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Green Facades as a New Sustainable Approach Towards Climate Change

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Abstract

For various reasons, sustainability today is producing an important and interesting approach between architecture and the environment. This is taking place in forms and with different degrees of intensity. Within the challenges of energy crisis and climatic changes architects started to develop new approaches to address the quest of energy demands in buildings.

One of these approaches is façade greening which started to take an important place in the last 10 years , it's not considered a new innovation, where applying green facades is not a new concept; however it has not been approved as an energy saving method for the built environment.

Vertical greening can provide a cooling potential on the building surface, which is very important during summer periods in hot climates. The cooling effect of green facades has also an impact on the inner climate in the building by preventing warming up the façade.

Within this quest, this paper is focused on the analysis of the effect of green facades systems on the building temperature and addressing different types of green facades systems and their thermal effect.

Key Words*: Living walls systems, energy saving, temperature, façade greening, climate change*

1. Introduction

”The ficus and climbing plants had developed in an unvaryingly perpendicular direction, imposed by the density of the element which had produced them. Motionless, even after I had parted them with my hands, the plants immediately returned to their original position. This was the realm of verticality.” [1]
Exterior Vegetation has been used for centuries, primarily in the form of various climbing plants with or without the support received spread over facades to give a green appearance to the environment [1] (Dunnett and Kingsbury, 2006:9), In recent decades living walls, vertical greening of facades of buildings or noise barriers have been realized. Vertical greening offers an outstanding number of public

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and private benefits such as: aesthetical, social, ecological and environmental, and fits in the principle of ecological engineering as defined by Odum [2]

The contribution of plants on building facades is essential for the improvement of the sustainability of the built environment. Their implementation is also ecologically and aesthetically acceptable as an adequate architectural feature that upgrades facades. Their exploitation leads to an energy conscious design approach that prevents densely populated urban areas from transforming into a deteriorated natural environment. [3]

The façade greening of building walls, known as vertical greenery systems (VGSs), has yet to be fully explored and exploited. Simply due to the sheer amount of building walls, the widespread use of vertical greenery systems not only represents a great potential in mitigating the UHI effect through evapo-transpiration and shading, it is also a highly impactful way of transforming the urban landscape.[4]

Facade greening have advantages not only an active contribution to environmental and Nature are to be assigned, but also for building long-term Can lower operating costs. In addition, facade greening in larger Commercial areas of particular importance, since it is the local climate of a small settlement area affect materially. Here, these green forms are essential for dust control, for humidification and the cold air generation and hence to the promotion of human Health. They have therefore, like a green roof, the function of a local, natural air conditioning '. As many potentials and opportunities are already visible, is the subject a closer look in terms of a sustainable future value.

2. Green Facades and Urban Heat Island Phenomenon

Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality.

They can be developed on urban or rural areas. As it would be predictable, there is a minor fact regarding non-UHIs, since they typically do not correspond to a risk for the human being or the environment. In the meantime, UHIs have been abundantly addressed throughout decades in urban areas with an extensive variety of climates and landscapes (Fig. 1). [5]

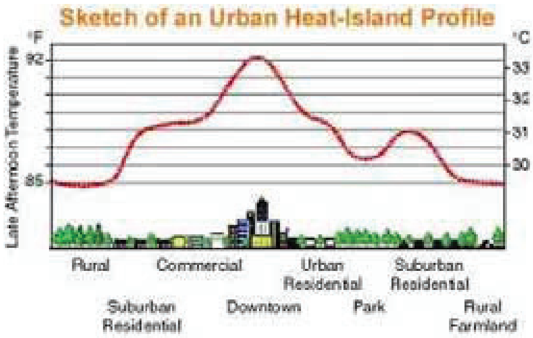

Figure.1 Urban heat island dealings [4]

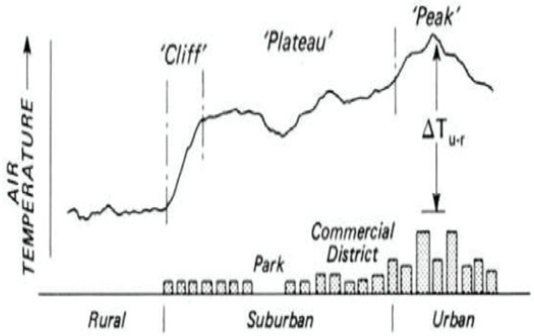

Figure 2. Longitudinal section of the urban island effect of chlorine. [6]

Impervious surfaces like facades and streets influence the microclimate around town increasing temperatures around the buildings and consequently to affect recently within the same discomfort and increasing the amount of energy used to condition [6] .A possible solution to this problem is the use of vegetated roofs and facades, which heat energy consumed by evapo-transpiration (figure 2).

