Assessing the True Cost of Energy Efficiency in New Buildings

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A prevailing myth says that energy-efficient buildings will be costly buildings that the average owner is unwilling or unable to buy. Most architects, engineers, and building owners seem to hold this idea as self-evident. Everyone favors energy-efficiency in principle, however, everyone also thinks "it's not in the budget. " Our experience at Montgomery County Government, Maryland, shows this preconception to be untrue. Montgomery County Government builds and renovates many government buildings each year as part of its capital improvement program. The fact is, highly-efficient buildings can be and have been built for no net increase in construction cost compared to "energy hog" buildings. In many cases energy efficiency even yields a reduction in the cost of construction along with improved quality, comfort and functionality. The answer lies in improved design approaches, integration between disciplines and taking advantage of numerous available cost trade-offs. If one can overcome the "design inertia" of the normal building process, one can find many significant energy reductions that are essentially free or even return money to the project. Energy-efficient buildings require more thinking, not more money.

Introduction

Montgomery County Government manages the design and construction of new government facilities including, libraries, police facilities, government service centers, offices and health and community centers. Consulting architects and engineers perform the design under guidelines that we have developed and enforce. Outside contractors construct the buildings under our observation. The guidelines we use to control design incorporate all essential energy efficiencies in an integrated "no cost" approach, yet remain simple enough for uninitiated consultants to understand and use. The criteria for integrated, energy-efficient building design have been developed over a number of years by this author, through life-cycle-cost analysis, research grants, demonstration projects and experience on numerous new building designs. The development of these *Energy Design Guidelines* has garnered several national awards, including a Technology Achievement Award from Public Technology Incorporated, an Energy Innovation Award from the U.S. D.O.E., and the FAME Award of Merit from the American Institute of Plant Engineers.

This paper presents a series of real-life examples we have observed in our work that illustrate the concept of saving energy in new buildings at no initial cost. This paper is not intended to be a technology review of the aspects covered. The level of detail will be targeted to building owners rather than technical specialists. The purpose is not to promote or explain particular technologies, but to demonstrate a different way of thinking about energy in new buildings. We will focus on the larger concept of how we can build energy efficiency into new buildings at no cost; an over-arching concept that is sometimes lost in technological details. While the concept has been recognized at least since the 1980's (Burt Hill 1987), systematic application of this concept in building programs is still rare. It is our hope that other building owners, inside or outside of government, will grasp the overall concept we are illustrating and begin to systematically apply it to building programs. We will first discuss lighting, using a detailed cost trade-off analysis to illustrate the concept. We follow with a range of other suggestive examples in less detail.

Example 1: Efficient Lighting Has the Lowest First Cost

Most designers assume that a more efficient lighting system has to increase building costs over the standard fixtures and designs they currently use. Our direct experience with high-efficiency designs shows quite the opposite to be true. Efficient lighting doesn't have to cost more in the total project context. In fact, one can usually reduce project first cost by using the most efficient available fixtures and designs. Overlaying three key concepts permits this reduction.

Key Concept 1 - Use Recommended Light Levels for the Task

Most lighting designers we encounter are still employing a 1970's approach to lighting design: illuminate all areas to a uniform level of 75 or 100 footcandles (fc), regardless of the type of task or location of the task in the room. This approach is simple for the designer, however, is not efficient or cheap or best for the occupants. In terms of energy, this approach leads to very high lighting wattage densities of 3 to 5 Watts per square foot, about half the installed power in a typical office building. The upper range of 5 + Watts per square foot typically uses excessively inefficient (and more expensive) fixtures, such as incandescent downlights with black baffles or fluorescent fixtures with small cell (1/2") paracube diffusers. Unfortunately, lighting wattage is not limited by most local energy codes in the U. S., as many people seem to assume.

