Organic Greenroof Architecture: Sustainable Design for the New Millennium

Making the most of your building's "fifth façade"

Environmental Quality Management/Summer 2005

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High-performance buildings, green design practices, and sustainable technologies are becoming increasingly important influences on architectural practices around the world. They are even beginning to influence standards within the construction industry.

Encouraged by growing interest and demand on the part of both the public and private sectors, multidisciplinary professionals -- from architects to environmental managers, from engineers to landscape architects and beyond -- are redefining the way we look at design and examining our environmental impacts on the Earth with an integrated, holistic approach.

Green Building. Green Architecture. Green Roofs.

“Green” anything nowadays is a hot topic and a buzzword -- sometimes wholeheartedly embraced, other times politically charged, sometimes even scoffed at. But perhaps this design adjective should be accepted simply as a common-sense approach and an indication of respect for both our natural and built environments.

But what constitutes "building green," and what does sustainability mean in the context of building design? In the United States, the Office of the Federal Environmental Executive defines green building as "the practice of (1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and (2) reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal -- the complete building life cycle.”[1]

The simplest definition of sustainability is design that meets the needs of the present generation without compromising the ability of future generations to meet their needs.

Noted green architect William McDonough asks us to imagine building structures that not only do not hurt the environment, but that contribute positively to ecosystems, and possibly even help heal disturbed landscapes.

The use of greenroofs on commercial buildings can help further the goal of maximizing the eco-friendliness of the built environment.

About this Article

This article presents an overview of the greenroof concept. Included is discussion of the history of greenroofs -- which, though relatively modern in their present form, are rooted in ancient vernacular architecture and in the innate human desire to connect the built environment with nature.

I discuss basic greenroof technologies, and explain some of the key ecological, economic, aesthetic, and psychological advantages that greenroofs offer to both users and owners.[2]

Global Concerns Drive the Search for Green Solutions

Several issues of global environmental concern have been driving a new "greater green." Factors such as global warming, air and water pollution, population growth, and loss of habitat and biodiversity have contributed to the call for improved environmental design.

In a 2001 "Special Report on Global Warming," *Time* magazine noted that the global mean temperature is expected to rise between 2.5ºF and 10.4ºF over the next 100 years. The United Nations weather agency recently stated that Earth's average temperature in 2001 was the second highest recorded since global records began 140 years ago.

The Kyoto Protocol, which is aimed at slowing global warming by reducing human impacts, went into effect in February 2005. The Protocol commits 35 industrialized countries -- the U.S. not among them -- to reducing their emissions of six greenhouse gases (principally carbon dioxide) to five percent below 1990 levels by 2012.

Some other indicators of environmental stress include the following:

- The U.S. Census Bureau reports that at midyear 2002, the global population reached 6.2 billion. The United States alone will be home to 420 million people by 2050, or 140 million more than in 2000.[3]
- Humans now consume natural resources 20 percent faster than nature can renew them.
- Use of fossil fuels increased by almost 700 percent between 1961 and 2001.

- Populations of land, freshwater, and marine species fell on average by 40 percent between 1970 and 2000.[4]

- Impervious cover has become a signature effect of contemporary land use. Our paving of open land and speculative development patterns resemble an urban equivalent of the "slash and burn" clear-cutting techniques that are still so prevalent in forestry and agriculture.

- As a result of our land use practices, we have developed over-stressed sewer systems and urgent stormwater management problems.

In an era when developing clean and renewable energy strategies and addressing ever-increasing energy consumption rates are so crucial to our economic and ecological future, it is clear that we need to fully examine eco-friendly alternatives that also make economic sense in order to truly create a sustainable world.

Global Answers Include Sustainable Greenroof Architecture

Greenroofs are not a panacea for our environmental construction ills. Nor should any one single design component carry that burden. The beauty and promise of sustainable architecture and design lie in the integration of roof, building skin, interior, site location, and overall building design.

But viewed as one layer of a green building strategy, greenroofs can play an important role. They can:

- reduce ambient air temperature, energy use, and utility costs;

- help cleanse the air and water;

- utilize local and recycled materials;

- extend the life of the roof;

- improve aesthetics; and

- create greenspace for humans and wildlife while providing a psychological and physical respite from urban surroundings.

What Is a Greenroof?

What exactly constitutes a greenroof? Greenroofs are simply vegetated roof covers constructed atop and across a roof deck. They sometimes are called ecoroofs, sky gardens, even skyrise gardens. As living roofs, they contrast starkly with the average inert, hot, barren roof.

