

## **Organic Greenroof Architecture: Design Considerations and System Components**

*Growing a new roof - sustainably*

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By Linda S. Velazquez

In the summer 2005 issue of this journal, I introduced the concept of greenroofs -- vegetated covers installed atop roof decks. I described some basic greenroof technologies, and explained some of the key environmental, economic, aesthetic, and psychological advantages that greenroofs offer.<sup>1</sup>

In this article, I discuss the design of greenroofs, with details on system components, maintenance, cost issues, and the range possible applications. I also offer some thoughts on the future of greenroof development.

### **Greenroof Design: General Considerations**

The greenroof design process is truly site specific, and requires open communication between the building owner and the design team.

#### ***Greenroof Function***

When beginning the design process, you should first consider how the roof is to function. Does the building owner desire only a thin vegetated ecological cover, or something more substantial, such as a green area with public access? Does the owner have a particular plant design scheme in mind?

#### ***Roof Deck Weight***

It is crucial to have a structural engineer or other capable licensed professional determine the roof's maximum weight loads, in addition to local snow loading requirements. Once you have made this determination, then work your way backwards in terms of accounting for the weights of all the greenroofing elements.

In projects where roof deck weight is an issue, the maximum growth media depth will be determined by the structural loading capacity of the roof. If weight restrictions become a problem, point loading over structural elements (such as columns or weight-bearing walls) is possible, and can allow heavier shrubs and even trees to be accommodated.

### ***Additional Design Issues***

Other items to be discussed in the design stage should include the following:

- types of plants desired;
- maintenance requirements;
- disability access;
- liability issues;
- architectural accents.

### **Greenroof Service and Product Providers**

Greenroof design and construction can be handled by a single-source provider from start to finish. Alternatively, the greenroof can be custom designed using local materials and resources.

The availability of greenroof service and product providers can vary depending on location. In Germany alone there are literally hundreds of providers and products available, but in North America we have considerably fewer choices.

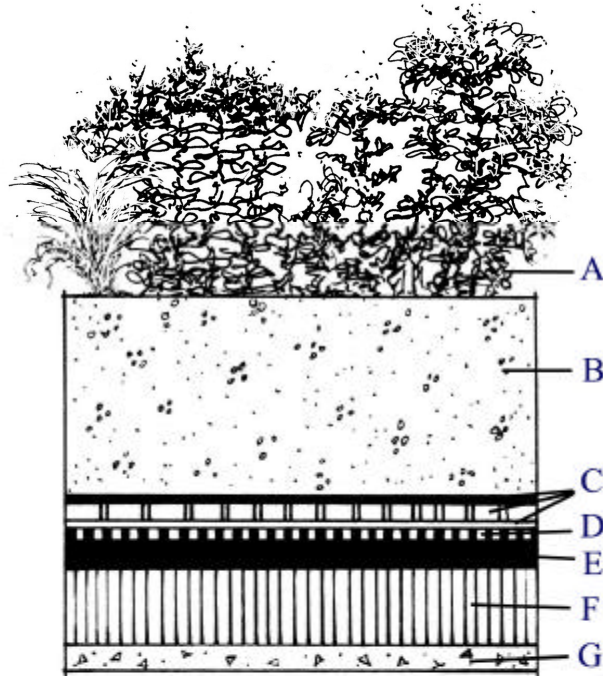
### **Greenroof System Components**

You must start with a structurally sound, damage-free roof. At a minimum, greenroof components include waterproofing, drainage, growth media, and plants. A wide range of materials is available for each. System types range from a single layer consisting of a pre-grown vegetated mat -- to the conventional multiple layered build-up method of various individual components -- to

self-contained modular units that include drainage, soil media, and plants in one.

An insulation layer is optional but recommended for most roof applications, except open air type structures. When used, it prevents water stored in the greenroof system from extracting heat in the winter or cool air in the summer. Traditional German-type systems are composed of individual layers applied over the roof deck; these systems are inverted roofing membrane assemblies, where the membrane is protected or buried under the insulation layer. In the United States, conventional roofing practices place the insulation either over or below the roof deck, but not above the waterproofing.

