Green on Top

Katrin Scholz-Barth

By combining stormwater management, energy efficiency, and urban ecology, green roofs present a unique business opportunity that can have tangible benefits for developers.

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More than half of the U.S. population now lives in coastal communities—roughly 141 million people—and the trend is growing. Seventeen of the 20 fastest-growing communities are located either entirely or substantially within 50 miles of the coast along the Atlantic, the Pacific, the Gulf of Mexico, the Great Lakes, and Hawaii. For more than two decades, it has been recognized that continuous urbanization and deforestation have resulted in major environmental problems for watersheds, estuaries, and coastal marine ecosystems. Caused by a complex chain of events, which vary from site to site, these problems are driven by the accumulation of nitrogen and phosphorus in fresh water on its way to the sea. Growing concern over the complexity of this very real environmental threat requires bold action on many levels—and developers are the first to feel the pinch when policies change or new ordinances are implemented, especially when it comes to stormwater runoff and its management.

The three most common sources of nutrient overenrichment in watersheds are urban stormwater runoff, discharge from septic systems, and atmospheric deposits. The many diffuse sources are collectively called nonpoint source pollution, which is carried and deposited into the country's watersheds. Nitrogen and phosphorus are the two most-tracked, nonpoint source nutrients that threaten the health of aquifer and surface water resources, as well as people and wildlife. As of 1996, nearly 14 percent of all nitrogen and 13 percent of all phosphorus nonpoint source pollution stemmed from developed lands.

As open space and undisturbed land are replaced with buildings and roads, and sealed with concrete and asphalt, these surfaces no longer allow water to infiltrate the ground. Dark rooftops and solid pavements absorb and store energy from the sun during the day and reflect it at night. This activity results in increased stormwater runoff; greater temperature differences between urban areas and open, undisturbed land (known as the urban heat island effect); altered weather patterns; and a loss of greenery in metropolitan areas.

Green Roofs in the United States

The view from the 15th floor of any hotel or office building in New York, Dallas, Atlanta, or other densely developed city most likely is of asphalt, concrete, or gravel rooftops that soak up and throw off heat in the summer, need frequent replacement or repairs, and during even mild rainstorms, generate rapid and unfiltered runoff. In densely developed city areas, rooftops create the climate phenomenon known as urban heat islands—areas significantly hotter than nearby, more open spaces. If the street temperature is 90 degrees, the rooftop can be as high as 180 degrees.

But at Chicago's City Hall, which is surrounded by high-rise office buildings, those with a view of the roof see a garden of grasses and colorful wildflowers. Not only aesthically pleasing, the roof garden is expected to lower the roof's temperature, provide thermal and acoustic insulation, control stormwater, convert carbon dioxide to oxygen, and reduce smog, as well as last longer than a traditional rooftop, pay for itself over a period of years, and even attract birds and butterflies. Looking for ways to reduce urban heat and address increasing demands on stormwater management systems, Chicago recently installed the 22,000-square-foot green roof from which it expects to see direct savings of $3,000 to $4,000 a year in heating and cooling costs.

With the use of drought-resistant plants that have been developed and advances in waterproofing systems, green roofs have been popular in space-scarce areas of Europe for decades. A number of cities in Germany and Switzerland even require them for commercial as well as some residential construction. There are more than 1 million square feet of green roofs in France, and Canada is quickly catching up. Although green roofs have been slow to take root in the United States, where a green roof installation can still cost double the price of a traditional roof, their long-term cost savings should increase demand, which should eventually reduce installation costs.

In order not to reinvent a successful process, a number of American companies are teaming with European partners that have decades of proven experience. At the same time, U.S. manufacturers of roofing and waterproofing systems are branching out into the green roof business and teaming with landscape architects. Some U.S. green roof projects have been in place long enough to prove their efficacy. The Gap, Inc., headquarters in San Bruno, California, has been the focus of much attention with its undulating, hilly surface roof of native grasses and wildflowers in a six-inch layer of soil over several sublayers of waterproofing material. (See "Designing to Sustain," page 50, December 1998 *Urban Land*.) The roof is self-sustaining, low maintenance, and provides thermal and acoustic insulation. The material underneath is protected from degradation by the sun's rays and extreme weather elements—the reason the roof is expected to outlast an unprotected surface by 20 years. The Gap expected to be paid back for the extra expense of the green roof in eight years, but now says that this will occur sooner.


