Analysis of Energy Savings In the Federal Sector through Utilities Service Programs

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ABSTRACT

As a result of insufficient appropriations for energy-related projects at federal sites, the Department of Energy (DOE) Office of Federal Energy Management Programs (FEMP) has encouraged the use of alternative financing as a method to fund energy efficiency, water conservation, and renewable energy capital retrofit projects. One of the potential avenues for agencies to obtain alternative financing is through their servicing utility. Since the passage of the Energy Policy Act of 1992 (EPACT), more than 1,200 projects have been facilitated in this manner. The amount of the capital investment per project has varied markedly, depending on the need of the federal agency, number of facilities at a specific site, and nature of the retrofit technology.

To promote the use of this financing mechanism, FEMP created the Federal Utility Partnership Working Group to foster enhanced relationships between utilities and both federal agencies and their sites so projects could be identified, designed, financed, and constructed. Formation of this working group also allowed FEMP the opportunity to collect, on a voluntary basis, specific information regarding individual projects to document results, which could assist in determining the contribution to mandated energy saving goals.

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Accurate and complete data existed for 528 of these projects to allow an analysis of total energy savings as a function of capital cost. Projects that consisted of the category labeled controls/upgrades/repairs yielded the largest energy savings per capital dollar of investment (-14,500 Btu per dollar). Other projects with high energy savings per capital dollar of investment included comprehensive upgrades, central plant upgrades, boiler/chiller replacement, and lighting and mechanical system upgrades. This article summarizes the findings from the analysis, provides some insight into the types of projects that yield the best savings per dollar of investment, and discusses possible explanations for the results.

INTRODUCTION

Energy programs within the federal government are led primarily by requirements set forth in EPACT and a specific Executive Order (EO 13123) that focuses on reduction of energy use per gross square foot in federal facilities. The legislation allows for agencies to use available energy services provided by local utility companies through demand-side management strategies to participate in energy efficiency programs that are available to all utility customers. The energy efficiency programs typically require utility customers to apply for available rebate funds that assist in covering the marginal cost of replacing low-efficiency end-use equipment with high-efficiency equipment. Utilities, in most cases, do not pay for the total cost of the equipment, but instead provide funding so their customers pay no *additional* cost for purchasing and installing more efficient equipment and have an incentive to participate in the program.

In the latter half of the 1990s, public utility commissions pushed for restructuring the electric utility industry as a means to create competition among energy providers and thus lower the unit cost of provided energy to electric customers. The new model produced business units that provided goods and services requested by customers. With specific energy reduction mandates set forth in both legislation and executive orders to be met, federal agencies saw the opportunity to acquire energy services from their local electric utility, while the utility saw this as a way to retain their valuable federal customer.

This provided an opportunity for agencies to partner with local servicing utilities as a way to implement a wide array of energy efficiency, water efficiency, and renewable energy projects through utility energy service contracts, also known as UESCs. Over the last decade, 80 utilities have entered into one or more UESCs with federal agencies. Typically, these services include the design, construction, and integration of energy efficient equipment for retrofit applications and access to existing available rebates. Because of limited funds for energy efficiency projects in the federal system, the utilities provided alternative financing arrangements that covered the cost of the capital equipment, engineering services, and debt service. To date, a total of over $1.3 billion has been invested by electric and gas utilities for over 1,000 projects at federal sites.

Starting in 1996, FEMP, through the Pacific Northwest National Laboratory (PNNL), began collecting specific information on UESC projects across the country. The initial intent of this effort was to provide basic information regarding the trend in capital investments of UESCs at federal sites. FEMP felt it vital to track UESC activity as a way to understand the investments that are required to meet the mandated energy savings goals under EPACT and EO 13123. Because there is no legislative mandate to provide details regarding the UESC projects, PNNL relied on voluntary reporting from both utilities and federal agencies. Fortunately, a majority of the electric utilities that were members of the Federal Utility Partnership Working Group (FUPWG) organized by FEMP also did a majority of the projects at federal sites.

It was realized that a more robust analysis of these data would provide valuable information regarding a relative measure of the energy reduction effectiveness of various installed technologies, the ability to test hypotheses regarding the effectiveness of installed measures across geographic regions and agencies, and the ability to help both utilities and agencies better identify projects that fit best in a federal operating environment. This article reports the findings of that analysis along with other pertinent data that allow a better understanding of the overall value of utility programs in the federal sector.

BACKGROUND

The initial purpose of developing the database that tracks the UESC activity allowed FEMP to track current trends in UESC projects.

Once the database was developed, additional uses were apparent, so additional information was incorporated. These included:

- Type of contracting mechanisms utilized.
- Capital investment, both from alternative financing and appropriated funding.
- Capital cost.
- Anticipated energy savings (million Btu).
- Anticipated cost savings (dollars).
- Type of energy conservation measure (ECM) to be installed.

Participants

A variety of utilities and federal agencies have reported data that have been entered into the database. Initially, investor-owned utilities entered into UESC agreements, but more recently other utilities, such as municipalities and cooperatives, have been active in entering into UESC agreements with their federal customers. As of July 2004, a total of 80 utilities have implemented UESC projects at federal sites. These sites have been distributed primarily among 20 federal agencies, including the Department of Defense (DOD).

Geographic Distribution

Projects are tracked according to the six DOE regions depicted in Figure 1.