The sections below describe the main greenroof components, from the structural support of the roof deck upward. Various protection layers (fleeces) and other optional elements may be sandwiched between these components. The diagram in **Exhibit 1** illustrates greenroof elements in a custom design for a semi-extensive system.



A: Plants - Ground Covers, Grasses, Dwarf Woody Ornamentals, Dwarf Conifers

B: Lightweight Substrate (Soil Mix) - 5" Average of Mr. Natural 75% Inorganic Expanded Slate to 25% Organic Matter

C: Drainage Layer - MiraDRAIN 6200: Non-Woven Filter Fabric; 3-D Polystyrene Core; Polymeric Protection Layer

D: Root Barrier - Permalon 12-Ply Polyethylene Laminate

E: 2-Ply Bitumen Roofing Membrane

F: 2" Rigid Insulation - ISO 2-Layers w/ R-8 to R-12, Staggered Joints

G: New Plywood Roof Deck - Sturdi-floor 3/4" Tongue n Groove

## 310 HauStudio Greenroof Material Section

By Linda S. Velazquez, Greenroofs.com

### ***Waterproofing***

The main function of any roof lies in its waterproofing capacity. Waterproofing options include impervious concrete, a hot or cold liquid-applied membrane, a specially designed singly-ply sheet membrane, or a built-up roof system consisting of three-plus layers.

Common choices for waterproofing material are modified bitumen, rubberized asphalt, polyvinyl chloride (PVC), ethylene propylene diene monomer (EPDM, a water resistant rubber), and thermoplastic polyolefin (TPO).

If the waterproofing material is organic, an additional root repellent barrier will be necessary to

prevent roots from damaging it. A flood test with at least one inch of water is necessary to ensure that the material being used can provide water tightness for a minimum of 24 hours (48 hours is even better).

### ***Drainage***

The drainage layer conveys excess water to external or internal drains. This is important because excess water not only could kill the plants, but also could result in an undesirable buildup of water on the roof deck. Some drainage products are designed for water retention, which allows water to be saved for future use by the greenroof plants through root uptake.

Aggregate choices include various granular media, such as gravel. Geocomposite types include high-density plastics, rigid and non-rigid foam boards, and modular units of plastic or metal. A non biodegradable filter fabric is placed on top of the drainage material to prevent fine growth media particles from clogging the drains.

### ***Growth Media***

This layer is critical to the long-term success of a living roof. Growth media consists of extremely lightweight engineered soil substrate that has as a high ratio of inorganic minerals to organic material. Let me stress the "engineered" part. We are not talking about using top soil here: Regular garden soil is heavy. It also can contain pathogens, undesirable insects, and weeds.

The properties necessary for growth media include good drainage and aeration; water holding capacity; and nutrient holding or cation exchange capacity (CEC). The growth media must not settle (lose volume) or blow away, and must provide stability for the plants.<sup>2</sup>

Inorganic components in the growth media could include materials such as expanded slate and shale, extruded clay, crushed recycled bricks and concrete rubble, lava, rock wool, and perlite. Much smaller percentages of organic matter may be added, such as well-rotted humus material (e.g., hen manure, guano, or mushroom compost). This can be augmented with organic fibrous material and a small amount of clay particles. This mixture holds and slowly releases essential trace elements necessary for the health

of the soil community. A shallow extensive greenroof may contain 100% inorganic media.

### **Plants**

The vegetation layer is the most vital and exciting part of the greenroof, and judicious research into each project's appropriate plant material selection is essential.

After assessing geographic and climatic considerations (such as cold and heat tolerances, rainfall, humidity, wind, and sun/shade exposure), the depth of the growth substrate will actually determine the choice of plants.

