**	**The Met** **Bangkok**	**Consorcio Santiago** **Santiago**	**CH² Council House 2** **Melbourne**	**One PNC Plaza** **Petersburg**	**Pasona Headquarters** **Tokyo**	**Parkroyal on Pickering** **Singapore**
Year of completion	2007	2009	2013	2013	2009	1993	2006	2009	2010	2012
Climate Classification	Equatorial, fully humid	Warm Temperature with fully humid, warm summer	Equatorial monsoonal	Equatorial, winter dry	Equatorial, winter dry	Warm Temperate, Summer Dry, Warm Summer	Warm Temperature with fully humid, warm summer	Snowy Winter; fully humid, warm summer	Warm Temperature with fully humid, warm summer	Equatorial, fully humid
Building Height	120 meters	39 meters	268 meters	Ashton:134 meters Skyle: 10	231 meters	58 meters	42 meters	129 meters	34 meters	89 meters
Structural Material	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete	Steel	Concrete	Concrete
Massing										

Number of Stories	36	16	73	Ashton: 32 Skyle: 10	69	17	10	30	9	15
Building Function	residential	residential	residential	residential	residential	Office	Office	Office	Office	Office
Green Wall Type	Façade-supported green wall (metal mesh)	Façade-integrated living wall(vegetated mat)	Façade-integrated living wall(modular green wall)	Façade-supported green wall (metal mesh)	Façade-supported green wall (metal mesh); Tree planters on balconies	Facade – Supported green wall (Horizontal aluminium slats)	Façade-supported green wall (metal mesh)	Façade-integrated living wall (modular living wall)	Façade-supported green wall (metal mesh);Vertical farm	Stepped terrace garden(some cantilevering)
Location on Building	South façade	North facade	Living wall on "internal Skypark south and west facades	Ashton Tower: green wall on east and west facades from Skyle Tower: green wall on east and west facades	podium has a green walls in north and south facades tower has a green walls in east and west facades balconies and sky terraces have a tree planters on north and south facades	On north and west facades	North facade from I st to 9th floor	South facade of offset core Surface	South and east facades, plus internally integrated into main lobby and offices	Numerous levels, predominately on north and south facade
Plant Species	Plumeria - Yellow Iris - Boston fern	Acacia, Allocasuarina, Carex trifrda, and Viola	coco peat, blazed rice husk, perlite and laca	coco peat, smouldered rice husk, perlite and laca	Tristellateia Australasia, Jasminurn laurifolium, Thunbergia laurifolia, and Thunbergia grandiflora.	Bougainvillea Parthenocissus quinquefoila Plumbago capensis White banksia roses	Cissus Antarctica – Clematis aristata - Pandorea pandorana - Tecomaria capensis - Trachelospermum jasminoides	Carex variegated, Heuchera Purple Varietle, Ajuga, Brass Button, Lysimachima numm, Euonymus, Sedum, and Fern	uncommon assortments of mild	Plumerias, Tall plumbs, Bucidas buceras, Ficus Lyrata, Monsteras, Alocasias, Calatheas and Lee ow creeper.
Total Percentage of Green Coverage	10%	0.7%	0.4%	23%	14%	22%	7%	1%	20%	11%

4.2. Discussion on the findings

The literature review on vertical green systems and precedents studied prove that these systems have advantages as well as disadvantages. Although it has many benefits at city scale, nonetheless it is not possible to persuade people to apply such systems due to being novel innovations as well as still being more expensive systems in comparison to conventional buildings. Moreover, according to literature review a few bodies says that putting greenery at high-rise buildings was a silly idea, when you consider the vaulting the building needs to go to, to oblige such increments.

It went ahead to clarify that it would be significantly more viable and gainful to the planet ecologically to re-establish one hectare of the wetlands than to put one hectare of vegetation and plants on high-rise buildings. However, considering high-rise buildings in cities, they almost look identical in appearance in different cities, and addition of green wall systems give them a specific identity, not to mention other urban scale benefits of such systems. Regardless of advances in a variety of fields, urban regions with skyscrapers are basically still comprised of rectilinear, cooled, glass-and-steel hard boxes. As Ken Yeang proclaimed 40 years ago, we have to begin fabricating our urban communities out of the delicate and common, rather than the hard and generally unnatural. Obviously there are enormous difficulties in actualizing such a dream and, as the ten precedents imply this may well be possible in near future.

