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Lighting Energy Efficiency Opportunities at Cheyenne Mountain Air Station

by J.C. Molburg, A.J. Rozo, J.K. Sarles, R.A. Haffenden, P.R. Thimmapuram, and J.D. Cavallo

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SUMMARY

The physical and operational attributes of the Cheyenne Mountain Air Station (CMAS) provide a unique opportunity for evaluating lighting-related energy conservation measures. CMAS is an intensive user of electricity for lighting because of its size, lack of daylight, and 24-hour operating schedule. Argonne National Laboratory recently conducted a lighting energy conservation evaluation at CMAS. The evaluation included inspection and characterization of existing lighting systems, analysis of energy-efficient retrofit options, and investigation of the environmental effects that these lighting system retrofits could have when they are ready to be disposed of as waste. Argonne devised three retrofit options for the existing lighting systems at various buildings: (1) minimal retrofit — limited fixture replacement; (2) moderate retrofit — more extensive fixture replacement and limited application of motion detectors; and (3) advanced retrofit — fixture replacement, reduction in the number of lamps, expansion of task lighting, and more extensive application of motion detectors. Argonne used data on electricity consumption to analyze the economic and energy effects of these three retrofit options. It performed a cost analysis for each retrofit option in terms of payback.

The analysis showed that lighting retrofits result in savings because they reduce electricity consumption, cooling load, and maintenance costs. The payback period for all retrofit options was found to be less than 2 years, with the payback period decreasing for more aggressive retrofits. These short payback periods derived largely from the intensive (24-hours-per-day) use of electric lighting at the facility. Maintenance savings accounted for more than half of the annual energy-related savings under the minimal and moderate retrofit options and slightly less than half of these savings under the advanced retrofit option. Even if maintenance savings were excluded, the payback periods would still be impressive: about 4.4 years for the minimal retrofit option and 2 years for the advanced option. The local and regional environmental impacts of the three retrofit options were minimal.

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by

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1 PROJECT OVERVIEW AND BACKGROUND

1.1 BACKGROUND

Each year, Cheyenne Mountain Air Station (CMAS) consumes approximately 43 million kilowatt-hours (kWh) of electrical energy, primarily for space conditioning, lighting, and communications systems. It now purchases most of this power from the local utility, at a cost of about 4¢/kWh. A declining fraction, currently about one-third, is self-generated, at a cost of about 14¢/kWh. Given the current share of self-generation, CMAS's annual power cost is about $3.1 million. Even though the continuing shift to grid power will result in substantial savings, additional savings could be realized through improvements in lighting energy efficiency. Such efficiency improvements would also offer two indirect benefits: (1) reduced need for fuel if grid power were to become unavailable and (2) reduced number of local and regional environmental effects from CMAS operations.

In view of these potential benefits, Argonne National Laboratory (ANL) was asked to evaluate opportunities for lighting-related energy conservation at CMAS. The evaluation included an on-site inspection of current lighting systems, analysis of energy-efficient retrofit options, and investigation of the environmental effects that these lighting system retrofits could have when they are ready to be disposed of as waste. The project team is associated with ANL's Existing Buildings Efficiency Research Program. The work was done with the support of the CMAS Environmental Office.

1.2 RESEARCH INTERESTS

Because ANL seeks projects that extend the boundaries of technical analysis, its interest in the CMAS project, with its extraordinary operating environment, was high. Most of the buildings included in the project scope are located inside Cheyenne Mountain. Such a location has significant implications for lighting systems, particularly because the facility is operated 24 hours (h) per day. In addition, the CMAS Environmental Office expressed concern about the environmental effects that might result from the disposal of any materials associated with a retrofit program. This interest is consistent with one of ANL's strong program areas: environmental and regulatory research.

The unusual environment and uses of CMAS offer an opportunity for further lighting-related research that was not in scope of this study. In particular, the psychological effects of lighting systems as well as the effects of these systems on the health and performance of CMAS personnel could be studied. Aside from a consideration of color rendering and ambient noise, these issues have not been addressed.

1.3 OBJECTIVES

The overall objective was to estimate the potential energy and economic benefits available as a result of energy-efficient lighting retrofits. Retrofit options had to be consistent with environmental regulations and the maintenance of an effective work environment. The overall objective was to be achieved by completing a series of tasks to be identified during the project. The statement of work for the lighting audit and energy efficiency study at CMAS proposed six tasks. After the site survey on March 26-27, 1996, discussions with the lead CMAS environmental officer led to minor task revisions. The task descriptions listed below allow the original objectives to be accomplished but more precisely define the work to be undertaken.

1. Establish baseline electrical energy use.

2. Survey all areas (except where security restrictions apply) of the underground buildings and aboveground administrative facilities to assess existing light levels and existing equipment and the potential for energy savings from redesigning or retrofitting equipment. Categorize rooms and spaces according to how they are used.

3. Recommend up to three levels of retrofit for each usage category.

4. Estimate the life-cycle costs for each retrofit option. These estimates will cover the initial investment for materials and labor; cost for disposal of existing fixtures; and net energy, maintenance, and ultimate disposal costs.

5. Describe the advantages and disadvantages of each option, considering convenience, reliability, color rendering qualities, and lighting adequacy per Illuminating Engineering Society (IES) standards, in addition to the cost analysis.

6. Prepare a report on the analysis of the life-cycle and social costs of all existing and potentially cost-effective lighting systems, taking purchases, installation, maintenance, removal, and proper disposal into account.

1.4 SCOPE

CMAS consists of 14 buildings and support facilities located inside the mountain and several administrative, security, and support buildings located outside. The interior buildings were of primary interest, although the scope of work was extended to include two exterior administrative buildings. Because of security restrictions, information on usage and current lighting was unavailable for several areas within the mountain. Lighting retrofit options were defined for each accessible area, and an analysis of the retrofit cost and energy savings was conducted for these options. Up to three options were evaluated for each room type. Options include task lighting, luminaire refurbishment or replacement, and automatic controls.

Costs for retrofit equipment, installation labor, and waste disposal were considered in the analysis. The figure of merit is simple payback — the quotient of net investment and annual cost savings. These savings include the direct savings from reduced lighting energy demand and the indirect savings from reduced cooling load attributable to reduced energy consumption by the lighting. A penalty for increased heating demand was also assigned. Maintenance and disposal cost savings or penalties for each retrofit option were included in the total savings figure.

1.5 METHODOLOGY

1.5.1 Lighting Survey

Basic lighting retrofit options are well-defined as a result of more than a decade of aggressive lighting retrofit programs. These basic options, which are listed in Section 4, have broad applicability. However, each facility is unique in terms of architectural features, existing lighting systems, daylight availability, usage patterns, and occupant preferences. The unique character of a given facility can only be captured by an on-site survey. On March 26 and 27, 1996, the project team performed a survey of accessible CMAS facilities. Findings of that survey are incorporated in the results and recommendations of this analysis. Each accessible room was surveyed for (1) current installed lighting fixture type and count, (2) current light levels, (3) primary room function, (4) occupant preferences and concerns, and (5) aptness of retrofit options. The survey was supplemented by reference to electrical system drawings to establish exact fixture specifications and counts.

1.5.2 Analysis of Retrofit Options

Current installed lighting energy consumption was estimated from the fixture count, fixture specifications, and operating hours. Each proposed retrofit option implies a room-by-room change in fixture specification and count. Lighting control options, such as motion detectors, imply a change in operating hours as well. These changes were reflected in calculated energy use under each retrofit option. The cost of retrofit was balanced against the energy savings (including heating and cooling effects) and maintenance and disposal savings in a simple payback calculation, which provides the figure of merit for evaluation of the retrofit options. Payback is simply the ratio of initial investment to annual reduction in energy and other costs. The initial investment included both equipment cost and installation labor. Calculations were implemented on spreadsheets (available on the CD-ROM version of this report), and a sensitivity analysis was conducted by marginally altering the price of electricity.

1.5.3 Waste Disposal

Fluorescent lamps contain small amounts of mercury, which has been shown to be hazardous to the environment and human health. In addition, ballasts can contain polychlorinated biphenyls (PCBs). Proper disposal of fluorescent lamps and ballasts has been researched for this project by Argonne lawyers specializing in environmental issues. This report describes proper disposal methods and provides a list (in Appendix B) of recyclers registered with the Ohio Environmental Protection Agency.

2 FACILITY DESCRIPTION

2.1 BUILDINGS AND ENVIRONS

CMAS is located on the outskirts of Colorado Springs on and within Cheyenne Mountain at an elevation of 7,200 ft. Of the 335,000 ft^2 of building space, 201,000 ft^2 are in the 17 administrative buildings and 91,000 ft^2 are in industrial facilities. Fourteen buildings and facilities are within the mountain. The largest of these are three-story, steel structures similar in layout to conventional office buildings. Enclosed corridors connect all interior buildings. The facilities include open office spaces with dividers, individual offices, conference rooms, shops, medical facilities, exercise facilities, a commercial kitchen, a cafeteria, storage areas, and physical plant facilities. An ongoing program of facility maintenance and upgrades has resulted in a very diverse array of lighting systems.

The mountain interior provides a unique context for building energy systems. Although there is a complete absence of daylight, CMAS's need for lighting fixtures is only slightly greater than that of a conventional location, since lights are required for operation in nonperimeter spaces in any facility. The lack of daylight also does not increase the number of hours that the lights need to operate, since lights in most buildings are on even in daylight hours. However, the lack of daylight restricts design and retrofit options, which could normally exploit daylight. The unusual environment of the mountain interior also affects the interaction of the lighting and space conditioning system. Normally, lighting provides a substantial fraction of building heating energy and increases the air conditioning load substantially as well. Therefore, a reduction in lighting power consumption decreases the energy consumption for air conditioning but increases the demand for heat. The net benefit is a trade-off that reflects the relative demand for heating and for air conditioning in a particular setting. Although ANL has not studied CMAS's heating and cooling requirements in detail, CMAS environmental staff reported that very little heat is required, even in winter months. This situation could reflect a tempering effect of the mountain mass, reduction in wind-related heat loss, high occupancy, or the extensive lighting loads. In this case, the result is a favorable balance, in which reduced lighting power consumption will result in net savings in space conditioning.

2.2 FACILITY USAGE

The key issue with regard to facility usage is that the CMAS operates on a 24-h basis. It therefore experiences a full lighting load for roughly twice the number of hours as do typical commercial facilities. This situation therefore doubles the rate of payback for any lighting retrofit. The usage issue that is second in importance is the diversity of usage, which is described in some detail in Sections 3.1.1 and 6.1.

3 LIGHTING SURVEY

3.1 GENERAL FINDINGS

3.1.1 Room Types and Tasks

Sixteen room types were defined according to the tasks that are performed in them. These room types, which are listed in Table 1, can be used to simplify the analysis of retrofit options by allowing generic options to be specified for each room type. In addition, the survey burden is reduced because information from one room can be extrapolated to other rooms of the same type that were not accessible for the survey.

TABLE 1 Room Types and Lighting Usage

Room Type	Lighting Used	Number of Hours
Corridors	Primarily fluorescent, with some incandescent	24
Stairwells	Fluorescent	24
Tunnels	Incandescent	24
Caverns	High-intensity discharge (HID)	24
Storage	Fluorescent	8
Bathrooms	Combination of fluorescent and incandescent	12
Mechanical rooms	Combination of fluorescent and incandescent	4
Open office	Primarily fluorescent	8
Private office	Primarily fluorescent	8
Conference rooms	Combination of fluorescent and incandescent	6
Dining rooms	Combination of fluorescent and incandescent	6
Control rooms	Primarily fluorescent	24
Computer rooms	Fluorescent	24
Maintenance shops	Fluorescent	12
Medical rooms	Fluorescent	24

3.1.2 Lighting Retrofit Concerns

The lighting survey team was introduced to room occupants, many of whom seemed to view the prospect of a lighting retrofit with some concern. In general, they were very satisfied with the current lighting systems and perceived that lighting levels would be reduced by the retrofit. The occupants were assured that this was not the intention. Nevertheless, it is common practice in lighting retrofits to reduce lighting levels in over-lighted areas. Two situations call for such lighting reductions. One is where current lighting is excessive for the tasks at hand. The other is where general or background lighting can be reduced and replaced with task lighting. (The complete absence of daylight in the interior buildings may be a psychological factor to be considered when deciding whether to retrofit, but such considerations were outside the scope of this analysis.)

Some occupants were more enthusiastic about the prospect of a lighting retrofit, identifying specific needs or shortcomings in the existing system and expressing support for the energy savings motive. Some specific requests were for (1) improved task lighting in the medical examination facilities, (2) glare reduction in central computing facilities, and (3) reduced background lighting in some office areas with high computer usage. Other concerns included light color rendition, audible ballast hum, and harmonic interference with existing electrical system operations.

3.1.3 Current Lighting Systems and Levels

Current lighting levels were found to be adequate to excessive, except in some areas affected by shadowing caused by partitions and a few areas with lamps that were not operating. Many areas also experienced lighting well below system design levels because of the deterioration of plastic diffusers, dirt accumulation, and lamp aging. Table 1 provides more specifics. The fact that existing lighting systems were largely below original design effectiveness yet remained adequate suggests that less installed wattage could be used, particularly if the retrofit fixtures are more regularly maintained or less prone to deterioration.

Lighting system upgrading had accompanied CMAS building renovations, even though energy conservation had not been the focus of these upgrades. The renovated areas, which incorporate more effective and more efficient systems, have provided an in-house example of how efficiency can be served without compromising lighting adequacy.

Most general office areas had adequate lighting for accomplishing office tasks without a need for supplemental, or task, lighting. However, shadowing caused by partitions did create a need for some task lighting, which was provided by shelf-mounted fluorescent fixtures.

3.1.4 Heating and Cooling

As described above, lighting systems affect heating and cooling loads. Therefore, the survey included discussions with site engineers to characterize the heating and cooling systems and their typical operating profiles. In general terms, industrial areas (those with mechanical equipment) do not require heat. Most building areas are primarily offices and do require some heat during the winter. Table 2 lists the building areas that require some heating. Specific operating hours for the heating system were not available, so the heating hours are handled parametrically in the analysis.

3.2 SPECIFIC DATA

3.2.1 Lighting Levels

Light meter readings were taken in the surveyed rooms. These readings and the IES standards for the tasks performed in those rooms are summarized in Table 3.

3.2.2 Fixture Inventory

A fixture inventory was taken as part of the survey. Time did not permit examination of each fixture to verify ballast type and bulb specifications, but the survey results, supplemented by data from engineering drawings of the lighting systems, have provided an accurate estimate of current installed lighting. The detailed inventory appears in Appendix A. Table 4 provides a summary of the fixture inventory.

TABLE 2 Areas Requiring Some Heating

Bldg.	Heat Required
3	All three floors require some heat, although not much heating demand is expected
4	Some heat demand occurs in Oct.-May
5	Third floor only requires heat; very little is required
6	Office areas require some heat
7	Office areas require some heat
8	This is being converted to office areas and will require some heat
9	First floor only requires heat
10	Office areas require some heat
11	Third floor only requires some heat
12	No heat is required

TABLE 3 Current Lighting Levels

Room Type	Example Room	Meter Readings (foot-candles)	IES Standard
Corridors	In Bldg. 1, third floor	5-10	5 - 10
Stairwells	In Bldg. 1	15-20	10- 20
Tunnels	At Bldg. 4 entrance	15-30	5 - 10
Caverns	At entrance to facility	50-60	None
Storage	Rooms 4204, 4201, and 12107	25-65	50 - 100
Bathrooms	Room 4207	30-40	5 - 10
Mechanical rooms	Room 1106	15-25	15 - 20
Open office	Room 4102	20-30	30 - 50
Private office	Room 4102B	30-50	30 - 50
Dining rooms	Room 1309	35-55	40 - 50
Control rooms		Lights on dimmer controls	
Computer rooms	Room 2101	95-100	25 - 30
Maintenance shops	Room 4105	450-600	500 - 750
Medical rooms	Room 1205	45-55	50 - 75

TABLE 4 Summary of Lighting Fixtures in Interior Buildings[a]

	Fluorescent per Type of Fixture				Incandescent	
Bldg.	1-Lamp	2-Lamp	3-Lamp	4-Lamp	<100 W	> 100 W
1	161	136	71	26	73	59
2	24	94	3	75	22	79
3	9	73	7	207	3	84
4	45	180	6	28	17	45
5	22	105	9	1	21	17
6	30	36	0	28	20	5
7	24	92	0	4	34	20
8	6	122	0	66	31	15
9	30	239	0	40	18	31
10	14	65	0	43	13	18
11	23	222	64	0	19	30
Total	388	1,364	160	518	271	403

[a] This table lists most, but not all, of the existing fixtures and includes the most likely retrofit candidates. Exit lighting and some other special-purpose lighting are excluded.

4 GENERAL RETROFIT OPTIONS

The lighting system retrofit encompasses a broad spectrum of activities, from replacing bulbs to using automatic controls to changing room or building usage. This section provides a context for the retrofit options that ANL has analyzed by listing the full spectrum of retrofit activities identified in the IES lighting ready reference document. Although some of these activities are not applicable to CMAS, it is useful to itemize the full set of activities from which recommended options have been built. The descriptions here are from the referenced IES publication. Some are taken verbatim from its checklist of energy-saving lighting ideas.

4.1 TASK LIGHTING

The basic concept of task lighting is to reduce the total lighting load by providing lighting as required for a particular task. General background lighting can be reduced to levels required for safety or aesthetics. A related opportunity is to reduce current lighting where it exceeds that required for the task at hand. Only in extreme cases is task lighting to be provided in areas with no visual task requirements. Identifying such opportunities requires a detailed review of daily operations, which could not be done under the scope of this study. Solutions include reducing general lighting and supplementing it with task lighting, grouping work areas according to task, isolating unused areas to eliminate lighting use, removing stacks or lighting obstructions, lowering luminaires, relocating luminaires, eliminating partitions (which cause shadows), and using light-colored room surface treatments.

Among the concerns raised by these approaches are that (1) the lighting system operating costs are a secondary consideration to effective task performance, and reorganization of work spaces must consider performance factors first, and (2) very specific lighting system designs reduce the flexibility of space utilization options.

4.2 LIGHTING EQUIPMENT

The focus of the analysis was on lighting equipment options for energy conservation, primarily the retrofit of more efficient fixtures and lamps. However, lighting equipment options include more than lamp and fixture retrofit and replacement. One important option is to upgrade luminaire maintenance through regular washing and replacement cycles. A maintenance schedule is nearly as important as an equipment retrofit program. Equipment replacement options include these:

- Use lamps with higher output per watt input.

- Replace a group of low-wattage incandescents with fewer high-wattage lamps.

- Use reflector (R), parabolic aluminized reflector (PAR), or ER[1] lamps to obtain required light with lower wattage.

- Use reduced-current ballasts.

- Use low-maintenance luminaires.

- Use ballasts that can accommodate high-pressure sodium or metal halide lamps.

- Use multilevel ballasts to allow for intermittent reduction in light.

- Substitute high-pressure sodium lamps for existing mercury lamps (retrofit ballast is required).

- Use heat removal luminaires to reduce the operating temperature of the lamp and excess heat in occupied space.

4.3 DAYLIGHT

The exterior buildings would better exploit outside daylight if the lighting near daylight areas could be reduced. The most demanding visual tasks could be located near sources of daylight. Window treatments could be modified to better use daylight. However, the use of daylight must be evaluated in the context of its effect on heating and cooling loads, since overall energy efficiency might require restrictions on peak "daylighting."

4.4 CONTROL SYSTEMS

The most basic control system option for improving efficiency is to install selective switching, so that lighting for small areas can be independently controlled. Switches and dimmers can be installed to provide the flexibility required for spaces with alternative visual tasks. Conference rooms at CMAS have such systems. Flexibility can also be provided with plug-in luminaires. These can accommodate changes in room use since they can be readily interchanged. Photocells provide

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[1] These designations refer to integral reactors. A PAR is often used in conjunction with a tungsten-halogen capsule in a flood lamp. This type of lamp is a convenient replacement for conventional incandescent lamps.

on-off capability, particularly in response to varying daylight. Time switches can provide on-off functionality synchronized to work schedules. Manual alternatives include reminders to shut lights off and coding systems to remind crews of any preferred on-off schedule. Motion detectors and occupancy sensors provide an alternative to timer controls for rooms used irregularly. The most sophisticated control systems operate with low-voltage controls and computer supervision.

4.5 MAINTENANCE

The basic maintenance requirements are to replace bulbs, clean reflectors and diffusers, and repair failed components. Replacing failed luminaires with high-efficiency models as a matter of routine maintenance procedure is a relatively slow way of accomplishing a retrofit, but it has virtually no additional cost. Luminaires should be selected with consideration given to their rate of deterioration and maintenance requirements. New fluorescent fixtures with open grids, for example, deteriorate less quickly and accumulate less dirt than enclosed fixtures with plastic diffusers.

