CHAPTER 5

Building Blocks

A bank whose workers don't want to go home — A creek runs through it — Green buildings and bright workers — Just rewards and perverse incentives — Windows, light, and air — Every building a forecast — Harvesting bananas in the Rockies — Urban forests — Walkable cities

IN SOUTHEASTERN AMSTERDAM, AT A SITE CHOSEN BY THE WORKERS BEcause of its proximity to their homes, stands the headquarters of a major bank.[1] Built in 1987, the 538,000-square-foot complex consists of ten sculptural towers linked by an undulating internal street. Inside, the sun reflects off colored metal — only one element in the extensive artwork that decorates the structure — to bathe the lower stories in everchanging hues. Indoor and outdoor gardens are fed by rainwater captured from the bank's roof. Every office has natural air and natural light. Heating and ventilation are largely passive, and no conventional air conditioners are used. Conservatively attired bankers playfully trail their fingers in the water that splashes down flow-form sculptures in the bronze handrails along the staircases. The building's occupants are demonstrably pleased with their new quarters: Absenteeism is down 15 percent, productivity is up, and workers hold numerous evening and weekend cultural and social events there.

These results surpassed even the directors' vision of the features, qualities, and design process they had mandated for their bank. Their design prospectus had stipulated an "organic" building that would "integrate art, natural and local materials, sunlight, green plants, energy conservation, quiet, and water" — not to mention happy employees — and that would "not cost one guilder more per square meter" than the market average. In fact, the money spent to put the energy savings systems in place paid for itself in the first three months. Upon initial occupancy, the complex used 92 percent less energy than an adjacent bank constructed at the same time, representing a saving of

$2.9 million per year and making it one of the most energy-efficient buildings in Europe.

Architect Ton Alberts took three years to complete the design of the building. It took so long mainly because the bank board insisted that all participants in the project, including employees, understand its every detail: The air-handling design had to be explained to the landscape architect, for example, and the artwork to the mechanical engineers. In the end, it was this level of integration that contributed to making the building so comfortable, beautiful, and cost-effective. When it was done, the structure became the most readily recognized in all Holland after the Parliament House. Since the headquarters building was completed, the bank that was then called NMB has gained a dynamic new public image and corporate culture, though whether this is directly related to the new building's design is impossible to prove. It has grown from the fourth- to the second-largest bank in Holland, changed its name to ING, and bought the venerable English merchant bank Barings.

When Michael and Judy Corbett began Village Homes in Davis, California, in the 1970s, there was no housing development like it. It featured mixed housing types on narrower streets, greenbelts with fruit trees, agricultural zones among the houses, natural surface drainage, solar orientation, and abundant open space. By the 1980s it had grown to encompass 240 homes on 70 acres, and had become a dearly loved neighborhood with a delightful ambience, lower utility and food costs, and a strong community spirit.[2]

One example of its unique design philosophy was the use of natural drainage swales instead of costly underground concrete drains, a choice that saved eight hundred dollars of investment per house. Those savings paid for much of the landscaping of the extensive parks and greenbelts, while the swales allow enough water to soak in that the landscaping needs one-third to one-half less irrigation water. The drainage swales are themselves part of the greenways, which not only provide routes for pedestrian and bicycle circulation but are also a focus for community life. The houses — some nearly hidden behind grapevines, flowers, and shrubs — face one another across the greenways. Cars are parked discreetly around the back on narrow (twenty-four-foot-wide), tree-shaded streets.

The street and greenway networks enter the site from opposite directions, like interlocking fingers, so they don't cross. Safe from traffic, children can play in the heavily used and watched greenways. Thanks to the vibrant street life and the strong sense of community, the crime rate is only one-tenth that of adjacent subdivisions built in the usual car-dominated, "dead worm" layout. The average number of cars per household is 1.8 in Village Homes, compared to 2.1 elsewhere in Davis.

The narrower streets not only reduce the level and speed of traffic and save money and land but also require less paving material, which improves the summer microclimate: Because trees can shade the entire street, there's far less dark paving exposed to sunlight to absorb and reradiate solar heat. Combined with passive-solar design and proper site orientation, this feature raises comfort and cuts energy bills by half to two-thirds — an impressive achievement for 1970s design and materials.

Residents were also allowed to conduct business in their homes, an activity that was illegal in many American communities at that time. Community organic gardens and edible landscaping provide fresh fruit for breakfast. Village Homes is also able to help finance its parkland maintenance by selling its organic crops of vegetables and almonds — the fruits, so to speak, of investments originally paid for partly by eliminating those eight-hundred-dollar-per-lot storm drains.

Because it has proven to be so desirable a place to live, Village Homes, originally modest in its market positioning, now realizes some of the highest resale prices per square foot of floorspace in Davis. Units sell in less than one-third of the normal listing time (that is, when they are listed for sale — most are quickly snapped up by word of mouth) and fetch eleven dollars per square foot above normal market value. At first considered so quirky that agents wouldn't show it, Village Homes is now described by real estate brochures as "Davis's most desirable subdivision."

The Inn of the Anasazi is a fifty-nine-room luxury hotel located just off the Governor's Plaza in Santa Fe, New Mexico. The building began its life in the 1960s as an ugly steel-and-glass box — a sort of giant shipping container used as a juvenile detention center and penitentiary headquarters. In 1991, the developers of the inn transformed it into an adobe-style structure that looks centuries old.

The inn is extremely comfortable and fairly efficient. But the vision that inspired it reflected more than a simple desire to conserve physical resources. Its construction materials, furniture, and art are produced from local resources by traditional artisans. Its toiletries are made from traditional Native medicinal herbs, and, like the art in the rooms and lobby, are also sold by the hotel for the makers' benefit. Staff are drawn from all three local cultures — Native, Hispanic, and Anglo — and are not only trained in conflict resolution but often provide it to other community organizations as a free service. Staff members are also paid for two hours' volunteer work a week for local groups, and can choose to sign a "Right Livelihood" agreement authorizing them to undertake ecologically responsible work in the name of the hotel. Staff turnover is minimal — a source of wonderment to competing hostelries, whose management are now requesting seminars offered by the inn to learn how they can emulate this success.

The hotel's celebrated gourmet restaurant obtains 90 percent of its ingredients from local organic farmers, many of whom are Hispanic land-grant families. (Keeping their land in agricultural production protects them from losing it to taxation at development value.) Leftover food goes to homeless shelters, kitchen scraps to an organic pig farm, table scraps to compost. With time, ever more and deeper links integrate the hotel into its place and its peoples. Why isn't every building so organically rooted?

Or so profitable: Despite its high prices, the inn broke even in its second year of operation — a rarity for a new hotel. It has 83 percent average annual occupancy, unheard-of in Santa Fe's highly seasonal market, and gets a high 35 percent repeat traffic.