A much larger variety of plant selections is available for intensive roofscapes. For extensive greenroofs, appropriate plants are types that can grow in harsh environmental conditions with very thin growing substrates like those found in crevices and rocks, dry meadows, edges of woods, and steppes. Alpine and other extreme-weather ground covers, such as succulents, and some flowering herbs, bulbs, native grasses, mosses, wildflowers and other perennials are excellent choices because of their hardiness, shallow root structure, and horizontal growth habits.

Options for planting methods include using vegetated mats, which also provide drainage and moisture retention; sowing seeds; spreading "sprigs" (chopped bits of sedum cuttings); hydro-planting a mix of seed and sprigs; planting plugs; and using containerized plants of various sizes.

One note about native vs. introduced species: Coming from the field of landscape architecture, I would be remiss if I did not encourage the use of native plants in any landscape. After all, what better way to promote the *genius loci* (the sense or spirit of place) than with vegetation native to each region?

The problem with doing this, however, is that roofs are unnatural spaces for plants to survive, let alone thrive. For a greenroof to succeed, we must choose true proven survivors -- those plants that are known to flourish in rooftop settings.

One such group of plants is sedums, of which over 1,000 species exist in the world. They are by far the most

popular choice for extensive greenroofs because they look great and perform exceedingly well overall.

I recommend experimenting with a small number of natives -- perhaps up to 20% -- until enough study has been conducted to determine their long-term viability in various geographic regions. Once enough hardy natives are identified, greenroofs planted with native species could truly reflect the ecological and cultural sensitivity of each community.

### **Greenroof Maintenance**

Greenroofs may be designed to be low maintenance, but not no maintenance. Requirements are dependent on the roof's function, desired look, and local climate.

### ***Watering Requirements***

Initial watering for the first few seasons is necessary for plant establishment, and there must be a water supply nearby. Irrigation systems are optional. Elaborate systems can be placed under the drainage layer. More simple and inexpensive systems can be created by using drip irrigation or even a hose if practical. Ecological options are also available for powering irrigation systems by using solar energy for both active and passive irrigation.

Passive irrigation refers to the process of storing rainwater in the form of ponding across a membrane or drainage layer. Some of this water eventually wicks back up through the planting medium, while the excess is allowed to drain off. Single-layer systems may use polypropylene filter fabrics under vegetated mats as a water storage medium.<sup>3</sup>

A truly self-sustainable active irrigation method uses cisterns for rainwater catchment. These systems can be set at roof or ground level, using solar panels or cells to power the irrigation process.

### ***Semi-Annual Maintenance Inspections***

Every roof needs to be checked periodically, and greenroofs are no exception. It is recommended that owners at least perform semi-annual maintenance reviews, at which

time they can look for problems such as invasive weeds, disease, and stray tree seedlings.

On-site maintenance staff can perform the inspections. Alternatively, owners can enter into yearly contracts with a landscape contractor. In any case, no matter how low-growing and drought tolerant, plants are still living, breathing beings, and should be cared for and monitored.

### ***Fire Prevention***

Fire prevention is also a concern. It is important to ensure access to an adequate supply of water in case of fire, which can occur in any type of building.

In addition, it is important to choose plants that are inherently non-flammable (such as succulents or others that store water), while staying away from ornamental grasses and certain mosses that could become kindling material in extremely dry conditions. Succulent plants and a high-inorganic growing media can actually act as a fire barrier.

Make sure that the greenroof has a 12- to 36-inch vegetation-free zone around the perimeter and edges of roof protrusions -- both for a fire break and to allow sure-footed access to the roof by firefighters. Materials used in the perimeter can include crushed gravel, pebbles, or concrete pavers.

### **Greenroof Cost Issues**

In Germany, greenroof costs are relatively low (about \$4 to \$13 per square foot) because the country has an established greenroof market and economic incentives. Prices in North America for extensive greenroofs commonly range from \$10 to \$25 per square foot (including roofing membranes, which are the most expensive component of any roof). Intensive greenroofs can cost from \$25 to \$100 per square foot, or more.

