EUA Cogenex - U.S. DOE
Forrestal Building Lighting Retrofit
Profile #100

Executive Summary

The U.S. Department of Energy's retrofit of its own headquarters, the James Forrestal Building located at 1000 Independence Avenue, is a unique and symbolic project for a number of reasons. Its shared savings financing plan, funded in part by the local electric utility, and financed by EUA Cogenex, a leading energy service company, represents an important trend in the capture of energy efficiency in the United States. The retrofit required essentially no outlay of U.S. taxpayers' dollars and will result in a revenue stream of savings over time. Less well known, however, is the living proof that energy efficiency can not only save energy but can enhance the quality of the workplace. Retrofitting 37,000 fixtures has provided far more attractive lighting and workers report high levels of satisfaction with the project. And while energy efficiency gains were clearly made, light levels were increased by 165% from an average of 30 footcandles to 50 footcandles to enhance the quality of the workplace.

From a project management standpoint the project was also exemplary. Asbestos in the ceilings made the fixture retrofits complex. Nevertheless, work was completed on time and in 178 days. At the height of the activity, fully 675 fixtures were retrofitted each night using 20 men working ten-hour shifts, four days a week. To address the asbestos, minimal intrusions were made in ceiling panels. Crews working at night worked in concert with clean-up crews following installers, all checked and cleared for security purposes. (The Forrestal Building is perhaps one of the most secured building in Washington after the Pentagon due to DOE's role with nuclear energy for both civilian and military applications).

The Forrestal retrofit also is a model of the Federal Energy Management Program. The seven-year shared savings arrangement coordinated by EUA Cogenex, an energy service company located in Lowell, Massachusetts, allows the DOE to engage in the retrofit with no out-of-pocket expenses and will result in savings of $400,000 annually. A million dollar prescriptive rebate from Potomac Electric Power Company provided additional support for the project participants to engage in more sophisticated retrofits. Under the terms of the agreement, for the first three years the DOE will retain 27% of its energy savings while paying EUA the 73% balance. For the final four years, the DOE will keep 85% of its savings while paying EUA Cogenex the remaining 15%. As such the Forrestal Building retrofit is a primary example of effective leveraging resources through Federal government, energy service company, and utility collaboration.

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Sector: *Federal buildings*

Measures: *Comprehensive relighting including high-efficiency fluorescent lamps, fixtures, specular reflectors, ballasts, and occupancy sensors*

Mechanism: *Seven-year shared energy savings contract between EUA Cogenex and the U.S. Department of Energy coupled with a $1.16 million rebate from Potomac Electric Power Co.*

History: *Proposed in 1989; 1990 building energy analysis; RFPs issued in 1991; 1992 live test demonstrations; retrofit work completed in 1993; extensive post-installation monitoring continues*

1993 PROGRAM DATA

Energy savings:	*5,566 MWh*
Capacity savings:	*1,187 kW*
Annual cost savings:	*$399,057*

CUMULATIVE DATA

Seven-year energy savings:	*38,962 MWh*
Lifecycle energy savings:	*83,490 MWh*
Seven-year cost savings:	*$2,793,399*

CONVENTIONS

For the entire 1994 profile series all dollar values have been adjusted to 1990 U.S. dollar levels unless otherwise specified. Inflation and exchange rates were derived from the U.S. Department of Labor's Consumer Price Index and the U.S. Federal Reserve's foreign exchange rates.

The Results Center uses three conventions for presenting program savings. ANNUAL SAVINGS refer to the annualized value of increments of energy and capacity installed in a given year, or what might be best described as the first full-year effect of the measures installed in a given year. CUMULATIVE SAVINGS represent the savings in a given year for all measures installed to date. LIFECYCLE SAVINGS are calculated by multiplying the annual savings by the assumed average measure lifetime. CAUTION: cumulative and lifecycle savings are theoretical values that usually represent only the technical measure lifetimes and are not adjusted for attrition unless specifically stated.

As the Federal government puts increased emphasis on energy-saving strategies, the United States Department of Energy (DOE) recently completed an energy-efficient lighting retrofit of its headquarters in the nation's capitol. Spurred primarily by the passage of the Energy Policy Act (EPACT) of 1992 and facilitated under the guidelines of the Federal Energy Management Program (FEMP) and Executive Order 12902, this exemplary initiative leads a campaign promoting energy-efficiency improvements for buildings across the country. In September of 1993, through the joint efforts of the United States Department of Energy, EUA Cogenex (an energy services company), and the local utility, Potomac Electric Power Company, the landmark retrofit was completed.

THE U.S. DEPARTMENT OF ENERGY

The U.S. Department of Energy (DOE or the Department) was created in 1977 under the Department of Energy Organization Act. This legislation consolidated into one cabinet-level department the responsibilities previously carried out under the Atomic Energy Commission, the Energy Research and Development Administration, and several other small independent energy-related agencies. Now DOE and its contractors employ approximately 146,000 men and women, more than one-third of whom fill positions in DOE's scientific, engineering, and technical workforce. The Department also has an extensive field structure of national laboratories, research facilities, regional operations and support offices, and regional power administrations that are dispersed across urban and rural areas of the United States.[R#22]

In the Washington D.C. metropolitan area, the DOE currently occupies thirteen buildings. The largest of those buildings is the James Forrestal Building, the subject of this profile.

EUA COGENEX

EUA Cogenex Corporation (EUA) is an energy service company that is a subsidiary of Eastern Utilities Associates, an investor-owned utility which had gross revenues of greater than $566 million in 1993. EUA, located in Lowell, Massachusetts, was organized in 1983 as the Citizen's Heat and Power Corporation to meet the increasing need for managed energy use and has since become a national leader in the field of energy management.

EUA provides cost-effective energy services for a wide variety of business, industrial, and utility clients, ranging from Fortune 500 companies to small, family-run operations. It assists Federal, commercial, industrial, institutional, and retail facilities in making their use of energy more efficient, less costly, and more environmentally sound. EUA does this by helping businesses reduce their use of electricity. Additionally it specializes in increasing an industrial client's energy independence through the development and installation of cogeneration facilities. The company also works with major utilities through demand-side management contracts to help them avoid building expensive new generating facilities and transmission lines. EUA now offers a water management and conservation program to its existing customers.[R#14]

EUA's major business area is the Northeast although it conducts business nationally in more than 32 states from coast to coast. It maintains offices in Massachusetts, New York, California, Texas, and Washington, D.C. Additionally, the company works internationally providing economic analysis and engineering design and implementation of energy programs for utility, commercial, industrial, and institutional clients from several other countries. EUA's flexible programs include guaranteed/shared savings agreements, lease-purchase arrangements, and DSM utility payments which require no up-front client capital outlay.[R#2,14]

Day-to-day management of EUA is performed by its President, Joseph Fitzpatrick, a former Energy Secretary for the Commonwealth of Massachusetts. The company's gross revenues have increased dramatically in the past several years. From 1988 to 1992 gross revenues increased from $3.9 million to $28.3 million. The number of employees for the same time span has burgeoned from 20 to over 150. Employees include financial experts, project managers, engineers, economists, and administrative and marketing personnel with strong experience in the complex technologies and issues of energy management. Projections put the company's revenues at $67.7 million in 1997. To date, the company has financed over $170 million in energy investments.[R#14] ☞

EUA has managed more than 800 contracts in about 1,000 buildings. Clients included Gillette, Digital Equipment Corporation, Eastman Kodak, AT&T Network Systems, Columbia University, and The U.S. Department of Energy (the subject of this profile). EUA also implemented programs with utilities such as Boston Electric, Massachusetts Electric, Jersey Central Power and Light, Consolidated Edison, Commonwealth Electric, and Potomac Electric Power Company.