What do a Dutch bank, a California tract development, and a New Mexico hotel have in common? All three projects are archetypes of a successful fusion of resource efficiency, environmental sensitivity, attention to human well-being, and financial success that has been called "green development."[3]

Buildings, however much we take them for granted, are where Americans spend about 90 percent of their time. They use one-third of our total energy and two-thirds of our electricity. Their construction consumes one-fourth of all wood harvested; 3 *billion* tons of raw materials are used annually to construct buildings worldwide.[4]

In the recent past, most choices about building design and materials have been made carelessly, yielding low returns on human capital or actual losses to society. In the future, the design paradigm illustrated by these three examples can yield far greater benefits to people, their pocketbooks, and the earth. Green buildings compete in bottom-line terms as well as in aesthetics. They are relatively inexpensive to build, operate, and convert to their next use, as human needs inevitably evolve. Their mechanical systems to maintain comfort are small and well designed, or better still, eliminated by design. More buildings will be built around, within, or from recycled old ones. New materials are being supplemented by rediscovered ancient ones like rammed earth, straw bales, adobe, and caliche (a dense clay) — all nontoxic, safe, durable, and versatile. High technology will make its own contributions. Slender carbon-fiber-reinforced layers are already cost-effectively integrated into wood-frugal structural beams, creating a sense of lightness that extends through structural and seismic design. These innovations are part of a new design thinking that emulates the airy strength of spiderwebs and feathers, enclosing the most space with the least structural materials.

Such buildings' resource and economic efficiency and their environmental sensitivity spring not merely from a desire to save money and prevent pollution but from a deeper consciousness that integrates design arts and sensibilities too long sundered from architecture and engineering. At its best, green development fuses a biologically and culturally informed appreciation of what people are and want, and a tool kit of technologies to fulfill those needs. Their most extraordinary prototypes, like the three projects described in the preceding pages, occur when all these elements are integrated and their synergies captured. At first the results seem magical, in the sense of Arthur Clarke's remark that "any sufficiently advanced technology is indistinguishable from magic." Yet now the practices that create that magic are starting to be widely valued and appreciated. They will drive a revolution in buildings and in how we inhabit them.

The benefits that can accrue from intelligent design extend far beyond the buildings themselves. The placement of structures on the land also affects our sense of community, for it determines both where we must go, and how we can do so, to travel between the places where we live, work, shop, and play. It also governs what land is available for farms, ranches, forests, wildlife, and wild places. Too few designers ask, as poet and farmer Wendell Berry has, "What does this place require us to do? What will it allow us to do? What will it help us to do?" Berry also said, "What I stand for is what I stand on" — reminding us that land must be measured not just in acres and dollars but in love and respect.

These three projects, and more described below, begin to redefine real estate development as more of an art — not simply one that does less harm but one that can actively rebuild community, restore pedestrian safety and access, and reduce the context for crime. And it's even more profitable.

GREEN BOTH WAYS

Fundamentally, green buildings are superior to ordinary structures as a result of the same sort of design integration that makes Hypercars better than ordinary cars. The shell, lighting, and internal machines, appliances, and equipment of the building are so energy efficient that indoor comfort can be maintained with little or no active heating or cooling. Energy savings can accumulate in green buildings in a way comparable to how weight savings increase in Hypercars. In both cases, a high level of design integration crossing traditional professional boundaries, and careful planning that takes the right steps in the right order, create synergies that both reduce cost and enhance performance: The better the design, the greater the benefits. The economic advantage of green design extends throughout and beyond the project's operating life, but it begins with the design, approvals, and construction process. Integrative design may also initially appear to be more costly, but that premium quickly vanishes as designers gain experience with it, and it is more than offset by the savings on hardware. Although many developers assume that green buildings must cost more to build, green design can actually *decrease* construction costs, chiefly by saving infrastructure expenses and by using passive heating and cooling techniques that make most costly mechanical equipment unnecessary.[5]

While efficient new buildings save around 70–90 percent of traditional energy use, and often several percent in capital cost, they offer three additional and even more valuable economic benefits:[6]

- Green projects typically sell or lease faster, and retain tenants better, because they combine superior amenity and comfort with lower operating costs and more competitive terms. The resulting gains in occupancies, rents, and residuals all enhance financial returns.
- The buildings' greater visual, thermal, and acoustic comfort creates a low-stress, high-performance environment that yields valuable gains in labor productivity, retail sales, and manufacturing quality and output. These improvements in turn create a key competitive advantage, and hence further improve real estate value and market performance.

- Better indoor air quality can improve health and productivity and reduce liability risks. The EPA estimates that building-related U.S. illnesses account for \$60 billion of annual productivity lost nationwide, and a wider study valued that loss as high as over \$400 billion.[7]

People are not simple, uniform entities that thrive in a box. They are, rather, complex living organisms that evolved in and still function best in a dynamic and diverse environment. The typical Western mechanical engineer strives to *eliminate* variability in human-made environments with thermostats and humidistats and photosensors, to maximize the conditions under which a statistical fraction of diverse people will feel "comfortable" according to a standard equation. In contrast, state-of-the-art Japanese buildings deliberately and constantly vary temperatures over a modest range. Their microchip controls deliver air not in a steady stream but in seemingly random gusts. They may even inject subliminal whiffs of jasmine or sandalwood scent into the ventilation system to stimulate the senses. This variability reflects the belief that people are healthier, happier, and more alert under subtly dynamic than under constant conditions. Western designers are starting to appreciate that this evolution-based view may offer a superior basis for design.

Few people have ever experienced real comfort — thermal, visual, or acoustic — but once they do, they tend to want more of it. Revolutions in technology, design, and consumer consciousness are already starting to create market conditions in which real estate developers and design professionals offer inferior products at their peril. Buildings that are alternately a solar oven or a walk-in refrigerator, with discomfort and energy bills to match, are coming to be seen as unacceptable. In the rapidly arriving era of green design, buildings that cost more than they should to construct and run and that work worse, look worse, and make informed customers feel worse than they demand will simply stand empty.

The theme of superior worker satisfaction and performance runs like a golden thread through the fabric of green development. Consider these examples:[8]

- Lockheed's Building 157 in Sunnyvale, California, used sophisticated daylighting to save three-fourths of its lighting energy and make the space more attractive and easier to work in. The owners expected to recover the cost of installation in four years. Yet a 15 percent drop in absenteeism and a 15 percent gain in labor productivity paid for the daylighting in the first year. Moreover, the lower overhead gave the company the edge in a tough contract competition, and the profits from that unexpected contract earned Lockheed more than it had paid for the whole building.

- When sorting speeds and accuracy at the main mail-sorting office in Reno, Nevada, suddenly shot up from unimpressive levels to the best performance in the western United States, managers realized that a lighting retrofit introduced to save energy had also enabled workers to see better. Accompanying changes in ceiling design had also reduced distracting and fatiguing noise.
- VeriFone renovated a 76,000-square-foot, tilt-up concrete warehouse in California into a new distribution headquarters.[9] The old building had few windows, and its air-handling system was inadequate to filter out pollutants from outside air. The retrofit included daylighting, a new filtration system, nontoxic materials, and improved energy efficiency, while meeting the low budget of $39 a square foot. The 65–75 percent energy saving was predicted to pay back in 7½ years — an after-tax annual return of 10 percent — but the 45 percent decrease in absenteeism was an unanticipated bonus.
- When Boeing Corporation retrofitted the lighting systems in its design and manufacturing areas, it not only cut the lighting energy by up to 90 percent (and recovered the investment in less than two years) but also helped workers to see defects in the aircraft they were constructing. The result was a valuable improvement in avoided rework, on-time delivery, and customer satisfaction.
- Wal-Mart's experimental "Eco-Store" in Lawrence, Kansas, installed a novel daylighting system in half the store and normal fluorescent lighting in the rest. Cash registers hardwired to corporate headquarters revealed significantly higher sales of merchandise on the daylit side as compared to sales in other stores. Workers preferred it, too. Now Wal-Mart is experimenting with daylighting in its other prototype stores.