But every project is unique, and there are creative ways to lower the cost. Economy of scale is also very relevant here. For example, the Ford Motor Company River Rouge Plant greenroof in Dearborn, Michigan came in around \$4 per square foot. This extensive greenroof measures over 450,000 square feet and has an extremely thin growing



medium of one inch. In this case, vegetated mats of nine sedum varieties were used.

Generally, residential applications can be more expensive. On the other hand, a design-build service called Hadj Design in Seattle can consult, design, and install residential greenroofs, from the roof deck through planting, for budgets as low as \$9.00 per square foot.

In any case, since the public welfare is at stake here, this is not an arena where the common contractor practice of "value engineering" is acceptable. High standards of design, materials, and installation are essential for quality control.

### **Greenroofs: Eco-Friendly Architecture at Any Scale**

Buildings designed for sustainability are rapidly gaining public and private acceptance the world over and are setting the architectural standard for the future. Greenroofs play an important role in promoting sustainable design.

There are numerous greenroof application types. Listed below are just a few greenroof project examples:

#### ***Governmental Projects***

- Toronto City Hall has a demonstration greenroof of eight plots covering 3,200 square feet (installed 2000).
- The Pentagon's Renovation Project includes the Remote Delivery Facility and the LEED-certified Athletic Center, both with greenroofs (2001).
- Chicago City Hall's greenroof measures 20,300 square feet (2001);
- Seattle Justice Center greenroof: 8,500 square feet (2002);
- Seattle City Hall greenroof: 13,000 square feet (2003);

- Multnomah County, Oregon's Multnomah Building greenroof: 12,000 square feet (2003);
- Atlanta City Hall greenroof: 3,000 square feet (2003).

### ***Commercial Projects***

- An 8,000-square meter intensive greenroof atop MAG-Galerien in Geislingen, Germany, covers a huge shopping mall and is used as a public park (installed 2001).
- Soldier Field, home to the Chicago Bears, is a 5.5-acre intensive greenroof over a parking garage (2003).
- The Banco Santander in Madrid is a multi-use intensive megastructure that measures approximately 1,100,000 square feet (2004).
- Millennium Park in Chicago ties with the Madrid project (noted above) as the largest intensive greenroof in the world, at a whopping 24.5 acres or 1,067,000 square feet (2004).

### ***Industrial Projects***

- In 1992 ECOVER designed and built what they refer to as "the world's first ecological factory" in Oostmalle, Belgium. It includes an extensive greenroof of 5,000 square meters, or about two acres.
- Ford Motor Company's River Rouge Plant in Dearborn, Michigan (2003), at 454,000 square feet, used to be the largest greenroof in North America, prior to construction of Millennium Park. Certainly it still is the world's largest *extensive* greenroof.

### ***Corporate Headquarters***

- The 69,000-square foot GAP headquarters in San Bruno, California has won numerous awards for its undulating roofs, which mimic the surrounding hills (1997).
- Ducks Unlimited national headquarters near Winnipeg, Canada: two greenroofs totaling 28,190 square feet (2002).

- ZinCo International, located in southern Germany, is one of several German greenroof manufacturers with impressive large headquarters. Every single building at ZinCo headquarters is greened, and the campus contains 12 extensive greenroofs, with some dating from the 1970s. In addition, a new highly stylized intensive greenroof was completed in 2003.

### ***Airports***

Numerous airports in Europe, including those in Amsterdam (AMS), Frankfurt (FRA), and Zürich (ZRH), have greenroofs that cover millions of square meters.<sup>4</sup>

### ***Hotels***

The Royal York Fairmount Hotel in Vancouver, Canada has a greenroof that houses a culinary garden of native and exotic herbs and vegetables for guests. The operators of the hotel estimate that they save \$30,000 (Canadian) a year, while providing organically and locally grown specialty herbs for their restaurant (project installed in 1997).<sup>5</sup>

### ***Medical/Health Care Facilities***

- The 6,000-square foot Life Expression Wellness Center, located in Sugar Loaf, eastern Pennsylvania, has a curving extensive greenroof (2001).
- Chicago's Schwab Rehabilitation Hospital has an intensive 10,000-square foot rooftop park and garden for horticultural therapy (2003).

