

## Metal Bio-Façades and Decreasing of Thermal Effect

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### **Abstract**

**Background:** Metal bio-façades has an important impact on thermal behavior of buildings. They consist of green façade net & green façade panel in metal unit (living walls covered by climbing plants). This system is worked on lowering the temperature, good ventilation, CO<sub>2</sub> uptake, reduces the harmful rays. As well as it has environmental sustainability and low cost as compared to electrical conditions. **Objectives:** This study aims to study metal bio-façades adjacent to the wall and away from it, the factors affecting them and the comparison between them & bio-façades adjacent to the wall without metal structure. With taking into account the aesthetic side. **Subjects and Method:** This study was studied many factors which affected on metal bio-façades as materials, environmental changes, plant selection & Thermal performance and collective systems & sustainability. **Practical studies:** The researcher studied types of façades as bio-façades without metal structure, bio-façades with metal structure adjacent to the wall, and bio-façades with metal structure away from the wall 60 cm and compare between them. **Results and discussion:** All bio-façades can control the temperature of the building. The third façades is the best. It has a lot of advantage as extend along to the building, easy installation and assembly & clean, reduces thermal effects, allows movement of air force & formation and distribution of plants in a manner absolute, allows distributed at different levels, easy maintenance., It must finish the walls to maintain the aesthetic appearance, Can be moved from place to place and distance from the wall as a result of the disappearance of the insects inside it is difficult. **Conclusion:** Metal bio-façades are very important for hot areas to improve the weather around buildings. Moreover, they had beautiful design, good health and comfort for human body.

### **KEYWORDS:**

**Metal Bio-Façades - Environmental Sustainability - Climbing Plants -Thermal Performance.**

### **1-INTRODUCTION**

Bio-façades (sometimes referred to as living walls) using climbing plants are technique, deliberately vegetated Façades. There are less established guidelines on their use. Bio-façades contributes not only in reducing the building's thermal loads but also in reducing the effects of the urban heat island in densely built-up areas in a hardly natural environment. The current green systems are built in situ/on site and are very expensive. Hence the need is create pre-vegetated systems which improve the buildings' energy savings. (1) [M. Chanampa 2010]. Bio-façade systems have a history of durability and functionality, compared with other Green façade systems that can make their inclusion cost effective into projects of all scales. By understanding these important considerations and following an advanced template, designers can include sustainability benefits of green façades into the building and site.

Green façades are an important component of

buildings; they separate and provide distinction between internal spaces, improve comfort, health and safety, and enable more effective space utilization. From a building physics perspective heat transfer through partition walls is ignored where temperatures and conditions in the internal spaces on either side of the partition are the same. Life cycle Assessments of building components commonly focus on the interplay between embodied and operational energy. (2) [Reza Brouna 2011]. With the growing energy crisis there is a renewed interest in built with considerations to climatic conditions for keeping the inside building spaces cool in summer and warm in winter, which leads to thermal comfort in buildings without (or with minimum) any expenditure of conventional energy. (3) [Vineet Veer Tyagi 2007]. The designers have promoted the idea of integrating plants into the envelopes of buildings to address both aesthetic and energy concerns. Such vegetated walls traditionally include vines or bushes growing directly along

the façade and wire supports. Mainly as a result of the high energy requirements of air-conditioning equipment used to maintain a comfortable living/working environment and to guarantee indoor air quality. Indeed, these sectors have greater opportunities to moderate energy consumption without reducing the level of comfort and well-being of people. (4) [Hanan M. Taleb June 2014]. Plants are functioning as a solar filter and prevent the adsorption of heat radiation of building materials extensively. Applying green façades is not a new concept; however it has not been approved as an energy saving method for the built environment. (5) [Katia Perini 2011].

Plant layer added to the façade can improve its effective thermal resistance, depending on a range of inputs for wall parameters, climate zones, and plant characteristics (particularly leaf area index). These improvements are especially pronounced in predominantly warm climates with high solar radiation and, to a lesser extent, low wind speeds. The model developed herein can ultimately be used both to assess façade thermal improvements in existing buildings retrofitted with Green façades and to design Green façades for optimal energy efficiency in new construction. The reductions in façade surface temperatures behind vegetation have also been shown to lead to reductions in energy use. For example, Di and Wang measured a 28% reduction in the peak cooling load through a west-facing wall of a building covered with thick ivy on a clear summer day. Despite of previous studies have demonstrated that a variety of Green façade types can reduce cooling loads in some climates and conditions, most previous vegetated wall experimental investigations have been limited to evaluating the effects of a particularly narrow range of plants. Additionally, results are typically valid only for the particular settings of the experiments and typically over a short time period. (6) [Irina Susorova 2013].