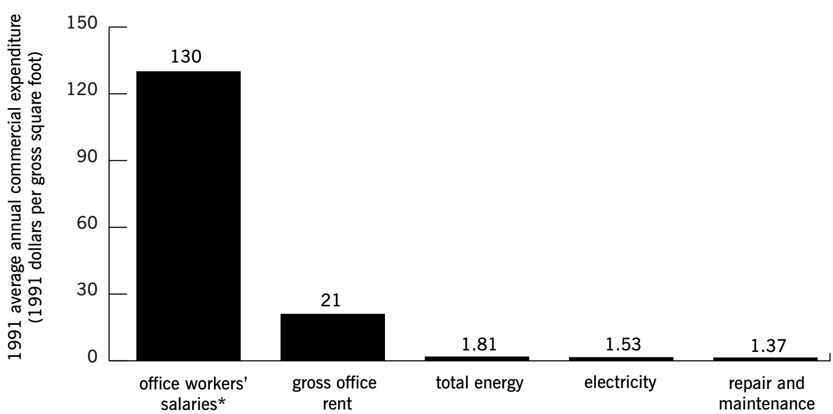
Examples like these represent an untapped source of potential savings for many companies. These and other well-measured case studies now show consistent gains in labor productivity of around 6–16 percent when workers feel more comfortable thermally, when they can see what they're doing, and when they can hear themselves think.[10] Yet as shown in the graph on page 90, typical American offices spend about one hundred times as much per square foot for people (payroll, benefits, employer taxes, and individual equipment) as for energy. It may be that managers can't afford *not* to retrofit buildings to save energy, because doing so can also make workers more productive. If labor productivity goes up just one percent, that will produce the same bottom-line benefit as *eliminating* the entire energy bill. The gains in labor productivity that the case studies show would therefore be worth at least ten times as much as the direct energy savings, which themselves are worth tens of billions of dollars a year to businesses throughout the United States.

This might seem a commonsense sort of conclusion, yet it has been overlooked until now. For the past sixty years, business schools have been teaching the myth that only management — not working conditions — can substantially affect employee productivity.[11] Obviously, workers tend to do better when respected and paid attention to. But working conditions also matter, and have been too long neglected.

REWARDING WHAT WE WANT

Conventional buildings are typically designed by having each design specialist "toss the drawings over the transom" to the next specialist. Eventually, all the contributing specialists' recommendations are integrated, sometimes simply by using a stapler. Green builders, in contrast, are insisting on the sort of highly integrative design process that was used by the Amsterdam bank, a process that melds diverse skills and perspectives into a whole that is greater than the sum of its constituent parts. One of the best ways to ensure that this takes place is to have the architects, engineers, landscapers, hydrologists, artists, builders, commissioners (specialists who get the building working properly between construction and occupancy), occupants, maintenance staff, and others who have a stake in a particular building all design the building together. All these stakeholders collaborate in a "charrette" process — a

COMPARING PEOPLE, ENERGY, AND OTHER COSTS OF RUNNING AN OFFICE BUILDING



*excluding benefits, equipment, and other overhead short, intensive, teamwork-oriented, multidisciplinary roundtable — to ensure that key synergies between design elements are captured and that those elements work together to yield big energy and resource savings at the lowest possible cost.

One reason that buildings are inefficient is that the compensation paid to architects and engineers is frequently based directly or indirectly on a percentage of the *cost* of the building itself or of the equipment they specify for it. Designers who attempt to eliminate costly equipment therefore end up with lower fees, or at best with the same fees for a greater amount of work. Energy engineer Eng Lock Lee irreverently describes the resulting mechanical-engineering standard operating practice typical of large building projects as follows:

- Take previous successful set of drawings.
- Change the box that indicates the name of the project.
- Submit drawings to client.
- Building is constructed.
- Client gripes about discomfort.
- Wait for client to stop griping.
- Repeat process.

This safe but uninspired procedure calls for mechanical equipment that is big, complex, and costly. It will work, after a fashion, and usually no one will sue because there is no liability for in*ef*ficiency — only for in*suf*ficiency. The engineer won't be held responsible for the capital or operating costs, even though the equipment is probably severalfold larger and less efficient than it should be. The engineering looks cheap to the owner; indeed, the engineer's one-time fee is less than *one-thousandth* as much as the tenant organization's long-term payroll costs for employees whose productivity, as noted above, depends significantly on the comfort produced by that engineer's handiwork. So by skimping on design, the owner gets costlier equipment, higher energy costs, and a less competitive and comfortable building; the tenants get lower productivity and higher rent and operating costs. Since World War II, such backward priorities and inverted incentives have led the United States to misallocate about $1 *trillion* of capital for the construction of about 200 million tons[12] of air-conditioning equipment, plus 200,000 megawatts of utility capacity to power them (two-fifths of the total national peak load) — neither of which would have been necessary had the same buildings been optimally designed to produce the same or better comfort at the least cost.[13]

An obvious remedy for this mess is for a developer to stipulate a positive incentive for achieving efficiency. Pilot projects launched by Rocky Mountain Institute in 1996–97 are now testing how much more efficient buildings can become if their designers are rewarded for what they save, not what they spend. Through simple supplementary contracts, designers would keep a portion of several years' measured energy savings as a bonus fee.[14] Rewards can also be balanced with penalties for poor performance. The incentive can also be paid partly up-front and partly several years later, trued up to measured savings, so the designers have the right inducement to see that their intentions are fully realized in construction, commissioning, training, and operation. Like a Chinese "wellness doctor," they could even be paid a small performance-based fee for attending to sustaining and improving the building's performance throughout its life.

But perverse incentives for design professionals are only one symptom of a much larger problem. In a typical large deal, the real estate value chain consists of twenty-five or so parties who conceive, approve, finance, design, build, commission, operate, maintain, sell, lease, occupy, renovate, and dispose of the property. Most if not all of these parties are systematically rewarded for inefficiency and penalized for efficiency.[15] Repairs to incentive structures are needed for the entire range of real estate practitioners, their professional societies, public-policy bodies, and other market actors.[16]

Encouragingly, productive tools are starting to emerge. For example, lease riders can stipulate a fair sharing of savings between landlords and tenants so both have an incentive to overcome the "split incentive" problem, in which one party selects the technology while another pays its energy costs. Savings commonly built into self-owned space are often missing from rented space. Tenants traditionally devote little attention to the efficiency of the office equipment, lights, and terminal air-handling equipment they install. They would be more conscientious if, when they were shopping for and negotiating a lease, a landlord showed them a graph of the extra direct and common-space utility bills, and the extra rent (for the capital cost of mechanical systems in a new building) that they would have to pay if they made those tenant-finish choices inefficiently — or the discounts they could earn if their designers collaborated with the landlords to minimize total building costs. Similar split incentives burden the manufacturers and consumers of all kinds of equipment used in buildings and factories. Much of this equipment is inefficient and designed for low initial cost alone, since its designers, builders, and vendors are not liable for the user's operating costs and since most buyers don't shop carefully. Indeed, for the majority of equipment, efficient models simply aren't available — at least until a big customer demands them, as Wal-Mart successfully did for daylighting and air-conditioning systems. It's remarkable how quickly "Sorry, we don't make that" changes to "When do you want it?" once the customer offers a huge order.