Recently EUA Cogenex acquired EUA Nova, a new division whose scope of services include design, manufacture, and installation of 3M Silverlux specular reflectors. The company serves as an energy consultant and designer of energy-efficient lighting systems. Through this acquisition, EUA Cogenex ensures itself a steady supply of energy-efficient lighting products it needs, controls the quality of the product, and reduces the cost of its conservation services by eliminating a third party supplier. EUA has also acquired the James L. Day Co., now named EUA Day. This company is one of the oldest and largest distributors of building automation systems in the country. This acquisition will also give EUA a direct connection with the supplier of an essential component in energy management systems.[R#14]

POTOMAC ELECTRIC POWER COMPANY

Potomac Electric Power Company (PEPCO) is an investor-owned electric utility serving the electricity needs of 1.9 million people in the Washington metropolitan area. PEPCO's 640 square mile service territory includes the District of Columbia and major portions of Montgomery and Prince George's counties in Maryland. PEPCO's service territory is unique, having virtually no heavy industry. The Washington metropolitan area remains one of the nation's major markets with a well-educated and affluent population.[R#23]

PEPCO had operating revenues of $1.7 billion in 1993. In the same year the utility had a generating capability of 6,576 MW and a 60-minute peak load of 5,754 MW resulting in a reserve margin of 14%. This peak load was 3.6% higher than 1992's peak of 5,546 MW. Based on average weather conditions, PEPCO estimates that its peak demand will grow at a compound annual rate of approximately 1%, reflecting continuing emphasis on conservation and energy use management programs coupled with growth trends. Energy sales were 25,694 GWh in 1993 received by 666,265 electric service customers. Over 45% of these sales were to commercial customers, 15% to the Federal government, and the rest to residential customers. In 1993 PEPCO's average price per kilowatt-hour was 6.60¢, a 3.8% rate increase over 1992.[R#23] ■

The Federal Government is the nation's largest single energy consumer. In fiscal year 1992, it spent $8.7 billion on direct energy purchases for its own facilities and operations with an additional $4 billion subsidizing the energy expenses of low-income households. Fully $3.65 billion went to buildings and facilities with approximately $1 billion of the direct expenditures spent annually on lighting the government's 500,000 buildings and facilities around the world. Much of this energy is inefficiently used.[R#8,25]

Since the mid-1970s the government has worked to improve its energy efficiency although the level of effort has varied. According to the DOE, between 1975 and 1989 energy efficiency initiatives saved close to $7 billion worth of energy, about 5% of the government's direct energy spending and nearly three times more than the $2.5 billion invested in energy conservation measures by the government, proving the cost effectiveness of the retrofits.[R#8]

Despite this achievement, considerably greater savings are still possible, especially in the area of inefficient, costly-to-operate lighting which is still common throughout the millions of square feet of office space owned and leased by the Federal government. Upgrading more than 500,000 Federal buildings with energy-efficient lighting could lower Federal lighting electricity use by 25-30% and save approximately $250 million annually in electricity bills. Beyond its direct savings, the Federal government has the opportunity and responsibility to set a good example for efficient energy use while reducing Federal spending, reliance on imported oil, and adverse environmental impacts.[R#8,17]

Historically, there have been three longstanding constraints to implementing more energy-efficient practices within Federal facilities. The first has been access to capital, as constrained budgets and regulations on budget expenditures often preclude investments in efficiency. The second barrier relates to Federal procurement and contracting regulations that have effectively delayed energy efficiency retrofit implementation. The third barrier has been simply a lack of information about the extent of investment opportunities and about the best funding mechanisms. [R#10]

To overcome these barriers the Federal government has developed several programs and policy initiatives that relate specifically to Federal building energy use. For instance, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is a program designed to assist Federal agencies in adopting energy efficiency measures in buildings, transportation, and operations. The program was established in the mid-1970s in response to legislation and Executive Orders directing Federal agencies to reduce energy use.

The Federal Relighting Initiative, a program sponsored by FEMP, is designed to meet the specific needs of Federal facility managers in making their buildings more energy efficient via the installation of more efficient lighting. Its theme is "Relighting for Energy Efficiency and Productivity" and its objective is to retrofit all Federal facilities by providing facility managers with the tools to support technical analysis and large-scale implementation. The goal of the Relighting Initiative is to improve building efficiency and productivity by relighting all Federal facilities with high-quality and cost-effective lighting systems. Most government facilities are at least 25 years old, making them, like the Forrestal Building, prime candidates for lighting system upgrades.[R#6,7]

The Omnibus Budget Reconciliation Act of 1985 enables Federal agencies to upgrade their facilities for energy efficiency through shared energy savings agreements and addresses the fundamental barrier to Federal facility retrofits, namely access to capital. When implemented, as was the case with the Forrestal Building lighting retrofit, the law creates a unique provision in that all shared savings type contracts are structured to require the contractor (such as an energy service company) to incur all costs of energy savings measures within a Federal building. Thus beyond evaluation of the contractor's proposals and the installation of metering devices in the building to evaluate contractor performance, no capital investment on the part of the government is permitted nor required.[R#7]

Two other major developments have occurred more recently that serve to promote energy efficiency in Federal facilities. First, the passage of the National Energy Policy Act of 1992 (EPACT), one of the most comprehensive energy laws ever passed, and second, President Clinton's Executive Order 12902. EPACT set a goal of 20% reduction in energy use in existing Federal buildings relative to 1985 by the year 2000. President Clinton's Executive Order (EO) 12902, signed on March 8, 1994, has served as another driving factor in spurring Federal energy efficiency initiatives. EO 12902 raised EPACT's efficiency goal to 30% by the year 2005 giving greater attention to this opportunity for savings.[R#8,10] ■

PROJECT OVERVIEW

The James Forrestal Building, located a short distance from the U.S. Capitol in Washington D.C. along Independence Avenue and the mall that stretches from the Capitol to the Washington Monument, was constructed in 1968 and initially housed the Department of Defense. At that time it was informally known as the "Little Pentagon." In 1977 the Department of Energy moved into the building. While the Forrestal Building is the DOE's headquarters, technically the DOE is the building's tenant. As such it pays the General Services Administration $35 million each year to occupy the space.[R#28]

The Forrestal Building actually consists of three separate buildings, interconnected north, south, and west wings. The building is 1.63 million square feet in size and contains 1.3 million square feet of office space and corridors and 315,000 square feet of parking space. Currently it houses more than 4,500 employees.

Like many buildings of its vintage, the Forrestal Building's lighting was seriously outdated. Prior to the retrofit, the building's lighting system was configured with 36,832 lighting fixtures consisting primarily of 1x4 foot fixtures containing two, T-12 34 and 40-watt fluorescent tubes with standard magnetic ballasts. Not only could a retrofit to more efficient lighting systems save money, but a retrofit could greatly improve the quality of light and overall ambiance within the building, potentially improving morale and productivity.[R#28]

PROJECT TIMELINE

November 1989, Project initially proposed: In November of 1989 a shared energy savings relighting project was proposed for the Forrestal Building. The proposed project would not only serve to retrofit the building's lighting systems with newer, more efficient sources, but would also serve as a major demonstration project for the Federal Relighting Initiative operated by the Federal Energy Management Program, not coincidentally operated by the DOE.[R#10]

May 1990, Baseline metering began: In May of 1990 Pacific Northwest Laboratory (PNL) performed the first of three planned metering activities. PNL, a DOE laboratory facility located in Richland, Washington, began by conducting an energy audit to determine the building's baseline energy consumption. The audit revealed that 32.7% of electricity consumption in the building was used for lighting and that a large amount of lighting was on all the time.[R#10]

May 1991, Request for proposals issued: In May of 1991 a request for proposals (RFP) for a shared energy savings agreement lighting retrofit was issued. The proposal contained the results of the baseline metering work performed by PNL and described the Live Test Demonstration that would be required of all qualified bidders. The RFP required the contractor to achieve a minimum of a 20% energy consumption reduction while maintaining adequate lighting levels for employees.

In response to the RFP, nearly two dozen energy service companies submitted bids. The DOE's technical team headed up by E. James Vajda, Assistant Director for the Office of Administrative Services and Project Leader, was then responsible for evaluating the bids and selecting four finalists to perform live tests to demonstrate their proposed retrofits.[R#7]

March 1992, Live Test Demonstrations performed by bidders: Between March 9-16, 1992 the four energy service companies that had passed the DOE's initial screen conducted live tests of their proposed retrofits. Using a single conference room within the facility, each bidder mocked up the fixtures with their proposed retrofit. PNL conducted extensive evaluations of lighting and energy levels required for each configuration.

June 1992, PEPCO changed its rebate schedule: In June 1992 Potomac Electric Power Company (PEPCO) announced that it had shifted the project's avenue for rebates to their "Custom Rebate" program and concurrently revised its list of equipment eligible for rebates. Electromagnetic ballasts, for example, were dropped from eligibility, changing the economics of the project. As a result, two of the four contractors requested additioanal live tests with different products. The retests took place in August of 1992.[R#17]

February 1993, Contract awarded to EUA Cogenex: In February of 1993, the DOE awarded the contract – and its first shared energy savings contract – to EUA Cogenex. Under the shared energy savings contract, EUA incurred all of the up-front project costs and was to be paid a portion of each year's shared energy savings over a seven-year period.

March 1993, Retrofit work began: In March of 1993, less than a month after the contract was awarded, EUA began the retrofit under a tight timeline. Ed Liston, EUA Cogenex's Vice President and Project Manager, called the retrofit an "exercise in logistics" to avoid contract penalties. He commented that, "EUA was only given 10 days notice before it had to begin the project. Ballasts were in short supply and so was labor." Nevertheless, EUA began the retrofit on time despite numerous challenges not the least of which was the required security clearance for all workers involved in the project.[R#2]

One of the most challenging aspects of the retrofit itself was the presence of asbestos. Strips of asbestos that the DOE did not want disturbed were encased in an unusual metal-pan ceiling. Stripping the old lighting without disturbing the asbestos required that the project involve tandem, triple, and quad-wiring between fixtures without performing construction above the ceiling where the asbestos was located.