It is interesting to examine project data by region because it reveals the dominant areas of UESC activity. Figure 2 shows the level of activity by DOE region, based on total capital cost of currently awarded projects. The western region is the dominant player, mainly because California has a large number of federal sites and high energy rates, which is an incentive for implementation of projects. The southeast region has been an active region historically for UESC as well. There are a number of large army installations in the southeast region that rely on UESCs to accomplish their energy-efficiency goals. Both the northeast and central regions have been less active in UESCs. There are significantly fewer federal sites in the northeast region. It is not so apparent why there is less activity in the central region. This may be the result of the following. First, this region has many smaller municipal and cooperative electric

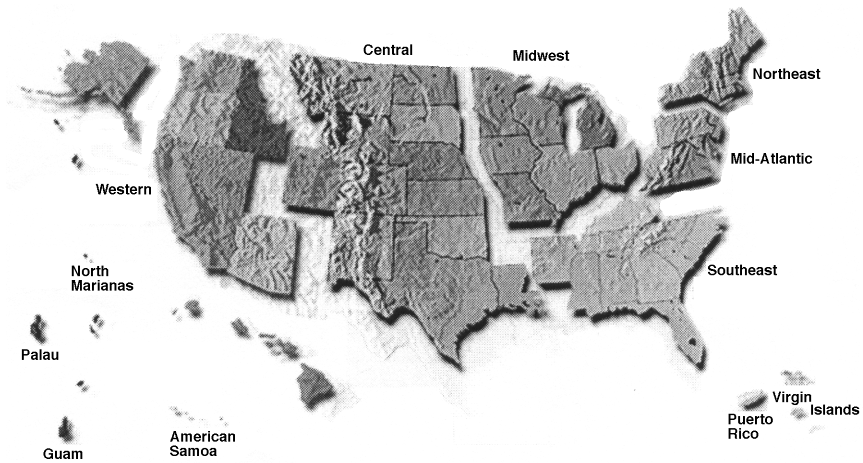

Figure 1. DOE Regions

utilities that until recently have not been involved in the UESC process. Second, a large fraction of the federal sites in this region are located in Texas, which has deregulated so utilities are not in the business to provide energy services to their customers.

Analysis by agency was also examined, and DOD was found to participate in UESCs more than every other agency. This should not be surprising, as DOD accounts for 70 percent of federal facility energy consumption. Therefore, the most reasonable breakdown was to look at all civilian agencies versus DOD. Figure 3 shows the total activity of UESCs for awarded projects in each DOE region broken down by

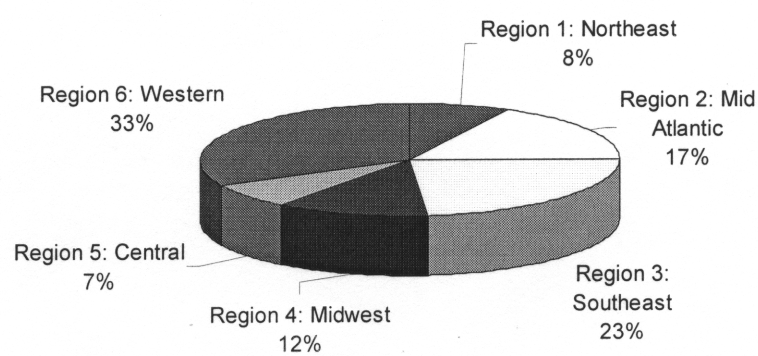

Figure 2. Distribution of Capital Investment at Federal Sites by DOE Regions

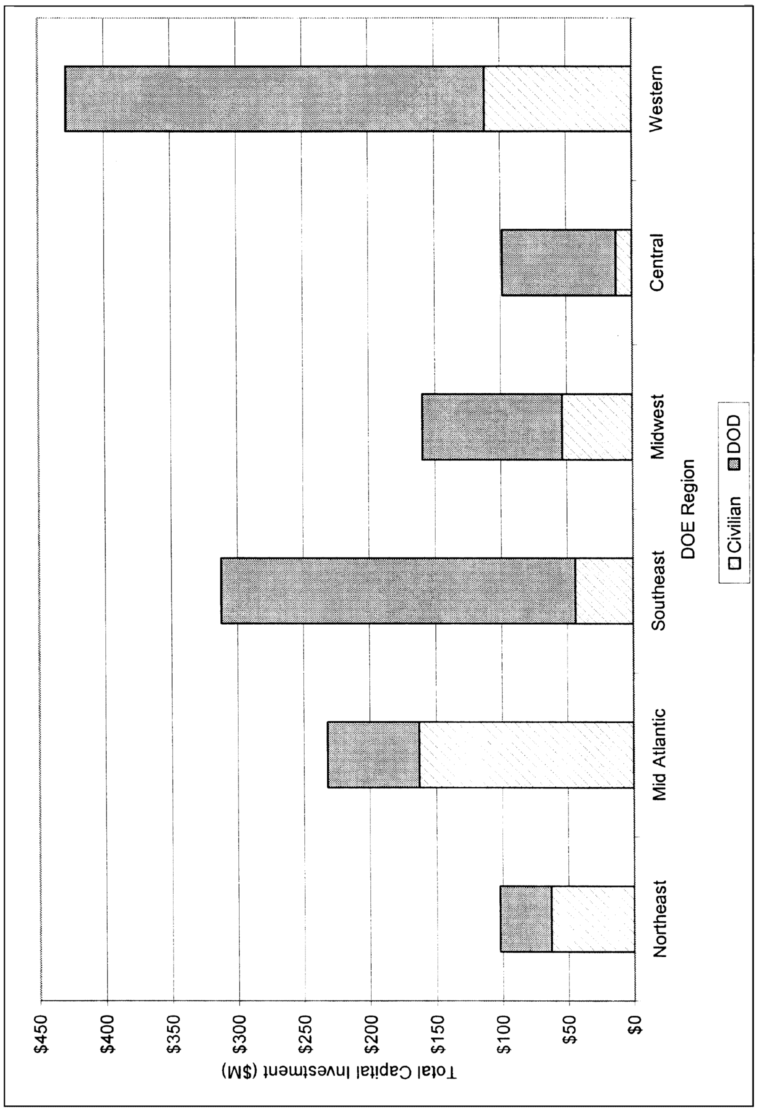

Figure 3. Investment of awarded projects by DOE region and agency type

civilian agencies and DOD. This chart shows that DOD installations dominate the UESC market for southeast, midwest, central, and western regions, but the northeast and mid-Atlantic regions have predominantly civilian UESC projects.