For example In Thailand, green façades are also becoming popular landscape design for home and building for the main purpose of decoration rather than energy or environmental solutions. Ministry of energy encourages energy efficient law in terms of overall thermal transfer value and roof thermal transfer value which can be applied by using insulated material, tinted and shading device. There is insufficient information in performance of plants in such area to suggest the application, and few researchers investigated this topic. (7) [Sunakorn P 2007]. Investigated

thermal performance and CO<sub>2</sub> uptake ability of climbing plants façade find in the tropical climate. Recently, Thailand Green Building Council just launched Thai's Rating of Energy and Environmental Sustainability (TREES), adapted from U.S.A.'s LEEDS that gives credits to the use of green roof and wall in Heat Island Mitigation section (8) [Siamese 2009]. The operational energy is currently the main focus of sustainability in building regulations, embodied energy and associated environmental impacts are gaining importance in absolute and percentage terms, as operational energy consumption is reduced. (9) [Vukotic L 2010]. The temperature causes an increase of the cooling energy use (air-conditioning machines) and accelerates the formation of urban smoke, so these unpleasant conditions should be moderated before affecting the health of human beings. (10) [Alexadri, E 2008]. The biological activities of the foliage may lower the indoor-outdoor air temperature and save cooling energy use in buildings. Consequently, green covering becomes the only promising and stabilizing choice. (11) [Kumar. R; Kaushik 2005]. Some of them are based on hydroponic cropping systems, such as the living walls designed by the French botanist Patrick Blanc They use a support structure providing an inorganic substrate into which the plants are inserted and they can be classified as passive or active systems. Active systems are designed with ventilators which force an air flow through the substrate and plant rooting system. Therefore, the air is filtered and purified in a process known as bio-filtration. (12) [A. Franco 2012]. Bio-façades are created by vines and climbing plants that are rooted in soil or containers, growing up wards or cascading down, and require a structure to maintain their position, develop growth, and survive through seasonal exposures. As shown in Figure (1), green roof systems constitute a vegetation layer, growing medium layer, water retention layer, filter layer, drainage layer, and root barrier. . (13) [Bianchini and Hewage 2012].

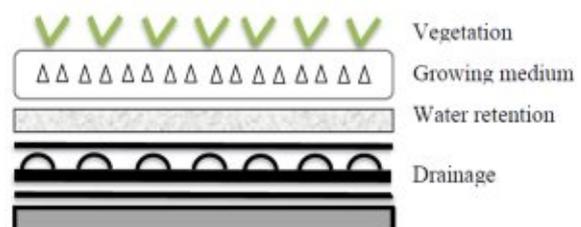


Figure (1) the sections of green roof layers  
Source: (13) [Bianchini and Hewage 2012].

Living walls are sometimes called green walls, vertical gardens, or vertical greenery. Generally, living walls feature ivy and vines, tropical plants living walls or green walls are self sufficient vertical gardens that are attached to the exterior or interior of a building Figure (2). They differ from green façades (e.g. ivy walls) in that the plants root in a structural support which is fastened to the wall itself. The plants receive water and nutrients from within the vertical support instead of from the ground for interior walls. (14) (Haibo Feng, 2008).



Figure (2) Living walls, Source: (14) (Haibo Feng, 2008)

## **2-. SUBJECTS & METHODS**

Many metal bio-façades in different areas were being study in some factors as materials, environmental changes, plant selection & Thermal performance and collective systems & sustainability.

### **Materials:**

Metal bio-façades are a composite structure of steel because it is intrinsically sustainable: It can be recycled repeatedly without any loss in quality. In comparison carbon based organic compounds. (15) [A North American Aluminum Industry Sustainability Report: 2011]. Metal bio-façades structural has evolved into a viable design component that can provide multiple benefits and aesthetic value to a wide variety of building types. Metals are well suited to sustainable development goals. They are not biodegradable and have virtually an unlimited lifespan and the potential for unlimited recyclability. Thus metals can be considered as renewable materials. (16) [Milan Porhinčák 2013]. And using PVC pipe used for wetting had holes separated; leaving holes each grid of the substrate to obtain a homogeneous wet pattern. It was inserted between the layers of each substrate sample with the holes directed vertically. (17) [Franco 2011].

