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Summary of Initial Examination of Lighting-Only Utility Projects in the Federal Sector

A.E. Solana
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Prepared for
U.S. Department of Energy
Federal Energy Management Program
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Summary

The Pacific Northwest National Laboratory (PNNL)[b] completed an analysis of Federal utility energy projects that implemented exclusively lighting upgrades. This work complements earlier work on the entire database of all projects that have been awarded at Federal sites through programs offered by the servicing utility for the site. The objective of this analysis is to better understand the lighting-only projects through determination of the relationship of capital invested and the resulting energy and cost savings, in terms of geographic locale, project size, and potential according to specific lighting technologies and/or control technology implemented. This information should be useful to the various Federal agencies as they form their agency-wide implementation plans to meet energy savings goals established by the Energy Policy Act of 2005 and Executive Order 13423 (72 FR 3919-3923).

The results of this analysis are mixed. The general trend of the effectiveness of the lighting-only projects, as measured by energy savings per capital dollar invested, has decreased over time, and the average project payback has increased. Smaller capital projects, those under a capital cost of $50,000, show better results than larger projects that are over $1,000,000. The distribution of the number of smaller projects varies markedly over time and appears to be primarily provided by only a handful of utilities. Geographically, projects completed in the Central and Mid-Atlantic regions of the country show the highest level of effectiveness, but that is probably the result of fewer projects done in those regions compared both the Southeast and West regions. In terms of simple payback, the difference is minor between the regions.

Only a small fraction of the total lighting-only database (23%) has sufficient information to categorize a project by specific lighting technology. Within that subset, most of the projects are a combination of several lighting technologies, to further complicate the analysis approach. In the absence of specific detailed engineering data for the projects, the effectiveness of the combination projects are compared to representative effectiveness for the specific lighting technologies that make up the project. Some of the projects report effectiveness values below the typical effectiveness value for any single lighting technology of the combination, indicating the data reported could be in error or the project may have had extenuating circumstances.

[b] Operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC05-76RL01830.

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Introduction

Previous analyses (Stoughton et al., 2006a; 2006b) focused on developing a relationship of capital cost invested and energy and cost savings for utility projects at Federal sites. Utility projects can be accomplished by a variety of contractual tools and can also include partial funding via appropriated funding or specific rebates provided by utilities. To facilitate the analysis process of any specific energy conservation measure (ECM), the term Utility Energy Savings Contracts (UESC) is used to generically identify projects completed by utilities at Federal sites irrespective of the tool used.

By characterization of the projects by ECM, the relative value of each measure is normalized to energy savings per dollar of capital investment. The ECM categories used in the previous analysis activities were broad in nature according to normal categories accepted within the energy management community. They included boiler/chiller upgrade or replacement, central energy plant modification, conversion of central energy plants to distributed energy sources, heating, ventilation and air conditioning (HVAC)/motor/pump upgrades, update to both lighting and mechanical systems, installation of renewable energy sources, installation of controls or upgrades/repairs, comprehensive upgrades of equipment or buildings, lighting-only upgrades, and other measures. The intent of this research is to uncover key trends in UESC projects at Federal sites that were classified as lighting-only projects. This ECM is addressed because lighting is a common and well known end use in all building types. By examining this single ECM project category in more detail, various questions can be addressed that deal with the following topics:

- What has been the trend in lighting projects under UESC? Do projects differ in results for cost and energy savings over time? Are different lighting technologies being employed over time?
- Which lighting technologies are dominant? Are innovative and new lighting technologies being implemented through projects under UESC?
- Are projects in the Federal sector achieving a reasonable level of savings compared to other sectors?
- What factors and characteristics may be contributing to or causing these trends or levels observed (e.g., geographic region, project size)?

Data Set

Previous analyses of utility project data at Federal sites (Stoughton et al. 2006a; 2006b) have utilized the data collected by PNNL under activities for the U.S. Department of Energy's Office of Federal Energy Management Program (FEMP). The data was obtained from two primary sources: directly from the agencies implementing the projects and from the utilities that executed the projects for the agencies. Data was provided on a voluntary basis, so the quantity and quality of the information varies markedly. In most cases, there has been no access to specific details regarding engineering calculations of capital cost, anticipated energy savings, and resulting cost savings, or actual figures upon completion of the project. In other words, data presented here could be metered and verified, estimated from billing data, or just estimated before project completion.

During fiscal year 2006, the utility project database was moved onto the FEMP FEMPCentral database system with additional project information input directly by National Laboratory staff involved in assisting agencies in getting projects implemented. The initial question regarding data quality was addressed via a limited check of the anticipated range of data based on results from previous analysis activities. If the inputted data falls outside that range, the data is flagged and Laboratory staff is notified, who would then verify the information that was provided, often by contacting either the site or utility representative. In several cases, erroneous data has been identified and the entry corrected in the database. In other cases, project data was retained as the result of obtaining additional verification information.

The database has a total of 283 projects classified as lighting only. However, the data for this number of projects is not complete so the information is not useful for some of the specific data analysis undertaken in this effort. Therefore, the number of projects used in various aspects of the analysis varies slightly. The entire database is dynamic because additional data is being added periodically and data is being adjusted based on results to inquiries and completion of projects. In general, the database used for this analysis was essentially the same as the June 2006 set described in Stoughton et al. 2006b, but with some additional data added, some corrections made to previously collected data, and some data included based on the nature of the analysis activity.

Trends Over Time

Several parameters have been examined to begin to answer some of the questions regarding trends. Initially, individual project information regarding energy savings per dollar invested values, or "project effectiveness," was studied. Figure 1 provides a time-based scatter plot along with a simple linear fit of 166 of the lighting projects. This figure shows projects that had data available to compute project effectiveness expressed in British thermal units (Btu) versus capital cost in dollars ($) (Btu/$). For this analysis, capital cost includes the actual material cost as well as the installation cost. This data subset consists of all projects that were identified with specific lighting technologies or just identified as "lighting" without specific indication of the lighting technologies installed.

There appears to be a slight downward trend in lighting projects' overall effectiveness over time. To further demonstrate this point, prior to 1999 the average effectiveness value was 14,000 Btu/$ for all reported lighting projects. During the time period from FY 2003 through FY 2006, the average Btu/$ value drops to just over 6,000. This figure also shows that projects were not implemented in a constant fashion over time because three distinct "groupings" appear for data during the periods of December 1995 through June 1997, December 1998 through December 2000, and since December 2001. This

