Considerations for Advanced Green Facade Design

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Over the past two decades, green facade technology has evolved into a viable design component that can provide multiple benefits and aesthetic value to a wide variety of project types. This in depth discussion deals with the required considerations for successful green facade installations and projects. Green facade systems have a history of durability and functionality, compared with other green wall 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 facades into the building and site. This paper draws on 18 years of collected knowledge, observation, implementation, and experimentation to describe successful strategies that include system selection, design, plant selection, maintenance and client/owner education. For a basic overview of green walls: *Introduction to Green Walls: Technology, Benefits, and Design* (2008), see this link.

ABOUT GREEN WALLS

To design a successful green facade, there must be a clear understanding of the concepts for creating "green walls". The terminology "green wall" describes a vegetated vertical surface and is an inclusive description of two very distinct concepts. Green facades are created by vines and climbing plants that are rooted in soil or containers, growing upwards or cascading down, and require a structure to maintain their position, develop growth, and survive through seasonal exposures. Green facades are easily scalable and rely on the adaptable characteristics of a broad range of plant species. The term "Living Wall" refers to a newly developed technology that relies on a prefabricated modular or monolithic vertical soil or hydroponic system to root plants on a vertical plane. This new concept of living walls can also be thought of as a vertical garden, 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 facade installation, and living walls have very significant ongoing maintenance and plant replacement operating costs.

A wall mounted, modular, three-dimensional, green facade system, Chicago, IL

This paper focuses entirely on designing and specifying green facades.

CHALLENGES AND OPPORTUNITIES

The greening and preservation of urban space has become an important consideration for cities, municipalities and communities, mostly based on the pressure from increased population density on existing infrastructure. As impervious surface area and building sizes increase to meet demand, water quality, storm water management and Urban Heat Island (UHI) effect have become primary challenges for designers and policy makers. Seattle and Chicago, as well as the County of San Mateo, California have implemented design recommendations for the integration of organic, living systems within the built environment, such as green roofs, green walls and vegetated swales, that can act as a bridge to alleviate the increased demands placed on existing infrastructure. This concept, also known as Living Architecture, promotes biomass to cool urban areas, support the growth of tree canopies to improve air quality and rain gardens to mitigate stormwater runoff. The Living Architecture concept 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.

A freestanding green facade integrated into a green street demonstration project, Chicago, IL

An east facing, three story, green facade attached to an urban parking structure, Seattle, WA

Urbanization has created opportunities and challenges in the built environment with the primary goal to increase the energy efficiency of buildings. Building energy consumption and the need for energy efficiency have largely been responsible for the creation of the USGBC LEED® green building program, and is currently a net zero initiative for all new and retrofit GSA construction by 2030. Buildings account for over 40 percent of all energy use in the U.S. and in 2006, Architecture 2030 issued the 2030 Challenge; it asks the global architecture and building community to adopt the target of a 'carbon neutral' state by 2030. The 2030 Challenge also recognizes that buildings are the major source of global demand for energy and materials that produce by-product greenhouse gases (GHG). Slowing, and then reversing the growth rate of GHG emissions is the key to addressing climate change and keeping the average global temperature below 2°C (above pre-industrial levels). These targets may be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power and/or purchasing (20% maximum) renewable energy.[1]

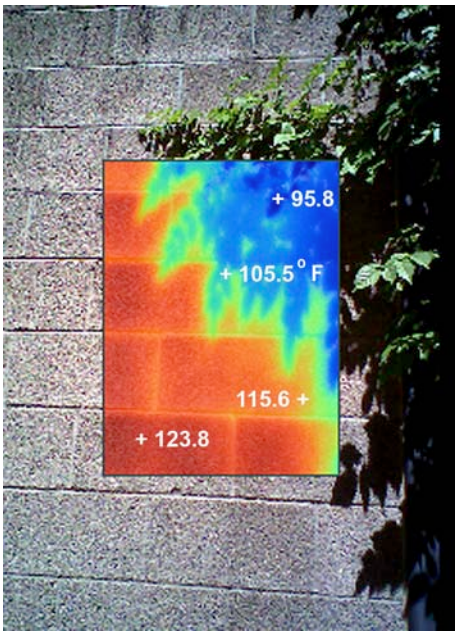
The implementation of green walls, green facade walls in particular, can help to accomplish the building energy efficiency targets proposed by The 2030 Challenge. Recent research conducted by David Tilley, PhD, at the University of Maryland has concluded that by incorporating a green facade wall on southern and western elevations, existing building

envelope R values for typical residential construction can be substantially increased during the cooling period of summer months, correspondingly reducing energy demand for cooling. Additional conclusions of this three year study found in common building construction practices:

- Green facade walls cool the exterior of buildings by as much as 25 degrees F.
- Green facade walls reduce indoor air temperatures by reducing the heat flux into the building's exterior walls and indoor space.
- Maintaining healthy, vigorous plants on a green facade wall can reduce exterior wall temperatures, thereby saving money on cooling costs.
- Green facade walls can improve the energy balance of buildings through reflectance and transpiration.

These conclusions are based on the shading benefits from the vegetation component of green facade walls and these benefits can help designers achieve desired energy reduction targets. The integration of shading benefits of green facade walls into a building program influences site development, and the added benefits from green walls to other elements of green infrastructure can be developed.

