A Facilities Manager's Guide to GREEN BUILDING DESIGN

By Walter Simpson

As campus energy officer, I occasionally lecture to architecture students about the University at Buffalo's (UB) energy conservation program. I show the students a series of slides depicting the energy design failures of our buildings and how we have tried to correct those failures through literally hundreds of retrofit projects.

The students are shocked when they hear about UB's electrically heated buildings. They are also surprised to hear about new buildings where we have retrofit thousands of lighting fixtures as soon as the buildings were accepted. (The original design called for T-12 lighting a few years after T-8s had proven themselves reliable and more efficient.)

At some point near the end of my lecture, I get the inevitable question, namely, "What is UB doing to improve the design of its new buildings—so that doing all those energy retrofits won't be necessary?!"

I reply by explaining that we stopped building electrically heated buildings a decade ago (though they never should have been built in the first place), and we are making progress designing more efficient buildings. But the truth is that we have not come far enough.

Going Beyond Energy Efficiency

During the 1990s the architectural profession in the United States identified the various principles of "sustainable," "high performance," or "green" building design. This approach goes further than energy efficiency by applying environmental principles to all aspects of building design. "Green buildings" have less impact on the natural environment. They can be healthy, naturally lit, attractive buildings with lower operating and lifecycle costs.

The multiple benefits of green building should speak to college, university, and K-12 facilities professionals. There are many reasons why we should be interested in this new architectural movement.

Most campuses have energy conservation, recycling, and green campus initiatives. An obvious next step is to include green building design in your palate of green campus programs—especially considering the substantial, long-term operational and environmental impact of new buildings. A campus commitment to green design says something very positive about a school and may provide substantial public relations, recruitment, and retention benefits as well.

According to Worldwatch Institute, 40 percent of the raw materials annually extracted from the earth are transformed into building materials. Buildings are also responsible for an estimated 40 percent of global energy consumption—and the associated smog, acid rain, and global warming emissions. Climatologists are now telling us that unless we significantly reduce fossil fuel burning and carbon dioxide emissions, average global temperatures could rise by 8 to 10 degrees Fahrenheit by the end of this century. New building design must respond to this challenge by reducing fossil fuel use and carbon dioxide emissions while producing other dividends.

Defining Green Design

Green building design is a holistic, integrative, and collaborative process. It is ecologically, not "ego-logically," driven. It should begin at the first stages of planning and design and

***Walter Simpson is energy officer for the University at Buffalo, a SUNY school, and can be reached at wsimpson@facilities.buffalo.edu. He is a two-time recipient of APPA's Rex Dillow Award for Outstanding Article in* Facilities Manager.**
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consider a variety of design issues. While these elements can be broken down in a variety of ways, here is a representative list:

- "Build/No Build" decision
- Site decision, planning, and design
- Use of renewable energy
- Energy efficiency
- Efficient materials use
- Ecological building materials
- Water management
- Indoor environment
- Recycling—during construction and by occupants
- Building commissioning
- Green operations and maintenance

Pop quiz! What is the most conserving, least-polluting building imaginable? Correct answer: the building that is never built!

Green design begins with the decision to build. Our motto should be: build it small if at all. Campus leaders need to ask themselves whether a new building is really needed. Can program needs be met through renovations of existing space? Can space be designed more flexibly and used more efficiently in order to minimize construction?

Given the high cost of new construction, these would seem like obvious questions but they are often given insufficient consideration. New construction is sexy, a way to make a statement and leave a legacy. Moreover, budgetary anomalies may make new construction dollars available while renovation (as well as M&O) budgets are starved. These factors may lead to unnecessary building.

My own school is in a build-out mode, adding new buildings while campus population remains roughly the same. The end result is more "built-space" per student, faculty, and staff person than ever before. This structural inefficiency significantly impacts energy and materials consumption.

Respect and Restore the Site

Site issues become paramount once a decision to build is made. Even if a full-blown environmental impact statement (EIS) is not required by law, this is the time to do an environmental assessment. It is also time to involve the campus community in a public participation process to gain valuable input and build campus consensus.

Urban campuses may have the option of building on a "brownfield," an abandoned commercial or industrial site. While brownfield development typically involves legal and liability issues, remediating and restoring these already used sites is generally environmentally preferable to building on an undisturbed "greenfield."

"Sprawl" describes spread out development which reduces population density, increases travel needs and distances, wastes energy, and destroys open space. Sprawl can apply to campuses as well as communities. Campus siting decisions should promote density, community, and alternatives to gas-guzzling car use.

