The Green Wall as sustainable tool in Mediterranean cities: The case study of Limassol, Cyprus

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Abstract: - Urbanization causes an enormous impact on the environment which leads to an urban jungle, a concrete chaos, substituting forests and decreasing natural vegetation. An innovating and efficient way of 'attacking' issues of urban life, which have been also embraced by other developed countries, is the implementation of Vertical gardens as a Natural Based Solution. Therefore, in this paper, Vertical gardens were analyzed and assessed thoroughly, to acquire a general perspective of their functions, abilities, operations, benefits and risks, impacts and the process behind how they offer a higher quality of living.

Furthermore, all of these aspects were analyzed in regard to the city of Limassol, Cyprus. The suggested implementation in Limassol will be conducted, discovering the bare facades within the area and analyzing their quantitative characteristics. The proposal for implementation will be introduced, along with the main design idea, the analysis and the imprinting of the application. This paper pursues to offer alternatives to building designers as well as to the city planners in order to increase the green spaces in to the urban environment.

Key-Words: - Vertical garden, living wall, green facade, landscape walls, urban area, sustainability, modular system, urban vegetation

1 Introduction

The cities are growing worldwide while the vegetation is reduced, and the air temperature increases due to the appearance of urban heat islands [1]. The urban vegetation can improve this phenomenon by reducing the heat transfer between a building and its nearby environment and by providing solar shade that absorbs energy from the sun [2].

Buildings incorporating vertical greens have an important role in mitigating this by reducing the heat transfer between a building and the adjacent landscape and by providing protection from solar irradiation [3].

The vegetation can increase comfort levels due to transpiration procedures, wherever the energy required to evaporate and transpire water translates to a reduction in temperature. The water evaporates and the relative humidity increases. The suggestion for vertical green as an air conditioning simulates this phenomenon, wherever the airflow is focused in such a way that it is cooled and moistened. [4]

The use of vertical green as a cooling structure for buildings nowadays is an innovative research area [5].

Ottelé [6] displays how a solid vertical green layer on the building façade acts as an insulator, due to a stationary layer of air forming between the green area and the façade. Moreover, he demonstrates how plant leafs keep water on their surfaces longer than most construction materials, providing an additional thermal barrier. This is then taken a step further by Stec [7], where he investigates the use of plants as bio-shading systems in dual covering facades. He shows how the plants' convert heat contribution importantly decreasing the sensible heat gains the building would otherwise receive.

The overall aim of this paper is to assist in the education of the public and professionals towards acknowledging and accepting Living walls as a sufficient sustainable solution. Lack of extensive knowledge is the main issue when it comes to Vertical gardens [5]. They offer an abundance of advantages towards the environment, the economy, climatic conditions, psychologic and social aspects

and of course aesthetic, which people are not yet aware of, thus through this paper hopefully this could be altered, resulting in increased implementations of
Living walls, leading to a better ecosystem, improved urban webs and more importantly a superior quality of life [5]. In this research the objective is the potential reintroduction of urban greenery into an existing formed built environment, where potential implementations are not feasible. Special interest placed on bare facades where all of them were recorded within a study area and how these walls could be applied with Vertical garden systems. The city of Limassol, on the island of Cyprus is the chosen area of interest, were the possibility of introducing these implementations will be thoroughly analyzed. The proposal for implementation finally introduced with the main design idea deriving from the site analysis of the area. The system and plant species that have been selected and introduced, along with an assessment of the proposed implementation and finally can be guidelines for similar case studies.

2 Vertical Gardens

'Vertical garden' could be a more modern approach with a variety of succulents hanging from the wall or an edible vertical garden [5].

Vertical gardens or otherwise known as Vertical greens, living walls, Green walls or even Green facades are all descriptive terms which are used to refer to all forms of vegetated wall surfaces. Vertical gardens are the result of going 'green' on vertical surfaces with various plants, either ground rooted, embedded into the wall material itself or with constructed panels along the facade, attached, and/or with systems regulating their growth [9].

2.1 Types and Systems of Vertical Gardens

2.1.1 Green Wall Systems: A Green wall system can be simply defined as a wall being covered by plants; and can be divided into two categories; Natural Green walls and Artificial Green walls [5].

2.1.2 Natural Green Walls: The plants in this case are either planted in the soil, or a planter or container, absorbing water and nutrients from the soil (fig. 1). The addition of irrigation is not necessary but sometimes desirable. Green Facades are mostly seen outdoors [10].

2.1.3 Green Facades: There are three systems used for Green facades, these are the modular trellis panels, the grid systems and the wire-rope net systems.

Fig. 1. Green Façade in Limassol (source: authors)

"The building block of this modular system is a rigid, light weight, three-dimensional panel made from a powder coated galvanized and melded steel wire that supports plants with both a face grid and a panel depth" Timur (2013) [13]. The purpose of these systems is to support the Green facade away from the building's surface, thus the plants could not attach themselves on the building, as seen in Figure 2. The panels could be easily piled and linked in order to cover large areas as well as creating different shapes and styles. They are usually manufactured with recycled materials such as steel, and due to their rigidness, they can be placed between structures or could be used as freestanding Green walls [6].

2.1.4 Artificial Green Walls: Artificial Green Walls or otherwise known as Vertical gardens and Living walls, do not use climbing plants. The plants are placed in growing mediums located in the modular. Water and nutrients are provided by the felt or from the growing medium and an irrigation system is essential. Living Walls can be implemented both in interior and exterior walls [10].

