The Russian Backlash Over Kosovo ❋ Biomimicry in Architecture

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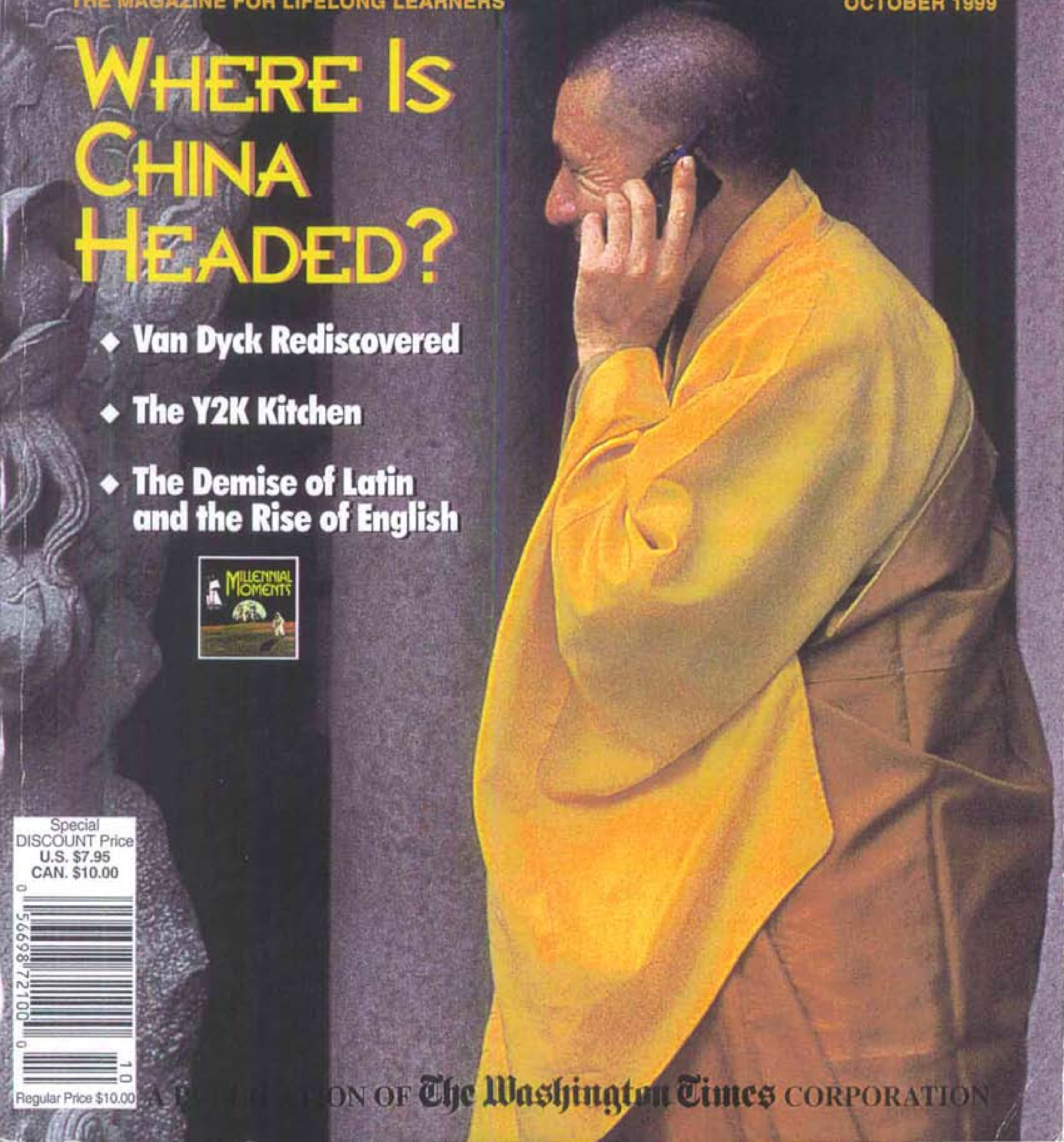

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Robert J. Berkebile and Jason F. McLennan

In the rapidly dawning era of environmental responsibility, architecture will flourish if it replaces the haughty metaphor of buildings as machines with the holistic metaphor of buildings as flowers.

We do not seek to imitate nature, but rather to find the principles she uses.

—***Buckminster Fuller***

In the future, the houses we live in and the offices we work in will be designed to function like living organisms, specifically adapted to place and able to draw all their requirements for energy and water from the surrounding sun, wind, and rain. The architecture of the future will draw inspiration not from the machines of the twentieth century but from the beautiful flowers that grow in the surrounding landscape.