The greatest potential of greenroofs lies in their capacity to cover impervious roof surfaces with living, breathing, permeable plant material. Greenroofs are healthy, sustainable, and regenerative roof landscapes that can help protect our environment by diminishing developmental impacts on our communities. They are one sustainable design element in the palette of today's ecological designer.

Integrated Living Roofs

Integrated design is essential for delivering a cost-effective green building. Successful practitioners have come up with ways to get the whole team collaborating effectively and thinking outside the box. Not only are they delivering green projects within conventional building budgets, but many are doing it for a conventional fee.

As designers and community and business leaders, we can choose to mitigate the many negative effects of a building's footprint by incorporating various green design principles. As an alternative to imposing our built structures onto the land without considering the function of under-used roof surfaces (beyond waterproofing), we can incorporate organic greenroof architecture as a way of designing with nature to evoke displaced landscapes and restore a measure of greenspace.

Imagine looking down from an airplane with a bird's eye perspective. Instead of seeing huge expanses of concrete or black tar roofs imposing themselves on the natural environment, you see moving stands of flowering, multi-colored plants.

The roof now blends into the landscape as a naturalistic meadow scene. Or designed gardens and parks create a new "fifth" façade for human recreation with flowering shrubs, trees, and vegetated spaces.

These scenarios are technologically possible, and greenroofs do not require particularly high-tech design. It is important to understand, however, that these are engineered systems consisting of various material layers which must work in tandem to perform correctly.

A Quick History of Greenroofs: From Ancient Mesopotamia to the 21st Century

Combining plants with architecture is not a new idea, and neither are greenroofs. Since early recorded times, natural and created landscapes have been integrated into the urban fabric.

Designed elevated greenspaces have existed as long as humanity has been concerned with architecture. Manipulating our living spaces logically also includes using natural areas and garden designs as artistic expressions and a way to connect back to nature.

The sloping walls of the Ziggurat of Nanna, built around 2100 B.C., were covered with trees and shrubs. The fabled Hanging Gardens of Babylon, which included lush roof gardens and terrace greening, represent the earliest known interpretations of roof greening, built between the 8th and 10th centuries B.C.

Earth-sheltered huts dating from the Viking era have been found in Ireland and Scotland. In addition, around 1000 A.D., sod-covered roofs were used in Iceland and Scandinavia. Later on, early 19th century settlers in Canada and the northern United States introduced grass roofs.

"Garden cities" have been developed from Persia to Renaissance-era Paris, and later from Russia to Berlin, London, and New York. Modernist architects such as Le Corbusier, Frank Lloyd Wright, and Roberto Burle Max promoted the benefits of roof gardens, and incorporated them into the fabric of their designs. Still-successful modern greenroofs from the 1930s include the five famous Rockefeller Roof Gardens in New York, and the Derry and Tom's Garden in London (the modern Kensington Roof Gardens).[5]

Greenroofs today can be found throughout Europe and around the world. But the development of greenroofs from an expression of vernacular architecture to a viable sustainable construction roofing alternative took place in modern Germany. There, greenroofs have evolved through trial and error, the repeated testing of materials, and ultimately the development of industry standards and codes. It is estimated that Germany now has over 800 greenroof projects.[6]

Modern Greenroof Pioneers in Germany and North America

True modern greenroofs were introduced in Germany in the early 1970s by manufacturers, landscape architects, and university researchers. In 1971 Gerda Gollwitzer and Werner Wirsing outlined the principles of modern greenroofs in their book entitled *Roof Areas Inhabited, Viable, and Covered by Vegetation.* Hans-Joachim Liesecke outlined the basis for intensive greenroofs in his 1972 report entitled Dach und Terrassengärten [Roof and Terrace Gardens]. Others followed, notably Kolb, Hans Luz, Hans Kienle, and Bernd Krupka.

Acceptance of greenroofs in the European marketplace came in the 1980s, when systems were enhanced through use of reliable root barriers and sophisticated forms of buildup that guaranteed safety and a long lifespan. Credit for many of these developments goes to the German greenroof companies ZinCo, optima (now split into two companies, optima and Optigrün), and Bauder. They were the pioneers of modern greenroof technology, especially with regard to root resistant bituminous waterproofing.

Pioneers and proponents of greenroofs in North America from the early 1990s include Tom Liptan, ASLA, of the City of Portland, Oregon; Charlie Miller, P.E., of Roofscapes, Inc.; Katrin Scholz-Barth, a civil and environmental engineer; and especially two prominent veteran landscape architects from the sphere of traditional roof garden design -- Cornelia Hahn Oberlander, FCSLA, FASLA, in Canada, and Theodore Osmundson, FASLA, in the United States.