Of course, sprawl and transportation issues apply to siting new campuses as well as individual buildings. The University at Buffalo's newer campus is in the suburbs and is not well served by public transit, bicycling, or walking. A faculty colleague once estimated that UB students, faculty, and staff commute by car to and from campus a total of 120 million miles a year! A downtown campus location would have vastly reduced this car travel, annually saving millions of gallons of gasoline and thousands of tons of tailpipe pollution. A downtown UB campus would have also helped revitalize Buffalo, a city that is now a shadow of the thriving commercial and cultural center it was 100 years ago.

Trees and green space beautify campuses. Sacrificing these assets is generally a bad idea. Siting buildings in beautiful natural spots on campus has an appeal, but the benefit is lost if building there destroys those spots.

Having selected a site, green design asks planners to respect that site by protecting and restoring its natural systems and by trying to reconnect the site to regional natural systems. Natural assets of a site, such as trees and vegetation, wildlife and habitat, watershed, open space and aesthetics, should be conserved.

By returning rain water to the ground or a wetlands (instead of storm sewers), watershed values of the land can be respected. Paving should be minimized, but, where needed, porous paving materials should be considered. Landscaping should be low maintenance and emphasize native plants. The building should blend in with its natural surroundings, enhancing beauty and enjoyment of the site.

Energy benefits can accrue by adapting to the microclimate of a site. Can the building be shielded from cold winter winds? Can it benefit by cool summer breezes? Trees or berms can deflect or focus winds. Trees and other vegetation can also provide shade and reduce summer ambient temperatures.

Site selection should also be informed by solar access. Can a building be oriented on this site with an unobstructed southern exposure? Are there existing buildings (or other objects) which will cast shadows and block the sun's light and heat?

There are lots of ways to do daylighting poorly. For example, direct sunlight may be introduced into buildings, producing uncomfortable glare. Sunlight also may be introduced through skylights or atria, which lose too much heat in the winter or gain too much heat in the summer (thus increasing heating or cooling costs). And too often we see daylit spaces where the electric lights are on needlessly during daylight hours.

But daylighting can be done correctly with wonderful results. Good designs avoid direct sun and glare. The light is bounced, diffused, and brought into the interior of buildings. Electric lighting is turned off or dimmed with "daylight harvesting" controls. People rave about open floor plans, access to windows, and daylit interior spaces. The best designs allow most occupants to have visual contact with the outdoors. Satisfaction and productivity in these buildings is typically very high.

Daylighting strategies go beyond high-tech windows and include horizontal light shelves on windows to reflect sunlight into a space while blocking direct solar gain in summer. Daylighting also makes appropriate use of clerestories, courtyards, and atria. A variety of glazing options are available.

Window technology has advanced significantly in the last decade. Different glass coatings and gas fills (between layers of glass) can maximize energy performance. Window selection should be fine-tuned by orientation, location, and application. Spectrally selective windows may be specified

Sunlight to the Rescue—Using Clean, Renewable Energy

Breaking our fossil fuel addiction is imperative. Green design helps us do that by promoting the use of clean, free solar energy. Solar homes work even in cold, snowy Buffalo. But what about using solar energy in commercial or institutional buildings? At first blush it might seem difficult but it can be done. There are a number of possibilities:

- Daylighting
- Passive solar space heating
- Solar water heating (pools, domestic hot water)
- Photovoltaic electricity generation
- Buy "green power"

The most obvious and proven way to use solar energy in campus buildings is daylighting. Effective daylighting uses sunlight to provide superior lighting for occupants while reducing lighting energy costs.

with high insulating value and different transmissivity characteristics for daylight and solar heat (depending on what is needed for that building type and application).

Passive Heating and Cooling

Passive solar heating may be defined as using sunlight for heating without the use of special collectors or mechanical fans or pumps. This is accomplished by south-facing glass that readily admits solar energy (as opposed to rejecting it). The building envelope itself becomes a solar collector. East and especially west-facing glass is minimized to prevent unwanted solar gain in the cooling season.

Clear glass that permits solar heat gain is desirable for passive solar heating. Yet this is a liability in the summer when it will add to the building's cooling load. Some means of sun control or deflection is needed to block sunlight during the warmer months. This can be accomplished with overhangs, shelves, louvers, awnings, trellises, or shades. Computer energy modeling of projected energy use can assist in glass selection, balancing the benefits of daylighting, solar heat gain in winter, and solar rejection in summer.