ABOUT URBAN HEAT ISLAND



Infrared photography demonstrating temperatures on the building surface, Tempe, AZ

As urban centers grow, ecosystem services become altered and even replaced. Roofs and pavement comprise over 60% of surface area in some cities.[2] These changes cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures in the landscape known as the Urban Heat Island (UHI). Urban Heat Island effects lead to increased air conditioning costs, air pollution levels, heat and pollution-related illnesses and even death. Natural, pervious surfaces and vegetation can play an important role in the mitigation of UHI effects. According to the EPA, trees and vegetation lower surface and air temperatures by providing shade, and through evapotranspiration. Shaded surfaces, for example, may be 20–45°F (11–25°C) cooler than the peak temperatures of unshaded materials. Plants absorb water through their roots and emit it through their leaves. This movement of water is called "transpiration." Evaporation, the conversion of water from a liquid to a gas, also occurs from the soil around vegetation and from trees and vegetation as they intercept rainfall on leaves and other surfaces. Together, these processes are referred to as evapotranspiration, which lowers temperatures by using heat from the air to evaporate water. Evapotranspiration, alone or in combination with shading, can help reduce peak summer temperatures by 2–9°F (1–5°C).[2] The Sustainable Sites Initiative (SITES™) specifically advocates for the use of shade trellises and green facades to increase shading. SITES™ is an interdisciplinary partnership led by the American Society of Landscape Architects (ASLA), the Lady Bird Johnson Wildflower Center at The University of Texas at Austin and the United States Botanic Garden to transform land development and management practices through the nation's first voluntary guidelines and rating system for sustainable landscapes, with or without buildings.[3] For a peer reviewed credit list documenting contributions of green facades within SITES™, follow this link.

Additional green building certification programs such as LEED® 2009, recognize the inherent shading benefits of vegetation and also promote the use of native plant material to achieve credits within the scoring system. The utilization of regionally appropriate native plant material is a benefit that dovetails specifically with green facade walls and this flexible combination can play a large role in helping to increase coverage of the vegetated area to maximize point totals and make designed landscapes more layered, biologically diverse and sustainable. In addition to maximizing additional credits within the Sustainable Sites (SS) portion of LEED certification, the incorporation of green facades can contribute within Water Efficiency (WE), Materials and Resources (MR) and Innovation In Design (ID) credit areas. Click here for a comprehensive review of green facade credit contributions to LEED®.

DEVELOPING PROGRAMS

Seattle's Green Factor program has been designed to increase the ecological and aesthetic functions of landscape while providing a high degree of flexibility and incentives for new development. The selected strategies, including green walls, encourage layers of vegetation and increased stormwater infiltration in order to shift the ecological function of the urban landscape toward pre-development conditions.[4] The San Mateo County Sustainable Green Streets and Parking Lot Design Guidebook implements landscape-based stormwater management facilities countywide and has the potential to minimize pollution, stream degradation and localized flooding. The maximum tier of "green streets", Level 5, advocates for the use of green walls to allow for the building, site and street frontage to become one integrated space for stormwater management.[5] A recent study in the United Kingdom has found additional benefits beyond stormwater management for green walls within green streets programming. "A new research study by Professor Thomas Pugh at Lancaster University and other scientists in the UK has found that adding trees, bushes, innovative systems like green walls, or even ivy or other creeping vines, can cut street-level nitrogen dioxide (NO^2) and microscopic particulate matter (PM), two of the worst forms of pollution, by eight times more than previously thought. Many urban streets have high levels of these types of pollution, far exceeding healthy amounts for humans".[6]

There are additional biophilic, aesthetic, restorative and psychological benefits when integrating green facade walls into projects and research has turned into reality with green walls being incorporated into urban health care facilities and healing gardens. In addition, green facade walls are being introduced into wind modeling to evaluate the effects for site and building design. With this adaptable technology, a strong case can be made for the incorporation of green facade walls as a standard building component that can easily be designed into various project types.

Green facades create shaded pedestrian areas and reduce Urban Heat Island effects, Valley Metro Light Rail, Phoenix, AZ

Green facade elements help with stormwater management and improve air quality, YVR Light Rail, Vancouver, B.C.

Green facade systems provide a support for plants that have unique structural characteristics and growing habits. Choosing a green facade system that matches up the living plant component with the spectrum of design considerations is the focus of this section.

TWO-DIMENSIONAL SYSTEMS

Let's look at the two types of structural green facade systems. The first are two-dimensional solutions that consist of vertical cables, horizontal cables, rods, grids, or nets and are made from a variety of materials. Manufacturers have created entire systems of solutions for assembly and attachment to a building facade or vertical plane. 2D cable configurations require being held in tension and the loading of connectors at the attachment points is a critical factor. The design and placement of the connectors is related to the span of the facade and may require specific engineering and structure to ensure performance under increasing loads. Cable systems and their attachment components are most often made from stainless steel that can add to durability and strength, but also increases costs. 2D systems are generally installed in a simple plane, and require additional structure to create shapes, turn a corner or modulate a surface. The attachments for cables are shallow in depth, and unless there are additional support connection methods, the green facade will be close to a building surface. If structure is available, a vertical two dimensional cable facade can be attached at top and bottom but can not be used for a cantilevered configuration. Rigid 2D system components, from materials like steel or wood, are dimensionally larger than flexible 2D system components from materials like cables, rods, cable nets, or woven wire fabrics. A primary consideration for designing with a two dimensional facade system is how the plants inhabit and connect to the facade structure and how the system's design might influence the plant growth and infill of the facade.