Two Greenroof Types: Extensive and Intensive

Greenroofs are vegetated roofs with engineered soil (also known as the substrate or growth media) and plants layered above a concrete, wood, or metal roof deck. They can substitute for gravel, shingle or tiles. Imagine a roof lasagna-like assembly with a meadow on top.

The bottom line is that the plants are planted directly onto the roof, not just in containers. The layers vary from system to system, and certain elements vary in their placement above the roof deck. At the very least, however, all greenroofs include waterproofing (single or multi-ply), drainage, soil, and plants.

Over the past 35 years, sound German engineering, technology developments, and testing standards have led to greenroof systems that range from virtually maintenance free to quite elaborate.

There are two main types of greenroofs -- extensive and intensive (also referred to as low-profile and high-profile); the names indicate maintenance requirements. The two designs can also be combined.

The type of greenroof that is appropriate for a given application must be determined by the site owner and designer, with a view to how the roof is to function. Greenroofs can be used successfully in both new and retrofit construction. They are limited only by the slope or pitch of the roof, existing load requirements, and budget factors.

See **Exhibit 1** on the following page for a chart describing the differences between extensive and intensive greenroofs.

Extensive vs. Intensive Greenroofs

Low-Profile/ Ecoroofs	High-Profile/ Roof Gardens
• Low growth media: 1" – 6"	• > 6"-15' and deeper
• Lightweight: 12 – 50 lbs/sf	• Heavier weights: 50 lbs/sf +
• Low growing plants: 1"– 24" H	• Trees, shrubs and more
• Less variety of plants: Alpine types, succulents, herbs, some grasses and mosses	• Huge variety of plant selection, depending on loads, design & budget
• Usually non-accessible	• Designed for human recreation
• Slopes up to 30° & higher	• Relatively flat
• Less expensive: $12-$25/sf	• More expensive: $25-$40/sf +
• Low water requirements	• Irrigation usually necessary
• Low maintenance	• Higher maintenance

Extensive Greenroofs

Extensive greenroofs employ fewer and thinner build-up layers, and thus are lighter and less expensive systems. They are used when the owner primarily desires an ecological roof cover with limited or no access for recreation. Less growth media is used, and the appropriate plants are low-growing, hardy Alpine types.

Plants for extensive greenroofs must be tolerant of high heat, drought, wind, and frost. They must also be self-regenerative in nature, and have low maintenance requirements overall.

Media depths range from one inch up to about six inches. A popular misconception is that a flat roof is ideal, but in fact flat roofs present drainage issues. Ideally the roof should have a gentle slope of at least 1.5 - 2% to allow for natural drainage properties. Generally, extensive greenroofs can be installed on slopes of up to 30°, although there are greenroofs with 40° slopes. Reinforcement will be necessary at steeper pitches using cross battens or underlying grid structures to hold the plants and engineered soil in place, as well as to deal with wind shear.

Roofs with strong wind uplift or with slopes 15° and higher should be protected during establishment with an erosion control net in the form of jute or other natural biodegradable fiber.

Intensive Greenroofs

Intensive greenroofs look more like a traditional roof garden. They can incorporate a much wider variety of plants (such as flowering shrubs, vegetables, and even trees) because the substrate depths can be designed to be as deep as the designed roof load will support. Depths start at about six inches up to 15 feet.

The main difference between a roof garden and an intensive greenroof is that a greenroofing system is applied on top of the entire roof deck surface, allowing unimpeded drainage and a more even weight distribution over the whole roof.

Architectural accents -- such as waterfalls, ponds, seating areas, and the like -- can be part of an intensive greenroof system. Such roofs can provide recreation areas where people can interact with nature and with one another. These systems can take advantage of otherwise forgotten (and usually ugly) rooftop space by creating active areas for contemplation and play.

The Advantages of Greenroofs

Loss of greenspace and its inherent natural processes are by-products of our modern "asphalt jungle." Plants and engineered soil atop a greenroof enhance the environment through the natural processes of evapotranspiration and photosynthesis, thereby ameliorating the surrounding ecosystem.

The specific benefits of (and market drivers for) greenroofs run the gamut from easing environmental stress to creating an eco-friendly corporate image to reestablishing endangered bird species. The following sections discuss the advantages of greenroofs in more detail.

