Negawatts for Buildings

by Amory B. Lovins & William D. Browning

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Real-estate publications seem to be drowning in articles on the problems facing the industry in the 1990s. The recession and overbuilt markets have made leading battles fiercer than usual. Rent concessions and tenant improvements are swallowing bigger chunks of project returns.

Growing environmental consciousness is also putting pressure on property developers and managers. As one building manager recently said to us, "I pretty much ignored environmental issues, until my tenants started asking me questions about indoor air quality, drinking water quality, and building energy use that I couldn't answer."

Cutting a building's energy use is one of the easiest and most effective ways of responding to many of these problems and issues. One developer, for example, renovated a 20-year-old office building in Los Angeles, repositioning it for the Class A market. The developer modernized the lobby, modified the mechanical and lighting systems, upgraded interior and exterior finishes, enhanced the landscaping-- all standard measures. He also eliminated the majority of the building's energy use through the use of advanced glazings, efficient lighting, and better though not yet optimal HVAC design. The energy-saving measures will pay for themselves in 5.9 years, and a utility rebate will reduce the payback period to three years. Another office retrofit in California, done as a utility experiment, saved over three-fourths of the electricity, including over 90% of the air-conditioning energy.

Such dramatic energy savings are possible even with buildings less than ten years old. Buildings that have already done a lot to save electricity can start all over with a menu of technologies that were not available even three years ago.

The Electric Efficiency Revolution

As the costliest form of energy, electricity is by far the most lucrative kind to save. Electricity cost U.S. consumers about $170 billion a year, including $100 billion for businesses. Expansions of the electric supply devour about $60 billion of capital per year -- the same as total investment in all durable-goods manufacturing industries.

Each unit of saved electricity saves three or four units of fuel, chiefly coal, at the power plant. Saving electricity avoids much pollution, because power plants use one-third of all fuel and produce one-third of the resulting carbon dioxide (CO_2), one-third of the nitrogen oxides (NO_x), and two-thirds of the sulfur oxides (SO_x). Saving electricity therefore yields great environmental as well as economic leverage.

And because saving electricity is cheaper than making it, pollution is avoided not at a cost but at a profit. For example, replacing a 75-watt incandescent lamp with an 18-watt compact fluorescent lamp yields the same light for 13 times as long; keeps a ton of CO_2 and about 20 pounds of SO_x from being emitted by a coal-fired station; and generates tens of dollars of net wealth, because the new lamp saves tens of dollars more in utility bills, replacement lamps, and the labor to install them than it costs. It also defers hundreds of dollars in utility investment. That's a green investment in two ways -- environmental quality and greenbacks.