Together with MetalOptics, the reflector supplier used, EUA developed a wiring technique which allowed for this wiring to be completed safely and without contamination. First installers stripped the fixtures and drilled holes in them. Then they threaded a rod with the wiring where a gap had been left from the old fixtures and ran it through the holes from fixture to fixture. By choosing to use single ballasts for several lamps and fixtures, EUA reduced the intrusion of the installations.[R#2,17,19]

James Vajda said, "Crises were common, but we (the Vajda/Liston project management team) handled them calmly and didn't panic. Working nights from 6:30 p.m. to nearly 6:00 a.m., we retrofitted up to 675 fixtures a night using 20 men working 10 hours per day for four days a week. This retrofit included covering the offices, stripping out the old fixtures and ballasts, rewiring and installing the new measures, cleaning afterwards, and filling out manifests for proper disposal of old tubes, ballasts, and fixtures with Full Circle Ballasts Recyclers. Eventually we installed over 32,777 fixtures in 178 days. We had to leave the building's offices as clean or cleaner. Positive reinforcement helped keep the crews going through the long hours."[R#4]

Another challenge was that 9,000 out of the 32,000 lamps had already been delamped. This meant that not only was there poor quality lighting, sometimes as low as 12 footcandles in some areas, but also the building was energizing thousands of ballasts with no tubes in them. Some estimates have this alone accounting for roughly $52,000 of unnecessary annual electricity costs with no benefit of light. EUA was able to work with this and still achieve significant savings as well as profit with superior lighting.[R#2]

September 30, 1993, Construction complete: In 178 days and on time (what project leaders called "record time") the construction phase of the project was completed. This was a remarkable accomplishment considering that the building is the second most secure in Washington after the Pentagon due to its role with nuclear energy for both civilian and military applications. After EUA completed the project the DOE had 30 days to perform post-installation inspections.[R#2,10,17]

October 1993, Post-installation monitoring begins: In October and November of 1993 Pacific Northwest Laboratories conducted extensive monitoring and metering of the newly installed lighting systems. In addition, whole building energy analysis by Texas A&M University's Energy Systems Laboratory that began in 1986 continues to date. ☞

PEPCO REBATES	NUMBER OF MEASURES	REBATE PER MEASURE	REBATE PAID
Specular Reflectors	32,777	$25.00	$819,420
Electronic Ballasts (4 Lamps)	3,673	$29.00	$106,517
Electronic Ballasts (3 Lamps)	341	$23.00	$7,843
Electronic Ballasts (2 Lamps)	7,092	$19.00	$134,748
Electronic Ballasts (1 Lamp)	2,878	$19.00	$54,682
Occupancy Sensors	287	$35.53	$12,746
Fluorescent Lamps (F32T-8)	32,777	$0.75	$24,582
Total	79,825		$1,160,543

November 1993, PEPCO issues rebate: A key element in making the project financially viable was the prescriptive rebate of $1,160,544 provided by PEPCO to EUA Cogenex, allowing EUA to "buy down" the overall cost of the project.

MEASURES INSTALLED

As shown in the PEPCO Rebate table, measures installed include high efficiency electronic ballasts replacing standard magnetic ballasts, 32-watt T-8 fluorescent and 4,100k temperature tubes with specular reflectors replacing old 34 and 40 watt standard T-12 fluorescent tubes, and infrared occupancy sensors.

Specular Reflectors: EUA installed 32,777 specular reflectors manufactured by MetalOptics and 3M Silverlux. Specular reflectors make fluorescent fixtures up to 20% more efficient by directing more light to where it is needed. In most cases, the efficiency is increased enough to compensate for the permanent removal of some lamps and ballasts, providing for further savings in avoided replacement and maintenance costs. PEPCO issued rebates of $25 per reflector, which totaled $819,425 paid to EUA.[R#24]

Electronic Ballasts: The installation of 13,984 low power electronic ballasts manufactured by Magnetek Triad was performed. Electronic ballasts which operate at a higher frequency are the most efficient ballasts currently available, providing up to 40% savings over conventional ballasts. Lighting quality is also improved since electronic ballasts result in a reduction in the level of flickering and humming. Additionally they commonly run 12 degrees cooler than conventional ballasts, resulting in an "HVAC bonus" as less internal heat gain has to be removed. For the Forrestal Building, electronic ballasts controlling four, three, two, and one-lamp(s) were installed. Rebates for each installation ranged from $29 for the four-lamp ballast to $19 for the two and one-lamp ballasts. Combined, PEPCO issued a rebate of $303,790 for all electronic ballasts installed in the building.[R#24]

Occupancy Sensors: EUA installed 287 infrared occupancy sensors manufactured by Leviton. Occupancy sensors automatically turn lights on whenever an area is in use and turn lights off after a period of inactivity. They are ideal for rooms that are not continuously in use, such as conference rooms, bathrooms, classrooms, and storerooms. Occupancy sensors can save an additional 15-20% in energy use. PEPCO issued a rebate of $35.53 per sensor, totaling $12,746 for all the sensors installed.[R#24]

Fluorescent Lamps: EUA installed 32,777 high efficiency TL*80 T-8 fluorescent lamps manufactured by Philips Lighting Company. These slim, one inch diameter T-8 lamps increase light output to an industry-leading 3,050 lumens, achieve a lamp efficacy of more than 100 lumens per watt and deliver a high color rendering index (CRI) of 85. Rare-earth trichromatic phosphors inside the Philips T-8 make the high CRI and lumen output possible. A patented electrode guard helps maintain light output throughout the life of the lamp. When installed in conjunction with electronic ballasts, the Philips TL*80 lamps consume 43% less energy. The PEPCO-issued rebate was $0.75 per two or three foot T-8 lamp, totaling $24,582 for the entire building.[R#24,25]

A majority of fixtures were retrofitted with just one TL*80 lamp and a specular reflector. Because less lamps were used to achieve necessary light levels, another 20% in energy savings was achieved.

After the installation, PEPCO verified that their rebated products were properly installed. James Vajda escorted Steve Kiesner, Coordinator of PEPCO's Commercial Energy Services Department, around the building and showed him the various installed measures. Kiesner then cross-checked invoices with the suppliers to assure that the measures installed were correct.

After the 30-day post-installation inspection period, and in a departure from routine shared savings contracting, DOE assumed full ownership of the fixtures. ESCOs generally have rights to the fixtures in shared savings arrangements, but don't own the fixtures outright. Most real estate law says that fixed equipment becomes the property of the building owner, but in the case of bankruptcy the energy service company can claim rights of ownership. In the event that a building is destroyed by fire or natural disaster, the building owner is liable for energy savings owed on a shared savings contract.[R#17]

During the seven-year term of the contract two group relampings will also have to be performed by EUA Cogenex at no cost to the DOE. These will occur at 48 and 83 months. Costs for the relampings exceed $100,000. Since DOE takes over operation and maintenance at 84 months, it wanted to make sure it had new lamps in place at that time. EUA now has a customer service center located near the Forrestal Building and has implemented a 24-hour response time for equipment failure.[R#4]

LAMP AND BALLAST WASTE DISPOSAL

The Forrestal Building retrofit also stands as an exemplary model for hazardous waste disposal methods. Ballasts installed before 1979, like those in the Forrestal Building prior to the retrofit, contain poly-chlorinated biphenyls (PCBs) with each PCB ballast containing approximately one ounce of virtually pure PCB dielectric fluid. Safe disposal of old PCB ballasts was a primary concern of the DOE when planning the Forrestal relighting project.[R#4,26]

Traditional disposal options such as incineration involve unacceptable environmental risks and can be very expensive. Disposal in landfills is inexpensive but is not a recommended option since ballasts contain liquid PCB oil which may eventually leak into the environment. As ballasts rust and degrade, contamination of surrounding areas is a serious risk. These environmental dangers can be ameliorated where permanent destruction of PCBs occurs.

Seizing an opportunity to provide a model for hazardous waste disposal methods, EUA Cogenex subcontracted with FulCircle Ballast Recyclers, a division of FulCircle Recyclers, Inc., a Massachusetts-based company that specializes in hazardous waste recycling and has developed a method of recycling the solid materials from PCB ballasts as well as safely disposing of old fluorescent lamps. Each ballast was "demanufactured" and separated into its original components. The PCB capacitor and PCB-contaminated asphalt potting material were incinerated, thus eliminating the risks associated with landfills. The remaining materials (copper coils, silicone, steel, sheet metal and wires), which constitute 80 percent of the weight of a PCB ballast, were shipped and sold to foundries for metals reclamation allowing EUA to recoup some of its disposal costs.[R#4,17,26]

Old fluorescent tubes also contain mercury and phosphorous. While EUA was not under contract to dispose of lamps in state of the art ways, it made sure that filters were changed daily in their tube crushing machine to capture the hazardous chemicals and then properly dispose thereafter. While this step may seem minor, when considering over 32,000 tubes, the effect was impressive.