Environmental Benefits

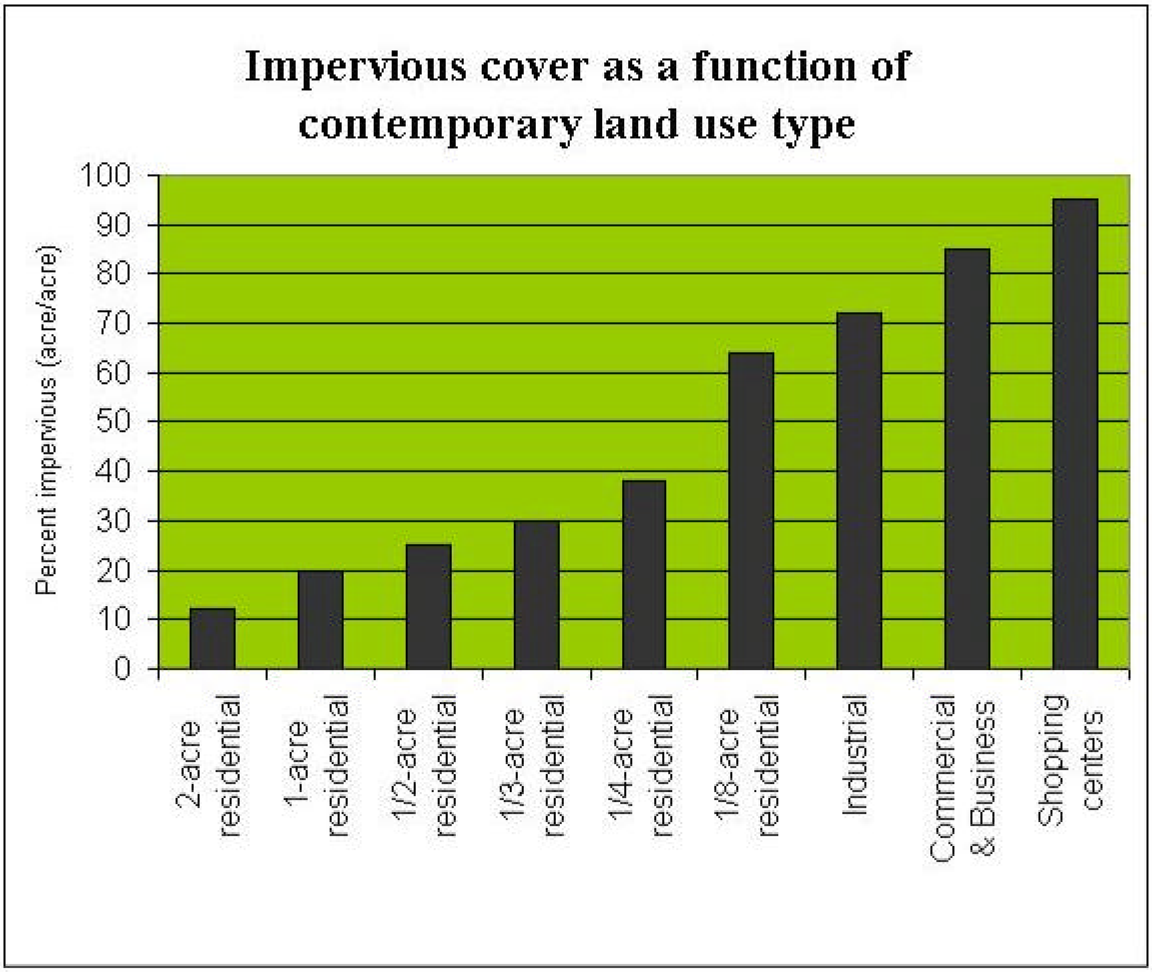
Stormwater Management

Greenroofs reduce stormwater volume and slow down water flow, thus helping to alleviate the pressure on stormwater infrastructure systems.

Many large, older U.S. cities (such as New York, Philadelphia, and San Francisco) have combined sewer systems where wastewater from storm drains and sewage pipes is intermingled. During heavy rains, runoff from impervious surfaces such as rooftops and pavements can cause overflow in already over-burdened systems, resulting in contamination of lakes, rivers, and other freshwater sources. **Exhibit 2** shows the percentage of impervious cover that is typical of various contemporary land use types.

Greenroofs capture and retain huge amounts of water that otherwise would go down the storm drains, absorbing anywhere between 50 to 95 percent of the rain that falls on site. Factors affecting retention rates include the intensity of the storm, depth of media, and plant mass.

The intelligent use of best management practices (BMPs) includes greenroofs that intercept and delay rainfall runoff and reduce the peak flow rate. These practices can result in significant environmental improvements, as well as long-term savings to building owners and municipalities.