In addition, vegetated roofs and green spaces contribute to vertical mixing of air, so the temperature over them tends to be lower than the surrounding areas built. Warm air rises over the hard surfaces and is replaced by the fresh air and reducing the heat island effect. [7]

The vegetation can help improve local air quality by reducing the "smog" and oxygen production. The "smog" may be reduced in two ways, with decreasing particle suspended in the air and reducing the temperature. Because of the available space in the cities, the planting trees and shrubs is often not a viable option. Thus, vegetated facades are configured as a interesting option that uses a space traditionally forgotten. [8]

In all climates studied vegetated facades have a more significant effect in reducing temperatures in the urban canyon, while the act covers most urban level. In general, best results are obtained when combining the two, facades and roofs. [9]

Studies done with models suggest that vegetated facades can reduce the effect urban heat island around 2 degrees Celsius, improving air quality, thermal comfort and health human, with savings in electricity consumption of 5% to 10% [10].

2. Green Facades and its environmental Impact on Buildings

In recent years, has been enumerated by various authors and a number of advantages disadvantages associated with the vegetation of the buildings. These aspects have been studied, tested and described in greater or lesser extent depending on authors, the countries of the possibility of obtaining objective data; the time needed experimentation, etc.

Lately also considering using the strategy of building plants urban and in relation to the environment. It is considered that the building to support vegetation has a decisive role in the strategy of urban vegetation as part of its essential relationship with the environment must have in the city. The consideration of roofs and facades, ie, of the skin of the building to support different models of urban vegetation, must be properly studied and included in the planning and ordinance related [11].

Vegetation can play an important role in the topo-climate of towns and the microclimate of buildings. With buildings, some vegetative climatic effects could be made by combining green cover on walls, roofs and open spaces in the vicinity of buildings [12]

Many researches proved that vegetation on building façade can be effective on the level of building environmental performance, Lambertini [13] presented a pictorial collection of the most important architectural projects that embraced the emerging trend of designing and cultivating once inconceivable greenery on a vertical plane while Dunnett [1] cited the associated benefits and reasons for integrating green techniques of organic architecture into our built environment as well as provided a massive collection of appropriate plant information and extensive plant directories for both rooftop gardens and vertical greenery systems.

Lastly, Van Bohemen [14] showed within an ecological engineering context the impact of the greening of outdoor walls and questioned the hesitation to implement vertical greenery systems as outer layer of buildings with special emphasis on the relationship between particulate matter and aerosol deposition with vegetation.

3. Thermal Impacts:

3.1 Thermal Impacts: Temperature Reduction

Research showed that the humid climates can achieve substantial benefits of a maximum temperature decrease of 8.4 _C with vertical greenery systems in an urban canyon [15]. This is significant as the distribution of ambient air in a canyon influences the energy consumption of buildings as higher temperatures in canyon increase heat convection to a building and correspondingly increases the cooling load [16].

It was also noted that vegetation can alleviate UHI directly by shading heat-absorbing surfaces and through evapotranspiration cooling [17]. Vegetation can dramatically reduce the maximum temperatures of a building by shading walls from the sun, with daily temperature fluctuation being reduced by as much as 50% . Through evapotranspiration, large amounts of solar radiation can be converted into latent heat which does not cause temperature to rise. In addition, a façade fully covered by greenery is protected from intense solar radiation in summer and can reflect or absorb in its leaf cover between 40% and 80% of the received radiation, depending on the amount and type of greenery [18].

In terms of vegetated facades, the presence of a barrier blocking the transmission of plant radiation to the interior but also outwards, becoming a potential tool of isolation. Other interesting effects in terms of temperature regulation in buildings are the ability to reduce wind speed falling to the facades of the building, and modifying the climate of the intermediate space Plant remains from the screen and the facade of the building.

The transfer of heat energy through a concrete wall is significantly lower if is externally coated by a layer of vegetation (Figure 1) [18].