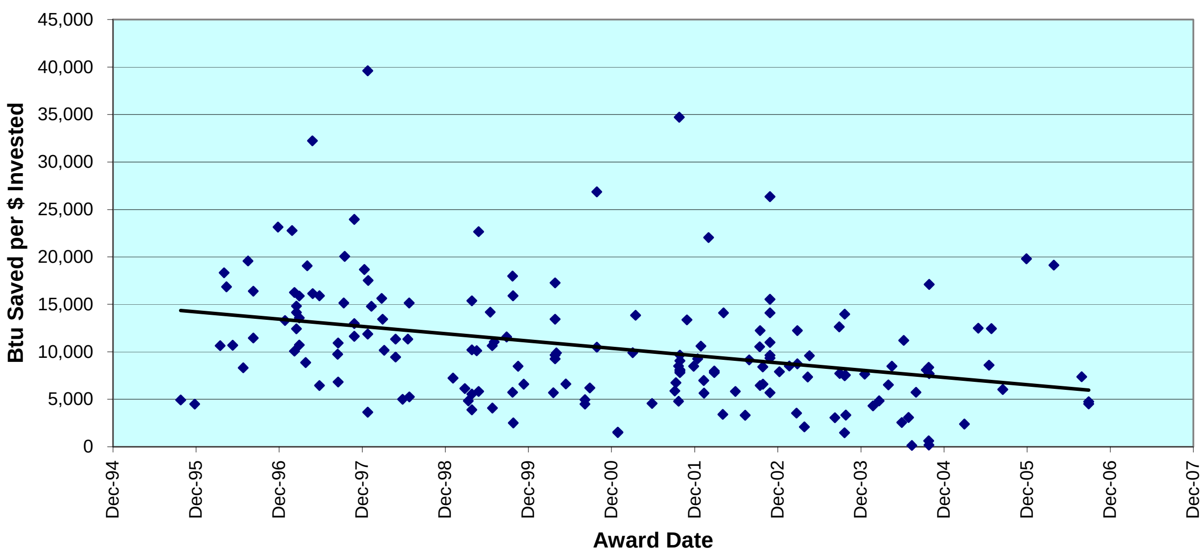

Figure 1. Regression of Scatter Plot of Btu per Dollar Invested Values over Time for Lighting-Only Projects

could be related to the entry or decline of utilities providing energy services to their Federal customers. It should be noted that outliers have not been removed from this data. In reviewing the individual project information, the higher values are related to projects that appear to be more lighting controls-focused than lighting replacement.

Previous analyses conducted on the UESC database for all lighting-only projects have a predicted value of 5,643 Btu/$ and 6,906 Btu/$ invested, respectively (Stoughton et. al 2006a; 2006b). Those values represent the slope of the line for all calculated values for Btu/$. The slope differs from the average because it was a predictor of energy savings based on the amount of capital funds invested, while the average is a comparison of relative savings regardless of how much investment is made, or an average value of Btu saved per dollar spent. For instance, a low value slope would indicate that for each dollar of investment made toward installation of lighting technologies, the marginal predicted savings may not be as effective as a dollar investments made in other energy conservation measures. A low average indicates that no matter what the capital cost invested for a specific project, the resulting savings are expected to be relatively low. The slope is used to predict savings for projects with known level of investment, while the average is more useful to determine the effectiveness of specific types of projects. Thus, by knowing the effectiveness of specific lighting technology projects, we can determine if one technology has more value in terms of energy saved compared to another. This information could be important in determining how to bundle various energy conservation measures with various Btu/$ values into a single project.

Data for simple payback was also evaluated to determine the overall effectiveness of the lighting-only projects. Simple payback for lighting projects over time seems to also present a trend of decreasing effectiveness. Figure 2 shows a simple linear regression of a scatter plot of the 172 projects with both annual cost savings and capital cost. The annual cost savings value is dependent on the tariff rate the site would pay for each unit of power delivered by a utility. This figure shows a trend of decreasing effectiveness because the simple payback rate is increasing over time. Prior to 1999, the average simple payback for lighting projects was 4.4 years. But in the time period from FY 2003 through FY 2006, the average simple payback had increased to 6.4 years. Outliers have not been removed from this dataset.

Figure 2 shows a large cluster of projects in the late 1990s compared to the most recent time period, as opposed to the pattern of “lumping” illustrated in Figure 1. This unexpected disparity illustrates varying data reporting practices among those providing the data. These facts could be a factor in skewing the average value and indicates some further investigation is required to provide more robustness to the results.

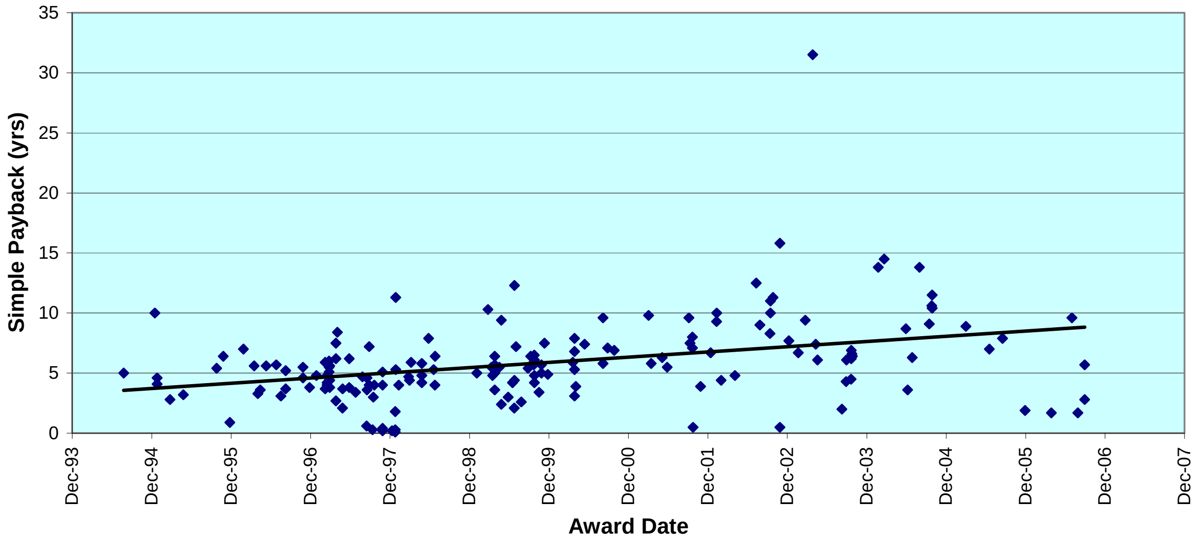

Figure 2. Regression of Scatter Plot of Simple Payback over Time for Lighting-Only Projects

You might also notice that one project has a simple payback of over 30 years! In reality that is a data point that should not have been included, because it is atypical and skews the overall data. That particular project was a lighting replacement for a sensitive facility. Prior to the lighting replacement effort, there was a large amount of maintenance costs related to relamping because the facility was operational 24 hours a day, 7 days a week. By upgrading the lighting, the amount of anticipated maintenance cost was significantly reduced, and ultimately it resulted in reduced security concerns. The project was allowed to proceed not based on energy savings, but on the resultant improvement in infrastructure, reduced maintenance cost, and reduced security concerns. A similar type of situation also may have impacted some of the other projects with simple paybacks above 10 years.

Size (Capital Cost of Projects)

In an effort to explain the reduction in project effectiveness over time, the size (capital investment) of lighting projects was analyzed. We wanted to understand if projects were getting larger or smaller over time, and if this had any effect on the relative effectiveness. The analysis approach was to group projects according to specific ranges of capital cost. Simple quartile charts were developed to look at the relationship between the capital investment of the project and its effectiveness. Figure 3 is based on data for 198 lighting projects and reveals that as the size of the project gets larger, the overall effectiveness decreases somewhat. Figure 4 shows that the payback seems to be increasing, consistent with data from Figure 3. Possible explanations for this trend include:

- larger Federal projects have not been taking advantage of volume discount for material purchases, or procurement requirements have increased, driving the Btu/$ value up compared to similar non-Federal projects

- larger projects included advanced lighting technologies with higher first cost but without accounting for longer fixture lifetime, maintenance/replacement savings, and future control savings, or

- larger projects incorporate more combined lighting technologies, mixing more effective retrofits with less effective retrofits for an overall less effective and higher payback project.