Redrawn from Bruce Ferguson's "Introduction to Stormwater: Concept, Purpose, Design," 1998.

Water Quality Improvement

Greenroofs also filter and cool water runoff. They can help prevent nitrogen, phosphorus, and toxins from entering streams and waterways. Heavy metals and nutrients found in stormwater are bound in the engineered soil of the greenroof instead of being discharged into groundwater or streams and rivers.

Greenroofs can remove over 95 percent of the cadmium, copper, and lead, and 16 percent of the zinc, from rainwater. They can also substantially reduce nitrogen levels.[7]

Coastal cities such as Seattle and Portland, Oregon, have experienced warming of the water in their rivers and bays resulting from discharge of heated stormwater. This temperature change can greatly affect the health of cold water fish populations, such as salmon.

Greenroofs can help counteract this effect. They act as a sponge, absorbing the majority of rain that falls on site. The remaining water that does eventually run off is filtered and cooled through evapotranspiration made possible by the plants and engineered soil medium.

Heat Mitigation

In natural landscapes, vegetative canopy biomass greatly lowers air temperatures. By contrast, the artificial and altered surfaces common in urban land- and roofscapes greatly raises them. Average city rooftops can easily reach 150 to 175°F in the summer.

In urban areas, tightly sealed surfaces -- such as asphalt and concrete in parking lots and on rooftops -- soak up heat during the day and then reradiate it back into the Earth’s atmosphere after sunset as thermal infrared radiation.

This creates an urban "heat island" effect, with the heat that is released at night forming a dome of higher temperatures over the city. The temperature in downtown Atlanta, Georgia, for example, often is 10°F warmer than that of the surrounding outlying areas. Urban heat islands contribute to our growing global warming problem, and can also affect the local weather by creating unproductive convective thunderstorms.

Used on a large scale, greenroof infrastructure could help reduce the urban heat island effect by lowering ambient air temperatures. A 2002 study in Toronto by Environment Canada estimated that urban temperatures could dip by 1 to 2°C if just six percent of the city’s roof tops were green.[8]

Chicago has adopted an energy conservation ordinance that includes an urban heat island reduction provision. The ordinance, which became effective in June 2002, includes minimum standards for solar reflectance and emissivity as set by the International ASTM (formerly known as The American Society for Testing and Materials). The ordinance requires all new and refurbished roofs to install greenroofs or reflective roofing.

Air Quality Improvement

In urban downtown areas, ventilation is sometimes inhibited by tall buildings, which reduce wind speed and trap heat in air pockets. Pollutants can remain suspended for days.

Greenroofs can filter and bind dust particles, and naturally filter airborne toxins. Smog, sulphur dioxide, carbon dioxide, and other pollutants are absorbed and filtered through the foliage, naturally cleansing the air. Atmospheric dust is held until rain washes it off into the greenroof soil substrate.

Greenroofs can also help mitigate the ozone problem in urban areas by reducing the heat island effect, which contributes to ozone creation. In Atlanta, the heat island effect doubles the amount of ozone that is produced.

Studies have shown that an increase in ozone levels adversely affects sufferers of asthma and other breathing conditions. Increasing vegetated areas, including greenroofs, can greatly improve air quality.[9]

Erosion and Sedimentation Control

Greenroofs can help protect watersheds and sewer systems. They act as erosion barriers by reducing stormwater volumes, and assist in the control of sediment transport and soil erosion. Plants and media properties (friction, root absorption, and substrate matter) can prevent substances from entering a stream corridor or other body of water.

Wildlife Habitat Conservation, Creation, and Restoration

Although greenroofs are not intended to be replacements for natural areas located at ground level, they nevertheless can provide some habitat for wildlife. In a landscape ecological context, greenroofs create an artificial or man-made edge, while also serving as a vegetative habitat patch.

These greenroof patches, set within the matrix of a city, can accomplish several ecological functions. If multiple greenroofs were grouped and designed as vegetated corridors, some semblance of landscape connectivity could be achieved.

Such corridors could offer respite for migrating birds and butterflies. Studies show that birds will travel up to 19 stories, and butterflies up to 20 stories, above ground in search of food and cover.

Even in densely populated areas, greenroofs can attract beneficial insects, birds, bees, and butterflies. Such greenspace also can introduce or increase biodiversity into a highly urbanized setting. In the UK and Switzerland, for example, researchers are monitoring the levels of endangered bird, spider, and other invertebrate species which were found to have come back to the city after construction of greenroofs on previously disturbed sites.

