Chapter 1 Green Building Approaches

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A common assumption in recent years is that the built environment will necessarily degrade the natural environment. But for most of Earth's history, structures built for shelter have typically enhanced bio-diversity and benefited the surrounding community. Beaver dams, for instance, create pools where wetlands form, supporting a vast array of diverse life not possible in the original stream. Why should an office building be any different?

Green building is a way of enhancing the environment. Done right, it benefits human well-being, community, environmental health, and life cycle cost. This means tailoring a building and its placement on the site to the local climate, site conditions, culture, and community in order to reduce resource consumption, augment resource supply, and enhance the quality and diversity of life. More of a building philosophy than a building style, there is no characteristic "look" of a green building. While natural and resource-efficient features can be highlighted in a building, they can also be invisible within any architectural design aesthetic.

Green building is part of the larger concept of "sustainable development," characterized by Sara Parkin of the British environmental initiative, Forum for the Future, as "a process that enables all people to realize their potential and improve their quality of life in ways that protect and enhance the Earth's life support systems." As the World Commission on Environment and Development (the Brundtland Commission) phrased it, "Humanity has the ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."

Ideally, green building is not just an assemblage of "environmental" components, nor a piecemeal modification of an already-designed, standard building. In some cases, these incremental approaches add to the building's cost, while producing marginal resource savings. It is much more effective to take a holistic approach to programming, planning, designing, and constructing (or renovating) buildings and sites. This involves analyzing such interconnected issues as site and climate considerations, building orientation and form, lighting and thermal comfort, systems and materials, and optimizing all these aspects in an integrated design.

To capture the multiple benefits of synergistic design elements, the "whole system" design process must begin early in the building's conception and must involve interdisciplinary teamwork. In the conventional, linear development process, key people are often left out

Figure 1.1
The Phipps Conservatory and Botanical Gardens Welcome Center in Pittsburgh, PA, was built targeting a LEED Silver rating. Photo courtesy IKM Incorporated – Architects *(Photographer: Alexander Denmarsh Photography.)*

of decision-making or brought in too late to make a full contribution. Thorough collaboration, on the other hand, can reduce and sometimes eliminate both capital and operating costs, while at the same time meeting environmental and social goals. In addition, the process can anticipate and avoid technical difficulties that would have resulted in added expense to the project. Collaboration can also produce a "big picture" vision that goes beyond the original problem, permitting one solution to be leveraged to create many more solutions—often at no additional cost.

It is precisely the integrated approach described above and the multiple benefits thereby achieved that allow many green buildings to cost no more than standard buildings, even though some of their components may cost more. Green design elements may each serve several functions and allow other building components to be downsized. For example, better windows and insulation can allow for smaller heating systems; photovoltaic panels can double as shade for parking or can replace a building's spandrel glazing.

The U.S. Green Building Council's (USGBC's) LEED® (Leadership in Energy and Environmental Design) rating system for commercial, institutional, and high-rise residential buildings is an instrument used to evaluate environmental performance from a "whole building" perspective over a building's life cycle, providing a definitive standard for what constitutes a green building. It should be used not just to "rate" a building, but as a tool to facilitate greening the building early in the design process. The USGBC has asserted that a LEED-certified or Silver-rated building should not cost more than a conventional building. (Gold- or Platinum-rated buildings may cost more, but they also may involve cutting-edge technologies or significant energy-generation capacity not found in standard buildings.)

Recent studies have corroborated that LEED buildings, in general, fall within the typical cost ranges of their conventional counterparts.[1] One study that did show up to a nominal 2% first cost premium for LEED buildings, demonstrated a tenfold return on this initial investment in operational savings over the life of the building.[2]

Many cities also have local green building guidelines or rating systems that are similarly useful and are sometimes associated with incentives (such as rebates, reduced fees or taxes, and/or an expedited permit process). Some cities *require* that LEED or their local green building guidelines be followed (typically for government buildings). *(See Chapter 9 for more on the LEED rating system, and Chapter 10 for financial incentives.)*

Players in the real estate market are realizing that green development is good business. Developers, builders, and buyers are discovering that green enhances not only health and quality of life, but also the bottom line.

Potential Benefits of Green Building

- Reduced capital cost
- Reduced operating costs
- Marketing benefits (free press and product differentiation)
- Valuation premiums and enhanced absorption rates
- In some cities, streamlined approvals by building and zoning departments
- Reduced liability risk
- Health and productivity gains
- Attracting and retaining employees
- Staying ahead of regulations
- New business opportunities
- Satisfaction from doing the right thing

Resource Efficiency

Buildings make up 40% of total U.S. energy consumption (including two-thirds of the country's electricity) and 16% of total U.S. water consumption. They are responsible for 40% of all material flows and produce 15%– 40% of the waste in landfills, depending on the region.[3] Clearly, large-scale improvements in resource productivity in buildings would have a profound effect on national resource consumption. According to *Natural Capitalism*, a book by Paul Hawken, Amory Lovins, and Hunter Lovins, *radical* improvements in resource efficiency are readily possible—today's off-the-shelf technologies can make existing buildings three to four times more resource-efficient, and new buildings up to ten times more efficient.[4]