In terms of first cost, the existing approach of using uniform, high light levels uses a large number of fixtures, about 16 per 1000 square feet of office or roughly $1.00 per square foot in material cost. In terms of the occupant comfort and productivity, this level of light is unneeded and even detrimental in today's computer offices where reading Video Display Terminals (VDT's) may constitute the main task. Instead of allowing the designer to follow this approach, one should insist that light levels vary according to the room function and task locations within the room. We require current recommended lighting levels of the Illuminating Engineering Society (IESNA, 1993). These levels are generally much less than 100 fc. For example, IES recommends 30 footcandles for many office tasks, and 15 fc in lobbies, lounges, rest rooms, corridors and storage spaces. Higher levels of light, in the 75 fc range, must be localized on a task surface, such as a desk top, and not provided throughout a space. Higher light levels may be economically achieved using overhead lighting through localized-general lighting or through task lighting approaches described by IES. Following IES design recommendations rigorously will reduce the number of fixtures (and first cost) required up to 40%, and lower the lighting energy density into the range of 1.8 to 2.5 Watts per square foot. This step is a win/win situation on both energy and first cost. However, this reduction is only the beginning. One should consider the second key concept—using much better fixtures than a standard 4-lamp fluorescent troffer or incandescent downlight.

Key Concept 2 - Use the Highest Efficiency Lighting Equipment

Perhaps the most efficient system for office lighting available today consists of fluorescent troffers with electronic ballasts, T8-lamps and deep-cell (3-inch deep) parabolic diffusers. A 3-lamp fixture of this type can provide the same illumination on a task surface as a standard 4-lamp troffer with acrylic prismatic lens while using 55% less energy (83 Watts versus 184 Watts). Typically, l-lamp (39 Watt) and 2-lamp (64 Watt) T8/ Electronic fixtures are more appropriate than 3-lamps for meeting the IES illuminance Categories C and D that cover most office tasks, and will use even less wattage. Designs using these fixtures, and the IES light levels discussed above, will fall into the range of 0.9 to 1.2 Watts per square foot, a decrease of 60 to 80% in energy over standard design. Adding localized or task lighting concepts can push energy as low as 0.7 Watt per square foot. The occupants will benefit as well—the parabolic diffuser provides superior glare control to control reflections in VDT screens and T8 lamps provide superior color rendering with more natural skin tones compared to T 12 "Cool White" lamps.

Another important tool for achieving the highest lighting efficiency is the compact fluorescent lamp. Compact fluorescent fixtures are now available that can fill virtually any incandescent lamp application. For example, we use downlights with two, 13 Watt twin-tube compact fluorescent lamps to replace the typical 100 to 150 Watt incandescent downlight commonly specified by designers. Some designers still want to use incandescent downlights for dimming in conference rooms or auditoriums. We have found it quite acceptable to use compact fluorescent downlights, even in these applications, by providing multilevel switching of the two lamps in each downlight to vary the light level, instead of continuous dimming.

The cost of each high-efficiency fixture, T8/electronic or compact fluorescent, is greater than a standard fixture. However, an important cost reduction now becomes available in the size of the air-conditioning system for the building. Reducing the air-conditioning first cost is the third key concept in cost control.

Key Concept 3 - Take Advantage of Lower Air-Conditioning Size and First Cost

Lowering the lighting load from 3 to 5 Watts per square foot down to about 1.0 Watt per square foot permit one to significantly reduce the size and first cost of the air-conditioning system, typically by 20 to 30% in our experience. In buildings with central chillers, typically greater than 30,000 square feet, this size reduction can produce major first-cost savings in ductwork, air-handlers, chillers, pumps, piping and the associated electrical service. Even in small building, however, the effect can be significant. In one 20,000 square foot residential treatment center we observed a reduction from 15 ton to 10 ton rooftop air-conditioning units and from 3/4 ton to

1/2 ton in console heat-pump units used in the building. This reduction will not happen automatically, however—one must insist that the designer take actual lighting wattage into account in the cooling load calculation. We observe that most designers still do not use actual lighting wattage in their calculations, rather, they assume 3.0 Watts per square foot and never actually check the lighting design. Insist that the design team coordinate on this point. Coordination may be verified by checking the listed lighting wattage in the input to the cooling load calculations. A budget limit of no more than 1.2 Watts per square foot is reasonable for preliminary calculations, and the designer should use actual lighting wattage in all final cooling calculations. The first-cost savings are well worth the effort. Let us summarize by adding up and comparing the overall project costs of standard versus high-efficiency lighting.