### ***Single-Family Residential***

- The leader in residential greenroofs is Patrick Carey of Hadj Design in Seattle, who is also the director of the Northwest EcoBuilding Guild. Together, they are responsible for at least 30 projects in the Pacific Northwest, ranging from car ports and chicken coops to house additions and new residential structures (projects installed from 2001 to the present).
- I have completed a small urban residential project (670 square feet) in downtown Atlanta on a loft

covering a converted warehouse in a historic district (2001).

### ***Multi-Family Residential***

- The Hundertwasserhaus Plochingen (the Hundertwasser Multi-Family Development) is situated near Stuttgart, Germany in a live-work-play development. The development contains more than 50 greenroofs, including a Gaudí-inspired private, lush courtyard intensive greenroof situated over a supermarket, designed by the famous architect Hundertwasser (1994).
- The Hamilton Condo Apartments have an 8,500-square foot extensive greenroof atop their one-story building in Portland, Oregon (1999).
- The Gold LEED-rated Solaire Building in New York City was the first green residential high-rise in North America, with a 5,000-square foot intensive greenroof on top and a 4,800-square foot extensive greenroof on the 28th floor (2003).

### ***Educational/Research Institutions***

- Schule Unterensingen, a K-12 school near Stuttgart, Germany has over ten separate greenroofs totaling approximately 15,000 square feet, located atop every building and covered walkway; 200 solar panels and an extensive greenroof grace the top roof of this large school (2002).
- Numerous university test plots exist, especially in Europe. In North America these include: Laval University and the British Columbia Institute of Technology in Canada, the Autonomous University of Chapingo in Mexico, Penn State, Michigan State, North Carolina State, Carleton College, the University of Georgia, and the University of Vermont.
- The Peggy Notebaert Nature Museum in Chicago has 17,000 square feet of extensive and intensive greenroofs (2003).

### ***Nature Centers***

The Coffee Creek Center in Chesterton, Indiana, a mixed use development, sports a greenroof over the Visitors' Pavilion (2000).

### ***Religious Institutions***

Over eight acres of intensive greenroofs cover the Church of Latter-Day Saints Conference Center in Salt Lake City, Utah (2000).

### ***Parking Facilities***

- Jacobs Island is a 6000-square meter landscaped intensive greenroof located atop an underground parking garage in the center of residential London (1997).
- A large extensive pilot project greenroof was constructed over a multi-story carpark in Singapore (2003).
- The new 750-car Ram's Head parking garage at the University of North Carolina will soon be covered by a large intensive greenroof (in progress).

### ***Greenroof Industry Support in Germany***

The greenroof industry is well established and supported in Germany, where greenroofs represent approximately seven percent of all new roof construction, and where more than one billion square feet of greenroofs have been installed since the late 1980s.<sup>6</sup> According to the UK organization English Nature, 13.5 million square meters of greenroofs were installed in Germany in 2001 alone.<sup>7</sup>

Many direct and indirect subsidies exist to help defray higher up-front costs. For example, the federal state of Nordrhein Westfalen offers grants of €15 per square meter of greenroof. Munich pays \$3.13 per square foot, up to 50% of capital costs.

Approximately 30 German cities have zoning districts requiring greenroofs, especially for flat roofs on industrial buildings. Currently, about 30 percent of all German municipalities support greenroofs. Many use them as

"compensational greenspace," with 70 percent currently offering direct subsidies.<sup>8</sup>

Established professional associations in Germany have developed interest in greenroofs and supported the market. Within the past 25 years, leading the way has been the Forschungs-gesellschaft Landschaftsentwicklung Landschaftsbau e.V. (Landscape Development and Landscape Construction Research Society, or FLL).