State-of-the-Art Lighting Retrofits

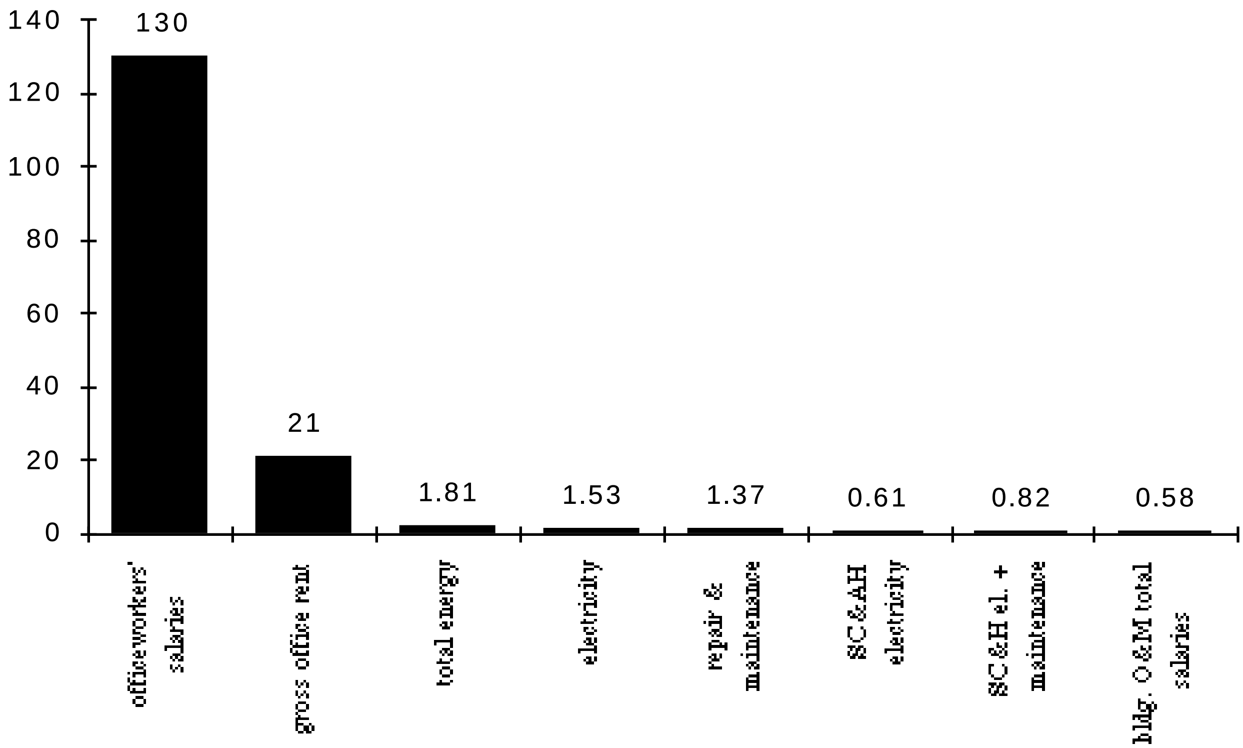
Lighting, which uses one-fifth of all of U.S. electricity (or one-quarter when its net effect on space conditioning is counted), has probably the greatest potential for saving energy and making profits. Lighting costs business tens of billions of dollars a year. In a typical big office building, about one-third of the electricity goes directly to lighting. Furthermore, the heat produced by lighting represents the largest cooling load that many buildings have. So directly and indirectly, lighting uses well over half the building's electricity and a larger share of its peak electricity demand.

Most commercial lighting is fluorescent. Skillfully retrofitting fluorescent fixtures of any age, even supposedly efficient ones, can generally cut their energy use by around 70 to more than 90 percent, saving over $1 per square foot per year on lighting, space cooling, and lighting maintenance costs.

Such a retrofit can cost around $2 per square foot. Half that is saved over time by reduced maintenance requirements for 50 percent fewer lamps and 50 to 75 percent fewer ballasts than before the retrofit. The net-present-valued cost of the retrofit thus is only about $1 per square foot, which will be paid back in one or two years. In new construction, the payback is immediate because the capital costs saved by downsizing the mechanical systems exceed the extra costs of a better lighting system.

The retrofit provides the same amount of light as before, but it will look better and building occupants will be able to see better. A good retrofit requires understanding the qualitative difference between lighting and lighting design. Lighting provides light in a space in order to meet average footcandle requirements, energy-efficient lighting design provides for necessary illumination while also creating pleasant, attractive and visually exciting spaces. This advantage plus improved and more reliable thermal comfort probably mean happier and more productive workers--a benefit worth more to the bottom line than lower energy bills. This is an extremely important point. While saving $1 per square foot in energy costs has a significant effect on building financial performance, it is totally swamped by the benefit of keeping occupants -- at an average cost of $130 per square foot -- happy and productive. please refer to chart

building operating costs using 1990 $/rentable sq ft-y, BOMA data except officeworkers' salaries



The building should be worth more (though few commercial property appraisers yet recognize this significant value) and should enjoy a much larger competitive margin. Leasing brokers often fight over rent differences of 5 to 10 cents a square foot, whereas lighting retrofits alone can save close to $1 a square foot per year--operating savings that can be used for buildout, rent concessions, or whatever it takes to attract tenants. What other building improvement can produce a direct annual return of more than 40 percent on capital and provide the margin to win markedly higher occupancies?

Fluorescent lighting retrofits should generally include imaging specular reflectors, thin (T-8) lamps with tri-stimulus-phosphor, tunable high-frequency ballasts, and dimming and occupancy controls. They will achieve the results described here only if skillfully designed and installed as an integrated package. Imaging specular reflectors, made of very shiny metal bent into a customized, computer-designed shape, are available for both new fixtures and retrofits.