Net Impact on Project Cost

Which is really cheaper, standard lighting designs or the highest-efficiency design available today? When all first costs are considered in total, as in Table 1 "Evaluating the True Cost of Energy Efficiency", the highest-efficiency system turns out cheapest to build. The high-efficiency system also has far lower operating costs and far lower maintenance costs because of the lesser number of lamps and ballasts. This table presents a win/win/win scenario for (1) first cost, (2) energy and (3) maintenance that should interest every building owner or developer.

The owner may pocket this available savings, or use it to pay for additional, worthwhile energy-saving controls such as occupancy sensors, tri-level switching arrangements, photocell controls or time control of interior lighting.

Example 2: Integrated EMS/DDC Systems Reduce First Cost of Controls

In buildings greater than 10,000 square feet, automatic temperature control requirements are sufficiently complex that it now costs less to accomplish control through integrated Energy Management/Direct Digital Control systems rather than through built-up, ad hoc pneumatic control panels. Energy Management/DDC systems adapt to the building through low-cost programming changes rather than the expensive, hardware-based logic controllers needed for conventional pneumatic air control panels. These Energy Management/DDC systems have been considered the domain of large buildings, over 100,000 square feet, due to cost. However, because of the electronics price revolution, the simplest DDC units can now be purchased and installed for around $3,000. Even the simplest unit adds a wealth of flexibility for temperature and energy control, comfort monitoring, and remote communication that pneumatic systems lack. In 1993 we obtained alternate bid prices for DDC versus pneumatic controls in two small buildings; a recreation center and a

Table 1. Evaluating the True Cost of Energy Efficiency

	Efficient Lighting	**Standard Lighting**
Lamp:	T8	T12
Ballast:	Electronic	Efficient
Diffuser:	Parabolic	Prismatic
Cost per Fixture	$111	$60
x No. of Fixtures	1080	1600
Total Fixture Cost:	$119,880	$96,000
Lighting Wattage:	90 kW	294 kW
Incremental **Cooling First Cost:**	**$51,200**	**$167,200**
	Efficient System	**Standard System**
Total Project Cost:	**$171,080**	**$263,200**

[Costs Based on 100,000 Square Foot Office Building] library, both around 22,000 square feet. Both bids indicated “no change” to use DDC rather than pneumatic controls, even for these relatively small buildings. Our experience is that Energy Management/DDC controls provide substantial energy reductions and have now passed the cross-over point with cost of non-electronic control systems.

Example 3: Variable Frequency Drives Replace Inlet Guide Vanes

After lighting, air-handling fans use the largest amount of energy in typical office buildings. Most large air-handling systems today produce a variable air volume by using inlet guide vanes to throttle air flow as needed. These systems far exceed the efficiency of constant volume systems. However, Variable Frequency Drives (VFD’s) can produce a further energy improvement of about 50% by reducing the fan speed electronically and not throttling the air inefficiently. VFD’S also provide a much finer level of control than guide vanes. In the past, VFD’s have been an expensive option. However, the steady cost drop in electronics components has now brought VFD’s down to being close to equal on a first-cost basis with inlet guide vanes and the motor starters they replace. VFD’s are currently required in our new buildings on all VAV air-handlers.

Example 4: Thermal Energy Storage with No Added Cost

Ice-Storage systems have great potential to lower air-conditioning costs through reducing peak electrical demands of a building. Experience shows that the cost to build the storage system need not be higher than a conventional cooling system. The storage tanks may cost more, however, the air-handling system and ductwork can be made much smaller and less costly in compensation. Low-temperature water (32°F instead of 44°F) provides the key to smaller chilled-water pumps and piping, while low-temperature air distribution (42°F air instead of 55°F) permits much smaller and less costly air-handlers and ductwork throughout the building. As an example, we have recently built one 100,000 square foot building with ice-harvesting thermal storage and low-temperature air distribution. The storage pit was built into the foundation of the building at a relatively small added cost. The designer estimated the total first cost of the system would be comparable to a normal chiller system. In fact the low bid on the building was 20% below the anticipated construction budget based on conventional systems. The utility bills for the first year of operation at this building have been $0.95 per square foot per year. Thus we achieved a very low operating cost with apparent savings in first cost.