4.6 OPERATING SCHEDULE

Operating schedule options are a sophisticated version of "turn the lights off when you leave the room." They require a review of occupancy and use patterns. Some alternatives are to (1) schedule cleaning during rather than after operating hours, (2) restrict parking during low-use periods to specified lighted areas, and (3) educate occupants on the efficient operation of various lighting types. Incandescent lamps, for example, should be turned off immediately after use. Fluorescent lamps should be turned off if they are not needed for a period of more than 5 minutes. HID lamps should be turned off if they are not needed for 30 minutes or longer.

5 WASTE DISPOSAL ISSUES

5.1 REGULATIONS

5.1.1 Fluorescent Lamps

Currently in Colorado, fluorescent lamps that contain mercury may be a hazardous waste under the Resource Conservation and Recovery Act (RCRA). According to the Colorado Code of Regulations (CCR), the generator of the waste is responsible for determining if the waste bulbs demonstrate the characteristic of toxicity (6 CCR 262.11; 261.24). If the waste fails the toxicity characteristic leaching procedure (TCLP) test for mercury (0.02 mg/L), it would be considered a hazardous waste.[2]

Therefore, as a hazardous waste, lamps may be accumulated at or near the point of generation in an amount less than the equivalent of 55 gal, as long as the containers are compatible, in good condition, and labeled with the words "hazardous waste" or other words describing the contents (e.g., "waste fluorescent lamps"). As long as the waste does not exceed the 55-gal limit, there is no time limit on the accumulation of the lamps. However, if the number of bulbs exceeds the equivalent of 55 gal, the waste must comply with generator standards. These allow hazardous waste in any amount to be stored for 90 days, as long as the containers are compatible, in good condition, and labeled with the words "hazardous waste." The storage area must be supervised by a trained manager who performs weekly inspections. The area must be maintained to prevent release of the hazardous waste, and there must be emergency response planning for the area.

If storage of the waste lamps is to exceed the 55-gal and 90-day limits, the storage area has to obtain a treatment, storage, and/or disposal facility permit from the Colorado Department of Public Health and the Environment (CDPHE), and the storage facility has to comply with all the siting, security, design, and operation requirements for a permitted facility.

Shipment of waste lamps off site to a treatment or disposal facility requires the use of a hazardous waste manifest containing the name of the RCRA-authorized shipper and the properly permitted destination facility. A copy of the manifest, signed by the receiving facility, must be returned to the Defense Reutilization and Marketing Office (DRMO) at Fort Carson, Colorado, within 35 days. The manifested shipment must be accompanied by a Certificate of Land Disposal

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[2] The generator may also declare the waste a hazardous waste without chemical analysis, on the basis of process knowledge. However, a treatment, storage, or disposal facility may require a chemical analysis to accept the waste.

Restriction containing the information that the treatment or disposal facility needs to allow proper land disposal of the waste.

The CDPHE's policy prefers recycling to treatment and disposal (Cathy Hadivek, CDPHE, telephone conversation with R. Haffenden, ANL, May 7, 1996). If lamps are to be recycled, crushing (as a necessary step of a legitimate recycling process) is exempt under RCRA Section 261.6(c). Crushing activities may occur at the generator's or recycler's facility and still remain exempt. However, the generator must ensure that the crushed bulbs are ultimately recycled and not disposed of in a landfill (EPA, Office of Solid Waste and Emergency Response, letter on crushing of mercury-containing lamps, to RCRA Compliance Branch, Land Division, Alabama Department of Environment, June 5, 1995). Appendix B contains information from a publication by the State of Ohio EPA listing U.S. fluorescent lamp recyclers.

In Colorado, crushing waste lamps in accumulation tanks or containers to make them more suitable for recycling or reclamation or to reduce their volume or toxicity is permitted by 6 CCR 1007-3, Section 110.21(d)(1). However, the mercury vapor must be captured by the treatment process. Also, the generator must comply with all generator standards and must file a Notification and Waste Analysis Plan with the CDPHE 30 days before beginning the treatment activity. Therefore, the Colorado generator may crush the waste lamps to consolidate them for disposal or recycling.

5.1.2 PCB Fluorescent Lamp Ballasts

If the ballasts are not leaking, they are considered solid waste under the Toxic Substance Control Act (TSCA) and can be disposed of in a solid waste landfill, with the permission of the landfill operator.[3] They do not have to be shipped with a manifest, and there is no time limit on storage pending disposal.

If the ballasts are leaking, they must be disposed of in an EPA-approved PCB incinerator, according to TSCA. Leaking PCB ballasts must be in drums clearly labeled with the words "caution: contains PCBs" on a yellow label (40 CFR 761.40) and must bear the name and address of the generator, weight, the date the ballasts were first removed from service, a description (e.g., RQ

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[3] A PCB small capacitor may be disposed of as municipal solid waste (40 CFR 761.60(b)(2)(ii)). A small capacitor is a capacitor that contains less than 1.36 kg (3 lb) of dielectric fluid. The following assumptions may be used if the actual weight of the dielectric fluid is unknown. A capacitor whose total volume is less than 1,639 cm^3 (100 $in.^3$) may be considered to contain less than 1.36 kg (3 lb) of dielectric fluid, and a capacitor whose total volume is more than 3,278 cm^3 (200 $in.^3$) may be considered to contain more than 1.36 kg (3 lb) of dielectric fluid. A capacitor whose volume is between 1,639 and 3,278 cm^3 may be considered to contain less than 1.36 kg (3 lb) of dielectric fluid if the total weight of the capacitor is less than 4.08 kg (9 lb).

Polychlorinated Biphenyls, 9, UN231.5, PG II), and a unique container tracking number. Leaking ballasts must be shipped with a hazardous waste manifest. The generator must receive a certificate of disposal from the disposal facility.

The CDPHE encourages generators to use TSCA incineration facilities for the disposal of all PCB articles (leaking and nonleaking) because such facilities handle the waste in an appropriate manner (Cathy Hadivek, CDPHE, telephone conversation with R. Haffenden, ANL, May 8, 1996). Incineration is costly, but as a result of using the approved methodology, the generator will not have the long-term liability associated with drums that contain a large quantity of ballasts that are releasing PCBs to a landfill.[4] Under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), anyone disposing of more than 1 lb of PCBs or mercury in any landfill is a potentially responsible party in any subsequent Superfund cleanup of that landfill.

If leaking PCB small capacitors are to be stored pending disposal, storage areas must comply with the TSCA requirements. Compliance includes having an adequate roof and walls to prevent rain from entering and an impervious floor with continuous curbing of 6 in. and no drains, expansion joints, or other openings. The storage area must be properly placarded and inspected every 30 days for leaking articles or containers. All containers and articles must also be marked with the date they were removed from service.

Many facilities maintain an annual document log that includes all manifests and certificates of disposal and identifies each PCB article placed in storage.[5] For shipments of leaking capacitors, which require a manifest to an EPA-approved TSCA disposal facility, the generator must maintain the final signed manifests and certificates of disposal for each shipment of PCBs for three years.

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4 Contact the EPA regional office to ascertain its definition of "large quantities." Usually, if a combined amount of 3 lb or more of PCBs is contained in a number of small capacitors, the capacitors should be managed as large capacitors, which includes being disposed of by incineration (see *PCB Question and Answer Guide*, 1994 edition, published by the EPA, Operations Branch, Chemical Management Division, Office of Pollution Prevention and Toxics).

5 This requirement applies only to owners or operators of a facility that stores at any one time at least 45 kg (99.4 lb) of PCBs contained in containers, or one or more PCB transformers, or 50 or more PCB large high-voltage or low-voltage capacitors. A storage facility that stores only small capacitors would not be required to keep such a log.

5.2 COST ANALYSIS FOR DISPOSAL OF BULBS AND BALLASTS

5.2.1 Ballasts

The following guidelines should be used to determine if ballasts contain PCBs:

1. All ballasts manufactured through 1979 contain PCBs.

2. Ballasts manufactured after 1979 are assumed to contain PCBs unless labeled "no PCBs."

In Colorado, PCB-containing ballasts must be handled and disposed of as hazardous waste. Hazardous waste disposal from CMAS is handled by the Fort Carson DRMO. Intact, nonleaking, non-PCB ballasts may be disposed of as solid waste. PCB-containing ballasts that have been damaged and are leaking require special handling and must be incinerated in an EPA-approved, high-temperature incinerator.

5.2.2 Tubes

Fluorescent light tubes contain mercury, which, under RCRA, demonstrates the characteristic of hazardous waste (D009). The disposal of mercury-containing waste is regulated by the EPA under 40 CFR 261. Such waste must be tested to determine proper handling requirements. The number of tests being performed must be sufficient to ensure a valid classification of each type of tube being discarded. If the tubes pass a TCLP test, they can be disposed of in any municipal solid waste landfill. If the tubes fail, they must be handled as hazardous waste and disposed of through the Fort Carson DRMO.

The CMAS solid waste contractor, Waste Management of Southern Colorado, has disposed of fluorescent tubes as solid waste. After the tubes had passed TCLP tests, they were packaged to ensure safe handling and picked up as a special shipment.

5.2.3 Disposal Options

There are three disposition destinations for tubes and ballasts. Solid waste landfills can be used for non-PCB ballasts and tubes that pass the TCLP test. Hazardous waste can be disposed of through the Fort Carson DRMO for ultimate disposal in an approved hazardous waste treatment, storage, and disposal (TSD) facility. Alternatively, tubes and ballasts can be sent to a recycling facility. A list of companies that recycle fluorescent light bulbs was obtained from the CDPHE. The costs for the various options are presented in Table 5 and summarized below:

1. Recycle both tubes and ballasts: $7,643.

2. Dispose of both tubes and ballasts as hazardous waste: $15,562.

3. Dispose of tubes that have passed TCLP tests as solid waste for $313 and dispose of all ballasts as hazardous waste for $7,000: $7,313.

4. Dispose of tubes that have passed TCLP tests as solid waste for $313 and recycle ballasts for $5,250 plus $793: $6,356.

The calculations assume that all ballasts must be disposed of as hazardous waste. If some ballasts were labeled "no PCBs," disposal costs would decrease accordingly. Such non-PCB ballasts could also be recycled, but the cost of recycling is much higher than the cost of disposal as solid waste. However, a conservative assumption is that most ballasts are likely to require handling as hazardous waste.

TABLE 5 Disposal Costs[a]

		Weight (lb)			Cost of HW Disposal ($)		Cost of HW Recycling ($)		
HW Item	Quantity	Each	with Packing	Total	per Pound	Total	per Item	Total	Savings (%)
Tube	5,000	0.63	1.25	6,250	1.37	8,563	0.32/unit	1,600	81
Ballast	2,500	3.25	3.50	8,750	0.80	7,000	0.60/lb	5,250	25
							Other charge	793	
Total						15,562		7,643	51

		Weight (lb)			Cost of SW Disposal ($)	
SW Item	Quantity	Each	with Packing	Total	per Pound	Total
Tube	5,000	0.63	1.25	6,250	0.05/lb	312
Total						313

[a] HW = hazardous waste, SW = solid waste.

6 ENERGY EFFICIENCY ANALYSIS

6.1 ENERGY ANALYSIS OVERVIEW

The analysis of energy usage under the different retrofit options was conducted by means of spreadsheets designed specifically for this purpose. The spreadsheets are provided on the CD-ROM version of this report. They may also be requested upon written request. Summary tables of the cost savings are provided as Tables A.1-A.14 in Appendix A. Table 6 shows the options for retrofit considered for each fixture or control.

6.2 LIGHTING ENERGY SAVINGS

Analysts strongly believe that total cost savings should be considered when decisions related to a proposed lighting retrofit are being made. However, they may view maintenance savings separately. For these reasons and to facilitate decisions, the payback periods for the retrofit options were separated. Table 7 shows the retrofit payback periods, with and without estimated maintenance savings. Interior and exterior buildings are treated separately.

TABLE 6 Specifications for Three Levels of Retrofit

Existing System	Minimal Retrofit	Intermediate Retrofit	Advanced Retrofit
T-12, 40-W fluorescent			
1-lamp fixture	Replace with T-12, 34-W fluorescent	Replace with T-8, 32-W fluorescent with electronic ballast in existing luminaire	Replace with T-8, 32-W fluorescent with electronic ballast, parabolic reflectors
2-lamp fixture	No change in lamp count	No change in lamp count	Replace with 1-lamp fixtures with added task lighting
3- and 4-lamp fixtures	No change in lamp count	No change in lamp count	Replace with 2-lamp fixtures with added task lighting
Incandescent, <100 W	No change	Replace with compact fluorescent	Replace with compact fluorescent
Incandescent, >100 W	No change	Replace with PAR 38 floods	Replace with PAR 38 floods
Switch control only	No change	Add motion detectors in selected storage facilities	Add motion detectors in selected storage and industrial facilities and in small offices

TABLE 7 Summary of Cost Analysis for Retrofits

a. Interior Buildings without Maintenance Savings

Retrofit	Annual Amount ($)					
	Lighting Saved	Cooling Saved	Heating Penalty	Total Saved	Retrofit Cost ($)	Payback Period (yr)
Minimal	12,544	3,950	683	15,811	69,351	4.39
Moderate	41,746	13,147	2,277	52,616	197,831	3.76
Advanced	69,724	21,959	3,803	87,880	235,503	2.68

b. Interior Buildings with Maintenance Savings

Retrofit	Annual Amount ($)						
	Lighting Saved	Cooling Saved	Heating Penalty	Maintenance Saved	Total Saved	Retrofit Cost ($)	Payback Period (yr)
Minimal	12,544	3,950	683	19,840	35,651	69,351	1.95
Moderate	41,746	12,147	2,277	81,075	133,691	197,831	1.48
Advanced	69,724	21,959	3,803	82,295	170,175	235,503	1.38

c. Exterior Buildings without Maintenance Savings

Retrofit	Annual Amount ($)					
	Lighting Saved	Cooling Saved	Heating Penalty	Total Saved	Retrofit Cost ($)	Payback Period (yr)
Minimal	2,039	642	111	2,570	11,055	4.30
Moderate	3,713	1,169	203	4,679	11,498	2.46
Advanced	7,144	2,250	390	9,004	19,492	2.16

d. Exterior Buildings with Maintenance Savings

Retrofit	Annual Amount ($)						
	Lighting Saved	Cooling Saved	Heating Penalty	Maintenance Saved	Total Saved	Retrofit Cost ($)	Payback Period (yr)
Minimal	2,039	642	111	3,234	5,804	11,055	1.905
Moderate	3,713	1,169	203	10,505	15,184	11,498	0.757
Advanced	7,144	2,250	390	10,487	19,491	19,492	1.000

All payback periods are short, whether or not maintenance is included. This result indicates the strong benefit of an energy-efficient retrofit in a heavily used installation like CMAS.

6.3 SPACE CONDITIONING ENERGY SAVINGS

All electrical power delivered to the lighting system eventually manifests itself as heat. Unless the system is specially designed to remove heat by means of ducts that allow air to flow through the fixtures and away from the room, this heat adds to the cooling load or reduces the heating requirement for the lighted space. In any case, the energy converted to light and transferred to the space affects the space conditioning requirement. A net energy savings results from the reduction in the electrical load for lighting, which is the product of the balance between the cooling energy benefit during chiller operation and the heating energy penalty during boiler operation.

6.3.1 Cooling System Savings

The energy savings estimate for the cooling system is based on the assumption that 1.25 kW of power is required per ton of air conditioning load. This figure has been recommended by ASHRAE for this type of calculation. Specific data for the CMAS system may differ. This area is open for further investigation.

6.3.2 Heating System Penalty

The heating system energy penalty is estimated on the basis of the assumption that the entire lighting load is converted to heat, so any reduction in lighting load directly increases heat demand. In fact, some heat from lighting fixtures is simply exhausted with purged air. In addition, a system efficiency of 85% is assumed. That is, 75% of the chemical potential energy in the fuel is converted to heat in the conditioned space. The balance is lost as flue gas sensible heat, combustion loss, duct loss, and piping heat loss. The 75% figure may exceed actual system performance. The errors implicit in these simplifying assumptions offset each other.

6.4 COST ANALYSIS

6.4.1 Cost Methodology

The cost analysis is essentially a payback period analysis with enhancements to reflect the effect of a retrofit decision on lighting maintenance costs. A payback analysis is commonly used in lighting analysis because of its simplicity and because the concept of years required to cover initial investment is easily understood. The basic payback period is the ratio of initial investment to resulting annual energy savings. It does not account for differences in future investments that arise because of differences in equipment lifetimes and cost. It also does not account for the fact that existing equipment may be worn and will eventually be replaced. Finally, a payback value gives no indication of the total value of savings.

The basic payback approach has been enhanced by the addition of a maintenance savings calculation. Most energy lighting retrofits also result in reduced maintenance costs because the retrofit equipment has a longer expected life. Maintenance savings can be added to the energy savings so that payback is calculated on the basis of total savings.

As an example, consider the decision to retrofit an existing fluorescent fixture by only replacing the lamp. Without the retrofit, a cost for maintenance is incurred for routine bulb replacement. The expected bulb life of the standard 40-W T-12 lamp is 9,000 h. Thus, about 97% (8,760/9,000) of the existing bulbs would be replaced each year if they were used on a 24-h basis. This calculation is based on the assumption that the existing bulbs are uniformly distributed by age (e.g., 5% of the bulbs are in the last 5% of their expected life at any time). The annual maintenance cost per existing lamp would therefore be 97% of the lamp replacement cost, including labor. For the retrofit 34-W T-12 lamp, the expected bulb life is 15,000 h. Initially, the retrofit bulbs would not be uniformly distributed by age because they would be installed at the same time. However, after a few years of random replacement, the lamps would be distributed uniformly by age, and 58% of them (8,760/15,000) would be replaced each year. Thus, the annual maintenance cost per existing lamp would be 58% of the lamp replacement cost. The actual maintenance cost in the first year is expected to be much lower because all the bulbs are new. This fact improves the payback calculation. However, the 58% figure has been used here because it is more representative of the long-term maintenance cost.

The maintenance savings is the difference between the maintenance cost for ongoing replacement of the existing lamps and the maintenance cost for ongoing replacement of the longer-lived retrofit lamps; i.e., 97% of the existing lamp replacement minus 58% of the retrofit lamp replacement. This savings per lamp is multiplied by the number of lamps. A summary of the maintenance savings for each unit retrofit is provided in Table 8. The calculations have been performed as outlined above. Two additional assumptions are reflected in the calculations. First, maintenance is assumed to occur at the end of the year and has been discounted at 10% to the beginning of the year when retrofit occurs. Second, because of the long expected life of electronic ballasts, significant failure rates are not expected for many years, so zero maintenance costs are assumed. Certainly, ballast failures will not affect the payback calculation.

TABLE 8 Maintenance Savings per Fixture

Existing Component	Retrofit Scenario	Retrofit	Maintenance Savings ($)
T-12, 40-W, 1-lamp fixture	Minimal	Replace lamps with T-12, 34-W lamps	3.50
	Moderate	Replace with new T-8, 32-W, 1-lamp fixture	12.75
	Advanced	Replace with new T-8, 32-W, 1-lamp fixture	12.75
T-12, 40-W, 2-lamp fixture	Minimal	Replace lamps with T-12, 34-W lamps	7.00
	Moderate	Rebuild fixture with two T-8, 32-W lamps and one electronic ballast	20.00
	Advanced	Replace with new T-8, 32-W 1-lamp fixture and electronic ballast	22.60
T-12, 40-W, 3-lamp fixture	Minimal	Replace lamps with T-12, 34-W lamps	10.50
	Moderate	Rebuild fixture with three T-8, 32-W lamps and one electronic ballast	27.25
	Advanced	Replace with new T-8, 32-W, 2-lamp fixture and electronic ballasts	29.90
T-12, 40-W, 4-lamp fixture	Minimal	Replace lamps with T-12, 34-W lamps	14.00
	Moderate	Rebuild fixture with four T-8, 32-W lamps and one electronic ballast	34.50
	Advanced	Replace with new T-8, 32-W, 2-lamp fixture and electronic ballasts	39.70
Magnetic ballast	Moderate[a]	Replace with electronic ballasts	5.50
Incandescent <100 W	Moderate and advanced	Replace with compact fluorescent	13.90
Incandescent >100 W	Moderate and advanced	Replace with 75-W, PAR 38	56.70

[a] This maintenance savings is incorporated in the fixture rebuild and new fixture maintenance costs as listed above. It is isolated here for information only.