The building as a machine

The history of architecture in the twentieth century can be seen as one of buildings emulating machines and technology. Machines such as the internal combustion engine have symbolized progress and mankind's mastery over nature for the last 100 years. They have allowed us to achieve comfort in any climate, to traverse long distances in little time, and have revolutionized everything from food production to clothing manufacture. Machines are the ultimate metaphor for the buildings—both commercial and residential—of today. The great architect Le Corbusier went so far as to say that "houses are machines for living in."

As machines, our buildings also began to look more and more similar, regardless of culture or climate. With machines as metaphors, buildings took on the characteristics of clinical assembly-line productions. An office building in Singapore now resembles an office building in Manhattan, and both share the same "perfect," climate-controlled indoor environment. At the same time, the loss of regional differences began to undermine the uniqueness of place, impeding understanding of what local culture and climate have to offer. The twentieth century has seen the decline of art and "artfulness" in buildings. Engineering and technological solutions have become dominant factors in design, ensuring that buildings are indeed "machines for living in."

Unfortunately, like the machines of our age, today's buildings use energy and materials wantonly, depleting resources in ways that are beginning to alter the very climate on which we all depend. According to the U.S. Green Building Council,

■ It doesn't look like a flower, but the EpiCenter pilot project illustrated here and scheduled to be constructed in 2000 at Montana State University at Bozeman will test many advanced technologies linked in synergetic cycles that mimic natural processes.

The Building as a Flower

The living building will

- Harvest all its own water and energy needs on site.
- Be adapted specifically to site and climate and built primarily with local materials.
- Operate pollution free and generate no wastes that aren't useful for some other process in the building or immediate environment.
- Promote the health and well-being of all inhabitants, consistent with being an ecosystem.
- Comprise integrated systems that maximize efficiency and comfort.
- Be beautiful and inspire us to dream.

—R.J.B. and J.F.M.

buildings consume 30 percent of America's total energy and 60 percent of its electricity while generating 2.5 pounds of solid waste per square foot of floor space for construction alone. Five billion gallons of water are used per day just to flush toilets! The root of the problem was the shortsighted belief that technology combined with a great deal of energy was the answer to any design problem.

And yet, just a few centuries ago there was a different model for buildings and a different relationship with nature. In preindustrial times, buildings could be compared to living organisms in that they evolved in response to climate and topography, changing form and composition as necessary to protect what was inside from the elements, while regulating temperature and humidity to the greatest extent possible. This evolution produced vernacular forms that differed from locale to locale, just as plants and animals differ from biome to biome.

One need only compare the igloos of the Inuit with the adobe structures of the Southwest to understand how climate and culture have shaped architecture. Both the igloo and the adobe house were built to temper the harsh extremes of climate, using only the materials at hand. Neither building type significantly altered the environment, and both helped define the culture of their builders.

But Western society was never completely satisfied with a close relationship to nature. It was quick to follow the ideas of individuals such as Francis Bacon, who sought "dominion over nature" using the scientific method. As early as the seventeenth century, architects began to look to science for technologies that would keep buildings warm no matter how cold it was outside and cool no matter how hot. Only in the twentieth century, however with new design freedoms made possible by technologies such as insulated glass, air-conditioning, and central heating systems, did architecture move decisively away from the model of living organisms toward a model based on the machines that were making these changes possible.

Unfortunately, in our haste to surge ahead with "progress," architects lost the ability to discern between practices that were damaging to environmental health and those that were not. We forgot the hard-learned lesson that how you get someplace is as important as getting there. Amory Lovins, founder of the Rocky Mountain Institute in Snowmass, Colorado, reminds us that what we want is comfort, not higher energy bills and oil spills. It isn't our intentions that are wrong but rather the path we chose to get there. What is needed is a return to the old metaphor, one that respects regional differences and environmental health while embracing *appropriate* technologies that can provide the comfort, service, and security we now expect.

Changing the metaphor

"To emulate nature, our first challenge is to describe her in her terms," says computer scientist Michael Conrad in *Biomimicry: Innovation Inspired by Nature* by Janine Benyus. "The day the

