Office Building Retrofit to Produce Energy Savings of 75%

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A collaborative project on a 110,000 square foot (SF) Los Angeles office building energy retrofit is expected to save 79% over baseline conditions, dropping from 354 KBtu/SF/yr to 72.7 KBtu/SF/yr source energy consumption, and from 157 KBtu/SF/yr to 31.7 KBtu/SF/yr site energy.

Connected lighting lead for the building is currently 1.77 Watts per square foot (W/SF), while projected lighting lead will drop to 0.69 W/SF. Total air conditioning tonnage will be reduced from 417 to 242 tons. A manual will be prepared to help tenants save energy.

To determine how much of the predicted energy savings are realistic, billing and monitoring results from another low-energy building are presented. After 3 years, total energy consumption of the retrofitted NRDC office is 7% below predictions, although the areas where savings were achieved differ somewhat from predictions. The reasons for these discrepancies are discussed. Results from a post-occupancy survey of the NRDC office space are presented and the effects of an educated tenancy on energy consumption are discussed.

Introduction and Overview

A unique public/private partnership has collaborated to design a retrofit package for a 110,000 square foot Los Angeles office building that is predicted to save 79% of the electricity, and 81% of the natural gas over the pre-retrofit consumption.[1] These energy savings are expected to reduce energy costs by 66% as shown in Table 1. Total project payback is estimated at 5.3 years, 2.7 years with an incentive from the municipal utility.[2]

The loss of the building's major tenant provided a window of opportunity to undertake a major energy retrofit. A private developer on the west side of Los Angeles hired an energy service company (ESCO) to do an energy savings assessment on the recently purchased building. The ESCO teamed up with the local municipal utility and a national environmental group to "push the envelope" of available energy savings in the building. The new owners believe that having advanced energy-saving systems, in conjunction with other environmental considerations, will give them a competitive advantage over other buildings in the area. The owners plan to distribute a comprehensive tenant education manual to discuss building energy-saving features.

Project Background

The building owners desired to embody their belief that it is real estate projects can incorporate environmental sensibilities, while benefitting the property owner. Having been inspired by other low-energy building projects, the owners wanted to produce a showcase energy efficient building. They felt that a successful demonstration of congruence between environmental and economic goals would establish them firmly as socially responsible developers, while simultaneously providing an example and inspiration to others. The owners' ultimate plan is to show the financial and environmental benefits of advanced energy efficiency in commercially-viable buildings. The demonstration is intended to educate their peers in the business community to these benefits and influence the financial community's lending criteria to include an energy-efficiency component.

Table 1. Savings Summary

	Existing	Retrofit	Savings	%
Operating Expenses	$278,000	$93,400	$184,600	66
Electric kWh	3,069,000	647,000	2,422,000	79
Electric kWh/SF/yr	27.9	5.9	22.0	
Gas KBtu	6,692,197	1,263,000	5,429,000	81
Gas KBtu/SF/yr	61.0	11.5	49.5	
Site KBtu/SF/yr	157.0	31.7	124.0	79
Source Energy Cons. (KBtu/SF/yr)	354.0	72.7	281.0	79

Note: numbers may not add due to rounding.

Building Description: Pre-retrofit

The project building is one of two twin 5-story buildings. The rectangular building's length is oriented northwest/southeast, while the width is oriented northeast/southwest.

Pre-retrofit Lighting System

Lighting in the main office spaces is provided by lensed, 4-lamp, 2x4 recessed troffers on eight-foot center. These fixtures contain standard 34 Watt lamps with energy-saving core/coil ballasts. Corridors and service areas are lit using 2-lamp 2x2 recessed lensed troffers with energy-saving magnetic ballasts and T-12 U-lamps. Entryways and foyers use 75 and 150 Watt PAR lamps for down-lighting. Most office spaces are single-switched, with some having interior and window zones that are separately switched. Connected power density for the lighting system has been calculated at 1.77 Watts per square foot.[4]

Base Case Building Shell

The windows are principally comprised of single-pane light-bronze glass, with localized solar film treatments on the second-floor south-western exposure. Protruding vertical concrete fins shade the windows as the sun's angle moves across the sky. However, the orientation of the building is such that, at peak solar times, the sun is almost perpendicular to the building's long face. The windows comprise 33% of the building's face, and 14% of the floor area.