2.1.5 Vertical Systems: Vertical gardens or the systems, which are based on artificial layers and pots of soil, they are fundamentally dependent on the addition of nutrients into the layers and on irrigation systems [9]. *"Characteristic for this greening principle are the use of planter boxes filled with artificial substrate/potting soil or modular prefabricated panels equipped with artificial substrates and they are called Living Wall Systems (LWS)"* Ottele, (2011) [6]**.**

2.1.6 Living Wall Systems: Living wall systems are devised of vertical modules, pre-vegetated panels or

planted blankets. The panels are designed from expanded polystyrene, plastic, synthetic fabric, metal,

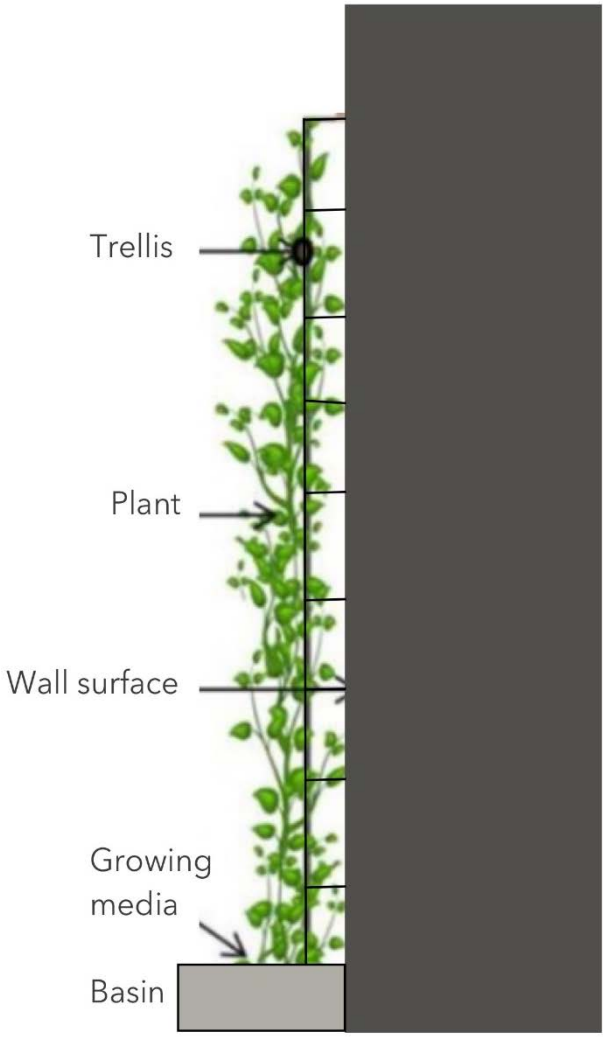

Fig. 2. Green Façade with a Cable Wire System (source: authors)

clay and concrete, allowing them to withhold great density and diversity of various plants.

Therefore, living walls require further protection in comparison to Green facades because of their density and diversity in vegetation. Fundamentally a Living wall consists of three things, a metal frame, following a PVC layer and an air space although certain care needs to be contributed on the selection of the vegetation to ensure better results and longevity. Generally, they require a self-automated watering and nutrition system, driving their maintenance to the minimum [6].

2.1.7 Landscape Walls: Continuing, Landscape walls are the development of landscape 'berms' and a calculated implementation in an approach to green architecture.

Fig. 3. During Construction (Living wall), Shopping Center, El Nos Roncadelle, Italy (source: authors)

Fig. 4. After Completion (Living Wall), Shopping Center, El Nos Roncadelle, Italy (source: authors)

The primary functions of Landscape walls are noise reduction and slope stability (fig. 5). These walls are sloped instead of vertical. Usually they are constructed from several layers of materials such as plastic or concrete and with enough space for plant growth [11].

2.1.8 Vegetated Walls: Vegetated mat walls or 'mur vegetal' is a distinctive Green wall first established by Patrick Blanc. It consists of two layers of

synthetic fabric with pockets which support growing media and plants.

Fig. 5. A vegetated steep slope, at Meydan Shopping Mall, Istanbul, Turkey. Design by Foreign Office Architects (Esbanh, 2011) [12]

A frame is used to hold up the fabric wall and following a waterproof membrane is situated against the buildings wall due to the high moisture content (Fig. 6). Through the irrigation system which pumps water from top to bottom, nutrients are also distributed [12].

2.1.9 Modular Living Walls: Finally, Modular Living walls surfaced partially using modules on green roof implementations and with numerous technological advances. They are usually rectangular, square or semicircle panels holding growing media which support plant material, an example of a Vertical garden can be seen in Fig. 7.

3 Pros & Cons

3.1 Benefits

3.1.1 Environmental Advances: A Vertical garden offers immediate environmental advances by reducing organic compounds from our polluted cities. Plants act as bio-filters and purifiers having a dramatic influence in the improvement of air quality in cities by removing or reducing airborne pollutants from both the inside or outside of a building's air. Studies have shown that they are considerably less concentrations of toxins in the air surrounding a Vertical garden. Theoretically speaking, if one Living wall is situated in every house in a row of 50 houses, then this is equivalent to having 50 trees planted on the street. By acting as purifiers, plants replace CO2 with oxygen, this means that the air breathed is fresher and healthier [13].