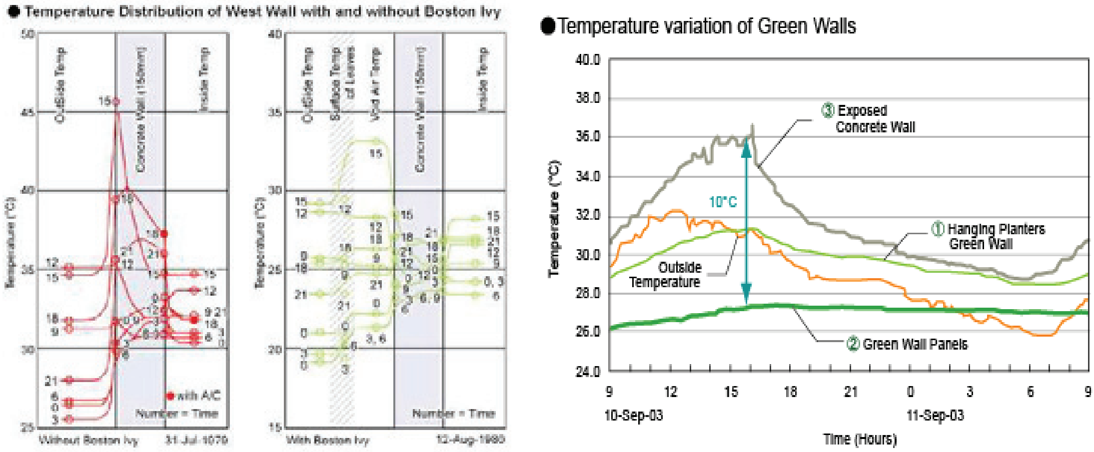

Figure 3. Distribution of temperatures across eastern façade, and no ivy.[19]

In a traditional facade covered with ivy is measured by thermo-graphy systems infrared temperature variations of up to 5 degrees insulating effect, both winter and summer [20].

In studies on facades were measured up to 25% improvement in heat loss in a north wall (Minke and Witter 1983), but depends on the insulation levels of the building [21].

Moreover, surface temperatures of vertical greenery systems have been observed in different settings at the University of Toronto since 1996 [22]. These results have consistently demonstrated that areas with vertical vegetation are cooler than light-colored bricks, walls and black surfaces that are typically found in urban areas. Lastly, in Japan, experiments show that vines can reduce the temperature of a veranda with south-western exposure [23]. In Africa, a temperature reduction of 2.6 _C was observed behind vegetated panels of vines [24].

Therefore, together with the insulation effect of vegetation, temperature fluctuations at the wall surface can be reduced from between 10 _C and 60 _C to between 5 _C and 30 _C [25]. Finally, the benefits are remarkable plants of the walls in terms of energy conservation used for heating in winter.

3.2 Thermal Impacts: shading and insulation

The use of vegetation in vegetated facades as a blocker of solar radiation is clearly, with the advantage that the traditional elements Meta-Plastic or metal that are going and this heat will radiate back into the surrounding the building, while the vegetation does not. The magnitude of this effect depends crucially on the density of the foliage.

The temperatures of the different layers of a double-skin facade are generally lower if Plants used against slat space inside. For the same solar radiation, increasing the temperature is two times lower than in the case of plants with respect to the slats. Moreover, temperature never exceeds the plants not

35 ° C, while the slats can exceed 55 ° C.The installation of plants in an internal double skin to reduce consumption Energy conditioning system by up to 20% [26].

The physiological process that occurs in plants implies that a small portion of solar radiation incident to be done for photosynthesis, and the rest is used in the evaporation of water, which makes the plant go a mechanism of temperature regulation. This leads to the vegetation gets effective blocking of solar radiation without increasing its temperature. The transmittance a leaf is 0.2 and the absorbance of 0.5. Actually, when solar radiation affects the vegetation is in the way many leaves, the combined effect of the plant mass that transmit and reflects be reduced to virtually cancel themselves.

In the experiment "Bioshader" conducted at the University of Brighton, an office was compared with the window covered with vegetation like no other cover, and reductions were measured the internal temperature of 3.5 º C, with highs of up to 5.6 ° C. We also measured the solar transmittance of the foliage, which ranged from 0.43, with a single layer leaves, up to 0.14 with five layers of leaves, corresponding to a reduction in radiation solar crosses 37% for a layer, up to 86%, with five layers of leaves (Figures 4, 5 and 6) [27].

So the shadow is directly possibly most obvious benefit of the vegetation. The facades vegetated provide shade and aesthetic use. While requiring some maintenance, façade vegetation offers shadow effects similar to other artificial systems with a plus evaporative cooling [28].

As a result of the natural shade of the vegetation contribute to saving the facades vegetated energy in buildings by the acondicionament them. The magnitude of this effect depends on the density of the foliage. The ivy is the species that provides the maximum cooling effect, comparable to the effect of shade trees [5].