Pre-retrofit Mechanical System

The building's mechanical systems are typical of those specified in the mid-1960s. Two centrifugal chillers, with a total 417 tons of capacity, provide the cooling for the constant-volume, dual-duct heating, ventilation and air conditioning (HVAC) system. Although they are 20 years old, the existing chillers could have their life extended 7 to 10 years with a major overhaul.

A remnant from an era where energy consumption was not considered an important factor, the dual-duct system controls building temperatures by simultaneously heating and cooling the indoor air. Chilled air in the cold-deck is combined in terminal mixing boxes with air from the hot-deck that is heated by hot water coils from a 3200 thousand Btu/hr boiler. The system had 4 additional air-handlers on the 2nd floor to meet the large cooling needs of the previous tenant. The system limited fresh air ventilation to only 10% through fixed louvers.

One of the most glaring inefficiencies in the operation of the existing system is its partial load performance. After implementing the lighting and window upgrades, the existing system would have spent approximately 75% of its run-time operating at 25% capacity, which for centrifugal chillers is the least efficient part of their load curve.

Baseline Energy Consumption

Historical Energy Use Is an Inappropriate Benchmark

Determining baseline energy use for this building was not a straightforward calculation. The building's major tenant, a 24-hour airline reservations center had recently vacated the building. Around-the-clock operation and large computer energy loads, as well as the concomitant air conditioning loads, strongly skewed energy consumption compared with expected consumption for this type of building. In fact, the building's per-square-foot energy consumption was approximately twice the service territory average for offices.[6] Since this tenant occupied 55% of the building's floor space, pre-retrofit energy consumption patterns are very different from what would be expected once the building attracts new tenants. Thus, little information about future energy performance or energy savings can be learned from historical billing records.

Calculation of Baseline Energy Use

The challenge was to develop a base case that would accurately reflect the type of tenancy expected after the retrofit was complete. To accomplish this, the ESCO team drew on audits they had performed on several Los Angeles buildings of similar vintage and characteristics, as well as an audit of existing tenants in the building. Using these audits, comparisons, and "professional judgement," the ESCO created a "typical" tenant energy use profile that was substituted for the airline tenant. Characteristics of this "base case" building were then simulated using an energy simulation model and annual consumption was estimated. This figure was cross-checked with billing information from previous audits.

The Need for a Standardized Calculational Protocol

The delays and disagreements that occurred over the designation of baseline energy consumption in this project indicate the need for a standardized calculation protocol for cases when historical energy consumption patterns are inappropriate to determine energy savings after the completion of a major retrofit.

We believe that the need for such a protocol will increase in the future as electric utility demand-side management programs focus on the "lost opportunities" within their service territories and target buildings that are at the point of major remodel; large-scale renovation projects will most likely occur after the loss of a major occupant, which can lead to problems determining baseline energy use similar to those encountered during this project.

Proposed Retrofit Design

Design Process

The building's design was achieved through an iterative collaborative process. Weekly design meetings brought together representatives of the owner, the environmental group, the municipal utility, lighting and HVAC experts from the ESCO, private building design practitioners, as well as academics.

In these meetings, members of the design team would brainstorm different design configurations and project definitions. Critical issues surrounding HVAC, lighting and the building envelope were resolved through a consensus-seeking process. When disagreements arose over the effect or feasibility of a suggested measure or design proposal, alternatives were modelled and the results presented for discussion at the next week's meeting.

Design Characteristics

The participants in the project did not want to engage in typical system-by-system analysis of the energy-saving potential. Everyone was committed to looking at the whole building as an integrated system. Given this approach, special attention was paid to the interactions between lighting, HVAC and the building envelope. The design strategy first was to reduce internal building loads to the degree possible, then to design an HVAC system to handle those loads.