### **Environmental Changes:**

This system works as cover and can be used as a façade. It is an outer envelope with a different bioclimatic function and appearance according to

the vegetal species selected, depending on the orientation of the building. The bio-façade systems create suitable environmental in building, Cooling in summer, warming in winter and decrease radiation in it.

### **Plant selection:**

Plants were used in these facades Blue trumpet vine, Ivy gourd (*Coccinia grandis*) and Mexican creeper (*Antigonon leptopus*). It was found that Blue trumpet vine grew very fast and gave a consistent density and full leave coverage through minimum pruning. (18) [Garde F. 2013]. Attached to this metal bio-façade frame is the drip irrigation system, this —water supply and power supply for an automatic drip irrigation system should be connected (at the top of the wall or for individual panels, depending on the system). A standard fertilizer loop is recommended for the injection of liquid nutrients for the plants.

### **Collective Systems & Sustainability:**

Metal bio-façade design offers an innovative characteristic consisting of the incorporation of a continuous plant irrigation system. The whole system is hung from a structure on an exterior wall: a metallic framed panel with creeper vegetal species moves through horizontal guides. The panel has a metallic plant container where the plant grows and a continuous gutter is placed underneath. The water inside the gutter never has contact with the substrate. Both are connected by porous wicks, keeping the substrate wet but not flooded. The creeper plant has roots inside the plastic cells filled with substrate. These plastic cells are wrapped in felt. An important part of the water can be recyclable. The substrate must be neutral enough for the plant growth. In order to prevent excessive dryness and to retain water in the extended summer periods elements are included in the substrate. The kind of creeper plant species varies with the climate conditions where this system is applied and its orientation. After considering several deciduous creeper species for the specific case of Madrid, the ones chosen have:

- Short root development. This condition is directly related to the size of the plant pot where the roots are in. Thus, to achieve a minimum substrate thickness (about 10 cm) this element needs to have a depth of 25 cm. These minimum dimensions also ensure sufficient root protection against direct solar radiation.
- Growth control of a defined volume. Having lesser maintenance in the metal system is an important value in social housing. Therefore, it is

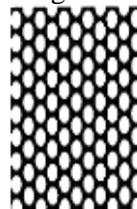
important that the creeper species do not require pruning or additional uncomfortable work. It is necessary to guarantee a maximum development capacity of the green cover's plant species selected. Based on these criteria, it must use species such as the climbing hydrangea. In north exposure deciduous species are not appropriate, in these cases perennials such as small ivy leaves (*Hedera helix*). In addition to incorporating vegetation of easy implementation and quick replacement, this system allows a better controlled germination in nursery. Some advantages of this technique are that vertical gardens do not consume urban surface and need little maintenance work. Moreover, these green-inputs turn conventional windows into fragrant or productive ones. Depending on the creeper type and façade openings they may become domestic vegetable gardens with particular vegetal species.

The plants are inserted through a horizontal opening into a kind of pocket formed between the layers of fiber. These substrates are a porous medium that must allow plant development and enhance epiphyte growth, while also allowing air and water to flow through them. The following substrates were tested: - PR: Comprising three layers, the external and internal ones made of an insect mesh and polyester fiber between them. (19) [Wang Z, Zhang JS 2011] Wall mounted, modular three-dimensional panels, with standoff brackets, provide access to keep plants off the wall, Oakland, CA. The walls consist of a metal frame, PVC interior frame, a cloth layer made of polyamide, PVC -pipe drip irrigation system and supplemental lighting setup. The metal frame is the first part of the construction. This layer, made of metal which is coated with water proofer, is attached to the concrete wall with screws. For the design method this frame work is placed on the outside of the newly designed return piping. (20) [ASHRAE 2009]. This metal frame provides, — an air layer [between the plant roots and wall] that acts as a very efficient thermal and phonic isolation system. Riveted into this frame is PVC interior frame. Although porous to allow air flow, this frame provides stability for the entire structure and support for the plants. (21) [Gates D.M. 2003].

### **3- PRACTICAL STUDIES**

The study compares between bio-façades without metal structure, Bio-façades with metal structure adjacent to the wall, and Bio-façades with metal structure away from the wall 60 cm. The façade panel in steel unit includes thermal insulation, a

galvanized steel structure and metallic mesh. The galvanized is protected from corrosive effects against extreme climate and corrosion figure (3). The joints among faces are done with high resistance wire staples using cable and wire-rope net systems. Cables are employed on green façades that are designed to support faster growing climbing plants with denser foliage. Wire-nets are often used to support slower growing plants that need the added support these systems provide at closer intervals. They are more flexible and provide a greater degree of design applications than cables. Both systems use high tensile steel cables, anchors and supplementary equipment. Various sizes and patterns can be accommodated as flexible vertical and horizontal wire-ropes are connected through cross clamps.