Because appraisers, too, rarely credit efficient buildings for their energy savings, the value of the efficiency cannot be capitalized, making financing and valuation more difficult. (A few appraisers are just beginning to capitalize savings in net operating income.) Leasing brokers typically base pro forma financials on average *assumed* operating costs, rather than on actual ones. Few buildings have efficiency labels and few renters have access to past energy bills with which to gauge expenses. In response, some jurisdictions have instituted right-to-know laws, while others obtain similar results by training renters and buyers to be inquisitive. Some leasing brokers have begun to distinguish their services by offering advice on minimizing occupancy costs. Home and commercial-building energy rating systems are emerging. A more transparent and accurate market is starting to recognize that buildings' energy efficiency is an important constituent of their financial value. The ability to upgrade America's inefficient building stock depends largely on creating better market-based information and accurate incentive structures for both tenants and owners. An important step will be the U.S. Green Building Council's release in 2000 of the Leadership in Energy and Environmental Design (LEED) rating system,[17] which provides a national standard for evaluating and comparing green building performance.

Another way to improve the efficiency of new buildings, even multifamily or multi-tenant structures, is for energy utilities to apply "feebates" for energy hookups, just as for efficient cars. Under the feebate system, you either pay a fee or receive a rebate when you connect to the gas or electric system, but which alternative and how large it is depends on how efficient your building is. Each year, the fees pay for the rebates, which makes for a politically attractive revenue-neutrality. Unlike building codes and appliance standards — which are better than nothing, but quickly become obsolete, and offer no incentive to improve upon the standards — feebates drive continuous improvement: The more efficient you are, the bigger rebate you get. You also get it up front, very close to when the design decisions are being made, so it is more likely to influence the design than are the long-term operating costs you may experience later.[18] Feebates to save energy have been tried only in small-scale U.S. experiments but are successfully used by some providers of water and wastewater services.

TRANSFORMING COMMERCIAL BUILDINGS

While design standards are continuing to improve, many successful projects prove that the current state of the art can make commercial buildings that synergistically achieve multiple goals.

For example, S. C. Johnson's 250,000-square-foot Worldwide Professional Headquarters, completed in 1997 in Racine, Wisconsin, sought to save half its energy, prevent pollution, reduce risk and waste, approach zero net water use, and restore biodiversity nearby. It's also a far more pleasant space to work in — and to eat in, since its dining facility is supported by on-site orchards and food gardens.

Equally impressive is the 15,704-square-foot Antioch, California, regional office of the California State Automobile Association.[19] This 1994 building combined better insulation and solar features with advanced windows, daylighting, and efficient artificial lighting to save 63 percent of the energy permitted by the state's strict and supposedly optimal Title 24 code. It's also the cheapest CSAA structure ever built, and its annual energy savings alone are worth twice their cost.

The characteristics that make these buildings superior are straightforward. First, a well-designed new commercial structure will have the physical shape, and will face in the direction, that takes the greatest advantage of solar gain and deflects unwanted heat or wind. These simple considerations alone generally save about a third of a building's energy use at no extra cost.[20] In fact, a carefully designed building will use not just its orientation and form but also its thermal mass, shading, surface finishes, landscaping, and other architectural elements to optimize its passive-solar heat gains and passive cooling.

Proper building alignment also provides glare-free natural light throughout the structure with the help of such techniques as curved light shelves, light pipes, light-colored surfaces, and glass-topped partitions. Whatever the weather, so long as the sun is above the horizon, artificial lighting is rarely required. The electric lights will automatically dim or turn themselves off according to daylight unless overridden. Less lighting puts less heat into the building, reducing the need for air-conditioning. Students even learn better in daylit schools, with better physical health and growth and sharply higher test scores.[21]

Modern electric lighting systems are designed to deliver light precisely in directions that wash the ceiling and walls, not flood the room's empty volume. Advanced light sources eliminate flicker, hum, and glare and produce pleasant and accurate color because the lamps are tuned to the way the eye sees red, green, and blue. Adjustable swing-arm task lights on desks combine with variable ambient lighting to control contrast and beautify the space. These features make visual tasks easier and less fatiguing. All the lighting and most of the daylighting options can be profitably retrofitted; available equipment can fit almost any use. Typical savings in lighting energy range from 80 to 90 percent at the same or lower cost in new buildings, or around 70 to 90 percent with one-to-three-year paybacks in most retrofits. Better lighting equipment often more than pays for itself just by costing less to maintain, before its electrical savings are counted.[22] It may even cost less up front to buy and install. Technology improves so rapidly that it may be worth re-retrofitting lighting systems every few years. A 1998 Malden Mills warehouse retrofit saved 93 percent of lighting energy, greatly improved visibility, and paid back in eight months (six after a utility rebate), even though the replaced system was of a type — metal halides — normally considered very efficient and hence traditionally used to improve on ancient incandescent and mercury-arc lamps.[23]

Good lighting is complemented by ergonomically designed and superefficient office equipment. For example, high-contrast, glare- and flicker-free flat-screen liquid-crystal displays adapted from portable to desktop computers are justified today by any one of the five advantages they offer — better visibility and reliability, saved energy, saved desk space, and avoidance of potential health concerns about electromagnetic fields. With all five advantages combined, the liquid-crystal screens are the best choice despite their higher price. New varieties of high-performance office equipment, including printers, faxes, and copiers, reduce their heat load to a total of as little as a fifth of a watt per square foot, about one-third of the norm.[24] Comparable gains can be achieved by carefully selecting everything from the watercooler to the coffeemaker.

Dramatic improvements can also be made in the building's shell or envelope that separates people from weather. Improved insulation and airtightness are important factors, but the key innovation in this area is "superwindows." These entered the market in the early 1980s and have become steadily more sophisticated, diverse, and widely available.[25] Superwindows, which keep people warm in the winter and cool in the summer, typically combine two or three invisibly thin coatings (which let light pass through but reflect heat) with heavy gas fillings such as krypton to block the flow of heat and noise. Mass-produced versions competitively priced at about 10–15 percent above double-glazed windows can insulate four and a half times better, or as well as eight sheets of glass. The most efficient units insulate as well as twelve sheets of glass, but look like double glazing and cost less than triple glazing. Superwindows have enabled experimental superinsulated eighties and nineties buildings to maintain comfort with no heating or cooling equipment in outdoor temperatures that range from about –47 to 115°F. They're often "tuned" so that on different sides of a building they all look the same but have different infrared properties, a feature that independently optimizes the flow of heat and of light across the building shell in each direction. This technique can make a building so passive that it needs few or none of the elaborate and unreliable active control systems that, in marketing parlance, define a "smart" building. A truly smart building keeps you comfortable without controls.