Reducing energy use in buildings saves resources and money while reducing pollution and CO_2 in the atmosphere. It also leverages even greater savings at power plants. For instance, if electricity is coming from a 35%-efficient coal-fired power plant and experiencing 6% transmission line losses, saving a unit of electricity in a building saves three units of fuel at the power plant.[5] Process losses exaggerate the problem. Take a typical industrial pumping system, for instance. Insert 100 units of fuel at the power plant to produce 30 units of electricity; 9% of this is lost in transmission to the end user, 10% of the remainder is lost in the industrial motors, 2% in the drivetrain, 25% in the pumps, 33% in the throttle, and 20% in pipes. Of the original 100 units of fuel, the final energy output is a mere 9.5 units of energy.[6]

As Amory Lovins has said, “It’s cheaper to save fuel than to burn it.” But full financial benefits will *only* be realized by using an integrated, resource-efficient approach. (High-performance windows *will* increase first costs unless the reduction in heating and/or cooling load is factored into the sizing of the mechanical system.) Just as important as what goes into a green building is what can be left out. Green building design eliminates waste and redundancy wherever possible.

One of the key ways of reducing resource consumption and cost is to evaluate first whether a new building really needs to be built. Renovating an existing building can save money, time, and resources, and can often enable a company (or a family, if it is a residential building) to be located in a part of town with existing infrastructure and public transportation, enhancing convenience and reducing sprawl. Next, if a new building is required, it should be sized only as large as it really needs to be. Smaller buildings require fewer building materials, less land, and less operational energy.

The American cultural assumption is that we should buy (or lease) as much square footage as we can afford. In the residential sector for instance, the average new house size has steadily increased from 983 square feet in 1950 to 2,349 square feet in 2004, while the average number of people per household has shrunk from 3.38 in 1950 to 2.60 in 2004.[7] Yet smaller houses and commercial buildings allow the budget to be spent on quality, rather than what may be underused quantity.

Energy

The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy needed. In buildings, great opportunity lies in simple design solutions that intelligently respond to location and climate. For instance, for most North American sites, simply facing the long side of a building within 15 degrees of true south (and using proper shading to block summer, but not winter sun) can save up to 40% of the energy consumption of the same building turned 90 degrees. *(See Chapter 5 for more on solar heat gain.)*

> Each year in the U.S. about $13 billion worth of energy—in the form of heated or cooled air—or $150 per household escapes through holes and cracks in residential buildings.
> —*American Council for an Energy-Efficient Economy*

Attention to making the building envelope (exterior walls, roof, and windows) as efficient as possible for

Resource Efficiency: Key Points

- Reduce transportation energy use (and commute time—a valuable human resource) by siting the building within proximity of and convenient to the population who will use it. Brownfield/infill sites, for instance, are usually within an urban core and already connected to public transportation systems.
- Orient the building to optimize solar gain (in the Northern Hemisphere, this means maximizing southern exposure) and provide shading where appropriate with calculated overhangs or other shading devices. Take advantage of prevailing summer breezes, provide winter wind protection, and orient roofs to accept photovoltaics and solar water panels. Also, take advantage of local vegetation (such as shade trees) and topography (consider building into a hillside or a berm to mitigate temperature extremes). On an urban site, map shadow patterns from adjacent buildings to optimize solar gain on the proposed building.
- Optimize building envelope by specifying high-performance insulation, window glazing, roof materials, and foundation, as appropriate for the local climate. (Specifications in Houston will be very different from those in Anchorage.)
- Use durable, salvaged, recycled, and recyclable materials.
- Use renewable materials that are harvested in a manner that preserves the resource for the long term—such as certified wood from sustainably managed forests.
- Use local, low-tech, indigenous materials and methods to avoid the high energy and resource consumption associated with transportation and to support the local economy and cultural tradition.

the climate can also dramatically reduce loads, especially in "skin-dominated" buildings (residences and other small buildings). For this type of building, optimal sealing, insulation, and radiant barriers, combined with heat-recovery ventilation, can reduce heat losses to less than half that of a building that simply meets code.[8]

Heat travels in and out of buildings in three ways: radiation, convection, and conduction, all of which must be addressed to reduce unwanted heat transfer effectively.

Radiation is the transfer of heat from a warmer body to a cooler one (regardless of position). The way to stop radiation heat transfer is by using reflective surfaces. A reflective roof, for instance, can reduce solar heat gain through the roof by up to 40%. Radiant barriers in attics or crawl spaces can also be used to reflect heat away from or back into occupied spaces of a building. Using light pavement surfaces (or better yet, reducing pavement as much as possible) will lower ambient air temperature around a building, thus reducing the building's cooling load. High-performance window glazing often includes a thin film or films to reflect infrared light (heat) either out of a building (in a hot climate) or back into a building (in a cold climate). Passive solar design in cold climates usually involves allowing the sun's radiation to enter a building and be absorbed into thermal mass for re-release later.

Convection is the transfer of heat in a fluid or gas, such as in air. Green buildings achieve natural ventilation by using convective forces, such as wind, and differences in humidity and temperature. Typically, we experience convection as unwanted heat loss. It is what we experience when we feel a cold draft next to a leaky window or when a door is opened and cold air rushes in. Methods of preventing convective heat transfer include providing an air barrier; sealing gaps around windows, doors, electrical outlets, and other openings in the building envelope; providing air-lock entrances; and using heat recovery ventilators, which transfer 50%–80% of the heat from exhaust air to intake air in cold climates, and vice versa in hot ones. They are an excellent way to ensure adequate ventilation in a tightly sealed house, while maintaining high energy efficiency.