4.3. Recommendations

Vertical green systems can be applied in specific high-rise building projects. However, in their application the architect needs to come together with the other project leaders to be able to apply this project. It is critical to ensure that there is an interdisciplinary discussion at the onset of the design strategy.

4.3.1. Climate Considerations

All elements of climate (counting the occasional fluctuations) ought to be assessed at the onset of considering vertical green system such as light, hours of daylight, sun’s radiation, overcast cover, air temperatures, relative humidity, wind speed, month to month precipitation, and so on since this will to a great extent make the design team decide on the green wall type. Specifically, wind speed can be an issue with vegetation at very high meters. Vertical greenery ought to be shielded from dominating high wind speeds wherever conceivable, and particularly potential vortex shedding at building corners and other inclined regions, concerning atmosphere. Consider the suitable developing period for the plants (entire year or part-year), and how this may influence the decision of evergreen or deciduous plants.

4.3.2. Planning and Design

The design team ought to plainly characterize the essential targets of the vertical green system before deciding what the most fitting system to utilize is. For instance, fundamental destinations could include:

1. achieving expanded wall protection or shading to lessen building energy utilization
2. modifying the quick small scale atmosphere

3. Air filtration reduction
4. Providing inhabitant with psychological advantages
5. delivering horticultural advantages
6. providing style and marking
7. screening unattractive zones
8. providing recreational zones
9. expanding existing level greenery into the vertical domain
10. Providing bug, flying creature and little creature natural surroundings, and so forth.

Moreover, what needs to be considered is whether the vertical greenery configuration conforms to nearby construction standards, easements and scene mandates. Numerous urban areas confine how much parts of a building (living or dormant) can extend from the exterior in a provided guidance. Are there gainful motivating forces offered by neighbourhood arranging committees to empower green wall usage? Is the vertical green system and planting decision fitting to the building capacity (business, inn, private, institutional, blended utilize), particularly regarding angles, for example, get to and maintenance? Has adequate space been left in every one of the three measurements to permit all the planting to achieve expected development? Is the introduction of the green wall ideal, regarding components, for example, sun, wind (dodging vortex shedding), rain, commotion, and so forth?

Is there the potential for other building components to be acquainted with shield the green wall from high winds? Is a lower-maintenance administration favoured (in this way climbing plants/façade supported green walls are likely more reasonable), or are larger amounts of standard support (connected with exterior coordinated living walls) adequate? Has the possibility to augment the association with existing greenery inside/around the site been considered and amplified? Can trees (existing or new) be utilized at the ground plane to shade the initial few stories of the building? Is there the possibility to present noteworthy sky plants in the building, and connection these to the outside green facades or living walls?

Can nonstop 'eco-halls' be made by connecting vertical green systems together, and perhaps connecting additionally to interior spaces? What rate of green coverage is sought over a single facade? Has the potential for recolouring by overflow from water system or soil been considered on adjoining building surfaces? Consider the essential wall material/itemizing and whether there is a danger of plant animal categories getting to be distinctly Invasive and bringing about facade or even auxiliary harm after some time. Has the base divider been adequately waterproofed/nitty gritty to guarantee the correct interface with the green wall (particularly a living wall)? Have materials around the green wall system been painstakingly determined in order to maintain a strategic distance from consumption/keep running off and unfriendly impacts on plant wellbeing? When introducing a green wall on another building, it is great practice to stage the venture in a manner that the green wall is introduced in the last phases of development, to keep any superfluous harm to the system by different exchanges Have neighbouring building proprietors been counselled, to gage their response to executing a green wall (particularly if access from bordering properties is required)? Is the financial plan for the vertical green system adequate to cover establishment, as well as progressing maintenance (and intermittent plant/framework substitution) for the life of the building? Has the capability of utilizing the vertical greenery as an instructing device to take in more about urban supportability been considered?