6.4.2 Existing Component Replacement Cost

Table 9 lists the costs and component lifetimes assumed for estimating existing component maintenance costs. The costs for multiple lamp fixtures are simple multiples of the single-lamp cost. Replacements are assumed to occur on an as-needed basis only, so that only one lamp or ballast is replaced at a time. The cost figures for multiple-lamp fixtures are costs for maintaining those fixtures over time, not for the simultaneous replacement of all bulbs in the fixture.

6.4.3 Retrofit Component Costs

Table 10 lists the lifetimes of components used in the retrofit options. Table A.15 in Appendix A lists the equipment cost. The retrofit labor cost includes a 20% reduction as an economy of scale, since the retrofit involves the simultaneous replacement of multiple lighting components. The retrofit total cost is used to estimate the initial cost of a retrofit option. The maintenance total cost is used to estimate the maintenance savings as described in Section 6.5.1.

A single-lamp fixture is not included in the fixture rebuild options because it is cheaper to replace single-lamp fixtures than to rebuild them. Therefore, single-lamp fluorescent fixtures are replaced in the moderate retrofit option. Larger fixtures are rebuilt.

6.4.4 Cost Calculations for Interior and Exterior Buildings

Detailed cost tables in Appendix A list the energy (in kilowatt-hours) and dollar savings for each floor in each building. (The spreadsheets used to calculate the savings are provided on the CD-ROM version of this report.) Summary tables for each retrofit option are given in Tables 11-13. The summary tables focus only on the cost savings, retrofit costs, and payback period.

6.5 SENSITIVITY ANALYSIS

To examine the robustness of the results, a sensitivity analysis of the payback under different assumed electricity rates was conducted. The method used was to marginally alter the price of electricity in the spreadsheets and recalculate the costs, savings, and payback period. The results of numerous marginal changes are graphically presented in Figure 1. Additional sensitivity analysis can be implemented if further research is undertaken.

TABLE 9 Costs for Existing Component Replacement

Component	Life (h)	Cost ($) Ballast	Lamp	Labor	Total
T-12, 40-W fluorescent					
1-lamp fixture	9,000		5.75	2.58	8.33
2-lamp fixture	9,000		11.50	5.16	16.66
3-lamp fixture	9,000		17.25	7.74	24.99
4-lamp fixture	9,000		23.00	10.32	33.32
Magnetic ballast	90,000	22.50		32.28	54.78
Incandescent					
< 100W	1,000		1.50	2.58	4.08
> 100W	750		4.50	2.58	7.08

TABLE 10 Retrofit Component Lifetimes

Component	Life (h)
T-12, 34-W, 1-lamp	15,000
T-8, 32-W, 1-lamp	20,000
T-8, 32-W, 2-lamp	20,000
T-8, 32-W, 3-lamp	20,000
T-8, 32-W, 4-lamp	20,000
T-8, 1×4, 1-lamp	20,000
T-8, 2×4, 2-lamp	20,000
Electronic ballast	240,000
Compact fluorescent light	10,000
75-W, PAR 38 floodlight	2,500

TABLE 11 Summary of Cost Analysis for Minimal Retrofit Option

	Annual Amount ($)						
Bldg.	Lighting Saved	Cooling Saved	Heating Penalty	Maintenance Saved	Total Saved	Retrofit Cost ($)	Payback Period (yr)
1	1,656	521	90	2,625	4,712	9,177	1.95
2	1,181	372	64	1,824	3,312	6,375	1.92
3	2,216	698	121	3,514	6,307	12,285	1.95
4	1,181	372	64	1,873	3,361	6,546	1.95
5	581	183	32	921	1,652	3,218	1.95
6	472	149	26	749	1,344	2,618	1.95
7	494	156	27	784	1,407	2,741	1.95
8	1,135	357	62	1,799	3,229	6,289	1.95
9	1,475	464	80	2,338	4,197	8,173	1.95
10	698	220	38	1,106	1,985	3,866	1.95
11	1,455	458	79	2,307	4,140	8,063	1.95
101	1,982	624	108	3,143	5,642	10,744	1.90
617	57	18	3	91	163	311	1.90
Total	14,583	4,593	796	23,072	41,452	80,407	1.94

TABLE 12 Summary of Cost Analysis for Intermediate Retrofit Option

	Annual Amount ($)						
Bldg.	Lighting Saved	Cooling Saved	Heating Penalty	Maintenance Saved	Total Saved	Retrofit Cost ($)	Payback Period (yr)
1	6,512	2,051	355	11,965	20,172	30,482	1.51
2	5,038	1,587	275	9,640	15,990	16,797	1.05
3	7,195	2,266	393	13,712	22,781	26,081	1.14
4	4,224	1,330	230	8,091	13,415	20,265	1.51
5	2,043	644	111	3,916	6,492	10,893	1.68
6	1,347	424	73	2,630	4,328	7,620	1.76
7	2,655	836	145	3,891	7,237	9,905	1.37
8	2,985	940	163	6,075	9,837	16,656	1.69
9	3,649	1,149	199	8,550	13,150	24,453	1.86
10	2,218	698	121	4,163	6,959	10,178	1.46
11	3,880	1,222	212	8,442	13,333	24,501	1.84
101	3,554	1,119	194	10,075	14,554	11,167	0.77
617	159	50	9	430	631	331	0.52
Total	45,461	14,318	2,480	91,580	148,878	209,330	1.41

TABLE 13 Summary of Cost Analysis for Advanced Retrofit Option

	Annual Amount ($)						
Bldg.	Lighting Saved	Cooling Saved	Heating Penalty	Maintenance Saved	Total Saved	Retrofit Cost ($)	Payback Period (yr)
1	10,324	3,251	563	12,641	25,654	33,743	1.42
2	8,688	2,736	474	10,283	21,233	19,405	0.99
3	14,466	4,556	789	14,996	33,228	34,284	1.15
4	7,785	2,452	425	8,721	18,533	20,965	1.24
5	3,751	1,181	205	4,218	8,945	10,951	1.35
6	2,701	851	147	2,869	6,274	8,683	1.54
7	4,127	1,300	225	4,151	9,352	9,767	1.12
8	6,723	2,117	367	6,735	15,208	18,874	1.40
9	8,344	2,628	455	9,380	19,897	25,248	1.42
10	4,440	1,398	242	4,556	10,152	11,552	1.26
11	8,089	2,548	441	9,189	19,385	26,392	1.53
101	8,454	2,663	461	10,951	21,607	34,148	1.83
617	351	110	19	464	906	982	1.21
Total	88,242	27,791	4,814	99,154	210,374	254,995	1.34

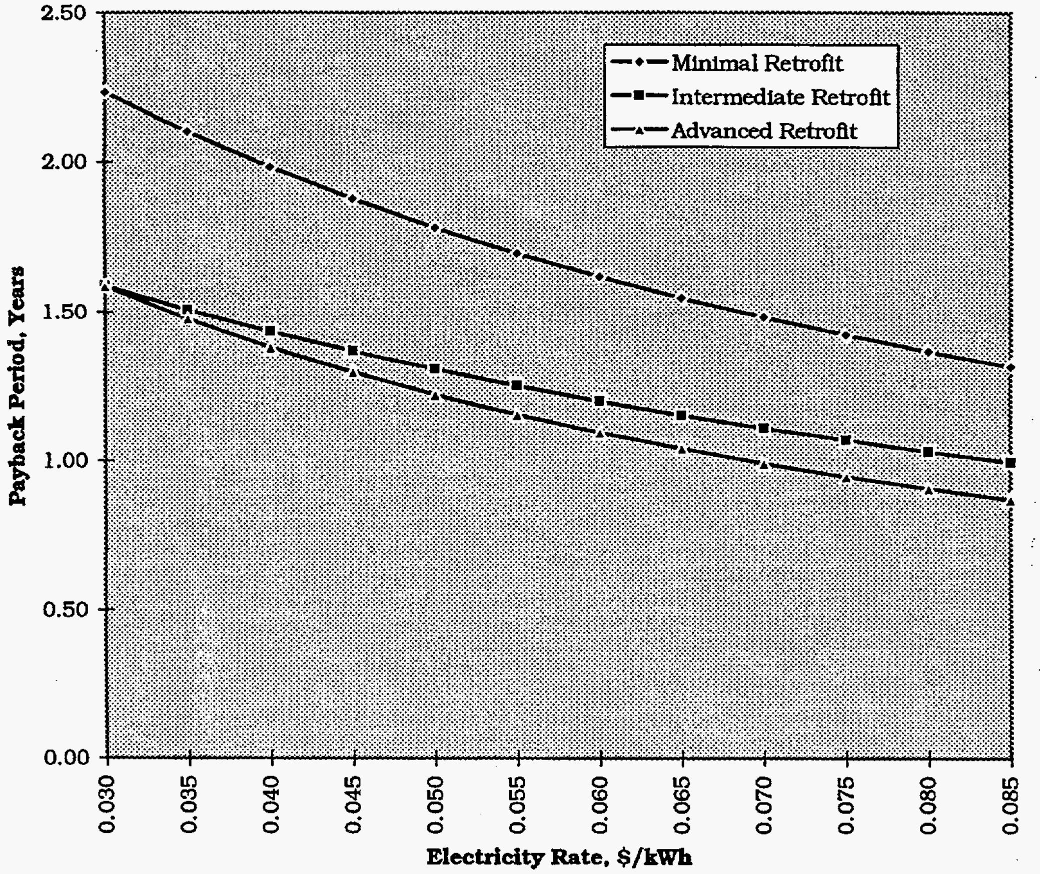


FIGURE 1 Sensitivity of Payback to Electricity Rate

7 RECOMMENDATIONS

Since the payback periods for all three options are less than two years, it would seem that the best option would be the one that requires the least outlay of funds. However, this is not the case. As detailed in the cost analysis section of this report, other factors must be considered when selecting which lighting option to implement. For this reason, we recommend that CMAS pursue the advanced retrofit option.

The minimal retrofit option only takes advantage of lower-wattage lamps. It does not address light levels, light quality, or harmonics — all issues that affect the work space. By ignoring fluorescent ballasts, it postpones the inevitable disposal issue. The lamps used in this option do improve energy efficiency by reducing lumen output. (For a typical two-lamp system, lumen output is reduced by 18% to 20%). However, unless these energy-saving (ES) lamps are installed only in areas that are currently overlit, their use might reduce light levels below recommended IES standards. Finally, there is no guarantee the estimated savings from this option would be fully realized; there is nothing to prevent the reinstallation of 40-W lamps sometime in the future. For these reasons, we could not support the minimal retrofit option.

Of the two remaining retrofit options, the advanced retrofit would be the most cost-effective option because it would reduce the overall number of fixtures while maintaining or improving light levels as determined by IES standards. Implementation of this option would result in the best overall reduction in the use of energy for lighting and further reduce costs by reducing cooling requirements. Installing light control systems in selected areas should reduce overall energy use even more. Estimates of energy savings resulting from control systems were not factored into the energy use totals; energy use figures for the areas where controls might be used were based on a 24-h period of operation. The use of control systems in areas of infrequent use would decrease energy demand, since lights would be shut off when people are not present. The advanced retrofit option would also immediately reduce light maintenance costs, not only because most fixtures and lamps would be new but also because the expected life spans of the recommended light equipment are longer than those of the existing equipment. (For example, magnetic ballasts are rated for 90,000 h of operation; electronic ballasts, which run cooler, are estimated to run for 240,000 h, more than two and one-half times longer.) This feature translates into a decrease in long-term maintenance costs. Finally, and most importantly, the lamps recommended in the advanced retrofit option can provide a better quality of light for the price. T-8 lamps provide a color rendering index (CRI) range of 70 to 85, which compares favorably with natural daylight's CRI of 80 to 89. For installations that never receive natural daylight, light quality is an important consideration.

APPENDIX A:

DETAILED COST TABLES

TABLE A.1 Overall Cost Savings from Using Retrofit Options at CMAS

Minimal Retrofit

BLDG	Currently Installed KW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Cost	Payback (years)
1	54.28	49.78	4.50	8,760	39,420	119.15	15.35	$1,656	$521	$90	$2,625	$4,712	$9,177	1.95
2	41.34	38.13	3.21	8,760	28,120	84.99	10.95	$1,181	$372	$64	$1,824	$3,312	$6,375	1.92
3	66.39	60.37	6.02	8,760	52,770	159.50	20.55	$2,216	$698	$121	$3,514	$6,307	$12,285	1.95
4	37.08	33.87	3.21	8,760	28,120	84.99	10.95	$1,181	$372	$64	$1,873	$3,361	$6,546	1.95
5	18.07	16.50	1.58	8,760	13,823	41.78	5.38	$581	$183	$32	$921	$1,652	$3,218	1.95
6	13.18	11.90	1.28	8,760	11,248	34.00	4.38	$472	$149	$26	$749	$1,344	$2,618	1.95
7	19.02	17.68	1.34	8,760	11,773	35.59	4.59	$494	$156	$27	$784	$1,407	$2,741	1.95
8	30.63	27.55	3.08	8,760	27,016	81.66	10.52	$1,135	$357	$62	$1,799	$3,229	$6,289	1.95
9	39.41	35.41	4.01	8,760	35,110	106.12	13.68	$1,475	$464	$80	$2,338	$4,197	$8,173	1.95
10	21.14	19.24	1.90	8,760	16,609	50.20	6.47	$698	$220	$38	$1,106	$1,985	$3,866	1.95
11	39.84	35.89	3.95	8,760	34,637	104.69	13.49	$1,455	$458	$79	$2,307	$4,140	$8,063	1.95
101	48.08	42.69	5.39	8,760	47,199	142.66	18.38	$1,982	$624	$108	$3,143	$5,642	$10,744	1.90
617	6.50	6.34	0.16	8,760	1,367	4.13	0.53	$57	$18	$3	$91	$163	$311	1.90
TOTALS	434.98	395.34	34.09	8,760	298,646	1,049.45	135.24	$14,583	$4,593	$796	$23,072	$41,452	$80,407	1.94

Intermediate Retrofit

BLDG	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Cost	Payback (years)
1	54.28	36.58	17.70	8,760	155,052	468.65	60.39	$6,512	$2,051	$355	$11,965	$20,172	$30,482	1.51
2	41.34	27.65	13.69	8,760	119,951	362.55	46.72	$5,038	$1,587	$275	$9,640	$15,990	$16,797	1.05
3	66.39	46.84	19.56	8,760	171,319	517.81	66.73	$7,195	$2,266	$393	$13,712	$22,781	$26,081	1.14
4	37.08	25.60	11.48	8,760	100,565	303.96	39.17	$4,224	$1,330	$230	$8,091	$13,415	$20,265	1.51
5	18.07	12.52	5.55	8,760	48,653	147.05	18.95	$2,043	$644	$111	$3,916	$6,492	$10,893	1.68
6	13.18	9.52	3.66	8,760	32,079	96.96	12.49	$1,347	$424	$73	$2,630	$4,328	$7,620	1.76
7	19.02	11.81	7.22	8,760	63,221	191.09	24.62	$2,655	$836	$145	$3,891	$7,237	$9,905	1.37
8	30.63	22.52	8.11	8,760	71,061	214.78	27.68	$2,985	$940	$163	$6,075	$9,837	$16,656	1.69
9	39.41	29.50	9.92	8,760	86,890	262.63	33.84	$3,649	$1,149	$199	$8,550	$13,150	$24,453	1.86
10	21.14	15.11	6.03	8,760	52,805	159.60	20.57	$2,218	$698	$121	$4,163	$6,959	$10,178	1.46
11	39.84	29.30	10.55	8,760	92,392	279.25	35.99	$3,880	$1,222	$212	$8,442	$13,333	$24,501	1.84
101	48.08	38.42	9.66	8,760	84,613	255.74	32.96	$3,554	$1,119	$194	$10,075	$14,554	$11,167	0.77
617	6.50	6.07	0.43	8,760	3,793	11.46	1.48	$159	$50	$9	$430	$631	$331	0.52
TOTALS	434.98	311.41	113.47	8,760	993,988	3,271.54	421.59	$45,461	$14,318	$2,480	$91,580	$148,878	$209,330	1.41

TABLE A.1 (Cont.)

Advanced Retrofit

BLDG	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Cost	Payback (years)
1	54.28	29.17	25.12	8,760	220,007	664.97	85.69	$9,240	$2,910	$504	$12,035	$23,681	$33,743	1.42
2	41.34	20.21	21.13	8,760	185,081	559.41	72.09	$7,773	$2,448	$424	$9,783	$19,581	$19,405	0.99
3	66.39	32.05	34.34	8,760	300,836	909.28	117.17	$12,635	$3,979	$689	$13,961	$29,886	$34,284	1.15
4	37.08	18.37	18.71	8,760	163,900	495.39	63.84	$6,884	$2,168	$376	$8,221	$16,897	$20,965	1.24
5	18.07	9.09	8.99	8,760	78,744	238.00	30.67	$3,307	$1,042	$180	$3,968	$8,137	$10,951	1.35
6	13.18	6.76	6.42	8,760	56,257	170.04	21.91	$2,363	$744	$129	$2,670	$5,648	$8,683	1.54
7	19.02	8.81	10.22	8,760	89,501	270.52	34.86	$3,759	$1,184	$205	$3,947	$8,685	$9,767	1.12
8	30.63	14.90	15.73	8,760	137,812	416.54	53.68	$5,788	$1,823	$316	$6,210	$13,505	$18,874	1.40
9	39.41	19.93	19.49	8,760	170,724	516.01	66.50	$7,170	$2,258	$391	$8,727	$17,765	$25,248	1.42
10	21.14	10.58	10.56	8,760	92,488	279.55	36.02	$3,884	$1,223	$212	$4,250	$9,146	$11,552	1.26
11	39.84	21.04	18.81	8,760	164,749	497.96	64.17	$6,919	$2,179	$377	$8,521	$17,242	$26,392	1.53
101	48.08	29.49	18.59	8,760	162,883	492.32	63.44	$6,841	$2,155	$373	$10,054	$18,677	$34,148	1.83
617	6.50	5.68	0.82	8,760	7,209	21.79	2.81	$303	$95	$17	$433	$815	$982	1.21
TOTALS	434.98	226.05	189.51	8,760	1,660,099	5,531.76	712.86	$76,868	$24,209	$4,193	$92,782	$189,666	$254,995	1.34

TABLE A.2 Cost Savings from Using Retrofit Options at Building 1

Minimal Retrofit

BLDG	Floor	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
1	FIRST FLOOR	11.55	10.33	1.22	8,760	10,722	32.41	4.18	$450	$142	$25	$714	$1,282	$2,496	1.95
1	SECOND FLOOR	20.89	18.68	2.20	8,760	19,290	58.30	7.51	$810	$255	$44	$1,285	$2,306	$4,491	1.95
1	THIRD FLOOR	21.84	20.77	1.07	8,760	9,408	28.44	3.66	$395	$124	$22	$627	$1,125	$2,190	1.95
TOTALS		54.28	49.78	4.50	8,760	39,420	119.15	15.35	$1,656	$521	$90	$2,625	$4,712	$9,177	1.95

Intrermediate Retrofit

BLDG	Floor	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
1	FIRST FLOOR	11.55	9.05	2.51	8,760	21,961	66.38	8.55	$922	$290	$50	$2,537	$3,700	$6,351	1.72
1	SECOND FLOOR	20.89	15.93	4.96	8,760	43,458	131.35	16.93	$1,825	$575	$100	$4,387	$6,688	$12,624	1.89
1	THIRD FLOOR	21.84	11.61	10.23	8,760	89,632	270.91	34.91	$3,765	$1,186	$205	$5,040	$9,785	$11,507	1.18
TOTALS		54.28	36.58	17.70	8,760	155,052	468.65	60.39	$6,512	$2,051	$355	$11,965	$20,172	$30,482	1.51

Advanced Retrofit

BLDG	Floor	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
1	FIRST FLOOR	11.55	6.18	5.37	8,760	47,059	142.24	18.33	$1,976	$622	$108	$2,588	$5,079	$7,344	1.45
1	SECOND FLOOR	20.89	12.16	8.73	8,760	76,484	231.17	29.79	$3,212	$1,012	$175	$4,390	$8,439	$15,017	1.78
1	THIRD FLOOR	21.84	10.83	11.01	8,760	96,465	291.57	37.57	$4,052	$1,276	$221	$5,057	$10,163	$11,381	1.12
TOTALS		54.28	29.17	25.12	8,760	220,007	664.97	85.69	$9,240	$2,910	$504	$12,035	$23,681	$33,743	1.42

