
Pacific Northwest National Laboratory

Operated by Battelle for the
U.S. Department of Energy

Updated Analysis of Energy and Cost Savings for Utility Service Programs at Federal Sites

K.L. McMordie-Stoughton

W.F. Sandusky

A.E. Solana

D.J. Bates

October 2006



Prepared for
the U.S. Department of Energy
Federal Energy Management Program
under Contract DE-AC05-76RL01830

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/ordering.htm>



This document was printed on recycled paper.

(8/00)

Updated Analysis of Energy and Cost Savings for Utility Service Programs at Federal Sites

K.L. McMordie-Stoughton
W.F. Sandusky
A.E. Solana
D.J. Bates

October 2006

Prepared for
the U.S. Department of Energy
Federal Energy Management Program
Under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

Pacific Northwest National Laboratory (PNNL) completed a re-analysis of data in the updated Department of Energy (DOE) Federal Energy Management Program (FEMP) utility energy service contract (UESC) database and also expanded the analysis to uncover information on additional areas. This updates and expands on analysis originally performed in 2004 (Stoughton et al. 2006), and the intent was multi-fold. The first objective was to provide key information to both FEMP and Federal agencies on the relationship of capital cost invested and energy and cost savings for UESC projects and the distribution of project payback by energy conservation measure (ECM) categories. The second objective was to determine if recent modifications¹ in the database had resulted in significant changes to the initial analytic results. The final objective was to develop metrics that could be used to allow for rapid screening of the data because it is entered into the database by a variety of staff.

A key result of the analysis is the ability to predict energy and cost savings for UESC projects when the information is unknown. It should be noted that all UESC project information is collected on a voluntary basis from utilities and Federal agencies. These utilities and Federal agencies provide data periodically on current and up coming UESC projects. The data is not always complete and accurate. Therefore, using the analysis results to estimate energy and cost savings when this data was not provided is a very useful tool to help FEMP understand a more complete picture of UESC savings and effectiveness. Presently, annual energy savings is being estimated in 31% of the projects in the UESC database, while 25% of the projects have estimated annual cost savings by using the results of this analysis. The analysis results are now being used in an automated screening process to identify outliers in the data to ensure that project data received is reasonable.

The key findings of the analysis are:

- There was a large influx of projects that center on low cost controls, upgrades, and repairs, representing a 38% increase in capital investment. This type of project also has the highest energy savings per dollar invested and one of the shortest simple paybacks among the type of projects examined.
- For the entire UESC database between the previous analysis periods, there is a 12% increase in capital investment.
- For the dataset that was used in the analysis, there was a 9% drop in the total number of projects but an 8% increase in total capital investment between the two analysis periods.
- New information was uncovered during the reexamination that showed a large number of small projects did not ultimately proceed to implementation. The majority of these projects were lighting focused. This resulted in a significant change in the predicted energy savings for lighting projects because these erroneous data points were excluded from the reexamination.

¹ Between the two analysis time periods, it was uncovered that a group of projects were determined not to have been implemented, which may have caused significant changes to the analysis results.

- The distribution of the data for annual energy saved per dollar invested and simple payback fits a “log-normal” distribution curve. Log-normal distribution, simply stated, means that the values tend to spike early in the dataset and taper off slowly. This suggests what is expected for UESC projects’ -- simple payback tends to stay within the 10-year limit while a few go beyond it.
- The Lighting Only ECM category has a relatively low energy saved per dollar invested value and short simple paybacks because lighting projects are typically driven by cost savings from high electricity costs, instead of energy savings. To understand these issues better, further investigation is warranted. PNNL staff are currently examining this ECM category further to uncover any information on types of lighting technologies implemented and typical savings they are achieving, and whether these savings are within the expected range.

Table of Contents

EXECUTIVE SUMMARY.....	iii
BACKGROUND	1
DATASETS	3
Annual Energy Savings per Dollar Invested	4
Simple Payback Dataset	6
ANALYSIS RESULTS	9
Slope Estimates from Linear Regression	9
Percentile Analysis	11
KEY OUTCOMES	15
CONCLUSIONS.....	17
REFERENCES	19
APPENDIX A: Technology Category Descriptions.....	1
APPENDIX B: Outliers	1
APPENDIX C: Determining Prediction Values and Bounds for Excluded Categories.....	1

Figures

Figure 1: Capital Cost of Projects by ECM Category for July 2004 and June 2006 Entire Datasets	3
Figure 2: Project Count by ECM Category for July 2004 and June 2006 Energy Saved per Dollar Invested Analysis Datasets	5
Figure 3: Capital Cost of Projects by ECM Category for July 2004 and June 2006 Energy Saved per Dollar Invested Analysis Datasets	6
Figure 4: Project Count by ECM Category for June 2006 Simple Payback Analysis Dataset.....	7
Figure 5: Capital Cost of Projects by ECM Category for June 2006 Simple Payback Analysis Dataset	7
Figure 6: Energy Savings by ECM Category for both the July 2004 and June 2006 and Payback Analysis Dataset.....	8
Figure 7: Log-Normal Distribution for Boiler/Chiller ECM Category for Simple Payback	12

Tables

Table 1: Slope Estimates from Simple Linear Regression Model for Annual Energy Saved per Dollar Invested (Btu/dollar) – Comparison of June 2006 and July 2004 Analysis.....	10
Table 2: Slope Estimates from Simple Linear Regression for Dollar Invested per Annual Cost Savings..	11
Table 3: Screening Bounds for Annual Energy Saved per Dollar Invested and Simple Payback	13

BACKGROUND

PNNL initially performed a statistical analysis of the utility project information to gain a better understanding of the relationship between annual energy savings and capital investments (annual Btu saved per dollar invested) for specific ECM categories at Federal sites (Stoughton et al. 2006) . This is identified as the July 2004 dataset analysis in this report and will be used for comparative purposes with the current analysis effort, which is identified as the June 2006 dataset analysis. The respective ECM categories are listed in Appendix A. The July 2004 dataset analysis effort provided an insight regarding the types of measures being installed and established a preliminary metric for evaluating data reported for future projects. Because additional data had been included in the data base since the first analysis effort was completed, the original analysis could be reexamined and additional information generated.