Even better windows will soon reach the market. Nearing commercialization are aerogel glazings whose almost invisible, lighter-than-air silica foam can insulate several times better than today's best superwindows. Next out of the lab will be glazings whose solar-powered microchips and sensors continuously vary their light- and heat-transmitting properties to maximize comfort with no external controls or intervention.

The building envelope does not simply keep out the weather and noise, let in light, and present an architectural face to the world. It should also integrate insulation, thermal mass (often incorporated into wall materials), and passive control functions. And in the newest structures, such as New York's Four Times Square and many European showcase buildings, it has one additional function: It's the power station. Photovoltaic power generation is now commercially available, at increasingly attractive prices, in such forms as opaque or clear glass, asphalt-like shingles, standing-seam metal roofing, and other elements that directly replace normal parts of the building shell. They look and work the same as ordinary building materials but produce electricity whenever struck by light, even through clouds. An efficient building surfaced with such materials can renewably produce more daytime electricity than it uses. The better of the world's half million solar-powered homes[26] do just that.

Thus the best mid-1990s efficiency achievements — buildings that save around 99 to 100 percent in heating energy and 97[27] to 100[28] percent in air-conditioning energy — can be bested by making the building a net *exporter* of energy. For example, the world's largest residential solar development, now being built at the Sydney (Australia) Olympic Village, will include a kilowatt of solar cells installed on the roof of each unit. Yet because of good passive design, the units will also maintain comfort with no air-conditioning, freeing most of the solar power for other uses. In 1998, the 350-room Mauna Lani Bay Hotel, a AAA Five-Diamond resort on the Kona-Kohala coast of the island of Hawai'i, turned its 10,000-square-foot roof into a hundred-kilowatt power station — the biggest on any hotel in the world — by retiling it with solar cells.

Smaller buildings can use photovoltaics that produce alternating current, the power that comes from a wall outlet but of higher quality and with no pollution. Such "AC-out" photovoltaics function like any plug-in appliance, except that when you plug them in and shine sunlight on them, they put electricity back into the building rather than drawing from it — say, 250 peak watts from a four-by-six-foot panel. This innovation makes on-site solar power convenient and increasingly affordable for unsophisticated users, for renters who prefer to take their solar units with them when they move, and for the 2 billion people who still lack electricity. As *The Economist* put it, "Just as villages that have never seen a telephone pole now never will because of cellular technology, others that have never seen an [electric transmission-line tower] . . . could be spared them in favor of solar panels. . . ."[29]

In buildings a lot of energy is used to blow air around. This can be reduced by using nontoxic materials for both construction and cleaning, and by ventilating during construction. Once toxicity is designed out, green buildings usually let occupants open nearby windows or vents. Further fresh air, if needed, can be introduced silently and unobtrusively at floor level, rising to displace stale air. Such "displacement ventilation" can often be controlled individually by each user, or automatically, or both. As the exhaust air flows passively up and out, its heat or coolness, moisture or dryness can be recovered. Many such designs use 100 percent fresh air, with none recirculated. Either way, the bonuses of advanced ventilation design include better health, blessed quiet, and major energy savings.

Other vital benefits emerge from *combining* many of these green-building features. For example, Rocky Mountain Institute has helped major firms to devise a new kind of speculative office building that melds under-floor displacement ventilation, under-floor wiring, superwindows, daylighting, superefficient lighting suspended from and bounced off the ceiling, and certain structural innovations. Costly ducts and, if desired, the suspended ceiling to hide them are virtually eliminated. This raises the ceilings, helping to distribute light, but reduces the height between floors, so six stories, not the usual five, can fit within building codes' seventy-five-foot high-rise limit. Comfort, beauty, and visual performance are much improved. Total construction cost is unchanged, and may even fall slightly. Energy cost falls by half, or by about three-fourths if tenants can be educated and incentivized to choose efficient equipment. The greatest benefit for fast-moving businesses, which tend to rearrange people every six to eighteen months, is that reconfiguration cost is greatly reduced. There's no need to rearrange the lighting or ventilation, and all the plug-in power and signal wiring is instantly accessible — just pop up a carpet tile from the raised floor. This flexibility alone is so valuable that in the first year of occupancy it saved Owens-Corning $300 per worker per move, or $1.35 per square foot per year — equivalent to three-fourths of an average office building's total energy bill.

Some advanced buildings move air with highly efficient fans and low-friction ducts that cut fan energy to only a tenth of industry norms while reducing noise and capital cost. But the most innovative buildings have no fans at all. Instead, they design with computational fluid dynamics — simulations of airflow driven by natural buoyancy and calculated by supercomputers — to move the air passively and silently. Using this technique, the 107,000-square-foot Queens Building — a

1993 engineering teaching and laboratory structure at DeMontfort University in Leicester, England — eliminated all its chillers and fans, maintained comfort, and cut $1.4 million out of its construction cost. Sixty percent of the building's shell area consists of operable windows or vents. The mechanical engineering students have to learn about mechanical equipment from diagrams because the school has no such equipment to demonstrate; the electrical engineering students learn lighting design in daylit rooms with the lights off. The building had the lowest construction cost ($110 per square foot unfinished, or $184 finished and completely equipped) of any recent engineering building known to its architect. A follow-on design is expected to eliminate cooling, air-handling, *and* probably heating energy for the new EpiCenter materials-science research facility at Montana State University in Bozeman. It is also expected to cut capital cost.

In the few climates so extreme that some heating or cooling (more commonly just dehumidification) is still required, these functions will increasingly be performed not only with far greater efficiency (the demonstrated energy savings range from about 65 to 100 percent) but also without using electricity or fuel directly. Rather, these functions will be powered by waste heat from on-site fuel cells, microturbines, or all-weather solar devices. For example, a retrofit of a multimillion-square-foot corporate campus is currently being planned to use modular miniature gas turbines to make the required electricity. The turbines' waste heat will provide heating, cooling, and dehumidification. The system will be profitable against the utility's electricity prices, which are near the national average.

RECYCLED BUILDINGS, MATERIALS, AND LAND

Design innovations are not confined to new buildings. Green design will slowly replace or retrofit nearly all the old structures too. For example, in 1992 the National Audubon Society recycled a century-old, 98,000-square-foot building at a cost roughly 27 percent below that of building anew, and toward the lower end of the market range. Yet the retrofit not only achieved two-thirds energy savings but also created a superior working environment with excellent daylighting and 30 percent more fresh air, established 70 percent efficient recycling of office wastes, and greatly reduced if not eliminated toxic hazards. Accomplishing all this repaid its cost in five years — three years counting utility rebates. Similarly, in 1996, when the City of San Diego retrofitted the

73,000-square-foot, 13-year-old Ridgehaven municipal office building to be the most efficient commercial structure in town, the 60 percent reduction in energy cost yielded a four-year payback. The retrofit also used low- or no-toxicity, sustainably sourced, high-recycled-content materials for greater durability, recycled over 40 tons of construction debris, and improved indoor air quality.[30] Combining technical with *financial* innovations can yield even more impressive results.