A network of metal to strengthen



Transparent material carriers of water



Part of metal mesh for metal containers of plastic tubes, plastic textile fibers, industrial plant ivy or grape.

Figure (3) Source (13) [Bianchini and Hewage 2012]

The second group of structural for green façades is three-dimensional systems that have unique design capabilities. 3D systems consist of sections that have length, width and depth, and are created specifically to enhance the growth and maintenance of green façade plants. 3D units are made from thin gauge steel wire in different ways. One approach uses two wire grids held apart by intermittent wires and welded to a perimeter steel frame for strength in mounting. The wire grids are either woven or welded at various spacing. Another 3D system uses a structural panel with an integral truss that does not require a surrounding frame for mounting or strength. The advantage of 3D systems for façade design is the panel depth that provides additional structure for plant material support and long-term maintenance. Vine-type plants require a host to attach to for vertical growth and support, and use a variety of evolutionary characteristics to attach to the host support. An example would be an Ivy or Wisteria, both of which are tenacious and can do significant damage to a building façade. Some vines are main-stem twine's, and other vines use

tendrils that can twine or curl around another plant or a component of a façade trellis.

Another mechanical plant is leaf hooking, and this involves the leaf pattern and plant strength hooking partially around a host structure until its growth advances to surround the support elements figure (4). Many green façade plants can be vine-like in their vertical growth characteristics, but are actually plants that are woody in nature and are runners and scramblers. This group relies on the structural host to support the plant lying upon or growing through the host, and they tend to be plants with long and leggy extensions, such as Bougainvillea. Within these various descriptions, some plants prefer to grow directly to the top of the support and then take significant time to spread, and others prefer to be spread early and then continue to grow vertically.



Figure (4) Bio-façades on wall.(Climbing plants adjacent wall) source the researcher

Ultimately, the green façade structure design should take into account the growing characteristics of these different plant growth habits. Aerial root plants in close proximity to a building surface will migrate to the building and abandon the façade structure, runners and scramblers may require additional maintenance to establish on a 2D system. (22) [Brown RD & Gillespie TJ 1995]

The wall model is comparing the predicted and measured façade temperatures. Knowledge of the surface temperature reductions between the bare and vegetated façades allowed for estimation of other façade properties, such as a decrease in heat flux through the wall (assuming a constant R-value for the wall itself) and thus the instantaneous effective R-value of the plant layer. Several assumed plant and wall parameters were used in conjunction with the measured weather data (air temperature, solar radiation, relative humidity, and wind speed at the façade) as inputs in the model. Due to equipment limitations, the experiment measured only the global horizontal solar radiation, which was

adjusted by modeling solar radiation on both a horizontal and a vertical surface using solar geometry. Broadly speaking the effect is achieved in a number of ways as follows:

Climbing plants growing directly against the wall or trained against a trellis - A trellis of steel wires or mesh is used as a support for climbing plants, which can be rooted into the ground or substrate-filled planters, which can be supported at height if required. Such systems are usually irrigated but can survive without irrigation if rooted into the ground

Hydroponic Green façades - These systems are usually constructed from plastic mesh, geotextiles, fabrics or horticultural mineral wool or combinations of materials fixed to supporting frames or boards. Plants grow without substrate or soil and rely of irrigation and nutrients added to irrigation water modular Green façades - Usually manufactured from purpose made HDPE modules containing cells which are filled with growing medium and planted. Modules are fixed to a wall or frame and may be combined to cover large areas. The system operates based on the evaporation of water from the substrate of the active living wall, producing a significant decrease in temperature and an increase in the humidity of the air. The change of phase from liquid to vapor requires energy extracted from the hot air from the outside or from warmer indoor air. The result is a cooling effect and an increase in the air moisture content. In thermodynamics the process is termed adiabatic, and the enthalpy remains virtually constant. (20) [Ashrae 2009]