TABLE A.3 Cost Savings from Using Retrofit Options at Building 2

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
2	FIRST FLOOR	25.92	23.80	2.124	8,760	18,606	56.24	7.25	$781	$246	$43	$1,239	$2,224	$4,331	1.95
2	SECOND FLOOR	6.40	5.83	0.576	8,760	5,046	15.25	1.97	$212	$67	$12	$336	$603	$1,175	1.95
2	THIRD FLOOR	9.02	8.51	0.51	8,760	4,468	13.50	1.74	$188	$59	$10	$249	$485	$869	1.79
TOTALS		41.34	38.13	3.21	8,760	28,120	84.99	10.95	$1,181	$372	$64	$1,824	$3,312	$6,375	1.92

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
2	FIRST FLOOR	25.92	17.62	8.307	8,760	72,769	219.95	28.34	$3,056	$963	$167	$5,700	$9,552	$9,690	1.01
2	SECOND FLOOR	6.40	4.43	1.968	8,760	17,240	52.11	6.71	$724	$228	$39	$1,196	$2,108	$3,994	1.89
2	THIRD FLOOR	9.02	5.60	3.418	8,760	29,942	90.50	11.66	$1,258	$396	$69	$2,744	$4,329	$3,113	0.72
TOTALS		41.34	27.65	13.693	8,760	119,951	362.55	46.72	$5,038	$1,587	$275	$9,640	$15,990	$16,797	1.05

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
2	FIRST FLOOR	25.92	12.59	13.337	8,760	116,832	353.13	45.51	$4,907	$1,545	$268	$5,801	$11,986	$12,500	1.04
2	SECOND FLOOR	6.40	3.09	3.313	8,760	29,022	87.72	11.30	$1,219	$384	$66	$1,226	$2,762	$3,830	1.39
2	THIRD FLOOR	9.02	4.54	4.478	8,760	39,227	118.56	15.28	$1,648	$519	$90	$2,756	$4,833	$3,075	0.64
TOTALS		41.34	20.21	21.128	8,760	185,081	559.41	72.09	$7,773	$2,448	$424	$9,783	$19,581	$19,405	0.99

TABLE A.4 Cost Savings from Using Retrofit Options at Building 3

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
3	FIRST FLOOR	9.76	8.91	0.86	8,760	7,516	22.72	2.93	$316	$99	$17	$501	$898	$1,750	1.95
3	SECOND FLOOR	9.60	8.69	0.91	8,760	7,937	23.99	3.09	$333	$105	$18	$529	$949	$1,848	1.95
3	THIRD FLOOR	39.53	35.27	4.26	8,760	37,318	112.79	14.54	$1,567	$494	$86	$2,485	$4,460	$8,687	1.95
3	AB/BB	7.50	7.50	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		66.39	60.37	6.02	8,760	52,770	159.50	20.55	$2,216	$698	$121	$3,514	$6,307	$12,285	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
3	FIRST FLOOR	9.76	7.07	2.69	8,760	23,599	71.33	9.19	$991	$312	$54	$2,431	$3,681	$5,392	1.46
3	SECOND FLOOR	9.60	7.02	2.58	8,760	22,627	68.39	8.81	$950	$299	$52	$1,864	$3,061	$3,960	1.29
3	THIRD FLOOR	39.53	30.88	8.66	8,760	75,818	229.16	29.53	$3,184	$1,003	$174	$7,999	$12,013	$16,557	1.38
3	AB/BB	7.50	1.88	5.63	8,760	49,275	148.93	19.19	$2,070	$652	$113	$1,418	$4,026	$171	0.04
TOTALS		66.39	46.84	19.56	8,760	171,319	517.81	66.73	$7,195	$2,266	$393	$13,712	$22,781	$26,081	1.14

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
3	FIRST FLOOR	9.76	4.94	4.82	8,760	42,258	127.73	16.46	$1,775	$559	$97	$2,463	$4,700	$5,438	1.16
3	SECOND FLOOR	9.60	5.01	4.59	8,760	40,191	121.48	15.65	$1,688	$532	$92	$1,888	$4,015	$5,407	1.35
3	THIRD FLOOR	39.53	20.23	19.31	8,760	169,112	511.14	65.87	$7,103	$2,237	$387	$8,193	$17,145	$23,268	1.36
3	AB/BB	7.50	1.88	5.63	8,760	49,275	148.93	19.19	$2,070	$652	$113	$1,418	$4,026	$171	0.04
TOTALS		66.39	32.05	34.34	8,760	300,836	909.28	117.17	$12,635	$3,979	$689	$13,961	$29,886	$34,284	1.15

TABLE A.5 Cost Savings from Using Retrofit Options at Building 4

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
4	FIRST FLOOR	12.28	11.02	1.26	8,760	11,038	33.36	4.30	$464	$146	$25	$735	$1,319	$2,570	1.95
4	SECOND FLOOR	12.26	11.19	1.07	8,760	9,356	28.28	3.64	$393	$124	$21	$623	$1,118	$2,178	1.95
4	THIRD FLOOR	11.94	11.06	0.88	8,760	7,726	23.35	3.01	$325	$102	$18	$515	$924	$1,799	1.95
4	AB/BB	0.60	0.60	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		37.08	33.87	3.21	8,760	28,120	84.99	10.95	$1,181	$372	$64	$1,873	$3,361	$6,546	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
4	FIRST FLOOR	12.28	9.03	3.26	8,760	28,514	86.18	11.11	$1,198	$377	$65	$2,461	$3,970	$7,201	1.81
4	SECOND FLOOR	12.26	8.21	4.05	8,760	35,469	107.21	13.82	$1,490	$469	$81	$2,491	$4,369	$6,739	1.54
4	THIRD FLOOR	11.94	8.22	3.73	8,760	32,640	98.65	12.71	$1,371	$432	$75	$3,026	$4,754	$6,312	1.33
4	AB/BB	0.60	0.15	0.45	8,760	3,942	11.91	1.54	$166	$52	$9	$113	$322	$14	0.04
TOTALS		37.08	25.60	11.48	8,760	100,565	303.96	39.17	$4,224	$1,330	$230	$8,091	$13,415	$20,265	1.51

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
4	FIRST FLOOR	12.28	6.27	6.02	8,760	52,691	159.26	20.52	$2,213	$697	$121	$2,504	$5,293	$8,080	1.53
4	SECOND FLOOR	12.26	5.72	6.54	8,760	57,282	173.13	22.31	$2,406	$758	$131	$2,539	$5,571	$6,812	1.22
4	THIRD FLOOR	11.94	6.24	5.71	8,760	49,985	151.08	19.47	$2,099	$661	$115	$3,065	$5,711	$6,059	1.06
4	AB/BB	0.60	0.15	0.45	8,760	3,942	11.91	1.54	$166	$52	$9	$113	$322	$14	0.04
TOTALS		37.08	18.37	18.71	8,760	163,900	495.39	63.84	$6,884	$2,168	$376	$8,221	$16,897	$20,965	1.24

TABLE A.6 Cost Savings from Using Retrofit Options at Building 5

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
	FIRST FLOOR	6.62	5.90	0.72	8,760	6,307	19.06	2.46	$265	$83	$14	$420	$754	$1,468	1.95
5	SECOND FLOOR	5.18	4.96	0.23	8,760	1,997	6.04	0.78	$84	$26	$5	$133	$239	$465	1.95
5	THIRD FLOOR	5.57	4.94	0.63	8,760	5,519	16.68	2.15	$232	$73	$13	$368	$660	$1,285	1.95
5	AB/BB	0.70	0.70	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		18.07	16.50	1.58	8,760	13,823	41.78	5.38	$581	$183	$32	$921	$1,652	$3,218	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
5	FIRST FLOOR	6.62	5.21	1.41	8,760	12,352	37.33	4.81	$519	$163	$28	$1,466	$2,119	$4,778	2.25
5	SECOND FLOOR	5.18	2.78	2.40	8,760	21,059	63.65	8.20	$884	$279	$48	$1,231	$2,346	$1,610	0.69
5	THIRD FLOOR	5.57	4.36	1.22	8,760	10,643	32.17	4.15	$447	$141	$24	$1,122	$1,685	$4,312	2.56
5	AB/BB	0.70	0.18	0.53	8,760	4,599	13.90	1.79	$193	$61	$11	$97	$341	$193	0.57
TOTALS		18.07	12.52	5.55	8,760	48,653	147.05	18.95	$2,043	$644	$111	$3,916	$6,492	$10,893	1.68

Advanced retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
5	FIRST FLOOR	6.62	3.47	3.15	8,760	27,594	83.40	10.75	$1,159	$365	$63	$1,494	$2,955	$4,627	1.57
5	SECOND FLOOR	5.18	2.47	2.72	8,760	23,818	71.99	9.28	$1,000	$315	$55	$1,227	$2,488	$1,964	0.79
5	THIRD FLOOR	5.57	2.98	2.60	8,760	22,732	68.71	8.85	$955	$301	$52	$1,150	$2,353	$4,167	1.77
5	AB/BB	0.70	0.18	0.53	8,760	4,599	13.90	1.79	$193	$61	$11	$97	$341	$193	0.57
TOTALS		18.07	9.09	8.99	8,760	78,744	238.00	30.67	$3,307	$1,042	$180	$3,968	$8,137	$10,951	1.35

TABLE A.7 Cost Savings from Using Retrofit Options at Building 6

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
6	FIRST FLOOR	2.99	2.74	0.26	8,760	2,260	6.83	0.88	$95	$30	$5	$151	$270	$526	1.95
6	SECOND FLOOR	4.62	4.12	0.49	8,760	4,310	13.03	1.68	$181	$57	$10	$287	$515	$1,003	1.95
6	THIRD FLOOR	4.97	4.44	0.53	8,760	4,678	14.14	1.82	$196	$62	$11	$312	$559	$1,089	1.95
6	AB/BB	0.60	0.60	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		13.18	11.90	1.28	8,760	11,248	34.00	4.38	$472	$149	$26	$749	$1,344	$2,618	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
6	FIRST FLOOR	2.99	2.05	0.94	8,760	8,269	24.99	3.22	$347	$109	$19	$602	$1,040	$1,460	1.40
6	SECOND FLOOR	4.62	3.51	1.11	8,760	9,689	29.28	3.77	$407	$128	$22	$971	$1,484	$3,544	2.39
6	THIRD FLOOR	4.97	3.81	1.16	8,760	10,179	30.77	3.96	$428	$135	$23	$974	$1,513	$2,451	1.62
6	AB/BB	0.60	0.15	0.45	8,760	3,942	11.91	1.54	$166	$52	$9	$83	$292	$165	0.57
TOTALS		13.18	9.52	3.66	8,760	32,079	96.96	12.49	$1,347	$424	$73	$2,630	$4,328	$7,620	1.76

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
6	FIRST FLOOR	2.99	1.51	1.48	8,760	13,000	39.29	5.06	$546	$172	$30	$608	$1,296	$1,793	1.38
6	SECOND FLOOR	4.62	2.49	2.13	8,760	18,624	56.29	7.25	$782	$246	$43	$983	$1,969	$3,506	1.78
6	THIRD FLOOR	4.97	2.61	2.36	8,760	20,691	62.54	8.06	$869	$274	$47	$996	$2,092	$3,219	1.54
6	AB/BB	0.60	0.15	0.45	8,760	3,942	11.91	1.54	$166	$52	$9	$83	$292	$165	0.57
TOTALS		13.18	6.76	6.42	8,760	56,257	170.04	21.91	$2,363	$744	$129	$2,670	$5,648	$8,683	1.54

TABLE A.8 Cost Savings from Using Retrofit Options at Building 7

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
7	FIRST FLOOR	5.34	4.79	0.56	8,760	4,888	14.77	1.90	$205	$65	$11	$326	$584	$1,138	1.95
7	SECOND FLOOR	6.96	6.74	0.22	8,760	1,892	5.72	0.74	$79	$25	$4	$126	$226	$440	1.95
7	THIRD FLOOR	5.92	5.35	0.57	8,760	4,993	15.09	1.94	$210	$66	$11	$333	$597	$1,162	1.95
7	AB/BB	0.80	0.80	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		19.02	17.68	1.34	8,760	11,773	35.59	4.59	$494	$156	$27	$784	$1,407	$2,741	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
7	FIRST FLOOR	5.34	4.15	1.19	8,760	10,459	31.61	4.07	$439	$138	$24	$1,258	$1,811	$3,854	2.13
7	SECOND FLOOR	6.96	3.05	3.91	8,760	34,278	103.60	13.35	$1,440	$453	$79	$1,195	$3,010	$2,258	0.75
7	THIRD FLOOR	5.92	4.41	1.51	8,760	13,228	39.98	5.15	$556	$175	$30	$1,327	$2,027	$3,572	1.76
7	AB/BB	0.80	0.20	0.60	8,760	5,256	15.89	2.05	$221	$70	$12	$111	$389	$221	0.57
TOTALS		19.02	11.81	7.22	8,760	63,221	191.09	24.62	$2,655	$836	$145	$3,891	$7,237	$9,905	1.37

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
7	FIRST FLOOR	5.34	2.92	2.42	8,760	21,234	64.18	8.27	$892	$281	$49	$1,283	$2,407	$3,708	1.54
7	SECOND FLOOR	6.96	2.69	4.27	8,760	37,431	113.14	14.58	$1,572	$495	$86	$1,196	$3,177	$2,296	0.72
7	THIRD FLOOR	5.92	3.00	2.92	8,760	25,579	77.31	9.96	$1,074	$338	$59	$1,357	$2,711	$3,543	1.31
7	AB/BB	0.80	0.20	0.60	8,760	5,256	15.89	2.05	$221	$70	$12	$111	$389	$221	0.57
TOTALS		19.02	8.81	10.22	8,760	89,501	270.52	34.86	$3,759	$1,184	$205	$3,947	$8,685	$9,767	1.12

TABLE A.9 Cost Savings from Using Retrofit Options at Building 8

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
8	FIRST FLOOR	13.72	12.11	1.60	8,760	14,034	42.42	5.47	$589	$186	$32	$935	$1,677	$3,267	1.95
8	SECOND FLOOR	5.56	5.12	0.43	8,760	3,784	11.44	1.47	$159	$50	$9	$252	$452	$881	1.95
8	THIRD FLOOR	10.26	9.21	1.05	8,760	9,198	27.80	3.58	$386	$122	$21	$613	$1,099	$2,141	1.95
8	AB/BB	1.10	1.10	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		30.63	27.55	3.08	8,760	27,016	81.66	10.52	$1,135	$357	$62	$1,799	$3,229	$6,289	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
8	FIRST FLOOR	13.72	11.06	2.66	8,760	23,310	70.46	9.08	$979	$308	$53	$2,584	$3,818	$6,245	1.64
8	SECOND FLOOR	5.56	3.56	2.00	8,760	17,529	52.98	6.83	$736	$232	$40	$1,191	$2,119	$3,099	1.46
8	THIRD FLOOR	10.26	7.64	2.63	8,760	22,995	69.50	8.96	$966	$304	$53	$2,147	$3,365	$7,009	2.08
8	AB/BB	1.10	0.28	0.83	8,760	7,227	21.84	2.81	$304	$96	$17	$153	$535	$303	0.57
TOTALS		30.63	22.52	8.11	8,760	71,061	214.78	27.68	$2,985	$940	$163	$6,075	$9,837	$16,656	1.69

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
8	FIRST FLOOR	13.72	7.10	6.62	8,760	58,000	175.31	22.59	$2,436	$767	$133	$2,651	$5,722	$8,854	1.55
8	SECOND FLOOR	5.56	2.51	3.05	8,760	26,727	80.78	10.41	$1,123	$354	$61	$1,205	$2,620	$3,042	1.16
8	THIRD FLOOR	10.26	5.03	5.24	8,760	45,859	138.61	17.86	$1,926	$607	$105	$2,201	$4,628	$6,674	1.44
8	AB/BB	1.10	0.28	0.83	8,760	7,227	21.84	2.81	$304	$96	$17	$153	$535	$303	0.57
TOTALS		30.63	14.90	15.73	8,760	137,812	416.54	53.68	$5,788	$1,823	$316	$6,210	$13,505	$18,874	1.40

TABLE A.10 Cost Savings from Using Retrofit Options at Building 9

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
9	FIRST FLOOR	12.73	11.49	1.25	8,760	10,932	33.04	4.26	$459	$145	$25	$728	$1,307	$2,545	1.95
9	SECOND FLOOR	12.72	11.44	1.28	8,760	11,248	34.00	4.38	$472	$149	$26	$749	$1,344	$2,618	1.95
9	THIRD FLOOR	13.06	11.58	1.48	8,760	12,930	39.08	5.04	$543	$171	$30	$861	$1,545	$3,010	1.95
9	AB/BB	0.90	0.90	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		39.41	35.41	4.01	8,760	35,110	106.12	13.68	$1,475	$464	$80	$2,338	$4,197	$8,173	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
9	FIRST FLOOR	12.73	9.20	3.54	8,760	31,002	93.70	12.08	$1,302	$410	$71	$2,759	$4,400	$8,329	1.89
9	SECOND FLOOR	12.72	9.74	2.99	8,760	26,166	79.09	10.19	$1,099	$346	$60	$3,046	$4,431	$8,563	1.93
9	THIRD FLOOR	13.06	10.34	2.72	8,760	23,810	71.96	9.27	$1,000	$315	$55	$2,621	$3,881	$7,313	1.88
9	AB/BB	0.90	0.23	0.68	8,760	5,913	17.87	2.30	$248	$78	$14	$125	$438	$248	0.57
TOTALS		39.41	29.50	9.92	8,760	86,890	262.63	33.84	$3,649	$1,149	$199	$8,550	$13,150	$24,453	1.86

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
9	FIRST FLOOR	12.73	6.23	6.51	8,760	57,019	172.34	22.21	$2,395	$754	$131	$2,813	$5,831	$8,032	1.38
9	SECOND FLOOR	12.72	6.71	6.02	8,760	52,709	159.31	20.53	$2,214	$697	$121	$3,105	$5,895	$8,272	1.40
9	THIRD FLOOR	13.06	6.77	6.29	8,760	55,083	166.49	21.45	$2,313	$729	$126	$2,685	$5,601	$8,697	1.55
9	AB/BB	0.90	0.23	0.68	8,760	5,913	17.87	2.30	$248	$78	$14	$125	$438	$248	0.57
TOTALS		39.41	19.93	19.49	8,760	170,724	516.01	66.50	$7,170	$2,258	$391	$8,727	$17,765	$25,248	1.42

TABLE A.11 Cost Savings from Using Retrofit Options at Building 10

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
10	FIRST FLOOR	4.19	3.85	0.35	8,760	3,048	9.21	1.19	$128	$40	$7	$203	$364	$ 709.67	1.95
10	SECOND FLOOR	7.77	7.21	0.56	8,760	4,941	14.93	1.92	$208	$65	$11	$329	$591	$ 1,150.16	1.95
10	THIRD FLOOR	8.17	7.19	0.98	8,760	8,620	26.05	3.36	$362	$114	$20	$574	$1,030	$ 2,006.66	1.95
10	AB/BB	1.00	1.00	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$ -	
TOTALS		21.14	19.24	1.90	8,760	16,609	50.20	6.47	$698	$220	$38	$1,106	$1,985	$ 3,866.49	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
10	FIRST FLOOR	4.19	3.06	1.14	8,760	9,978	30.16	3.89	$419	$132	$23	$1,107	$1,635	$ 2,409.94	1.47
10	SECOND FLOOR	7.77	5.17	2.60	8,760	22,794	68.89	8.88	$957	$302	$52	$1,450	$2,657	$ 3,579.64	1.35
10	THIRD FLOOR	8.17	6.64	1.54	8,760	13,464	40.70	5.24	$565	$178	$31	$1,467	$2,180	$ 3,913.25	1.80
10	AB/BB	1.00	0.25	0.75	8,760	6,570	19.86	2.56	$276	$87	$15	$139	$487	$ 275.66	0.57
TOTALS		21.14	15.11	6.03	8,760	52,805	159.60	20.57	$2,218	$698	$121	$4,163	$6,959	$10,178.49	1.46

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
10	FIRST FLOOR	4.19	2.28	1.92	8,760	16,810	50.81	6.55	$706	$222	$39	$1,124	$2,014	$ 2,283.92	1.13
10	SECOND FLOOR	7.77	3.88	3.89	8,760	34,094	103.05	13.28	$1,432	$451	$78	$1,476	$3,280	$ 3,600.57	1.10
10	THIRD FLOOR	8.17	4.18	4.00	8,760	35,014	105.83	13.64	$1,471	$463	$80	$1,512	$3,366	$ 5,391.68	1.60
10	AB/BB	1.00	0.25	0.75	8,760	6,570	19.86	2.56	$276	$87	$15	$139	$487	$ 275.66	0.57
TOTALS		21.14	10.58	10.56	8,760	92,488	279.55	36.02	$3,884	$1,223	$212	$4,250	$9,146	$11,551.84	1.26