A wide variety of measures were analyzed for efficiency and cost effectiveness. In addition to various measures within each building system, different combinations of systems were analyzed in an effort to identify the optimal mix of energy efficiency and cost-effectiveness. Table 2 presents measures used in the final package.

Utility Incentive Program

An interesting factor that partially drove the design process was the building's status as a "demonstration project" for the municipal utility's new DSM program. Since both the building and the program were under co-development, unforeseen delays occurred as the utility and

Table 2. Energy-Saving Technologies Used

HVAC Options
General system configurations
1. Conversion of constant volume double duct to variable air volume (VAV).
2. VAV with fan powered boxes.
3. VAV with reheat.
4. Installation of a heat pump system using existing condenser water.

Alternative chilled water
1. Retaining the existing centrifugal chillers.
2. Water cooled rack chiller unit.
3. Air cooled roof-mounted chiller unit.
4. Chilled water with off-peak storage.

Lighting
1. Lighting Sources:
   Fluorescent:
   --28W T-8 --9W & 13W PL
   --17W Biaxial--20W Biaxial
2. Fixtures; various lenses and louvers
   1x1 2x2Wall-Washers (PL)
   1x4 2x4Recessed Cans (PL)
3. Ballasts
   Electronic-with dimming capability

developer worked out issues regarding baseline determination, eligible measures and performance criteria. Through the collaborative process that had been established, the parties were able to resolve their differences.

Unfortunately, delays due to the development of the utility's program incentive criteria caused the developer to incur significant carrying costs. This and other mitigating factors led the utility to augment the energy savings incentive with a "research" award to evaluate the performance and cost-effectiveness of the various control strategies being implemented in the building.

As shown in Table 3, the utility paid $482,000 to the developer, split between $312,000 for lighting, window film and variable speed drives and $170,000 for the energy controls system. This incentive results in a levelized cost to the utility of 2.3¢ per saved kWh over 10 years.[7]

Table 3. Financial Parameters

Measure Cost		
HVAC		$518,000
Window Film		$40,000
Lighting		$255,000
Controls & Monitoring		$170,000
TOTAL		$983,000
Utility Incentive		
Energy Savings		$312,000
Controls		$170,000
TOTAL		$482,000
NET PROJECT COST		$501,000
Estimated Annual Savings:		$184,000
Simple Payback:		2.7 Years
Cost of Conserved Energy (10 years)		
Perspective	@3%	@7%
Utility (1)	2.3¢/kWh	2.8¢/kWh
Owner's (2)	$4.27/MMBtu	$5.19/MMBtu
Societal (3)	$8.38/MMBtu	$10.18/MMBtu
Current Retail Prices		
Electricity	$26.38/MMBtu	($0.09/kWh)
Natural Gas	$5.78/MMBtu	($0.58/Therm)

(1) Electricity only. Based on $482,000 first cost.
(2) Based on $501,000 first cost.
(3) Based on $983,000 first cost.

Lack of Agreed-Upon Baseline

Determination of a baseline upon which the utility would calculate incentives was a major area that needed resolution. Both parties had conflicting needs in this case. The utility did not want to extend more of an incentive than the project deserved under cost-effectiveness criteria, while the owners wanted to maximize their incentive.

The primary issue was whether to use California's Title-24 as the base-line or some combination of "current practice" and Title-24. To achieve the energy performance of a Title-24 building, the owners would have had to do very little in the way of modifications. According to computer simulations, minor lighting retrofit and the application of window film would have brought the building within the energy budget required by Title-24 for a building with the same configuration.[8] However, the "standard practice" criterion of the utility program meant that many of the HVAC measures being considered would not be eligible for an incentive.

Incentive for the HVAC System

This treatment of the HVAC measures presented the developer with a quandary; the abstract goals of the project conflicted with real-world financing criteria. The largest single cost of the proposed retrofit package was replacing the existing HVAC system. Yet, the requirement that the building comply with "standard practice" of existing buildings meant that the majority of the capital cost HVAC replacement would have to be borne by the developer.