In order to improve the vegetation growth, its roots must be inside a substrate with essential nutrients. To do that we use a plastic cell called "Atlantis" (made of recyclable polypropylene) that has holes which allow the introduction of humus, polymers, potassium salts and vermiculite, which is placed inside the Gabion. The cell is rectangular, perforated horizontally and vertically. Polymers or hydro-gels are elements that increase the substrate capacity to retain water and reduce the need for irrigation allowing the use of low quality water. Water, fertilizers and stimulators are absorbed and stored in the root zone. The dose to cover the plants should be between 100 to 150 g/m<sup>2</sup>. The substrate is vital for the sustenance of the vegetation, being the source of food and shelter of the roots. Another key element is drip irrigation which entails applying small amounts of water in localized areas with a variable

number of emission points. Once constructed as a monolithic piece the gabion is placed on a metal grid that acts as the support element where the modules are established.



Figure (5) some types of bio-façades  
Source: (16) [Milan Porhinčák 2013]

The thermal insulation (extruded polystyrene) applied is selected according to the climatic zone, has a correct porosity for vapor diffusion and it is sold in a modular form. This kind of insulation is located between the metal structures to satisfy the transmittance required by the Spanish legislation. It has to be rustproof due to the contact with moisture generated by the plants and the irrigation itself. Moisture reduces the ability to limit the flow of energy between inside and outside. This element improves the ventilated façade insulation and the thermal performance of the walls by reducing the heat bridges as well as problems related condensations. The link of the gabions to the structure is accomplished by angular anchorages leaving an air gap between the interior wall and the external cladding (gabion). These anchors have to be able to withstand wind forces and impacts, and they must be galvanized in order to prevent corrosive effects and allow modules substitutions if necessary.

Blue trumpet vine has big round soft leaves that move easily by wind flow. Though it covers well but the maximum layers will not be more than 4-5. The smaller and denser leaves may provide better thermal effect by increasing surface for evapotranspiration. This experiment was carried out in the beginning of summer. Though the thermal performance increased, indoor temperature in the daytime had not reached comfort zone (22 °C - 28 °C). The application of bio-façade can better be applied to pre-cooling of the fresh air intake before air condition system. Not only energy efficient purpose, but it can also enhance air quality by absorbing CO<sub>2</sub> and dust particles. Leaves In tropical climate, air temperature affected by leaves are always lower than ambient air, while in temperate climate, it can be higher than ambient air and can perform like insulation in winter. Relative humidity

increase from plants occurred only in daytime while relative humidity of ambient air is the lowest. The increase of relative humidity is not significant (maximum of 6.8 %) give minor effect to thermal comfort. At night while relative humidity of outdoor air is the highest, the normal room had higher relative humidity than test room with leaves protected.

- Green façade walls cool the exterior of buildings by as much as 25 degrees F.
- Green façade walls reduce indoor air temperatures by reducing the heat flux into the building's exterior walls and indoor space.

#### **4- RESULTS & DISCUSSIONS:**

From previous study, it is clear that:-

- 1- Metal bio-façade away from wall 60 cm is the best type compared with metal bio-façade on wall.
- 2- Metal bio-façade on wall is better than bio-façade.
- 3- General all bio-façade can control the temperature of the building through bio-façade types and the factors affecting it as following:-

The study shows the comparison between all bio-façades as following table (1). Bio-façades are an investment which provides a significant number of social, environmental and economic benefits that are both public and private in nature:-

- 4- • Increased energy efficiency (from cooling in the summer and warming the winter).
- 5- • Sequesters carbon
- 6- • Additional amenity space
- 7- • Air cleaning
- 8- • Biodiversity preservation and habitat creation.
- 9- • Aesthetic benefits