Technology Categories

The types of technologies, or energy conservation measures (ECMs), that are implemented within a specific UESC project vary markedly, and more than one can be combined into a single project. Each project was then binned into one of the following ECM categories according to the primary measure that was implemented:

- **Analysis—**projects in this category include feasibility studies or project design. In general, no specific energy savings are associated with this activity.

- **Boiler/Chiller—**projects in this category include primarily boiler or chiller retrofit/upgrade, usually at a single building or on a small scale.

- **Central Plants—**projects in this category include large multi-unit boiler and chiller or central plant upgrades.

- **Comprehensive Upgrades—**projects in this category include those with more than one type of ECM installed where no other information was provided on the specific ECMs installed.

- **Controls/Upgrades/Repairs—**projects in this category are dominated by lower cost or non-capital-intensive ECMs, including upgrades to existing systems, installation of energy management control systems, installation of thermostats, boiler tune-ups, and steam trap repair or replacement, but exclude major equipment retrofit and replacement.

- **Distributed Energy—**projects in this category include the installation of distributed generation, cogeneration, and emergency generators.

- **HVAC/Motors/Pumps—**projects in this category include smaller projects that involve mechanical improvements of systems that serve single buildings and other smaller mechanical systems.

- **Insulation/Envelope—**projects in this category include the replacement of existing windows with more efficient technology, weather stripping, and roof insulation.

- **Lighting Only—**projects in this category include only lighting retrofits (including lighting controls).

- **Lighting and Mechanical Systems—**projects in this category include lighting retrofits in addition to other technologies, but where lighting is still the primary activity.

- **Renewables—**projects in this category include geothermal, solar, and wind energy technologies.

- **Water—**this category includes projects dominated by water conservation projects.

- **Other—**this category includes projects that do not fit into any other categories; examples include demand control or transformer replacement.

- **Unknown—**this includes projects where no description was provided of the installed ECM.

Figure 4 shows the total investment for awarded projects in each ECM category by agency type (civilian and DOD). The figure excludes five categories: insulation/envelope, analysis, water, other, and unknown, because these categories are significantly smaller in terms of capital investment than the rest of categories. This shows DOD is predominantly involved in large multi-measure projects that include lighting and mechanical system upgrades. In addition, DOD has invested heavily in central plant upgrades. Civilian agencies have mostly invested in multi-measure projects, as well as lighting projects. There have also been a few large distributed energy projects. DOD has been the primary implementer of renewable projects to date. This may also be expected because many of the DOD sites have large land areas suitable for implementing renewable energy projects.

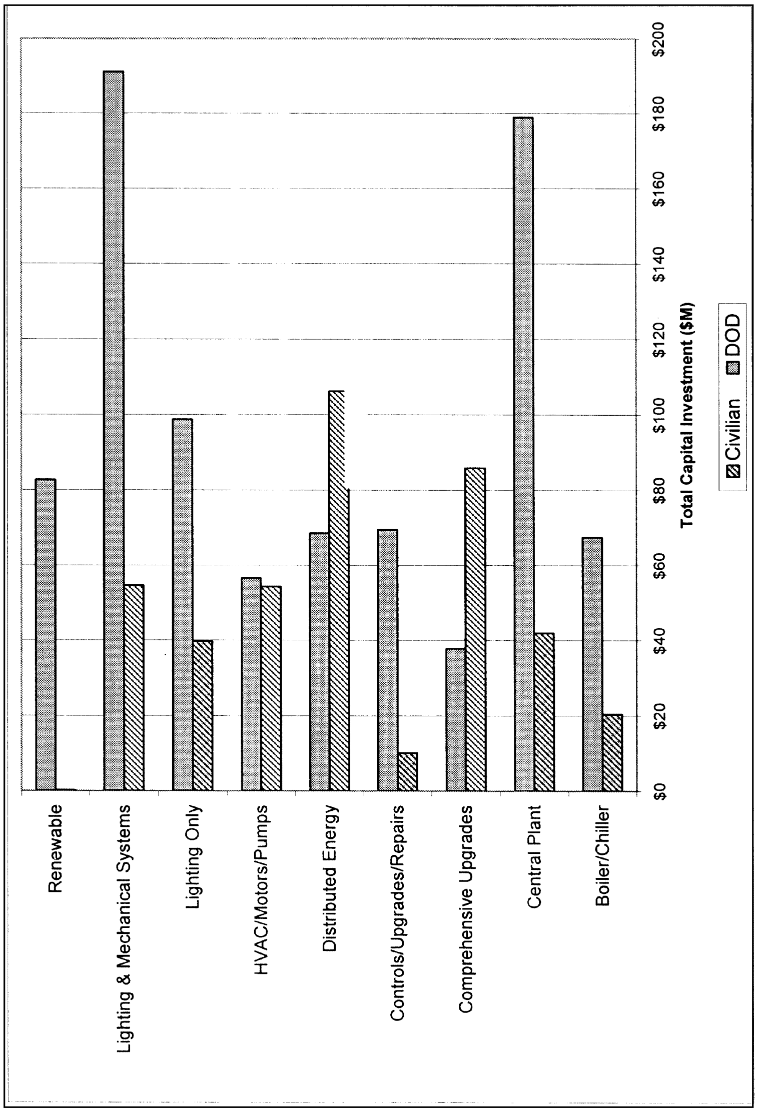

Figure 4. Projects by ECM Category for DOD and Civilian Agencies for Entire Dataset

Several of the federal installations have implemented a multi-phase UESC project that entails multiple measures installed over several task orders. For civilian agencies, a total of 72 installations have implemented multi-phase projects representing over $287 million in investment. For DOD, 82 installations have implemented multi-measure projects totaling over $683 million in total capital investments.