With reflectors, half the lamps can be removed for virtually the same amount of light delivered: watts per delivered foot-candle fall by around 35 to 50 percent. The reflectors make virtual images of the missing lamps, making it look as if they were all still in place, yet they need no electricity or maintenance.

The reflectors' secret is less in their shininess than in their sophisticated shape. Shop carefully. Many reflectors lack good optical design, and some can worsen performance. One size does not fit all. Beware of makes not designed differently for different fixtures or room positions, or not requiring the relocation of the lamps that remain in service.

The relocated remaining lamps should be replaced with tri-stimulus-phosphor lamps that provide up to 18 percent more light per watt than normal lamps--up to 26% with thinner (T-8) lamps. The more pleasant and accurate color of these phosphor's makes reading easier and furnishings and flesh tones more attractive.

Tunable high-frequency electronic ballasts save electricity 15 ways--a sort of electronic Wonder Bread. They intrinsically save about 35 to 40 percent of the lighting energy by losing less energy themselves and by making the lamps run better at high frequency, which also eliminates hum and flicker. The ballasts also need less design margin against abnormal lampwall temperatures or supply voltages.

A thin fiber-optic stalk poked down through the ceiling tile dims the lamps automatically according to the amount of daylight striking the work surface. (Manual dimming is an option too.) The dimming system also brightens the lamps as they dim with age or dirt, and lets occupants modulate light across space to match visual tasks. Occupancy sensors can be added--in a neat switchbox holding both infra-red and ultrasonic sensors--to turn off the lights when people leave the room.

Reflectors, better lamps, high-frequency ballasts, dimming systems, and occupancy sensors together will typically cut directly used lighting energy per useful foot-candle by 70 to 80 percent. Avoiding overlighting, using task lighting, cutting glare with polarizing lenses, using light-colored finishes and furnishings that bounce light around, using top-silvered blinds and glass-topped partitions to bounce light farther into the core of the building, and improving maintenance will further increase the savings, often to more than 90 percent.

The payback for state-of-the-art fluorescent lighting retrofits is under two years, not to mention the bonus savings on space-conditioning energy: for each unit of lighting energy saved, around one-third of a unit of electric space-conditioning energy-and one-half a unit in peak electric demand--is saved. Lighting levels stay the same; lighting quality is much better.

A further step that may be attractive for some facilities is the addition of advanced skylights for daylighitng. There are several benefits associated with the use of daylighting. Operating costs can be substantially reduced when a building is daylit. Evidence supports an increase in worker productivity and a drop in absenteeism in daylit buildings. Some companies have received a competitive advantage because of this productivity increase.[1] The daylight half of Wal-Mart's Lawerence, Kansas, Ecomart store has shown a higher sales rate then the conventionally lit half. Wal-Mart is considering retrofitting rooftop daylight monitors on the roofs of existing stores, partially for energy savings, mostly to create a better shopping environment.

Replacing incandescent lamps with compact fluorescent lamps saves 75 to 85 percent of the electricity, and extends lamp life by five to 13-fold. Even greater savings may be obtained by using modular compact fluorescents assembled from different pieces--a small magnetic or electronic ballast, an adapter (usually built into the ballast) to screw it on a normal nondimming socket, a plug-in lamp or two, and often an optical reflector, globe, or decorative accessory.

After 10,000 hours of use, only the $3 to $6 plug-in tube--but not the whole assembly--will need to be replaced. By saving up to a dozen lamps and trips up the ladder, replacing incandescent lamps with compact fluorescent lamps repays their higher initial costs even before they begin to work to save electricity. In fact, saving a kilowatt-hour (kWh) costs around *minus* 5 to 20 cents: that is, the per-kilowatt-hour savings in present-valued maintenance (for replacement lamps and their installation labor) is 5 to 20 cents more than the new equipment costs. It's better than a free lunch; it's a lunch you are paid to eat. The economics of lighting retrofits are extremely attractive, and can be captured with minimal dispruption of existing tenants.

Superwindows, Office Equipment, Motors, and Mechanicals

[1] From an article written by William D. Browning, called 'NMB Bank Headquarters', in *Urban Land*, The Urban Land Institute, June 1992.