Today buildings are frequently "reincarnated," becoming a new element of community life and to gain commercial value. Stewart Brand's sound 1994 advice in *How Buildings Learn* — "Every building is a forecast. Every forecast is wrong" — is already leading to such flexibility-enhancing innovations as walls, pipes, and other interior elements that can be easily moved. Some of the recently built outstanding green buildings, such as the Audubon and Natural Resources Defense Council headquarters buildings in New York or the Inn of the Anasazi in Santa Fe, are recycled buildings. This saves the energy and landfill space embodied in construction materials, which are responsible for 40 percent of all materials flows and mainly end up as waste whose disposal typically costs 2–5 percent of construction budgets. Depending on the region, between 15 percent and 40 percent of the content of American landfills is construction waste — seven tons per typical 1,800-square-foot house.[31]

If an entire building can't be recycled, the next best approach is often to reuse wood, bricks, and other materials from prior structures. This is preferable to sourcing new materials from sustainably harvested wood and other natural materials, because the materials were already produced and needn't be produced afresh. The energy required to create the materials (wood, Sheetrock, wiring, plumbing, masonry, et cetera) in an energy-efficient building can exceed the heating and cooling energy it will use in a half century.[32] Reusing that embodied energy saves both energy and capital costs. Southern California Gas Company's Energy Resource Center was built at about 31 percent lower cost by recycling an old building and using 80 percent recycled materials.[33] Dismantling buildings and selling their materials can also be profitable.[34] British Columbia Building Corporation's 1991 prison demolition cost 26 percent less and reduced landfilling by 95 percent, because selling recovered materials more than paid for the dismantling crew's welcome extra six weeks' work. Regional and local marketplaces are springing up on the Internet to hook up providers and users of recycled building materials, both conventional and imaginative. (In Audubon House, the only incandescent lamps in use are those that were crushed and recycled into nonslip floor tiles.) Vermont's largest construction firm, when converting an IBM office complex, had to remove 5,500 4-by-10-foot sheets of drywall. Landfilling them would have cost about $20,000. Because there wasn't a drywall-remanufacturing plant close by, they were advertised as free take-aways and quickly snapped up.[35] While building the Rose Garden arena in Portland, Oregon, Turner Construction rerouted 45,000 tons of concrete, steel, gypsum, paper, and other construction waste to recyclers, reducing its volume of waste sent for disposal by 95 percent, and turning what would have been disposal costs into $190,000 of income.

Sites can be recycled as effectively as materials. Many military bases, such large tracts as Denver's former Stapleton Airport, and numerous infill sites are being creatively reused. The U.S. Environmental Protection Agency is helping private developers mitigate any remaining toxic materials so they can build on the nearly half million abandoned or underused industrial "brownfield" sites throughout the United States. For example, Portland, Oregon, recycled a heavy industrial site into a bustling and financially successful ten-acre mixed-use development called RiverPlace after a public-private partnership assessed, and the developers paid for, the toxic-waste cleanup. The main obstacle to such redevelopment is fear of liability, but both the EPA and some states are changing the rules to encourage safe reuse of these mostly urban sites, whose good access to transit, infrastructure, and workers gives them a market advantage over greenfield sites.

HOMEBUILDING JOINS THE REVOLUTION

Most Americans go home to buildings as inefficient and uncomfortable as those in which they work and shop. Most U.S. houses, compared with those built in line with today's best practice, are drafty, poorly insulated boxes designed with most of the same deficiencies as commercial buildings, plus a few new ones. For example, typical Pacific Northwest homes have hot-air ducts so leaky that 25–30 percent of gas heating energy, or 40–50-plus percent of electric heating energy, is lost before it ever reaches the rooms. This wastes energy and money, makes temperatures uneven, and can even threaten the occupants by sucking in toxic furnace exhaust.[36] Similarly, a typical three-kilowatt California central air conditioner delivers only two kilowatts of cool air; the rest leaks out of the ducts.[37] Such faults are easily fixed, the latest method being to spray into the ducts a sort of nontoxic aerosolized chewing gum called Aeroseal that automatically lodges in the cracks (up to dime-sized) and seals them up. This eliminates over 90 percent of the duct leakage. It can yield a typical internal rate of return around 30 percent per year, an annual U.S. saving upward of $1 billion, and a displacement of ten giant power plants.[38] Ducts shouldn't leak in the first place, but many are carelessly installed.

Although homebuilding is an extremely fragmented sector of the U.S. economy — its unit of production is often the pickup truck — encouraging progress is being made. As with commercial buildings, these advances embrace integrated design processes, new technologies, and a more biological and adaptive understanding of human needs.

Archetypes of today's most efficient houses, in climates ranging from subarctic to fully tropical, have existed since the 1980s, and some much earlier.[39] American superinsulation techniques have adopted and adapted the best from Scandinavian and Canadian practices. Superwindows marketed as early as 1983 could gain net heat in the winter, even facing north. For example, Rocky Mountain Institute's 4,000-square-foot headquarters[40] stands at an elevation of 7,100 feet in western Colorado in a climate that occasionally gets as cold as –47°F. There is only a 52-day nominal growing season between hard frosts here, and midwinter cloudy spells last as long as 39 days. Still, the building has no heating system aside from two small woodstoves. Yet its 99 percent space-heating savings made it cost *less* than normal to build in 1982–84, because its superinsulation, superwindows, and 92 percent efficient heat-recovering ventilators added less cost than was saved up front by eliminating the furnace and ductwork. Moreover, the structure was able to save half the water usage, about 99 percent of the water-heating energy, and 90 percent of the household electricity — for which the bill, if the building were only a house, would be about five dollars a month, before taking credit for its manyfold larger photovoltaic power production. The energy savings repaid all the costs of those efficiency improvements in ten months. That was achieved with 1983 technologies; today's are better and cheaper.

Such a building can also keep its occupants more alert, happy, and healthy. It features curving forms, natural light, and waterfall sounds. It lacks mechanical noise (because there are no mechanical systems) and most electromagnetic fields. It has low air temperature, high radiant temperature, ample winter humidity in a high-desert climate, good indoor air quality, and a central semitropical garden offering the sight, smell, ions, oxygen, and occasional taste of the plants. Bougainvillea blooms over ponds in which frogs jump while turtles, carp, and catfish swirl below. You can come in out of a blizzard to the scent of night-blooming jasmine and the blur of a miniature hedgehog running silently about eating bugs. In December 1997, RMI harvested its twenty-sixth indoor banana crop — perhaps the world's altitude record for passive-solar bananas.