Two-dimensional stainless steel cable system with long vertical spans, Dallas, TX

THREE-DIMENSIONAL SYSTEMS

The second group of structural solutions for green facades are three-dimensional systems that have unique design capabilities. 3D systems consist of panels that have length, width and depth, and are created specifically to enhance the growth and maintenance of green facade plants. 3D panels 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. This modular panel has reduced material weight and creates some unique opportunities to cover large surfaces without perimeter frames, and for creating shapes.

Wall mounted, modular, three-dimensional panel with mature growth

Structural panel systems are rigid, can span openings, and can be mounted vertically, horizontally, or between structural elements as freestanding facades. Attachment details for 3D panels connect at the perimeter frame, or when using the truss panel, can alternately be located at the edge or within the panel field. Panel mounting details are available to create variable spacing off of a building surface, creating additional flexibility. 3D panels are rigid and the attachment design does not require resisting the same tension forces as 2D cable systems. Panel attachments primarily are engineered to resist weight loads and wind forces, and in some cases can be designed for limited cantilevers.

The distinct advantage of 3D systems for facade 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. The most obvious plant attachment for a vine is an aerial root system that is so strong it can hold the plant to a building without any additional support. An example would be an Ivy or Wisteria, both of which are tenacious and can do significant damage to a building facade. Some vines are main-stem twiners, and other vines use tendrils that can twine or curl around another plant or a component of a facade trellis. This group of plants is suitable for 2D systems and generally travels along the cable or rod system, opportunistically attaching. In this case, the plant must develop significantly to infill space between supports and increase its leaf canopy. Another mechanical plant attachment 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. Many green facade 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. Ultimately, the green facade 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 facade structure, runners and scramblers may require additional maintenance to establish on a 2D system.

Aerial root species attached directly to the building surface

Vine tendril attached to a three-dimensional panel

Section III *System Selection*

After understanding the components of each type of system, a designer needs to make conscious choices regarding the opportunities and constraints to incorporate the appropriate green facade system into a project. The selection process can be linear in fashion and by completing a checklist of design considerations, successful project implementation can

occur. It is important to note that this may not be a comprehensive list, but at a minimum, these considerations should be taken into account. It is equally important to make sure that there is interdisciplinary discussion at the onset of design, as one design consideration from an architectural perspective may affect the landscape architect, landscape contractor, horticulturalist, landscape maintenance contractor and ultimately, the client.

Scale: Scale is a critical factor when proposing and designing green facades. Specific green facade systems have the adaptability to be included on projects as small vignettes, to installations that include entire building elevations. There are basic applications for each type of system and it is important to understand what the possibilities are for each. Three dimensional panels are modular and can either be wall mounted or freestanding while being utilized at both ends of the scale spectrum. Cable systems are tensioned and are limited in their potential for inclusion in freestanding applications. Wall mounted installations of green facades are considered a building application, but there are possibilities for extending various scales of thematic components throughout the entire site. Consider if a single system type provides for all design elements, or if a combination of systems is required to exectue the proposed design.

Planters with irrigation and drainage mounted to multi-level parking structure, Ridgeland, MS

Budget: The most successful means of maintaining a green facade system design within a project's budget is to have it incorporated as part of the building envelope, since landscape specific applications may have a tendency to be value engineered out of projects. Make certain that budgets include all aspects of a green facade system. Typically, product manufacturers provide a material cost only. Budgets should be adjusted to account for shipping, fasteners, installation of the system components, plants and plant materials, planting bed/soil preparation and irrigation installation costs. Ultimately, the budget discussion needs to be expanded to include maintenance expenses at the onset of the design process, so that designs can facilitate the long term requirements of both the physical system and plant material.

Surface-mounted green facade with plants trimmed to panel edges, Playa Vista, CA

Concept Considerations: System selection should be consistent with the conceptual intent of the design. For example, if the conceptual intent is to provide for 100% vegetative coverage on a building elevation, cable systems utilizing a vertical and horizontal layout probably will need to be supplemented or enhanced to achieve the intent. It should also be noted that the growth habit of vining plant material is to grow vertically; extensive, horizontal spans without immediately adjacent plant material underneath will require significant maintenance to achieve the desired conceptual effect. In addition, maximum soil volume allowances need to be considered in the conceptual phase in order to successfully execute the design in the field and for long term survivability of the facade planting.

Architectural considerations: There are architectural considerations for facade attachment that need to be considered when determining the appropriateness of certain systems. Regional building construction variations can present challenges and a masonry split faced block will have different attachment requirements than a stucco facade with plywood backing. Attention should be given to attachment locations and whether the building envelope may need to include additional support material in order to facilitate mounting. Mounting locations cannot be located on glazing and the appropriate mounting structure should be determined during the design development process. Dead and live loads need to be verified by structural engineers to ensure that the system attachment method is compatible with the type of construction. Product manufacturers should always provide specifics regarding minimum pull out values of fastener types and recommendations for all building types..

Engineering requirements: Snow, ice, wind and weight loads should always be confirmed by a structural engineer for wall-mounted applications. Post imbed lengths also need to be recommended by a structural engineer for freestanding applications. Wind exposures and engineering requirements also change relative to height/elevation changes and there are regional building codes that need to be followed. Typically, codes do not allow for green facades to be used exclusively as handrails or crash barriers and local codes will need to be assessed for ventilation requirements for open and closed space on parking structures. Green facade systems have different component weights and the weight of heavier gauge systems need to be accounted for. Some 3D systems require a metal frame or trim for attachment and this additional weight also needs to be taken into consideration for engineering.