Conduction is the transfer of heat across a solid substance. Every material has a specific conductivity (U-value) and resistance (the inverse of the U-value, called the R-value). Insulation is made of materials with particularly high resistance to conductive heat transfer (high R-values). In climates with significant indoor/outdoor temperature differentials, it is important to insulate the entire building envelope—roof, walls, and foundation. Although heated or air conditioned buildings in any climate benefit from insulation, the greater the indoor/outdoor temperature differential, the more insulation is needed.

Windows

Much of a building's heat transfer occurs through its windows. Therefore, one of the most critical ways to reduce all three types of building heat loss (or gain) is by selecting the appropriate, high-performance window for the given conditions. Important window properties include solar heat gain coefficient (SHGC), heat loss coefficient (U-value), and visible transmittance. The appropriate combination of these properties will depend on the climate, solar orientation, and building application. Ultra-high-performance windows combine multiple glazing layers, low-emissivity coatings, argon or krypton gas fill, good edge seals, insulated frames, and airtight construction. Because metal is a particularly good conductor, metal window frames need a "thermal break" (an insulating material inserted to block the conductive heat transfer across the metal) to achieve high performance. High-performance windows have multiple benefits besides saving energy. These include:

- Enhancing radiant comfort near the windows (thereby allowing perimeter space to be used and sometimes enabling perimeter zone heating/cooling to be eliminated).
- Allowing the HVAC (heating, ventilation, and air conditioning) system to be downsized (thereby reducing first costs).
- Reducing fading from ultraviolet light.
- Reducing noise transfer from outside.
- Reducing condensation and related potential for mold and extending the life of the window.
- Improving daylighting—quantitatively and qualitatively.

Heat Load

Besides entering through the building envelope, heat can also be generated inside the building by lights, equipment, and people. Especially in large, "load-dominated" buildings, many of which tend

Figure 1.2
Daylighting should be considered early in a building's design. In the case of Whitman-Hanson Regional High School in Whitman, MA, large, highly-insulated low-E coated windows paired with straight corridors bring outdoor light deep into the school's interior, thereby reducing energy costs as less artificial light is required to light the building.

today to be air-conditioned year-round, installing efficient lighting and appliances (which emit less heat) will significantly reduce the building's cooling load. Using daylight as much as possible will reduce cooling loads even more, because daylight contains the least amount of heat per lumen of light. (Incandescent lights are the worst—and thus the least "efficient"; they are basically small heaters that happen to produce a bit of light.)

Integrated Design

Integrated design makes use of the site's natural resources, technological efficiency, and synergies between systems. Once the building envelope is efficiently designed to reduce heat flow, natural heating and cooling methods can be used to greatly downsize, or even eliminate, fossil-fuel-based mechanical heating and cooling systems. Techniques include daylighting, solar heating, natural ventilation and cooling, efficient and right-sized HVAC systems, and utilization of waste heat.

Daylighting

Daylighting provides important occupant benefits, including better visual acuity, a connection to nature, and documented enhancements to productivity and well-being; it also reduces operational energy costs when electric lights are turned off or dimmed while daylight is ample. This emphasizes the importance of integrating all the mechanical systems—daylighting, lighting, and HVAC. It is also important to design systems to modulate with varying loads. *(See Chapter 7 for more on daylighting.)*

Passive & Active Solar Heating

Many methods of solar heating are available. They include passive solar (direct, indirect, and isolated gain), solar water heating, and solar ventilation air preheating. **Direct solar gain** occurs when sunlight strikes a high-mass wall or floor within a room; **indirect gain** (or a Trombe wall approach) is achieved by installing glazing a few inches in front of a south-facing high-mass wall, and letting the collected heat radiate from the wall into the adjoining occupied space; and **isolated gain** involves an attached sunspace, such as a greenhouse. Active solar heating systems can be used for domestic hot water and for hydronic radiant heating (warm fluid, typically piped in a floor slab or below a finish floor, radiates heat directly to people in the room, which is generally more efficient than heating air). *(See Chapter 5 for more on solar heating.)*

Other Efficient Cooling Methods

There are multiple techniques for natural ventilation and cooling. For example, in hot, dry climates, **thermal chimneys** and **evaporative cooling** are effective (and have been used for thousands of years in the

Middle East). A thermal chimney uses solar energy to heat air, which rises and is exhausted out the top of the chimney, causing a natural convection loop as cooler air is drawn into the building (sometimes through a cool underground duct) to replace the exhausted hot air. Evaporative cooling draws heat from the air to vaporize water, making the resultant air cooler and more humid. This works in dry climates, where it may be desirable to add humidity. **Earth sheltering** and **earth coupling** take advantage of the vast thermal mass of the ground, which remains a constant temperature at a certain depth below grade (the depth depending on the climate). Earth sheltering can also protect the building from inclement weather, such as strong wind.

In a climate with a large diurnal temperature swing, **thermal mass cooling** can be accomplished by allowing cool nighttime air to flow across a large indoor building mass, such as a slab. The cool thermal mass then absorbs heat during the day.