Economic Benefits

Establishment of a thriving greenroof industry could have innumerable effects on the economy, including the creation of many new jobs in manufacturing, construction, and design, as well as in installation and other services.

Greenroof construction usually entails higher initial costs, but life cycle analysis reveals that these costs can be offset through extension of the life of the roof, avoided maintenance and replacement costs, reduction in cooling and heating costs, increased developable space, reductions in local impact fees, and the opportunity to take advantage of the amenity of greenspace at roof level.

Other economic benefits may be harder to quantify, but include acoustical insulation (resulting in noise suppression effects ranging from 8 dB up to 50 dB), glare reduction, decreased charges for stormwater infrastructure rehabilitation, and the goodwill and publicity generated from having a high-profile greenroof project.

Some of the key economic benefits of greenroofs are discussed in more detail below.

Increased Roof Longevity

Greenroofs in Europe have easily lasted from 40 to 75 years, or even much longer. Common theory holds that roof life can be at least doubled, and perhaps tripled or more, with a greenroof. The main reason for this is that the multiple layers protect the waterproofing membrane and structural elements from damaging ultraviolet rays, wind, and temperature fluctuation extremes.

In Europe, Japan, and North America, major greenroof providers will issue at least a 20-year assembly warranty and performance guarantee. In Germany, direct greenroof subsidies are available in about 30 cities. They range from $0.51 to $6.20 per square foot, based on avoided maintenance and replacement costs.

Reduced Energy Consumption and Costs

Thermally insulating greenroofs offer energy savings. Benefits vary by geographic region and type of system, but it is agreed that they can reduce peak energy demand by lowering cooling and heating needs, at least for the floor directly below the greenroof.

Some experts argue that some published energy reports have been exaggerated. They nevertheless agree it is impossible to issue blanket statements regarding energy savings for every region of the world, since many factors contribute to the figures. When estimating energy savings, it is essential to study each climate individually, using thermodynamic data.

That said, in December 2000, Weston Solutions design consultants conducted an energy study for the City of Chicago which estimated that it would be possible to save $100,000,000 in avoided energy costs annually with the greening of all the city's rooftops. The study's bottom line stated that "[p]eak demand would be cut by 720 megawatts -- the equivalent energy consumption of several coal-fired generating stations or one small nuclear power plant." Weston also declared that, in general, reductions of up to 50 percent of cooling costs and 25 percent of heating costs could be achieved, at least for the floor directly below the greenroof.[10]

A 2003 study commissioned by Seattle's Office of Sustainability and the Environment states that the Seattle Justice Center is saving as much as $148,000 each year due to its greenroof.[11]

Understanding how heat moves through a greenroof can be tricky, however. Engineer and energy modeler Chris Wark of Green Roof Innovations explains:

> Energy usage is reduced primarily due to the solar heat management of the foliage and thermal mass of the soil substrate (not the plants). Plant leaves transfer nearly all excess solar energy to the surrounding air and absorb the rest, while the soil mass provides an additional benefit of dampening temperature fluctuations. Leaf transpiration is one of the ways in which the solar heat is transferred to the air. If enough water is available, additional heat can be removed from the plant, but this is a minor effect with succulents. The fact that leaf temperatures of many different studied plants tends toward ambient air temperatures proves this. In most cases, a green roof comes with a heating penalty if any moisture is at all retained in the soil (and it is).

Chris and Wendy Wark have reported results from a study done on commercial buildings in Northern California using DOE-2[12] and a proprietary roof heat transfer model developed by their parent company, Shade Consulting. Their study indicated that an uninsulated greenroof could reduce the building heating/cooling system's demand for most of the year by 30 percent over a conventional dark roof with R-18 rigid insulation and without a radiation barrier.[13]

Increased Developable Space

Major cities that are embracing sustainable design have acknowledged the economic benefits of greenroofs and are helping to pass the savings they generate along to owners and builders. For example, city officials may reduce impervious coverage requirements for developers who incorporate greenroofs into their site plans.

Depending on local ordinances and applicable BMPs, officials may allow greenroofs to be installed in lieu of conventional stormwater management elements. Greenroofs can significantly reduce the required size of unsightly, space-wasting, and expensive retention ponds or underground galleries, or even completely eliminate the need for these elements.

In some cities, floor-to-area development ratios can also be increased. In Portland, Oregon, for example, builders can now increase their floor area ratio (FAR) when they include a greenroof that covers at least 60 percent of the roof surface. This FAR bonus grants an additional three square feet of floor area per square foot of greenroof, to be added to the footprint of the building.