Fig. 6. Shopping Centre El Nos, Roncadelle, Italy (source: authors)

Fig. 7. Modular System, Shopping Center El Nos, Roncadelle, |Italy (source: authors)

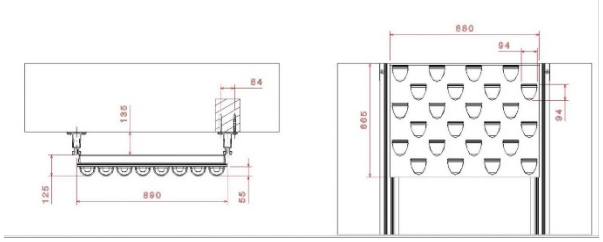

Fig. 8. Modular Construction (Construction detail by Vert Green Evaluation)

3.1.2 Improved Air Quality: It is scientifically proven that leaves improve air quality; why else would the Amazon forest be referred to as 'the lungs of the world'. A Vertical wall will help improve the air around it acting as an air filter by purifying the polluted air and releasing oxygen. When implemented in an office space, the existence of a Green wall can result in greater employee productivity and general health; as clean air leads to greater concentration, much healthier employees and eventually less sick days announced [17]. Improvement in air quality from plants has been measured to reduce coughs up to 30% and dry throat up to 20%; substantial differences in the air humans breathe [6].

3.1.3 Water Conservation: A huge benefit is how Vertical gardens manage water. First of all, watering is very efficiently handled as it is done through an irrigation system.
Waste water is collected by a basin at the bottom of the garden where it can be emptied out. This water can also be recycled and inserted back into the wall, thus all the water is used and there is little to waste [13].

3.1.4 Mitigating the UHIE: An Urban Heat Island is an urban area which is notably warmer than a surrounding rural area; for the avoidance of mistaking this with global warming, scientists call this effect the Urban Heat Island Effect (UHIE). One of the main reasons UHI flourishes is the excessive urban development; and Green walls are a popular solution for 'cooling' cities down and reducing the UHI [6].

3.1.5 Minimum Intrusion: As plants grow vertically, many pests cannot reach the plants therefore minimum use of pesticides is needed, saving costs on chemicals. Also due to better air circulation and plenty of sunshine it is less likely for plants to suffer from diseases such as mildew, fungus and others [6].

3.1.6 Restoring Natural Habitats: The dis-appearance of natural habitats is the number one threat to wildlife nowadays and they are vanishing at an alarming rate. Vertical gardens be part of the solution; trying to restore natural habitats. With the careful choice and implementation of plants, birds and butterflies can be attracted to a Green wall. Ideal conditions can be created so bees, birds and butterflies can survive with water, food, protection and eventually raise offspring on the wall [14].

3.1.7 Building Protection: Building protection is primarily resulting from the reduction of temperature variations on the building envelope.
This reduction in temperature variation leads to a decreased contraction and expansion in building materials, therefore extending the structure's lifespan. Vertical gardens also protect the structure from ultra-violet rays and rain acidity, as a result this reduces cracks and the carbonization on the envelope of the building, for these reasons the structure's functionality and durability is extended [5].

3.1.8 Decrease in Energy Costs: Living walls come and act as natural air-conditions, balancing humidity levels for our comfort, though the process of evapotranspiration. Therefore, in the summer our houses and offices are cooler and, in the winter, acting as an insulator we are warm; which in turn reduces our over-the-top bills all year round [14]. Studies have shown that interior Green walls can reduce electricity bills up to 30% [15].

3.1.9 Insulation and Saving Energy: Vertical gardens are able to reduce energy consumptions a building may require through insulation and management of temperatures. The Tokyo Institute of Technology, through variable tests on walls has discovered the ability of Green walls to lower temperatures on a wall of up to 10C, although results vary depending on what direction the wall is facing, sun coverage etc. [6].

3.1.10 Increase in Value: Vertical gardens have demonstrated the ability to increase property value as mentioned earlier. American and British studies discovered an increase in a property's value by 6-15% when possessing a Vertical garden [6].

3.1.11 Beauty and Drama: Plants are considered one of the fastest and cost-effective measures for correcting negative awareness, improving a building's profile, and eventually enhancing the visual facility, economic and social state of a city. The implementation of Vertical gardens has shown to increase the value of properties, the amenities of a building, initiating a higher public praise and transforming them into newly dramatic city landmarks [15].

3.1.12 Aesthetically Good: No-one who has ever seen a Green wall from up-close can say they are not impressed, especially from large-scale ones, like the

ones Patrick Blanc creates. The human eye is not custom to used to seeing a garden vertically, so it immediately catches our eye. Wherever it is placed, Green walls turn a boring and dry space into an alluring and 'cozy' environment. Think of it like this; it is a great first impression when someone strolls into your company's reception and a great natural subject to conversation when having guests over at home [16].

3.1.13 Reduced Noise Levels: It is quite unexpected when considering that plants can help reduce noise levels. This is one of the least known benefits which plants possess. Green walls can reduce background noise in noisy, loud communal dinning spaces or even reduce noise pollution from busy traffic roads. This is done by foliage absorbing and then reflecting the noise coming its way, so if someone let's say wishes for a calm and relaxing room at their residence; a Living wall is the ultimate [17]. As mentioned before due to the plants absorbing features, noise can be reduced by up to 5 decibels if places near a workspace. Also, it acts as a noise buffer and reduces outside noise and vibrations with up to 40dB inside workplaces and homes [6].