MARKETING

A comprehensive campaign was developed in order to raise awareness of the project and to provide employees within the building with an understanding of the purpose and benefits of energy-efficient practices. A series of promotional materials such as exhibits, buttons, flyers, table tents, and light switch covers were developed for use at various points in the ☞

project to get employees involved and to keep them interested and informed.[R#26]

The centerpiece promotion of the retrofit was a portable exhibit designed for lobby and hallway use to inform Forrestal employees and visitors about the project. The exhibit explained the mission and objective of the Federal Relighting Initiative and highlighted key features of the project.[R#26]

A series of informational flyers were also distributed and placed on employee desks and cafeteria tables to provide employees and visitors with more detailed information. Awareness of the project was reinforced by three-sided informational tent cards placed in high visibility areas throughout the building. Buttons expressing project awareness were handed out and light switch covers were put in place to promote conservation and to reinforce the hardware retrofit.[R#18,26]

Outside of the actual building, the Forrestal retrofit has been marketed and promoted in countless newsletters such as Energy User News, PEPCO's End Use, and EUA's Cogenex Informer. Additionally the DOE has published numerous newsletters which have been distributed nationwide explaining the project and highlighting its success as the flagship of the Federal Energy Management Program.

STAFFING REQUIREMENTS

Staffing for the Forrestal Building retrofit involved four primary groups: DOE, EUA, PEPCO, and Texas A&M University.

The DOE's E. James Vajda was the project manager for the retrofit and spent over half of his time working on the retrofit. He was assisted by the engineering expertise of Mike Scincovich and collaborated with Lou Harris, FEMP program manager. Other related DOE staffing who devoted only part of their time included two contractors, two lawyers, three engineers, and a building manager. In addition, PNL staff -- technically part of the DOE -- provided invaluable assistance.[R#2,13]

EUA staffing included a project manager at the sight who worked full time over the course of the retrofit. EUA Vice President Ed Liston along with other engineering assistants working on procurement and coordination of the retrofit back in Lowell at EUA's headquarters devoted a combined equivalent of 1 FTE. EUA subcontracted Thayer Electric to perform the actual installation of the lighting measures. This group averaged 20 persons per night working full time for the 178 day duration of the retrofit. Other EUA staffing included an audit team of four for two weeks.[R#2]

PEPCO staffing consisted of Steve Kiesner, Coordinator of PEPCO's Commercial Energy Services Department, who calculated the rebate to be extended to EUA and verified the measures installed.

Staffing for Texas A&M University, which has an ongoing responsibility measuring the retrofit's savings, first involved the installation of three data loggers in the Forrestal Building. (Installation of additional metering equipment was minimal because meters for chilled water, steam, and some electric already existed.) Thanks to automated software and data transmission via modem, ongoing measurement at Texas A&M University's Energy Systems Laboratory only requires part-time efforts to download weekly hourly data, produce inspection plots, and prepare monthly reports. ■

Since the Forrestal Building retrofit represents one of the DOE's first major shared energy savings projects, special effort was given to carefully measure every aspect of the project in order to create a well documented case study to serve as a model for all Federal agencies and potentially for private sector applications. Thus, monitoring and evaluation have played important roles in the Forrestal retrofit, starting long before the construction activity and continuing to date.

Beginning in 1990, Pacific Northwest Laboratory (PNL) conducted energy use monitoring efforts and provided empirical data which has been used to confirm predicted results of the retrofit. To accomplish these goals, three distinct but integrated monitoring activities were planned and implemented: baseline monitoring of the existing lighting loads; performance monitoring of proposed lighting retrofits; and post-retrofit monitoring of the new lighting loads.[R#27]

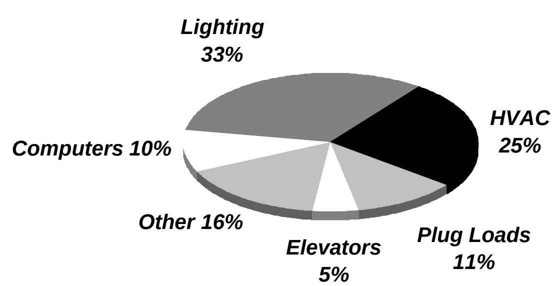
BASELINE MEASUREMENTS

The first step at the Forrestal Building was to establish the baseline lighting loads. The baseline profiles not only provided prospective bidders with an idea of the magnitude of the lighting retrofit, but also provided DOE with an empirical pre-retrofit measurement of the lighting loads that could later be used to evaluate the success of the retrofit.

Initial field measurements were taken from May 14 through May 23, 1990. The results of the baseline monitoring produced detailed weekday and weekend end-use profiles of the Forrestal Building electrical consumption and demand. While the lighting energy consumption at that time was found to be regular and predictable by time-of-day and day-of-week, one striking feature was the relatively large portion of the maximum lighting load that occurred 24 hours a day. Thus, it was obvious that a large amount of lighting was left on continuously.[R#27]

The disaggregated building energy use of baseline lighting loads produced interesting results. As shown in the pie chart below, 32.7%, or 9,961 MWh of electrical consumption was used for lighting. This put estimated annual lighting costs at $647,012. HVAC consumed the next largest slice of the pie at 25.2%, plug loads 11.3%, computers 9.5%, elevators 5.1%, and other made up the final 16.2%. Since the Forrestal Building is served by district hot water and chilled water provided by the Federal government's district heating and cooling plant, the HVAC electrical loads are primarily fan loads.

FORRESTAL BUILDING DISAGGREGATED ELECTRICAL CONSUMPTION (kWh)



The Forrestal Building receives steam and chilled water from the Central Heating and Refrigeration Plant operated by the General Services Administration (GSA) located just a few blocks away. Steam is metered at the Forrestal Building with an electronic, insertion-type, axial, turbine steam meter. The chilled water is metered both at GSA's Center plant and at the Forrestal Building using clamp-on ultrasonic meters. Electricity and natural gas are separately metered within the building and are provided by local suppliers.[R#7,10,28] ☞

THE LIVE TEST DEMONSTRATION

A field of 21-23 energy service companies responded to the DOE's RFP. The technical evaluation team directed by James Vajda, consisted of three additional graduate engineers: Vic Petraloti (In-house Energy Management), K. Dean Devine, P.E., (DOE Federal Energy Management Program), and Mike Scincovich (DOE Engineering and Facilities). This team of engineers technically evaluated the offers received. After the list was narrowed down to four companies, arrangements were then made to perform a Live Test Demonstration (LTD) of each contractor's proposed retrofit package. The strategy was to empirically evaluate the bidders by giving them a chance to prove which could best meet the technical requirements of the LTD and thus would be most qualified to perform the Forrestal retrofit.

The second step PNL undertook at the Forrestal Building was to technically evaluate the bids received in response to the RFP. To implement this strategy, a single conference room in the building was set up as a test room. The process for PNL staff was to measure the baseline performance of the test room, allow the retrofit contractor to install the proposed retrofit, and repeat the required measurements. Once measurement of the retrofit was complete, the test room was restored to its original configuration and the process was repeated for the next contractor.[R#27]

The RFP explicitly listed three requirements: 1) power consumption had to be at least 20% lower than baseline power consumption in the test room; 2) the lighting levels had to reach a minimum of 50 footcandles at desk tops and 30 footcandles in other areas; 3) the retrofit could not degrade any aspect of building performance below pre-retrofit levels. This third requirement was geared primarily toward total harmonic distortion (THD) levels associated with the lighting system.[R#26]

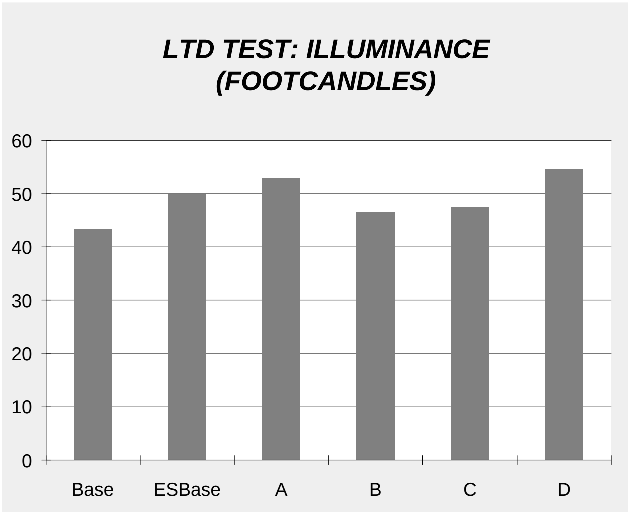
PNL evaluations in the LTD included measurement of power consumption for room lighting as a whole and for each lighting fixture in the room. Lighting levels were recorded at five locations on the work surface and 18 locations in the rest of the room. Power quality measurements were also taken on the room lighting system as a whole and were taken to ensure that the retrofits did not raise the total harmonic distortion (THD) above current levels. The conference room used for the LTD contained six, 2*4, two-tube drop-in light fixtures in a suspended acoustic tile ceiling.[R#10]