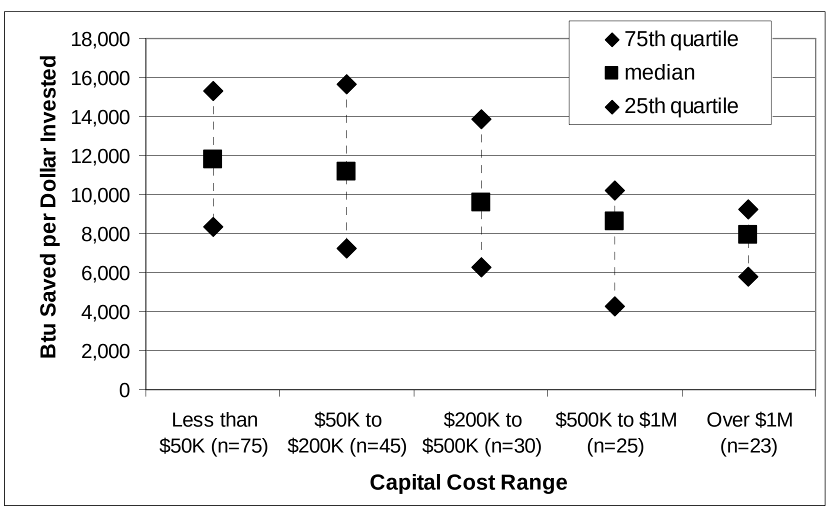

Figure 3. Energy Saved per Dollar Invested Values for Range of Capital Investments of Projects

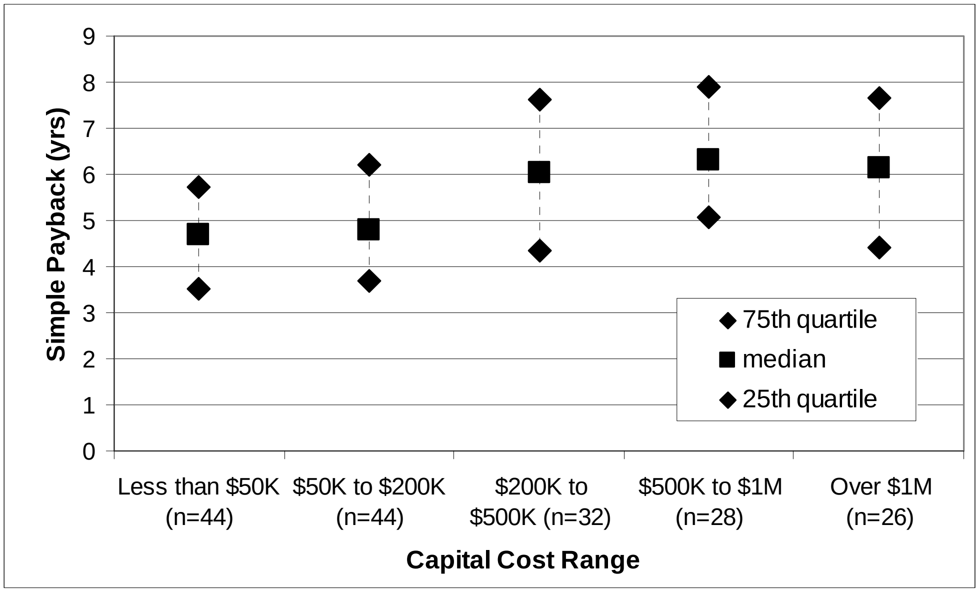

Figure 4. Simple Payback for Range of Capital Investments of Projects

Figure 5 shows number of projects by capital cost groupings over time. In general, there is an overall decrease in the number of lighting-only projects. The most drastic changes are seen in small projects (projects with a capital cost of less than $200,000). This may be attributed to the fact that one utility reported a large number of small lighting projects in the early 2000s, while other utilities completed a large number of small projects in the late 1990s, particularly in 1997. Whether there was a specific emphasis on lighting projects during these time periods is unknown, but this does create spikes in trending of the data. Middle sized and large projects have stayed relatively flat over time, although larger projects (over $1 million) have not been reported since 2004. Except in small lighting projects, it appears that lighting-only projects have been decreasing in number over time. Perhaps utilities, FEMP, or other influencing factors switched focus. Or, if new lighting is still being installed with similar frequency, lighting measures are possibly being bundled more often with non-lighting measures in recent years.