The dataset used in the July 2004 dataset analysis was the best available data on utility projects at that point in time. Since the completion of the original analysis, additional data on UESC projects has been collected and data used in the original analysis could be examined in more detail. For example, the database was reviewed and inquiries were made to various sites to confirm project completions and investigate what appeared to be potential duplication of reported projects to ensure the quality of the data. Outliers in the dataset were reexamined to identify the rationale for either the uncharacteristic high or low energy and/or cost savings, to further enhance the quality of the database.

The updated analysis results will be utilized to provide prediction of annual energy and cost savings where this data is not known. The results are also being used as part of an automated screening process to identify future outliers entered in the database by comparing entered data against typical annual energy and cost savings by ECM category for previous reported projects. Both of these outcomes help to further ensure the data quality and ensure the information is complete and accurate.

DATASETS

Basic information on changes that occurred since the first analysis is captured in Figure 1 by comparing information for the datasets (July 2004 and June 2006). The figure shows the total capital investment by ECM category for all projects for both datasets. Overall, there is a 10% increase in capital investment from July 2004 to June 2006, increasing from \$1.36 billion to \$1.49 billion. There was an overall 9% drop in number of projects from 1,214 in July 2004 to 1,102 in June 2006 as a result of deleting some of the lighting projects from the data base.

The largest influx of capital investment between the two time periods was for Controls/Upgrades/Repairs projects; representing a 38% increase in total capital investment from \$80 million to \$110 million. These projects typically have very attractive energy and cost savings, which may explain the large increase. This will be further examined in the following sections of the report.

There was also a substantial increase in the investments in boiler and chiller projects, as well as central plant projects, 23% and 10% increase, respectively. The only category that dropped in capital investment was the Lighting Only category, which actually had a 1% drop in overall investment. This was caused by a substantial number of canceled lighting projects being removed from the dataset between July 2004 and June 2006. This is discussed in more detail in the next section.

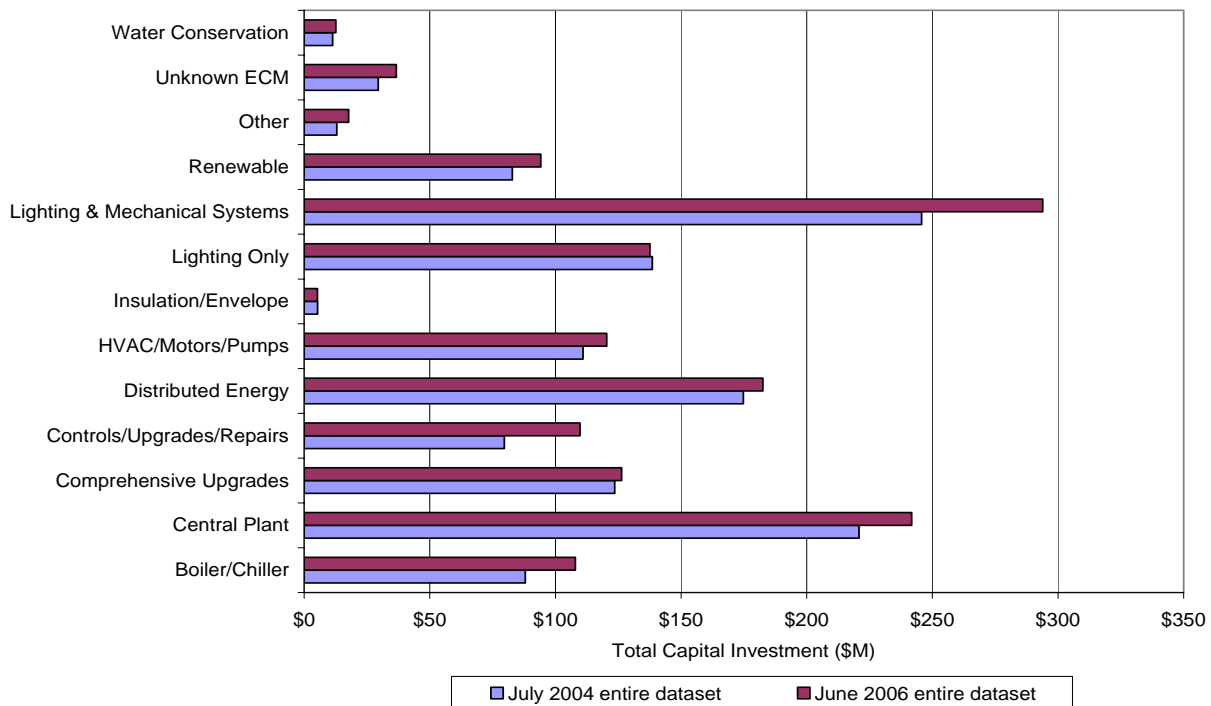


Figure 1: Capital Cost of Projects by ECM Category for July 2004 and June 2006 Entire Datasets

There were two sub-sets of data used for the analysis: 1) data on annual energy saved and capital investment and 2) data on annual cost savings and capital investment. This next section will summarize the analysis datasets.