ANALYSIS OF ANNUAL ENERGY SAVINGS PER DOLLAR INVESTED

In 2004, a statistical analysis of the project information was undertaken to attempt to understand the relationship between annual energy savings and capital investments (annual Btu saved per dollar invested) for each specific ECM category. The analysis provides insight regarding the ECMs being installed at federal sites through UESC agreements and potential development of some useful rules of thumb for evaluating future projects. The nature of the statistical analysis, however, provides information regarding the variance in the results that may prove useful in understanding the uncertainty in estimates that were developed. Because of the quality of data, only nine ECM categories, representing 528 projects, were used in the analysis. Figure 5 shows the total number of projects in each ECM category of the analysis dataset.

Table 1 shows the percentage breakout for each of the ECM categories. A percentage for both the total number of projects and the total capital investment is included. A significant number of the projects were categorized as “lighting only” projects, yet yield a modest percentage of the total investment. This was the result of a large number of “lighting only” projects with small capital investment.

There were many external variables for each individual project that could impact savings estimates, such as climate, fuel prices, and hours of occupation of the facility. Therefore, a wide range of acceptable project energy savings values could be considered acceptable for any one ECM group. For 23 projects, however, the reported results fell out of this “typical” range. The data for each project were further examined by checking with the reporting utility regarding the data that had been reported. For these projects, one or more of the following was found: inaccurate reported capital cost or energy savings data, an anomaly in the project’s cost or savings calculation process that could not be

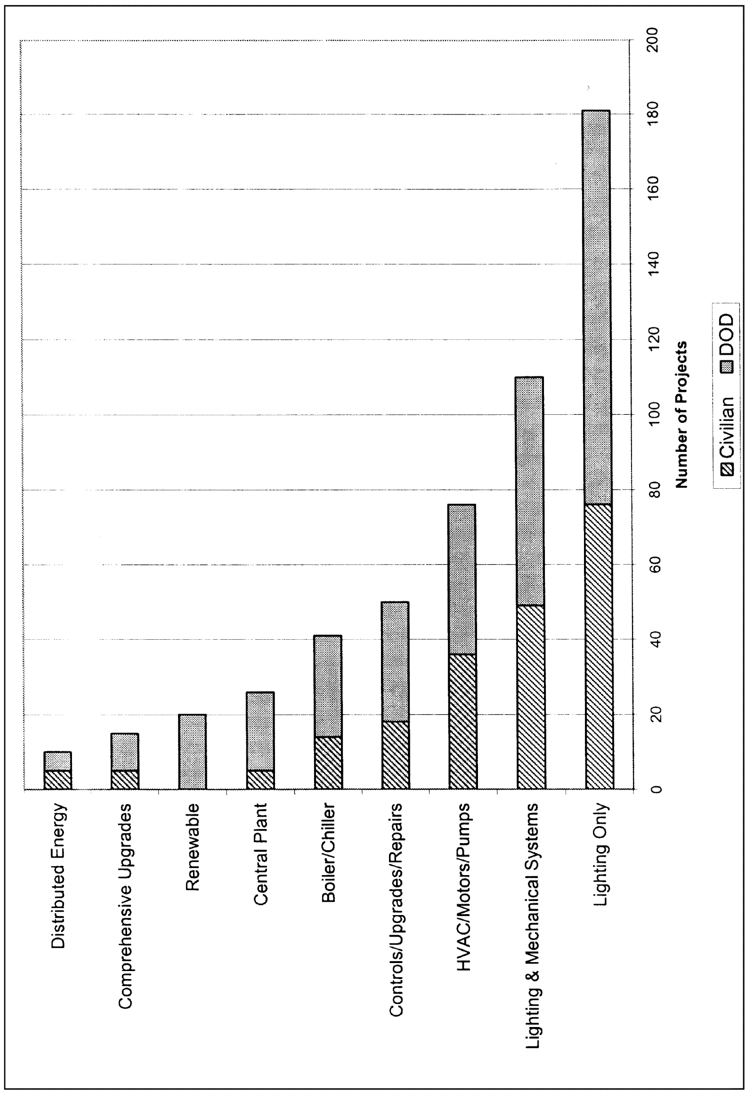

Figure 5: Number of Projects in Each ECM Category for Analysis Sub-Dataset

explained, or ambiguous project description, which could have led us to potentially place the project in the wrong ECM category. Instead of trying to obtain revised data or make corrections, the data for these projects were excluded from further analysis activities to better analyze an acceptable range of value for each ECM.

Table 1. Percent Breakout by ECM Category for Total Count and Total Investment of Analysis Dataset

Technology Category	*Percent of Total Count*	*Percent of Total Investment*
Lighting Only	34%	11%
Lighting and Mechanical Systems	21%	30%
HVAC/Motors/Pumps	14%	9%
Controls/Upgrades/Repairs	9%	5%
Boiler/Chiller	8%	8%
Central Plant	5%	17%
Renewable	4%	8%
Comprehensive Upgrades	3%	4%
Distributed Energy	2%	9%
TOTAL	100%	100%

Figure 6 shows total capital investment for each ECM category broken out by DOD and civilian agencies. The analysis sub-dataset is fairly representative of the entire data population described above in Figure 4. However, for the civilian agencies, there are significantly fewer data regarding comprehensive upgrades and distributed energy projects because data for energy savings were not available for projects for these types of agencies. The analysis sub-dataset for DOD projects is more representative of their population dataset, but the sub-dataset has lower investments for central plants, lighting-only projects, and distributed energy projects.