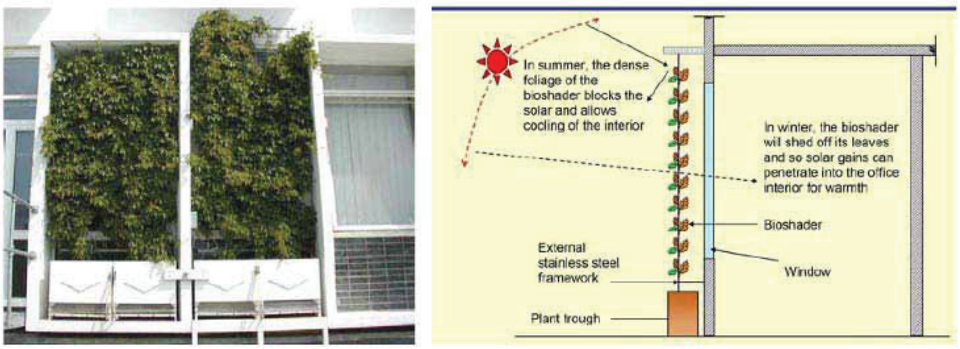

Figure 4. The Bioshader experiment [27]

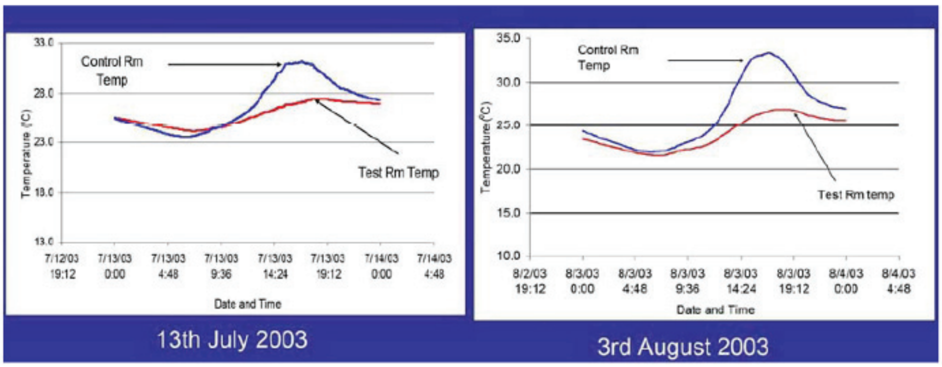

Figure 5. Experiment "Bioshader." distribution of temperatures [27]

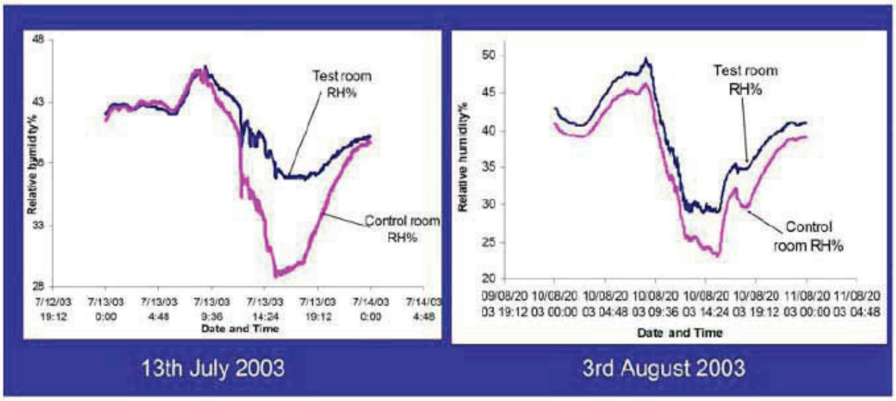

Figure 6. Experiment "Bioshader." Distribution of relative humidity [27]

In an experimental investigation of the effect of shading buildings walls with plants, it is suggested that more thermal energy flows into the non-shaded walls due to direct exposure to the sun and resulted in higher surface wall temperature. The energy absorbed will advance into the inner wall surfaces, resulting in elevation of the interior temperature. Consequently, when an air conditioning system is used to cool the room, more energy will be consumed [29].

3.3 Evaporative Cooling

In tropical climate, the cooling effect of plants was confirmed by measuring the temperature atmosphere at different altitudes. The maximum difference in temperature was 4.2 ° C. From this study it follows that the cooling effect is limited by the distance (height) [30].
Regarding the performance of vegetated facades, these require maintenance, but offer similar shadow effects that other systems a plus evaporative cooling and beauty [31].
The project of the Institute of Physics of the Humboldt University of Berlin, Adlershof, combining management of rain water and energy savings with natural conditioning through walls vegetated with technical and conditioning. Both the shadow created by plants as the effect of cooling influences the energy consumption of the building, becoming a true air conditioning passive (Figure 7) [32].

The evaporative cooling to the blades and the soil depends on plant type and exposure. The measures project in Berlin-Adlershof, a test meter with 40 cm depth of soil washed down artificially using rainwater stored previously, with two plants Wisteria, evapo-transpiration are annually about 2 liters. This is 2 x 2670 kJ, which represent an effect of energy around 1.483 kWh cooling load per year [32].