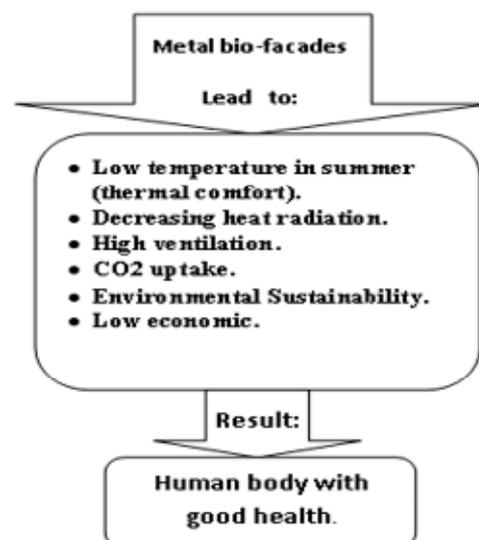


TABLE (1) The Comparison between Three Types of Bio-façades

Elements	Bio-façades without metal structure	Bio-façades with metal structure adjacent to the wall	Bio-façades with metal structure away from the wall 60 cm
<b>Allow to rise.</b>	Limited rise	Extend along to the building	Extend along to the building
<b>Ease of installation and assembly.</b>	There is no structure	Easy installation and assembly	Easy installation and assembly
<b>Cleaning process.</b>	Difficult to clean	Difficult to clean	Easy to clean
<b>Time the growth of plants.</b>	Needs a very long time	Needs a long time	Growing rapidly
<b>Reducing effect of thermal.</b>	Reduces the thermal impact to some extent	Reduces the thermal impact to some extent	Reduces thermal effects
<b>Allow the movement of the air force.</b>	Prevent the entry into force of the air	Reduces the force of the air	Allows the movement of the air force
<b>Aesthetics.</b>	Takes the form of a fixed	Allows the formation and distribution of plants in a manner	Allows the formation and distribution of plants in a manner absolute
<b>The nature of the plants connected to the land.</b>	The need for contact with the ground	The need for contact with the ground	Allows distributed at different levels
<b>Regular maintenance.</b>	Difficult	Difficult	Easy
<b>Influence on the wall.</b>	Walls are not always finishing.	Don't link to the nature of finishing walls.	It must finish the walls to maintain the aesthetic appearance.
<b>Moving.</b>	Cannot be moved.	Cannot be moved.	Can be moved from place to place.
<b>The disappearance of insects.</b>	Allow the disappearance of insects.	Allow the disappearance of insects.	Distance from the wall as a result of the disappearance of the insects inside it is difficult.
<b>Means of irrigation and plant nutrition.</b>	Linked to the land and be limited.	Metal structure allows the transfer of water distribution pipes on all surface structure.	Metal structure allows the transfer of water distribution pipes on all surface structure.

The Compression demonstrated that a plant layer on a façade can effectively reduce exterior surface temperatures on building façades, daily temperature fluctuations indoors, exterior wall temperature gradients, and, as a result, heat flux through the exterior wall, particularly on days with high isolation. The analysis showed that plant layers with dense foliage (high leaf area indices) and with leaves parallel to the wall (high attenuation coefficients) are likely the most successful in reducing façade surface temperatures and heat flux through façades. On hot sunny days, a plant layer on a brick façade was estimated to reduce its exterior surface temperature, depending primarily on wall orientation, leaf area index, and radiation attenuation Green façade energy calculations depend on design, the metal wall orientation, sun angle, wind flow and microclimate around the

building

This study is expected increase in demand for cooling in buildings. Hence, the employment of additional evaporative cooling systems will be even more necessary to reduce the thermal load of the building. In this context, the use of urban greening systems alone or in combination with conventional air-conditioning systems in buildings may, in addition to providing a high ornamental and environmental value, contribute to reduce energy consumption. The urban greening movement is a response to the loss of green spaces in cities and buildings through the use of many technologies contributing to the goal of urban sustainability. It aims to transform buildings and urban spaces into biotopes, providing many energy and environmental benefits Living walls on façades and inside buildings and the installation of green roofs are

the most innovative urban greening techniques.

The carried out to compare air temperature of a wall with bio-façade and a wall without. Natural ventilation was added to both walls and the thermal performances were compared. It has been found that bio-façade performance increased when wall air velocity was high with covering plants façades from the case with natural ventilation figure (3).

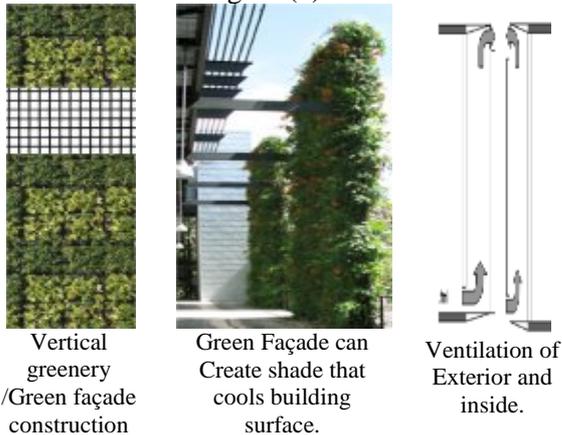


Figure (3)

Source: (13) [Bianchini and Hewage 2012].