The initial decision was to keep the existing system in place, refurbishing the chillers and changing the distribution system's configuration. The utility and the environmental group pushed hard for an HVAC upgrade. The utility had calculated that the owners' payback criteria could be met through the proposed incentive package, even though the bulk of the HVAC cost would still be borne by them. Finally, concerns about chlorofluorocarbons (CFCs) and the viability of replacing the chiller in the future led the owners to decide that replacement was the best option at this time.

Lighting System Retrofit

As with most energy retrofits, the lighting system was key to the entire package. The project team wanted to look at a combination of technology and design to achieve a high-quality, low power density package. The recommended lighting system is projected to consume 0.7 W/SF, without adjusting for the effects of controls, which reduce the effective coincident lighting load.[9]

Lighting Technology

The project will be using many advanced lighting technologies simultaneously to take advantage of the synergies available between components. Downlighting will use an array of lighting fixtures ranging from 2-lamp 2x4 recessed troffers with T-8 lamps and low harmonic distortion electronic ballasts to 1x1 bi-axial lamps and compact fluorescent wall-washers. The lighting system will use occupancy sensors to eliminate use during unoccupied times and ambient light level sensors to eliminate use when natural daylighting is sufficient. In addition, a facility management system (FMS) will monitor the building occupancy to turn off certain common area lighting when an entire floor is vacant.

Lighting Design Strategies

A variety of other considerations were taken into account to make the lighting system provide superior lighting services. The lighting designers expect to deliver at least 50 footcandles to the task surface area and have general area lighting levels at 25 to 30 footcandles, well within the 3 to 1 ratio between task and non-task areas suggested for good lighting practice.[10]

Because the owners have limited control over the energy use patterns of the occupants, they decided against providing a task-ambient lighting strategy. One concern is that the use of incandescent task lighting could dramatically increase the energy consumption for lighting. The owners intend to educate prospective occupants about the availability and performance of fluorescent task lighting options through the tenant manual.

As new tenants move in, their furniture plans will be used to do the lighting design so that the light can be used as effectively as possible. Fixtures will be located relative to the furniture to minimize glare and veiling reflections. In larger individual offices, wall-washers will be used to bring up the illuminance of the walls, giving the impression that the room is brighter than a simple photometric reading would indicate.[11] These strategies will be enhanced by light-colored surfaces, which were specified for all interior spaces.

Building Shell Retrofit

The area of greatest energy efficiency potential in the building shell is the glazing system. One option considered was replacing the existing glazing with a double pane, low heat-transmitting, high light-transmitting system. Another alternative was a window film treatment with similar properties. Since the film performed almost as well as the double-pane option and cost substantially less, it was chosen as the preferred strategy.[12] Solar gain will drop from 524 KBtu/hr to 403 KBtu/hr as a result of the window film retrofit.

Because of southern California's mild climate it was determined that adding insulation would not be cost-effective. This is particularly true given of the building's solar orientation and very low heating load; post-retrofit gas cost is expected to be less than $4,200 per year.[13]

HVAC System Retrofit

Mechanical System

Multiple combinations of HVAC systems were simulated by computer to chose the most energy-efficient alternative. (See Table 2 above.) Based on overall performance and system flexibility, a 242-ton air-cooled reciprocating chiller system with 8 staged compressors and 16 condenser fans was chosen. The constant volume system will be changed to a variable air volume (VAV) system with an economizer cycle. The current supply and return fans will be retrofitted with variable speed drives (VSD) that will allow the system to closely match its output with the building's cooling load. The HVAC upgrade is expected to reduce cooling energy consumption by 53% or 122,000 kWh/yr.

HVAC Controls

The facilities management system will optimize several aspects of HVAC performance to reduce energy consumption. The FMS will be able to the start/stop time of the HVAC system, as well as the run-time and speed of the VSD fans. The system will also be able to optimize the operation of the economizer cycle and the temperature for the chilled water.