Rigid, lightweight, three-dimensional panels being installed on a multilevel building, Golden, CO

Site considerations: A pre and post site inventory should be conducted to determine the suitability of planting footprints, available soil volumes, sun orientation, drainage, water availability and microclimates. This will also help to determine appropriate plant material selection since plants do not respond equally to any of these variables. It is also recommended that a soil test be conducted after construction to determine the macro and micro nutrient levels of existing soils. Consideration should be given to installations that occur within areas that experience snow events. Snow removal and storage should be discussed with facility managers and landscape contractors in order to prevent any damage to the system and/or plant materials from these future activities.

Building code considerations: Local building codes regarding Right-of Ways (ROW), landscape ordinances and easements should also be consulted. Sometimes, green facades extending from a building wall can extend into easements or ROWs and consideration for the dimensions of the planting area must be taken into account. More and more local landscape ordinances are advocating for the incorporation of green facades to help alleviate potential zoning use issues and there may be certain height requirements that must be met in order to achieve compliance.

Modular, three-dimensional green facade system adapted to a tubular steel frame with integrated planters and irrigation, Vancouver, B.C.

Environmental considerations: A thorough site inventory will help to identify most environmental considerations that need to be taken into account, but additional thought should be given to basic plant functions, tolerances and characteristics. In urban environments that experience snow events, salt injury can be detrimental to plant material and soils. When salt accumulates in the soil, excessive sodium (Na) from salt destroys soil structure, raises soil pH, reduces water infiltration and soil aeration leading to soil compaction and water runoff. Build-up of deicing salts in the plant can interfere with photosynthesis and other plant processes like respiration and transpiration. Salt tolerance of plant material is also a consideration in coastal environments. Plant functions should be determined since some plant material produces blooms that are attractors to pollinating insects, such as bees, while other plant material like grape vines produce fruit that may stain adjacent surfaces. Drought continues to be a major environmental factor in most parts of North America. According to the National Weather Service Climate Prediction Center, in August 2012 drought covered over 60% of the 48 contiguous states and ¼ of the US was experiencing extreme to exceptional drought.[7] Drought creates an increased demand on water resources and in these conditions, native plants and drought-tolerate plantings are strongly recommended. Environmental considerations should also take into account the water use requirements of the entire site and the balance between usage, efficiency and conservation. Opportunities to include green facade systems within rainwater harvesting and greywater technology can occur on many projects and should be strongly considered in drought stricken areas. Conversely, green facades can also play a role within stormwater management plans for handling surface runoff and the reduction of off-site water discharge. Green facades have been successfully incorporated into vegetated swale and rain garden projects. Native vine varieties that thrive in seasonally inundated conditions should be considered for bioretention or additional low-impact development techniques.

This rain garden with integrated green facade is a key component to the stormwater management strategy, Oakland, CA

Soil volume considerations: The amount of soil that is made available for plant's roots to grow into is a consideration that is often not taken into account. Soil volume is critical for the long term success of plants in all locations regardless if in the ground or in planters. Historically, determining appropriate soil volumes for plant material has been based upon research looking at shade tree survivability in urban environments. The most significant body of work in this area of research has been forwarded by James Urban, FASLA in his book *Up By Roots* (ISA Press 2008). Urban's research states that a 16" caliper tree requires 1,000 c.f. of available soil volume or 2 c.f. of soil volume for every 1 s.f. of crown. Based on this research as a guideline, the following soil volume recommendations can be extrapolated for vines:

2" caliper = 100 c.f.	5'W x 10'L x 2'D
4" caliper = 200 c.f.	10'W x 10'L x 2'D
6" caliper = 400 c.f.	10'W x 10'L x 4'D

Visual observation of green facade installations over 15 years old has shown that vine plant material can reach caliper dimensions of six to eight inches and at-grade planting beds with an unlimited available soil volume provide the best option for maximum plant material height and spread.

A LIVING COMPONENT

Plant considerations: Appropriate plant selection is critical to the success of green facade systems. In addition to simply determining a plant's hardiness, there are certain minimum requirements that must be determined to assess the appropriateness for each system. Twining and vining plants are conducive to cable and cable net green facades, while vines that cling, climb with tendrils or suckers may be utilized on three-dimensional systems. Some shrubs that have vertical growth habits, such as Climbing Hydrangea and Sunspot Euonymus, may also be successful on a three dimensional system. Client/owners should be made aware that evergreen plant materials, such as English Ivy, can be problematic in northern climates without significant maintenance. English Ivy is typically used as a horizontal ground cover and to maintain this plant as a vertical element, vines need to be attached directly to green facade systems with regular pruning maintenance. Plants also can have a specific mature height and varying growth rates to achieve mature height. Priority should be given to regionally native plant material since it is typically drought tolerant and adaptable to local weather conditions. Regionally native plant material can also be more resistant to pests and diseases. As a rule of thumb, designers should strive for mixed planting designs that offer diversity, seasonality and eliminate the establishment of plant monocultures. The number of plants to incorporate into a system should also be given attention. Typically, cable systems require one plant per vertical cable, while multiple plants can be used on 3D systems. Plant spacing on 3D systems can vary greatly and is determined by the size of plant material upon installation and expected mature size. The following guidelines can be used to help determine plant quantities, but consultation with local landscape architects, native plant societies, landscape contractors and horticulturalists is strongly recommended:

Seven year old installation of Trumpet Vine with 40 foot height and six inch caliper, Fullerton, CA

#1 Container	18"-24" o.c.
#3 Container	24"-36" o.c.
#5 Container	36"-48" o.c.
#7 Container	48"

For a downloadable list of recommended plant material for 3D systems based on USDA Hardiness Zones, click here. 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. The USDA maintains a database that reflects current information regarding regionally introduced, invasive and noxious species.[8]

These vines planted directly into the ground have ample soil volume and correct spacing for full coverage to four storys, Fullerton, CA

Irrigation considerations: Everything that grows needs water and irrigation for green facade systems typically falls into one of two categories. At grade planting beds with typical vine plant material is the most common application. These planting plans can be watered within the scope of a standard irrigation plan. Within a green facade system planting, there is no need to water any part of the plant other than the root zone. Raised planters or container planters are the other type of application and water source should be a conscious determination, especially if included in a rooftop application. These installations most likely will have a defined soil volume and while that is a very critical consideration, frequency of watering and drainage within the soil volume is also paramount to the survivability of the plant material. Additional investigation should be given to the type of soil medium or mix that is being incorporated into the planter. An irrigation professional should be consulted in any installation in order to determine delivery system, watering frequency, rate and irrigation source.

Proper soil volume, irrigation delivery and maintenance are successfully demonstrated in this18 year old green facade installation, Universal City, CA

Maintenance considerations: Unfortunately, maintenance for a majority of green facade installations is either too infrequent or more appropriately, non-existent. Green facade systems are one-half static system and one-half living system. Designers of green facade systems can play a critical role in educating the client/owners 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. Special attention should be given in the design phase to installations that are over eight feet in height, since anything taller will require the use of a ladder to properly maintain plant material. 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 facades. Conscious design decisions also need to address the clearance between the wall and the back side of the green facade 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 facade.

A clearance of 18 inches from the wall is recommended for wall-mounted installations over eight feet tall; 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 facade system.

Wall mounted, modular three-dimensional panels, with standoff brackets, provide access to keep plants off the wall, Oakland, CA

Lifecycle and sustainability considerations: How long do we expect these systems to last? 5, 10, 15, 30, 50 years? Experience has shown that well maintained systems, both physically and horticulturally, can last 18 years or more. Product manufacturers that have completed a Life Cycle Assessment (LCA)

are using 30 years as a baseline for product 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.

Specifications: As previously described, not all green wall systems are alike. Product specifications are written to guarantee that a client/owner is getting exactly what is designed for a certain application or need. Since there are many variations within green facade systems, strict adherence to specifications must be maintained so that acceptable substitutes are compared on an equal basis. Manufacturers that provide 3 part specifications should be identified and utilized.

Expectations and survivability: System selection, expectations and long term viability will be different depending on the diversity of the design team. The key to long-term success of a green facade system is to include as many disciplines within the design process as possible. As documented here, green facade systems can be far reaching in their scope and adaptability. One important design consideration is expected lifecycle of the green facade system. Some projects will be legacy projects maintained for decades, while others may be in place for a shorter period to keep in line with current design trends. If a project is expected to be replaced or renovated within a shorter time frame, systems that are conducive to Design for Deconstruction (DfD) principles should be utilized. For example, retail and hospitality projects typically have short design durations and some high visibility projects are typically renovated or reconstructed within a 12-15 year landscape plan. Many resources are available and multiple disciplines need to be included in order to achieve expectations. One of the best tools for managing expectations is to complete a Post Occupancy Evaluation (POE) after installation. Either formally or informally, POEs are a great way to engage clients, designers, facility managers and contractors to determine successes and areas of improvement on both existing and future green facade projects.

Green facade plants are pruned at the pedestrian level to create a shade canopy above, Valley Metro Light Rail, Tempe, AZ

Section IV *Insuring the Install: A Checklist for Success*

After a green facade system has been selected and all of the design programming has been completed, the design team should initiate the shop drawing process with the product manufacturer. Shop drawings are an important tool that will expose any deficiencies or oversights in the construction documents and design. Another important tool that can be utilized to insure a successful project is an installation checklist. Installation checklists can include a wide variety of considerations and help to create awareness between designers and contractors. Since green facades can be complex installations, here are just some of the items that might be included on such a list:

Scopes and contractors: The type of green facade system and installation will dictate the contractor's scope of work. Large, multi-story, wall mounted installations typically will be awarded to contractors that have experience with building veneer, concrete precast and

tilt-up systems. These contractors are capable of working at higher building elevations and are familiar with attachment considerations such as no-drill zones. Miscellaneous metals and structural steel contractors are typically best qualified to build large, free-standing green facade applications that require a steel support system. Plant material installation will be completed by another contractor, as well as the irrigation installation. Simple wall mounted and freestanding fence installations can easily fall under the scope of landscape contractors and this is an excellent way to combine the green facade construction, landscape contracting and irrigation scopes. For larger freestanding fence projects, fencing contractors can be very efficient and are very experienced with post layout and post imbed requirements. Recently, specialized green roof installers have been including green facade systems under their scope of services. These contractors are already familiar with working on rooftop installations and green facades can require specific considerations, such as roof deck penetrations and parapet wall attachments.

Contractor qualifications: At a minimum, contractors should be familiar with accurately estimating installation costs of the green facade system, the scope of work to be performed and being able to successfully complete the installation according to approved shop drawings. Additional qualification considerations can be assessed on a project by project basis.