Thus, the evaporation of water is the most inexpensive and effective to cool a building. a meter cubic consumes 680 kWh of water evaporated. Vegetating facades of a building provides result in significant additional evapo-transpiration, which represents a high potential for reducing temperatures of the surfaces of buildings and improving the environment inside and around the building.

The evapo-transpiration is the most important environmental benefit of vegetated roofs and facades in urban areas. This influences the urban hydrology, in reducing the temperature of the surfaces and improves the management of runoff rainwater [26].

Moreover, the experiment "Bioshader" conducted at the University of Brighton, was compared an office with the window covered with vegetation like no other cover, and verifies that the humidity level in the office with Bioshader was always higher than the office without this mechanism, demonstrating that the use of vegetation provides a lot of moisture environmental bonus to dry indoor environment [27].

Figure 5. Institute of Physics, University of Humboldt [32]

Finally, the cooling effect due to evapo-transpiration of plants (trees), resulting in decrease in temperature around the building. The water evaporated by trees can increase the absolute humidity up to 1-2 kg of water per m3 of dry air [29].

3.4 Variation of the effect of wind on the building

The degree of wind protection offered by a green barrier depends primarily on the speed and wind direction, the dimensions of the barrier (height, width and length), density and penetrability of the material that is finally on its way. In considering the use of vegetation as a modifier of the effect of wind on buildings, space must be careful not to obstruct the ventilation in summer, and not encourage drafts in the winter [33].

One of the ways in which green facades can increase the energy efficiency of a building by the wind. In winter, the cold wind plays a crucial role in reducing the temperature inside buildings. Even in airtight buildings, the wind reduces the effectiveness of regular insulation. Protecting the building of wind cold, the heating demand can be reduced by 25% [34].

However, It should be taken into account the ability to reduce the wind speed that affect the facades of the building and the climate change that occurs in the space between the screen and vegetable the facade of the building. This effect can offset the negative effect of the screens vegetated in winter because of the shadow effect [22].

It is observed that is becoming more emphasis on the positive aspects of plant buildings than the negative, although the latter may become more conditions while making a decision project.

Available data reflect cases widely scattered, both in terms of building systems and plant species used, such as geographic location, with different climate, which hinders the comparison and interpretation.

4. Case Study: the vertically integrated green house

The following case study is focusing on a façade greening system was developed by ARUP Engineers in the United States of America as a new potential for building integrated agriculture, the main challenge here was to reduce energy use in buildings which also integrate the idea of façade farming and food production in addition to energy savings and thermal comfort in buildings, we used this case study in particular, from what is well known that vegetation has a great effect on urban heat island mitigation and the diversity in benefits that are produced by this system not only environmental benefits but also food production potentials.

4.1 System description

The Facade Farm integrates hydroponic food production into a double skin facade for installation on new high-rise buildings and as a retrofit on existing buildings with adequate solar exposure.

The Vertically Integrated Greenhouse (VIG) is a patented system, consisting of plants grown on trays suspended by a simple cable system, and all planting and harvesting occurs at the bottom level. Systems modules can rise as high as 10 or 20 stories each.

Vertical facades at northern latitudes admit a fairly even distribution of sunlight throughout the year. During the winter, produce prices peak and conventional produce either has to travel great distances or is grown hydroponically in leaky greenhouses with substantial energy requirements. In contrast, a well designed vertical greenhouse integrated with the energy management system of a building, can be energy positive.[35]

4.2 Vertically Integrated Greenhouse (VIG)

The VIG is structured in modules that are 40 m high. Crops are cultivated in innovative plant cable lift (PCL) systems, composed of two wire cables looped around pulleys, driven by a computerized motor on the farming level. Shallow trays of plants, 2.0 m long, are suspended between the cables by swivelling clamps at each end as shown in figure 6.

The PCL design is based on a well-established hydroponic method called nutrient film technique (NFT). A thin film of water runs along the bottom of each tray, delivering nutrients to the roots of leafy plants, before flowing down to the next tray. The solution is recovered at the farming level for reuse. Transpiration is limited to 10% of the flow rate by design.[35]

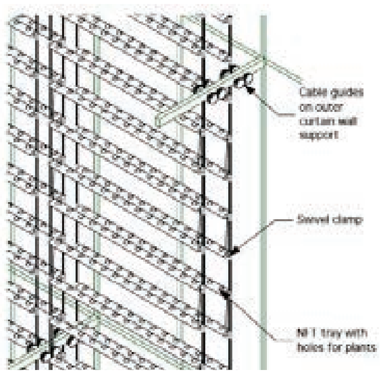

Figure 6. Plant Cable Lift (PC) system [35]

4.3 Environmental features

4.3.1 Adaptative Solar Control System

An adaptive control system alters the angles between rows of plants in the manner of Venetian blind, maximizing solar absorption diurnally and seasonally.