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The roof of the Gap, Inc., headquarters in San Bruno, California, has an undulating surface planted with native grasses and wildflowers in a six-inch layer of soil over several sublayers of waterproofing.

In Philadelphia, the Fencing Academy has had a green roof since 1998, put in place as part of a building renovation—and illustrating that existing structures can be retrofitted. The roof contains 2.75-inch-deep sedum and herbs, weighing less than five pounds per square inch when dry and less than 17 pounds when saturated. Architect William McDonough, Charlottesville, Virginia, perhaps the nation's chief proponent of green roofs, convinced Ford Motor Company chairman William Ford, Jr., to include a green roof on the new River Rouge vehicle assembly complex in Michigan. (See "Industrial Meets Environmental," page 34, March 2001 *Urban Land*.) Now under construction, it will be the world's largest green roof (about 454,000 square feet). "This is not environmental philanthropy, this is sound business," notes Ford.

In Portland, Oregon, when the nine-story Hamilton West apartment building opened for occupancy in December 1999, a key feature was a rooftop garden that uses a membrane of modified bitumen roofing under the lightweight layers of soil materials to create a green roof. Be-

Green roofs provide one stormwater management solution that can simultaneously improve the energy performance of buildings, air quality, and the urban ecology—all without taking up additional land. By transforming a roof from the single task of waterproofing buildings to a multifunctional system, green roofs can result in as many cost savings to developers and owners as ecological advantages to communities and watersheds. It requires, however, a departure from traditional cost estimating and value engineering. To optimize the benefits of green roofs, civil, mechanical, and waterproofing engineers need to collaborate and cross-reference their work. Only if all the concerns of each discipline involved are sufficiently addressed can green roofs become an accepted measure to mitigate runoff, improve energy efficiency, and extend the life of roofing systems.

There are two different types of green roofs: intensive and extensive. Intensive green roofs require a minimum of one foot of soil depth to accommodate intensive-care vegetation such as large trees, shrubs, and other manicured landscapes. They are constructed of multiple layers with elaborate irrigation and drainage systems. The greatest disadvantage is that they add considerable loads (from 80 to 150 pounds per square foot) to a structure and require intensive maintenance. The main advantage is that rooftop gardens and rooftop terraces are designed to be accessible, and provide an additional amenity.

In contrast, extensive green roofs range from as little as one to five inches in soil depth and are mainly built for their ecological benefits. They are not designed for public use but can be accessed for routine maintenance walks, generally performed once a year. Depending on the soil depth and type of substrate, loads can vary from 15 to 50 pounds per square foot. What makes extensive green roofs so attractive is that they become an integral part of the building and function as the single most effective solution to combat urban runoff from impervious surfaces. At the same time, the vegetation layer in such an unusual place adds aesthetic value to a structure.

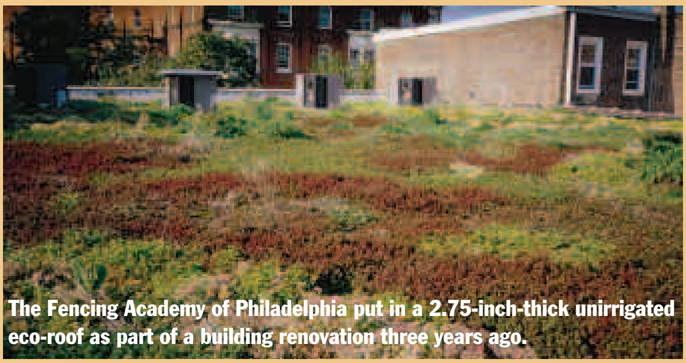
cause of the project's success, especially in light of the large amount of rainfall in the area, Portland now offers incentives to builders that use green roofs in their projects.

Green roofs are being installed all over the country, their vegetated surfaces planted with hardy ground cover, chosen for its ability to survive various climates and harsh environments and its need for minimal maintenance. One such project that is in the works is a 30,000-square-foot roof of an old department store that is being rehabilitated in Baltimore.