Matching contractors with appropriate scope of work and equipment will help alleviate installation issues, Riverdale, MD

Training and experience: Priority should be extended to contractors that have past experience with installing the specific green facade system. Some green facade product manufacturers might provide installation training and certification to contractors. Also, product manufacturers might have preferred installers in certain areas and should be able to provide a listing of contractors that have placed purchase orders in the past.

Kit of parts: Designers and contractors need to be familiar with the components of green facade systems and what is required for installation purposes. What does the product manufacturer provide and what additional requirements, such as fasteners, etc. are required to complete the installation? What are the lead times? How are the shop drawings delivered? In addition, contractors should familiarize themselves with how the system will be delivered to the job site. Initiating proper lines of communication between designer, product manufacturer, general contractor and subcontractor can help to manage expectations and effectively coordinate scheduling for the installation.

Scheduling: Project complexity will be the main driver of job site scheduling and coordination. Installations that require multiple contractors and scopes will require linear project management in order for successful completion. A basic green facade installation sequence should be the construction of the static green facade system, followed by irrigation installation, if required, and then plant material. If multiple contractors are performing different scopes, it might be beneficial to complete any punch out inspections before moving on to the next step.

Punch out: Understanding what to look for during the punch out process is vital to the long term success of the green facade system. As far as the static system is concerned, there are two specific areas that require attention. The attachment system should be examined to determine if adherence to installation specifications were met. Especially on projects that are designed to meet exacting engineering requirements, proper clip placement, proper clip spacing and panel connections need to be inspected for compliance. On wall-mounted applications where fastening systems penetrate the building envelope, waterproofing integrity needs to be maintained and should be assessed. The other area that requires specific attention is the exterior coating of the static system. Powdercoated green facade systems can be compromised during installation and any exposed metal surfaces need to be re-sealed with an approved touch-up product. This is also critical if there have been any field modifications made to the green facade system. Any incidental metal filings that have collected on the system need to be removed in order to prevent surface rust staining. For the living system evaluation, there are two components that need to be inspected for design compliance. Irrigation systems need to be evaluated to determine if proper coverage is being achieved. Additional verification should include proper delivery rate, duration and frequency of delivery. Plant material should be examined to determine if specified sizes are installed, that they have not incurred damage, have proper spacing, are properly attached to the static system and proper mulch depths are maintained. The inclusion of a recommended planting detail within construction document submittals is an excellent way to prevent landscape contracting deficiencies in the field.

Green facade technology can create shade that cools building surfaces, and also provides privacy screening, Tempe, AZ

Warranties: Product manufacturers provide warranties that are specific to their static green facade systems and guarantees vary. Check with the product manufacturer to determine what coverage is provided. Plant material warranties should be provided by the landscape contractor and plant warranties are typically guaranteed to be free of disease or damage and plant survivability is the responsibility of the contractor for one year.

Maintenance specifications: Writing green facade maintenance specifications is an excellent way to manage long term expectations and provide a successful, lasting installation. Maintenance specifications can help to spell out explicitly the horticultural services that need to be provided by landscape maintenance professionals. Currently, there are no industry accepted performance specs for green facade systems and it would be the responsibility of the design team to write and enforce.

Multiple, three-dimensional panels with easy maintenance access help to reduce reflected light and heat gain in an arid environment, Las Vegas, NV

Section V *Empowering the Owner: An Understanding of Static and Living Systems*

While design considerations and proper implementation are critical to the long term success of a green facade project, the education of the client/owner regarding the intricacies of this technology should not be overlooked or omitted. Throughout this discussion, we have covered the differences between the two complementary components of static and living systems within green facade technology. The client/owner should also be made aware of these two distinctly different components and the maintenance strategies necessary to ensure success. During the conceptual design phase, an overall maintenance strategy should be discussed to determine what the requirements will be to maintain both the static and living systems. Discussion should also be centered on the maintenance commitment level of the project. Definitions regarding maintenance can be varied and some clients might believe that "low maintenance" translates into "zero maintenance" especially when taking into consideration budget items. By exposing these issues during the design process, a client/owner definition or commitment level can be understood so that responsible design can occur. Maintenance commitments can also affect design decisions. For example, it would not be responsible design to specify plant material that reaches a mature height of 50' onto an 8' tall installation without a significant maintenance commitment from the client/owner.

Experience has also shown that certain vertical markets tend to have different maintenance commitment levels. Hospitality, retail, commercial and health care vertical markets typically plan budgets accordingly towards maintenance or at a minimum, contain line items that include some level of landscape maintenance. Education, civic and government budgets for landscape maintenance are dependent upon available funding and are significantly susceptible to being reduced or eliminated. Maintenance should be mandatory for all green facade installations to make sure that this capital expenditure appreciates in value.

Inspection of system components and plant material is crucial for proper specification enforcement, Tempe, AZ

After these discussions, a client/owner can now understand that there are two types of components and maintenance is required on some basis for both. In order to determine a maintenance budget for both components of the green facade system, the frequency of performing maintenance tasks must be determined. Specific maintenance tasks will be discussed in detail, but frequency is simply described as the number of times those tasks will be undertaken. At a minimum, maintenance should be completed on the green facade system on an annual basis. The owner/client of higher visibility projects may opt for bi-annual or monthly maintenance applications. Labor costs will be a major portion in determining maintenance costs, but landscape maintenance

estimators should also take into consideration the requirements for specialized equipment to access, prune and inspect systems. A simple, 3 dimensional, freestanding fence application at a height of 8' that requires no specialized equipment should be approximately $1.50-$1.80 per square foot for maintenance labor per application. Local labor rates may vary and materials necessary for standard horticultural maintenance practices or maintenance required to the static system are not included. Maintenance budgets can also be adjusted depending upon the maturity of the installation. Newer installations will require less frequent maintenance than established systems simply due to the size of the plant material.