Regional Variances in Investment Levels

Figure 7 provides information on how individual project capital cost varies for the analysis sub-dataset by DOE region. Data are provided on median values along with the 25th and 75th quartile values. Looking at the quartile values provides an insight to the distribution of capital cost of the various projects around the mean value.

Figure 7 shows that the distribution of quartiles tends to vary significantly by DOE region, but the majority of the projects' capital costs lie on the smaller end of distribution for all regions. Except for the mid-Atlantic and midwest regions, the median project capital cost is under $1 million. The western region has a very small median value due to the large number of small capital cost projects in that region. The midwest region has the largest mean capital investment cost, as well as distribution for projects in their region. This is the result of some very large multimeasure projects that have been implemented in that region.

ANALYSIS RESULTS

A curve-fitting analysis was performed on annual Btu saved versus total capital dollar invested data for each ECM category reviewed. Completing this analysis for each ECM category indicated a relationship existed between the amount of energy saved and the capital investment for that particular ECM group. As a result of the scatter in the data, the analysis process was completed using the assumption that either a simple linear or simple non-linear relationship existed between the two variables. These relationships can be expressed in the following manner:

- Simple linear: $Y = a_0 + a_1 X$ (1)

where Y = Energy savings in Btus
X = Capital investment in dollars
a_0 = Y intercept (Btu)
a_1 = Slope (Btu/dollar)

- Simple non-linear: $Y = aX^b$ (2)

where Y = Energy savings in Btus
X = Capital investment in dollars
a = Constant (Btu/dollar)
b = Exponent

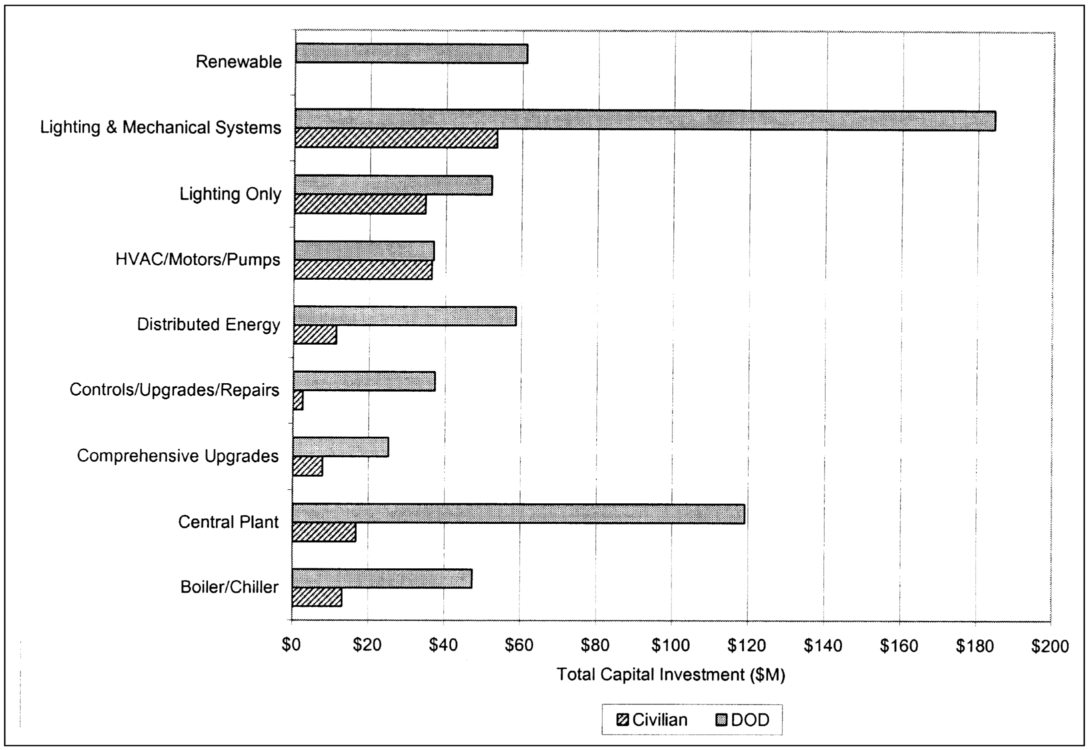

Figure 6. Capital Investment by ECM Category for DOD and Civilian Agencies for *Analysis* Sub-Dataset