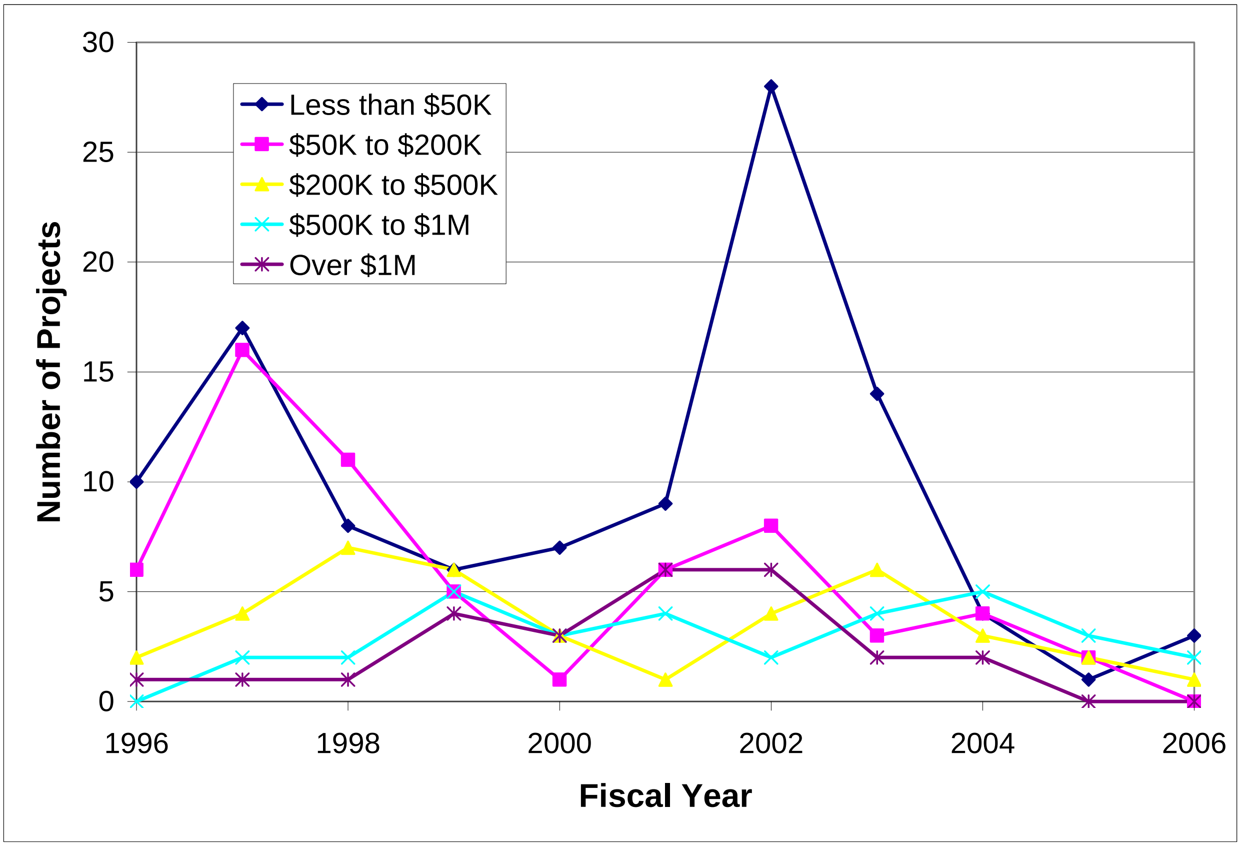

Figure 5. Count of Lighting Projects by Cost Grouping over Time

Figure 6 shows the total capital cost over time in cost grouping. The data from Figure 6 helps to examine the variance found in Figure 5. It shows how the total capital cost invested in a year does not necessarily correlate with the number of projects implemented. Here the more drastic variance can be seen with larger projects, while smaller projects' total investment maintains a relatively constant level. However, the total capital investment for all projects does not maintain a constant level, and in some cases, the same utility funded more than one multi-million dollar project in the same year. Therefore, total capital investment is not necessarily a driving factor for why and when projects are implemented.

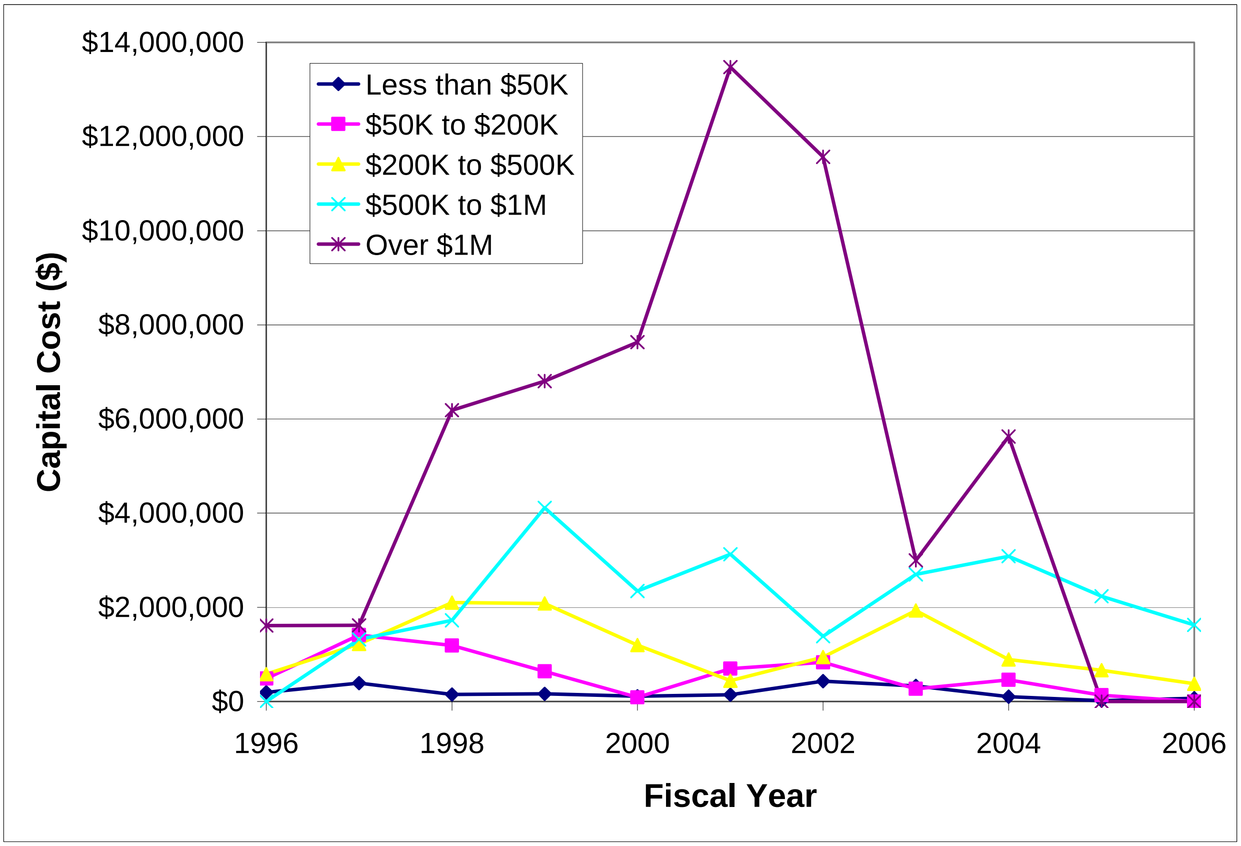

Figure 6. Total Investment of Lighting Projects by Cost Grouping Over Time

Project Region

Another question that we wanted to address involves investigating the geographic location where the project was implemented and the impact that has on the projects' effectiveness. For example, regional cost variances or savings from interactive building effects (reduced heat generated by lighting results in reduced cooling requirements and increased heating requirements) may have been included as part of the proposed projects in some regions, resulting in some lighting projects appearing more effective than others. The quartiles in Figures 7 and 8 show the six regions in the US previously designated by DOE, and the spread of relative energy savings data for each region. Data is scarce for many of the regions, but it is still apparent that the Northeast is the only region with much variance from the others. If a project is aiming for a 10-year payback, a higher price results in higher cost savings and, therefore, requires less energy savings. The Northeast has the highest prices; California, where many projects in the West are implemented, also has high prices; and the Southeast has relatively low prices. Because of these higher costs, the lighting projects completed in the Northeast region could more easily have been based on lighting technologies with lower relative savings, such as T8 lighting in facilities with fewer operating hours. An alternative explanation for this pattern is interactive building effects. While it is unknown if gathered data includes whole-building energy consumption or just lighting energy consumption, the data trend seems to show the possibility. For the categories with a significant amount of data, the Southeast and the West, which is almost 80% of the total, the savings follow the climate trends. The Southeast requires the most cooling, and therefore achieves more overall savings with lighting retrofits (less heat is generated). Parts of the West (the desert regions) also require a lot of cooling, but other parts of this region (the Pacific Northwest) require less cooling and therefore the region as a whole shows slightly less savings. The Northeast, the coldest region, would require more energy for heat to maintain space comfort after a lighting retrofit, and therefore receives less overall savings. The other three regions do not appear to follow this pattern. This could be because of a lack of metered data.

All simple paybacks seem to fall within a relatively narrow range of 5 to 7 years, with no regions significantly more or less than another. However, despite this similarity, the Northeast region is not as effective when it comes to energy savings. In other words, the Northeast is saving less energy per dollar spent than the other regions, and yet has similar dollar savings per dollar spent. This could be the result of high electricity prices in that region, which would be reflected by lighting-only projects (which save primarily electricity). Therefore, projects that are less energy-effective can be implemented in that region and still fall within UESC 10-year payback requirements. In the West, there is a very large distribution of paybacks among the projects. This may be the result of the dramatic difference in energy prices between California and the Pacific Northwest region.