Annual Energy Savings per Dollar Invested

The datasets for the analyzing annual energy saved per dollar invested between July 2004 and June 2006 had some large changes. The key changes in the datasets are because new project information was collected between the time periods; existing project information was updated that may have changed cost and savings information; and reported errors in completion dates, duplication in reported projects, and project cancellations were uncovered. For example, it was discovered that a few projects had been accidentally entered twice because the project information was collected from two different sources. The data was reconciled and one project deleted so that duplication was no longer taking place. Also, where possible, PNNL staff contacted data sources to verify project information. Project's capital cost and savings information was updated when new and more accurate information was entered into the database.

The ECM categories that had sufficient information² for running the statistical analysis changed somewhat between the two datasets. In the July 2004 analysis, three ECM categories were eliminated because the total project count was too small: Insulation/Envelope, Water Conservation, and Other. In June 2006, Insulation/Envelope and Water Conservation categories were also eliminated from the analysis but in addition Distributed Energy ECM category was eliminated. The Other category was examined in June 2006 because sufficient project information had been obtained by that date. The Distributed Energy ECM category had a major decline in projects between the two reporting periods because new information was obtained that revealed projects had not been awarded³ compared to what was previously reported. (See Appendix A for a full description of each ECM category.)

Figure 2 shows the number of projects in the two analysis datasets by ECM category. There was a 9% drop in the total number of projects from July 2004 to June 2006. Lighting Only projects dropped by 24 projects since July 2004, representing a 13% decrease for that category. Comprehensive upgrades dropped by 5 projects, presenting a 33% decline in this category. All of the other categories had minor fluxes in number of projects.

An explanation for the decrease in total project number was because a considerable number of small projects were omitted from the June 2006 dataset after a more thorough investigation of the project information was performed. It was uncovered that a large number of small projects that were in line to receive funding from a public benefit fund did not secure their funding and therefore the projects were cancelled or put on hold. These projects were small in terms of capital cost, so the impact on total capital investment was less influential.

² Ten projects were considered sufficient for running the regression analysis.

³ Large distributed energy projects such as cogeneration systems are possibly more difficult to fund and contract, so there is a propensity to see these projects be put on hold or be canceled.

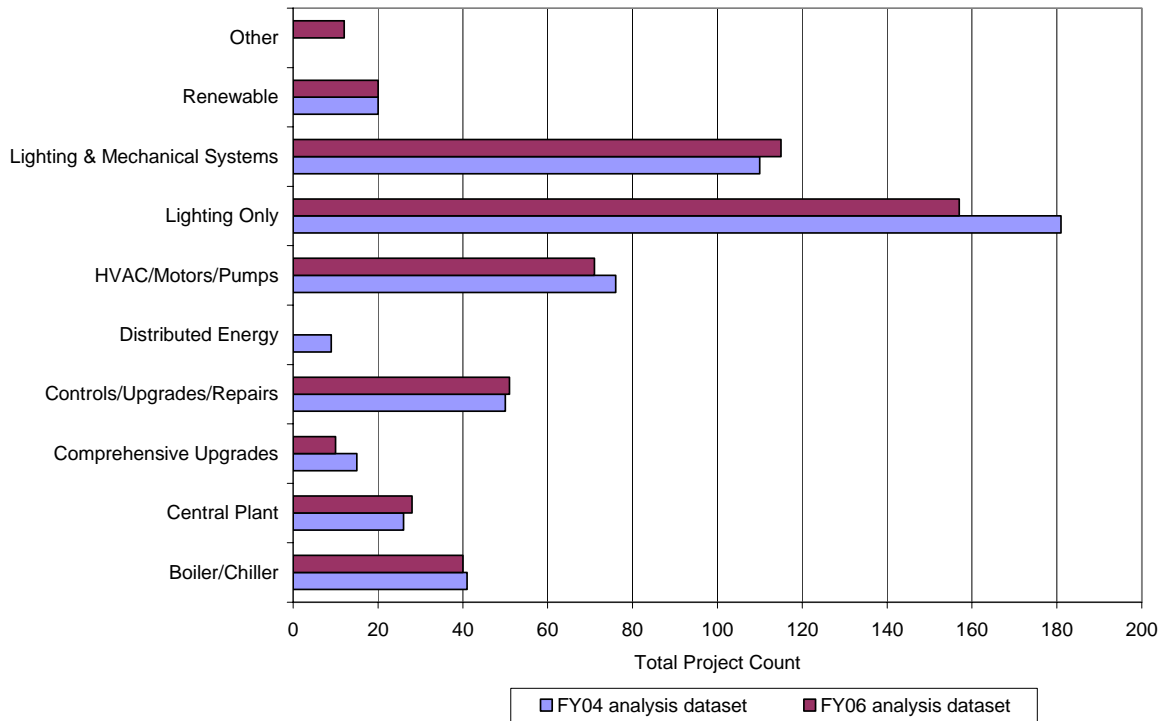


Figure 2: Project Count by ECM Category for July 2004 and June 2006 Energy Saved per Dollar Invested Analysis Datasets

The drop in overall project number does not reflect a drop in UESC activity. There was an actual overall increase in investments levels between the two analyses, as shown in Figure 3. Figure 3 depicts the total capital investments for the annual energy saved per dollar invested analysis datasets. There is an 8% increase in total capital investment between the two analyses. Controls/Upgrades/Repairs category represented the largest increase in capital cost. The average project size had a large jump in this category between the 2004 and 2006 data base , so while the project count increased by only 2%, the investment rose by 78%. There were several very large projects awarded between this time frame, which caused the large increase in project investment. It is not well understood yet if these types of projects are increasing in scope, because there are too few data points to understand the correlation at this point.