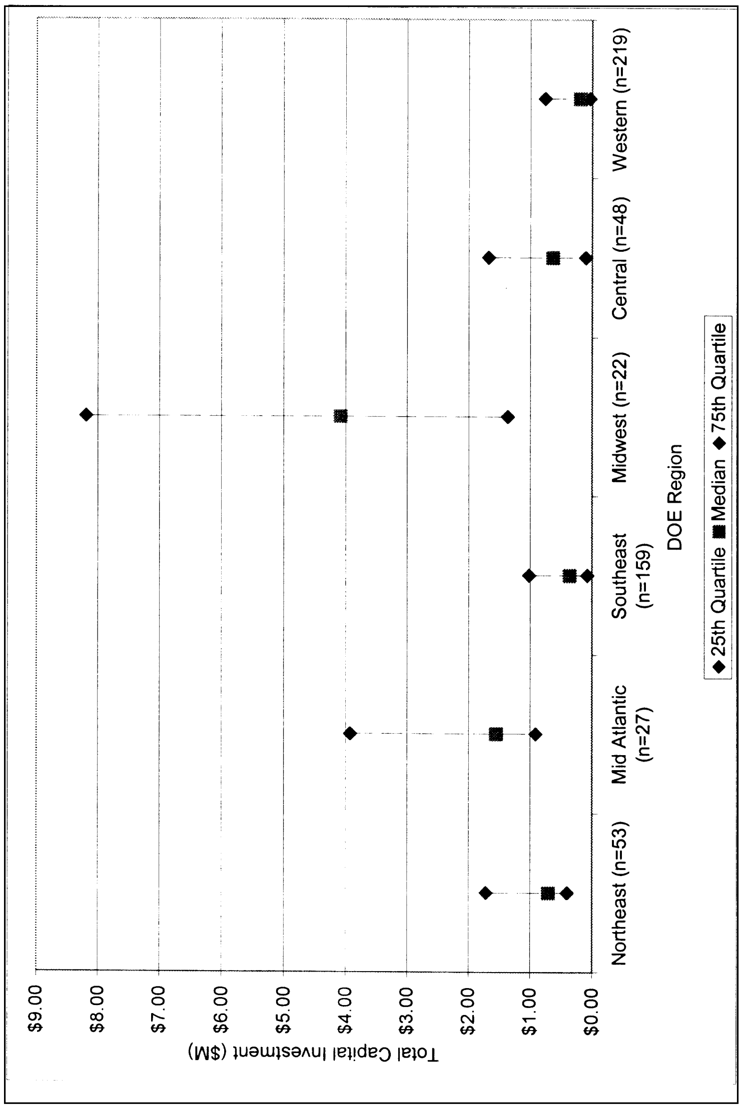

Figure 7. Distribution by Project Cost for DOE Regions for Analysis Sub-Dataset

This simple non-linear relationship was fit as a log-log model by taking the logarithm of both sides of Equation 2 and shown below in the expanded form.

$$\text{LogY} = \text{Log a} + \text{bLogX} \qquad (3)$$

Both models were investigated with and without an intercept term. For the simple linear model, a no-intercept term would force the model's regression curve through the origin (0, 0). This approach could be considered reasonable based on the premise that capital investment must be made for savings to occur. However, the no-intercept approach could be incorrect because some amount of up-front investment is required for savings to occur. After considering the two options, the no-intercept approach was used for both models because low- and no-cost techniques can often result in energy savings.

Initial results indicate there was difficulty in discriminating between the results of these two models, mostly because the project data were scattered. While the log-log model has a tendency to be less affected by "outliers," at first glance there was not a large difference between the two models.

However, there are tradeoffs in using either model. From a "modeling the uncertainty" perspective, the two models will produce very different uncertainty results because:

- The simple linear model assumes a constant uncertainty on Btu savings regardless of how many dollars are spent, e.g., the uncertainty is 1,000 Btu whether the capital expenditures are $10,000 or $ 1,000,000 (or any other amount).

- The log-log model assumes a proportional uncertainty on Btu savings. For example, for a capital expenditure of $10,000, the uncertainty might be 1,000 Btu, while at $1,000,000 it might be 10,000 Btu.

Neither of these uncertainty models was clearly superior to the other, so results are presented for both.

Because the initial analysis was completed by modeling Btu savings on capital expenditures, conclusions can apply only to these two parameters. For graphical scaling reasons, capital expenditures were converted to units of millions of dollars of capital expenditures to match the million Btu (MBtu). Any statistical relation between MBtu and millions of dollars of expenditures will be the same as between Btu and dollars of capital expenditure.

Simple Linear Fit Model

Table 2 below gives the estimated slope (MBtu-saved/$M-invested or Btu saved/$ spent) of the line plus a measure of the uncertainty of the slope for each ECM measure. Doubling the standard error gives an approximate 95 percent confidence interval on the slope. Figure 8 gives a visual comparison of the slopes and their uncertainties.

Table 2. Estimates from Fitting Simple Linear No-Intercept Model Annual MBtu Total Savings = Slope * Total Capital Cost ($M) Slope is in units of MBtu-saved/$M-invested (or Btu-saved/$-invested)

Energy Conservation Measure	*Slope*	*Standard Error*
Boiler/Chiller	10,539	1,091
Central Plant	9,502	1,403
Comprehensive Upgrades	10,072	2,787
Controls[Upgrades/Repairs	14,051	761
Distributed Energy	2,103	766
HVAC/Motors/Pumps	7,097	948
Lighting Only	5,643	270
Lighting & Mechanical Systems	9,383	511
Renewable	5,964	1,241

Log-Log Model

Table 3 gives the constant (MBtu-saved/$M-invested or Btu-saved/$-invested) plus a measure of the uncertainty of the constant for each ECM class, as well as an estimate of the exponent plus its standard error.