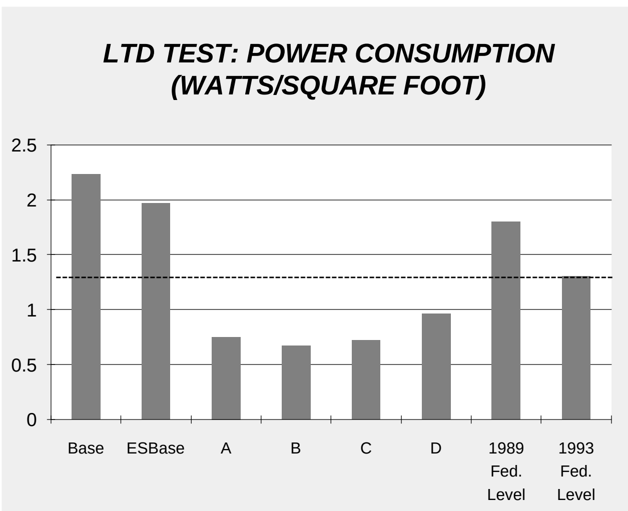
The results of the LTD compare the baseline configuration (Base) of the room as described by the RFP, the baseline representing the best technology currently available to the building maintenance staff (Energy Saving Baseline, ESBase), and the four proposed retrofits (A, B, C, D).

LTD: POWER AND ILLUMINANCE TEST RESULTS	POWER (WATTS/SQUARE FOOT)	ILLUMINANCE (FOOTCANDLES)
Base	2.23	43.4
ESBase	1.97	50.0
A	0.75	52.9
B	0.67	46.6
C	0.72	47.6
D	0.96	54.7

According to PNL and DOE staff, "The retrofits proposed by the four contractors were remarkably similar. The retrofit strategy for all four contractors was to clean the fixtures, relamp the fixtures with single T-8 tubes, install silvered reflectors, and tandem-wire two or more fixtures with a single electronic ballast."[R#10]

Illuminance: All proposed retrofits met the LTD illuminance requirements of 50 footcandles on the work surface and 30 footcandles in the other areas. Contractor D, the winning contractor (EUA Cogenex), had the highest illuminance at 58.0 footcandles for the work areas and 51.3 footcandles for the other areas largely because the company elected to illuminate





all six fixtures in the room for aesthetic reasons, while other bidders proposed to illuminate only four fixtures..

Power Consumption: All proposed retrofits easily met the requirement of at least a 20% reduction in the power consumption of the test room. A comparison of the power consumption on a per-square foot basis for each of the lighting configurations was also compared with 1989 and 1993 Federal energy standards. All the proposed retrofits had lighting power densities well below 1993 Federal standards of 1.3 watts/square foot. Contractor D, the winning contractor, had the highest lighting density at 0.96 watts/square foot. Illuminating all six fixtures significantly increased the measured total power consumption of their configuration compared with the other three contractors' retrofits. On a per-lit-fixture basis, however, the energy savings were almost identical among the four contractors.[R#10]

Total Harmonic Distortion (THD): All contractors met the requirement that THD be held to no more than current levels in the test room. This was expected due to the age and nature of the ballasts involved. The baseline (Base) configuration contained older inductive ballasts originally installed in the building in 1968. The energy saving baseline (ESBase) configuration contained much newer inductive ballasts with a lower THD. All four contractors installed electronic ballasts which typically have higher THD than inductive ballasts.[R#10]

POST-INSTALLATION MONITORING

PNL's third step at the Forrestal Building was to evaluate the lighting load after the retrofit. Post-retrofit monitoring was conducted from October 23 through November 2, 1993. Sixty-five, 277 volt lighting panels were metered to determine the lighting profile. Procedures, equipment, and data processing for the post-retrofit monitoring were similar to those of the baseline monitoring.[R#27]

The results of the post-retrofit monitoring showed peak demand savings of 53.5% of total lighting load, with daily consumption reduced 55.4%. On an annual basis, the demand savings were estimated to be 56.0%.[R#27]

In addition to PNL's monitoring efforts, whole-building electricity and thermal energy consumption have been and continue to be measured and monitored by the Energy Systems Laboratory of Texas A&M University using a state-of-the-art data acquisition system. ☞

Monitoring efforts began as early as 1986 and involved Texas A&M's Jeff Haberl, P.E., Ph.D. One of these efforts, initiated in September of 1991, included whole-building hourly monitoring equipment (also used in Texas LoanSTAR program monitoring) which were installed and used to develop an hourly baseline record of pre-retrofit, whole-building energy use. Monitoring has continued through 1994 and will continue until a monitoring system is developed that can be facilely turned over to the DOE so that in-house staff can continue to monitor the building.[R#28,29]

The methodology that has been applied to calculate the gross, whole-building electricity savings from the lighting retrofit uses a basic before-after analysis of the whole-building electricity use. Whole-building monitoring efforts show that the measured gross electricity savings from the lighting retrofit deliver within 90% of the estimated savings. The total savings for the 12-month period from August 1993 to July 1994 was 5.566 million kWh which is about 9.5% below the estimated savings of 6.146 million kWh. This resulted in roughly a 20% decrease in whole-building electrical use from previous years. Measured reductions in monthly peak hourly electric demand performed within 74 to 91% of estimated demand reductions. Billed demand savings for the same period varied from 959 to 1,187 kW, very close to the estimated 1,300 kW demand decrease. Texas A&M's post-retrofit monitoring has proven that actual savings from the retrofit match closely with the estimated pre-retrofit savings projections.[R#28]

While the electricity savings resulting from the lighting retrofit were confirmed by Texas A&M's monitoring efforts, their efforts also revealed that dollar savings weren't necessarily congruent with this. Due to ensuing mechanical problems with air handling systems and pulse initiators measured dollar savings have been difficult to determine and less than projected.

PRE- AND POST-OCCUPANT SURVEYS

In order to evaluate the effects of the lighting retrofit on the occupants of the Forrestal Building, at the request of the Federal Energy Management Program the National Institute of Standards and Technology (NIST) conducted a pre- and post-retrofit occupant survey. Physical measures of the lighting, including task illuminance, surround illuminances, and typical task contrasts were taken in March of 1993 before relamping started.

The DOE identified the locations to be evaluated and selected at least 325 typical spaces in consultation with NIST staff. NIST then administered a questionnaire in which occupants were asked to assess the overall lighting quality of the building. These measures were used to provide baseline information and to call attention to areas where lighting improvements were needed.[R#26]

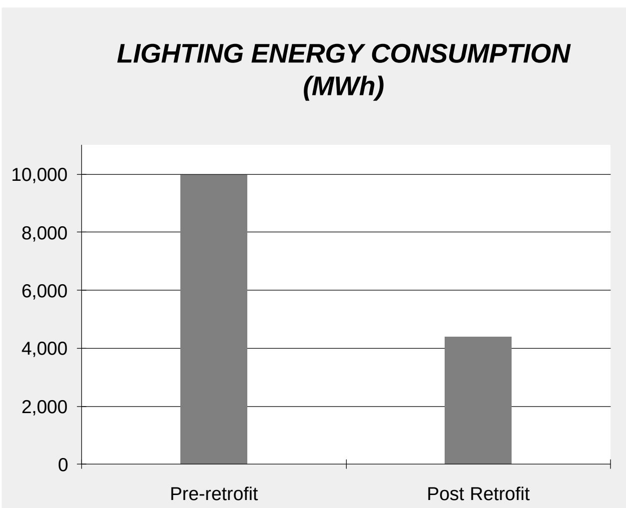
After the retrofit was completed and occupants were given a chance to adjust to their space, the procedure was repeated in December of 1993 for a post-retrofit survey. NIST completed the analysis of all data and correlated both the lighting data and the occupant response data from before and after relamping to determine significant trends. This data will be used to determine where retrofits were especially effective and where additional renovation may be needed.

Preliminary findings of the survey reveal that the relighting significantly improved the lighting conditions in the Forrestal Building. Physical data indicate that the retrofit successfully improved the illuminance in offices, with fewer dark sports on the ceiling, and brighter surfaces in upper portions of walls. The measured illuminance increased to levels above those specified by the DOE and were significantly higher than those measured before the retrofit. The goals of the retrofit, not to degrade the existing lighting system but to maintain it, were exceeded. Occupants viewed their lighting significantly more positively after the retrofit, while the physical measurements indicated improvement as well. Now NIST plans to develop a procedure for administering similar pre- and post-retrofit evaluations in other relamped Federal facilities to be used as model for the Federal Relighting Initiative.[R#26,32] ■

SAVINGS OVERVIEW	ANNUAL ENERGY SAVINGS (MWh)	7-YEAR CUMULATIVE SAVINGS (MWh)	LIFECYCLE SAVINGS (MWh)	ANNUAL CAPACITY SAVINGS (MW)
1993	5,566	38,962	83,490	1.187

Immediately after the Forrestal Building lighting retrofit, lighting energy consumption was slashed by 56.2% while total electricity consumption was reduced by 20%. The retrofit cut total annual electricity consumption from 27,721 MWh to 22,155 MWh. As a result of the retrofit lighting electricity has been reduced from approximately 9,960 MWh to just over 4,394 MWh annually, representing a reduction of 5,566 MWh annually.