3.1.14 Peacefulness: Vertical gardens have demonstrated their strength of holding a viewer's attention, diverting awareness from themselves and troublesome thoughts and transferring viewers to a serine state of mind. Physiological and psychological issues offered by the city life can be eased through a physical and spiritual connection to nature. Participants in the study of Texas A&M and Surrey University reported feeling more attentive at the presence of plants, 12% more productive and less stressed in an environment with plants rather than no plants at all [6].

3.1.15 Psychological Impact: Numerous studies have shown that the existence of plants in the workplace reduces sick days and increases productivity. They also make a home more inviting, despite being pleasant to watch; plants fill the room with fresh oxygen. Greenery can also be related to food, health, life and a certain connection deep in our subconscious. Since most of civilization lives and works in urban areas and unfortunately spends most of their time indoors, empty walls and interiors can be brightened and reinvigorated with the feeling of abundance offered by the plants [19].

Surprisingly or not, Vertical gardens are the source of an abundance of benefits as demonstrated above. The amount of advantages, ecological, economic, social, psychological, environmental and many other, these purifying gardens offer, are breathtakingly over the top; there is no doubt about it. Unfortunately, though, disadvantages through the years have been visible on Green walls, therefore they need to be accounted for as well.

3.2 Risks of Vertical Gardens

3.2.1 Moisture Issues: In contrast to what it is generally believed Green walls are beneficial to facades. Rainwater is guided away, before it can reach the facade offering protection. Nevertheless, it is discussed that there are potential moisture problems with aged Green facades and unfortunately this is partly true. If for whatever reason the facade gets wet, it will dry up slower if there are climbing plants on the facade (direct). This is due to the limited solar radiation and air flow penetration between the facade and the plant, slowing down the evaporation rate. However, by covering the facade with trailing plants, this does not promote in any circumstance the moisture of the façade [9].

3.2.2 Damage and Deterioration: Plants have been wrongly accused of damaging walls they are covering by ripping out mortar and inserting roots into joints. Plants will not damage walls as long as the wall is in good shape. However, where deterioration has already started, plants can indeed fast forward the process of deterioration. Although from examples of ancient walls with plant growth in cracks which are still standing surely contradicts this accusation. Despite the fact that roots can insert themselves into joints they protect the facade from further deterioration from nature (sun, rain) and can help expand the life of a building by 'holding' the facade together. Damages can be seen only when removing plants from facades therefore revealing stains from sup on marble and limestone walls or extending damage on walls that are of stone and wood. New forms of damages are surfacing for Vertical gardens; these issues are related to Living wall concepts, existing mainly in dead vegetation and moisture. Though a good design, with appropriate water irrigation and suitable selection of plant species, can assist in order to avoid these small problems. Also, findings show potential for climbing plants acting as a protective layer which mitigates deposition of particles on buildings in urban areas but also the concentration of historic buildings made with stone as foliage cover reduces decay [9].

3.2.3 Maintenance: Maintenance plays an important role in the life of a Living wall; therefore,

if maintenance is for whatever reason absent then negative effects on both the facade and the garden will occur. By careful planning and thoughtful designing of the support system of most Green facades, minimum maintenance will be acquired. Facades covered with Living wall systems (LWS), with complex planting schemes will need more maintaining. Mainly, maintenance is related to the vegetation rather to the construction itself however the irrigation systems of LWS must be deflated during winter time to prevent frosting damages though additional requirements of nutrients must be refilled once in a while. Vegetation maintenance mainly consists of pruning twice a year and replanting on places vegetation has dried out; for that reason, it is best to check the wall in spring [9].

3.2.4 Material Consumption: The varieties of Vertical garden systems available have numerous differences regarding the environmental impact they possess depending on the materials used. Materials of construction vary from panels, planter boxes, tubes, support structures, which are all synthetic materials produced from crude oil, aluminum or steel, therefore they are not environmentally 'good' materials. The production of these materials is damaging to the environment, thus, living wall systems have a higher environmental impact than Green facades. On the contrary, the use of ecological and organic materials for Green facades, such as wood, steel and wire, generate dangers of viability, deriving from water, microorganisms and the low pH environment of these systems [20].

3.2.5 Allergy Issues: When Living walls are implemented in interior spaces, allergic reactions may surface from the users of the building which could potentially be allergic to specific plants and their pollen. For avoiding issues of this kind, the plant selection should be conducted very carefully, so to select plants which do not produce large quantities of pollen, or through a small survey within the building users to establish if any users are allergic [20].

3.2.6 Lack of Knowledge: Unfortunately, the Vertical garden systems, technology, products and functionality are not broadly known. The majority of people, when thinking about Vertical gardens, the only thing which comes to mind is a climber plant, probably *Hedera helix*, growing upwards on a bare wall. Also, the research and awareness of Vertical gardens is still very restricted and minimized, or the research is restricted to local findings which limit the possibility of implementing them to different conditions [20].