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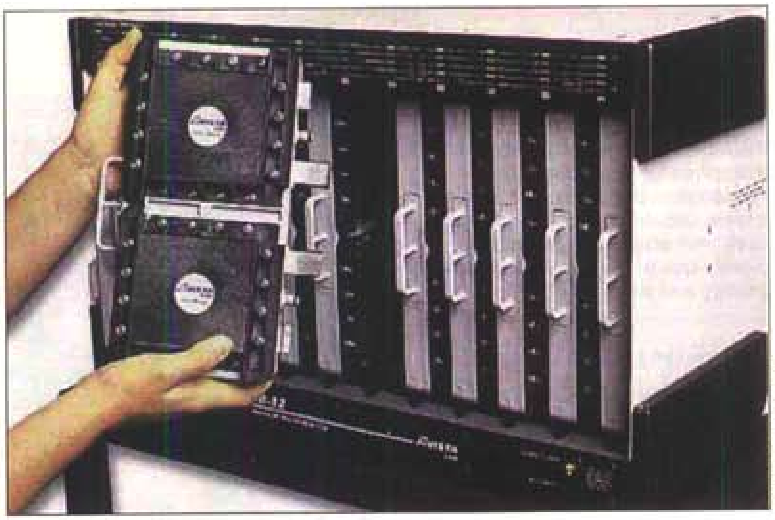
■ Ranging from cacti *(top right)* in the desert to daisies (*right below*) in the meadow, flowering plants, an apt metaphor for environmentally responsible buildings, demonstrate a wide variety of shapes and sizes, each well adapted to optimizing the plant's use of the locally available energy and water.

metaphors start flowing the right way, I think the machine-based models will begin to lose their grip."

Describing things as metaphors can provide clarity and allow us to understand complex systems quickly, but it can also lock us into a set way of thinking. For too long now, the machine as the metaphor for our buildings has implied an exploitative relationship with nature. The machine metaphor implies solving problems with brute force, using great amounts of energy. It is a nineteenth-century model that is being carried into the twenty-first century.

Architecture has often been described using metaphors, drawing comparisons to things that evoke similar emotional responses and sum up the intent of the architect's expression. Goethe once said, for example, that "architecture is music etched in stone." What is interesting with architecture, is that when the metaphor changes, new sets of rules emerge that can guide the design process. To us the most compelling model for the buildings of the future can be found growing almost everywhere on the planet: flowers.

Flowers are marvels of adaptation, taking various shapes, sizes, and forms. Some lie dormant through the harshest of winters, only to emerge each spring once the ground has thawed; others stay rooted all year round, opening and closing as necessary to respond to such changing environmental conditions as the availability of sunlight. Flowers are the perfect metaphor for buildings in the future: Like buildings, they are literally and figuratively rooted to place. In addition, flowers can draw resources only from the square inches of earth and sky that they inhabit. The flower must receive all its energy from the sun, all its water from the sky, and all its nutrients from the soil. Flowers are ecosystems, support-



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■ *Right:* Fuel cells, such as the modular unit shown here, will play a strategic role in the near future in providing energy for buildings. In the living building, hydrogen to run the fuel cells will be generated by renewable energy technologies (such as photovoltaics) that emit no pollution. *Bottom:* Twenty-first-century buildings will generate growing amounts of electricity from photovoltaic panels. In the glass wall shown here, photovoltaic cells (the dark components in the glass) are spaced to allow daylight between them, creating an interesting shadow pattern on the floor.

COURTESY OF PILKINGTON

ing and sheltering microorganisms and insects as our buildings do for us. They are also beautiful and can provide the inspiration needed for architecture to be truly successful.

In attempting to design buildings based on the design principles that have made flowers successful, we are finding it useful to measure our designs and innovations against a test set forth in Benyus' *Biomimicry*: "Is there a precedent for this in nature?" If so, the answers to the following questions about our designs and innovations will be yes:

Does it run on sunlight?
Does it use only the energy it needs?
Does it fit form to function?
Does it recycle everything?
Does it reward cooperation?
Does it bank on diversity?
Does it use local expertise?
Does it curb excess from within?
Does it tap the power of limits?
Is it beautiful?

Transparent PV panels now being developed will allow daylight to enter a building while still generating electricity.

Emerging biomimetic technologies

Many technologies currently in use or being developed are biomimetic in nature and will contribute to making the living building possible.

Perhaps the oldest biomimetic technology is photovoltaics, otherwise known as PV. Photovoltaics is a solid-state technology that directly converts solar radiation into electricity that can be stored or used on demand while producing no pollution. Many people remember the clunky, expensive panels that gained prominence in the seventies, but the technology has advanced considerably in recent years, becoming more efficient and able to integrate seamlessly into architecture. Although they were formerly mounted on top of roofs, solar panels can now serve as the roof material itself, replacing conventional metal roofs or shingles. *See also "BNIM Architects: Designing a Better World," on page 120.* Transparent PV panels, now being developed for use as windows and skylights, will allow daylight to enter a building while still generating electricity. This technological "multitasking" is integral to biomimetic technologies, which often do several jobs at a time. Photovoltaics will play an increasingly important role in buildings of the future.