In terms of capacity the retrofit reduced overall monthly peak hourly demand by 20.5%. This represents a peak capacity savings of 1,187 kW from a pre-retrofit total electrical peak demand of 5,577 kW.[R#7,19]



OTHER PROJECT BENEFITS

However energy savings are just one of the advantages of the retrofit. The quantity and quality of light also increased. Illumination was increased from an average of 30 footcandles to 50 footcandles, a 165% increase. The T-8 lamps now in place use three rare earth phosphors, giving them excellent color rendering characteristics. The lamps render colors more accurately and vividly, something which studies show can reduce worker error and even boost productivity and morale. Now DOE workers enjoy lighting levels in accord with scientifically determined guidelines for office lighting issued by the Illuminating Engineering Society of North America and with Federal Property Management Guidelines.[R#6]

Additionally the retrofit produced a bonus reduction in HVAC usage. Hot and humid summers of Washington D.C. result in extensive air conditioning use. The Forrestal retrofit reduces the amount of heat emitted from lamps and thus reduces the amount of energy needed to cool the building. All the building's employees reportedly are more comfortable, especially at night and on weekends when the air handlers are off.[R#21]

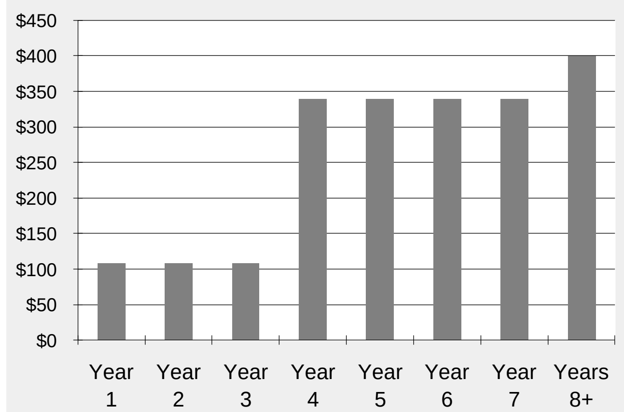
MEASURE LIFETIME

Each measure installed within the Forrestal Building retrofit has its own measure life. Note that the measure life of a fluorescent tube is between three and five years, however EUA is contractually bound to perform two group relampings within the seven-year period. This essentially increases the measure life, as far as DOE is concerned, to around 12 years. Other measures such as electronic ballasts, specular reflectors, and occupancy sensors have much longer measure lifes ranging from 15 to over 20 years. Thus, for the purposes of this profile a 15-year average measure life has been assigned for all the measures combined for the Forrestal Building retrofit.

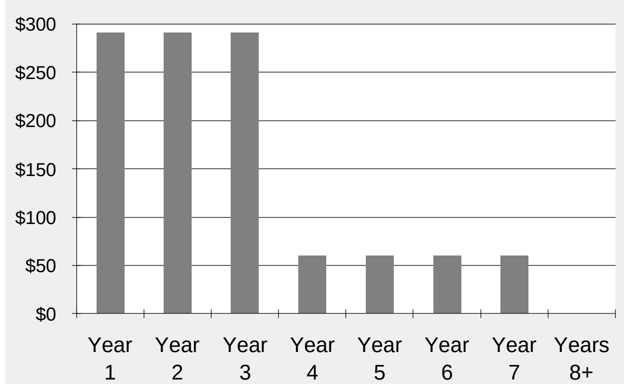
PROJECTED SAVINGS

The Forrestal retrofit will result in both energy and cost savings for the life of the measures. With savings of 5,566 MWh each year, the retrofit will result in a seven-year cumulative savings in energy of 38,962 MWh. A lifecycle savings of 83,490 MWh will result with a fifteen-year average measure life. However, projected savings go beyond the life of the measures as the retrofit has successfully created an energy conservation awareness in the employees that will last for many years, hopefully forever. ■

Cost of the Program



DOE ANNUAL COST SAVINGS (x1,000)



EUA ANNUAL SAVINGS ALLOCATION (x1,000)

In Fiscal Year 1993, the Forrestal Building's energy consumption cost U.S. taxpayers over $3 million per year, with $1,672,045 being spent for electricity, $3,141 for natural gas, $452,298 for steam, and $927,473 for chilled water. After the retrofit, the electricity bill dropped from $1,672,045 to $1,272,988, a savings of $399,057 or just under 24% of the pre-retrofit electricity bill. (The retrofit also resulted in a total cost savings for energy of approximately 13%.)

The retrofit of the Forrestal Building represents an exciting model for the U.S. government and ultimately U.S. taxpayers since it was completely financed by EUA Cogenex and will provide positive cash flow to the DOE in its first year. Under the shared energy savings contract, EUA incurred all of the up-front project costs and will be paid a portion of each year's shared energy savings over a seven-year period to cover all project expenses, including maintenance, and to earn an unpublished profit. After seven years, all the dollar savings will flow directly to the DOE and to taxpayers.[R#2]

For the first three years after the project the DOE receives a 27% share of the cost savings, a sum equal to $107,745, while the balance of 73%, or $291,312, is allocated to EUA. For the following four years the DOE will receive an 85% share of the cost savings, or $339,198, and EUA will receive 15% which equals $59,859. Over the course of the seven years of the shared savings agreement the DOE will save $1,680,027. (Using an annual discount factor of 4.7%, DOE estimates its net present value for the project to be $1,350,386.) EUA will receive $1,113,372 over that same seven-year period. As such, DOE will receive 60% of the savings over the seven-year contract term, with EUA receiving a 40% share. Thereafter, the DOE will accrue an estimated $399,057 in cost savings for each and every year for the life of the measures.[R#4]

Potomac Electric Power Company also played an important role in the project and provided a rebate of $1,160,544. While this rebate wasn't the driving force behind the success of the retrofit, it did "sweeten the deal" for both EUA and DOE. Even without the rebate the retrofit would have been cost effective but the value of the project to the DOE would have been less since either the retrofit would have been less comprehensive or DOE's savings percentage would have been cut significantly, potentially extending the shared savings agreement, and specifically the payments to EUA, past seven years.[R#6,19]

COSTS OVERVIEW	TOTAL ANNUAL SAVINGS	DOE SHARE OF SAVINGS	DOE COST SAVINGS	EUA SHARE OF SAVINGS	EUA COST SAVINGS
Year 1	$399,057	27%	$107,745	73%	$291,312
Year 2	$399,057	27%	$107,745	73%	$291,312
Year 3	$399,057	27%	$107,745	73%	$291,312
Year 4	$399,057	85%	$339,198	15%	$59,859
Year 5	$399,057	85%	$339,198	15%	$59,859
Year 6	$399,057	85%	$339,198	15%	$59,859
Year 7	$399,057	85%	$339,198	15%	$59,859
Total	$2,793,399	60%	$1,680,027	40%	$1,113,372

While a significant amount of DOE staff time and energy was devoted to the retrofit, the only capital expenditures incurred by DOE related to the project have been for extensive project monitoring and evaluation. PNL was paid $60,000 for its baseline energy analysis and disaggregation of end-uses within the building, and for work facilitating the Live Test Demonstrations, and post installation measurements. Texas A&M was awarded a $35,000 contract to perform post-installation metering specific to the project in addition to its whole-building analysis under a separate contract. FEMP commissioned NIST to perform pre- and post-installation occupant surveys independently. These and other costs were incurred to verify the efficacy of the retrofit and have been viewed as important expenses to explicitly document the project so that similar projects can be done in the future with similar levels of confidence of savings. In theory these costs will be amortized over a stream of subsequent projects.[R#4]

Unfortunately, cost savings from unadjusted utility bill comparisons do not always match the negotiated dollar savings from shared energy savings contracts. This was the case for the first months evaluated after the Forrestal retrofit. When evaluating the monthly difference between pre and post-retrofit savings staff would have had cause for alarm because none of the months showed electricity savings that equaled the projected savings, $33,255, or 1/12 of the projected $399,057 in annual savings. However, the predicted electricity savings from the lighting systems were indeed realized as estimated when more accurate evaluation was conducted and the reason for the bill savings discrepancy was identified. In fact, the projected cost savings from the retrofit were accurate but were hidden behind the coincidental increased monthly use of the malfunctioning air handling systems.[R#30] ■