Energy costs have influenced roofing choices for years, but many developers see a light-colored roof as the only energy-efficient solution. There may be a number of reasons for the current resistance to more green roof projects in the United States. One common fear is water accumulation on a roof. A commercial banker in Montgomery County, Maryland, shakes his head in disbelief when told about green roofs that are designed to catch water on the roof, absorb it, and hold it until it evaporates. "Financing to put water on the roof—never," he insists. Counters McDonough, "We need to start re-imagining the way we do things." People want to be assured of long-term, tangible benefits, yet businesses in the United States are not used to looking at things over the long term, says McDonough, citing Ford and the Gap as "enlightened" clients. He is not surprised that they are already reaping the benefits. The higher upfront costs in financing green roofs dissuade developers who may not look at life-cycle costs, where the real savings are found, adds McDonough. Planning for a green roof, which must occur early in the project planning process, requires a team with knowledge in plant biology and hydraulic engineering. Reliance on plant biologists is essential as green roofs will only succeed if the vegetation itself is successful.

The two basic classes of green roofs, intensive and extensive (see main story), use roof components that include a relatively light-weight, durable high-quality waterproof membrane covered by a lightweight, synthetic drainage grid that allows excess water to flow off; a filter fabric; the growing medium; and plants—all layered atop a conventional roof. The design is such that water is absorbed and filtered so that runoff is decreased and gradual. Reduced stormwater runoff can alter jurisdictional requirements and lower development costs, especially for buildings with large flat or slightly sloping roofs—5 percent to possibly 40 percent. The greater the slope, the more material, structural support, and labor to install. Evaporative cooling ameliorates the phenomenon of urban heat islands while lowering air-conditioning costs. The larger the roof surface, the greater—and quicker—the economic return will be.

Controlled experiments are underway at the University of Toronto and at Pennsylvania State University to determine the measurable benefits of green roofs. At Chicago's City Hall, both the Environmental Protection Agency (EPA) and the Department of Energy (DOE) will be monitoring the project, studying the success of a variety of plants, and making temperature comparisons with the adjacent tar-covered roof of city hall's partner building, the Cook County offices. The National Aeronautics and Space Administration (NASA) will provide infrared satellite photos to measure heat.


The Fencing Academy of Philadelphia put in a 2.75-inch-thick unirrigated eco-roof as part of a building renovation three years ago.

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A Canadian study, "Greenbacks from Green Roofs," prepared by the Environmental Adaptation Research Group for Canada Mortgage and Housing Corporation, supports the long-term financial and environmental benefits of green roofs, but points out some problems as well. Among the issues:

- some green roofs look worse in winter than standard roofs;
- improper maintenance can cause roof damage;
- consultants who design green roofs may not be around after they are built, causing concerns about liability and warranties;
- because no industry technical standards exist, there are no building code standards or warranty assurances;
- there is a lack of understanding about direct, tangible, and long-term economic benefits;
- maintenance costs often must be built into the budget and then are the first to be cut; and
- long-term maintenance requires initiative on the part of the owner/manager.

Local governments, particularly those with dense development and serious stormwater management issues, could have much to gain from the green roof movement and could place themselves at the forefront by providing tangible benefits to developers using green roofs, and by using green roofs on government buildings. For example, Portland, Oregon, and Montgomery County, Maryland, have begun to give such tangible benefits to builders using green roofs by cutting the fees for stormwater management. Schools and airports offer an attractive opportunity, since both typically have large roof areas. A number of proponents of green roofs contend that it is up to federal, state, and local governments to start looking at green roofs seriously as a cost-effective, environmentally sound stormwater management system in order for significant progress to be made in this important area.—**Joyce B. Siegel,** *a freelance writer in Montgomery County, Maryland, is a former public affairs officer of the Housing Opportunities Commission who is now an associate of the Innovative Housing Institute, which promotes mixed-income housing*

Intensive green roofs are not new to the United States. One example is the Pacific Telephone and Telegraph (PT&T) building in Sacramento, California, which was constructed with an intensive green roof back in 1962. The sensitive telephone and computer equipment housed in the building requires a perfectly humidified environment and therefore was placed directly beneath the half-acre rooftop vegetation, because the green roof provided additional insulation and shielded the roof from direct sun. This in turn resulted in an even and moderate indoor environment. Without the green roof, PT&T might have needed to invest in a costly and complex humidity monitoring and control system.