TABLE A.12 Cost Savings from Using Retrofit Options at Building 11

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
11	FIRST FLOOR	16.64	15.08	1.56	8,760	13,666	41.30	5.32	$574	$181	$31	$910	$1,633	$3,181	1.95
11	SECOND FLOOR	10.22	9.27	0.95	8,760	8,357	25.26	3.26	$351	$111	$19	$557	$999	$1,945	1.95
11	THIRD FLOOR	12.08	10.64	1.44	8,760	12,614	38.13	4.91	$530	$167	$29	$840	$1,508	$2,937	1.95
11	AB/BB	0.90	0.90	0.00	8,760	0	0.00	0.00	$0	$0	$0	$0	$0	$0	
TOTALS		39.84	35.89	3.95	8,760	34,637	104.69	13.49	$1,455	$458	$79	$2,307	$4,140	$8,063	1.95

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
11	FIRST FLOOR	16.64	12.06	4.58	8,760	40,121	121.27	15.63	$1,685	$531	$92	$3,614	$5,737	$8,218	1.43
11	SECOND FLOOR	10.22	7.15	3.07	8,760	26,911	81.34	10.48	$1,130	$356	$62	$2,135	$3,560	$6,536	1.84
11	THIRD FLOOR	12.08	9.86	2.22	8,760	19,447	58.78	7.57	$817	$257	$45	$2,569	$3,598	$9,499	2.64
11	AB/BB	0.90	0.23	0.68	8,760	5,913	17.87	2.30	$248	$78	$14	$125	$438	$248	0.57
TOTALS		39.84	29.30	10.55	8,760	92,392	279.25	35.99	$3,880	$1,222	$212	$8,442	$13,333	$24,501	1.84

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
11	FIRST FLOOR	16.64	9.44	7.20	8,760	63,072	190.64	24.57	$2,649	$834	$145	$3,596	$6,935	$10,590	1.53
11	SECOND FLOOR	10.22	4.96	5.26	8,760	46,095	139.32	17.95	$1,936	$610	$106	$2,172	$4,612	$6,365	1.38
11	THIRD FLOOR	12.08	6.41	5.67	8,760	49,669	150.13	19.35	$2,086	$657	$114	$2,628	$5,257	$9,189	1.75
11	AB/BB	0.90	0.23	0.68	8,760	5,913	17.87	2.30	$248	$78	$14	$125	$438	$248	0.57
TOTALS		39.84	21.04	18.81	8,760	164,749	497.96	64.17	$6,919	$2,179	$377	$8,521	$17,242	$26,392	1.53

TABLE A.13 Cost Savings from Using Retrofit Options at Building 101

Minimal Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
101	FIRST FLOOR	24.78	22.10	2.68	8,760	23,494	71.01	9.15	$987	$311	$54	$1,565	$2,808	$5,348	1.90
101	SECOND FLOOR	23.30	20.59	2.71	8,760	23,705	71.65	9.23	$996	$314	$54	$1,579	$2,833	$5,396	1.90
TOTALS		48.08	42.69	5.39	8,760	47,199	142.66	18.38	$1,982	$624	$108	$3,143	$5,642	$10,744	1.90

Intermediate Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
101	FIRST FLOOR	24.78	19.48	5.30	8,760	46,437	140.36	18.09	$1,950	$614	$106	$5,297	$7,756	$5,651	0.73
101	SECOND FLOOR	23.30	18.94	4.36	8,760	38,176	115.39	14.87	$1,603	$505	$87	$4,778	$6,798	$5,516	0.81
TOTALS		48.08	38.42	9.66	8,760	84,613	255.74	32.96	$3,554	$1,119	$194	$10,075	$14,554	$11,167	0.77

Advanced Retrofit

BLDG	Floor	Currently Installed KW	Retrofit KW	KW Savings	Hours per year	Lighting KWH Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
101	FIRST FLOOR	24.78	14.69	10.10	8,760	88,441	267.31	34.45	$3,715	$1,170	$203	$5,311	$9,992	$16,915	1.69
101	SECOND FLOOR	23.30	14.80	8.50	8,760	74,442	225.00	29.00	$3,127	$985	$171	$4,744	$8,684	$17,233	1.98
TOTALS		48.08	29.49	18.594	8,760	162,883	492.32	63.44	$6,841	$2,155	$373	$10,054	$18,677	$34,148	1.83

TABLE A.14 Cost Savings from Using Retrofit Options at Building 617

Minimal Retrofit

BLDG	Floor	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
617	FIRST FLOOR	6.50	6.34	0.16	8,760	1,367	4.13	0.53	$57	$18	$3	$91	$163	$311	1.90
TOTALS		6.50	6.34	0.16	8,760	1,367	4.13	0.53	$57	$18	$3	$91	$163	$311	1.90

Intermediate Retrofit

BLDG	Floor	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
617	FIRST FLOOR	6.50	6.07	0.43	8,760	3,793	11.46	1.48	$159	$50	$9	$430	$631	$331	0.52
TOTALS		6.50	6.07	0.43	8,760	3,793	11.46	1.48	$159	$50	$9	$430	$631	$331	0.52

Advanced Retrofit

BLDG	Floor	Currently Installed kW	Retrofit kW	kW Savings	Hours per year	Lighting kWh Saved	Cooling MMBtu Saved	Heating Penalty (MMBtu)	Lighting $ Saved	Cooling $ Saved	Heating $ Penalty	Maintenance $ Saved	Total $ Saved	Retrofit Costs	Payback (years)
617	FIRST FLOOR	6.50	5.68	0.82	8,760	7,209	21.79	2.81	$303	$95	$17	$433	$815	$982	1.21
TOTALS		6.50	5.68	0.82	8,760	7,209	21.79	2.81	$303	$95	$17	$433	$815	$982	1.21

TABLE A.15 Cost Components

Retrofit Description	# of Lamps	Estimated Total Costs: Total Costs Outside	Total Costs Inside	Maintenance $ Saved
Replace existing T-12s with 34 watt, T-12s	1	$ 11.96	$ 12.24	3.50
	2	$ 23.93	$ 24.47	7.00
	3	$ 35.89	$ 36.71	10.50
	4	$ 47.86	$ 48.94	14.00
Replace existing T-12s with 32 watt, T-8 with electronic ballast	1	$ 66.63	$ 70.30	12.75
Assume one new ballast per installation	2	$ 73.04	$ 76.97	20.00
	3	$ 79.44	$ 83.65	27.25
	4	$ 85.85	$ 90.32	34.50
Replace entire T-12 fixture with new T-8 fixture	1	$ 54.43	$ 57.82	12.75
1x4				22.60
Replace entire T-12 fixture with new T-8 fixture, 2x4, 2 lamps	2	$ 91.64	$ 96.73	29.90
Replace existing Incandescent with Compact Fluorescent	1	$ 27.29	$ 27.57	13.90
Replace existing Incandescent with 75 Watt PAR-38 Flood	1	$ 6.58	$ 6.86	56.70
Install Fluorescent Task Light	1	$ 25.57	$ 26.08	-5.00
Install Light Control System	1	$ 177.81	$189.34	-15.78

APPENDIX B:

FLUORESCENT LAMP AND BALLAST RECYCLERS

TABLE B.1 Fluorescent Lamp and Ballast Recyclers

Name	Contact Information	Services Offered
Lighting Resources, Inc.	1522 East Victory Street Suite 2 Phoenix, AZ 85040 (602) 276-4278 or (800) 641-9253 Fax: (602) 276-5432	Fluorescent lamps and ballasts
Lighting Resources, Inc. Attn: John Chilcott	386 South Gordan Street Pomona, CA 91766 (714) 622-0881 or (800) 572-9253	Fluorescent lamps
Mercury Recovery Services	2021 South Myrtle Avenue Monrovia, CA 91016 (818) 301-1372	Fluorescent and HID lamps
Mercury Technologies International	30677 Huntwood Avenue Hayward, CA 94544 (800) 628-3675 Fax: (510) 429-1498	Fluorescent and HID lamps
Mercury Technologies International	9520 Jefferson Boulevard Culver City, CA 90232 (310) 836-4MTI Fax: (210) 836-3342	Southern California service center for fluorescent and HID lamps
Salesco U.S.A.	674 Via De La Valle Suite 203 Solona Beach, CA 92075 (619) 793-3460	Fluorescent lamps and ballasts and other PCB-contaminated material

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Compliance Plus, Inc.	110 Pepperidge Road Portland, CT 06480 (860) 342-2174 Fax: (860) 342-3742	Fluorescent lamps and ballasts and mercury switches
Luminaire International, Inc.	1018 36th Street Orlando, FL 32805 (407) 841-6569	Makes transportation arrangements within Florida but also operates outside the Florida area.
Mercury Technologies International	4317-L Fortune Place West Melbourne, FL 32904 (800) 808-4MTI Fax: (407) 355-3012	Fluorescent and HID lamps
Ballast & Lamp Recycling, Inc. (BLR)	1755 Mac Arthur Boulevard, NW Atlanta, GA 30318 (404) 355-1770 Fax: (404) 355-2022	Collects and transports fluorescent lamps and ballasts primarily from the southeastern United States. Sends lamps to Recyclights and ballasts to an EPA-approved incinerator.
Midwest Recycling & Mercury Recovery Services, Inc.	860 White Street Dubuque, IA 52001 (319) 556-8037	Fluorescent lamps and ballasts and various mercury chemicals and wastes
FulCircle Ballast Recyclers	Janet Ohm, Regional Manager North Central Office 2614 Stonewall Avenue Woodridge, IL 60517 (630) 434-0593 Fax: (630) 434-0594	Ballasts only

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Salesco U.S.A.	3800 North Wilke Road Suite 300 Arlington Heights, IL 60004-1267 (708) 259-8311 or (800) 881-6811	Fluorescent lamps and ballasts and other PCB-contaminated material
Ballast and Lamp Recycling, Inc. (BLR)	1002 West Troy Avenue Indianapolis, IN 46225 (317) 782-3228	Fluorescent lamps and ballasts
Lighting Resources, Inc.	5172 East 65th Street Indianapolis, IN 46220 (317) 577-9100 or (800) 466-9106 Fax: (317) 577-9161	Fluorescent lamps and ballasts. Has mercury retort facility.
Lighting Resources, Inc.	498 Park 800 Drive Greenwood, IN 46143 (317) 888-3889 or (800) 572-9253	Fluorescent lamps and ballasts
Lamp Recyclers of Louisiana, Inc.	46257 Morris Road P.O. Box 2962 Hammond, LA 70404-2962 (504) 345-4147 or (800) 309-9908 Fax: (504) 345-4775	Transports and recycles fluorescent and HID lamps. Transports and disposes of PCB and non-PCB ballasts.
Alta Resources Management Services	88-B Industry Avenue Springfield, MA 00104-9926 (413) 734-3399	Fluorescent lamps and ballasts

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Ensquare, Inc.	P.O. Box 1056 Brookline, MA 02146 (617) 776-7320 (612) 828-9722	Ballasts only
Global Recycling Technologies	P.O. Box 651 Stoughton, MA 02072 (617) 341-6080	Fluorescent lamps, ballasts, and dry-cell batteries
Salesco, U.S.A.	387 Page Street Stoughton, MA 02072 (617) 344-4074	Ballasts only
FulCircle Ballast Recyclers	Ron Waxell 1223 Clopton Bridge Rochester Hills, MI 48306 (810) 651-6589 or (800) 775-1516	Ballasts only
Dynex	23460 Industrial Park Drive Farmington Hills, MI 48335 (800) 733-9639	Ballasts only
Aagard Environmental Services	3291 Terminal Drive Egan, MN 55121 (612) 686-2371	Transports fluorescent lamps and ballasts for Recyclights.
Dynex	4751 Mustang Circle St. Paul, MN 55112 (800) 733-9639	Fluorescent lamps and ballasts

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Light Cycle, Inc.	1222 University Avenue St. Paul, MN 55104 (612) 649-1309	Fluorescent lamps and ballasts. Makes shipping arrangements.
Luminaire Recycling, Inc.	2161 University Avenue Suite 206 St. Paul, MN 55114 (612) 649-0079	Fluorescent lamps and ballasts, mercury switches, batteries (including Ni-Cad), and various mercury-containing chemicals
Mercury Technologies of MN	P.O. Box 13 Pine City Industrial Park Pine City, MN 55063-0013 (612) 629-7888	Fluorescent lamps
Recyclights	401 West 86th Street Minneapolis, MN 55420 (612) 948-0626 or (800) 831-2852 Fax: (612) 948-0627	Fluorescent lamps, mercury-containing devices, and dental amalgam
Retrofit Recycling, Inc.	RR 1, Box 41B Owatonna, MN 55060 (800) 795-1230 Fax: (507) 455-2192	Transports fluorescent lamps for Recyclights and offers fluorescent lamp consultation service in Midwestern counties
USA Lights	2007 County Road C-2 Roseville, MN 55113 (612) 628-9370	Fluorescent lamps

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Environmental Management Solutions, Inc.	P.O. Box 6434 High Point, NC 27262 (910) 869-8836 Fax: (910) 869-8704	Fluorescent lamps and ballasts
Transformer Service, Inc.	74 Regional Drive Concord, NH 03301 (603) 224-4006	Ballasts only
Mercury Refining Company	1218 Central Avenue Albany, NY 12205 (518) 459-3505 or (800) 833-3505	Fluorescent lamps, mercury button batteries, mercury switches
FulCircle Ballast Recyclers	Headquarters 509 Manida Street Bronx, NY 10474 (800) 581-0857 Fax: (718) 542-5335	Ballasts only
Eastern Environmental	473 Purdy Port Chester, NY 10573 (800) 808-PCBS or (914) 934-2100 Fax: (914) 934-9649	Ballast and fluorescent lamp recycling and transformer disposal.
American Recycling Co., Ltd.	7471 Tyler Boulevard Mentor, OH 44060 (216) 946-2221 Fax: (216) 946-0045	Fluorescent lamps and ballasts

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Clean Harbors Customer Service	4879 Spring Grove Avenue Cincinnati, OH 45232 (513) 681-5738 Fax: (513) 681-6246	Transports lamps or lamp components to a lamp retort or lamp recycling facility. Stabilizes lamps and delivers them to either a solid waste or hazardous waste landfill.
Dlubaks Glass Co.	11567 County Highway 110 Upper Sandusky, OH 43351 (419) 294-4466	Fluorescent and incandescent lamps and other glass materials
Environmental Recycling	5265 Tractor Road Suite B Toledo, OH 43612 (419) 269-1493 Fax: (419) 269-1594	Fluorescent lamps and nonleaking ballasts
I.G., Inc.	3476 Saint Rocco Court Cleveland, OH 44109 (216) 631-7710 Fax: (216) 631-7711	Fluorescent lamps, computer monitors, and televisions
LIGHTSOUT, Inc.	2301 Hamilton Avenue Cleveland, OH 44114 (216) 621-6367 Fax: (216) 621-7908	Collects and consolidates lamps for USA Lights and Ballasts Recycling, and ballasts for Full Circle Ballast Recyclers.
S.D. Myers	180 South Avenue Tallmage, OH 44278 (216) 633-2666, ext. 3344 Fax: (216) 633-6615	Ballasts only

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Sunpro	7392 Whipple Avenue, NW North Canton, OH 44720 (216) 966-0910 Fax: (216) 966-1954	Brokers fluorescent lamps and ballasts for industry and electrical equipment companies
USA Lamp and Ballast Recycling	5366 Este Avenue Cincinnati, OH 45232 (800) 778-6645 Fax: (606) 689-4594	Fluorescent and incandescent lamps and ballasts
Advanced Environmental Recycling Corporation	2591 Mitchell Avenue Allentown, PA 18103 (800) 554-AERC Fax: (610) 797-7696	Mercury devices, compounds and solutions, fluorescent and HID lamps, precious metals
American Waste Management, Inc.	P.O. Box 454 948 5th Avenue Coraopolis, PA 15108 (412) 262-0702 Fax: (412) 262-0701	Fluorescent and HID lamps and ballasts
Bethlehem Apparatus Co., Inc.	890 Front Street Hellertown, PA 18055 (610) 838-0701	Mercury lamps, mercury-containing thermometers, switches, batteries, and dental amalgam
Dlubak's Glass Co.	R.D. 1-274 Saxonburg Road Natrona Heights, PA 15065 (412) 224-6611	Glass materials, including fluorescent and incandescent lamps, CRTs, halogen lamps, and windshield glass

TABLE B.1 (Cont.)

Name	Contact Information	Services Offered
Ballast & Lamp Recycling, Inc. (BLR)	301 East 5th Avenue Suite 27 Corsicana, TX 75110 (903) 872-6866 Fax: (903) 872-6559	Collects and transports fluorescent lamps and ballasts. Sends ballasts to an EPA-approved incinerator and lamps to Recyclights.
NSSI, Inc.	5711 Etheridge Street Houston, TX 77087 (713) 641-0391	Fluorescent lamps and ballasts
Dynex	6801 Industrial Loop Greendale, WI 53129 (800) 249-3310	Fluorescent lamps and ballasts
Lamp Recyclers, Inc.	712 Packerland Drive P.O. Box 10794 Green Bay, WI 53707-0794 (800) 558-1166	Fluorescent lamps
Recycle Technologies, Inc.	1480 North Springdale Road Waukesha, WI 53186 (414) 798-3050	Fluorescent lamps and ballasts
Superior Services	P.O. Box 500 Port Washington, WI 53074 (414) 284-9101 or (800) 932-6216	Fluorescent lamps and ballasts. Has mercury retort facility.

APPENDIX C:

EPA INFORMATION ON FLUORESCENT LAMP DISPOSAL

United States
Environmental Protection
Agency

Air and Radiation
6202J

EPA 430-B-95-004
March 1995

LIGHTING WASTE DISPOSAL

Upgrading a lighting system will likely involve the removal and disposal of lamps and ballasts. Some of this waste may be hazardous, and you must manage it accordingly. This document provides an overview of issues relating to the disposal of lamps and ballasts. For project-specific assistance, please refer to the information resources provided at the end of this document.

Note: The information in this document is believed to be correct as of March 1995. EPA does not provide legal advice, nor does this document. Generators of lighting wastes should check with local, state and regional authorities for the most up-to-date information.

CONTENTS

DISPOSAL OF PCB-CONTAINING BALLASTS

ACTION CHECKLIST

- ✓ Investigate and follow state and local requirements for handling and disposing of ballasts.
- ✓ Identify ballasts that contain PCBs and ballasts that are leaking PCBs.
- ✓ Remove, handle, and dispose of *leaking* PCB-containing ballasts by high-temperature incineration.
- ✓ Green Lights recommends disposing of non-leaking PCB-containing ballasts in an environmentally responsible manner, such as by high-temperature incineration, recycling, or chemical or hazardous waste landfill.
- ✓ Maintain permanent records of PCB-containing ballast disposal.

DISPOSAL OF MERCURY-CONTAINING LAMPS

ACTION CHECKLIST

- ✓ Investigate and follow state and local requirements for handling and disposing of lamps.
- ✓ If you have not tested your mercury-containing lamp wastes to show that they are not hazardous, then assume they are hazardous and dispose of them as hazardous waste
- ✓ Mercury-containing lamps that test hazardous must be handled in compliance with hazardous waste regulations.
- ✓ Maintain permanent records of mercury-containing lamps that are disposed as hazardous waste.

PCB-CONTAINING BALLASTS

The primary concern regarding the disposal of used fluorescent ballasts is the health risk associated with polychlorinated biphenyls (PCBs). Human exposure to these possible carcinogens can cause skin, liver, and reproductive disorders. Fluorescent and high-intensity discharge (HID) ballasts contain a small capacitor that may contain high concentrations of PCBs (greater than 90% pure PCBs or 900,000 ppm). These chemical compounds were widely used as insulators in electrical equipment such as capacitors, switches, and voltage regulators through the late 1970s.

The Toxic Substances Control Act (TSCA) was enacted in 1976, and subsequently banned the production of PCBs in the United States. The specific regulations governing the use and disposal of PCBs are found in Volume 40 Code of Federal Regulations (CFR) Part 761.

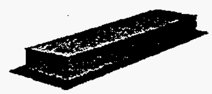
The proper method for disposing used ballasts depends on several factors, such as the type and condition of the ballasts and the regulations or recommendations in effect in the state(s) where you remove or discard them. TSCA specifies the disposal method for ballasts that are *leaking* PCBs. In addition, generators of PCB-containing ballast wastes may be subject to notification and liability provisions under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) — also known as "Superfund." To select the appropriate disposal method for PCB-containing ballasts, refer to the decision flow chart on the following page.

Because disposal requirements vary from state to state, check with regional, state, or local authorities for all applicable regulations in your area. For your convenience, information resources are listed at the end of this document.