Vertical spacing between trays on the cable can also be varied. Rows will be more tightly spaced in winter, when the sun is lower, resulting in steady yields year-round.

The vertical alignment of the front and back trays can be controlled by a slight turn of the pulleys, similar to adjusting a Venetian blind as shown in figure 7. This feature allows the VIG to track solar elevation in real time throughout the day and year, optimizing light capture. Occupants can see out of the building through the 'slats' formed by the dual row of plant trays.[35]

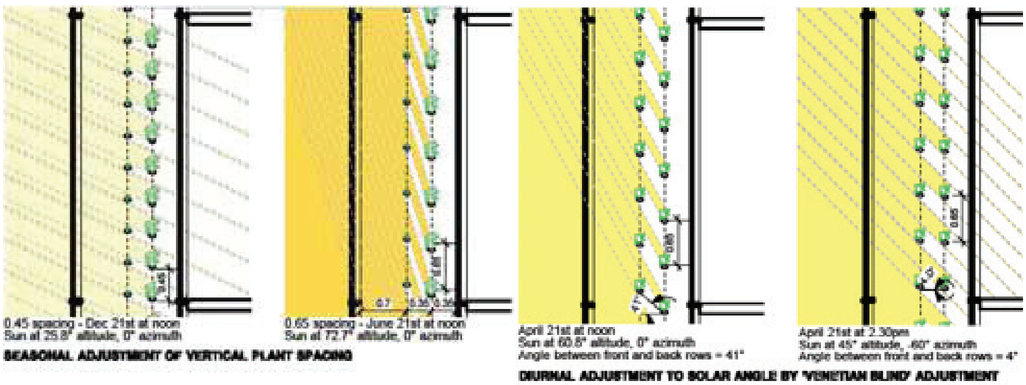

Figure 7. VIG solar control system[35]

4.3.2 Integration with HVAC System

The facade farm provides the building designer with an additional tool for managing energy demand and occupant comfort, through integration with the building's HVAC system. A wide number of potential operating modes exist, but two of the most significant are illustrated.

In winter, the VIG is an effective solar capture device, warming and insulating the glazed facade of the building. On winter nights, exhaust air from the building can be ducted to the VIG to maintain plant temperatures as shown in figure 8.

In summer, the VIG shades the interior of the building, and provides a source of fresh air to occupants with opening windows. The VIG reduces solar heat gain by absorbing energy as latent heat, through transpiration. The VIG also mitigates the urban heat island effect like a green roof [35].

The integrated VIG / building system is complex but has a host of benefits which have only begun to analyze and quantify, including carbon dioxide / oxygen transfer and cleaning of the building air, possibly allowing lower ventilation rates, it has also been applied as a part of a design proposal for two different projects in a different climatic zone which will be discussed as follows.

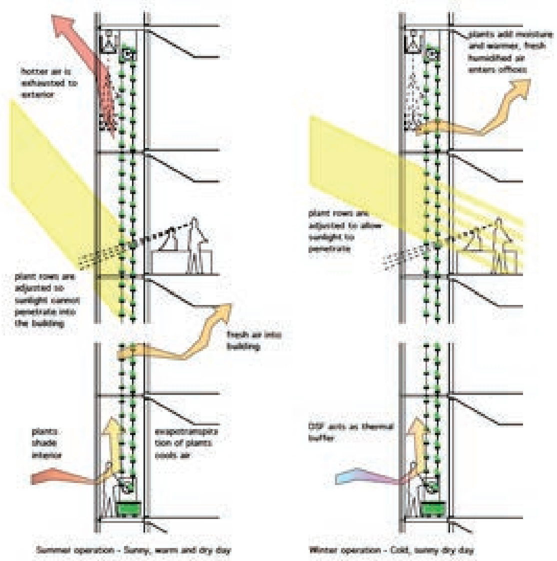

Figure.8 Interaction between VIG system and HVAC system during summer and winter

A. Bronx High School of Science

As part of a proposal to make this high school carbon neutral and energy positive, it has been proposed adding a large facade farm and enclosing the outdoor entry plaza into an all season student lounge area. The area of facade farm is adequate to supply all the students' recommended vegetable intake as shown in (figure 8 and figure 9).