Comparable results have been achieved in many different climates. In cloudy Darmstadt, Germany, Dr. Wolfgang Feist's no-furnace "Passivhaus" uses less than 10 percent the normal amount of heat (all produced by its water heater) and 25 percent the normal amount of electricity. It uses about as much energy for all its needs as a typical German house uses just for small appliances. In 1996, one of its architects, Folkmer Rasch, designed equally efficient public housing at competitive prices; by the Expo 2000 exposition in Hannover, a whole city called the Kronsberg Siedlung is to be built with quadrupled energy efficiency but at no extra cost. Forty similarly "hyperinsulated" homes needing no heating are being built in 1999 in two cold and cloudy Swedish cities.[41] Conversely, in muggy Bangkok, Thailand, where people feel comfortable outdoors for only 15 percent of the year, architect Professor Soontorn Boonyatikarn built an elegant and comfortable three-story, 3,750-square-foot house whose superwindows, overhangs, and other design features reduce its air-conditioning requirements by 90 percent, to a system so small that he couldn't find an engineer willing to work on it. The house cost no more to build than a standard model.[42]

Capital costs can even go *down.* A Pacific Gas and Electric Company experiment eliminated cooling equipment in two normal-looking tract houses. The first, in Davis, California, where peak temperatures can reach 113°F, was a mid-range ($249,500), 1,656-square-foot speculative home, completed in 1993. During three-day, 104°-plus heat storms, the indoor temperature didn't top 82°, and the neighbors came into the house with no air conditioner to take refuge from their own inefficient houses, whose big air conditioners couldn't cope. Yet if routinely built, rather than as a one-off experiment, the Davis house would cost about $1,800 *less* to build, and $1,600 *less* to maintain over its life than a comparable but normally inefficient home, because it had no heating or cooling equipment to buy or maintain. A later model did even better.[43]

Proving that such efficient houses are feasible is only the first step. Builders must still cope with fragmented regulatory jurisdictions, obsolete building codes and other standards, uninformed building inspectors, and homebuyers, appraisers, and real estate agents who ascribe no market value to energy efficiency, split incentives between landlords and tenants, and myriad other forms of market failure. Such hurdles can be cleared, however, and passive-solar heating is now becoming common in some regions.

Novelty can even be turned to marketing advantage. Some innovative builders offer guaranteed maximum heating bills of, say, $100–200 a year — a technique used by speculative builder Perry Bigelow of Palatine, Illinois, to sell more than a thousand comfortable no-furnace houses over more than a decade. In these homes a water heater provides all the space-heating backup needed, even without superwindows. (Of course, you don't *call* it a no-furnace house; instead, you market its advanced hydronic radiant heat.)

Most of the American houses that will exist a few decades from now have already been built. But fortunately, basic improvements can be made to the air- and heat-leaking shells of these structures. Thanks to the pioneering efforts of Canadian and Scandinavian engineers from the 1970s onward, innovative techniques for retrofitting superinsulation and "outsulation" onto existing homes, for sealing air leaks, and for using stick-on selective coatings and add-on selective glazings to make every window a near-superwindow are now fairly mature. Their widespread adoption can be coordinated with normal facade renovations or furnace or air-conditioner replacements to cut costs — or can even be combined with "gut rehabs" of derelict masonry row houses.[44]

APPLIANCES

Heat-tight homes can be complemented by a wide range of efficient appliances. The Environmental Protection Agency is working with hundreds of voluntary manufacturer partners to provide more efficient appliances with special Energy Star labels. These models can save the typical U.S. household about 30 percent of its energy bills with a 30 percent internal rate of return. Over the next 15 years, full adoption of Energy Star appliances could save American households as much as $100 billion.[45] (A similar effort now dominates the U.S. market for office equipment.) Another EPA/industry voluntary initiative will eliminate the need for about ten giant power plants and save U.S.

households $3 billion a year, by saving most of the "standby" energy used by equipment that's supposedly turned off.

But these devices represent only the beginning of a revolution in efficient appliances. Prototype washing machines have dirt and grease sensors to control fuzzy-logic chips that add fresh water and soap only until the water comes out clean. New induction cooktops save energy and have no hot element to burn an inquisitive child. Heat-pump clothes dryers are emerging. Twenty-odd innovations can save two-thirds of a typical house's water-heating energy yet repay their cost in about a year.[46] Appliances will also become better integrated with one another. A washing machine using a new kind of smart motor can perform a high-speed spin that wrings out almost all the water, then shakes out the wrinkles, using only a few percent as much energy for this form of drying as hot-air dryers require. Then, because the washing machine is made of polymers, it can become a microwave dryer — fast, easy on clothes, and efficient.[47]

Refrigerators use a sixth of U.S. households' electricity — the output of about thirty giant power stations. Most in-service refrigerators are poorly insulated boxes with their inefficient compressor mounted at the bottom, so its heat rises up into the food compartment. They typically have an undersized, dust-clogged, and hence fan-cooled condenser on the back, leaky air seals, internal heaters to prevent "sweating" caused by the thin insulation, and inefficient lights, fans, and defroster coils inside that generate still more heat. Each such refrigerator uses so much electricity that the coal burned to generate it would about fill up the whole inside of the refrigerator every year.

But again, recent improvements in design have dramatically improved the energy efficiency of refrigerators. If an average model sold in the United States in 1972, adjusting for the mix of refrigerator and freezer space, used what we might call a hundred "units" of electricity to cool a given volume, then:[48]

- By 1987, when California introduced efficiency standards, the average new refrigerator used only 56 units.
- In 1990, a new federal standard forbade the sale of units using more than 45 units. The best mass-produced unit used only 39 units but was not as expensive as the less efficient models that preceded it.
- In 1993, the federal standard was tightened to 35 units, and in 1997, to 25 units so as to adopt cost-effective new technologies.[49]

- In 1994, Whirlpool won a Swedish design competition with a 32-unit model, which the major U.S. makers agreed to cut to no more than 26 units by 1998.
- Since 1988, the Danish firm Gram has been mass-producing a 13-unit model, improvable readily to only 8 units — and with the best 1997 superinsulation, compressor, and other technologies to 1–2 units.[50]

Thus refrigerators that are available now can save about 87 percent — and with the best available technology could save 98–99 percent — of the normal 1972 amount of refrigerator energy. Yet they keep food just as cold — indeed, thanks to better controls, fresher for longer — and they look the same, make less noise, can be more reliable, and in mass production would cost about the same or less.

Cooking, too, can combine efficient pots and kettles that save about a third of the time and energy to heat food or water, efficient heating methods such as induction, and microprocessor controls to achieve and maintain just the desired temperature and no more. Thus a milk-based dessert that formerly required an hour of constant stirring to prevent scorching can simply be put on the chip-controlled cooker and left alone until done. These technologies for combining efficiency with convenience and better food quality also already exist.

The Technical University of Denmark found that combining all the appliance improvements demonstrated by 1989 could save three-fourths of appliances' total electricity while providing the same or better services. The extra cost involved would be recouped in fewer than four years — the equivalent of a bank account paying about 22 percent annual interest tax-free.[51] A decade later, the technologies are even better.

REDESIGNING COMMUNITY

Rethinking design is not only a matter of improving hardware but of looking at the larger context in which we live and work every day. For example, the amenity and land-use lessons of New Urbanism — integrating housing and other land uses within walking distance in compact communities — may soon combine with changing demographics, more flexible zoning, and fast-changing real estate attitudes to introduce further innovations. For example, clustering houses around mini-greens preserves privacy but offers shared pocket parks and gardens and fosters neighborliness. This in turn could make time-sharing of major capital items more attractive. Shared equipment, in tandem with the usual reforms from product longevity, design for takeback and remanufacturing, and minimum-materials design and manufacturing, could greatly decrease the net flow of materials through the household. Shared laundry facilities in apartment buildings could displace less efficient, less fully loaded, and less durable individual household washing machines, improving energy efficiency by about fourfold and materials efficiency by about tenfold.[52] New kinds of businesses may also emerge, like an experimental amalgam of a community center, indoor garden, child-care center, laundry facility, and Internet café.