Though not a passive technology, **radiant cooling** is more efficient than conventional systems that circulate conditioned air. Typically, radiant cooling involves running cool water through floor slabs, or wall or ceiling panels. In a hot dry climate, the water can be cooled evaporatively and radiatively by spraying it over a building roof at night, then collecting and storing the cooled water for use the next day. In a humid climate, dehumidification is needed in addition to cooling, but lowering humidity and providing airflow can enable people to be comfortable at temperatures up to nine degrees warmer than they otherwise would be.[9]

Renewable Energy

According to the National Renewable Energy Lab, "each day more solar energy falls to the earth than the total amount of energy the planet's 5.9 billion people would consume in 27 years." Solar energy is the only energy income the earth receives. (Wind, tidal, and biomass energy are all derived from solar energy.) Of course, the less energy we need after applying all the energy-efficiency measures, the less it will cost to supply the remaining energy demand with renewable sources.

After all practical steps have been taken to reduce energy loads, appropriate renewable energy sources should be evaluated. These include wind, biomass from waste materials, ethanol from crop residues, passive heating and cooling, photovoltaics, geothermal, tidal, and environmentally benign hydro (including micro-hydro) technologies. Clean, distributed energy production methods include fuel cells and microturbines. If a building is more than a quarter-mile from a power line, it may be less expensive to provide "off-grid" power than to connect to a grid.[10] This is a particularly valid consideration in developing countries. (In the U.S., building remote from the grid probably means pushing further into wildlands, which usually poses other sustainability issues.)

Third-Party Commissioning

Building commissioning—independent assessment of systems to ensure that their installation and operation meets design specifications and is as efficient as possible—can save as much as 40% of a building's utility bills for heating, cooling, and ventilation, according to Lawrence Berkeley National Laboratory.[11] The commissioning agent ideally gets involved with the project at its outset. Throughout the life of the building, ongoing, regularly-scheduled maintenance and inspection as well as formal "re-commissioning" ensure proper, planned performance and efficiency of the building and its mechanical systems. *(See Chapter 12 for more on commissioning.)*

Enhanced Security

An important benefit of widespread construction of energy-efficient buildings, building-efficiency retrofits, and renewable energy generation is the reduction of dependence on foreign fossil fuels, a trend that could greatly enhance U.S. security, while creating a more trade-balanced, resource-abundant world. Security is further enhanced by efficient buildings and distributed energy production lessening the need for large centralized power plants that could provide strategic targets for terrorist attack.

Demolition/ Construction Practices

With any site development, it is important to protect the watershed, natural resources, and agricultural areas, and therefore to be especially vigilant about erosion control and pollution prevention. Rather than degrading the surrounding environment, development can actually enhance it.

Demolition and construction should be carefully planned to reduce or eliminate waste. Typically, demolition and construction debris account for 15%–20% (in some places, up to 40%) of municipal solid waste that goes to landfills, while estimates are that potentially 90% of this "waste" could be reusable or recyclable.[12]

Ideally, planning for waste reduction begins not when a building is about to be demolished, but with initial building design. Buildings can be designed for flexibility to accommodate changing uses over time, for ease of alteration, and for deconstructability should the building no longer be suited for any use. Planning for deconstruction involves using durable materials and designing building assemblies so that materials can be easily separated when removed. For example, rather than adhering rigid foam roof insulation to the roof surface, installing a sheathing layer in between allows the insulation to be reused. Window assemblies can also be designed for easy replacement, which is not unlikely during a building's life.

Reusing and recycling construction and demolition waste is the "environmentally friendly" thing to do, and could also result in cost savings while promoting local entrepreneurial activities. A waste reduction plan, clearly outlined in the project's specifications, would require the following:

- Specification of waste-reducing construction practices.
- Vigilance about reducing hazardous waste, beginning by substituting nontoxic materials for toxic ones, where possible.
- Reuse of construction waste (or demolition) material on the construction site (for instance, concrete can be ground up to use for road aggregate).
- Salvage of construction and demolition waste for resale or donation.
- Return of unused construction material to vendors for credit.
- Delivery of waste materials to recycling sites for remanufacture into new products.
- Tracking and reporting all of this activity.

It is critical to note that reusing, salvaging, and/or recycling materials requires additional up-front planning. The contractor must have staging/storage locations and must allot additional time for sorting materials, finding buyers or recycling centers, and delivering the materials to various locations. *(See Chapter 3 for more on deconstruction practices.)*

Recycling

"Americans produce an estimated 154 million tons of garbage—roughly 1,200 pounds per person—every year. At least 50% of this trash could be, but currently isn't, recycled," according to Alice Outwater.[13] Recycling doesn't stop at the job site. The building should be designed to foster convenient recycling of goods throughout the life of the building. This usually entails easily accessible recycling bins or chutes, space for extra dumpsters or trash barrels at the loading dock, and a recycling-oriented maintenance plan.

Environmental Sensitivity

Learning from the Locals

Every region of the world has a traditional building culture or a "vernacular" architecture. Because people in the past could not rely on providing comfort through the use of large quantities of resources extracted and transported over long distances, they had to make do with local resources and climate-efficient designs. Thus structures in the hot, dry U.S. Southwest made use of high-thermal-mass adobe with water-cooled courtyards. New England homes used an efficient, compact "saltbox" design. In the South, "dogtrot" homes with high ceilings provided relief from the hot, humid climate.

But how did the first settlers decide how to build? It could be that they—and we—have a lot to learn from other types of "locals"—from the wisdom of the natural world. For example, according to their descendants, the original Mexican settlers of the San Luis Valley of Colorado, wondered how thick to make the walls of their adobe homes in the new climate. To answer the question, they measured the depth of the burrows of the local ground squirrels and built to those exact specifications.