4.4.3. Structural Support System

Has the auxiliary system (both essential system and optional exterior support) been intended to acc0unt for the extra stacking from the green façade and living wall at plant development, and with most extreme soil immersion and other forced burdens (individuals, snow, wind, seismic, and so on.)? Could lightweight froth or a comparable material be utilized to make 'mass" in grower where required (e.g., in ventured porches), to diminish the heaviness of overabundance soil? Is a hydroponic (to a great extent non-soil) living wall planting system possible to lessen general vertical green system weight?

4.3.4. Plant Selection

Allude to "plant solidness zones' concerning fitting plant decision regarding the neighbourhood atmosphere. Are the chosen plants local to the venture area, and along these lines actually more tolerant to nearby climate conditions, nuisances and sicknesses? Consider that an excessive amount of daylight can be impeding to a few plants, and comprehend the contrasting perfect natural surroundings for various plant sorts (level of shade, soil sort, and so on) to settle on the best decisions. Consider the advantageous potential for deciduous plants in specific atmospheres which, through leaf shedding in harvest time/fall, can permit all the more light/sun powered increase through in the seasons where it is maybe gainful. Has the required tallness, width and thickness of the green wall by and large been connected with the plant decision? The requirement for steady pruning to reduce plants unseemly for their application can be as quite a bit of an issue as those that don't develop to fill their space obviously. Has the way that regularly develops plants supported for quite a long time and once in a while years is required, and has this been considered in the determination procedure? Where will the principle planting medium be? On the off chance that in an exterior upheld green wall, will the grower boxes be contained at each floor, or each 2-4 stories? Is a coveted constant vertical surface of plants fancied and, assuming this is the case; will the climbing plants indicated have the capacity to traverse the vertical separation between the grower boxes?

4.3.5. Irrigation Systems

The determination of an irrigation system relies on upon the vertical greenery sort, system tallness, watering rate and recurrence, water system source, water stockpiling and potential reusing, and space necessity for hardware. Decide the measure of ordinary precipitation on the site, and how this can be utilized, either to straightforwardly water the plants, or to store water for reused irrigation and water system. Consider that a few plants in moist zones remove at any rate some of their water system from stickiness show noticeable all around. Is there adequate water weight to Supply water system at the normal statures? Irrigation systems are normally mechanized and robotized; both the pumps and control gear likewise require dependable electric Supply. Can water collecting be utilized? Is some component of manual water and irrigation system suitable?

It is prescribed that a programmed trickle irrigation system be utilized with living walls. Plant preparation, and also water system, is fundamental for most plants, contingent upon the species it is critical that the irrigation system does not over-water, submerged, or give uneven spread so that a few zones dry out, while others get to be distinctly over-soaked and ready for plant and creepy crawly pervasions. A trickle plate ought to be fused at the base of a living wall module to gather overabundance water overflow from the system. Irrigation and water system frameworks can be outfitted with a discretionary climate station to permit system conformity for climate conditions and the season of year. Furthermore, water sensors can be put inside a green wall to screen the dampness level and to consequently enact and deactivate the water system framework as required (sensors ought to be set in the plant root zone to convey a more precise perusing). Irrigation system ought to experience visit review to guarantee the correct system working and ought to incorporate the accompanying assignments: Irrigation system initiation in the spring months and deactivation in the fall (in cool atmosphere zones)

- Clearing garbage from water system spouts
- Inspecting water system controllers, sensors, valves, and manure injectors
- Inspecting and repairing water spillage in the channels
- Ensuring appropriate incorporation of water system and preparation for ideal plant development
- Checking for appropriate water stream and weight
- Replacing electronic gadget batteries, if necessary

4.3.6. Maintenance systems

- comprehensive support plan ought to represent intermittent assessments on three levels
- Building and structure envelope structural integrity
- Performance of the Irrigation and watering system
- Health of the plant

In the initial couple of weeks after the establishment, plant investigations ought to be directed week after week, then month to month from that point. As plants develop, investigations can be directed bi-month to month, or even quarterly. Amid an examination, the upkeep group ought to:

- Check for plant infections, weed development, and vermin invasion
- Prune shoots that are developing in the wrong heading or are infiltrating under building cladding or rooftop materials
- Thin intemperate or tangled development
- Evacuate and replant harmed or unhealthy plants in living wall modules
- Conduct a dirt test to guarantee appropriate supplement levels

While exterior supported vertical green systems ordinarily require intermittent maintenance just amid the foundation time frame (the initial a few years), living wall systems for the most part require general support amid their whole life expectancy. Will support of all ranges be embraced from inside the building site zone, or is get to require through area outside the site (open regions or abutting properties). Could access to all areas be accomplished direct starting from the earliest stage (by scissor lifts or careful selectors), at middle of the road stature levels (by means of settled gantries and stages), or through suspended stages from the rooftop, As a rule, it is suggested that the green wall maintenance administrations be done by a similar organization that introduced the green wall.

4.3.7. Other Risks

A green wall displays the danger of combustible material crosswise over conceivably the whole exterior of a building; connecting floors and inner fire breaks a fire insurance architect ought to be counselled. Have different dangers been considered, e.g., unapproved access to the building through climbing the green walls, particularly in the event that they drop down to ground level (e.g., by thrill seekers, hoodlums and different interlopers). This is as much an individual security/obligation issue as it is an issue of potential robbery or harm to property. Has the danger of material dropping on individuals underneath been considered? Most plant material is sufficiently light to not bring about issues, but rather this can't be said of bigger trees, their branches, and hard seeds, for example, pine cones. Have all plants been checked so they are not noxious, or unsafe if gulped or touched? This is particularly imperative in structures possessed by youthful youngsters.

Chapter 5

CONCLUSION

The purpose of this thesis was to locate the possible ways and criteria to organize and bring vertical green systems into high-rise building design and asses how the compromise of vertical greenery into the high-rise designing and structures arrangement can help to future designers and planners. The thesis examined the ways of integrating green into high-rise building structures outline, for better prosperity of our economy, society and the urban environment. In order to satisfy the prerequisites of objectives the discoveries are composed likewise all through this thesis work. For instance, the arrangements of coordinate plants into high-rise buildings and structures incorporates the four conceivable choices like façade-supported green wall, living wall, stepped terraced and cantilevering tree balconies which can be fused into the outline. The effects of these alternatives on living environment, for example, the advantages of green facades and living walls on environment, economy and society is illustrated with some of their disadvantages, and the accessible innovations to coordinate and introduce these choices into the high-rise building design strategies. Suggestions, discussion and recommendations were made to conquer a portion of the disadvantages and a few criteria and rules were proposed for good practice to make the 'Green Movement' feasible financially, socially and environmentally. These were supported by comparative case studies analyses. High-rise buildings dwellers and owners require nature for feeling better in the cities. People can have a better quality of life on this planet through plants and vegetation and they can take in an incredible arrangement from nature and its cycles. "Planting" idea requires basic and interdisciplinary arrangement. Notwithstanding while deciding the nuts and bolts, and in the preparatory arranging, it is fundamental that the pro specialists partake and contribute their insight. Outside and inside planting require basic arranging and an advantageous interaction amongst nature and innovation. This idea is economical, environmental and with the right arrangements, high acknowledgment and quality in both open air and indoor ranges are accomplished. Moreover, this idea secures our surroundings. Monetarily, the green engineering is financially savvy and future-orientated with developing acknowledgment and expanding commercialization and, obviously, it is imaginary. For the regular development of urban communities, the development of high-rise buildings and structures could not be halted rather the request expands step by step. Thus, this is the right time to think about re-establishment of the nature and bringing it back into the constructed environment. As we have seen, there are several methods for incorporating green in the building envelope and additionally inside it. Appropriate usage of the advantages and more open mindfulness on this respect can change our surroundings radically in the near future if every one of the procedures is followed carefully. We trust that the couple of downsides of vertical green systems shall be overcome soon and more alternatives will be developed to integrate vertical green systems into the high-rise building configurations which will hopefully draw the manufacturer's attention. In this manner we can have more of these systems being applied to high rise buildings; and there could be increasing demand for them due to the quality of life it presents to its users.

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