Although everything from earth-bermed houses to balconies with potted plants has been termed a "green roof," extensive green roofs are elevated roof surfaces *entirely* covered with a thin layer of soil and vegetation. They are not sod or grass roofs because the created environment on the roof requires different roof plantings.

Many watersheds have experienced the impact of runoff on ecosystems, and conservation groups and local governments have started to take action. The Chesapeake Bay Foundation recently announced that future growth around the Chesapeake Bay will overwhelm the progress that has been made cleaning it, unless drastic changes are made. Green roofs present an especially powerful tool for stormwater management control because they absorb rainwater and slow down or completely eliminate runoff. The soil layer and plants soak up water that would otherwise immediately run off into storm sewers. On average, 75 percent of water is retained on an extensive green roof, stored in plants and the soil layer. Only about 25 percent of water becomes runoff, several hours after the peak flow, but this is treated by the roof's vegetation. When the green roof reaches full saturation, excess water slowly percolates through the vegetation layer to a drainage outlet. The soil layer traps sediments, leaves, and other particles, treating runoff before it reaches the outlet.

Different soil substrate and vegetation cover provide different water-retention capacities. On average, a one-inch-thick moss and sedum layer over a two-inch gravel bed retains about 58 percent of water, a 2.5-inch-thick sedum and grass layer retains about 67 percent of water, and a four-inch layer of grass and herbaceous vegetation retains about 71 percent of water. A major two-inch rainstorm generates 1.25 gallons per square foot. A 2.5-inch-thick extensive green roof retains approximately 0.5 gallons of water per square foot, or 40 percent. Though the greatest cost benefit is provided by the first inch of soil and vegetation cover, it is recommended to install a 2.5- to three-inch soil cover to support and maintain a diverse and healthy plant community.

The District of Columbia, one of the signing partners of the Chesapeake Bay 2000 agreement, requires all developments of more than 5,000 square feet to implement a stormwater management plan to retain runoff. Underground sand filters are generally recommended for that purpose. Quantity control is of utmost importance in cities such as Boston, New York, Seattle, Portland, and Washington, D.C., because these cities are served by combined sewer systems with limited capacity. During heavy rainfall sewers become overloaded and occasionally overflow, resulting in discharge of untreated sewage with high concentrations of nitrogen and phosphorus into urban waterways. Quality control prevents sediments and pollution from reaching streams and rivers nearby.

Per each acre of impervious surface cover, the District of Columbia requires stormwater via underground sand filters that are ten feet wide, 50 feet long, and eight feet high. Precast or poured-in-place concrete tanks of this size cost between $26,000 and $35,000. Excavation for the sand filter costs approximately $25 per cubic yard. Waterproofing the underground tanks costs between $9 and $10 per square foot and presents a number of difficulties, such as complying with confined space regulations by the Occupational Health and Safety Administration (OSHA).

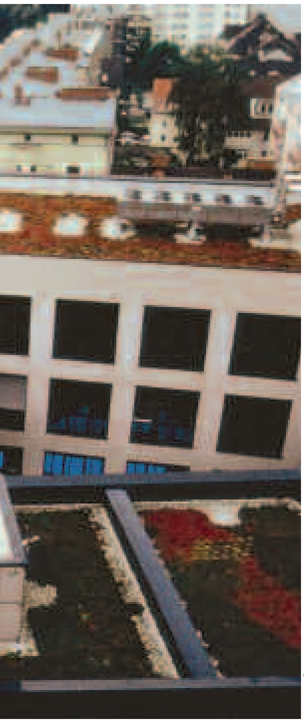
In addition, a one-time tap fee of $1,500 to $3,500 is charged to connect the tank to the city sewer system. Accumulated sediments and hydrocarbons must be removed and properly disposed of every six months. Pumps and other mechanical equipment require maintenance and occasional replacement, which all add to the costs. The Washington, D.C., Environmental Health Administration recognizes the treatment efficiency of a sand filter for phosphorus at 80 percent. Stormwater-related phosphorus is removed through absorption or by binding to the filter media; the other 20 percent of phosphorus is soluble and passes through. Once the absorption capacity of the filter media is exhausted, treatment efficiency becomes negligible. The sand filter becomes clogged and the media need to be replaced, approximately every three to five years.