Looking to nature for design solutions makes a lot of sense. Over the course of 3.8 billion years of evolution, poorly adapted or inefficient design solutions became extinct—those that are still with us can give us clues as to how our own buildings and site solutions can be better adapted. For instance, human-engineered drainage systems use concrete storm drains to remove water as fast as possible from where it falls, often channeling it to municipal sewage systems where it is mixed with sewage. As more and more of a city gets covered with impermeable surfaces, these combined stormwater/sewage systems cannot handle the load of big storms, which can overflow into streets and erode and pollute streams. By contrast, a solution modeled on natural drainage would have surface swales, check dams, depressions, temporal wetland areas, and ecologically appropriate plants to absorb water over a large area, closer to where it falls. Clustering development to allow for open areas where natural drainage can occur provides natural beauty and an effective stormwater solution, reduces the strain on the sewage treatment plant, provides habitat for other species, and costs less to build.

As is true with so many green building solutions, a roof covered in native grasses provides multiple benefits—it helps solve the stormwater runoff problem, increases roof insulation value, greatly extends roof life (due to blocked ultraviolet radiation), lowers ambient air temperature (by reducing radiation from the roof) thereby lowering the urban "heat island" effect, improves air quality (by producing O_2, absorbing CO_2, and filtering the air), increases wildlife habitat, adds beauty, and can provide pleasant, usable outdoor space, even in a crowded city. With growing awareness of all these benefits, an increasing number of cities around the world are providing incentives for green roofing, even mandating it for some buildings.[14]

Site Selection & Development

How can development leave a place better than the way it was found? A key tenet of green development is to promote health and diversity for humans and the natural environment that supports us. One approach is to restore degraded land to enhance long-term proliferation of life. Responsible site development also involves attention to human culture and community, as well as to the needs of other species in a diverse ecosystem.

Renovating existing buildings should be considered before looking for new building sites. This reduces construction costs, while salvaging an existing resource. Sometimes it keeps a building from being demolished, which is critical because a building's biggest energy use is typically associated with its construction. This approach may even preserve cultural heritage by keeping a historic building in use and maintained.

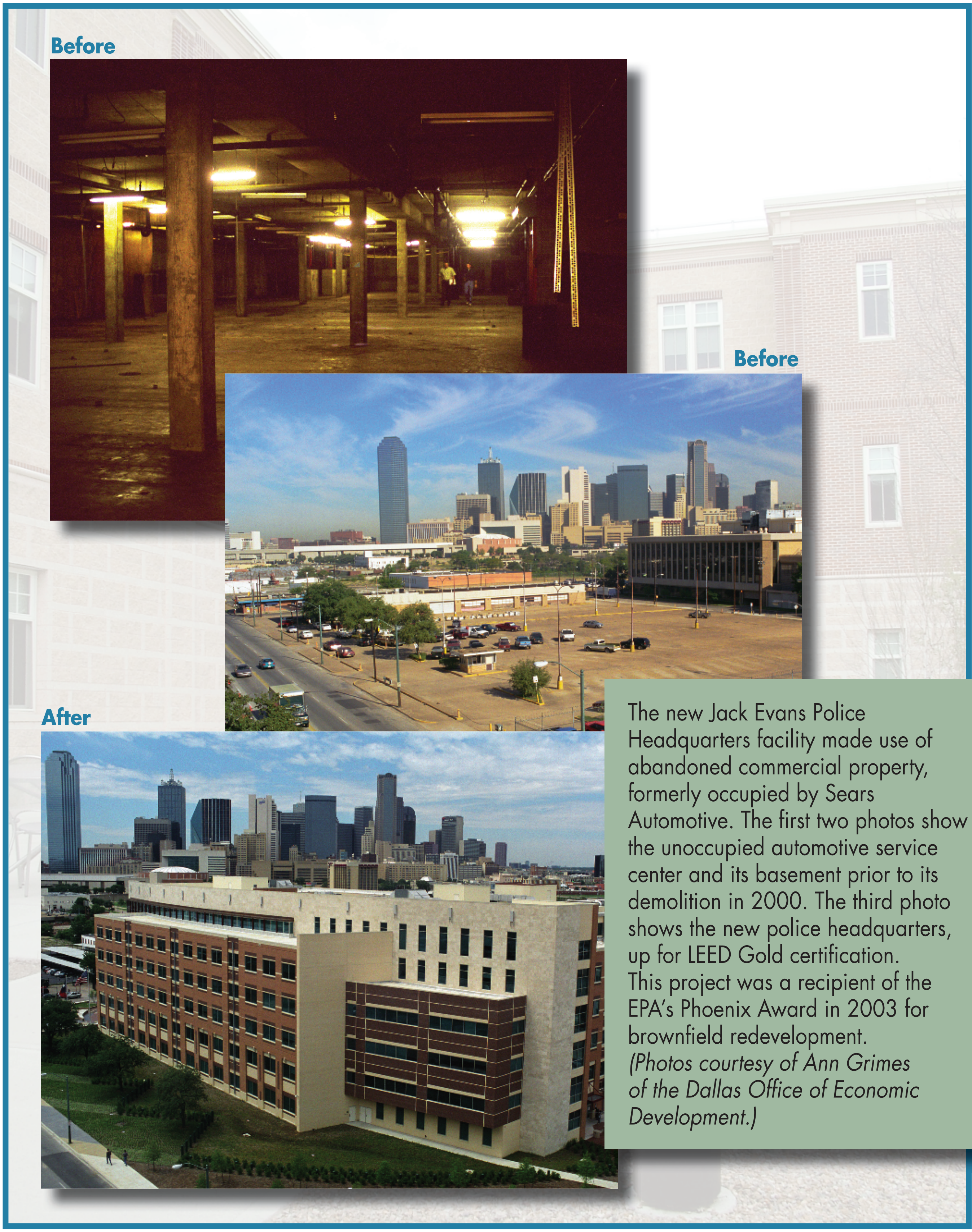
If no suitable existing building can be found, "brownfield" or infill sites should be evaluated next. **Brownfield** sites are abandoned industrial areas that often require remediation prior to new construction. If hazardous wastes are present, the use of the site should be carefully considered, even though remediation will be performed *(See Figure 1.3 for an example of an award winning brownfield rejuvenation project.)* **Infill** simply means building on a vacant site within an established urban area, rather than on the outskirts.