The City of Chicago also increases development square footage, known as floor area premiums, when developments include public amenities such as greenroofs.

Reduced Local Impact Fees and Increased Incentives

Reduced stormwater and impervious cover fees, as well as energy credits, grants, and tax incentives for greenroofs, have been in place in European countries such as Germany, the Netherlands, Switzerland, and Sweden for decades. For example, some German municipalities offer stormwater fee reductions of 50 to 80 percent.

Cities in the United States and Canada are now beginning to offer incentives as well. Portland, Oregon plans to reduce stormwater utility fees for buildings with greenroofs by July 2006. The City's Clean River Incentive and Discount Program promotes placement of ecoroofs atop commercial, industrial, institutional, multi-family, and single family residential properties.

New York, Seattle, Chicago, Toronto, Vancouver, St. Paul, Atlanta, and several cities around Washington, D.C., are among those working toward reducing various fees in exchange for greenroof development.

Greenroofs as Stormwater Mitigation Measures

Greenroofs can sometimes be used as stormwater mitigation measures. In Portland, Oregon, all building projects that will result in at least 500 square feet (46 square meters) of impervious surface are required to implement stormwater pollution reduction and flow control measures. Greenroofs are recognized as one of the acceptable approaches to meeting this requirement.[14]

Greenroofs as Heat Island Measures

In a concerted effort to combat the ever-increasing urban heat island effect in Tokyo, the city's "Tokyo Plan 2000" was implemented on April 1, 2001. It requires new buildings that are larger than 1,000 square meters (10,000 square feet), or over one-quarter acre, to green at least 20 percent of their useable roof space.

Other countries considering these types of measures include South Korea and Singapore. In the U.S., cities like New York would also greatly benefit from such measures.

Increased Points in the LEED™ Rating System

The U.S. Green Building Council (USGBC) has developed and oversees the LEED (Leadership in Energy and Environmental Design) Green Building Rating System®, a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. The four levels of certification include LEED™ Certified, Silver Level, Gold Level, and Platinum Level. Greenroofs qualify for at least six points in three categories, and more points are possible under specific conditions.

Many local, state, and federal agencies have adopted sustainable design stipulations that adhere to LEED™ principles. For example, in 2000, the City of Seattle adopted its Sustainable Building Policy, which requires many new city buildings to attain a Silver LEED™ certification rating. The requirement applies to new and renovated city facilities that are larger than 5,000 square feet.

The General Services Administration (GSA), a federal agency, requires buildings to be certified through LEED™, and encourages them to achieve a Silver LEED. EPA requires Silver LEED™ certification for new significant building construction or acquisition. NASA encourages its designers to strive for a LEED™ Gold rating, if cost effective.[15]

Increased Building Marketability

High-rise apartments, office space, and even hotel rooms with the enhanced natural view afforded by greenroofs can support higher rents or room rates and help maintain increased levels of occupancy. Resale prices also increase with the added value of additional greenspace.

Emerging Synergy with Solar Power

Greenroofs can be successfully combined with solar power projects. In Germany, construction of such combined projects has generated significant interest.

Studies show that the cooler temperatures found on a greenroof enhance the performance of photovoltaics, while the greenroof buildup provides a steady base for solar installations.

Combining greenroofs with solar power not only will capitalize on the technologies' energy use reduction potential, but also will help create a renewable energy source -- all without utilizing more land.[16]

Aesthetic Benefits

The restoration and revitalization of our cities should include adapting exterior architecture to meet the desires of communities. Few people would deny that urban areas are enhanced with the natural beauty and soothing aesthetics of living roofs.

The sections that follow briefly detail some of the aesthetic benefits of greenroofs.

Visual Relief

Commercial and industrial roofs no longer need to be unattractive, harsh eyesores. With the addition of greenroofs, we can create pleasing, vigorous, sustainable native and naturalized plant communities.

Integration into Natural Surroundings

Greenroofs can help buildings blend unobtrusively into suburban areas or the open countryside. Overhead views could actually be camouflaged if the planting design mimicked its surroundings.

Varied Design Possibilities

Greenroofs can be designed in many different forms, and can be used on sloped or flat roofs. Some owners might want naturalistic landscapes that resemble meadows planted with wildflower drifts. Others might prefer wildly geometric plans.

Psychological Benefits

Recreating natural landscapes through greenroofs can create beauty that is soothing to our psyches. And in utilizing greenroofs, we also accomplish many other objectives that help fulfill our need for purpose.