Air-Cooled vs. Water-Cooled System

Ironically, the efficiency of the chiller being installed is less than that of the chiller currently in place.[14] The current system is rated at 0.91 KW per ton, while the 242 ton air-cooled chiller consumes 1.23 KW per ton. However "efficiency" in this instance is misleading since the consumption rating for the water-cooled unit does not include energy required for condensation (i.e. condenser water pumps, cooling tower fans), whereas the air-cooled chiller includes condenser fan. When these factors are included, the effective efficiency for the water-cooled chiller becomes 1.05 KW/ton of cooling. The air-cooled chiller has an array of small reciprocating chillers and dedicated condenser fans that enable the unit to unload much more efficiently at part-load conditions than a centrifugal machine. In fact, extensive simulation showed that the partial-load performance of the multiple-fan/compressor unit led to lower annual energy consumption than the "more efficient" water-cooled system.

Tenant Manual

The owners of the building wanted the philosophy of the building's characteristics and energy saving features to be explicit, rather than hidden. They also believe that an educated tenancy will help the energy-saving features of the building achieve their full potential. For these reasons, the owners are compiling a tenant manual that will explain the energy-saving features of the building and the environmental benefits of low energy use.

The tenant manual will explain the way the lighting system was designed and how to operate and work with the control systems. The manual will also contain information about carpooling, local transit systems and bike routes. A lobby display about the lighting, energy and environmental benefits is also being installed.

Achieving Exceptional Energy Savings: Evaluation of a Low Energy-Office Space

During initial development of the Los Angeles project, several ESCOs we approached about the feasibility of achieving 70%-plus savings felt that such results were not realistic and expressed skepticism that such low energy use could be achieved in a commercially-viable space. Two years ago, we presented energy savings estimates for NRDC's low-energy office example in New York City. (Watson 1990) In this section, we review those estimates and compare them with the results of one years' monitoring of lighting and HVAC use and three years' worth of billing records. Below, we will evaluate the office's energy performance compared with original estimates, discuss discrepancies between the billing and monitoring results and tabulate the results of a post-occupancy survey.

Post-occupancy Survey Results

We conducted a 25-question post-occupancy survey of workers to assess their level of satisfaction with the lighting and environmental control systems of the office. The results are summarized in Table 4. With 90% of the workers responding, we found very high levels of satisfaction with not only the quantity of lighting and ventilation, but the quality as well. Over 78% and 49% of the respondents found that the amount of lighting and ventilation, respectively, was "just right."[15] Similarly, 73% and 55% felt that the quality of the lighting and air was above average or excellent. When the respondents were asked to compare the performance of the space with others in which they have worked, the level of approval increased.

Twenty-two percent found the amount of light to be either too much or too little and 51% of the occupants thought their spaces' ventilation too much or insufficient. Only

Table 4. Summary of Post-Occupancy Survey Results

Amount of:	Light	Ventilation
Too Much	15%	31%
Not Enough	7%	20%
Just Right	78%	49%
	Light Quality	Air Quality
Above Average/ Excellent	73%	55%
Poor	11%	13%
Relative to Other Office Environments Worked In		
Better	85%	81%
Same	8%	15%
Worse	7%	2%
Temperature	Too Hot	Too Cold
Summer	11%	44%
Winter	36%	27%

11% and 13% thought the quality of the lighting or air was unsatisfactory. The problem most frequently stated was that of temperature control, with 36% saying that their space is too hot during the winter and 44% saying it is too cold during the summer. Part of this dissatisfaction is likely to be an indication of the range of environmental preferences, in addition to a comment on the ability of the system to control temperature.

The responses to the questions did somewhat depend upon the location of the worker. In general, workers in the perimeter offices expressed a higher level of satisfaction with the systems than those located in the core offices, although both core and perimeter workers felt interior conditions were superior relative to other places worked by a comparable amount.[16] However, there is no question that temperature control is an area that needs to be addressed in the future to improve not only the energy performance of the building, but its responsiveness to the occupants' needs.