All three of these options—building renovation, brownfield, and infill development—preserve farmland and ecologically valuable natural areas and limit "urban sprawl." These options also tend to have lower infrastructure costs, because transportation infrastructure and utilities such as sewage, electricity, and gas are usually already in place. Finally, these sites are usually located close to existing schools, businesses, entertainment, and retail, enhancing convenience and potentially reducing automobile use.

When choosing a new building site, important considerations include the availability of a sufficient, rechargeable water source and access to renewable energy sources (such as solar, wind, geothermal, or biomass). Developing land that is ecologically sensitive (including wetlands or rare habitats), prime farmland, culturally/archeologically significant, or vulnerable to wildfire or floods should be avoided.

Where should a building be sited? "Buildings must always be built on those parts of the land that are in the worst condition, not the best."[15] Open space should not be the "leftover" area. After preserving (and sometimes restoring) the most ecologically valuable land in its natural state, additional open spaces for outdoor activities should be as carefully planned as the spaces within buildings.

Green development includes regional planning that gives priority to people, not to automobile circulation. The design of a green development should accommodate people who are too old, too young, or financially or physically unable to drive. Such developments include



The new Jack Evans Police Headquarters facility made use of abandoned commercial property, formerly occupied by Sears Automotive. The first two photos show the unoccupied automotive service center and its basement prior to its demolition in 2000. The third photo shows the new police headquarters, up for LEED Gold certification. This project was a recipient of the EPA's Phoenix Award in 2003 for brownfield redevelopment. *(Photos courtesy of Ann Grimes of the Dallas Office of Economic Development.)*

Figure 1.3
Brownfield Rejuvenation

public transit (preferably pollution-free), parks, pedestrian and bike trails, an unsegregated mix of housing types (from low- to high-income, all in the same neighborhood), and a balance of housing, business, and retail in close proximity. Other goals of a green development are to limit sprawl (with urban growth boundaries, for instance) and to provide distributed electricity generation systems (those located close to the user, such as fuel cells, photovoltaic arrays, wind microturbines, biomass, and geothermal).

Water/Landscape

A myriad of problems can result from impervious surfaces: urban heat islands (asphalt-laden cities that are several degrees hotter than surrounding areas), altered stream flows (lower lows and higher highs, increased flooding), and polluted waters (from unfiltered road- and parking-surface runoff). Fortunately, cities are starting to see the economic and social value of preserving and restoring natural capital. Shade trees can reduce ambient air temperature by 15 degrees. Natural drainage can be far less expensive up-front, and far less costly in avoided flooding, pollution, and stream damage in the long run. There are many options for reducing stormwater runoff from a site, including reinforced grass paving, porous asphalt, rainwater-collection cisterns, infiltration islands in parking lots, swales, dry wells, and planted stormwater retention areas.

One type of landscape often overlooked in development is edible plantings. Gardens, orchards, or crops can and should be incorporated into both residential and commercial projects. These plantings can serve all the functions of non-edible landscaping (e.g., cooling and stormwater absorption) and produce food as well. The Village Homes community in Davis, CA, for instance, has a revenue-producing almond orchard, as well as a wide variety of fruit trees interspersed along pedestrian paths.

Although turf grass serves to facilitate many functions, such as play and picnic areas, it need not be planted ubiquitously in areas that are not going to be used for those functions. The turf grass that is planted on lawns and corporate campuses is typically a non-native, monoculture crop that requires constant human input (mowing, watering, fertilizing, and dousing with pesticides and herbicides). These inputs are neither cheap nor environmentally sound. By contrast, native landscape is perfectly adapted to thrive in the local environment and therefore needs no irrigation or fertilizer, is ecologically diverse enough to resist pests, and provides free stormwater management. When landscape architect Jim Patchett replaced turf grass with native prairie on the Lyle, Illinois, campus of AT&T, multiple problems were solved, while maintenance costs dropped from $2,000 to $500 per acre.