The vegetation carries out two particular functions in these systems: Intercepting sunlight before the building gets warm, it is an energy saving instrument that controls solar radiation in the summer as well as avoiding overheating and temperature fluctuations inside the buildings. The sliding panel generates breeze through the windows during the summer. The cool surfaces provided by the leaves can be effective in reducing the energy used for cooling and heating. Besides, the air quality is improved, as a consequence of the photosynthesis process, by providing  $O_2$  and absorbing  $CO_2$ . In addition to the air quality improvement these techniques with vegetation are a microclimate modifier. These industrialized constructive strategies help not only to enhance the sustainability of the buildings but also to diminish the urban pollution. Integrating vegetal species in Architecture has benefits such as increase of the humidity, control of the solar radiation, decrease of the air temperature, thermal insulation, aesthetical effects, and psychological well-being. Vegetal species work as a skin protection that reduces deterioration in relation with the façades exposed to extreme climate conditions. As a sustainable solution, every component is recyclable or recycled (aluminum, polyethylene). Other environmental benefits include the improvement of air quality. Oxygen production

improvement of the working environment, reduce stress, absenteeism and enhancing acoustic comfort. They also increase biodiversity in the urban environment and contribute to the reduction of the urban heat island effect. The required considerations are for successful green façade installations. Most Green façades are designed using plant materials. The heat absorbed by the façade exterior surface is not necessarily transferred to the interior surface immediately. It is stored in the wall material and later is released into the indoor space with a time delay, which attenuates the heat flux through the wall. This thermal lag effect depends on the heat capacity of the wall material; for example, brick and concrete can store heat up to 6 h, depending on wall thickness, density, and specific heat capacity.

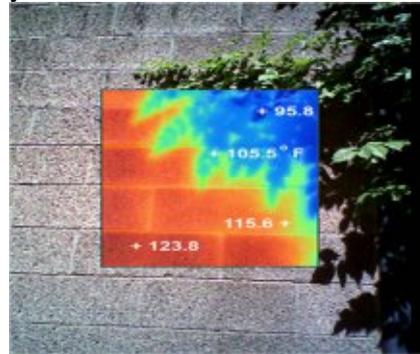


Figure (4) Infrared photography demonstrating temperatures on the building surface.

Source: (21) [Gates D.M 2003]

Leaf temperature a typical broad leaf is often represented as a flat thin plate that has radiation figure (4) and convective heat exchange with the surrounding atmosphere and evaporates water from its surface (conductive heat transfer is insignificant) Leaf surface temperature is a complex function of multiple factors, such as solar radiation, air humidity, wind speed, and internal leaf carbon dioxide concentration. (21) [Gates D.M 2003]. The Sustainable Sites Initiative specifically advocates for the use of shade trellises and green façades increasing shading. The integration of shading benefits of green façade walls into a building program influences site development, and the added benefits from green facade's to other elements of green infrastructure can be developed. As urban centers grow, ecosystem services become altered and even replaced. According to the EPA, plants and vegetation lower surface and air temperatures by providing shade, and through evapotranspiration. Shaded surfaces, for example, may be 11–25°C cooler than the peak

temperatures of unshaded materials. Plants absorb water through their roots and emit it through their leaves.

Bio- façades are requiring the care and maintenance of a garden with irrigation, drainage control and nutrients delivered and organized vertically. As any technology in its infancy, these systems have had great difficulty with consistent survivability of plant material over large surfaces for an extended period of time. Costs for producing a living wall are easily three to five times the cost of a green façade installation, and living walls have very significant ongoing maintenance and plant replacement operating costs. The application problems always come with cost of construction and maintenance. It is widely known that façade greening can enhance thermal comfort for indoor environment as well as outdoor by shading walls from solar radiation, reflecting and transmitting only a small amount of solar radiation into walls.. (22) [Brown RD, Gillespie TJ 1995]. By implementing control strategies the energy efficiency of all façade systems is significantly improved. For the naturally ventilated bio- façade, controlled openings are beneficial and a simple open close strategy is sufficient.

But the planting can result in problems of drying and burned foliage due to excessive moisture loss (i.e. forced transpiration). This is mainly a problem during the winter heating season when hot, dry, blowing air comes in direct contact with the foliage of the plant. On site construction equipment: Requiring use a range of manual and power operated tools and equipment such as saws, compressors, drills, welders and etc. In this paper since only the partition wall systems are investigated, the values of embodied energy of related equipment is estimated to be marginal, and therefore this value is not included. Manufacturing: Material embodied energy is related to the acquisition of raw materials, their processing and manufacturing. Interestingly Figure 2 shows that the three partition wall systems have completely different embodied energy during this stage, with the HCB option having 91.83 MJ/m<sup>2</sup>, less than the clay brick wall with 191.22 MJ/m<sup>2</sup> and more than.