Since passive solar heating works best with direct sun, it is best accomplished in commercial or institutional buildings in common areas like lobbies (not workspaces). Sufficient thermal mass (or a means of removing heat) is required to avoid overheating a sun-heated space. Thermal mass may be provided by normal construction materials such as a thick masonry floor (with dark colored tiles) or a mass wall. Special features such as water drums or columns can also be used.

Green Power—Solar Electricity

A green building should run on green power! That power can be generated on site or purchased.

One option is photovoltaic (PV) electrical generation. Green designers may incorporate PV into their designs despite its relatively high cost per kW of generating capacity.

As a rule of thumb, one square foot of photovoltaic solar-electric panel will produce about 10 watts of peak electric power if the panel is facing the sun and in full direct sunlight. This is not a lot of power. Real-life energy production from PV is a function of location, time of year, time of day, weather conditions, and panel tilt angle. To power an entire building with on-site photovoltaics means a lot of PV surface area or a very efficient building (or both).

We tend to think of PV as panels set up on racks or in sun tracking arrays. But PV need not be an add-on. PV can now be incorporated into the building envelope itself. Building Integrated PV (BIPV), as it is called, incorporates PV in curtain wall and roofing materials. PV (electricity-generating) windows are being developed. Needless to say, BIPV promises aesthetic and cost-saving benefits. In any event, greater use of PV will bring costs down.

What about fuel cells? Fuel cells are not a renewable energy source as long as they are running on natural gas (as most fuel cells do today). Nonetheless, some green buildings utilize fuel cells because they produce cleaner, more efficient electricity than the grid. Fuel cell prices will also come down with greater use. Fuel cells will eventually become renewable technologies once they are powered by solar-wind-biomass-generated hydrogen.

That leaves the option of buying green power in the deregulated electric marketplace.

In early 2001, electric deregulation looks like a colossal failure. Californians are paying much more for electricity than they did before deregulation. And they have experienced rolling blackouts as demand threatens supply. In my own state, New York, deregulation undercut much of the conservation and efficiency regime that existed in the early 1990s. Not surprisingly, electricity consumption is now climbing and there is increasing concern about generating capacity.

Nonetheless, electric industry deregulation may eventually make it possible for college and university campuses to buy environmentally friendly clean electricity. This power would come from newly developed windpower, biomass, PV, or landfill gas generating capacity. A green facility should be willing to pay a premium price to purchase green power.

Negawatts, Not Megawatts—Maximize Energy Efficiency

Green buildings must be energy efficient. By focusing on energy efficiency, the percentage of building energy needs provided by the sun can be maximized and fossil fuel reliance minimized. It is not enough to meet energy codes and standards such as ASHRAE 90.1. Green designers have pointed out that simply meeting the energy code should be no source of pride; if your building was any worse it would be illegal!

There are literally hundreds of strategies for designing energy efficient buildings. Here are some of the basic issues and opportunities:

Building Envelope

- Surface area to volume ratio (building shape, attached vs. stand alone, below ground vs. above)
- High level of insulation and tight construction for colder climates
- Location of entrances
- Super-windows (optimized for application)

HVAC—General Considerations

- First reduce all heating and cooling loads
- Size equipment smaller (for reduced loads)
- High efficiency equipment (including at part load)
- VAV vs. constant volume distribution systems
- Setback thermostats
- Proper zoning

- Heat recovery
- CO2 sensors and "demand control ventilation"
- Fuel choice (natural gas is cleanest fossil fuel; solar is much cleaner)
- High efficiency fans, pumps and motors
- EMS (to be used as more than sophisticated time clock)

Heating
- Boilers—modular, condensing; low NOX
- Cogeneration—natural gas-fired combined cycle; low NOX

Cooling
- Gas-fired chillers
- Dehumidify only when necessary
- Minimize summer reheat
- Avoid CFC and HCFC refrigerants
- Use economizer/free cooling cycles
- Operable windows (instead of mechanical AC)
- Natural ventilation including solar thermal chimneys, wind scoops, etc.
- Evaporative cooling (arid climates)
- Desiccant dehumidification (humid climates)
- Ground source heat pumps

Lighting
- Maximize daylighting
- Energy efficient T-8 lighting with electronic ballasts and reflectorized fixtures
- Lighting controls (motion detectors, photocells, daylight harvesting dimmers)
- Lower light levels (more appropriate to computer use)
- LED exit and traffic lights

Appliances and Office Equipment
- Buy maximum efficiency (Energy Star-compliant)
- Enable power management features

How energy efficient can your new building be? Efficient green commercial or institutional buildings can save 25 to 50 percent or more of the energy that would be required by conventional code-compliant building design.