Sewage Treatment

The average U.S. effluent production is about 100 gallons per capita per day, which creates a tremendous sewage burden. Most cities run sewage through primary and secondary treatment plants that use both mechanical and chemical processes, which typically remove about 90%–95% of the solids in the wastewater. Tertiary treatment can remove 99% of solids, but is rarely done because costs are considered too high for the marginal benefit. This means that in most cities, up to 10% of everything that is flushed down the toilet escapes the treatment plant and ends up in the waterways.[16]

The first goal for more sustainable sewage systems is to reduce the amount of effluent that needs to be treated in the first place with water-efficient (or waterless) plumbing fixtures. Waterless urinals not only reduce water consumption, they are also more sanitary and odor-free than standard urinals, because bacteria prefer wet surfaces. Composting toilets detoxify human waste without water (and produce usable fertilizer), but they do require a lifestyle adjustment.

After sewage is minimized, the most ecologically sound methods of treating it should be evaluated. Biological sewage treatment systems detoxify the waste from standard toilets and can treat sewage to tertiary levels. They can take several forms, including constructed wetlands, greenhouse systems, and algal turf scrubber systems. Whether the wastewater is being purified by bacteria, plants, invertebrates, fish, and sunlight in a series of tanks in a greenhouse, or by an outdoor wetland ecosystem, the idea is to use natural processes. This significantly reduces chemical use, energy use, and potentially, operational costs. Unlike conventional systems, these alternative systems also provide an amenity—they are appealing, typically odor-free, and can provide plants for sale to nurseries and purified water for reuse in the landscape. Some biological sewage treatment systems have even become tourist attractions.

Designing for People: Health & Productivity

Building Design & Materials

The recent exposure that "Sick Building Syndrome" has been given in the news media has raised awareness around the issue of how buildings affect the people occupying them. This is significant, because the average American spends 90% of his or her

Sick Building Syndrome

High-risk people: Elderly, children, and people with allergies, asthma, compromised immune systems, or contact lenses.

Symptoms: Headache; fatigue; congestion; shortness of breath; coughing; sneezing; eye, nose, throat, and skin irritation; dizziness; and nausea.

Multiplicative effects: Combining chemicals, poor temperature and lighting, ergonomic stressors, and job stress.

time indoors. Sick Building Syndrome has been attributed to tighter buildings and poor air quality caused by off-gassing of volatile organic compounds (VOCs) from modern finish materials (such as paints, adhesives, carpets, and vinyl); poorly vented combustion appliances; equipment and chemicals (such as copiers and lab or cleaning compounds); tobacco smoke; soil gases (such as radon, pesticides, and industrial site contaminants); molds and microbial organisms; and intake of outdoor air contaminated with pollen, pollution, or building exhaust.

Air quality should be protected by ensuring adequate ventilation and locating air intakes away from dumpsters, exhaust vents, loading docks, and driveways. Carbon dioxide monitors can be installed to ensure adequate (but not excessive) ventilation, thereby optimizing both air quality and energy efficiency. Heat recovery ventilators can capture heat from the exhausted air (or pre-cool the incoming air, depending on the climate). Most important, however, is to ensure the best possible air quality in the first place, when the building is constructed. Properly vent radon, use nontoxic building materials, and design wall, roof, and foundation assemblies to avoid mold growth by keeping rain and condensation out of them in the first place and providing a way for it to dry out if it does get in. *(See Chapter 7 for more on indoor air quality.)*

Maintenance

Protecting the indoor environment does not stop when building construction is completed. Air quality must be ensured through routinely scheduled maintenance and housekeeping. If roof or plumbing leaks are undetected or neglected, hazardous molds can develop. Also important is *how* a building is maintained and with what type of housekeeping products. A building can be carefully designed with nontoxic finishes, only to have the fumes from noxious cleaning products absorbed into soft finish materials.

Some systems are easier to maintain than others. For instance, it is more difficult for microbes to grow on metal air ducts than on those lined with fiberboard insulation, and the metal ducts are also easier to clean. Regularly changing air filters and maintaining carpets and other finishes is critical. Occupants and custodial staff should be educated so they understand how to protect a building's healthfulness and performance, as well as its appearance. Human exposure to harmful chemicals should be minimized, and procedures should be established to address potential accidents with hazardous chemicals.

A More Natural Indoor Environment

Despite the difficulty of pinpointing the cause of health problems, there is currently little doubt that poor indoor environmental quality plays a role in many common maladies such as headaches, eyestrain, fatigue, and even more serious illnesses such as asthma and chemical sensitivity. If poor lighting, stale air, harsh acoustics, and lack of connection to nature can compromise people's health at work or at home, what effect does improving these conditions have? Several studies of green office, school, and hospital buildings have shown that factors such as high levels of daylighting, views to nature, individual control of workplace environment, and improved acoustics are strongly related to improved health and productivity, including faster healing in hospitals, higher test scores in schools, lower absenteeism in offices, and generally lower stress levels.[17]

Factors that Enhance Productivity and Health

- Quality lighting, including high levels of daylighting
- Increased individual control of workplace, including lighting
- Heating and cooling
- Improved acoustics
- Improved indoor air quality
- Views to nature

Researchers in a field called "biophilia" are studying the correlation between building ecology (specifically more "natural" environments that feature views to nature, daylight, and fresh air) and good health. Their theory is that human evolution predisposed us to thrive in the natural environment, and thus connecting to it at work or at home positively impacts our performance and well-being. There may be other benefits as well. For instance, NASA research has shown that significant quantities of plants can purify many toxins from the air.[18]