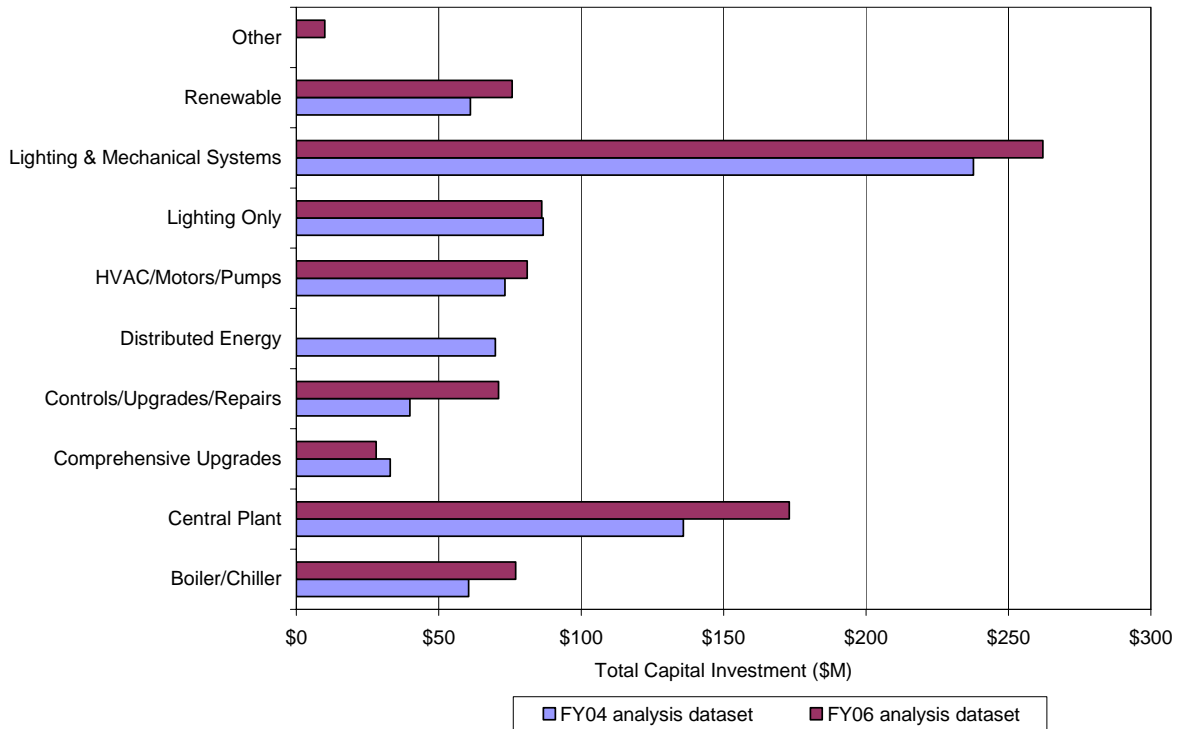


Figure 3: Capital Cost of Projects by ECM Category for July 2004 and June 2006 Energy Saved per Dollar Invested Analysis Datasets

Simple Payback Dataset

The June 2006 analysis also examined the relationship between capital investment and annual cost savings, otherwise known as simple payback. The July 2004 analysis did not investigate this parameter; however, it was felt that it was pertinent to expand the original analysis to understand the connections between project investment levels, annual cost savings, and the type of ECMs installed. This information can help to estimate annual cost savings when the data is unknown and also help identify those projects that have the high potential for cost and energy savings.

For the June 2006 dataset there were 539 projects totaling \$974.6 million in capital investment that had complete information on capital cost and annual cost savings. There were three ECM categories excluded, Water Conservation, Insulation/Envelope, and Distributed Energy, because of a lack of sufficient project numbers. Figures 4 and 5 show the dataset used in analyzing the simple payback relationship showing both number of projects and capital investment values. Figure 6 shows the overall energy savings from projects in both data bases.