4 General Design Principles

The principles of design, installation and maintenance of Living walls and Green facades differ according to the system chosen and the conditions of the building and natural environment. Factors needed to be carefully studied and applied for a successful and complete design approach, from professionals related to the process, such as designers, architects, engineers, agriculturists, landscape architects, manufacturers and staff, are the following:

- the aims and goals this specific installation is supposed to fulfil
- thorough analysis of the local climatic conditions and the microclimate (humidity, solar radiation, rainfall levels, wind speed and flow)
- thorough analysis of the planning structure (density of the building web, building factors, building weight etc.)
- thorough analysis of the building characteristics which the Vertical garden will be placed upon (height, construction materials, building orientation, facade)
- analysis of how much weight the building and facade can withstand, plus considering the extra weight which might occur from external factors such as snow and wind [21]
- choosing the appropriate system for installation according to the design aim, environmental as well as economic factors
- adjustment of the system with the building envelope and the connection of plants chosen, with the structural elements of the system
- using common materials for the least possible energy consumption and possibility of recycling
- appropriate plant choosing for the best possible adaptation of plants to the climatic conditions of the area
- realistic expectations regarding plants reaching their optimum growth and aesthetic value, as well as coverage of the full facade
- maintenance, correct selection of growth medium and irrigation, for accurate system handling and function
- cost of construction, installation and maintenance (short and long term)
- possibility of water recycling from the irrigation systems [20].

5 Considerations about Green Walls

Most Green walls are vertical planting systems on the exterior or interior of a building**.** "*The basic green wall system is created by providing a planting*

substrate into a modular wall system" Mcrae (2008).

The typical vertical planting system is made up of five parts:

- proper selection of plants -location
  -environment
  -interior/ exterior wall
- a modular panel system which can withhold the roots and the growing media
- an incorporated drip irrigation system with controls
- a catch basin to control falling water
- a structured support system [22]

Basically, everything is connected. The plants stay in place due to being rooted into the growing medium, which is contained in place by the Modular wall system and connected to the wall through a structural support system. The only factor which plays an important role to a successful Green wall is having a properly designed system to hold/maintain it [22].

There are several ground-breaking design differences between a Vertical garden design and a regular ground-level garden design. Listed below are some specific construction requirements /considerations for building a vertical greening system:

- even drainage throughout the system so the bottom rows do not receive more water than needed
- protection of the support system's integrity
- waterproof protection of the system
- a planting medium that will not deteriorate over a long period of time such as a synthetic product
- good irrigation and fertilization for best growth and sustainability
- purveying for maintenance
- plant adaptation to the environmental conditions at hand [22].

6 Plant Choosing

Plants commonly used in Vertical Gardens

Almost any plant can grow on a Vertical garden depending on the circumstances; although they can only thrive in their optimal environment. Most herbs and vegetables acquire hot summers and full sun to grow, in comparison to succulents that need to be dry and full to partly sunny, whereas ferns need shady or bright light areas which are cool at night and moist [23].

House plants are best used in indoor environments. Some plants could be native to the shady floors of tropical rain forests. Ideally, they need the same 21C° that a human need, to survive in an environment; so it is only natural that we want to fill our lives with greenery [24].

Indoor gardens have more limitations due to the low humidity and low light, although when it comes to outdoor gardens the options and choices are abundant. In general, the Philodendron family is the most durable. It consists of a large range of colours of foliage and bold roots and stems. They can be transplanted from cutting which allows them to literally spread easily and all over, and the Philodendron family can drop down as well as climb upwards [24].

7 Case Study - Implementation of Vertical Gardens on Bare Walls, Case Study Area: Limassol, Cyprus

Due to the extensive number of bare walls all around Limassol's city centre, it is highly unlikely to analyse and implement Vertical walls on the whole area. Therefore, a more specific and concentrated area of the city centre will be selected, in relation to all of the parameters mentioned previously, this area demonstrates more environmental issues from other urban and suburban areas of Limassol. In order to choose the best possible study area, some parameters and characteristics need to be consider so to acquire the best outcome possible. Some of these characteristics are the recognition of the main functions, establishing were the public, historic, cultural and significant buildings of the area are located, which area is lacking the essence of 'green', the density and height of buildings, where there are narrow streets, which areas are truly dense and no empty plots are available, irregularly shaped areas leading to many bare walls, which area has buildings constructed 20 to 40 years ago and are lacking insulation, high traffic volume leading to noise and environmental pollution and finally increased atmospheric and thermal pollution.

As a result, the center of Old Limassol is chosen, which is an area overflowing with old and new buildings, pedestrians and vehicle circulation. At this area, a Site Analysis will be conducted in order to gather information regarding bare facades, the area in general and finally selecting which facade will be implemented with a Vertical garden. One of the reasons this area was selected is due to the increased usability during the whole day. On a normal day around those streets there are students moving about from one building of the CUT University to another, people coming and going

from work, people visiting various businesses and shops, vehicles moving around for pleasure and work, and of course at night the bars in Saripolou Street stream with life.

Unfortunately, around these streets there are not many trees or plants, the only vegetation visible are some trees planted on the sidewalks. With the lack of green and the characteristic features of the urban web, the general urban microclimate of the case study area is formed. These conditions and the lack of available space for the growth of vegetation as a means of improvement, create a pressing mean of exploring all possible ways of covering bare facades.