Figure.8 New enclosed entry with facade farm to right and openings to horizontal rooftop greenhouse above.[36]

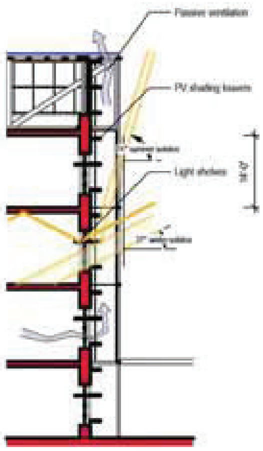

Figure.9 Section through proposed double skin facade at Bronx High School of Science. A facade farm is proposed for the southern facades.[36]

B. Green Market, Abu Dhabi

Green Market is a food market hall that grows its own food. The concept of the structure is to utilize solar energy as efficiently and completely as possible to grow crops, while providing shade, shelter, lighting, ventilation, and cooling to an enclosed space that is dedicated to other uses. Hydroponic growing trays can be configured horizontally (as in traditional greenhouses), vertically, or at other orientations, and can be stacked in one or two layers. In our building-integrated approach, the growing assembly forms a double skin enclosure for a space (figure 10).[36]

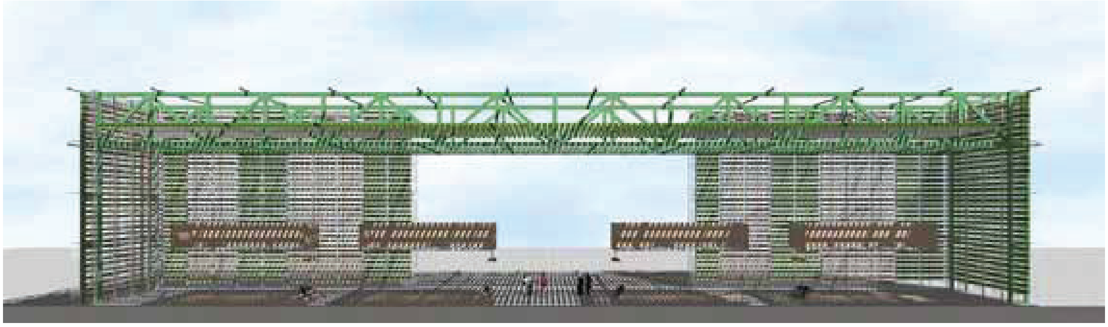

Figure.10 Cross section through green Market [36]

Normally, a glass greenhouse is an inappropriate construction type for occupied space for hot climates. In this application, however, the combination of shading and evaporative cooling provided within the greenhouse layer will provide a reasonable thermal envelope for a conditioned space, and a enough daylight will penetrate through the plants to provide abundant natural light within.[36]

This project synthesizes the potential of passive and active technologies, evaporative and absorption cooling, PV, day lighting with active control via moving growing trays, convective and stack ventilation, large open able areas for seasonal cooling to create a dynamic, exciting, and comfortable environment

Conclusion

- The integration of vegetation architecture in recent years has evolved conceptually from a primarily aesthetic design, gardening, or of artistic expression by the designer or the manifestation of economic power by the promoter, no a "vegetated architecture" in which the vegetation is another element of the building, with specific functions to develop the building as well as its relationship with the environment (energy aspects, acoustic protection material, support of biodiversity, etc.).
- Facade greening can be just as a great contribution to urban air , making this fact is already known, but not yet quantifiable. The collaborating parties endeavoured to keep the vertical greening system simple and robust which could provide the basis for benchmarking so as to encourage research and development of the vertical planting technology. In addition to creating visual comfort and mitigating urban heat island effect, a vertical vegetation cover could lower the temperature of a facade wall and buffered its fluctuation with time, leading to reduced power load in air-conditioning. Time lag in temperature increase reflected that a vegetated cladding could mitigate the potential impact of solar heat that continued to affect the indoor space after sunset. With a vigorous green cover on a facade wall, residents could be benefited by a cooler flat and cheaper electricity bill in addition to the ecological merits of the vertical green panels.
- In general, the use of vegetation, so well designed and managed, can be a useful tool for passive thermal control of buildings with the consequent energy saving. This can occur in four ways, often related, thermal insulation, and the interaction with solar radiation, ie shade, evaporative cooling, and the variation of the wind on the building. The parameters governing these mechanisms are summarized in Table 1.

	Temperature Reduction	Shading and Insulation	Evaporative Cooling	Variation of the wind on the building
Covers	-LAI: leaf area index. -Angle of the foliage. -Substrate: thickness, bulk density, moisture content and color. -Type of insulation of the building.	LAI: leaf area index	Type of plant. Exposure. Climate (dry / humid). Wind speed. Moisture of the substrate.	Foliage density and penetrability. Direction and wind speed.
Facades	Density of foliage. Barrier effect of the wind. Modification of the air space between. Substrate: thickness, bulk density, moisture content and color.*	Density of foliage. Number of layers	Type of plant. Exposure. Climate (dry / humid). Wind speed. Moisture of the substrate	Foliage density and penetrability. Orientation of the facade. Direction and wind speed.