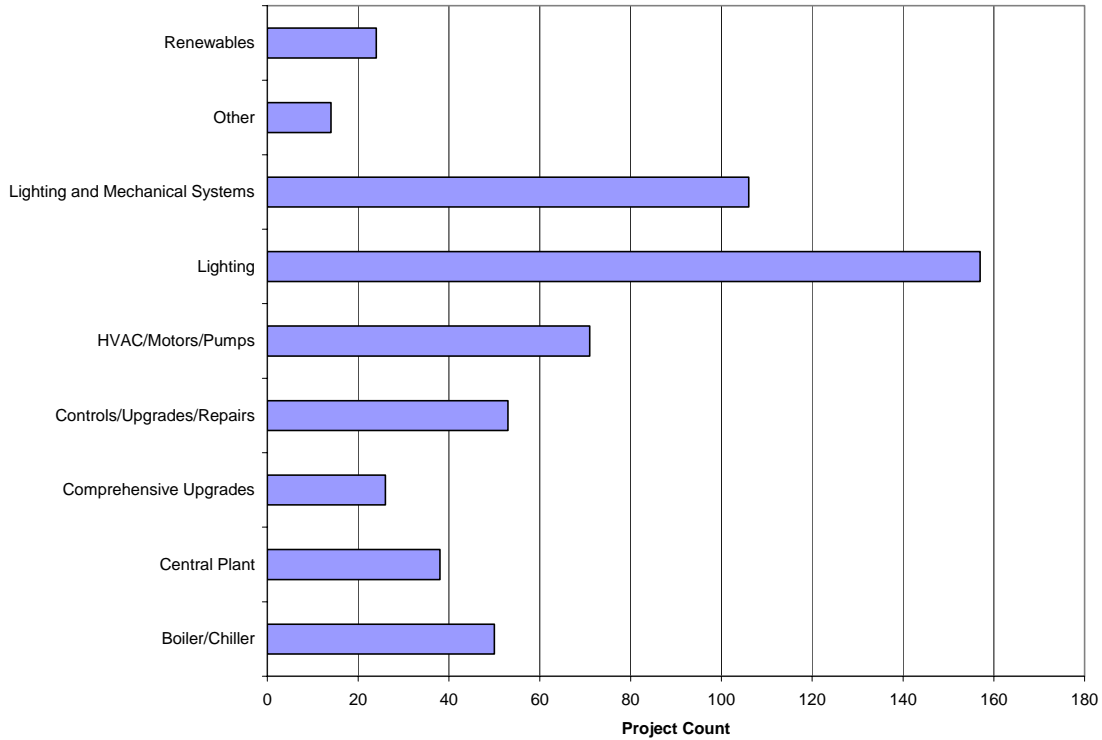


Figure 4: Project Count by ECM Category for June 2006 Simple Payback Analysis Dataset

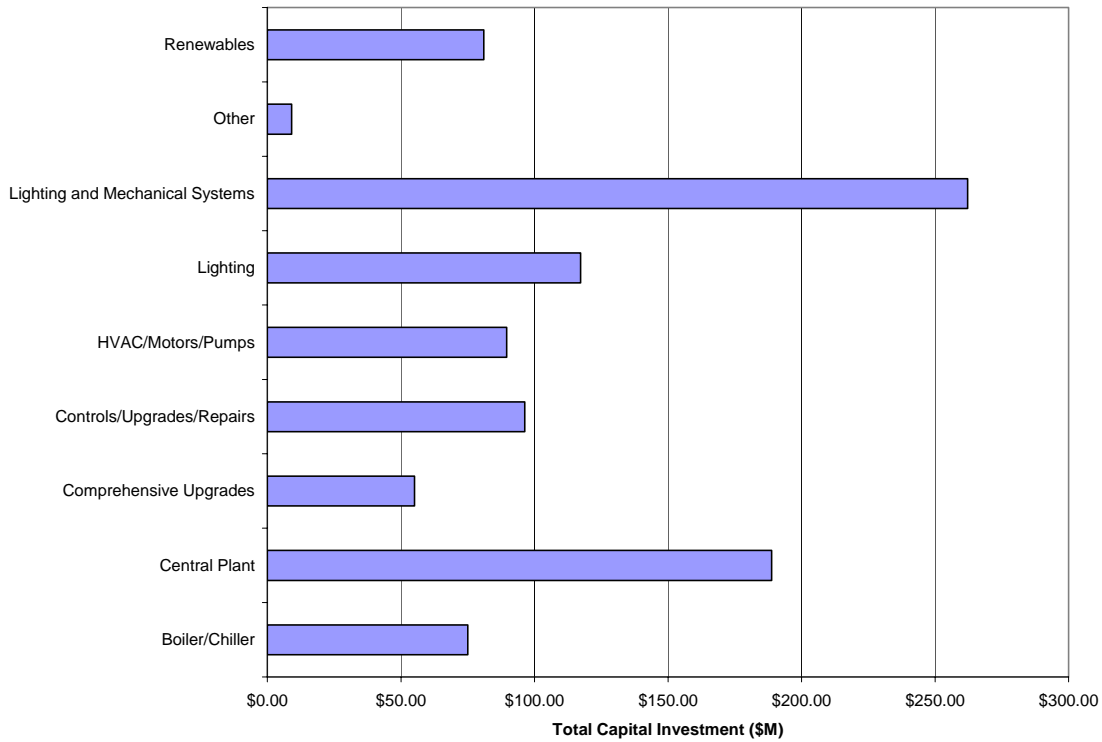


Figure 5: Capital Cost of Projects by ECM Category for June 2006 Simple Payback Analysis Dataset