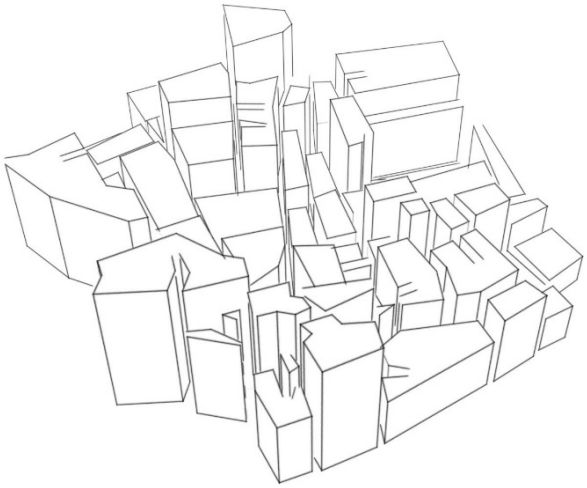

Fig. 9. Rendering of the area (source: authors)

7.1 Results

7.1.1 Selecting a Specific Study Area

Due to the extensive number of bare walls all around Limassol's city center, it is highly unlikely to analyze and implement Vertical walls on the whole area. Therefore, a more specific and concentrated area of the city center will be selected, in relation to all the parameters mentioned previously, this area demonstrates more environmental issues from other urban and suburban areas of Limassol. Additionally, it is an area which is constantly in motion by citizens and tourists, thus the city center illustrates the appropriate characteristics which could act as initial motives for the implementation of suggested Vertical garden proposals. The planning web, the density of the area, could be ideally improved, regarding its microclimate and aesthetic feel.

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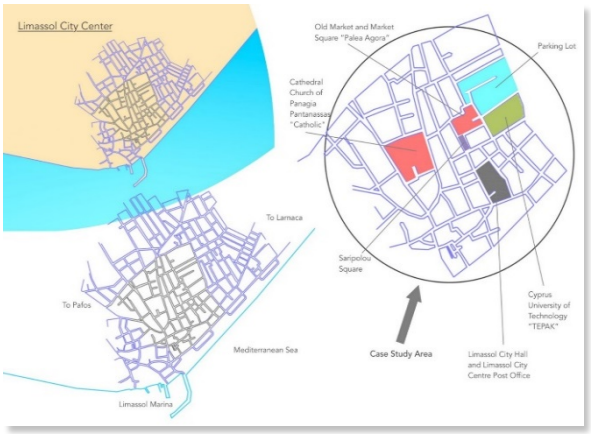

Fig. 10. Site analysis of the area (source: authors)

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The Case Study Area, in the city center of Limassol or as it is called by the locals 'Old Limassol' (Παλαιά Λεμεσός), the approximately area which will be analyzed is of 150,000m2, more or less 2km and approximately 5km are needed to walk the whole of this area.

One of the reasons this area was selected is due to the increased usability during the whole day. On a normal day around those streets there are students moving about from one building of the CUT University to another, people coming and going from work, people visiting various businesses and shops, vehicles moving around for pleasure and work, and of course at night the bars in Saripolou Street stream with life.

Unfortunately, around these streets there are not many trees or plants, the only vegetation visible are some trees planted on the sidewalks. With the lack of green and the characteristic features of the urban web, the general urban microclimate of the case study area is formed. These conditions and the lack

of available space for the growth of vegetation as a means of improvement, create a pressing mean of exploring all possible ways of covering bare facades.

7.1.2 Integration into the Surrounding Area

The final building chosen for the implementation proposal of the Vertical garden is located on Athinon Street in the case study area. This specific street is in the heart of Limassol's city center and it is the road leading to Saripolou's bars; a busy night life area. Therefore, it is a busy street throughout the day, being used by businessmen, shoppers, students and citizens going for a drink or a dinner both in the evening and lunch time and for everyday use.

The building is a two-story tall private residence, a classical structure, more than 30 years old. The first bare facade (97) orientation is facing the North, 2.5 meters high and 13.5 meters width, a rectangular shape with a total of 33.75m2. Due to windows located on the 2nd floor, only the first floor of the facade will be used. There is no potential for planting on the ground although the facade is on the ground level and it's not attached to any other building. The specific wall over the years has been vandalized on multiple times, as it provides a large surface for this function and it is found on a prime location. The pavement of this structure is small, with a limited pedestrian access. The 2nd bare wall (100) is facing the East, with a height of 12 meters and a width of 5 meter, making it a rectangular shape as well. Thankfully on this facade there is potential for planting on the ground.

Around the specific building there are multiple functionalities such as shops, coffee shops, businesses, churches, bars and residences. Following some maps and pictures will illustrate the bare facade chosen for the implementation.

7.1.3 Sun and Shade Conditions of Building and Outdoor Area

Parameters which influence the insolation on buildings is primarily the orientation and the slope in which the selected facade is facing, the geometric relation of the face in relation to the neighboring structures, the geometric width of the area and of course the date and time.

Regulating indicators of the insolation in regard to the geographic width and the atmospheric conditions are the orientation of the city's streets and their intersections. The insolation conditions affect decisively the conditions sufficient to natural lighting of buildings and thermal comfort of the buildings.

For investigating the solar and shading conditions of the selected facades, two specific dates were selected, with recordings every few hours for a better understanding of the subject.