Safety and Serviceability: The difficulty in managing a vertical garden is the safety and serviceability of the plantings. Specifically designed lift systems or ladder systems must be included to facilitate routine maintenance. Maintenance considerations: Embodied energy and air emissions associated with the

maintenance of building activities such as refurbishment, repainting etc. were computed based on the life span of materials and followed the same procedure as that used for the manufacture of building materials. Maintenance for a majority of bio- façade installations is either too infrequent or more appropriately, non-existent. Bio-façade systems are one-half static system and one half living system. Designers of bio- façade systems can play a critical role in educating the user regarding appropriate design of a system to make it easier for typical horticultural maintenance practices that will ensure the long term success of the total system. Additional attention needs to be given to installations that will require maintenance on multiple story projects. A comprehensive design program will specifically address how maintenance professionals will access or gain access to plant materials, irrigation components and soils requiring nutrient delivery. Access for maintenance is critical and consideration needs to be given to where ladders, scissor lifts and even bucket trucks can be located in order for the proper horticultural maintenance of green façades.

Conscious design decisions also need to address the clearance between the wall and the back side of the green façade system. Systems that are held within six inches or closer to structure will need to have specific plant material that twines in order to prevent attachment of the plants to the building façade. A clearance of 18 inches from the wall is recommended for wall-mounted installations; this will allow sufficient space to prune plant material and provide access behind the system. Design decisions can and will affect the maintenance and long term success of the green façade system. When making appropriate plant selection, please note that a small number of vines have been identified regionally as invasive and therefore should be avoided, especially if the installation is adjacent to undeveloped, open space or natural areas.

Lifecycle and sustainability considerations: How long do we expect these systems to last? Experience has shown that well maintained systems, both physically and horticultural. Product manufacturers that have completed a Life Cycle Assessment (LCA) are using many years as a baseline for façade lifecycle and plant material can last for centuries given ideal conditions. Project design and system selection should take into account an extended lifecycle time frame and consideration should be given to

the possibilities of landscape renovations and alterations.

Order to achieve the bio-façade is multidisciplinary and requires the cooperation, understanding and the applied skills of architects, landscape architects, engineers and horticulturalists. The integration of cross-disciplinary design is the basis for success in identifying and solving the unrealized opportunities between building and site development. In this paper the results from a series of Life Cycle Assessments of primary metal production processes for steel have been used to examine how metals may contribute to society's transition to sustainable development.



Figure (5) Wall mounted, modular three-dimensional panels, with standoff brackets, provide access to keep plants off the wall. Source: (15) [A North American Aluminum Industry Sustainability Report 2011].

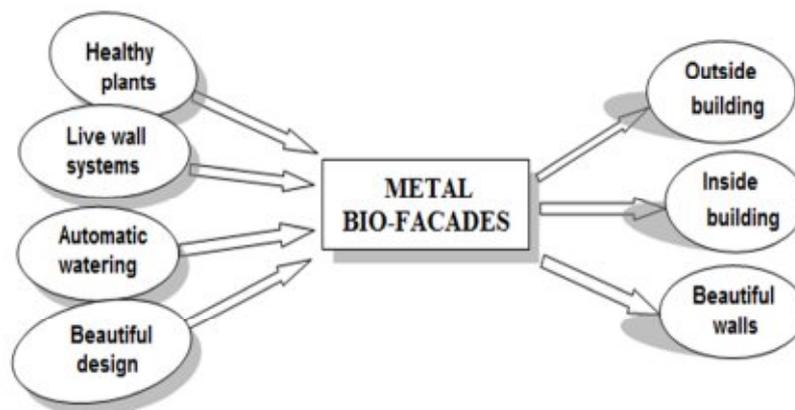


Figure (6) Source: the researcher

## 5. CONCLUSION:

Metal bio-façades are very important for hot areas to improve the weather around buildings. By comparing between bio-façades, metal bio-façades on wall and metal bio-façades far from wall 60cm, it is clear that the third bio-façades is the best solution. They control in temperature that thermal comfort, decreasing heat radiation High ventilation, CO<sub>2</sub> uptake, Environmental Sustainability, Low economic.

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