Identifying PCB Ballasts

Use the following guidelines to identify ballasts that contain PCBs.

- All ballasts manufactured through 1979 contain PCBs.
- Ballasts manufactured after 1979 that do not contain PCBs are labeled **"No PCBs."**
- If a ballast is not labeled "No PCBs," *assume it contains PCBs.*



Contains PCBs

Manufactured through 1979

Probably does not contain PCBs

Manufactured after 1979

It is extremely important to find out if a ballast containing PCBs is leaking *before you remove it from the fixture,* so that you can handle it properly.

Federal Requirements

Non-Leaking PCB Ballast Disposal

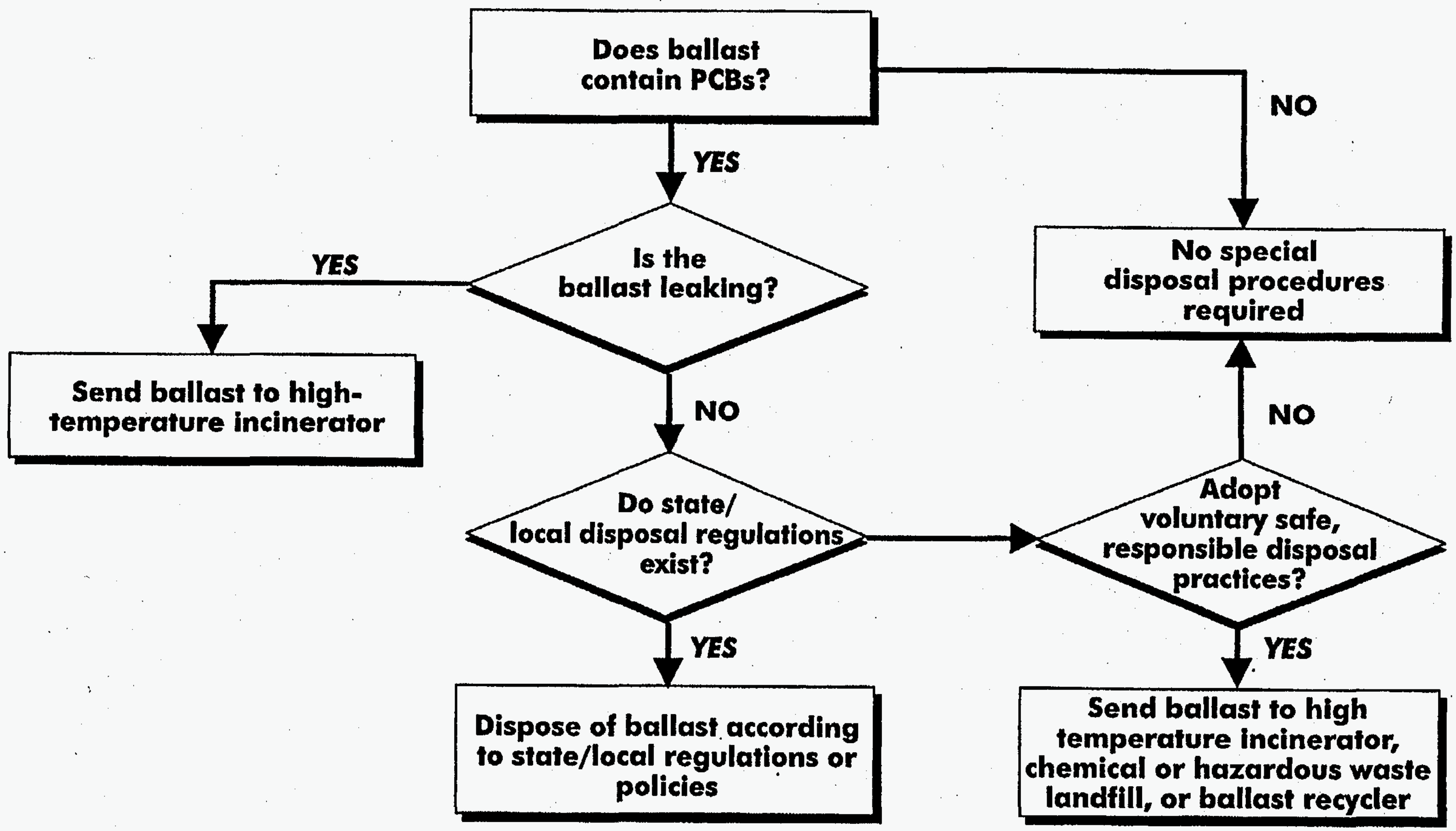
TSCA regulates ballasts that contain PCBs (40 CFR 761.60(b)(2)(ii)). Under TSCA, intact fluorescent and HID ballasts that are *not leaking* PCBs may be disposed in a municipal solid waste landfill. EPA recommends packing and sealing the intact ballasts in 55 gallon drums. Green Lights also encourages its participants to dispose of PCB-containing ballast wastes responsibly, and recommends high-temperature incineration, recycling, or a chemical or hazardous waste landfill.

In addition, CERCLA regulates the disposal of non-leaking PCB-containing ballasts. CERCLA requires building owners and waste generators to notify the National Response Center at (800) 424-8802. They must notify when disposing a pound or more of PCBs (roughly equivalent to 12-16 fluorescent ballasts) in a 24-hour period.

As a generator of PCB-containing ballast wastes, you could be liable in any subsequent Superfund cleanup at a municipal, hazardous, or chemical land disposal site, incinerator, or recycling facility.

EPA encouraged proper disposal of PCB-containing ballasts in the preamble to the 1979 PCB Ban Rule (44 FR 31514) and in the preamble to the final rule on August 25, 1982 (47 FR 37342).

"The EPA encourages commercial and industrial firms that use and dispose of large quantities of small PCB capacitors to establish voluntarily a collection and disposal program that would result in the waste capacitors going to chemical or hazardous waste landfills or high-temperature incinerators."


Does ballast contain PCBs?
YES
NO
Is the ballast leaking?
YES
Send ballast to high-temperature incinerator
NO
Do state/ local disposal regulations exist?
YES
Dispose of ballast according to state/local regulations or policies
No special disposal procedures required
NO
Adopt voluntary safe, responsible disposal practices?
YES
Send ballast to high temperature incinerator, chemical or hazardous waste landfill, or ballast recycler

Leaking PCB Ballast Disposal

A puncture or other damage to ballasts in a lighting system exposes an oily tar-like substance. If this substance contains PCBs, the ballast and all materials it contacts are considered PCB waste, and are subject to TSCA requirements. ***Leaking PCB-containing ballasts must be incinerated at an EPA-approved high-temperature incinerator.*** (See last section for a list of incinerators).

It is very important that you remove, handle, and dispose PCB-containing ballasts *properly*. Take precautions to prevent exposure of the leaking ballast, ***since all materials that contact the ballast or the leaking substance are also PCB waste***. Use trained personnel or contractors to handle and dispose leaking PCB-containing ballasts.

For proper packing, storage, transportation, and disposal information call the TSCA assistance information hotline at (202) 554-1404.

State Requirements

Non-Leaking PCB Ballast Disposal

Many states have developed regulations governing the disposal of non-leaking PCB-containing ballasts that are more stringent than Federal regulations. In addition, some EPA Regional offices published policies specifying ballast disposal methods adopted by individual states.

State standards can take several forms (e.g., written regulations, regional policies, written and verbal recommendations, transportation documentation). Some states do not regulate PCB-containing ballasts as toxic waste, but prohibit their disposal in municipal solid waste landfills. The table on the next page provides a listing of state regulations and recommendations. The last section of this document lists solid and hazardous waste agencies for states and EPA Regions.

All generators of PCB-containing ballasts should thoroughly investigate their state's regulations and follow local requirements.

Green Lights recommends three methods for disposing of *non-leaking* PCB-containing ballasts: high-temperature incineration, recycling, and chemical or hazardous waste landfill.

When upgrading lighting, make sure your contractor removes all disconnected PCB-containing ballasts from the lighting fixtures. Non-leaking PCB-containing ballasts may still be hazardous if left in upgraded fixtures, especially in case of fire.

High-Temperature Incineration

High-temperature incineration is the method preferred by many companies because it *destroys PCBs, removing them from the waste stream permanently and removing the potential for future CERCLA liability.* Incinerating a PCB-containing ballast costs more than sending it to a hazardous waste landfill, but this additional cost is one many organizations are willing to absorb.

Recycling Ballasts

Recyclers remove the PCB-containing materials (i.e., the capacitor and possibly the asphalt potting material surrounding the capacitor) for incineration or land disposal. Metals, such as copper and steel, can be reclaimed from the ballasts for use in manufacturing other products. You may recycle used non-leaking ballasts despite PCBs. The last section of this document contains a list of companies that recycle ballasts.

Chemical or Hazardous Waste Landfill

PCB-containing ballasts may also be disposed in a chemical or hazardous waste landfill. Landfill disposal is less expensive than high-temperature incineration or recycling, but does not eliminate PCBs from the waste stream permanently. While chemical or hazardous waste landfill disposal is an acceptable, regulated disposal method, your organization may be legitimately concerned about potential future CERCLA liability using this method.

Packing PCB Ballasts for Disposal

Despite the disposal method selected, ballasts are packed — according to PCB regulations — in 55-gallon drums for transportation.

- ☞ One drum holds 150 to 300 ballasts depending on how tightly the ballasts are packed.
- ☞ Fill void space with an absorbent packing material for safety reasons.
- ☞ Label drums according to Department of Transportation regulations.
- ☞ Note that tightly packed drums may weigh more than 1,000 pounds, which may present a safety risk, particularly when moving the drum for loading or unloading.

STATE REGULATIONS REGARDING BALLAST DISPOSAL

State	Comments
AK	Follow Federal Regulations.
AL	In-State landfill requires prior approval. Recommend incineration or chemical waste landfill.
AR	Follow Federal Regulations.
AZ	Municipal landfill requires approval from landfill operator.
CA	PCBs > 50 ppm are hazardous waste and must be placed in lab packs and disposed in hazardous waste landfill or incinerated.
CO	Non-leaking PCB ballasts require prior approval from solid waste landfill operator. Leaking PCB ballasts must be sent to high-temperature incinerator in accord to TSCA regulations. Non-PCB ballasts require approval from solid waste landfill operator
CT	PCB ballasts must be incinerated or sent to a chemical waste landfill.
DE	Follow Delaware Regulations Governing Hazardous Waste (DRGHW).
FL	Follow EPA Region 4 Policy.
GA	Follow EPA Region 4 Policy.
IA	Follow Federal Regulations.
ID	PCB-containing ballasts are governed according to EPA Region 10 policy (leaking ballasts or generation of more than 5 ballasts/year must be handled as PCB waste).
IL	Leaking PCB-containing ballasts meet definition of special waste (35 IAC).
IN	Disposing > 25 small capacitors of ballasts/day requires approval (329 IAC 4-1-10 (b) (1)).
KS	Follow Federal Regulations.
KY	Recommend recycling, chemical landfill, or incineration.
LA	PCBs > 50 ppm considered hazardous waste.
MA	Follow Federal Regulations.
MD	PCBs > 500 ppm regulated as acute hazardous waste. 1kg (based on entire weight of the ballasts) subject to full regulation as hazardous waste. Average limit is 1-2 ballasts.
ME	PCBs > 50 ppm regulated as hazardous waste.
MI	Follow EPA Region 5 policy.
MN	PCBs > 750 ppm regulated as hazardous waste. Ballasts may be handled as a special hazardous waste.
MO	Follow Federal regulations.
MS	PCB >50 ppm not allowed in municipal solid waste landfills.
MT	Follow Federal Regulations.
NC	PCB >50 ppm not allowed in municipal solid waste landfills.
ND	EPA has enforcement authority. ND encourages recycling through EPA approved process, TSCA incineration, or chemical landfills. Regulated PCB waste includes leaking PCB capacitors and ballast tar >50 ppm PCB.
NE	Follow Federal Regulations.
NH	Follow Federal regulations.
NJ	PCBs > 50 ppm considered hazardous waste.
NM	Follow EPA Region 6 policy.
NY	Ballast disposal must comply with 6NYCRR Part 364 (permitting of waste haulers) and 6NYCRR Part 360 (solid waste disposal).
OH	Follow Federal Regulations.
OK	Follow Federal Regulations.
OR	Follow EPA Region 10 policy (>5 ballasts/year must be incinerated or sent to chemical waste landfill.)
PA	PCBs > 50 ppm regulated by DER.
RI	PCBs > 50 ppm regulated as hazardous waste.
SC	Follow Federal Regulations.
SD	PCB ballasts are allowed to be disposed of at municipal landfills as long as the generator is not in the business of manufacturing these items.
TN	Follow Federal regulations.
TX	PCBs > 50 ppm are hazardous waste.
UT	Follow Federal regulations.
VA	PCB-containing materials regulated as Special Solid Waste. PCBs > 50 ppm may NOT be disposed or stored without EPA approval. PCBs between 1 and 50 ppm restricted to disposal in sanitary landfills or industrial waste landfills.
VT	PCBs > 50 ppm regulated as hazardous waste.
WA	Follow EPA Region 10 policy (>5 ballasts/yr must be incinerated or sent to chemical waste landfill.)
WI	Regulates all PCBs > 50 ppm as PCB waste.
WV	Follow EPA Region 3 policy.
WY	Recommend recycling of all ballasts. Follow EPA Region 8 policy.
Wash.DC	Follow Federal Regulations.

PCB Ballast Disposal Costs

High-temperature incineration and chemical or hazardous waste landfill costs can vary considerably. Disposal prices vary according to the following.

- quantity of waste generated
- location of removal site
- proximity to an EPA-approved high-temperature incinerator or chemical or hazardous waste landfill
- state and local taxes

When shopping for ballast disposal services, request cost estimates in terms of both pounds and number of ballasts. Typical F40 ballasts weigh about 3.5 lbs., and F96 ballasts weigh about 8 lbs. Negotiate with hazardous waste brokers, transporters, waste management companies, and disposal sites to obtain the lowest fees.

High-Temperature Incineration Costs

Incineration costs are calculated by weight.

- Costs range from $0.55/lb. to $2.10/lb.
- Average cost is $1.50/lb., which equals approximately **$5.25 per ballast.**

Note: Estimated costs do not include packaging, transportation, or profile fees.

Recycling Costs

When recyclers remove the PCB-containing capacitor, the volume and weight of the ballast are reduced. This change results in lower packing, transportation, and incineration or disposal costs.

Recycling costs are calculated by weight.

- Costs range from $0.75/lb. to $1.75/lb.
- Average cost is $1.00/lb., which equals approximately **$3.50 per ballast.**

Note: Recycling cost can range from $1.25 per ballast (if the PCB wastes are sent to a chemical or hazardous waste landfill) to approximately $3.50 per ballast (if the PCB wastes are high-temperature incinerated). Estimated costs do not include packaging, transportation, or profile fees.

Chemical or Hazardous Waste Landfill Costs

Chemical or hazardous waste landfill costs are calculated per 55-gallon drum.

- Costs range from $65/drum to $165/drum.
- Average cost is $100/drum, which equals approximately **$0.50/ballast.**

Note: Estimated costs do not include packaging, transportation, or profile fees.

Transportation Costs

Transportation fees are calculated as cents per pound per mile. They vary according to (1) the number of drums removed from the site, and (2) the distance from your location to the location of the high-temperature incinerator, chemical or hazardous waste landfill, or recycler.

Transporters may need to be registered or licensed to move hazardous wastes in certain states. Documentation of the movement of hazardous waste may be required even if a state does not regulate disposal or require the use of a licensed transporter.

Profile Fees

Operators of the high-temperature incinerator or chemical or hazardous waste landfill may charge a profile fee to document incoming hazardous waste. Profile fees vary depending on the volume of waste materials generated.

- Profile fees range from $0 to $300 per delivery.
- Fees may be waived if a certain volume or frequency of deliveries is assured or a working relationship has been established with a waste management broker, lighting management company, or other contractor.

Record Keeping

To track transported TSCA or hazardous waste, EPA requires generators to prepare a *Uniform Hazardous Waste Manifest.* The hazardous waste landfill, incinerator, or recycler that you use can provide this one-page form. The manifest identifies the type and quantity of waste, the generator, the transporter, and its ultimate destination.

The manifest must accompany the waste wherever it travels. Each handler of the waste must sign the manifest and keep one copy. When the waste reaches its destination, the owner of that facility returns a copy of the manifest to the generator to confirm that the waste arrived. If the waste does not arrive as scheduled, generators must immediately notify EPA or the authorized state environmental agency (see the last section), so that they can investigate and act appropriately.

In addition, require your contractor to provide you with documents verifying the disposal method, whether the PCBs are incinerated at high-temperatures or disposed in a chemical or hazardous waste landfill.

DEHP-CONTAINING BALLASTS

Di (2-ethylhexyl) phathatlate (DEHP) is a substance that was used to replace PCBs in certain ballast capacitors beginning in 1979. DEHP in its pure form is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA). However, once it has been used in a lighting ballast, *it is no longer hazardous* as defined by RCRA. (See 40 CFR 261.33, Part 261 Appendix VII, Section 268.34, and Section 268.43.)

DEHP is regulated under CERCLA—the Superfund law. The "Reportable Quantity" (RQ) of DEHP under CERCLA is 100 pounds. (See 40 CFR, Section 302.4.) This means that if you are disposing of 100 pounds or more of the material in a 24 hour period (approximately 1,600 fluorescent lighting ballasts), you are required to notify the National Resource Center at (800) 424-8802. It also means that parties involved with the disposal of DEHP ballasts may be held liable under Superfund if clean up of the DEHP is required.

DEHP has been found in ballasts designed for the following lighting fixtures: four foot fluorescent fixtures manufactured between 1979 and 1985; eight foot fluorescent fixtures manufactured between 1979 and 1991; and high intensity discharge (HID) fixtures manufactured between 1979 and 1991. Some ballasts manufactured during these periods may contain dry capacitors or substances other that DEHP. To make sure your ballasts do not contain DEHP, contact the manufacturer or send the capacitor to a laboratory for testing.

MERCURY-CONTAINING LAMPS

Fluorescent and high-intensity discharge (HID) lamps contain a small quantity of mercury that can be harmful to the environment and to human health when improperly managed. Mercury is regulated under RCRA, which is administered by the US Environmental Protection Agency. Under current Federal law, mercury-containing lamps — such as fluorescent and HID lamps — may be hazardous waste. In addition, incandescent and HID lamps may contain small quantities of lead that can also be potentially harmful to human health and the environment. To prevent these toxic materials from contaminating the environment, dispose of used lamps responsibly.

Federal Regulations

Resource Conservation and Recovery Act (RCRA)

RCRA requires generators of solid wastes containing toxic constituents (such as mercury) to determine whether or not the waste is hazardous by using generator knowledge or testing representative samples of that waste. According to RCRA, generators of used fluorescent and HID lamps are responsible for determining whether their lamp wastes are hazardous. *If you do not test used fluorescent and HID lamps and prove them non-hazardous, assume they are hazardous waste and dispose them accordingly.*

Generator Knowledge

To use generator knowledge in making a hazardous waste determination, the generator must have information on possible hazardous constituents and their quantities in the waste. Sometimes manufacturers generate solid waste as part of their manufacturing process, and can use process knowledge to determine whether the waste exhibits a characteristic of hazardous waste. However, with expired lamp wastes the generator has little process knowledge on which to make a hazardous waste determination (since he is not the manufacturer). The generator could base a determination on data obtained from the manufacturer, or he could refer to EPA's study entitled "Analytical Results of Mercury in Fluorescent Lamps" (dated 5/15/92, available in EPA's RCRA docket).

Testing Lamps To Determine If They Are Hazardous Waste

The Toxicity Characteristic Leaching Procedure (TCLP) identifies whether a waste is toxic and must be managed as hazardous waste. The test attempts to replicate the conditions in a municipal landfill to detect the mercury concentration of water that would leach from the landfill. If the mercury concentration exceeds 0.2 milligrams per liter, the lamp fails the toxicity test and is managed as hazardous waste.

When mercury-containing lamps are tested using the TCLP, the test results can vary considerably, depending on the lamp manufacturer, the age of the lamp, and the laboratory procedures used. These lamps often fail the TCLP. If you do not use the TCLP to verify that your lamps are non-hazardous, you should (1) assume that they are hazardous waste, and (2) manage them as hazardous waste. Contact your state hazardous waste agency for information on laboratories in your state that conduct the TCLP test. The cost to test one lamp is approximately $140. However, due to variability in TCLP testing for lamps, EPA recommends that more than one lamp be tested to make a hazardous waste determination.

For more information on RCRA regulations and waste identification, storage, transportation, and disposal, contact the RCRA hotline at 1-800-424-9346 (in the District of Columbia call 703-412-9810).