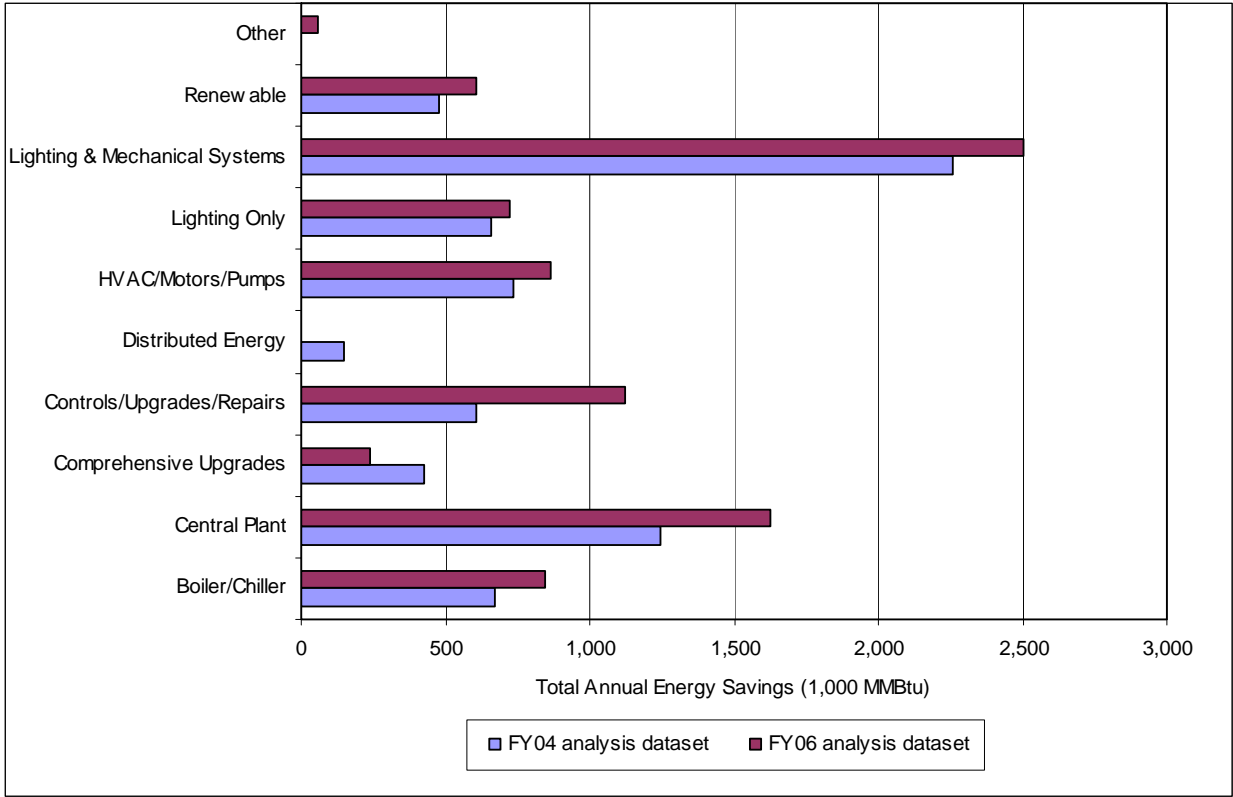


Figure 6: Energy Savings by ECM Category for both the July 2004 and June 2006 and Payback Analysis Dataset

ANALYSIS RESULTS

Slope Estimates from Linear Regression

A curve-fitting analysis was performed on two relationships by ECM category: 1) annual Btu saved versus total capital dollar invested data and 2) total capital dollar investment versus annual cost savings, or simple payback for that ECM. A simple linear regression was chosen based on the results of the original analysis done in 2004 (Stoughton et al. 2006), which showed that a linear regression was the best and simplest way to show the relationship between savings and capital cost. In the current analysis, this simple linear regression was developed for energy saved per dollar invested and simple payback by ECM category.

There was a two step analysis process. First, an initial linear regression was run for both datasets – energy saved per dollar invested and simple payback. Outliers were investigated for each ECM category for both datasets. Outliers were identified as those projects that had atypical energy or cost savings compared to the rest of the dataset and were excluded if data was found to be erroneous. Then the linear regressions were run again for the datasets with the outliers excluded. See Appendix B for a detailed explanation on the outlier process and observations.

In the tables and that follow, a visual representation is shown of the estimated slope for both energy saved per dollar invested and simple payback, developed from the linear regression analysis along with the uncertainty of the slope (standard error) for each ECM measure. (Doubling the standard error gives an approximate 95% confidence interval on the slope.)

Table 1 shows the results of the annual energy saved per dollar invested analysis and also draws the comparison with the results from the July 2004 analysis. The table shows the percent change in slope from July 2004 to June 2006. The changes for the two analysis products are mainly a result of excluding outliers (detailed below) and collection of new project data between July 2004 and June 2006. No significant change in the original analysis was identified except for the Lighting Only ECM. A statistically significant change in the original value for the slope was found because the confidence intervals (doubling the standard error) of the two slopes did not overlap. When the confidence intervals do overlap, it reveals that the change in slopes does not produce greatly different results.

Table 1: Slope Estimates from Simple Linear Regression Model for Annual Energy Saved per Dollar Invested (Btu/dollar) – Comparison of June 2006 and July 2004 Analysis

Energy Conservation Measure	June 2006 Analysis		July 2004 Analysis		% change in slope	Significant change ⁴
	Btu saved per dollar invested (slope of regression)	Standard error	Btu saved per dollar invested (slope of regression)	Standard error		
Boiler/Chiller	10,582	967	10,539	1,091	0.4%	no
Central Plant	9,888	1,110	9,502	1,403	4.1%	no
Comprehensive Upgrades	8,172	1,247	10,072	2,787	-18.9%	no
Controls/Upgrades/Repairs	14,343	1,265	14,051	761	2.1%	no
Distributed Energy	na	na	2,103	766	na	na
HVAC/Motors/Pumps	7,788	938	7,097	948	9.7%	no
Lighting Only	6,906	331	5,643	270	22.4%	yes
Lighting & Mechanical Systems	9,186	510	9,383	511	-2.1%	no
Other	5,390	675	na	na	na	na
Renewable	6,429	1,212	5,964	1,241	7.8%	no

Table 2 shows the results from the simple payback analysis for the simple linear regression model by providing the slope of the linear regression and the standard error. All of the ECM categories have a simple payback less than 10 years, which is consistent with the original requirements set forth in section 543, Energy Management Requirements of the Energy Policy Act of 1992 (EPACT 1992).