AVOIDED EMISSIONS: Based on 83,490,000 kWh saved over 15 years						
Marginal Power Plant	**Heat Rate BTU/kWh**	**% Sulfur in Fuel**	**CO2 (lbs)**	**SO2 (lbs)**	**NOx (lbs)**	**TSP* (lbs)**
Coal	**Uncontrolled Emissions**					
A	9,400	2.50%	180,004,000	4,271,000	863,000	86,000
B	10,000	1.20%	191,944,000	1,653,000	557,000	413,000
	Controlled Emissions					
A	9,400	2.50%	180,004,000	427,000	863,000	7,000
B	10,000	1.20%	191,944,000	165,000	557,000	28,000
C	10,000		191,944,000	1,102,000	551,000	28,000
	Atmospheric Fluidized Bed Combustion					
A	10,000	1.10%	191,944,000	505,000	276,000	138,000
B	9,400	2.50%	180,004,000	427,000	345,000	26,000
	Integrated Gasification Combined Cycle					
A	10,000	0.45%	191,944,000	340,000	55,000	138,000
B	9,010		172,657,000	123,000	41,000	8,000
Gas	**Steam**					
A	10,400		104,696,000	0	239,000	0
B	9,224		90,921,000	0	569,000	27,000
	Combined Cycle					
1. Existing	9,000		90,921,000	0	349,000	0
2. NSPS*	9,000		90,921,000	0	165,000	0
3. BACT*	9,000		90,921,000	0	23,000	0
Oil	**Steam--#6 Oil**					
A	9,840	2.00%	151,534,000	2,296,000	271,000	257,000
B	10,400	2.20%	160,718,000	2,278,000	341,000	165,000
C	10,400	1.00%	160,718,000	325,000	274,000	86,000
D	10,400	0.50%	160,718,000	955,000	341,000	53,000
	Combustion Turbine					
#2 Diesel	13,600	0.30%	201,127,000	400,000	622,000	34,000
Refuse Derived Fuel						
Conventional	15,000	0.20%	238,781,000	615,000	810,000	180,000

In addition to the traditional costs and benefits there are several hidden environmental costs of electricity use that are incurred when one considers the whole system of electrical generation from the mine-mouth to the wall outlet. These costs, which to date have been considered externalities, are real and have profound long term effects and are borne by society as a whole. Some environmental costs are beginning to be factored into utility resource planning. Because energy efficiency programs present the opportunity for utilities to avoid environmental damages, environmental considerations can be considered a benefit in addition to the direct dollar savings to customers from reduced electricity use.

The environmental benefits of energy efficiency programs can include avoided pollution of the air, the land, and the water. Because of immediate concerns about urban air quality, acid deposition, and global warming, the first step in calculating the environmental benefit of a particular DSM program focuses on avoided air pollution. Within this domain we have limited our presentation to the emission of carbon dioxide, sulfur dioxide, nitrous oxides, and particulates. (Dollar values for environmental benefits are not presented given the variety of values currently being used in various states.)

HOW TO USE THE TABLE

1. The purpose of the accomanying page is to allow any user of this profile to apply the Forrestal Building retrofit's level of avoided emissions saved over a 15-year measure lifetime to a particular situation. Simply move down the left-hand column to your marginal power plant type, and then read across the page to determine the values for avoided emissions that you will accrue should you implement this DSM program. Note that several generic power plants (labelled A, B, C,...) are presented which reflect differences in heat rate and fuel sulfur content.

2. All of the values for avoided emissions presented in both tables include a 10% credit for DSM savings to reflect the avoided transmission and distribution losses associated with supply-side resources.

*** Acronyms used in the table**

TSP = Total Suspended Particulates
NSPS = New Source Performance Standards
BACT = Best Available Control Technology

3. Various forms of power generation create specific pollutants. Coal-fired generation, for example, creates bottom ash (a solid waste issue) and methane, while garbage-burning plants release toxic airborne emissions including dioxin and furans and solid wastes which contain an array of heavy metals. We recommend that when calculating the environmental benefit for a particular program that credit is taken for the air pollutants listed below, plus air pollutants unique to a form of marginal generation, plus key land and water pollutants for a particular form of marginal power generation.

4. All the values presented represent approximations and were drawn largely from "The Environmental Costs of Electricity" (Ottinger et al, Oceana Publications, 1990). The coefficients used in the formulas that determine the values in the tables presented are drawn from a variety of government and independent sources.

PROJECT-SPECIFIC EMISSIONS CALCULATIONS

One of the interesting requirements of the project's request for proposals was that each potential contractor had to provide DOE with calculations of the avoided emissions of the proposed retrofit. Based on estimated annual savings of 5.2 million kWh and using the DOE/EIA-0348 "Electric Power Annual," EUA calculated that the retrofit would annually avoid 33.2 tons of sulfur dioxide (SO2), 16.0 tons of nitrous oxide (NOx), and 4,160 tons of carbon dioxide (CO2).

This amount of avoided tons of carbon dioxide also was used to determine the number of acres of trees that would be required to be planted to compensate for the emission. Different amounts of CO2 can be removed from the atmosphere per acre of forest annually depending upon the type of forest or land. For instance, Pace University's "Environmental Costs of Electricity" states that 3.6 tons of CO2 are absorbed by one acre of sycamore trees in a temperate climate and 7.86 tons of CO2 are absorbed by one acre of eucalyptus trees in a tropical climate. Data from the National Academy of Sciences report, "Policy Implications of Greenhouse Warming," gives 2.82 tons per acre when using economically and environmentally marginal crop and pasture lands and non-federal forest lands.[R#20]

EUA Cogenex used the assumption that 2.6 tons of CO2 would be removed per acre, a conservative number when compared to the National Academy of Sciences' (NAS) calculations. Using EUA's conservative calculation of 2.6 tons of CO2 absorbed per acre of trees, the building's savings of 4,160 tons of CO2 per year equals the effect of 1,600 acres of trees.[R#20] ■

LESSONS LEARNED

The Forrestal Building lighting retrofit presents a win-win solution for all parties involved. For the DOE, the lighting retrofit has led to increased lighting levels and greatly decreased lighting power consumption while maintaining power quality in the building. From the utility perspective, the reduction in weekly and daily peak lighting electrical demand of 1,187 kW at the Forrestal Building is sufficient incentive for the rebate provided. From EUA's perspective, the project reaffirmed that with cooperation of both the private and governmental sectors energy efficiency can be implemented at no cost to taxpayers. In fact, it can even make a profit![R#2,27]

Fundamentally, relighting the Forrestal Building exemplifies the DOE's commitment to its own policies and programs that promote energy efficiency. James Vajda of the DOE commented that, "We're trying to lead by example, but to do that, the first thing you have to do is work on your own buildings." Lou Harris of the FEMP concurs, "Through the Forrestal Building project, the DOE has set an example for energy programs among other Federal agencies and exhibits the DOE's leadership in this area." Clearly, the retrofit has resulted in pragmatic benefits while supporting DOE's greater vision in a most symbolic way.[R#12,25]

When the task group led by the DOE first met to discuss the strategies for implementation they did not know whether to make the RFP prescriptive or performance based. First time around, a draft prescriptive RFP was issued to interested lighting firms for comment. This unfortunately resulted in an inundation of responses to the DOE, each which had to be addressed by written response. The task group then realized that a performance-based RFP would cull the number of bidders down to only the ones best able to perform the comprehensive retrofit.

James Vajda commented that, "During the contracting process it was important not to assume anything, because changes were numerous." From May 21, 1991 to December 12, 1991, six amendments and five clarification letters were issued to prospective contractors. The amendments ranged from language change related to PCB disposal to Live Test Demonstration script changes.

The Live Test Demonstration allowed the task group not only to choose the best bidder to perform the installation but also proved to be the appropriate medium for valuable lessons learned. The demonstration showed that all proposals were easily able to meet all lighting retrofit requirements in terms of illuminance. This indicates that it should be possible to specify greater levels of lighting efficiency in future RFPs and still achieve desired power reductions.[R#10]

The demonstration also showed that merely cleaning the lenses of the existing fixtures would have provided about 4-5 additional footcandles of light. In fact, by cleaning the lenses alone, contractors could have met the requirements of the LTD.[R#10]

The winning bidder for the LTD proposed knocking the baseline lighting wattage density from 2.23 watts per square foot (and 1.97 for the baseline ESBase) to 0.96 watts per square foot. Other contractors proposed 0.75, 0.67, and 0.72 watts per square foot. All of these were below the Federal standards of 1.30 watts per square foot. Ironically EUA, the winning bidder, provided a retrofit that maximized lighting density at the expense of energy efficiency. This however, also resulted in the highest illuminance of all the bidders.[R#10]

Note that only the winning contractor, EUA Cogenex, elected to illuminate all six fixtures in the room. The RFP did specify a bonus for lighting all fixtures in each room, but this bonus was offered solely for aesthetic reasons since an illuminated fixture is visually more appealing than a darkened fixture.