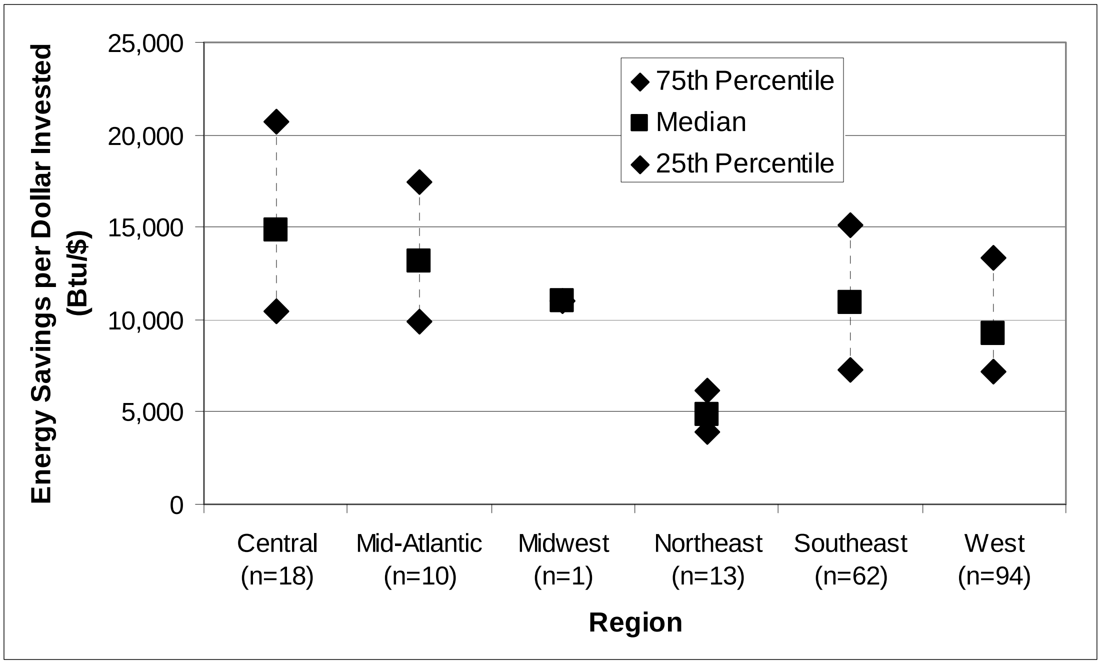

Figure 7. Energy Savings per Dollar Invested by US Region

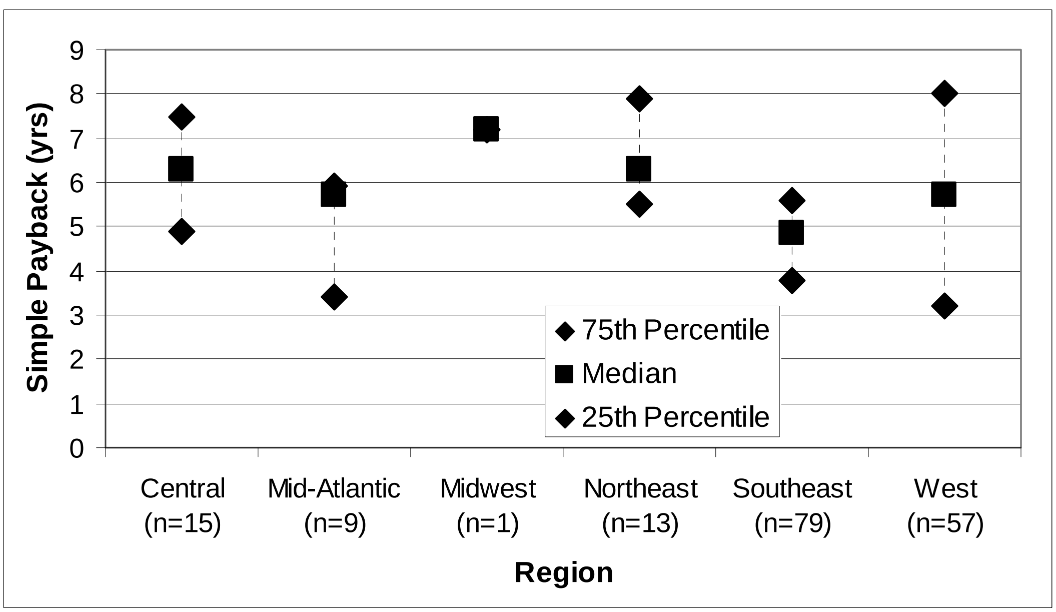

Figure 8. Simple Payback by US Region

Discrepancies between relative cost and energy savings may also be because of maintenance cost savings. If properly accounted for, these would result in greater cost savings (newer lighting technologies tend to last longer and, therefore, require fewer replacements), but yield no additional energy savings.

Figures 9 shows number of lighting projects by region over time. The effectiveness of the projects is shown in Figure 10.