Windows are an essential component of an energy strategy and superwindows, while having a higher initial cost, are essential to an energy efficient building. The term, superwindows, refers to double-glazed windows with several specifically selective coatings such as Heat Mirror film. These windows are visually transparent; however, they have a thin metal coating on the plastic film suspended between the glass which allows short-wave radiation (visible light) to pass through but long wavelength radiation (infrared or heat) cannot pass through. This is how R- values of 4.5 or more are achieved. Other coatings can be applied to either the glass and/or the plastic film to help control UV transmission which will protect fabrics, furniture and art. The addition of argon (krypton) gas into sealed windows increases the R- value to 5.3 or better. Additional layers and optimal window pane spacing can increase the center-of -glass R-values as high as R-11. The addition of argon or krypton to a window provides another benefit. Since these gases are heavier then air, they have the characteristic of deadening sound transmission, which leads to a more quiet building.

These windows can be selectively tuned to control the amount of visible light passing through. By mixing or specifically choosing specular and thermal performance, it is possible to choose the perfect window for different exposures. This process is called tuning the facade and can have dramatic results in balancing the light and heat flux across the shell of a large building.

One of the most important but least known electricity-saving opportunities is efficient office equipment. A notebook-sized 80486-class computer that uses one to six watts instead of 150 watts yields present-valued electrical savings that will about repay its marginal cost. Battery-powered portable computers now offer all the power and screen quality of desktop machines (or better), but are more rugged, ten times better shielded, do not cost $200 per workstation to wire an uninterruptible power supply, and are nearly as cheap. Other options are also worth consideration--cold-fuser photocopiers and printers; highly efficient, well controlled hot-fuser models; inkjet printers and fax machines; and , most simply, equipment turned off when not in use. At a minimum computers and peripherals that have received the *Energy Star* rating should be specified.

Energy-Efficient Office Equipment, a publication from the Rocky Mountain Institute's E-Source subsidary (See "Further Reading"), reports that electricity usage from office equipment can be cut by 96 percent by selecting models now on the market that work the same or better and cost the same or less than normally inefficient equipment. Compared with inefficient office equipment of identical functionality, the capital cost of a new building that will use the most efficient office equipment will be reduced by $2 average per square foot. And using efficient office equipment can save more than $60 per building square foot in present-valued operating costs.

Motors use over half of all U.S. electricity--even more primary energy than highway vehicles. High-efficiency motors and adjustable-speed drives can save about one-fourth of motor energy. Adding other improvements involving the choice, size, lifetime, and maintenance of motors, controls, plus better electric supply options and mechanical drivetrains, could together save around half of total U.S. motor energy, with a payback of about 15 months. An excellent place to start is with HVAC motors.

HVAC systems offer other large opportunities for saving electricity. Typical commercial buildings have space cooling and ventilation energy intensities on the order of 2 to 4 kWh per square foot per year, cooling loads of 100 to 400 square feet per ton, and total system energy use of 1.2kW per ton or greater (often nearer 2 kW per ton for rooftop units). Mechanical equipment often incurs capital costs of $6 to $12 per square foot.

More efficient lights, windows, and office equipment can greatly reduce the need for cooling, and hence the size of this costly equipment, wither in new projects or on replacement. (Mechanicals typically last about 20 to 30 years, but many systems now in operation may be replaced sooner because of CFC phaseout.) Reduced cooling loads (of 800 to 1,200 square feet per ton) require a system that is only one-half to one-third the size, bringing capital costs down to $3 to $6 or more per square foot.

For the cooling load that's left, alternatives already on the market--passive and nonrefrigerative cooling systems, improved controls and maintenance, and highly efficient (under 0.7 kW per ton) refrigerative cooling systems--can cut the energy intensity of space cooling by around 80 percent, to less than 1 kWh per square foot per year. In new building and some retrofits, the extra costs of higher-efficiency HVAC equipment often are less than the savings from downsizing the HVAC system to match reduced cooling loads.

Achieving such dramatic HVAC savings--down to whole system peak usage of only 0.14 kW per ton in one recent retrofit--requires whole-system engineering that synergistically combines proven, off-the-shelf components and pays meticulous attention to detail. Evaporative and desiccant cooling are among many passive and alternative cooling techniques. Efficient mechanical systems include larger heat exchangers, adjustable-speed drives, displacement ventilation, high-efficiency axial fans, mix and match chillers optimized at nonstandard conditions, and better pumps, pipes, and ducts. The governing principles for mechanical efficiency are low flow, low pressure, low friction, and low thermodynamic losses.