FLL by-laws and rules address issues relating to fire, wind, and uplift, as well as energy savings and the prevention of accidents. The most recent 2002 edition of their publication "Guideline for the Planning, Execution and Upkeep of Green-Roof Sites" is available in English. It is regarded as the standard within the industry.

## **North American Greenroof Resources**

### ***Organizations and Professionals***

Currently, some large advocacy groups based in North America are working to further the greenroof momentum. These include:

- the membership-based Canadian Green Roofs for Healthy Cities, which presents the annual Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show, now in its third year, and
- New York's Earth Pledge Foundation, which devotes an entire sub-organization to greenroofs, GreeningGotham.org.

There are also numerous smaller non-profit groups, including, among others:

- the Northwest EcoBuilding Guild in Seattle,
- Ecoroofs Everywhere in Portland, Oregon, and
- D.C. Greenworks in Washington, D.C.

Many individual professionals, company principals, and organizations offer greenroof conferences, training, and workshops.

Professional organizations such as the American Society of Landscape Architects (ASLA), the American Institute of Architects (AIA), and the Construction Specifications Institute (CSI) also are becoming involved as the popularity of greenroofs increases. In fact, the ASLA is currently completing the design of a proposed 3,300-square foot greenroof atop their headquarters in Washington, D.C.

### ***Greenroof Projects Database***

Integrated design is essential for delivering a cost-effective green building. My company, Greenroofs.com, believes this philosophy should also extend to disseminating and sharing information. The emerging greenroof market needs a comprehensive global reference source for greenroof projects.

We are working to catalog, maintain, and present greenroof case studies in one central location -- the Greenroof Projects Database. We have issued an open invitation for international collaboration among individuals, greenroof manufacturers, architects, researchers, students, governments, businesses, organizations and associations, inviting them to share their project profiles with our online community.

### ***ASTM's Green Roof Standards Task Group***

In 2001, ASTM International (formerly known as the American Society for Testing and Materials) established a Green Roof Standards Task Group to focus on providing national standards for greenroof technologies.

Current studies are evaluating a general standard practice for the greenroof industry, as well as several specific topics: lightweight media; plant selection, installation, and maintenance; dead and live loads; other components; and terminology.<sup>9</sup>

### ***Greenroof Grant Sources***

Sources for possible greenroof grants include various federal, state, and local agencies. Several greenroof projects have received funding through the United States Environmental Protection Agency's (EPA's) Clean Water Act

Section 319 program, which addresses nonpoint source pollution. One recipient was the extensive 30,000-square foot Montgomery Park Business Center greenroof project in Baltimore, which also received a grant from the Maryland Department of Natural Resources.

When seeking grants, it is important to: know your local resources; be able to explain how greenroofs can contribute to addressing the major ecological challenges facing most cities; and be a creative grant application writer.

### **The Future of Greenroof Development**

Extensive research within the field of greenroofs, the start of technical information dissemination about roof system performance, and case study reviews of existing greenroof projects are beginning to educate the general public and increase understanding among the various stakeholders about the fundamental requirements of successful greenroof performance.

One serious barrier to greenroof adoption -- and to green building in general -- is that the long-term savings which such projects can generate are not usually factored into construction and renovation budgets. Budget decisions typically are made on an "initial cost" basis (i.e., what it costs to build or renovate a building) rather than on the basis of "life cycle costs" (how much initial decisions on construction or renovation could cost or save over the 30- to 100-year life of a building).<sup>10</sup>

In North America, we need new regulatory code and ordinance provisions that promote greenroofs, as well as more voluntary economic assistance in the form of subsidies, matching grants, tax benefits, and other incentives. Such forms of support can help reduce capital costs and encourage a range of stakeholders to embrace the greenroof concept.

Just about everyone understands that greenroofs are an ecologically friendly form of architecture, but potential adopters also need to consider the bottom line. Demand and economies of scale dictate greenroof pricing. As demand increases and more projects are constructed, a greater supply side industry will develop. I feel confident that,



as this occurs, overall prices will fall to a level that is more affordable across the board.