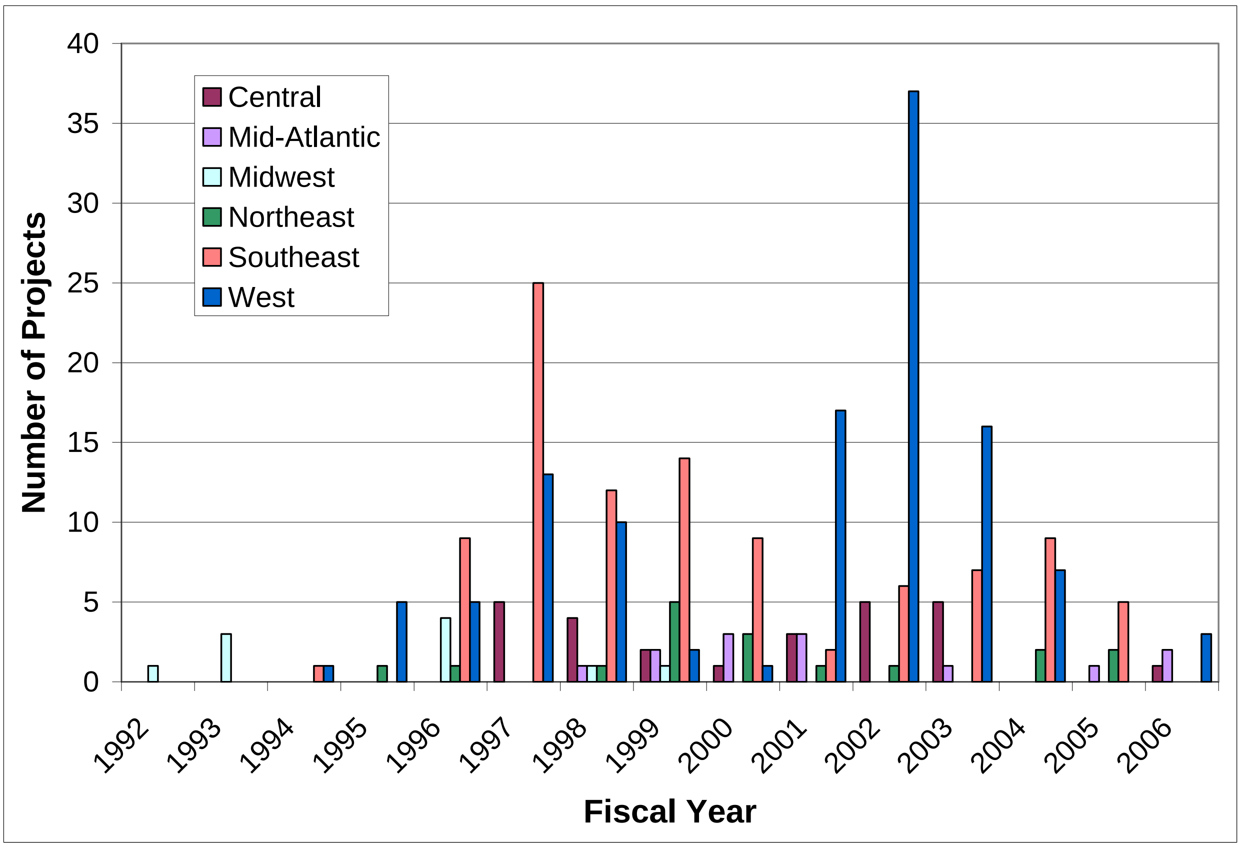

Figure 9. Total Number of Lighting Projects per Year in Each Region

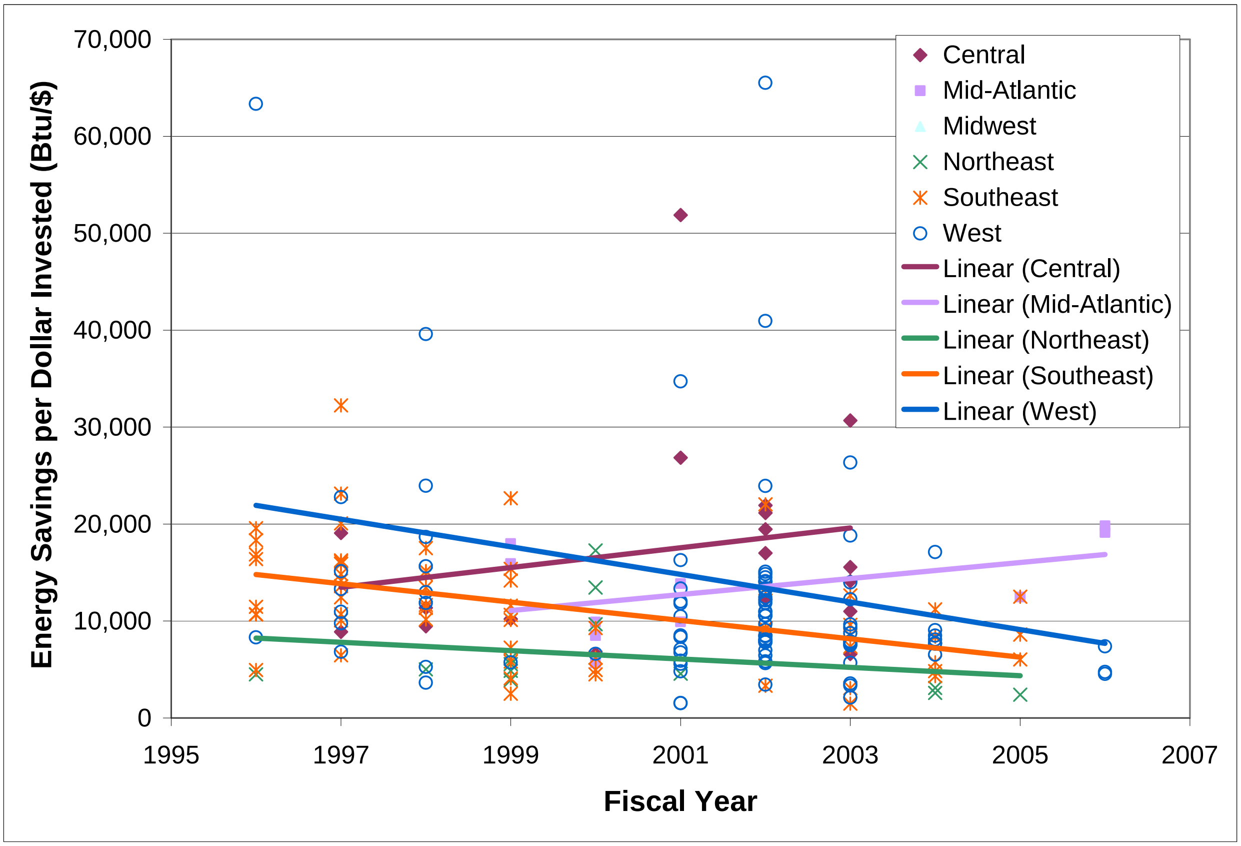

Figure 10. Project Effectiveness over Time by US Region

Because the Northeast has so few projects, which are spread evenly over the years, its low Btu/$ values probably do not affect the overall trend of decreasing effectiveness. However, the West and Southeast regions are dominant; these will affect the overall trend. In the years 1996 through 2000, the most projects installed in any one region was in the Southeast. In the following years, 2001 through 2003, the West region had more projects installed than any other region. As shown in Figure 7, the West is slightly less effective than the Southeast. This follows the trend shown in Figure 1, with a slight downward trend over time. Figure 10 shows both of these regions with decreasing effectiveness, also reflecting the trend found in the aggregate data. There is still the question of why effectiveness is decreasing, however. A more detailed look into the specific technologies implemented for each project may help give a better idea of why these trends are occurring.

Lighting Technologies Implemented

Only about 23%, or 66 projects, of all the lighting-only projects (283) included specific detailed information about what type of technology was implemented. This severely limited the extent of the analysis. This analysis is further complicated by the fact that a large majority of the projects are multi-technology installations. For example, the number of projects listed as only controls, light emitting diode (LED) exit signs, compact fluorescent lamps (CFLs), T8 fluorescent lamps, and daylighting technologies were limited to 8, 4, 4, 1, and 5, respectively, for a total of 22 projects. Therefore, 67% of the 66 projects included installation of two or more lighting technologies.

The most advanced lighting technology listed in the database to date for lighting-only projects was one project that included T5 fluorescent lamps for high-bay application. All other technologies listed are commonly installed, and not considered leading-edge technologies. It is unknown if the sites are reluctant to consider more advanced technologies, they feel their current lighting technology is adequate, or the current unit energy cost paid by many of the Federal facilities is low enough that project paybacks exceed the 10-year limit. This should be a point of emphasis regarding future projects and may require more extensive data collection and analysis to determine which Federal facilities can support leading-edge technologies. Current and projected unit cost of energy and more robust data regarding installation and maintenance cost for the Federal sector would have to be examined.

The most common types of lighting technologies implemented as a function of time is shown in Figure 11 and include:

- Lighting controls (in 39 projects)
- LED exit signs (in 12 projects)
- CFLs (in 12 projects)
- T8 fluorescent lamps (in 11 projects)
- daylighting (in 8 projects).