Environmentally Friendly Building Materials

Green design uses resources efficiently and selects environmentally friendly building materials and products. Obviously, smaller buildings use less material. Flexible, adaptive designs allow smaller structures to meet more needs, thus conserving materials. Designing interior spaces attractively with exposed structural members and less decorative surfaces, coverings, and finishes can also reduce the amount of materials required.

Ecological materials selection is a specialty unto itself. The designer must know how to identify and specify materials and products which perform well and have the least impact on the environment over their lifecycles. In reality, a balancing act is required but the goal is to pick materials/products which are:

- Local
- Indigenous
- Low embodied energy
- Reused, recycled and/or recyclable
- Renewable and sustainably harvested (no old growth timber)
- Non-toxic/non-polluting in manufacture, use and disposal
- Contain no ozone-depleting CFCs and HCFCs
- Durable
- Low-maintenance

The embodied energy of a product refers to the amount of energy it takes to extract raw materials and make the product. In effect, the product "contains" this energy and its energy-related pollution (as well as any other pollution created by the extraction and manufacturing process). For instance, ten simple clay-fired bricks "contain" the energy equivalent of one gallon of oil (say 140,000 Btus).

The embodied energy of a product is generally less if it is made from recycled waste material, e.g., approximately 10 to 20 percent less for recycled glass and plastic, 50 to 60 percent less for recycled steel, and 95 percent less for recycled aluminum.

Going Easy on Water

Green buildings are frugal on water. This makes sense because in many areas water is in short supply. Also, domestic tap water contains embodied energy (the energy required to purify it before use, pump it, and treat it after use) and this can be saved through water conservation.

In addition to using low-flow plumbing fixtures, green designers may specify waterless urinals and composting toilets. Gray water from sinks, showers and laundries may be reused for purposes not requiring potable water (e.g., toilets, irrigation, vehicle washing). Rainwater may be collected from roofs and used similarly. Rainwater may also be used to grow planted "green roofs," which have recreational, wildlife habitat, educational, and roof shading benefits.

Alternative water treatment strategies may be employed including the use of on-site biological waste treatment, using microbes and plants to break down waste. This can be accomplished with constructed wetlands or "living machines," which mimic the biological processes of wetlands.

A Healthy Indoor Environment

Green building design seeks to provide the healthiest of indoor environments. This enhances occupant satisfaction and productivity as well as reduces the risk of ending up with a "sick building" (and all the liabilities associated with that term). Thus, green designers address:

- Indoor air quality (IAQ)
- Light quality and light levels
- Acoustic issues and noise control
- Comfort and controllability of systems
- Contact with nature and outside

Source control is the primary IAQ strategy. Potential pollutants are identified and minimized at the source. The design seeks to exclude emissions from neighboring buildings, vehicles, and soil contamination (including radon). Air intakes must be located away from sources of pollution. Effective moisture control is used to curb humidity and prevent mold problems. Green designers specify low or zero VOC (volatile organic compounds) and odor-emitting building materials and equipment.

Ventilation is regarded as the secondary strategy for IAQ. This involves more than simply meeting ASHRAE ventilation codes and providing sufficient outside air to dilute and remove pollutants. Effective diffusers and proper zoning are essential to mix air or segregate it as appropriate.

"Economizer" cycles (which use 100 percent outside air when the "enthalpy" or "heat content" of outside air is less than that of indoor air) can be used during the swing seasons and summer to cool and flush a building. Use of heat recovery systems minimizes the winter and summer energy penalties associated with mechanical ventilation of buildings.

"Demand Control Ventilation" (DCV) is another energy efficient ventilation strategy. DCV uses carbon dioxide sensors to gauge building fan zone occupancy, controlling outside air dampers and air volumes accordingly.

What about operable windows? Surely, they go against the grain of commercial and institutional building design of the last few decades. We think of these buildings as being sealed boxes. Heating and cooling costs can increase if windows are open, depressurizing spaces and allowing additional volumes of unconditioned outside air to enter.

But operable windows provide ventilation, a sense of control for occupants, and a way of getting in contact with outside—all qualities of a healthy building. Green design asks designers to reconsider operable windows and mechanical air conditioning for commercial and institutional buildings. In some regions, operable windows and passive cooling strategies may be able to replace mechanical air conditioning entirely—especially if building cooling loads are minimized.

In other regions, operable windows may be part of an efficient building cooling strategy that relies on windows (and