The new village-style layouts with "granny flats" can also encourage a return to three- and even four-generation families. Indeed, despite the diverse and shifting conditions of contemporary family life, aspects of many of the best values and attitudes of the first half of the twentieth century, according to some sociohistorians, may reemerge with the help of ubiquitous wireless information and telecommunications systems that encourage both home-based and lifelong learning.

As in the commercial sector, progressive designers and developers are discovering many other ways to improve the quality of community life. In 1996–97, historical sleuthing disclosed that standard American street widths were generally enormous because of some 1950s civil-defense planners' notion that heavy equipment would need the space to be able to clear up rubble after a nuclear attack.[53] Returning to sensible widths, as developers and jurisdictions are starting to do,[54] enables the streets to be tree-shaded and encourages safer driving (people are more likely to be killed by a car in the suburbs than by crime in the inner city),[55] pedestrian use, and pleasant microclimates. It also creates vibrant street life, local "third places"[56] (like the English pub, neither home nor work) for friendly local association, real front porches, and houses that front onto and engage the street rather than blankly walling it off — all of which can reduce crime.

Better understanding of urban heat islands and vegetative shading is encouraging efforts in urban forestry and the use of lighter-colored paving and building surfaces. By helping bounce solar heat away, such measures could cool Los Angeles by about 6F°, a temperature drop that would cut the city's cooling loads by about 20 percent and smog by about 12 percent, saving more than a half billion dollars per year.[57] By 2015, as trees mature and roofs are replaced, the nationwide savings could include $4 billion a year on air-conditioning costs, 7 million metric tons of annual carbon emissions, and numerous deaths from air pollution and heat emergencies.[58] An urban tree keeps about nine times as much carbon out of the air as the same tree planted in a forest, and it also saves air-conditioning energy by keeping people and buildings cooled and shaded.[59] Making streets both narrower and tree-shaded in California's hot Central Valley communities could lower larger areas' summer temperatures by 10–15F°, greatly reducing air-conditioning energy costs.[60]

Urban hydrology meanwhile is launching a porous-surface, watershed-restoration movement that helps land absorb rainwater quickly and release it slowly. An important technique is helping plants to grow on and over buildings, not just near them. "Green" roofs growing grass, moss, or flowers are now so popular, sophisticated, and competitive in the German-speaking countries of central Europe that it's hard to get a permit for a flat-roofed building in Stuttgart without making the roof green. Even a major building at Amsterdam's international airport has a grass roof. These systems are encouraged and even subsidized because they reduce both flooding risks and cooling needs.[61] Following the lead of Village Homes, such cities as Scottsdale, Arizona, are replacing the civil-engineering tradition of costly concrete storm drains with natural drainage swales. These allow rainwater to flow where it has naturally gone, through the arteries of the earth.

This hydrological reform is part of a broader design movement that takes unnecessary infrastructure dollars out of the ground and invests them in houses, neighborhood support systems, and landscapes.[62] In 1974 a federally sponsored industry study called *The Costs of Sprawl*[63] found that on a given land area, a high-density planned development could leave over half its land area as open space, *and* significantly reduce road and utility investments, compared with a traditional suburban layout. Reducing the amount of paving would also reduce storm runoff. Shorter distances would lower automotive fuel use and air pollution. Clustering and attaching some homes so as to decrease the area of exterior walls would help too. This ensemble could reduce the cost for site preparation[64] by an estimated 35 percent, or $4,600 (1987 dollars), per house. Adopting a New Urbanist plan instead of large-lot sprawl for Haymount, a new town in Virginia, reduced projected infrastructure costs by 40 percent.[65]

Recently, developers started trying out these concepts — and discovered they could get lower costs *and* higher market value. In 1994, Prairie Crossing, a 667-acre residential development near Chicago, broke ground on infrastructure designed to minimize environmental harm. The developer made the streets 8–12 feet narrower than the suburban norm, minimized the area of impervious sidewalks, and installed vegetated swales and detention ponds instead of storm sewers. These measures saved $4,400 per lot, which was reinvested in common areas and other project amenities, increasing property values. Sacramento's 1,000-acre Laguna West development, which opened in 1991, invested $1,500 per house in a lake and street trees — and thereby raised its property values by $15,000 per house. Even more strikingly, in an Alabama project, waterfront lots laid out in standard suburban fashion recently sold for $7 a square foot, while lots across the street, in a traditional neighborhood layout that had no shoreline, sold for $22 per square foot.[66]

Such neotraditional projects are beginning to challenge the American habit of ceding community design to traffic engineering. Their popular acceptance and favorable economics show that the opportunities they create for "negacars" and "negatrips," for convivial communities, and for safer and better places to raise children can be welcome both to the yearnings of those who live there and to developers' bottom lines.

The unexpected and outstanding success of such integrated-design projects in real estate markets is starting to persuade developers to rethink many of their basic assumptions and to reimagine development as a tool for restoring nature and communities. Where these still-evolving trends will lead is not yet clear. But what is evident is that the isolation, car dependency, and social pathologies that afflict late-twentieth-century American suburbanism are an aberration.

Towns and cities are also starting to prevent unnecessary leaks of dollars out of the local economy through more productive use of local resources. They are finding that the most powerful form of local economic development, as the BBC's Malcolm MacEwan once remarked of a bathtub whose water keeps draining out, is to get not a bigger water heater but a plug. The plugs offered by advanced resource efficiency are turning out to be ever cheaper, simpler and more powerful engines for creating sustainable local economies from the bottom up.[67]

Designing great buildings and projects is not simply a way to earn a profit. It is about creating the spaces in which we live, grow, and learn. At first, Winston Churchill said, we shape our buildings, and then our buildings shape our lives. This high purpose requires designs that celebrate life over sterility, restraint over extravagance, beauty over tawdriness. Green buildings do not poison the air with fumes nor the soul with artificiality. Instead, they create delight when entered, serenity and health when occupied, and regret when departed. They grow organically in and from their place, integrating people within the rest of the natural world; do no harm to their occupants or to the earth; foster more diverse and abundant life than they borrow; take less than they give back. Achieving all this hand in hand with functionality and profitability requires a level of design integration that is not merely a technical task but an aesthetic and spiritual challenge.

There is a name for this challenge. Years ago, biologist Bill McLarney was inventing some advanced aquaculture at the New Alchemy Institute in Costa Rica. He was stirring a tank of algae one day when a brassy lady from North America strode in and demanded, "Why are you standing there stirring that green goop, when what really matters in the world is *love?*"

Bill thought for a minute and replied, "Well, there's *theoretical* love; and then there's *applied* love" — and kept on stirring. Today's best real estate developments, and the reasons we create them, are that application.