Thoughts on the Importance of an Educated Tenancy

Clearly, the occupants of the NRDC building are aware that the space is intended to embody the principle of the organization. They also clearly appreciate the aesthetics of the space and the degree to which it meets their needs for a pleasant functional space to work. Although we are unable to separate out this effect, we argue that the occupants' behavior and consciousness has had an effect on the energy consumption of the space, contributing to the better-than-expected energy performance.

Summary of Monitoring Results and Billing Analysis

During 1991, the energy consumption of the lighting and HVAC was monitored by the local electric utility, which was particularly interested in the energy savings resulting from the low-energy lighting system. Perimeter, core and task lighting were all explicitly monitored, as well as the 11th floor HVAC. Total lighting and HVAC was measured, while plug loads were not monitored.[17]

Discrepancies Between Expected and Actual Results

As summarized in Table 5, 1991 total energy consumption, based on billing data, was 17% below the engineering calculations, which in turn were almost 20% below the computer simulation results. The difference between the monitoring data and the billing data is assumed to be the plug-load since that explicitly was not monitored.

Lighting Differences. Monitoring shows a total coincident lighting load of 0.39 W/SF, 29% below predictions, and a 22% reduction in electricity use for lighting. Calculated connected load in the perimeter zone, was 0.66 W/SF, while the measured coincident peak was 0.3 W/SF. The core zone consumed 0.6 W/SF, 30% lower than the 0.86 W/SF originally assumed. The occupancy sensors performed about as expected, saving about 30% of the energy in the core zones. Insufficient data were available to differentiate the impact of perimeter office occupancy sensors from the daylighting contribution. However, the combination occupancy sensors and daylighting reduced electric lighting use by more than 50%, greater than expected.[18]

HVAC Differences. Imputed total HVAC use is about 14% less than expected levels, though the monitoring of the 11th floor indicates that the individual floors behaved somewhat differently than originally assumed. Based on the monitoring data, we assume that the top floor HVAC unit operated more than expected, while the two lower floors ran slightly less.[19] The HVAC also used substantially less during the summer and "shoulder"[20]

Table 5. NRDC Office Energy Performance (1991)

	Expected (1)	Measured	Diff.
HVAC			
Peak (KW)	111	111(2)	0%
Energy kWh	170,000	146,500	-14%
Lighting			
Peak (KW)	17	9 (3)	-47%
Energy (kWh)	38,000	29,700	-22%
Plug Load			
Peak (KW)	29	14 (4)	-52%
Energy (kWh)	65,000	32,300	-52%
Total (1991)			
Peak (KW)	157	134 (5)	-15%
Energy (kWh)	276,000	228,800	-17%

Three-Year Performance: Engineering Estimates vs. Billing Results

Year	Billing	Engineering	Diff.	Cumulative	Expected	Diff.
1989 (6)	213,660	222,210	-4%	213,660	222,210	-4%
1990	280,287	276,146	1%	493,947	498,356	-1%
1991	228,822	276,146	-21%	722,769	774,502	-7%

(1) See Watson 1990. Numbers may not add due to rounding.
(2) Peak KW from billing minus measured KW from lighting and imputed KW from plug load.
(3) Measured coincident peak times net square footage (22,800 SF).
(4) Assumed to be the difference between billed kWh and measured kWh.
(5) From billing. Plug load was not measured.
(6) Year beginning April 1, 1989. All other years, January 1 to December 31.

months than predicted. Winter usage was significantly higher, since the perimeter heating system was generating so much heat that the chillers were turning on. We originally thought that outside air would be able to do all of the cooling during the winter. However, because the ystem uses minimum outside air when the temperature is below 45°, the cooling benefit from ventilation is reduced.