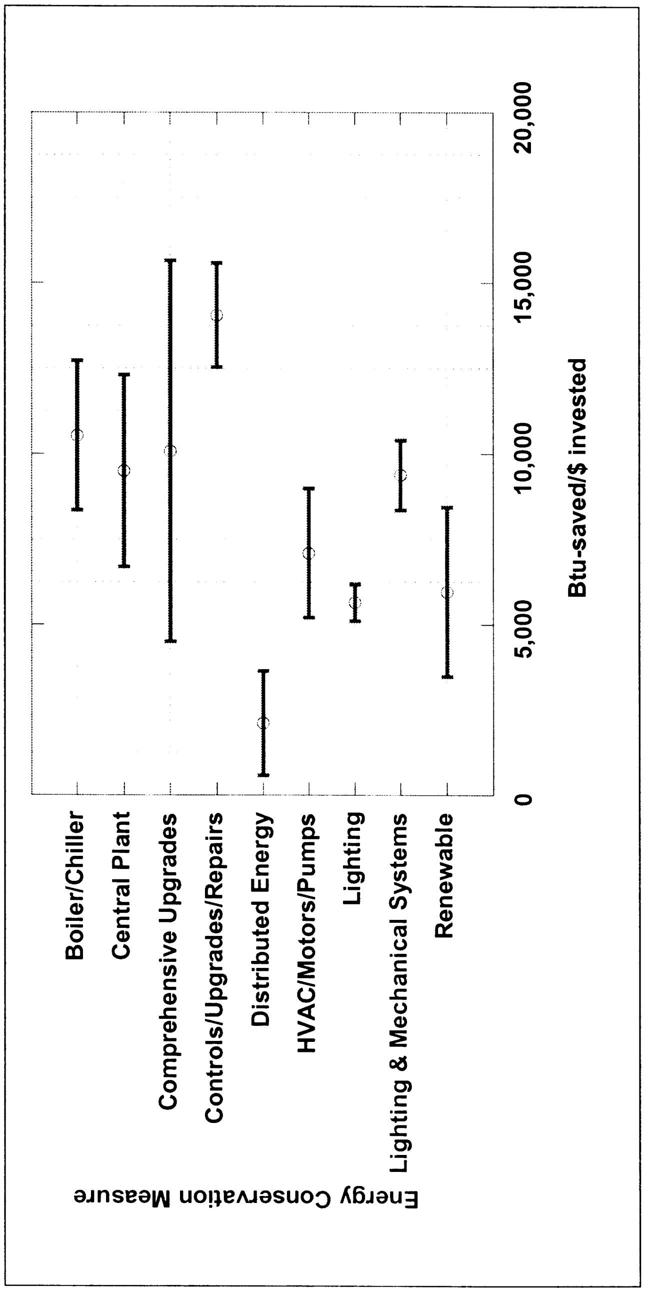

Figure 8: Estimated Slopes and Approximate 95 percent Confidence intervals for Simple Linear Model

Doubling the standard errors gives approximate 95 percent confidence intervals on the constant and the power term. Figure 9 gives a visual comparison of the constants and their uncertainties.

Table 3. Estimates from Fitting Log-Log Model
Annual MBtu Total Savings = Constant * [Total Capital Cost ($M)]$^{\text{Exponent}}$
Constant is in units of MBtu-saved/$M-invested (or Btu- saved/$-invested)

Energy Conservation Measure	*Constant*	*Standard Error*	*Exponent*	*Standard Error*
Boiler/Chiller	9,143	1,305	0.939	0.085
Central Plant	5,680	1,310	1.070	0.137
Comprehensive Upgrades	10,203	2,390	0.980	0.190
Controls/Upgrades/Repairs	10,738	2,021	1.039	0.067
Distributed Energy	6,915	2,036	0.911	0.129
HVAC/Motors/Pumps	7,052	986	0.918	0.053
Lighting	6,998	526	0.847	0.029
Lighting & Mechanical Systems	8,239	474	1.008	0.028
Renewable	7,618	1,534	0.846	0.113

Note: The constant in the log-log model is not typically a slope parameter, as it is in the linear model. However, because the exponent is relatively close to one in all cases above, it may be useful to view the constant as an approximate slope for comparative purposes.

DISCUSSION OF RESULTS

Simple Linear Model

The highest return on investment resulted from controls/upgrades/repairs ECM projects (~14,100 Btu per dollar of investment). These types of projects require small capital investment or might be considered maintenance activities compared to equipment retrofit. Be-

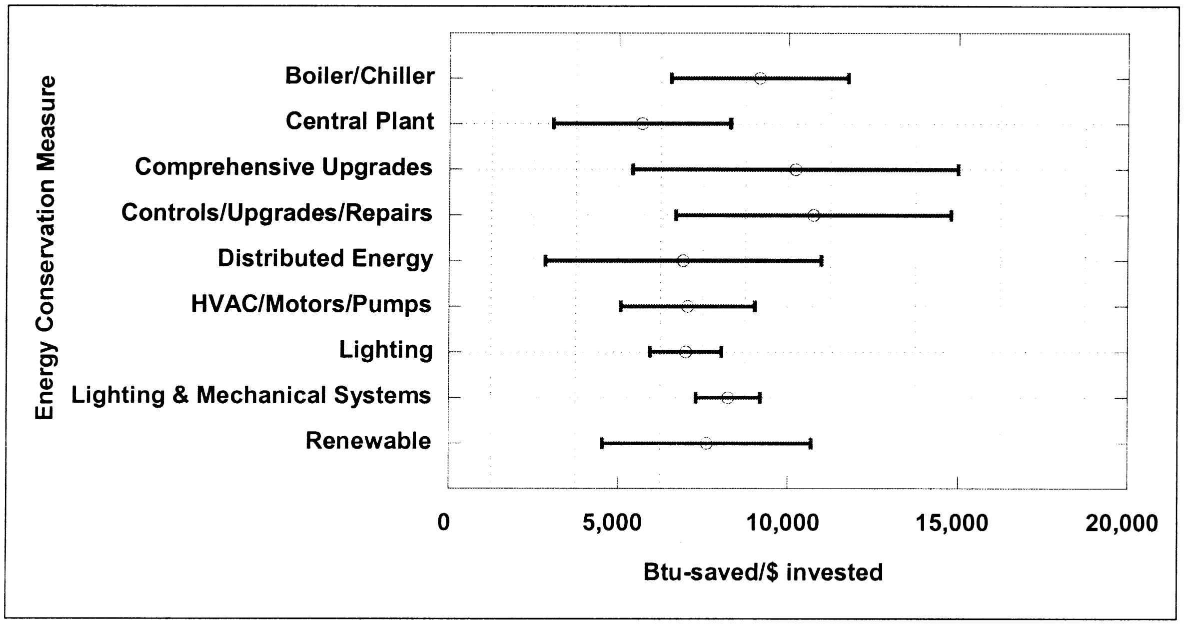

Figure 9: Estimated Constants and Approximate 95 percent Confidence Intervals for Log-Log Model