Daylighting projects may include skylights and windows; controls and sensors near windows; solar tubes; and/or direct beam daylighting (a sun-tracking device that gathers sunlight and transports it to a fixture inside for distribution). What exactly was implemented or replaced is most likely not the same in every case, and this would have a large impact on project effectiveness, adding further uncertainty to understanding the trends seen.

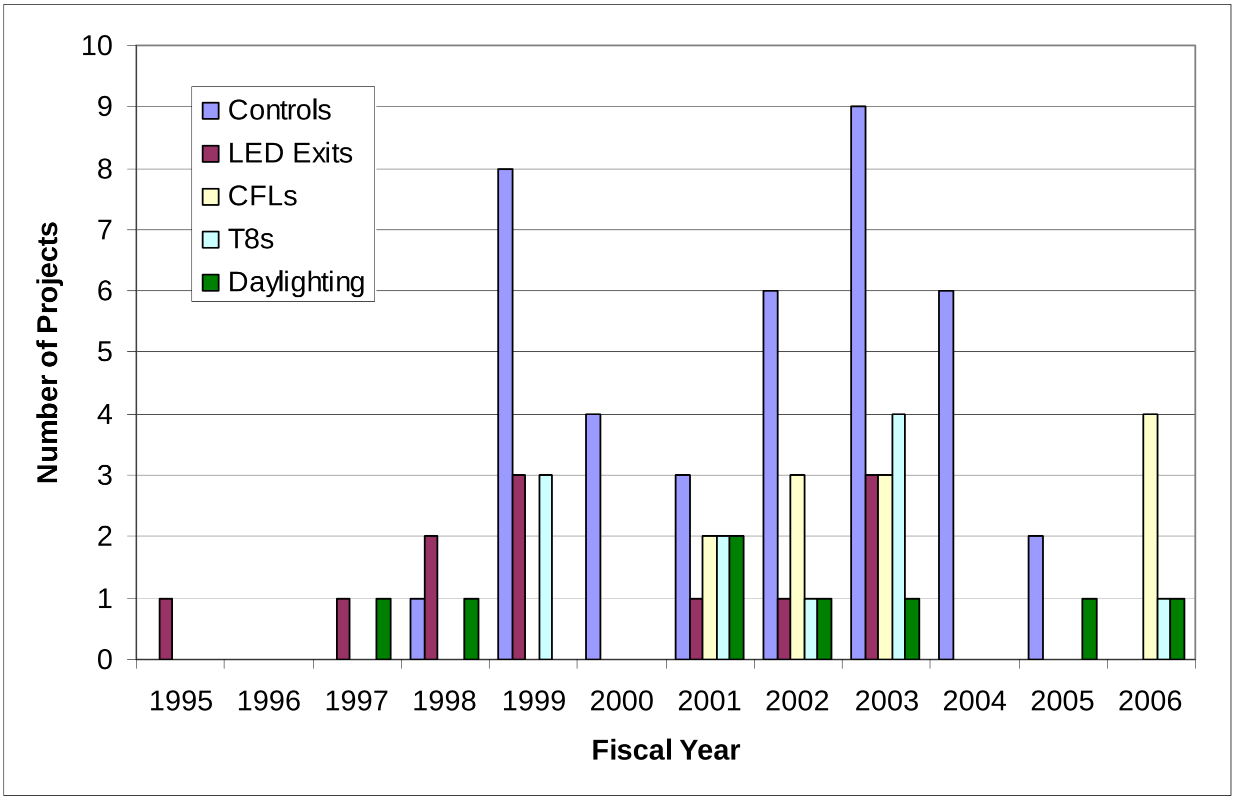

Figure 11. Lighting Projects by Year and Type

Current Lighting Technologies Information

Because of this lack of access to detailed project information, it was difficult to categorize and determine a “typical” amount of savings for specific lighting technologies that were installed. Savings from controls, for example, are completely dependent on the system that is being controlled: how much more time the lights will be off compared to previously, whether they respond to occupancy or sunlight or set time periods, and the type and number of fixtures being controlled. Additionally, the type of control system would be chosen based on these same factors. Therefore, both the cost of the project and the savings depend significantly on a number of unknowns, and no “typical” savings can be determined for this retrofit. However, an example can be given here. Consider installation of occupancy sensors in 50 offices to keep the lights off in these offices about 35% of the 4,000 hours per year they were previously on. Calculated savings is 28,971 Btu per dollar, with a simple payback calculated at 2.4 years, based on 1 hour time installation at $20 per hour (Turner, 2005). This example is representative of the relatively low cost and high savings resulting from some controls installations, but not all.

Daylighting is similarly inconsistent, as previously mentioned - the exact project implemented is unclear, and therefore, it is impossible to tell what type and how much electric lighting is impacted and reduced.

A T8 fluorescent lighting replacement project usually means replacing existing T12 fluorescent lamps and ballasts, but even here, there are options that could vary the estimated resulting energy savings and associated cost. There are options with regular T8s versus Super T8s, number of lamps per fixture, ballast type, reflectors, and lenses, for instance. One basic option is replacing existing energy-saving T12 lamps and magnetic ballasts with T8 lamps and two-lamp electronic ballasts. According to information from E Source (E Source, 2005) replacing 12 T12 fixtures with magnetic ballasts with T8 lamps and two-lamp electronic ballasts, the savings would be 5,678 Btu per dollar invested with a 5.5-year payback. Installing four-lamp electronic ballasts instead would increase the savings to 8,404 Btu per dollar, with a 3.7-year payback. Super T8s have greater energy savings but greater cost, resulting in 8,240 Btu per dollar invested, with a 3.8-year payback. Adding or changing reflectors, lenses, and controls increases the savings and the installation cost, with savings exceeding 10,000 Btu/$, depending on the options installed (E Source, 2005).

CFL retrofits are straightforward because the lamp was designed to replace the existing incandescent bulb. CFLs generally use about 1/3 of the energy of an incandescent lamp, and the payback is typically about 6 months (Turner 2005, E Source 2005). Turner (2005) estimates that for replacement of 111 incandescent fixtures, operating constantly, the calculated savings would be 79,728 Btu per dollar. This figure is based on a savings of 120 watts per fixture at a cost of $45 for the fixture and installation. For a single fixture operating 2,500 hours per year, the calculated savings is 50,297 Btu per dollar (E Source 2005). The simple payback would be about 1 year based on energy savings alone, but maintenance cost savings shortens it even more. The effectiveness of this technology should be improving over time because the price of CFLs has been continually dropping as a result of increased demand, and the technology is still improving. Because CFLs are so cost effective, an overall project typically combines CFL replacement with other lighting technologies that have longer paybacks and may not be funded on their own. The impact of combination lighting projects will be discussed in a later section.

The LED technology is similar to the CFL technology in terms of improving technology and increased demand so costs are still going down. LED exit signs are an extremely cost-effective retrofit for incandescent exit signs because exit signs run continuously. Because the useful life of LED lighting is much longer than similar incandescent lighting, associated maintenance cost is reduced. For an office building with 117 exit signs, the calculated energy savings is 16,748 Btu per dollar, with a payback of 2 years (Turner, 2005). In another example, a realty firm replaced existing exit signs with LED lighting, with about 10% receiving new signs and the rest retrofit kits. Retrofit kits are less expensive, and the total estimated savings was 26,551 Btu per dollar, with a payback between 1 and 2 years (E Source 2005).