Behavioral Differences. The initial engineering estimates were informed by several months of being in the space and observations of occupant behavior. This may in part explain why the energy use predicted by the engineering calculations is below that estimated by simulation. But, neither the engineering estimates, nor the computer simulation attempted to predict people's behavior turning lights on and off or the utilization of daylight. In addition, both the engineering and computer calculations most likely underestimated the amount of time occupants are out of the office on business-related travel.

Conclusions

The loss of a major tenant in a building provides a good opportunity for major energy retrofit. However, resulting occupancy changes may render historical energy use records inappropriate for assessing baseline energy consumption for the purpose of determining energy savings. A calculational protocol should be established for these cases. This protocol will be especially useful for utility programs where an incentive based on the achieved savings is paid.

The proposed Los Angeles project and the updated results of the NRDC office space indicate that cost-effective buildings using over 70% less energy than those built 20 years ago are feasible today. If these trends continue, large attractive buildings that use little to no non-renewable fuel sources are imminent. More work needs to be devoted to assessing the energy consumed in producing building materials and the implications of that energy intensity on the true lifecycle energy use of the building.

Endnotes

1. Air Conditioning Company, Inc.: Trace 600 Energy Analysis 6310 San Vicente Building, March 5, 1992.

2. Total project cost is estimated to be $983,000, with annual energy savings of $184,500; utility incentive payment: $482,000. Commitment letter from L.A. Department of Water and Power to Dan Emmett of Douglas, Emmett & Co. 3/10/92.

3. The other building is under separate ownership.

4. The bottom floor is 29,560 SF, the second floor 35,010 SF, and the top three floors 15,029 SF each.

5. Sycom Enterprises, "Project Report: 6310 San Vicente Blvd, Los Angeles, CA" December 4, 1991.

6. Ibid. The building's energy bills dating back to 1988 showed operating expenses of $3.50 for energy, more than double for a typical Los Angeles office building, according to LADWP.

7. The calculation assumes a 3% discount rate. At 7%, the utility's cost would be 2.8¢/kWh, commercial electricity rates average 9.0¢/kWh in LADWP's service area.

8. Compliance with Title-24 is based on an energy budget that is dependent on the occupancy type of the building.

9. Daylighting or occupancy controls can reduce coincident peak lighting loads by up to 30% if used separately, 40% if used together. However, the building is being retrofitted as new tenants move in, so we do not yet know what fraction of the lighting will be controlled in which manner.

10. Illuminating Engineering Society, LEM-1-1982 Table 6 p.19

11. This strategy was used very successfully in NRDC's offices.

12. The window film alternative chosen has a shading coefficient (SC) of 0.34 and an overall U-Value of 0.94. The window replacement alternative would have resulted in a SC of 0.28 and a U-value of 0.24. In Los Angeles' mild sunny climate, the difference in U-value will not result in significant energy loss. The chosen alternative is expected to have a payback of 3 years, while the replacement alternative would pay back in about 20 years.

13. Building gas use is expected to be only 5733 therms/yr.

14. This caused the utility a great deal of consternation at the outset.

15. Task lighting was used less than predicted. Fifty-five percent of the occupants with task lighting responded that they use their task lights infrequently, including many located in the interior offices.

16. More detailed evaluation of the occupant survey is available from the author by request.

17. There are currently large discrepancies in monthly energy consumption between the billing and the monitoring, although the annual totals are roughly what was expected. We are currently investigating these discrepancies, but nothing conclusive is available at this writing.

18. We had expected approximately a 40% total contribution. The reduced usage may have something to do with an educated tenancy.

19. The 12th floor had much greater solar loads due to skylights. In addition, the 3-story atrium undoubtedly allowed internal gains to migrate from lower floors--further adding to the top floor machine's work.

20. May and October are considered "shoulder months".

Reference

Watson R. K. 1990. " Case Study in Energy Efficient Office Renovation; NRDC's Headquarters in New York City " *Commercial Data, Design, and Technologies-Proceeding from the ACEEE 1990 Summer Study on Energy Efficiency in Buildings*, Volume 3, pp. 3.225-3.238. American Council for an Energy Efficient Economy, Washington, D.C.