Once maintenance frequency and general budget discussions have been conducted, then the project team can begin to look at the specific tasks that need to be incorporated into a maintenance plan. As previously stated, a maintenance plan needs to take into consideration the two complimentary components; static and living systems. Beginning with the static system, a comprehensive plan will include at a minimum the visual inspection of the green facade system. This inspection will help to identify potential problems and should include the following:

- A maintenance contractor or facility manager should visually look for any tensioning adjustments that need to be made for cable systems. As plant materials mature, it will add additional weight to a cable system and this may require a readjustment of specific areas affected or the entire system.
- Additional visual inspection should be conducted for corrosion. Any signs of corrosion that did not show up in the punch out process need to be remediated immediately. Corrosion can compromise the integrity of any coated metal green facade system, including stainless steel. For powdercoated systems, any corrosion needs to be removed with a wire brush and an approved sealing product needs to be applied. In addition, irrigation may cause calcium, iron or other mineral deposits upon the surface and these unsightly build ups should be cleaned or irrigation should be redirected, if possible.
- All fasteners to the structural system need to be visually inspected. Compromised galvanized coated fasteners will bleed onto surrounding surfaces and any occurrence should be remedied. Also, attention should be given to the waterproofing integrity of the building envelope. Silicon caulks and epoxies might degrade due to exposure and may need to be removed, replaced or replenished.
- All cable, clip and panel attachments to the structural system need to be visually assessed. Attachment systems typically include more than one part and all missing bolts, nuts, wing nuts, spacers, etc. need to be replenished.
- Any damaged panels, cables, clips or other attachments should be replaced as soon as possible.

In addition to the static system, developing a comprehensive maintenance plan and identifying maintenance tasks for the living system needs to be discussed. Laying out a basic annual maintenance strategy is typically the best approach. From an annual maintenance list, client/owners will be able to determine services that need to be performed for bi-annual and monthly applications. A comprehensive annual maintenance plan would include the following services:

Client expectations can only be matched if there are discussions for maintenance

- Bed Clean Up Application - This application includes the general clean-up of the planting bed, raised planter or any area where plant material is installed. All weeds, trash, debris and leaf clutter should be removed from the plants and in particular, underneath the plants. Any organic material collected should be composted and any grading issues should be resolved, so that a fresh 1"-2" layer of mulch can be applied. This is particularly critical around the crown of the plant or where the plant originates from the ground. Too much soil or mulch around the crown of plants can be detrimental to the plants necessary functions to survive.
- Mulch Application - This application is the replenishment of the mulch layer. Mulch is a critical component in retaining moisture into the ground, controlling soil temperatures, slowing surface runoff and suppressing weeds. There are many options regarding mulch choices; hardwood, stone, gravel, pine straw, etc. and the organic choices will require more periodic replenishment. Organic mulches should be replenished on an annual basis. Stone and gravel mulches will also need replenishment over time in order to maintain the designed aesthetic, but not typically on an annual basis. The advantage of organic mulch is that it adds to the organic conditioning of the surrounding soil through decomposition. As a rule of thumb, organic mulches need to only be replenished annually as a 1"-2" layer unless certain plant or site considerations dictate otherwise.

Proper soil preparation and plant spacing, with irrigation placed in advance, before mulch layer application

- Pruning Application - The goals of this application are to control plant material growth and restrict plant material from growing on the building envelope. Pruning can also help to force plants to grow in specific directions and if done correctly and at the right time can invigorate new growth. While all of the maintenance tasks are important, the pruning application is the most critical and if client/owners had to fund just one of them, this would be it. While green facade systems have a living component, it is not a "thinking" system and plant material needs to be manually manipulated to go or stay where we as designers intend to utilize it. For 2 dimensional systems, plant material needs to be pruned to attach to the cable or wire. Appropriate twining plants on 2D systems will produce multiple "leaders" and any leader that does not attach needs to be removed. This is to insure that the plant is directed onto the cable and additional growth away from the cable will not occur. The removal of the additional material will also help the plant to expend available nutrients and water to the preferred growth. Pruning for 3 dimensional systems can be somewhat less intensive, but plant material still needs to be maintained on the panel system itself. 3D systems are typically used at larger scales and can facilitate the growth habits of very aggressive plants. These vigorous growing plants can and will grow in a multitude of directions. Pruning techniques should keep all plant material on or within the 3D system. This is especially critical on the building envelope and any plant material growing back to structure or traveling across an attachment system back to structure should be removed. The simple

rule of thumb for pruning 3D systems is to use the panels as a pruning template. Any plant material growing outside of the template or frame of the system should be removed. This technique also helps to increase plant coverage on the panels, which is ultimately the overall goal for inclusion. Freestanding fence applications may require less front or back pruning, but pruning the top and sides of the installation should always be recommended.