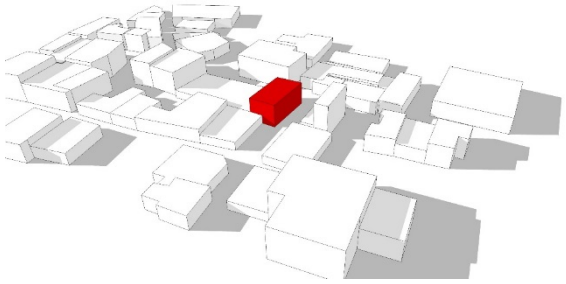

Fig. 11. Sun and Shade Exposure on January 25th 2016 - 09:00 am (source: authors)

7.1.4 Ventilation Conditions of Building

The specific location of the facades and due to their orientation along with the structures which neighbor the building, which are more or less of the same height, act as protection mechanisms from strong winds 'attacking' the facade. The road's width and orientation of the intersections also adjust the wind flow of the area. Although during the winter times were there are stronger winds due to fact that the structures location is close to the coastline, the building experiences stronger winds than other locations in the mainland.

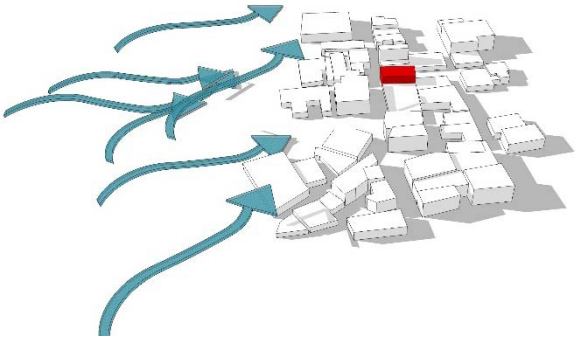

Fig. 12. Ventilation in the area (source: authors)

7.1.5 Planting in the Surrounding Area

Vegetation in the surrounding area of the selected facade is average. Trees are mostly situated on pavements along Ellados Street, from Catholic Church until Spartis Street, and along Athinon Street as well as Kitiou Kyprianou Street. The trees were planted by the city district for enhancing the greenery in the area (Fig. 13). Other vegetation is seen in some yards of private residences.

Table 1, Quantitative Analysis (source: authors)

Number	Street	Height(m)	Width(m)	Sqm2	Possibility of Planting on Ground	Wall Situated on the Ground	Attached to other Building	Type of Building
90	Kyprianou	3.5	15	52.5	No	Yes	Yes	House
91	Kyprianou	5	10	50	No	Yes	Yes	House
92	Kyprianou	4.5	6	27	No	Yes	Yes	House
93	Kyprianou	5	12	60	No	No	Yes	House
94	Kyprianou	3	7	21	No	No	Yes	House
95	Kyprianou	13	25	325	No	No	No	Business
96	Kyprianou	4	13	52	No	No	Yes	House
97	**Athinon**	**2.5**	**13.5**	**33.75**	**No**	**Yes**	**No**	**House**
98	Athinon	4.5	16	72	No	Yes	Yes	Business
99	Athinon	3.5	24	84	No	Yes	Yes	House
100	Athinon	12	5	60	No	Yes	Yes	Block
101	Athinon	9	12	108	No	No	Yes	Business Block
102	Athinon	3	8	24	No	No	Yes	House

After investigating there are more than 60 trees planted on the pavements and around 20 in private residences. It's not that vegetation is scarce or absent from the area although it could be substantially increased; thus, the Vertical garden will do just that. Additionally, the trees on the pavements are of the same species thus the Living wall could diversify this continuity. The following rendering demonstrates the vegetation available in the surrounding area of the chosen facade and the pictures below provide a feel of the area.

Fig. 13. Planting in the area (source: authors)

7.1.6 Bare Facades - Quantitative Characteristics

The chart demonstrates the quantitative analysis of the walls found in the study area.

In completing the collection of data within the study area in regard to bare walls, the total amount of surface area comes to be 13,409 m2. Walls 97 and

100 are in red as they are the walls selected for implementation.

7.1.7 Main Idea of Design Proposal

The main objective of this design proposal is the tackling of environmental issues, the improvement of the urban web's microclimate as well as the enhancement of the quality of life for everyone. Taking into consideration the density of the urban web, the lack of urban green and the important advantages greenery can provide to an area, instead of hopelessly searching for empty spaces to create green areas, the bare facades in the area could be utilized towards the city's advantage with the implementation of Vertical garden systems.

More specifically by evaluating the environmental conditions of the study area such as solar radiation, wind flow, shading and planning characteristics, being road widths, building heights and density, along with all of the issues of the size and orientation of the bare facades and their importance to the configuration of the overall appearance of the region and the micro environmental conditions, the specific goals of the design are the following:

- improvement of air quality
- reduction of the UHIE
- reduction of the atmospheric pollution
- reduction of the energy consumption
- building protection from weather conditions
- aesthetic improvement of the building and area

With this modern yet ancient approach of the implementation of a Vertical garden system, the collaboration and merging of the urban with nature can be made possible. Simultaneously the effort to create a recognizable sustainable approach in the city center with the greenery of the facade mingling with the architecture and character of the city center, hopefully a harmony of the two will be established.

7.1.8 System Implementation on Bare Wall

Since the bare facades do not possess any openings and by being on the ground floor; the application of the system is made easily. The only difficulty will be the constant vehicle circulation, fortunately the pavement will provide with some easy access for the installation. In order to achieve an easy and quick, installation, coverage of plants, absorption of atmospheric gases and reduction of thermal contribution and temperatures; a Modular Living wall system needs to be applied for the bare facade number 97 and a Cable Wire system as a Green facade for bare wall number 100.