In Germany, an entire service industry has formed around installing green roofs. Shown here is a two-inch-thick soil and vegetation roof cover used to control runoff (above) and a six-inch-thick cover (at right).

Instead of building costly underground sand filters that must be structural and are difficult to waterproof and to maintain, green roofs reduce peak flows and runoff by absorbing rain. Excess water slowly percolates through the soil so that it is treated by the time it reaches the drainage outlet. The plants take up nitrogen and phosphorus as their nutrients, reducing what otherwise would become nonpoint source pollution.

With their many plants, green roofs treat stormwater runoff biologically. The bacteria and fungi attached to the dense root system break down nitrogen and phosphorus to make it available for the roots to take up as nutrients. This process—photosynthesis—occurs naturally, powered by the sun, and its intensity depends on the season, slowing during the dormant season. The treatment efficiency increases over the lifetime of the green roof because plants mature and grow denser. A recent article in the *New York Times* pointed out that "harnessing the absorptive power of a plant's roots appears poised for a much-expanded role. Hundreds of species of plants, together with the fungi and bacteria that infuse the rhizosphere (the ecosystem around roots) represent the botanical equivalent of a detox center."

At $15 per square foot, an extensive green roof may prove to be a realistic and cost-competitive alternative for stormwater quality and quantity control. In densely populated areas, the aesthetic and air quality improvements can be welcome added values. Green roofs could be the single most-effective solution—short of eliminating parking lots—to reduce the amount of runoff and thereby the amount of sediment flow and nutrient intake into watersheds. In-



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stalling green roofs might eliminate the need for additional stormwater quantity and quality controls. Another promising economical benefit is the insulation value of a green roof. The vegetation layer protects the roofing system from ultraviolet (UV) radiation and extreme temperature differentials, which improves energy efficiency and extends the life expectancy of the roofing system by two to three times.

The U.S. Environmental Protection Agency (EPA) is in the process of publishing regional nutrient criteria for the entire country that will be more stringent. Cities are under pressure to comply with their National Pollutant Discharge Elimination System permits; the most common violation is exceeding the total maximum daily loads allowed for nutrients stemming from urban runoff.

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Locally, communities create their own stormwater management requirements to protect and maintain riparian buffer zones and to restore water quality. Cleanup efforts in North Carolina require local governments to reduce the amount of nitrogen in stormwater runoff and to limit nitrogen in any new development. Studies by the Department of Public Works in Durham, North Carolina, found that impervious surface cover produces 21 pounds of nitrogen per acre per year in the local area. Under state regulations, any new development in Durham will be limited to 3.6 pounds of nitrogen per acre per year, which represents an 83 percent reduction in nutrients from runoff. Developers in this area will have to be creative to meet this reduction level. Conventional treatment practices for treating stormwater runoff are not very effective—wet detention ponds and sand filters remove between 25 and 35 percent of the nitrogen. The city of Durham does not prescribe a means by which to achieve this level, but it recognizes the benefits of green roofs and welcomes green roofs for new development as a low-impact alternative.

"There are only a few gems for every hundred of new technologies, and green roofs seem to be the most promising method for stormwater control. They reduce peak runoff rates and the temperature of water compared to runoff from conventional roof. This is very important considering the adverse impacts of thermal shock on aquatic life. But we are seeing the greatest benefits of green roofs in the potential for controlling nutrients. The EPA is just beginning to roll out regional nutrient criteria, and states will have to adopt their own water quality standards for nutrients over the next three years. Interest in green roofs is only going to grow," says John Cox, an engineer with the Department of Public Works–Stormwater Services.

In the United States, more often than not, these types of regulations are perceived as obstacles to development. Not so in Europe and Japan. Europe has been using green roofs successfully for more than 30 years to reduce construction and maintenance costs of infrastructure such as sewer systems. And, as reported by ABC News earlier this year, Tokyo's metropolitan government now requires rooftop greening on new and renovated buildings. The local Japanese development community is supporting this new measure, noting that it "makes excellent ecological sense." More than half of the building owners interviewed said they were enthusiastic about green roofs and affectionately named them "islands of calm" for the community.