Biomimicry

1. Nature as model. Biomimicry is a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems (for example, a solar cell inspired by a leaf).
2. Nature as measure. Biomimicry uses an ecological standard to judge the "rightness" of our innovations. After 3.8 billion years of evolution, nature has learned what works, what is appropriate, and what lasts.
3. Nature as mentor. Biomimicry is a new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it.
—*Janine Benyus*, **Biomimicry: Innovation Inspired by Nature**

Another electricity-producing technology, the fuel cell, is poised to change the way we power our automobiles, computers, cell phones, and buildings. All the major automobile manufacturers, including Chrysler, Ford, General Motors, and Honda, are racing to produce the first commercially viable fuel cell cars, which are expected to be released as early as 2004. Prototype vehicles today release drinkable water from the tailpipe instead of carbon dioxide, carbon monoxide, and ozone. When used in buildings, fuel cells can provide steady, uninterruptible power with minimal to zero environmental impact. Fuel cells are similar to a battery in that they produce electricity through electrochemical reactions, but unlike batteries, they never run down so long as a fuel containing hydrogen is supplied to the system.

As hydrogen runs through a fuel cell, it encounters a semipermeable membrane designed to permit the flow of protons while inhibiting electrons. The electrons must flow around the membrane to rejoin the protons, thereby generating an electric current. If fuel cells are run off of fossil fuels such as gasoline or methane, they produce some pollutant gases. In the future, when they employ hydrogen generated from water using renewable resources such as wind and solar

JASON MCLENNAN / COURTESY OF BNIM ARCHITECTS

Mini-wetland ecosystems, designed to purify wastewater and sustained only by sunlight and oxygen, will be another of the sophisticated technologies integrated into the building systems of the future.

power, they will be a zero-polluting energy source.

The pattern of cleaning a building's wastewaters by using biomimetic principles is starting to appear and will become more common. Ecological waste-treatment systems now re-create mini-wetland ecosystems using microorganisms and plants to purify wastewater from toilets or other industrial uses. These systems, first developed by a biologist named John Todd and originally called "living machines" (an interesting twist on the metaphor), rely on the power of living systems that view our waste products as food. It is important to remember that in nature, there is no such thing as waste. Only humankind creates things useless to all other forms of life. The ecological waste-treatment system is a series of complete and complex ecosystems, which are connected through gravity flow in such a way that dirty effluent entering from the high end is naturally and progressively cleaned as it feeds through the tanks containing the ecosystems. Unlike conventional waste-treatment systems, which use great amounts of energy and harsh chemicals, ecological waste-treatment systems clean water using only sunlight, bacteria, and plants.

A host of other biomimetic technologies is being developed for all areas of building construction, including insulation, windows, electric lighting, controls, and mechanical systems. These technologies are also being designed to be integrated with one another for greater efficiency and comfort. Emerging models showcase the use of biomimetic technologies and the integration that make them so successful.

A living laboratory for the new century

Many principles of the living building will be tested at a benchmark project called the EpiCenter in Bozeman, Montana, being designed by an international team of innovators, architects, scientists, engineers, and stakeholders under the leadership of BNIM Architects. The EpiCenter, funded by the National Institute of Standards and Technology and the students of Montana State University (MSU), seeks to redefine resource efficiency, including human resources. The facility will house new centers for integrated, collaborative research, including the Center for Computational Biology, the Center for the Discovery of Bioactive Compounds, and the National Resource Center, a research laboratory for "sustainable" building systems.

The EpiCenter is part of a larger architectural movement known as "sustainable design," in which buildings are designed to minimize energy and resource demands. What is unique about the project is the level of integration and ways of combining state-of-the-art "green technologies."

The building was envisioned as operating like a living organism with all systems interconnected.

The building was envisioned as operating like a living organism, with all systems interconnected for maximum efficiency and minimum environmental impact. It was designed to generate a significant portion of its power without pollution, clean all its own wastes on site, and respond actively to temperature changes while maintaining a comfortable indoor environment. Meeting the EpiCenter's design goals will require development of new standards and advances in the areas of energy generation, waste treatment, human health, and productivity and resource conservation.

To test some concepts and generate interest and enthusiasm

Changing the Approach

The significant problems we face today cannot be solved by the same level of consciousness that created them.