The Other ECM category had the shortest payback. This was somewhat of a surprising result. However, when the individual project data was examined, it is revealed that a good portion of these projects were driven by the desire to achieve electric demand savings, which typically achieves high cost savings. The Controls/Upgrades/Repairs and Lighting Only ECM categories resulted in very short (less than 4 years) paybacks, which was expected. Projects in the Control/Upgrades/Repair category are dominated by low cost upgrades, repairs, and controls that

⁴ Significant change in the slope is signified when confidence intervals (two times the standard error) of the two slopes do not overlap.

have low initial capital cost, yet result in high energy savings. Lighting Only ECM projects tend to have high cost savings because projects are dominated by electricity reduction, which produce short paybacks as well. One of the longest payback results was associated with the Lighting and Mechanical System ECM projects. This most likely reveals the impact of the “bundling” of ECMs. Bundling refers to projects that combine ECMs that have long paybacks with ECMs with short paybacks to meet the required 10-year payback. The other ECMs with long paybacks values, central plant and renewable projects, may reflect the impact of limited number of providers in the market, thus higher initial cost. This should not eliminate these ECMs from consideration because there might be other reasons to give these ECMs priority, such as meeting renewable energy goals, or the immediate need for infrastructure modernization at a particular site.

Table 2: Slope Estimates from Simple Linear Regression for Dollar Invested per Annual Cost Savings

Energy Conservation Measure	Simple Payback in Years (slope of regression)	Standard Error
Boiler/Chiller	5.63	0.27
Central Plant	6.85	0.31
Comprehensive Upgrades	5.50	0.28
Controls/Upgrades/Repairs	3.64	0.29
HVAC/Motors/Pumps	5.10	0.46
Lighting Only	3.65	0.12
Lighting & Mechanical Systems	7.62	0.24
Other	2.26	0.14
Renewable	7.21	0.60

Percentile Analysis

The updated analysis also included an expanded examination of percentiles⁵ for both energy saved per dollar invested and simple payback by ECM category. This provides a better understanding of the distribution of energy and cost savings for the entire datasets. The main conclusion from this percentile analysis was the data fits a log-normal distribution better than a normal distribution. Log-normal distribution, simply stated, means that the data tends to spike early in the dataset and taper off slowly. Normal distribution represents data as a “bell-curve” that shows the data evenly distributed in a symmetric pattern on either side of the peak. The fact that the UESC data fits a log-normal distribution suggests what is expected for utility projects, that simple payback tends to stay in the 10-year limit but a few go beyond it. The log-normal

⁵ Percentiles divide a dataset at regular intervals to understand how the data is distributed.

distribution also shows that energy saved per dollar invested values tend to achieve savings that result in a 10-year payback.

The log-normal distribution highlights the complexity of the implementing utility projects at Federal sites. Those projects that receive alternative financing through or from the utility require a capital investment have a simple payback of 10 years. But the financing contract of these projects can legally go beyond a 10-year term. In essence, the project is bound to a positive cash flow at year 10 of the contract term. However, if the site uses appropriated funds to buy down the project's cost, or the site pays for the entire project using appropriated funds, the simple payback may go beyond the 10-year time frame as long as it is life-cycle cost-effective. This is the primary reason why it is not uncommon for utility projects to go beyond the 10-year payback.

An example of this log-normal distribution is provided in Figure 7, which shows the log-normal plot of the Boiler and Chiller ECM category for simple payback values. The figure shows the data divided into bins, representing nine percentile groups. The numeric value above each bin represents the number of data points in that bin.

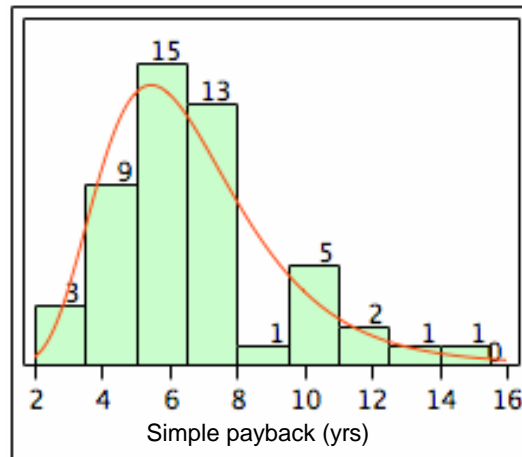


Figure 7: Log-Normal Distribution for Boiler/Chiller ECM Category for Simple Payback

A screening process for the UESC database was developed based on the percentile analysis. The 95th and 5th percentiles for each ECM category were used as the upper and lower bounds to identify the “typical” range expected for energy and cost savings. Table 3 shows the results of the upper and lower bounds for each ECM category.

Table 3: Screening Bounds for Annual Energy Saved per Dollar Invested and Simple Payback

Energy Conservation Measure	Btu saved per dollar		Simple Payback (yrs)	
	lower bound	upper bound	lower bound	upper bound
Boiler/Chiller	2,044	44,169	3.1	12.9
Central Plant	1,546	26,679	3.5	17.1
Comprehensive Upgrades	4,145	23,864	3.0	13.6
Controls/Upgrades/Repairs	2,291	48,509	2.1	14.1
Distributed Energy	0	12,170	4.1	10.0
HVAC/Motors/Pumps	1,552	35,994	1.3	16.1
Insulation/Envelope	2,561	45,837	1.7	10.0
Lighting Only	2,729	23,359	2.4	12.5
Lighting & Mechanical Systems	3,083	27,595	3.6	13.8
Other	1,543	45,160	0.9	10.2
Renewable	2,058	33,417	2.5	16.4
Water Conservation	0	45,242	3.7	10.0

See Appendix C for an explanation of how the prediction values and upper and lower bounds were developed for the ECM categories that were excluded from the analysis: Distributed Energy, Insulation/Envelope, and Water Conservation categories (these categories had relatively small numbers).