Example 5: High-Quality Exterior Fixtures Reduce Installed Costs

The same paradox of higher efficiency costing less to build occurs in exterior lighting as in interior lighting. The most efficient and expensive exterior lighting fixtures can produce the lowest installed first cost when used in a well-designed layout. The key in this case lies in the superior uniformity and spread of light produced by fixtures with high-quality optical designs. For example, a perimeter lighting design with quality “cut-off” fixtures can achieve the same minimum light levels with roughly half the number of fixtures (and half the total wattage) as standard “Wall-pack” fixtures. The cost per high-efficiency fixture runs only 15 to 25% higher than the inefficient one, however, only half as many are needed to provide the desired light level, leaving plenty of room for actually reducing first cost in this exercise.

Example 6: High Performance Windows Reduces First Cost

High-performance window systems can pay their own way in first cost through reducing heating and cooling systems size and first cost. As in the lighting example, this compensation will not occur automatically. One must insist that the properties of the windows be correctly used in the heating and cooling load calculations for the building. The architect and engineer must communicate to keep calculations in line with the window specified. A typical high-performance, moderately-priced glazing system would be double-pane, low-emissivity coated and tinted, with a thermal conductance of 0.33 Btu/hr-ft2-°F or less and a shading coefficient of 0.50 or less. The low shading coefficient reduces air-conditioning peak loads due to solar gain. The low thermal conductance permits only half the heat flow of normal double-pane insulating glass and can significantly reduce heating loads for the total building. The window frame and spacers must be insulating materials to avoid compromising the overall window thermal performance. Metal frames, even with “thermal breaks,” significantly degrade overall window performance. As an example of potential cost savings, the 100,000 square foot office building we recently constructed contained 15,000 square feet of exterior glass—a moderate amount and within new ASHRAE 90.1-1989 limits. By upgrading from average double-pane glass to high-performance glass we achieved the following cost reductions:

- Eliminate proposed baseboard hydronic heat system throughout the building. The high performance windows reduced perimeter heat losses below 300 Btu/linear foot, the threshold for not needing baseboard heating for local comfort.

- Substantially reduce the heating coil size in each exterior-zone mixing box for air distribution.
- Reduce piping and pump size for supplying hot water to coils.
- Reduce central boiler by 300,000 Btuh (30% in this building).
- Reduce mechanical room floor space by 150 square feet, saving approximately $30 per square foot.
- Reduce peak air-conditioning load by 10%, mainly through lower shading coefficient.

The first cost savings from the above items was $75,000 whereas the cost of upgrading the windows was $30,000. Once again we have a win/win situation for energy conservation and first cost savings.

Rebates

Throughout this discussion of first cost, we have omitted the subject of utility rebates for energy-efficient equipment and design. The point of this omission is that efficiency can be obtained without first cost penalties even before any rebates are considered. Utility rebates are available to our buildings and we are glad to accept them. In our case, we use the rebates to fund retrofit projects in other buildings. Utility rebates are additional "icing on the cake" if available in your area. However, rebates are not necessary to make an efficient building "break even" on first costs.

Summary

The above examples illustrate some of the key ways that energy-efficiency can be built into a building at little or no cost premium. In each case the building occupants also benefit from better comfort and quality. The key is to view projects from the standpoint of overall costs for complete designs and complete buildings, instead of focussing on unit costs for pieces of individual equipment or materials. The prevalent idea that efficiency must cost more is a myth that needs to be exposed.

Montgomery County has compiled the above-mentioned requirements and other requirements for energy efficient building design into an integrated book called *Energy Design Guidelines* (Balon 1993). Copies of the *Guidelines are* provided to all designers at the start of a project and enforced on a phase-by-phase program during design. In this way, energy efficiency is integrated into projects from the outset and energy control of the final design is assured.

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Ron Balon has spent the last 7 years managing energy-efficiency programs in new building design and retrofits for Montgomery County Government. His work on energy efficiency spans numerous research grant projects, demonstration projects, life-cycle-cost studies and actual building designs. Ron Balon is the author of *Energy Design Guidelines, an* award-winning, comprehensive approach to design and technology for high efficiency in new buildings and renovations.

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