Well-engineered systems are not only far more efficient. They also afford more precise control of temperature and ventilation, allowing the landlord to be more responsive and flexible in meeting tenants' changing needs. And they provide markedly superior comfort--even temperatures, virtual silence, an no drafts. However, being neither accustomed to nor rewarded for careful whole-building engineering, mechanical engineers tend to rely more on rules of thumb than on careful optimization.

The owner of a 350,000-square-foot Chicago office building formerly connected to chilled water from an adjoining building recently decided to buy its own chillers. Thermal simulation showed the right size was less than half the 1,000 tons conventionally specified--and would be roughly twofold smaller still with better lights and office equipment. Whole-building engineering offered savings of over $300,00 in mechanical capital costs, even more in operation costs. But to realize them, the owner had to pay a soft cost premium. Skilled designers cannot be expected to do the extra work if they are not paid for it. Ideally, they should be rewarded according to how much money they save the owner.

Big energy savings with superior performance depend on sophisticated and extremely detailed system integration. It's like eating a lobster: if you eat only the big, obvious chunks of meat in the tail and front claws, you miss a roughly equal quantity of tasty morsels tucked away in crevices. Real estate professionals have to make it worth the designer's while to dig in all those little crevices. The rewards can be great. Capturing downsizing opportunities and taking advantage of helpful interactions that yield multiple benefits for single expenditures can result in two or three times the savings with a total cost that is several times lower. Nonenergy benefits are also available. For example, smaller and quieter mechanical can open up more leasable space. The steps for completing an integrated retrofit of a commercial building are as follows:

A. **Understand occupancy and sociology** -- what do people want, and how do they use the space?

B. **Measure existing conditions** and simulate expected energy performance and how subsystems interact.

C. **Rigorously avoid internal heat gains,** via daylighting-integrated lighting systems using <0.7 W/ft^2 (with control savings, this will equal <0.4 W/ft^2), office equipment using ~0.2 W/ft^2, and equally efficient appliances and miscellaneous loads.

D. **Optimize the envelope** by paying attention to daylighting through windows "tuned" for optimal spectral and thermal performance on each elevation, shading, color, landscaping, thermal mass, venting, infiltration, acoustics, space flexibility, finishes, furniture, furnishings, and "junglification."

E**. Specify a far smaller and far more efficient HVAC system** starting downstream and working back. Eliminate, radically simplify, or downsize virtually everything; substitute passive and alternative for refrigerative cooling; improve any remaining refrigerative systems to <0.7 kW/ton including auxiliaries; optimize controls; size for efficient current occupancy and plan flexibility to accommodate expansion or increased loads.

Negawatt Leadership

Delivery systems for integrated, rapidly evolving technological packages are just beginning to develop. Only a handful of companies perform up-to-date, whole-system lighting retrofits with excellent aesthetics, and only a few engineers design superefficient HVAC systems. Energy service companies are growing to capture part of what ultimately will be about a trillion-dollar-per-year business opportunity worldwide, but few yet offer strong integrative skills and technological modernity. Many utilities, however, are helping their customers save electricity, not only by financing and marketing saved electricity, but also by explaining how to do it. Many utilities provide general and specific energy-saving information, finance energy efficiency with concessionary loans or even gifts, and provide rebates for buying, selling, installing, and specifying efficient equipment, for scrapping the old equipment, or for exceeding government standards of efficiency. In all, such efforts now receive about $2 billion a year in funding by U.S. utilities, an amount roughly matched by their customers. Utilities offer these incentives because saving electricity is cheaper than making it. Developers accept these incentives because electric efficiency makes buildings work better and cost less. It's a natural partnership.

Electric efficiency is a very rich and complex field that offers exciting new opportunities. The negawatt revolution now provides a way to cut construction costs, capture big returns on capital in renovations, dramatically cut operating expenses, often cut new-project capital costs, and make buildings more pleasant, attractive, and comfortable. The leadership of enlightened property companies is going to be vital in controlling pollution and boosting competitiveness through the use of these and other advanced techniques for resource efficiency.