cause these projects require lower capital investment for energy savings obtained, a higher Btu per dollar ratio results. It is also interesting to note that for the controls/upgrades/rep airs ECM projects, the standard error of the data indicates that there is a high level of certainty of energy saved per dollar of the capital investment.

The lowest return on investment resulted from distributed energy projects (-2,100 Btu per dollar of investment). Distributed energy projects themselves are not considered energy savings projects, but are more of an infrastructure improvement unless cogeneration or heat recovery elements are employed. The savings results from improved efficiency of the existing system, including eliminating previous energy losses or being able to downsize baseline energy requirements. Distributed energy projects require significantly larger capital investment than individual controls/upgrades/rep airs projects so the ratio of energy savings per dollar invested compared to controls/upgrades/repairs projects was expected to be lower.

Individual lighting-only projects provide lower energy savings per dollar invested than might be first expected. At first glance, this may be contrary to expectations. A large number of projects in this category were small capital cost projects that typically focused on only constant-use lights that resulted in higher energy savings. The larger capital cost lighting-only projects could have combined less effective lighting (limited use so less overall savings) with more effective ones, yielding an overall lower energy savings. Thus the analysis should not be considered representative of a single lighting replacement for a constant use fixture. It is interesting to note that this category had the lowest standard error, indicating the reported savings were fairly constant across all projects. One explanation of this is because the lighting-only projects represented the largest group in the analysis dataset. More data typically yield a lower standard error.

The expected savings for projects that include both lighting and mechanical systems are markedly higher than lighting-only projects. This was expected because efficient lighting systems typically provide an opportunity to downsize HVAC system requirements. The magnitude of the standard error is about twice that of lighting-only projects, but lower than the standard error for the controls/upgrades/repairs projects.

Both boiler/chiller and central plant projects have two of the highest returns on investment of the nine ECM types studied. They have relatively high standard errors, indicating a large variance in expected savings, most likely caused by the nature of these types of projects. Boilers/chillers, and central plants tend to be very site specific, and energy savings are dependent on a variety of factors that will differ from site to site. Comprehensive upgrades also have a similar return on investment, most likely the result of the bundling of ECMs, which occurs in this category. Many times a site will combine different projects to achieve an overall greater dollar and/or energy savings.

Log-Log Model

The relative ranking of the various ECMs using a log-log model is very similar to results observed from the linear model. Controls/upgrades/repairs remain the ECM with the highest return on investment, but at about 75 percent of that estimated using the linear model. Other changes occur both in the positive and negative direction. For the central plant measure, the estimated savings is about 60 percent of that predicted under the simple linear model, while energy savings for distributed energy technology projects is 3.3 times greater than that estimated using the simple linear model. This could have resulted because the log-log model better accommodates outliers in the data set, which occurred for most ECM categories.

CONCLUSIONS

The objective of this article was to provide summary information in two distinct areas. The first area was to provide baseline information regarding energy efficiency and renewable energy projects that have been implemented through UESC programs at federal sites. The second area was to provide information that relates energy savings to capital dollar invested. This objective was accomplished based on the best available data provided by utilities, or in some cases, directly from federal agencies.

Results of this analysis indicate the distribution of capital investment is not uniform across all regions of the country. This should have been expected given that the distribution of floor space in the federal sector is not uniform for all geographic regions. The analysis results indicate that one agency, DOD, has made the largest use of UESCs to implement projects at their sites. This should not be unexpected because

DOD is accountable for almost 70 percent of the total federal floor space. In four of the six regions of the country, the DOD total capital investment is significantly greater than all the other agencies. In the other two regions, however, civilian agencies have the largest share of capital investment through utility programs. The types of projects implemented at federal sites have varied according to agency. A majority of the capital investment at DOD sites has focused on lighting and mechanical system and central plant ECMs, while the majority of investment for the civilian agencies has been for distributed energy systems, comprehensive upgrades, lighting and mechanical system, and HVAC/motor/pump ECMs. Finally, only DOD has made capital investments in renewable energy systems through UESCs. On a pure project implemented basis, lighting-only projects have represented more than one-third of all projects, but only 11 percent of the total capital investment.

Using two curve-fitting techniques, a relationship between energy savings and capital investment for each project type was established. Neither of these techniques was determined to be superior. Thus, a simple linear model can be used to establish the relationship between energy saved per capital investment made. The largest energy savings per dollar invested resulted from projects classified as controls/upgrades/repairs. The analysis indicated a fairly narrow confidence interval for this ECM, which is important in developing a strategic energy plan. The largest confidence interval was associated with projects classified as comprehensive upgrades, indicating the need to clearly understand the contribution each ECM makes toward the total project savings. Higher project savings per dollar invested may result from careful selection of ECMs compared to trying to get as many ECMs installed as possible. The results of these analyses indicate energy programs should first be based on implementing activities to maintain or upgrade existing ECMs before consideration of large capital intensive retrofit projects. This does not mean to retain existing equipment beyond its normal useful life, but rather to focus on activities that ensure that equipment is operating correctly.

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