Table1. Parameters that affect the operation of the plant on building facades as a passive energy saving system

- Also, there is an important potential of lowering urban temperatures when the building envelope is covered with vegetation, It can be concluded that the hotter and drier a climate is, the greater the effect of vegetation on urban temperatures. However, it has been pointed out that also humid climates can benefit from green surfaces, especially when both walls and roofs are covered with vegetation.

As conclusion green facades benefits can be divided into two scales: public benefit scale and private benefits scale.

First, green facades public benefits:

Area of Impact	Description	Benefits
Reduce Urban Heat Island Effect	The temperature increase in urban areas caused by the replacement of "natural vegetation with pavements, buildings, and other structures necessary to accommodate growing populations." This results in the conversion of sunlight to heat. Vegetation cools buildings and the surrounding area through the processes of shading, reducing reflected heat, and evapotranspiration.	Promotes natural cooling Processes - Reduces ambient temperature in urban Areas -Breaks vertical air flow which then cools the air as it slows down -Shading surfaces/people
Improved Exterior Air Quality	Elevated temperatures in modern urban environments with increasing numbers of vehicles, air conditioners and	-Captures airborne pollutants and atmospheric deposition on leaf surfaces.

	industrial emissions have led to a rise in nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOCs), carbon monoxide (CO) and particulate matter.	-Filters noxious gases and particulate matter
Aesthetic Improvement	Green walls provide aesthetic variation in an environment in which people carry out their daily activities. Numerous studies have linked the presence of plants to improved human health and mental well being.	-Creates visual interest -Hides / obscures unsightly features -Increases property values -Provides interesting freestanding structural elements, etc.

Second, Green facades private benefits:

Area of Impact	Description	Benefits
Improved Energy Efficiency	Improves thermal insulation capacity through external temperature regulation. The extent of the savings depends on various factors such as climate, distance from sides of buildings, building envelope type, and density of plant coverage. This can impact both the cooling and heating.	- Traps a layer of air within the plant mass - Limits movement of heat through thick vegetation mass. - Reduces ambient temperature via shading and plant processes of evapo-transpiration. - May create a buffer against the wind during the winter months - Interior applications may reduce energy associated with heating and cooling outdoor air for indoor use.
Building Structure Protection	Buildings are exposed to the weathering elements and over time some of the organic construction materials may begin to break down, as a result of contraction and expansion shifts due to freeze-thaw cycles and UV exposure	-Protects exterior finishes from UV radiation, the elements, and temperature Fluctuations that wear down materials. - May benefit the seal or air tightness of doors, windows, and cladding by decreasing the effect of wind pressure.
Improved Indoor Air Quality	For interior projects, green walls are able to filter contaminates that are regularly flushed out of buildings through traditional ventilation systems. The filtration is performed by	- Captures airborne pollutants such as dust and pollen. -Filters noxious gases and VOC's from carpets, furniture and other building elements

	plants, and in the case of bio-filtration, micro-organisms.	
Noise Reduction	The growing media in living wall systems will contribute to a reduction of sound levels that transmit through or reflect from the living wall system. Factors that influence noise reduction include the depth of the growing media, the materials used as structural components of the living wall system, and the overall coverage.	
LEED	Green walls contribute directly to achieving credits, or contribute to earning credits when used with other sustainable building elements.	
Marketing	Improved aesthetics may help to market a project and provide valuable amenity space	

Green walls are a key component of living architecture and they will become increasingly important fixtures in our cities in the years to come. Green wall technologies provide a wide range of options for designers who are interested in using the building envelope to accomplish multiple objectives and to provide new free standing design features on the interior and exterior of buildings.

The Use of plants to alleviate the urban heat island effect and to improve the quality of the surrounding environment is becoming a key design consideration in modern building developments, where facades vegetation is emerging as an element of architectural composition and design to take into account the architecture and urbanism today, given the improved environmental effects which it produces.

Extending the plant or greenery onto the building façade has shown potential in improving air quality and reducing surface temperature in the built environment. The changes of carbon dioxide, carbon monoxide, temperature and relative humidity are found to be significant according to area with and without green walls.

Recommendations

There are several suggestions that are recommended to be implemented in designing for green facades as to improve the ambient and thermal condition.

- Plants and vegetation should be introduced extensively yet carefully on the building façade in the urban area. Selection of plants should consider their natural supporting mechanism and adaptability harsh environment.

- Plants and vegetation implemented on the urban façade should be located accordingly as to receive full sunlight in the highest amount of time possible.

- Maintenance of plants introduced on the vertical plane in the urban area should be considered as the plants will need sufficient watering and also regular trimming to prevent hazards.

- High relative humidity will offset thermal comfort especially when the temperature is high and no wind to overcome heat discomfort. Therefore it is important to consider the location of the green wall in enclosed areas as it will affect the temperature as well as humidity.

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