Through greenroofing, we nurture the built environment and incorporate the tenets of high-performance building and environmentally preferable design. We help clean the air and water, and promote energy efficiency. We create ecologically sustainable sites. We make better use of cultural and natural resources and materials.

Some of the key psychological benefits of greenroofs are highlighted in the sections that follow.

Appealing to Biophilia

A connection to nature appears to be a part of our evolutionary heritage -- a concept that sometimes is called "biophilia."

Perhaps because of this connection, being able to view and experience nature is excellent for our mental heath. Therapeutic roof gardens are becoming popular in hospitals, care centers, and similar settings. Experiencing the change of seasons is life-reassuring.

Frederick Law Olmstead, who is recognized as the founder of American landscape architecture, once said, "Humans have physiological reactions to natural beauty and diversity, to the shapes and colors of nature, especially to green, and to the motions and sounds of other animals."[17]

Making Employees Happier

If you were working in a typical stark office environment, what would you rather look down onto -- a natural scene (such as a flowing riverscape or flowering meadow) or a dreary grey and black expanse of roofs?

Clearly, greenroofs have the potential to make workers happier by enhancing their surroundings. This in turn could improve business profitability since it has been theorized that enhancing the emotional or physical comfort of employees can increase productivity and lower absenteeism.

Greenroofs help visually ease the stress created by the lack of greenspace in urban buildings. Natural views reduce aggression and increase calm.

Fostering a Sense of Community

Greenroofs can create sustainable interactive community spaces where people can garden, visit, play, and relax together. They also offer opportunities for educating the public through displays and interpretive signage describing the greenroof design process.

Conclusion

With greenroofs, we can make the decision to design with nature, instead of against her. Greenroofs can help mitigate some of our most pressing urban development issues, while also allowing us to reap economic benefits through reducing various building-associated costs and promoting a growing design and construction industry. Organic greenroof architecture can actually help restore the health of Earth's ecology.

Next Time

In a followup article that will appear in a future issue of this journal, I plan to offer more detail on greenroof design and related issues.

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Notes

[1] 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

[2] Unless otherwise noted, all information cited in this article comes from either Greenroofs.com or the research of Linda S. Velazquez.

[3] U.S. Census Bureau (2004, March). Global Population at a Glance: 2002 and Beyond. Available at http://www.census.gov/ipc/prod/wp02/wp02-1.pdf,

[4] Data on resource consumption, fossil fuel use, and species depletion comes from The World Wildlife Fund's 2004 Living Planet Report. Available at http://www.worldwildlife.org/about/lpr2004.pdf

[5] English Nature (2003). Green Roofs: Their Existing Status and Potential for Conserving Biodiversity in Urban Areas. English Nature Research Report Number 498. Available at http://www.english-nature.org.uk/news/news_photo/Greenroofs.pdf

[6] 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

[7] Johnston, J., & Newton, J. (1993). Building Green: A Guide to Using Plants on Roofs, Walls and Pavements. London: London Ecology Unit.

[8] National Research Council Canada Press Release (2002, October 9). Government of Canada Reveals Major Greenhouse Gas Reductions and Air Quality Benefits from Widespread Use of "GreenRoofs." Available at http://www.nrc-cnrc.gc.ca/newsroom/news/2002/green02_e.html

[9] Duffy, K. (2004, April 18). NASA Studies How to Cool Area as Heat Builds Up. Atlanta Journal Constitution. Available at

http://www.ajc.com/news/content/business/horizon/0404/19pavement.html?urcm=y

[10] Urban Heat Island Initiative Pilot Project: Final Report (2000, May 9). Prepared for the City of Chicago by Roy F. Weston, Inc. (now Weston Solutions, Inc).

[11] Steinbrueck, P. (2005, January 13). Putting a Green Cap Atop the Emerald City. The Seattle Times. Available at http://seattletimes.nwsource.com/html/opinion/2002149359_steinbrueck13.html

[12] DOE-2 calculates the hourly energy use and energy cost of a commercial or residential building based on information about the building's climate, construction, operation, and utility rate schedule, and its heating, ventilating, and air-conditioning (HVAC) equipment.

[13] Chris Wark, personal communication, November 2004.

[14] Environmental Building News, 10(11).

[15] 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

[16] Alt, F. (2004, September 14). Future Oriented Technologies: Green Roofs and Solar Power. Presentation at the International Green Roof Congress 2004.

[17] Quoted in Dramstad, W.E., Olson, J.D., & Forman, R.T.T. (1996). Landscape Ecology Principles in Landscape Architecture and Land-Use Planning, Cambridge, Massachusetts: Harvard University Graduate School of Design.