- Fertilization Application - In order to maintain a healthy vigorous appearance and to encourage growth, all plant material should be fertilized during this application. Water soluble, time released fertilizers are recommended and vine plant material responds well to a balanced, 12-12-12 application. In addition, herbaceous (soft twig) vine plant material growth can be supplemented with regular foliar fertilizer applications and is especially beneficial to heavy feeders such as Clematis varieties.
- Irrigation Check - All irrigation components should be visually checked and a physical run through of the system with visual inspection should occur. It is critically important to the long term survivability of plant material that the irrigation system be maintained in operating condition. Physically turning on the system and visual inspection of its operation is the only way to detect either over or under watering problems with irrigation systems. This is particularly critical when drip irrigation is utilized. Most drip irrigation components are underground, so the operational functionality and efficiency can only be determined by dead or underperforming plant material, unless there is periodic visual inspection. Any broken, damaged or underperforming components of the irrigation system need to be replaced immediately. It is recommended that Smart irrigation technologies be incorporated into the best management practices. It is also important to discuss the elimination or reduction of irrigation requirements as plant materials mature. The establishment period for new plantings is typically 1-2 years and consideration should be explored to increase future efficiency and reduce water usage.
- Plant Replacement - Any dead, diseased or inappropriate plant material should be removed and replaced. Any annual (plants that do not overwinter) vines should also be removed and replaced after the date of last frost. The health and vigor of plant material should always be assessed and long term strategies should be made for the replenishment of plant material over 15 years old.

These are the basic horticultural maintenance tasks that should be undertaken on an annual basis. The following guidelines of tasks outline how the services can be adjusted for bi-annual and monthly applications AFTER an annual application has occurred:

- Bi-annual maintenance (second application)
- Bed Clean-up
- Pruning Application
- Irrigation Check
- Plant Replacement
- Monthly maintenance (following initial application with consecutive, monthly applications)
- Bed Clean-up
- Pruning Application
- Irrigation Check
- Plant Replacement

Underestimating the importance of maintenance is extremely detrimental to managing expectations and needs to be a responsible component of designing, specifying and constructing green facade systems, green walls and landscapes, in general.

Now that there has been discussion of the advanced issues regarding green facade system design, technology and maintenance aspects, it is imperative that designers, client/owners and product manufacturers begin to look at making the industry better. This introspection begins with discussing what determines successful and unsuccessful projects. Metrics should be defined that will identify what makes installations fail or fall short of expectations and goals. One tool that can be very helpful in determining the metrics are Post Occupancy Evaluations (POE). Performing POEs on projects can either be a formal or informal process and the insights can be very enlightening pertaining to the intricacies of the design process, responsibilities and post construction condition of the installation.

Section VI *Owning the Future: Metrics for Determining Successes and Failures*

A basic format for conducting a POE can consist of the following components:

- Identification of design principals and contractors. Recovery of original drawings, purchase orders and additional project background information.
- Visual inspection of the static system and evaluation.
- Visual inspection of the living system and evaluation.
- Identification of process and execution issues.
- Identification of current issues.
- Recommendations for remediation
- Action plan and responsibilities

It should be noted that conducting a POE is not a liability discussion, but a process that helps to identify issues and remedies for both the evaluated project and future projects. Open lines of communication need to be maintained and it is important to recognize that this process is a learning opportunity for everyone involved. It is also highly recommended that all components of the POE be documented in order to share with participants and shareholders.

Understanding seasonal variations are an important part of design, plant selection, and maintenance considerations

Case studies are also an excellent way to document projects and typically less intensive than a POE. Case studies can simply include project background information, photo documentation, project description and principal identification. Case study models are readily available and one benefit of case studies is that they can easily be shared with like-minded designers and interested parties. Open information sharing with designers is critical to the betterment of the green facade industry and information sharing portals and clearinghouses should be encouraged.

There is also a need to develop an industry standard maintenance and performance specification. Green roof contractors are now being required to perform maintenance for two years and have been instrumental in introducing post installation guidelines. Green facade designers, contractors and product manufacturers should be proactive in assembling and forwarding maintenance and performance specifications in order to establish an acceptable standard. There is a substantial body of green facade projects that are over 10 and 15 years old and it will be imperative to evaluate these projects to determine accurate lifecycle considerations. Material recovery and reuse will need to be explored as well as recyclability of the static system.

IN CONCLUSION

For building energy efficiency, durability, natural beauty, cost effectiveness and adaptability, green facades offer the design community a substantial asset. The green facade industry continues to evolve and there are a significant number of projects that have thrived for more than a decade, demonstrating a long range return on investment. Installation techniques and construction adaptability will continue to improve, and innovative design applications will be further advanced as designers continue to push the envelope for green facade inclusion. The case for that inclusion can be strengthened by taking the described considerations into account. The completion of this outlined process will help to establish a mainstream acceptance of green facades as a standard building component.

MORE

A shortened 16 page version of this document is available for Continuing Education Credits: http://www.aecdaily.com (search greenscreen)

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8 http://plants.usda.gov/java/noxiousDriver

Resource Links

The Sustainable Sites Initiative (SITES™) Credit Contribution Review
http://greenscreen.com/resources/education/

LEED® V4 Credit Contribution Review
http://greenscreen.com/docs/Education/

Guidelines for Green Facade Plant Selection
http://greenscreen.com/docs/Plants/greenscreen_ Guidelines%20for%20Plant%20Selection.pdf

Guidelines for Green Facade Plant Installation
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Guidelines for Green Facade Plant Maintenance
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Introduction to Green Walls: Technology, Benefits, and Design (2008)
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