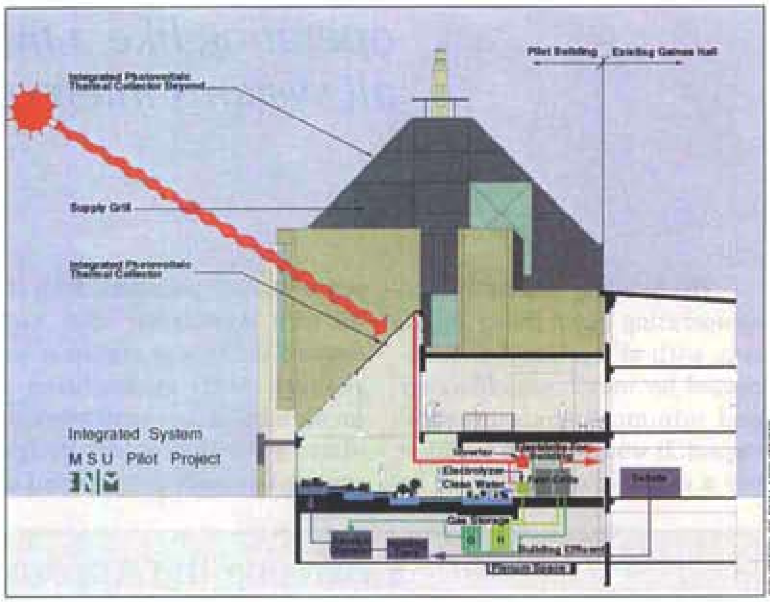
—Albert Einstein

Prior to the 1990s, architects believed that technology was the primary barrier to creating building designs that were resource efficient, healthy, and less polluting. We had seen significant advances in glass, lighting, carpeting, and adhesives, and Amory Lovins was working with Ford, Chrysler, and GM on a "hyper car" [see "The Car of the Twenty-first Century?" THE WORLD & I, August 1996, p. 149] that would travel across the United States on one tank of fuel (not necessarily gasoline) without creating pollution. We were convinced that similar advances in building materials and systems would facilitate dramatic advances in the quality of building designs and the performance of the built environment.

In this decade, architects have begun to realize that technology is not the limitation. In fact, technology has given us access to critical information, both local and global, and the tools to develop and analyze more options efficiently. The reality of our new position in approaching sustainable building designs is demonstrated in breakthroughs on our projects, including a series of national demonstration projects ranging from "Greening the White House" to "A Plan for Environmental Excellence in Antarctica." These advances have usually been achieved in the synergy resulting from the brilliance and diversity of team members working in a collaborative process and with access to the broadest range of appropriate technologies.

The quantity and quality of the synergistic breakthroughs experienced on projects seem to increase with the strength and diversity of team members and the quality of their relationship. If the collaborative team has a pronounced sense of community, clear goals, and an interest in searching for integrated designs that are inspired by nature, results improve dramatically. Establishing and maintaining this forum for discovery require more preparation, research, and participation by more people (both users and designers) than conventional building-design efforts do. More participation means more time and money. Fortunately, a growing body of evidence indicates that the additional investment delivers long-term benefits for the resulting designs. These benefits include increases in flexibility, durability, and human health and productivity, with decreases in energy consumption, pollution, and operating costs. ***—R.J.B. and J.F.M.***

■ *Right:* **A cross section of the planned EpiCenter pilot project highlights the ecosystem-like associations of the energy-management and wastewater-treatment systems, beginning with the welcome reception of sunlight and rainwater as crucial inputs to the system.** ***Bottom:*** **The biological heart of the EpiCenter pilot project, the ecological waste-treatment system, is to be kept under glass in a greenhouse-like facility nestled into the building's southeast corner.**



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for the larger building project, MSU and the design team began work this spring on a $7 million pilot project. Like the EpiCenter, the pilot will contain research and teaching laboratories for science and a mix of informal student space. Construction will begin on the pilot facility early next year.

Perhaps the most compelling example of the living-building approach being demonstrated is the Integrated Waste Treatment System. Here the function of ecological waste treatment is integrated with photovoltaics and fuel cells. The system works in the following way: Rainwater is collected from the center's roof and stored in a large cistern located in the basement. This water is then used for nonpotable applications such as flushing toilets or cleaning lab equipment (water for drinking fountains still comes from the municipal supply). After the water is used, it travels through the building to the ecological waste-treatment system located in a greenhouse on the building's south side. The water is then cleaned by an ecosystem of microorganisms and plant life and returned to the original cistern for reuse.

A portion of the water is diverted from this path and fed through an electrolyzer powered by the photovoltaic array. The electrolyzer "cracks" incoming water into its constituent components—hydrogen and oxygen—and stores them in tanks in the basement. The photovoltaics are also used to power the pumps, lights, and aerators of the ecological waste-treatment system. When there is inadequate solar radiation (such as at night or during extended cloudy periods), a switch is flipped and the process is powered by fuel cells located within the building.