Conditionally Exempt Small Quantity Generators

A conditionally exempt small quantity generator, as defined under RCRA, is a generator who disposes 100 kg or less of hazardous waste per month. Generators must add the weight of all the hazardous waste (lamps plus other hazardous wastes) that their business generates during a month. For lamp disposal, this quantity of waste includes the mercury in the lamp along with the glass, phosphors, and other materials (the weight of the entire lamp).

Conditionally exempt small quantity generators are excused from RCRA identification, storage, treatment and disposal regulations. To qualify as a conditionally exempt small quantity generator (if the only hazardous waste is mercury-containing lamps), a generator must dispose of fewer than 300-350 four-foot T12 fluorescent lamps or 400-450 four-foot T8 fluorescent lamps per month, depending upon the approximate weight of each lamp. EPA encourages all users of fluorescent and HID lamps to dispose of mercury-containing lamps responsibly to limit the release of mercury into the environment.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

CERCLA also regulates the disposal of mercury-containing lamps. The law requires building owners and waste generators to notify the National Response Center at (800) 424-8802 under certain conditions. For example, they must notify if they dispose of a pound or more of mercury (roughly equivalent to 11,000 four-foot T12 fluorescent lamps) in a 24-hour period. All generators of mercury-containing lamp waste (large, small, and conditionally exempt small generators) could be held liable in any subsequent Superfund cleanup at a land disposal site, incinerator, storage site, or recycling or other treatment facility.

State Regulations

States may develop regulations *that are more stringent than current Federal requirements.* Several states are currently considering regulations that will affect the transportation, storage, and/or disposal of mercury-containing lamps. Check with your Regional EPA office or state agency to confirm the most current rules and information on fluorescent and HID lamp waste management in your state.

Disposal of Used Fluorescent and HID Lamps

The following sections outline the storage, packing, transportation and disposal options for used mercury-containing lamps discarded as hazardous waste.

Used lamps that test hazardous or are determined hazardous by the generator must be disposed of at a hazardous waste landfill or sent to a lamp recycling facility. *Mercury-containing lamps should never be incinerated.* Most municipal incinerators and solid waste combustors lack the necessary control technologies to effectively remove mercury from the flue gas before it is released into the atmosphere.

STATE REGULATIONS REGARDING MERCURY-CONTAINING LAMP DISPOSAL

State	Comments
AL	Lamps failing TCLP test are handled as hazardous waste, including hazardous waste transporter requirements. Lamps and bulbs that are recycled are NOT subject to reduced hazardous waste management requirements.
AK	Follow Federal (RCRA) regulations.
AZ	Follow Federal (RCRA) regulations.
AR	Follow Federal (RCRA) regulations.
CA	Over 25 lamps per 24 hour period must be disposed of as hazardous waste.
CO	Lamps exhibiting a characteristic of a hazardous waste would be expected to be managed in accordance with the Colorado Hazardous Waste Act. Non-hazardous lamps can be disposed in solid waste landfill with prior approval of landfill operator.
CT	Mercury-containing lamps are subject to Federal (RCRA) regulations through TCLP testing, and if they fail the TCLP test, must be treated as a hazardous waste.
DE	Lamps failing TCLP test must be managed and disposed of as a hazardous waste. Onsite storage of fluorescent lamps determined to be hazardous waste, for periods in excess of those allowable by DRGHW for the individual generatorÆs status, would require a Treatment, Storage and Disposal Facility (TSDF) permit or hazardous waste Transfer Facility approval. Shipments of all hazardous waste lamps offsite must be initiated to a permitted TSDF via a permitted hazardous waste transporter. Each shipment must be accompanied by a Uniform Hazardous Waste Manifest.
FL	After July 1, 1994, lamps may not be burned in any municipal waste incinerator. Generators of > 10 lamps/month must arrange disposal in permitted lined landfills or recycling at mercury reclamation facilities in accordance with Florida Department of Environmental Protection (FDEP) guidelines.
GA	Follow Federal (RCRA) regulations.
IA	Lamps failing TCLP test are considered hazardous waste. Recycling recommended. EPA RCRA transportation requirements apply.
ID	Follow Federal (RCRA) regulations. Conditionally-exempt generators may dispose of mercury-containing lamps in a municipal landfill with prior approval from the landfill operator.
IL	Lamps exhibiting the toxicity characteristic are subject to hazardous waste management. EPA has enforcement authority in IL.
IN	Subject to RCRA through TCLP testing and may be regulated as hazardous waste under 329 IAC 3.1.
KS	Follow Federal (RCRA) regulations.
KY	Follow Federal (RCRA) regulations.
LA	Follow Federal (RCRA) regulations.
MA	Can be shipped to a recycler without manifest.
MD	Lamps exhibiting the toxicity characteristic subject to hazardous waste regulations. Persons who generate 100 kg or more of hazardous waste or who accumulate 100 kg or more of hazardous waste at any time (all hazardous waste, not just lamps) are fully regulated hazardous waste generators.
ME	Waste that contains 0.2 mg/l or greater of mercury (fluorescent lamps) are regulated as hazardous waste.
MI	Lamps which fail TCLP test are hazardous waste, recommend recycling.
MN	Mercury containing lamps must be stored according to Minnesota Pollution Control Agency (MPCA) guidelines and shipped to an existing recycling facility in accordance with MPCA requirements.
MO	Recommend management as potentially hazardous waste.
MS	Follow Federal (RCRA) regulations.
MT	Follow Federal (RCRA) regulations.
NC	Hazardous waste lamps and bulbs (including bulbs with RCRA metals above regulatory level) from a commercial source must NOT be placed in a municipal solid waste landfill. Intact lamps and bulbs that are recycled are subject to reduced management requirements.
ND	Encourage recycling. Must be managed as a hazardous waste when total quantities of all hazardous waste from a facility is > 220 lbs/month. Each Subtitle D landfill determines their acceptance of exempt quantities.
NE	Follow Federal (RCRA) regulations. Small-quantity generators need state approval for special waste disposal in solid waste (Subtitle D) landfill. A hazardous waste manifest is required for all regulated generators of hazardous waste. A bill of lading is recommended for all conditionally exempt generators.
NH	Hazardous fluorescent lamps that are NOT designated for recycling or which are broken are subject to NH hazardous waste rules.
NJ	Follow Federal (RCRA) regulations.
NM	Recommend Recycling. Follow Federal (RCRA) regulations.
NY	Mercury-containing lamps must comply with the hazardous waste management regulations (6NYCRR Parts 370-374 and 376) if they fail TCLP test for any hazardous constituent.
OH	Lamps designated for recycling are NOT considered hazardous waste, and are not subject to Ohio hazardous waste regulations.
OK	Follow Federal (RCRA) regulations.
OR	Follow Federal (RCRA) regulations.
PA	Landfill only when certification shows that waste has passed the TCLP test.
RI	Treat as hazardous waste. Log system is used for transporters and generators.
SD	Follow Federal (RCRA) regulations.
SC	Follow Federal (RCRA) regulations.
TN	Follow Federal (RCRA) regulations. Tube crushers must meet state regulations. State approval is required for disposal of non-hazardous lamps and hazardous waste from small-quantity generators in solid waste (Subtitle D) landfills.
TX	Follow Federal (RCRA) regulations.
UT	Follow Federal (RCRA) regulations.
VA	Follow Federal (RCRA) regulations.
WA	Recommends recycling.
WI	Hazardous waste lamps and bulbs (including bulbs with high lead concentrations) may not be placed in a solid waste landfill. Lamps and bulbs that are recycled are subject to reduced hazardous waste management requirements.
WY	Recommend recycling.
Wash.DC	Follow Federal (RCRA) regulations. No exemptions for small-quantity generators.

Hazardous Waste Landfill

A hazardous waste landfill — also known as a RCRA Subtitle C facility — is a landfill that is permitted under Subtitle C of RCRA and is engineered to contain hazardous waste. Incoming wastes are manifested by the facility and some incoming wastes are subject to treatment standards.

Recycling Fluorescent and HID Lamps

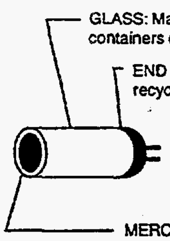
Any lamp may be recycled at permitted or licensed recycling facilities, regardless of whether the lamp tests hazardous. However, for lamps that are hazardous waste, generators must follow generation, transport, and storage requirements under RCRA Subtitle C. Recycling separates the toxic substances (such as mercury) from the glass, aluminum, and other lamp components, and all materials may be re-used in manufacturing other products. Some lamp recycling companies recycle HID lamps as well as fluorescent lamps. A list of companies that provide lamp recycling services is included in the last section.

Lamp Disposal Costs

The costs for lamp disposal by recycling or hazardous waste landfill can vary considerably. Prices vary according to the following.

- quantity of waste generated
- location of disposal site
- proximity to a permitted hazardous waste landfill or recycling facility
- state and local taxes

Negotiate with hazardous waste brokers, transporters, waste management companies, and disposal sites to obtain lowest fees.



Recycling Costs

Recycling costs for fluorescent lamps are typically calculated by linear foot. HID lamp recycling costs are typically quoted on a per-lamp basis.

- fluorescent recycling costs range from \$0.06/ft to \$0.15/ft
- average cost is \$0.10/ft
- approximately \$0.40 per F40 lamp
- HID recycling costs range from \$1.25/lamp to \$4.50/lamp
- average cost is \$2.50/lamp

Note: Estimated costs do not include packaging, transportation, or profile fees.

Chemical or Hazardous Waste Landfill Costs

Disposal costs for fluorescent lamps at a hazardous waste landfill range from 25-50 cents per 4-foot tube, not including costs for packaging, transportation, or profile fees.

Packing Lamps for Disposal

To prevent used fluorescent and HID lamps from breaking, lamps should be properly packed for storage and transportation. When lamps are removed and replaced with new lamps (e.g., during group relamping), the used lamps should be packed in the cardboard boxes that contained the replacement lamps. The boxes containing the hazardous waste must be properly labeled. Pre-printed labels or rubber stamps that meet Department of Transportation regulations are recommended for high-volume disposal.

Storing Lamps for Disposal

RCRA sets storage requirements for generators depending on how much hazardous waste they dispose each month.

- Small quantity generators dispose 100 to 1,000 kg of hazardous waste per month (which roughly corresponds to 350 to 3,600 four foot lamps), and can store hazardous waste up to 180 days.
- Large quantity generators dispose over 1,000 kg of hazardous waste per month (more than 3,600 four foot lamps), and can store hazardous waste up to 90 days.
- Conditionally exempt small quantity generators dispose 100 kg or less of hazardous waste per month and are exempt from RCRA storage requirements.

In addition to proper packing, care should be taken when stacking the boxes of used lamps for storage to avoid crushing the bottom boxes under the weight of the boxes on top. If you work with a contractor to maintain your lighting system, you may want to specify a safe storage arrangement in your contract. This approach ensures that your used lamps are not accidentally broken or crushed before they are sent to a disposal facility.

Some organizations crush their used lamps before disposal. This option should be pursued with care. The crushing equipment should have the approval of state and local authorities, and crushing methods should be evaluated *carefully*. The lamp should be crushed entirely *inside the drum or storage unit so that no mercury vapor enters the atmosphere.* There should also be adequate ventilation in the space where the crushing occurs. Under current EPA hazardous waste regulations, crushing lamps before sending them to a hazardous waste landfill may be considered treatment. Therefore, a RCRA treatment permit may be required.

Transportation

Registered haulers and other transporters of hazardous waste calculate transportation fees as cents per pound per mile. The costs will vary according to the number of lamps, drums, or other containers to be removed from the site and the distance from your location to the location of the hazardous waste landfill or recycling facility.

Profile Fees

Operators of chemical or hazardous waste landfills may charge a profile fee to document incoming waste. Profile fees vary depending on the volume of waste materials generated and may be waived if a certain volume or frequency of deliveries is assured. Establishing a working relationship with a lighting management company or lighting maintenance contractor who assists with the maintenance of your lighting system can reduce your disposal costs.

Record Keeping

To track transported waste, EPA requires generators to prepare a *Uniform Hazardous Waste Manifest.* This one-page form can be provided by the recycler or hazardous waste landfill where you dispose of your used fluorescent or HID lamps. The manifest identifies the type and quantity of waste, the generator, the transporter, and the facility to which the waste is being shipped. The manifest must accompany the waste wherever it travels. Each handler of the waste must sign the manifest and keep one copy. When the waste reaches its destination, the owner of that facility returns a copy of the manifest to the generator to confirm that the waste arrived. If the waste does not arrive as scheduled, generators must immediately notify EPA or the authorized state environmental agency (see the last section), so that they can investigate and take appropriate action.

In addition, require your contractor to provide you with documentation verifying that the lamps were properly recycled or disposed in a hazardous waste landfill.

Municipal Solid Waste Landfill

Lamp wastes generated in small quantities (see "Conditionally Exempt Small Quantity Generators" in the previous section) and used fluorescent and HID lamps that *do not test hazardous* under RCRA may be disposed in a properly managed municipal solid waste landfill (RCRA Subtitle D facility). The municipal landfill may impose restrictions or regulate incoming wastes in accordance with local rules or company guidelines. Disposal costs for lamps at a Subtitle D municipal solid waste landfill are approximately 2-3 cents per 4-foot lamp.

Generators may be legitimately concerned about potential future Superfund liability in connection with this disposal method. All generators of mercury-containing lamp waste, regardless of size, could be held liable in any subsequent Superfund cleanup at a municipal solid waste landfill.

EVALUATING DISPOSAL OPTIONS

Liability Issues

Under CERCLA, owners and operators of facilities and persons disposing hazardous substances may be held liable for response costs, if there is a release or threat of a release of a hazardous substance into the environment. Liability under CERCLA is broad and potentially costly, and can apply retroactively. All generators may incur Superfund liability for disposing mercury-containing lamps or PCB-containing ballasts in a dumpster, local landfill, or recycling, storage, or treatment facility. *Disposal of mercury wastes or PCBs in an environmentally sound manner, however, will help to minimize the potential for environmental contamination and thus also minimize the potential for liability.*

Impact of Lamp Disposal Cost on Profitability

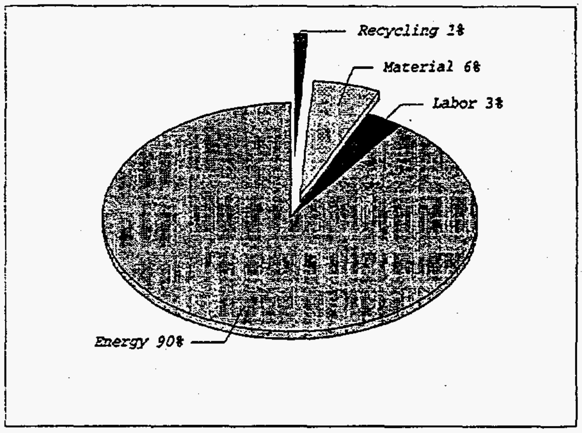
The overall impact of lamp disposal on the profitability of typical Green Lights lighting upgrade projects is minimal. The example below shows the impact of various lamp recycling costs on the internal rate of return (IRR) and the net present value (NPV) of a typical lighting upgrade project. The assumed project consists of upgrading a 4-lamp standard fluorescent system that uses magnetic ballasts and 40-watt lamps with a 4-lamp T8/electronic system and occupancy sensors. Without considering the cost of lamp disposal, the IRR and NPV were calculated at 47.1% and $52,242, respectively. Note that even when assuming lamp disposal costs of $1.50 per lamp — three times the average recycling cost — the IRR and NPV values decreased only slightly to 44.8% and $51,642, respectively. These results were obtained using the Green Lights analysis tool *Quikalc.*

Disposal Costs (per lamp)		
Lamp Disposal Cost	IRR	NPV
No fee	47.1%	$52,242
$0.50	46.3%	$52,042
$1.00	45.5%	$51,842
$1.50	44.8%	$51,642
$2.00	44.1%	$51,442
$2.50	43.4%	$51,242
$3.00	42.7%	$51,042
$3.50	42.1%	$50,842

Quikalc Assumptions

63% energy savings
Before: 2x4 4-lamp fixture, 40W T12 lamps, standard ballasts
After: 2x4 4-lamp fixture, 32W T8 lamps, electronic ballasts, occupancy sensors, 25% operating hour reduction

FLUORESCENT LAMP LIFE-CYCLE COST



The total cost of disposing of a lamp as a hazardous waste either by recycling or using a hazardous waste landfill can be put into perspective in three additional ways.

First, the cost of operating a lamp (including ballast losses) for its 20,000-hour life is $64 at the national average electric rate of 7 cents per kilowatt-hour. The 50-cent disposal cost is quite modest in comparison.

Second, replacing an old fixture with a new one usually costs about $100-$150, including installation. Disposing of an old fixture's lamps will cost approximately $2, depending on market conditions and disposal services purchased. If the new fixture uses half the electricity of the old fixture (as is typical with Green Lights upgrades), then the electric bill savings will pay for the cost of disposing of the old lamps after 310 hours of operation — about one month for most businesses. Essentially, lamp disposal will extend the payback of a project by approximately one month.

Third, as shown in the pie chart, the cost of disposing of a lamp as hazardous waste either by recycling or using a hazardous waste landfill represents only a small fraction of the total life-cycle operating costs of a lighting system. If operating a 2-lamp T8/electronic system, disposal as a hazardous waste represents only about 1 percent of total life-cycle operating costs.

- T8 lamps contain about 30 mg of mercury compared to 40 mg for T12 lamps
  - so less mercury is disposed of during relamping
- T8 lamps are more energy efficient than T12 lamps
  - so less mercury is emitted from fossil-fueled generating plants*

*(average emission is 0.04 mg/kWh)

Mercury Emissions and the Environment

The largest man-made sources of mercury in the atmosphere are fossil fuel combustion (58% of total) and municipal solid waste incineration (37% of total). When the mercury in a fossil fuel is heated in a combustor, it turns into a vapor. In vapor form, mercury is difficult to remove from the flue gas and easily escapes into the atmosphere. When moisture vapor in the atmosphere turns to rain, mercury returns to the earth and is deposited in streams, lakes, and other waterways.

The mercury that is released into the atmosphere by burning fossil fuels can be substantially minimized using efficient lighting technologies.

On average, fossil-fueled power plants emit 0.04 milligrams of mercury per kilowatt-hour sold. By *maximizing* the efficiency of your lighting system, you can *minimize* mercury emissions from the power plants that provide your electricity.

The graph on the next page illustrates the long-term benefit of upgrading to an efficient lighting system: *overall mercury emissions are significantly reduced.*

The amount of mercury emitted into the atmosphere through solid waste incineration and resource recovery facilities (which burn solid waste to produce energy) can be minimized if you adopt a sound lamp disposal practice. EPA will be proposing mercury emission limits for new and existing municipal solid waste incinerators in 1994.

WORKING WITH CONTRACTORS

Your lighting upgrade project specification should include provisions for proper handling and safe disposal of lamps, ballasts, and other hazardous materials that may be associated with the project.

Here are some general guidelines.

- Investigate your disposal options thoroughly.
- Do not expect your contractor to be well-versed in all disposal requirements and options.
- Ask your lighting or electrical contractor to provide disposal services (either directly or through a sub-contractor) as part of their contract.
- Be specific in your disposal requests (e.g., request high-temperature incineration of PCB-containing ballasts at an EPA-approved incinerator).
- Ask for certifications, licenses, and references from all subcontractors providing waste disposal services.

DEFINITIONS

CERCLA
The Comprehensive Emergency Response, Compensation and Liability Act of 1980. CERCLA — referred to also as "Superfund" — established cleanup and emergency response guidelines for releases of hazardous substances into the environment. A release of a hazardous substance in an amount equal to or greater than its "reportable quantity" (one pound for mercury and PCBs) in a 24-hour period triggers CERCLA notification requirements. CERCLA applies to any size generator.

Chemical Waste Landfill
A TSCA permitted landfill that accepts hazardous substances and extremely hazardous waste. These facilities must meet different engineering requirements than RCRA Subtitle C (hazardous waste) landfills.

Conditionally Exempt Small Quantity Generator (SQG)
A generator who generates 100 kilograms or less a month of a hazardous waste. Under RCRA, small quantity generators are exempt from RCRA regulations for the transportation, storage, treatment, and disposal of that hazardous waste.

Hazardous Waste Landfill
See Subtitle C landfill.

RCRA
The Resource Conservation and Recovery Act which regulates the management of solid (hazardous and non-hazardous) wastes. Under RCRA, generators of solid wastes are responsible for determining whether the solid wastes are hazardous and following RCRA transportation, storage, treatment, and disposal requirements for those wastes.