Quality Lighting

Daylighting

Quality lighting starts with well designed daylighting, which is more than just providing windows. In order to avoid glare (the difference in luminance ratio between a window and its adjoining spaces), daylight must be introduced—or reflected—deep into the building, and direct-beam light (such as that from standard skylights) should be diffused or reflected onto a ceiling. These goals can be accomplished using light monitors, clerestories, light shelves, advanced skylight systems, atria, courtyards, and transom glass atop partitions. Light-colored finishes greatly enhance the ambient brightness of the room. *(See Chapter 7 for more on daylighting.)*

Indoor Electric Lighting

With daylighting and electric lighting designed as an integrated system, the amount of electric lighting needed during most of the day can be reduced. For instance, if linear fluorescent fixtures are run parallel to window walls, those that are close to the window can be dimmed with automatic dimming controls when daylight is ample. Rather than dropping a set number of footcandles of light into an area, quality lighting is the careful art of directing light onto surfaces where it is specifically needed—primarily on walls and ceilings (not on floors).

Fixtures that provide mainly indirect, but also some direct light will create an even, glare-free ambiance, to which task lighting can be added to accommodate specific activities and individual preferences. Accent lighting can be added to create sparkle and to draw people into or through a space. Within a well-designed lighting system, efficient lighting fixtures, such as fluorescent tube lights, compact fluorescent lights (CFLs), and light emitting diodes (LEDs) will further reduce energy use.

Outdoor Lighting

Glaring outdoor light should be avoided in new installations and replaced in existing ones. Bright, glaring light can be intrusive and dangerous (elderly people often take minutes to adapt back to lower light levels), and it imparts light pollution to night skies. This is a serious issue, not only for astronomers, but also for natural systems such as the nesting and migration of birds. Hooded fixtures are a good choice to protect nighttime darkness. For security lighting, it is preferable to provide uniform glare-free illumination on horizontal surfaces (rather than bright spots of light) and to highlight important vertical surfaces—such as destination doorways. White light provides the best peripheral vision. Yellow light, as provided by low- and high-pressure sodium lamps, accommodates no peripheral vision at all.

Figure 1.4
Hooded outdoor lamps, such as this one, help protect nighttime darkness by directing light flow down, only where it is needed. *(Photo courtesy of the International Dark-Sky Association.)*

Individual Environmental Control

Operable windows, furniture with adjustable ergonomic features, dimmable lighting, and available task lighting are all examples of provisions for individual environmental control. Adjustable thermostats or, even better, under-floor air distribution with an airflow diffuser for each occupant, can provide individuals with temperature control. Such provisions allow people to maximize their personal comfort and provide psychological benefit as well. Even people who rarely open their windows appreciate being able to do so.

Green Building Hurdles

If green building has so many advantages, why isn't everyone doing it? There are currently several impediments to the universal practice of green building. First, although it has grown tremendously in the past few years, it is still a relatively new field, with the knowledge base continuing to grow among design and construction professionals. Second, developers and builders tend to try to keep things as simple as possible because "experimentation" adds time to a project, and time means money. Moreover, tried and true methods avoid liability risk, because lawsuits are often based on deviation from standard practice.

Market expectation also plays a role in a "Catch-22" fashion. Developers build what is selling on the market, while people buy what is available on the market. Without a large sample of green buildings to choose from, there is little room for market demand to drive construction of green buildings. Developers and builders who take the risk to build green are typically well rewarded, but if no one in the area has tried it yet, there may be few who are bold enough to be the first.

Misguided incentives cause yet another problem. Usually design decisions are made by developers and their hired design teams, but most of the financial and other benefits of a green building accrue to end users—owners or tenants who typically have no input in the design. Other less quantifiable benefits accrue to the community and society at large. Although there is growing evidence that green buildings provide lower operational costs and better quality environments, the mainstream market hasn't recognized this yet. Only when this happens will mainstream developers have the full incentive to build green, knowing that they will enjoy premium rents, lower turnover, fewer liability risks, and a better reputation.

Conclusion

Termites live in inhospitable climates of Africa, Australia, and the Amazon by building air circulation passages in the walls of their structures that can cool the inside by as much as 20°F. These termite mounds are as hard as concrete, but constructed out of locally collected soil, wood fiber, and the termites' own saliva.

We don't have to live in termite mounds to benefit from the ingenuity of their design. Nature's innovations—structures made and operated with local materials, current solar income, and no toxicity—should be the role models for our own built environment. We need to stop asking the question, "how can we do less harm?" and ask instead how we can *enhance* the human experience in the built environment, while enhancing the natural environment at the same time. Toxic building materials, energy-inefficient building systems and methods, and reliance on non-renewable energy sources are short-term, ultimately detrimental solutions. We need to start relying on solutions that are well adapted for life on earth in the long run.

Green building is a turn in the right direction. Sustainably designed new buildings can produce more energy than they consume; use local, nontoxic, low-energy materials; and enhance occupant experience, all while benefiting the surrounding community. And green buildings make good, long-term economic sense. When systems are properly integrated, overall first costs may be lower for green buildings than for standard buildings, while operational costs are almost always lower for green buildings.

Even more important, studies have shown that in green buildings, workers are more productive and take fewer sick days, students learn faster and are absent less often, and hospital patients heal more quickly and require less medication.[19] Green buildings are fundamentally better buildings; it's time for them to become the norm, not the exception.

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