Due to the walls being even and flat, the installation of the system will be easy. The Modular Living wall system includes a wall panel, inside panel, irrigation system, irrigation drip line, waterproofing, mounting strips and a basin. The plastic green wall panels can be screwed directly on the wall or on a metal frame which will be installed on the facade. The plastic panels can be provided by local importers. Inside the openings of the panel, plastic pots can be placed with the growth medium (soil) and plants. Inside the soil the appropriate nutrients and organic components will be present. Irrigation tubes will be installed through the available compartment on the panel and will be linked to a nearby water source. Underneath the system, there will be a basin for collecting the water remaining for irrigation.

For the Green Facade Cable wire system, the installation and components in need are much simpler. Designed to be prominent and very practical, these wires allow the designs to run both vertically and horizontally in order to create noticeable trellis grids. Mainly the components in need for a Cable Wire system are stainless steel hubs, stainless steel cable, stainless steel or wooden screws and plastic wire caps. Some diagrams following will demonstrate how the system will operate and provide further understanding of how and where the components will be positioned and their functionality.

The specific Living wall system can provide insulating abilities and contributes to energy saving. Due to the availability of the panels, the growth medium, the density and the quantity of plants used, the system has more impact on the reduction of the urban heat; it absorbs more gases and allows for less noise pollution. This Living wall system allows for a faster and more effective coverage of vegetation on the facade, given the possibility of replacing plants or tackling any issues which might occur with the wall. Hence, despite that there is a substantial installation cost, summarized around €500 per m2, due to the many advantages the Vertical garden provides, this compensates for any budget issues.

The Cable Wire system for the Green facade, is of course less costly, as the only elements it requires is the wires, firmly adjusted on the facade, soil and a basin on the bottom for the collection of water.

8 Discussion and Conclusion

With environmental issues being at their highest in dense urban areas, sustainable solutions are in order so to eventually improve quality of life. Taking into consideration the importance of greenery in such areas, the utilization of bare facades to create green spaces is an effective solution for tackling many issues. Living walls can be a useful and innovative

solution, as densely packed urban areas lack space. With the implementation of Vertical gardens, an urban web can experience numerous advantages related to environmental, economic, ecological, psychological, social and aesthetic aspects [5].

Rosenzweig, with a more pragmatic and empirical approach, suggested another line of conservation, known as 'reconciliation ecology' [25]. This is when urban areas are modified and adjusted in order to withhold larger varieties of species, of course without tampering with the areas of use [25].

Since the city of Limassol is characterized as dense, with noise and atmospheric pollution and an uneven building character, as any other modern city in the world, an appropriate plan for altering all of these aspects could be to initiate Vertical garden implementations. With the aid of various professionals and of course the city district, living walls could slowly though steadily be applied on bare facades.

In order to implement Vertical gardens, a specific study area was initially determined, this being in the heart of the city. In the study area chosen alone, through the aid of a quantitative research, there are 235 bare facades, totaling 13409m2 of dull, empty walls. The characteristics of the specific area were then collected, including historic buildings, shops and businesses, parking lots, greenery and graffiti. A determination of the application site and strategic design followed, along with recognition and analysis. A site analysis of the facades chosen was imminent, with sun, shade and ventilation conditions of the buildings and outdoor area.

Fig. 14. Final Rendering of Area (source: authors)

The planting surrounding the selected walls was gathered, as well as functional and environmental behavior. Pistola, produced a similar study in Kozani, Thessaloniki; she conducted a quantitative research of the bare facades of the area and found ways to implement vertical gardens on bare walls within the urban area [20]. We both found numerous bare facades in two large cities in the Mediterranean region, which indicates the overwhelming concept of urban areas needing to be redesigning in order for our quality of life to evolve.

Francis and Lorimer, argue that a suitable site for a living wall is particular between urban areas, *"…based on commercial and cultural differences in building design, relative density of urban development, and the sizes of individual buildings"* Francis and Lorimer (2011). This concept varies within three 'categories', one being that despite how huge a city is, the denser areas are found in the center, and reduce with distance from the center towards the suburbs. The second relies on the specific use of each building within the city center, with each different use their density varies. Finally, the third categories indicate that each specific area has differences within its housing density, depending on culture, patterns and socioeconomic factors [26].

Therefore, the proposal for implementation followed, introducing the main idea of design, analysis and imprinting. Systems, construction details and plant selection were proposed for all bare facades. As a result, final renderings of the potential Vertical gardens were demonstrated, illustrating the full potential and significant alteration these gardens would impose on the area.

Finally, through careful studying and analyzing, by educating the public and the city district authoritarians, hopefully in the future these implementations could be made possible and gradually one by one, these bare walls could become small ecosystems with the application of Living walls, creating a better quality of life not just for us but for future generations to come.

This research can be useful for the decision makers, planners and architects at the municipality of Limassol as well as at the building designers, while the methodology can be applied to similar cities to make their urban areas 'greener' and improve their microclimate and reduce the pollution. While the design can be successfully implemented to the facades to enhance the urban conditions. The green walls can be used as an alternative solution for indoor and outdoor walls and an extensive research can be done in the high-rise buildings concerning the method and the plant materials.

Fig. 15. Final Rendering of the area (source: authors)

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