RCRA Subtitle C Landfill
A landfill containing hazardous wastes that is permitted under Subtitle C of RCRA. Land disposal of hazardous wastes is restricted to permitted RCRA Subtitle C disposal facilities.

RCRA Subtitle D Landfill
A municipal solid waste landfill containing non-hazardous wastes permitted under Subtitle D of RCRA.

TSCA
The Toxic Substances Control Act of 1976 which regulates the handling, storage, transportation and disposal of polychlorinated biphenyls (PCBs).

INFORMATION RESOURCES

EPA Regional Offices

REGION I (ME, VT, NH, MA, CT, RI)
Environmental Protection Agency
John F. Kennedy Federal Building
Room 2203
Boston, MA 02203
(617) 565-3420

REGION II (NY, NJ, PUERTO RICO, VIRGIN ISLANDS)
Environmental Protection Agency
Jacob K. Javits Federal Building
26 Federal Plaza
New York, NY 10278
(212) 264-2657

REGION III (PA, WV, VA, MD, DE, WASHINGTON DC)
Environmental Protection Agency
841 Chestnut Building
Philadelphia, PA 19107
(215) 597-9800

REGION IV (TN, KY, NC, SC, GA, AL, MS, FL)
Environmental Protection Agency
345 Courtland Street, NE
Atlanta, GA 30365
(404) 347-4727

REGION V (IL, WI, IN, MI, MN, OH)
Environmental Protection Agency
77 West Jackson Boulevard
Chicago, IL 60604-3507
(312) 353-2000

REGION VI (NM, TX, OK, AR, LA)
Environmental Protection Agency
First Interstate Bank Tower at Fountain Place
12th Floor/Suite 1200
1445 Ross Avenue
Dallas, TX 75202-2733
(214) 665-6444

REGION VII (NE, KS, MO, IA)
Environmental Protection Agency
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7000

REGION VIII (MT, WY, ND, SD, UT, CO)
Environmental Protection Agency
Suite 500
999 18th Street
Denver, CO 80202-2405
(303) 293-1603

REGION IX (CA, NV, AZ, HI, AMERICAN SAMOA, GUAM)
Environmental Protection Agency
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-1305

REGION X (WA, OR, ID, AK)
Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101
(206) 553-4973

State Solid and Hazardous Waste Agencies

ALABAMA
Department of Environmental Management
Land Division — Solid/Hazardous Waste
1751 Federal Drive
Montgomery, AL 36130
(205) 271-7761/7735

ALASKA
Steve Willingham
Manager, Solid Waste Program
State of Alaska
Department of Environmental Conservation
410 Willoughby Avenue
Juneau, Alaska 99801-1795
(907)465-5158

ARIZONA
Anthony Leverock
Arizona Department of Environmental Quality
Hazardous Waste Permits Unit
3033 North Central Avenue
Phoenix, AZ 85012
(602) 207-4160

ARKANSAS
Tom Ezell
Manager, Programs Branch
Department of Pollution Control and Ecology
Hazardous Waste Division
PO Box 8913
Little Rock, AR 72219-8913
(501) 562-7444
Fax (501) 562-6532

CALIFORNIA
Mardis Coers
Department of Toxic Substances Control
PO Box 806
Sacramento, CA 95812-0806
(916) 322-0712

COLORADO
Scott Klarich
Environmental Compliance Officer
Monitoring and Enforcement Section
Hazardous Materials and Waste Management Division
Colorado Department of Health and Environment
Mail Code: HMWMD-HWC-B2
4300 Cherry Creek Drive South
Denver, CO 80222-1530
(303) 692-3369

CONNECTICUT
Department of Environmental Protection
Waste Management Bureau
79 Elm Street
Hartford, CT 06106
(203) 566-8476

DELAWARE
Department of Natural Resources and Environmental Control
Division of Environmental Control
Solid Waste/Hazardous Waste Section
Edward Tatnall Building
PO Box 1401
Dover, DE 19901
(302) 739-4403

Delaware Solid Waste Authority
PO Box 71
New Castle, DE 19901
(302) 736-5361

DISTRICT OF COLUMBIA
Department of Consumer and Regulatory Affairs
Environmental Regulation Administration
Pesticides, Hazardous Waste and Underground Storage Tank Division
Hazardous Waste Management Branch
(Hazardous Waste Disposal)
2100 Martin Luther King, Jr. Ave. SE,
Suite 203
Washington, DC 20020
(202) 404-1167

Department of Public Works
Public Space Maintenance Administration
Bureau of Sanitation Services
(Solid Waste Disposal/Recycling)
2750 South Capitol St., SE
(202) 767-8512

FLORIDA
Raoul Clarke, Environmental Administrator
Bureau of Solid and Hazardous Waste
Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, Florida 32399-2400
(904) 488-0300

GEORGIA
Vern George
Environmental Protection Agency
Toxics Branch
345 Courtland St., NW
Atlanta, GA 30334
(404) 347-1033

Department of Natural Resources
Environmental Protection Division
Land Protection Branch
205 Butler Street, SE
Suite 1154
Atlanta, GA 30334
(404) 656-2833

HAWAII
State of Hawaii
Department of Health
Environmental Management Division
Clean Air Branch
Asbestos Abatement Office
PO Box 3378
Honolulu, HI 96801-3378
(808) 586-8144

IDAHO
William Fritell
Department of Health and Welfare
Division of Environment
Bureau of Hazardous Materials
450 W. State Street
Boise, ID 83720
(208) 334-5879

ILLINOIS
Clarence L. Smith
State of Illinois
Environmental Protection Agency
2200 Churchill Road
Springfield, IL 62794-9276
(217)524-3300

INDIANA
Robert Snodgrass
Solid Waste Permit Section
105 South Meridian Street
Indianapolis, IN 46206-6015
(317)232-5976

IOWA
Lavoy Haage
Department of Natural Resources
Solid Waste Section
Land Quality Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319
(515) 281-4968

KANSAS
Ron Smith
Department of Health and Environment
Solid Waste Management Division
Forbes AFB Bldg. No. 740
Topeka, KS 66620
(913) 296-1500

KENTUCKY
Abby Myer
Department for Environmental Protection
Division of Waste Management
Ft. Boone Plaza
14 Reilly Road
Frankfort, KY 40601
(502) 564-6716 x242

LOUISIANA
Department of Environmental Quality
Office of Solid and Hazardous Waste
Solid Waste Division
PO Box 44307
Baton Rouge, LA 70804
(504) 765-0355

MAINE
Department of Environmental Protection
Bureau of Oil & Hazardous Materials Control
State House Station 17
August, ME 04333
(207)287-2651

Waste Management Agency
State House Station 154
August, ME 04333
(207)287-5300

MARYLAND
Ed Hammerburg
Department of Environment
Toxic Operations Program
2500 Boening Highway
Baltimore, MD 21224
(410) 631-3345

MASSACHUSETTS
Victoria Phillips, Environmental Analyst
Office of Hazardous Waste
Enforcement Division
1 Winter Street
Boston, MA 02108
(617) 292-5812

MICHIGAN
Department of Natural Resources
Hazardous Waste Division
PO Box 30241
Lansing, MI 48909
(517) 373-2730

MINNESOTA
Nancy Ellefson
Minnesota Pollution Control Agency
Solid or Hazardous Waste Division
520 Lafayette Road North
St. Paul, MN 55155
(612) 296-6300

MISSISSIPPI
Russell Smith
Department of Environmental Quality
Office of Pollution Control
PO Box 10358
Jackson, MS 39209
(601) 961-5171

MISSOURI
Department of Natural Resources
Division of Environmental Quality
Waste Management Program
Jefferson State Office Building
205 Jefferson Street
PO Box 176
Missouri Boulevard
Jefferson City, MO 65102
(314) 751-3176

MONTANA
Don Vidrine
Department of Health and Environmental Sciences
Environmental Sciences Division
Solid and Hazardous Waste Bureau
PO Box 200901
Helena, MT 59620-0901
(406) 444-1430

NEBRASKA
Department of Environmental Control
PO Box 94877
State Office Building
Lincoln, NE 68509
(402) 471-2186

NEVADA
Colleen Crips
Bureau of Hazardous Waste
333 West Nye Lane
Carson City, NV 89710
(702) 687-5872

NEW HAMPSHIRE
Robert C. White, Chief
PCB Section
Department of Environmental Services
Air Resources Division/Toxics Management Bureau
64 N. Main St., Caller Box 2033
Concord, NH 03302-2033
(603) 271-1370

Department of Environmental Services
Waste Management Division/Compliance Bureau
6 Hazen Drive
Concord, NH 03301
(603) 271-2942

NEW JERSEY
Sandor Juhasz
NJ Department of Environmental
Protection and Energy
Hazardous Waste Regulation Program
401 East State Street
CN 421
Trenton, NJ 08625
(609) 292-8341

NJ Department of Environmental Protection and Energy
Solid Waste Management Division
840 Bear Tavern Road
CN 44
Trenton, NJ 08625
(609) 292-8341

NEW MEXICO
New Mexico Environmental Department
Harold Runnels Building
PO Box 26110
Santa Fe, New Mexico 87502

Hazardous and Radioactive Materials Bureau
(505) 827-4308

Solid Waste Bureau
(505) 827-2775

NEW YORK
Sharon Rader
Division of Hazardous Substances Regulation
New York State Department of Environmental
Conservation
50 Wolf Road
Albany, NY 12233
(518) 485-8988

NORTH CAROLINA
Department of Environment, Health, and Natural
Resources
Solid Waste Management/Hazardous Waste Division
PO Box 27687
Raleigh, NC 27611
(919) 733-2178

NORTH DAKOTA
Neil M. Knatterud, Director
Health Department
Division of Waste Management
1200 Missouri Avenue
PO Box 5520
Bismarck, ND 58502-5520
(701) 328-5166

OHIO
Environmental Protection Agency
Office of Solid and Hazardous Waste
PO Box 1049
1800 Watermark Drive
Columbus, OH 43266-0149
(614) 644-2917

OKLAHOMA
Ellen Bussert
Oklahoma Department of Environmental Quality
Public Information and Education
1000 Northeast 10th Street
Oklahoma City, OK 73117-1212
(405) 271-7353

OREGON
Gary Galaba
Department of Environmental Quality
Waste Management Clean-up Division
811 S.W. 6th Avenue
Portland, OR 97204
(503) 229-5630

PENNSYLVANIA
Department of Environmental Resources
Bureau of Waste Management
PO Box 8471
Harrisburg, PA 17105-8471

PUERTO RICO
Environmental Quality Board
Solid and Hazardous Waste Bureau
PO Box 11488
Santurce, PR 00910
(809) 725-5140

RHODE ISLAND
Robert Nero
Department of Environmental Management
Air and Hazardous Materials
291 Promenade Street
Providence, RI 02908
(401) 277-2797

SOUTH CAROLINA
Board of Health and Environmental Control
Bureau of Solid and Hazardous Waste
2600 Bull Street
Columbia, SC 29201
(803) 896-4174

SOUTH DAKOTA
Department of Water and Natural Resources
Environmental Health Division
Joe Foss Building
Pierre, SD 57501
(605) 773-3153

TENNESSEE
Wayne Gregory, Technical Coordinator
Department of Environment and Conservation
Division of Solid Waste Management
5th Floor, L&C Tower
401 Church Street
Nashville, TN 37243-1535
(615) 532-0780

TEXAS
Alice Hamilton Rogers, P.E., Technical Consultant
Texas Water Commission
PO Box 13087
1700 North Congress Avenue
Austin, TX 78711-3087
(512) 463-7830

UTAH
Rusty Lundburg
Department of Environmental Quality
Division of Solid and Hazardous Waste
PO Box 144880
Salt Lake City, Utah 84114-4880

VERMONT
Stephen Simoes,
Hazardous Materials Coordinator
Department of Environmental Conservation
Hazardous Materials Management Division
103 South Main Street
Waterbury, Vermont 05671-0404
(802) 241-3888

VIRGINIA
Robert Lincoln, Waste Division
Virginia Department of Environmental Quality
Special Solid Waste Program
P.O. Box 10009
Richmond, VA 22240
(804) 527-5357

WASHINGTON
Vern Meinz, Environmental Engineer
Department of Ecology
Solid and Hazardous Waste Program
PO Box 47600
Olympia, WA 98504-7600
(206) 407-6753

WEST VIRGINIA
WV Division of Environmental Protection
Office of Waste Management
1356 Hansford Street
Charleston, WV 25301
(304) 558-5929

WISCONSIN
Department of Natural Resources
Bureau of Solid Waste Management
101 South Webster Street
Madison, WI 53707
(608) 266-1327

WYOMING
Department of Environmental Quality
Solid Waste Management Program
122 West 25th Street
(307) 777-7752

TSCA, RCRA, and CERCLA Information Phone Lines

Toxic Substances Control Act (TSCA)
Assistance Information Hotline
(202) 554-1404

RCRA/CERCLA Hotline
(800) 424-9346
in the Washington, DC Metro Area
(703) 412-9810

CERCLA National Response Center
(NRC) Hotline
(800) 424-8802

EPA-Approved Disposal Locations

Commercially permitted PCB INCINERATORS operating as of June 1993

Aptus, Inc.
PO Box 1328
Coffeyville, KS 67337
(316) 251-6380

Aptus, Inc.
Aragonite, UT
(801) 266-7787

Chemical Waste Management
PO Box 2563
Port Arthur, TX 77643
(409) 736-2821
Environmental Energy Group
Denton, TX
(817) 383-3632

Environmental Energy Group
PO Box 50764
Denton, TX 76206
(817) 898-1291

Rollins
PO Box 609
Deer Park, TX 77536
(713) 930-2300

Commercially permitted HAZARDOUS WASTE LANDFILLS operating as of June 1993

Chem-Security Systems Incorporated
Star Route, Box 9
Arlington, OR 98712
(503) 454-2643

Chemical Waste Management
Call 1-800-843-3604 for
information on CWM disposal
facilities nation-wide.

Envirosafe Services Inc. of Idaho
PO Box 16217
Boise, ID 83715-6217
(800) 274-1516

US Ecology, Inc.
Box 578
Beatty, NV 89003
(702) 553-2203
US Pollution Control, Inc.
Grayback Mountain
8960N Hwy 40
Lake Point, UT 84074
(801) 531-4980

Recycling Resources

Lamp Recycling Services

Advanced Environmental Recycling Corp.
2591 Mitchell Avenue
Allentown, PA
(800) 554-2372 or (215) 797-7608

Allied Technology Group
47375 Freemont Boulevard
Freemont, CA 94538
(510) 490-3008

Alta Resource Management Services
88-B Industry Avenue
Springfield, MA 01104-9926
(800) 730-ALTA or (413) 734-3399

Bethlehem Apparatus
Hellertown, PA
(215) 838-7034

Dynex Environmental, Inc.
6801 Industrial Loop
Milwaukee, WI 53129
(800) 249-3310 or (414) 421-4959
4751 Mustang Circle
St. Paul, MN 55112
(800) 733-9639 or (612) 784-4040

Global Recycling Technologies, Inc.
PO Box 651
Randolph, MA 02368
(617) 341-6080

Light Cycle, Inc.
1222 University Avenue
St. Paul, MN 55104
(612) 641-1309

Lighting Resources, Inc.
386 S. Gordon Street
Pomona, CA
(800) 57-CYCLE

Luminaire Recyclers Inc.
2161 University Avenue, Suite 206
St. Paul, MN 55114
(612) 649-0079

Mercury Recovery Systems
2021 S. Myrtle Street
Monrovia, CA
(818) 301-1372

Mercury Refining Co., Inc.
Albany, NY
(518) 459-0820

Mercury Technologies International, LP
Hayward, CA
(800) 628-3675
Los Angeles, CA
(310) 475-4684
West Melbourne, FL
(407) 852-1516

Mercury Technologies of Minnesota
Pine City Industrial Park
Pine City, MN 55063-0013
(612) 629-7888
(800) 864-3821

Nine West Technologies
Nashville, TN
(615) 399-1486

NSSI, Inc.
574 Etheridge Street
Houston, Texas 77087
(713) 641-0391

Recycle Technologies, Inc.
1480 N. Springdale Road
Waukesha, WI 53186
(800) 305-3040
(414) 798-3040

Recyclights
2010 E. Hennepin Avenue
Minneapolis, MN 55413
(612) 378-9571

Resource Recovery, Inc.
Edina, MN
(612) 828-9722 (service)
(701) 234-9102 (sales)

Superior Lamp Recycling, Inc.
Mineral Springs Facility
1275 Mineral Springs Drive
Port Washington, WI 53074
(800) 556-LAMP (5267)

USA Lamp and Ballast Recyclers
Call John Fortino at 1-800-778-6645
for information on disposal facilities.

USA Lights
2007 County Road, C-2
Roseville, MN 55113
(612) 628-9370

Ballast Recycling Services

Alta Resource Management Services, Inc.
88-B Industry Avenue
Spingfield, MA 01104-9926
(800) 730-ALTA or (413) 734-3399

Dynex Environmental, Inc.
6801 Industrial Loop
Milwaukee, WI 53129
(800) 249-3310 or (414) 421-4959
4751 Mustang Circle
St. Paul, MN 55112
(800) 733-9639 or (612) 784-4040

Eastern Environmental Technologies
Portchester, NY
(914) 934-2100

Ensquare, Inc.
Newton Upper Falls, MA
(617) 776-7320

FulCircle Ballast Recyclers
168 Brattle Street
Cambridge, MA
(800) 775-1516
Baltimore, MD
(717) 932-1022
New York, NY
(800) 581-0857
San Francisco, CA
(916) 649-9194
Los Angeles, CA
(800) 775-1516
Atlanta, GA
(800) 775-1516
Chicago, IL
(708) 434-0593
Detroit, MI
(313) 651-6589

Global Recycling Technologies, Inc.
PO Box 651
Randolph, MA 02368
(617) 341-6080

Lighting Resources, Inc.
Pomona, CA
(714) 622-0881

Light Cycle, Inc
1222 University Avenue
St. Paul, MN 55104
(612) 641-1309

Luminaire Recyclers Inc.
2161 University Avenue, Suite 206
St. Paul, MN 55114
(612) 649-0079

Recycle Technologies, Inc.
1480 N. Springdale Road
Waukesha, WI 53186
(800) 305-3040
(414) 798-3040

S.D. Myers
180 South Avenue
Tallmadge, Ohio 44278
(216) 633-2666

Salesco U.S.A.
Boston, MA
(617) 344-4074
Chicago, IL
(708) 803-0880
Dallas, TX
(214) 661-8819
Honolulu, HI
(800) 368-9095
Phoenix, AZ
(800) 368-9095
San Diego, CA
(619) 793-3460

Transformer Service, Inc.
Concord, NH 03302
(603) 224-4006

Transtec Environmental
Niagara Falls, NY
(716) 283-6174

USA Lamp and Ballast Recyclers
Call John Fortino at 1-800-778-6645
for information on disposal facilities.

United States Ballast
Wausau, WI
(800) 715-5267

THIS IS NOT A COMPLETE LIST OF COMPANIES WHO PROVIDE RECYCLING AND DISPOSAL SERVICES THROUGHOUT THE UNITED STATES. COMPANIES LISTED IN THIS SECTION ARE NOT ENDORSED BY THE EPA OR THE GREEN LIGHTS PROGRAM. EPA DOES NOT SCREEN LISTED COMPANIES AND CANNOT CONFIRM THE METHODS THESE COMPANIES MAY USE IN THEIR RECYCLING PROCESS.

GREEN LIGHTS

A Bright Investment in the Environment

Green Lights is an exciting and innovative program sponsored by the US Environmental Protection Agency (EPA) that encourages major US corporations and other organizations to install energy-efficient lighting technologies.

Organizations that make the commitment to Green Lights will profit by lowering their electricity bills, improving lighting quality, and increasing worker productivity. They will also reduce the air pollution caused by electricity generation.

For more information contact the Green Lights program office.

Green Lights Program
US EPA
401 M Street, SW (6202J)
Washington, DC 20460

Green Lights Information Hotline

☎ (202) 775-6650
Fax: (202) 775-6680

Lighting Waste Disposal is one of a series of documents known collectively as the *Lighting Upgrade Manual*. Other documents in the Manual are listed below.

Lighting Upgrade Manual

PLANNING

- *Green Lights Program*
- *Implementation Planning Guidebook*
- *Financial Considerations*
- *Lighting Waste Disposal*
- *Progress Reporting*
- *Communicating Green Lights Success*

TECHNICAL

- *Lighting Fundamentals*
- *Lighting Upgrade Technologies*
- *Lighting Maintenance*
- *Lighting Evaluations*
- *The Lighting Survey*

☛ To order other documents or appendices in this series, contact the Green Lights Hotline at (202) 775-6650. Look in the monthly Green Lights *Update* newsletter for announcements of new publications.

EPA Green Lights