To a lesser degree, we still need to educate our clients and the public in general about the benefits and possibilities of greenroofs. We also we need continued leadership from both the private and public sectors. Currently, many government agencies mandate LEED™ Certification as a minimum requirement, and others encourage LEED™ Silver as a goal. However, neither LEED™ nor any other system has yet been adopted government-wide.

The greenroof concept is not just for environmentalists and "tree huggers." It also must appeal to professionals, public officials, and community leaders. Greenroof advocates thus support continuing education for professionals and continuing standard development for greenroof products and installation in North America.

Many greenroof proponents are also calling for a set of international guidelines and measures, as well as new strategies aimed at convincing more governments about the benefits of greenroofs.

### **A Greener Vision for the Third Millennium**

From Hobbit-inspired dwellings to city halls, airports, and big-box mega shopping structures, greenroof architecture promises to become part of a global environmental framework of sustainable design. Greenroof technology offers a viable roofing alternative, and can serve as an appropriate tool for addressing our urgent urban ecological development needs.

Individual greenroofed structures may inspire others, but can one or two make a major impact on healing the environment? Perhaps not. But when viewed as potential infrastructure from a city planning viewpoint, greenroofs used on a meso-scale offer many attractive benefits and opportunities.

Even on a small scale, a greenroof that helps make one building more environmentally responsible allows the owner to send a message to others. It says: We are interested in goodwill, conservation, and sustainability.

In this third millennium -- the 21<sup>st</sup> century -- environmentally responsible innovation is multi-cultural and multi-disciplinary. It must cross all boundaries of place, profession, and politics. In the design process, respecting site topography and ecosystems is not just the job of landscape architects. Creating a beautiful, clean, and healthy building is not just the responsibility of architects. And promoting sustainability in design, buildings, lifestyles, and communities is not just the task of city planners and government officials.

Architecture and landscape architecture are about more than just buildings and land. They are also about the people, plants, and animals that live there.

If we can make our cities healthier by designing sustainably, they will become places where people will want to live, play, and work -- and economic growth will follow naturally.

Green design need not hinder economic development. Instead, beauty and sustainable design can inspire creative and forward-thinking developers who might actually drive further competition.

Designing with greenroofs offers an ideal architectural union of aesthetics, economics, and ecology. Architect Patrick Carey states that "greenroofs are the greenest thing one can do in construction except not to build at all."<sup>11</sup>

So we can continue to design in disregard of nature and consider Earth a commodity, or we can view our planet as a community, and design with nature. Barren rooftop or greenroof? The choice is ours.

### **Correction**

In my article entitled "Organic Greenroof Architecture: Sustainable Design for the New Millennium," which appeared in the summer 2005 issue of this journal, the caption for Exhibit 2 should have noted that the figure was adapted from Bruce K. Ferguson's *Introduction to Stormwater: Concept, Purpose, Design* (John & Wiley & Sons, 1998).

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#### **Sidebar Quote**

"We do not inherit the earth from our ancestors; we borrow it from our children." André Gide

## Notes

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- <sup>2</sup> Chuck Friedrich, personal communication, January 23, 2004.
- <sup>3</sup> Wark, C.G., & Wark, W.W. (2003, August). Green Roof Specifications and Standards. *The Construction Specifier*, 56(8). Available at [http://www.greenroofs.com/pdfs/newslinks-803\\_construction\\_specifier.pdf](http://www.greenroofs.com/pdfs/newslinks-803_construction_specifier.pdf)
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<sup>10</sup> Office of the Federal Environmental Executive (2003, September). The Federal Commitment to Green Building: Experiences and Expectations. Available at [http://www.ofee.gov/sb/fgb\\_report.pdf](http://www.ofee.gov/sb/fgb_report.pdf)

<sup>11</sup> Patrick Carey, personal communication, February, 21, 2005.