Combination Projects

Combination projects involve more than one technology, typically combining more effective technologies with less effective ones, yet still resulting in the overall project with a simple payback of less than 10 years. Figure 12 shows savings per dollar invested over time for combination projects and projects completed with only one technology type. It is apparent here that single projects have been known to have greater savings per dollar invested, but are rapidly decreasing in effectiveness. Combination projects are just slightly becoming more effective, but are not very effective overall. Since 2003, no single nor combination project has had over 20,000 Btu saved per dollar invested. If more combination projects are being implemented in recent years, as it appears, perhaps the overall trend in the lighting data will begin to follow the trend of these projects and slowly start to become more effective. The large single project (CFLs) with savings over 200,000 Btu/$ was eliminated from this chart. The large single project with savings over 100,000 Btu/$ is verified data; this was a lighting controls project in a laboratory testing facility.

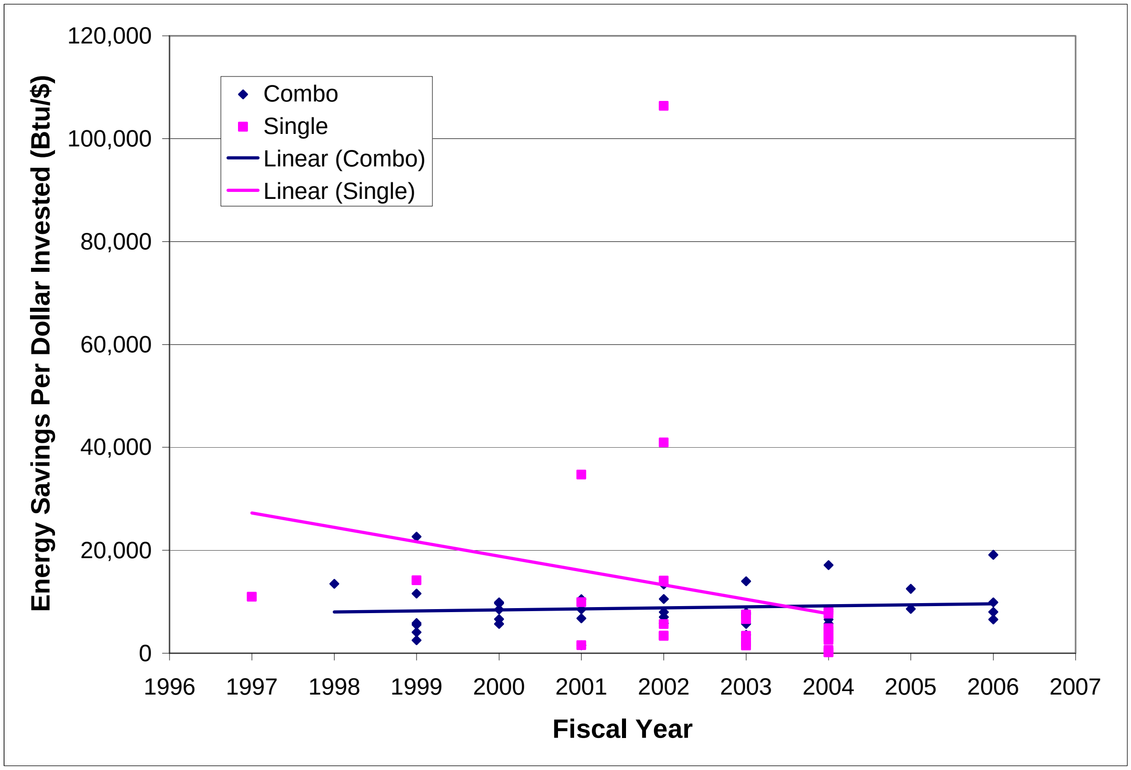

Figure 12. Effectiveness of Single versus Combination UESC Lighting Projects

It is not surprising that combination projects tend to be less effective than single lighting technology projects. Table 1 lists the projects with more than one of the following technologies installed: CFLs, LED exits, T8s, and controls. These technologies have an effectiveness that has been referenced in outside sources (Turner 2005, E Source 2005, Krepchin 1998) for comparison purposes. These "reference" values are listed in Table 1 for each technology in each project, alongside the calculated project energy effectiveness. Some project Btu/$ values fall within the range of "reference" Btu/$ values, and some do not. If indeed more specific information was available for the distribution of the specific light technology within the overall project, then a better predictor value could be obtained by a ratio method. The data reveals the overall project effectiveness value is lower than or on the lower end of the range of typical effectiveness for individual technologies. There are too many unknowns in the actual project values to explain why they seem to be less effective than non-UESC (non-Federal) projects.

Table 1. Combination Project Details

Fiscal Year	Project Technologies	Calculated Effectiveness (Btu/$)	"Reference" Effectiveness (Btu/$) by Technology
1998	LED exits, Other (fluorescent lights)	13,448	21,000; 8,000
1999	LED exits, Controls, Other (lamps, ballasts)	2,503	21,000; 28,971; 8,000
2001	CFLs, Controls	6,755	50,297; 28,971
2001	LED exits, T8s, Controls	8,518	21,000; 8,000; 28,971
2002	CFLs, LED exits, T8s, Controls	10,530	50,297; 21,000; 8,000; 28,971
2003	CFLs, LED exits, T8s, Controls	3,550	50,297; 21,000; 8,000; 28,971
2003	T8s, Controls, Metering	5,696	8,000; 28,971; unknown
2003	CFLs, LED exits, T8s, Controls	7,716	50,297; 21,000; 8,000; 28,971
2003	T8s, Controls	13,974	8,000; 28,971
2006	CFLs, LED exits, T8s	6,523	50,297; 21,000; 8,000
2006	CFLs, LED exits, T8s	8,026	50,297; 21,000; 8,000
2006	CFLs, LED exits, T8s	9,875	50,297; 21,000; 8,000
2006	CFLs, T8s	19,125	50,297; 8,000

Summary

Based on this analysis, lighting projects seem to be getting less effective over time, and in general seem to be less effective than non-Federal lighting projects. Costs associated with completing projects in the Federal sector, the difference in energy cost based on geographic location, and specific lighting technologies implemented may play a small role in these trends.

The size of the project does appear to impact the effectiveness of lighting projects; projects with a capital cost of $50,000 or less show the highest value for Btu/$ and the shortest payback. There is some indication of slight potential economic benefit resulting from economy of scale for projects exceeding $1 million of capital investment, as measured by simple payback.

Project location may also impact effectiveness because of energy prices and/or climate variability. Areas with higher prices tend to be less energy-effective, while lower prices force more energy savings for a similar cost savings. Warmer climates incur additional savings from air conditioning savings, while colder climates receive less overall savings from increased heating loads.

Further investigation into the types of lighting technologies employed in lighting projects in the Federal sector is necessary. Most of the projects with specific lighting technologies identified were combinations of one or more technologies. Information regarding the breakout of the various technologies is not available, so it is not possible to disaggregate savings, or capital cost, by technology type.

This analysis is intended to form the basis for similar analyses of other types of retrofit projects implemented at Federal facilities, to help provide clues regarding trends in use of retrofit technologies and relative impact in terms of predicted energy savings.

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