Green roof construction is similar to conventional gravel-ballasted roof construction. The river-rocks ballast is commonly used over single-ply roofing systems to prevent wind uplift of the membrane. On inverted roof membrane assembly roofs, the insulation is installed over the roofing membrane and therefore requires gravel ballast to hold down the insulation and protect it against UV radiation. The one difference between a gravel-ballasted and a green roof is that on a green roof, a root-resistant liner must be installed

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underneath to prevent roots from penetrating the membrane in search of water. Extensive green roofs weigh only a little more than the 12 pounds per square foot of gravel or river rocks and can be used just as well for wind-up lift protection. Green roofs become building-integrated systems performing many tasks.

The question remains: why are not more green roofs being installed? Currently, the cost of an extensive green roof in the United States ranges from $15 to $20 per square foot, including everything from waterproofing to plants, compared with $7 to $8 per square foot for gravel-ballasted roofs. These higher up-front costs for green roofs mainly stem from the additional materials going into a green roof. The lightweight soil substrate and plants are expensive and labor intensive to install. But, if one is spared from installing an underground sand filter for stormwater management, these higher initial costs can quickly become savings.

In Germany, an entire service industry has formed around the installation of green roofs, significantly reducing the labor and hence the green roof's initial costs. Vacuum trucks blow or pump the dry soil substrate onto the roof, and pregrown vegetation mats, similar to sod, are rolled out over the soil. Costs for extensive green roofs in the United States may soon be adjusted to between $8 and $15 per square foot, given installation demand as well as the availability of soil substrates and plants.

Other cost savings that a green roof provides should also be taken into account. During hot summer days, conventional roof surfaces can heat up to 170 degrees Fahrenheit, and in the winter, they are exposed to the cold. These extreme temperature fluctuations accelerate the deterioration of the roof over time. A thin vegetation cover moderates those extreme temperature differences and protects the roof from UV radiation. If installed correctly, a green roof can extend the life span of the roofing system and outlive a conventional roof by threefold. It takes some foresight, ingenuity, and excitement to implement green roofs as multifunctional roofing systems. Some benefits of green roofs—such as energy efficiency and a healthier microclimate—are hard to quantify because they are site specific. For instance, energy savings will be greater for a

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A 250-square-foot extensive green roof in Forest Lake, Minnesota, is shown before conversion (top), right after planting (above), and after two Minnesota winters (at right).

single-story office building or shopping mall than for a 12-story office tower. However, these benefits, combined with stormwater control, the improved longevity, and thermal insulation of a green roof, will warrant a short-term payback.

Funding for green roofs can be obtained through many sources, one of which is EPA's Clean Water Act Section 319 (nonpoint source pollution) grant program. Local funds also may

be available. For instance, the Critical Areas Program in Baltimore, Maryland, collects fees for impervious surface cover on new developments that are near the Inner Harbor. The money can then be redistributed to proj-ects that engage in ecological site planning and design, including the use of green roofs.

City governments could create incentive programs that help cover green roof installations upfront. Such programs could help to reduce sewer pipe sizes and maintenance costs, and could also decrease power demand during hot summer days, thereby helping to prevent blackouts.

Existing incentive programs could easily be adapted to include vegetated roof surfaces to reduce urban runoff. One such example is the reduced property tax assessments law for vegetative filter strips in the state of Illinois. This voluntary program, initiated by the Illinois Department of Agriculture's Office of Soil and Water Conservation, provides a tax reduction of up to five-sixths of the land value (the landowner pays only one-sixth of the taxes) in exchange for the development of vegetated filter strips, a conservation practice that can aid in reducing soil erosion, improving water quality, and providing significant habitat for grassland wildlife. Green roof technology aligns with all of those goals and also could form a logical extension of this existing program.

Green roofs can be seen as an opportunity to bring cities to life through stormwater management, energy efficiency, and urban ecology. But in the end, it will not be the technical argument of stormwater management that will lead the charge for more green roofs. It will be the developers, investors, architects, planners, regulatory authorities, and society at large who collectively have the capacity to change the environment. ■

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