According to both Lou Harris and James Vajda, maintaining adequate light levels was a primary concern. "We know there is a direct link between productivity and increased lighting, so choosing the right lighting system was important," said Vajda. According to Harris, "Not only has this project provided energy savings, dollar savings, and environmental benefits, but there has been tremendous improvement in the working environment."

Initial feedback on the retrofit was that the space was too bright. The retrofit produced lighting increases from 30 to 55 footcandles in work areas, improving illumination in hallways as well as desk areas. A few employees even thought that their skin appeared a different color. James Vajda gave the employees a few weeks to adjust, told them about the energy savings, and since then he's had nothing but plaudits.[R#17]

The post-retrofit monitoring performed by Texas A&M's Energy Systems Laboratory revealed that the measured gross electricity savings from the lighting retrofit agreed remarkably well (within 90% of consumption) with the estimated savings. Clearly, the lighting retrofit at the DOE Forrestal Building was successful and is saving energy at or near to the rates estimated.

However, many lessons were learned along the way during the monitoring process. Comparisons of unadjusted utility billing costs may not be sufficient to measure savings from lighting retrofits, even when whole-building savings amount to 20% or more. In the case of the Forrestal Building, differences in the utility's month-to-month unit cost factors and billing adjustments obscured the actual retrofit dollar savings from the lighting retrofit. Problems with air handling systems and pulse initiators contributed to abnormal usage profiles that necessitated the use of an empirical post-retrofit model to measure the actual lighting retrofit savings.[R#28]

Utility revenue meters can fail as well. Therefore it is recommended that redundant meters be used to detect the failure of utility meters. At the Forrestal Building metering problems were experienced with all three whole-building meters, including electricity, steam, and chilled water. Weekly inspection of the metered data proved invaluable in finding and fixing broken meters.[R#28]

The thermal energy effect from a lighting retrofit can be significant and should be included in the savings measurement. In the case of the Forrestal building the lighting retrofit has led to an estimated $80,000 (20%) increase in the annual steam energy use for heating as the more efficient lighting systems do not produce as much waste heat. However, chilled water costs are expected to decrease by a similar amount during summer months when internal heat gain from lighting is unwanted. Thermal energy savings are dependent on HVAC system types and utility costs and therefore require measurement at each site.[R#28,30]

Independent third party measurement of savings from energy conservation retrofits is highly recommended. Such third party firms should be required to use repeatable, consensus-based measurement and analysis techniques using NIST-traceable instrumentation to assure that an accurate, affordable, scientifically-defensible analysis has been performed.[R#28]

TRANSFERABILITY

According to James Vajda, the specifications put together for the Forrestal Building retrofit now provide a detailed set of generic specifications that can be used for similar government projects. In fact, Vajda can't imagine why other energy ministries around the world wouldn't adopt the Forrestal model! He said that there's no reason why every Parliament and government building can't be retrofitted as examples of how to save taxpayers money while shifting the cost of energy efficiency into the private sector.[R#4]

The transferability of this project is becoming increasingly important as Federal regulations mandate energy efficiency measures. The 1988 Amendments to the National Energy Conservation Act of 1987 mandated the phase-out of standard magnetic ballasts which represent nearly 80% of all applications. More recently the 1992 National Energy Policy Act has mandated the phase-out of many popular fluorescent lamp types, including those designated as "cool white and warm white."[R#6]

Although end users need not replace older, less efficient ballasts and lamps right away, soon the only available replacements will be energy-efficient ones. Retrofitting an entire lighting system now with energy-efficient components not only brings the system into compliance with current standards but it ultimately costs less than spot-replacing ballasts and lamps as they burn out one by one. It also creates a uniform system which is easier to maintain than a system that combines old and new components.[R#6]

As part of the Federal Relighting Initiative the Forrestal Relighting Project serves as a model to demonstrate that innovative lighting retrofits of Federal facilities can produce the energy savings needed to finance such efforts through shared energy savings procurements. To achieve comparable results in other Federal facilities, the Federal Relighting Initiative offers Federal facility managers the planning tools, procurement guidance, training, and technical assistance necessary to make informed decisions during each phase of the relighting process. For more information on this program and training courses available for government agencies, contact the Office of Federal Energy Management Programs, U.S. DOE, 1000 Independence Avenue, SW, CE-44, Washington D.C., 20585, (202) 586-5772. ■

References

1. Joseph Fitzpatrick, President, EUA Cogenex Corporation, Lowell, Massachusetts, personal communication July - August 1994.
2. Edward Liston, Executive Vice President, EUA Cogenex Corporation, Lowell, Massachusetts, personal communication, July - November 1994.
3. Linda Stout, Manager, Project Finance, EUA Cogenex Corporation, Lowell, Massachusetts, personal communication, July - August 1994.
4. E. James Vajda, fomer Assistant Director for the Office of Administrative Services, U.S. Department of Energy, personal communication, July - November 1994.
5. Stephen Kiesner, Coordinator, Commercial Energy Services Department, Potomac Electric Power Company, personal communication, July - August 1994.
6. Glenn Knopf, "DOE's Lighting System Upgrade Generates Energy Savings at No Cost to Taxpayers," Creative Marketing Alliance, Inc., March 1994
7. U.S. Department of Energy, Office of Administrative Services, Office of Federal Energy Management Programs, "Forrestal Building Lighting Profile," June 1993.
8. U.S. Congress, Office of Technology Assessment, "Energy Efficiency in Federal Facilities: Update on Funding and Potential Savings," OTA-BP-ETI-125, Washington, D.C., March 1994.
9. U.S. Department of Energy, "Forrestal Relighting Project-Overhead Series," Office of Administrative Services, Office of Federal Energy Management Programs, June 1993.
10. "The Live Test Demonstration (LTD) of Lighting Retrofit Technologies at the DOE Forrestal Building", Mark Halverson, P.E. (Pacific Northwest Laboratory), John Schmelzer (Pacific Northwest Laboratory), and Louis G. Harris (U.S. DOE).
11. "Emissions and Cost Estimates for Globally Significant Anthropogenic Emissions of NOx, N2O,, CH4, and CO2," DOE/EIA Annual Energy Review, May 1990.
12. Louis G. Harris, Federal Energy Management Program, U.S. Department of Energy, personal communication July - November 1994.
13. Mike Scincovich, Contracting Offices Representative, Department of Energy, personal communication, August - September 1994.
14. EUA Cogenex, "Promotional Brief," Eastern Utilities, 1993.
15. Project Study, "U.S. Department of Energy, James Forrestal Building, Washington, D.C.," prepared by EUA Cogenex, Lowell, Massachusetts.
16. The Results Center, "Tacoma Public Utilities, Fort Lewis Electric Efficiency Retrofit," Profile #71, November 1993.
17. Energy User News, "Lighting Retrofit at DOE Building may Serve as Shared Savings Prototype," by Frank Bryant, August 1993.
18. Forrestal Relighting Project updates and overhead transparencies, May 10, 1993 & June 10, 1993.
19. Program nominations to Energy User News for the Energy User News Efficient Building Awards Competition, submitted to Editor-in-Chief Virginia Hines, by Sara Bogosian, Manager Marketing and Communications, EUA Cogenex, September 9, 1993.
20. Correspondence between EUA Cogenex and the Princeton Economic Research Inc., July 11, 1993, regarding environmental benefits and trees.
21. Gregory Kats, Office of Policy, Planning, and Analysis, U.S. Department of Energy, personal communication, July 1994.
22. U.S. Department of Education, Office of Educational Research and Improvement, "Guide to Excellence," 1994.
23. Potomac Electric Power Company, "1993 Annual Report."
24. Potomac Electric Power Company, "Custom Rebate Program," August 1994.
25. Susan Rash, "Leading by Example: Retrofit Project at Department of Energy Headquarters Serves as Model for Commercial Buildings Nationwide," Ketchum Public Relations, September 1994.
26. Facility News Magazines, "DOE Leads by Example, Installs Energy Efficient Relighting System," June 1993.
27. M. A. Halverson, J. L. Stoops, J. R. Schmelzer, W. D. Chvala, Jr., J. M. Keller, "Lighting Retrofit Monitoring for the Federal Sector - Strategies and Results at the DOE Forrestal Building," Pacific Northwest Laboratory and U.S. DOE.
28. J. Haberl, T. Bou-Saada, E. James Vajda, "The U.S. DOE Forrestal Building Lighting Retrofit: Preliminary Analysis of Electrical Savings," Texas A&M University, August 1994.
29. Jeff Haberl, Manager, Texas A&M Energy Systems Laboratory, personal communication, October - November 1994.
30. American Society of Mechanical Engineers, "The U.S. DOE Forrestal Building Lighting Retrofit: Preliminary Analysis of Electricity Savings," J. Haberl, E.J. Vajda, L. Harris, November 1994.
31. Robin Roy, Office of Technology Assessment, personal communication, December 1994.
32. Belinda Collins, National Institute of Standards and Technology, U.S. Department of Commerce, Transmittal Slip, Preliminary Evaluation Results, December 1994.

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