KEY OUTCOMES

The intention of this analysis was to reexamine the previous analysis completed in July 2004 to refine the relationship between energy saved and dollars invested in utility projects. In addition, the June 2006 analysis was expanded to include the relationship between cost savings and dollars invested, while developing an understanding of the relative savings achieved in utility projects. A key outcome of the analysis is the calculation of the predicted energy and cost savings for all utility projects where that particular data is unknown. When savings information is not provided, the value is now calculated by using the slope of the regression (regression slopes are found in Table 1 and Table 2). The following bullets illustrate the calculations:

- Estimated Annual Energy Savings (Btu) = Slope of the Linear Regression (Btu/\$) x Total Project Investment (\$) (by appropriated ECM category)
- Estimated Annual Cost Savings (\$/yr) = Total Project Investment (\$) ÷ Slope of the Linear Regression for Payback (yr) (by appropriated ECM category)

Another key outcome of the analysis was the development of a screening process for future data received to identify when project savings are outside the typical range. As shown in Table 3, bounds were created (represented by data between the 5th and 95th percentiles) to indicate typical ranges of energy and cost savings by ECM category. If project information collected is outside these typical ranges, it prompts further investigation. This helps to ensure accurate data is being collected on project investment and energy and costs savings.

CONCLUSIONS

The main objective of this analysis was to ensure that prediction of energy and cost savings in the utility database is accurate and complete. The accuracy of the prediction values has not been tested globally on the entire database, but initial case by case tests of the prediction values show that they are a fairly good indicator of annual energy savings. The June 2006 analysis verified that the results achieved in the July 2004 analysis were acceptable, except in the case of the Lighting Only ECM category. The slope of the regression increased over 22% for lighting projects. The new results for the Lighting Only ECM category now ensure that a more accurate value is being utilized to estimate energy savings for lighting projects.

Another conclusion of the analysis is that there is further need for more in-depth analysis to understand UESC project trends. These are noted below along with other key observations from the analysis:

- Comprehensive Upgrade category had sizeable changes between the two analyses. The slope of the regression decreased by over 18%, as a result of outliers that were excluded from the June 2006 analysis. The project count for this category is relatively low, so the effects of taking out outliers had a big impact on both the slope and standard error of the regression. Further investigation may be warranted to understand the root of why there was a sizable change in this category.
- For most of the ECM categories, excluding outliers improved the standard error of the regression, which would be an obvious conclusion. However, for the Controls/Upgrades/Repairs and Lighting Only ECM categories, the standard error actually worsened. There is no apparent reason why this is the case. Further investigation may be warranted to uncover why the standard error did not improve with Lighting and Controls/Upgrades/Repairs projects.
- Largest energy saved per dollar invested and shortest payback was achieved through the Controls/Upgrades/Repairs ECM category because these projects have high energy savings potential and low initial cost requirements, which was the same conclusion as the July 2004 analysis.
- Lighting Only ECM category has relatively low energy saved per dollar invested values and short simple paybacks because lighting projects are typically driven by cost savings from high electricity costs, but not driven by energy savings. To understand these issues better, further investigation is warranted. PNNL staff is currently examining this ECM category in more depth to uncover any information on what type of lighting technologies are being implemented, and how these technologies might be impacting overall estimates of savings for this ECM
- The Other ECM category had on average the shortest simple payback and a small standard error. This was an unexpected result. This category has relatively small project count (12 projects), and as the category implies, these projects include a wide range of

measures. Large scatter in the data with a large standard error would be expected. However, after examination, several of these projects are dominated by demand savings such as plug power reduction and power factor correction. Low energy savings are typical for projects dominated by demand reductions because the cost savings are achieved through demand, not energy savings. It should be noted that this category also has short simple paybacks, which coincides with projects dominated by demand savings and not energy savings.

REFERENCES

Stoughton, K. M., A. E. Solana, D. J. Bates, and W. F. Sandusky. 2006. "Analysis of Energy Savings In the Federal Sector Through Utilities Service Program." *Strategic Planning for Energy and the Environment*. Vol. 25 (4), pp. 12-38.

EPACT 1992. The Energy Policy Act of 1992, Public Law 102-486.

APPENDIX A

Technology Category Descriptions

APPENDIX A: Technology Category Descriptions

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 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 installation of distributed generation, cogeneration, and emergency generators
- **HVAC/Motors/Pumps** – projects in this category includes smaller projects that involve mechanical system improvements of systems that serve single buildings and other smaller mechanical systems
- **Insulation/Envelope** – projects in this category include 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.

APPENDIX B

Outliers

APPENDIX B: Outliers

For the June 2006 analysis, outliers were investigated thoroughly for each ECM category for both energy saved per dollar invested and simple payback datasets. Outliers were identified as those projects that had atypical energy or cost savings compared to the rest of the dataset.

Based on the regression analysis described above, an index was calculated for each project by dividing the predicted savings over the actual savings. (For example, an index of 1.0 would reveal that the project's actual savings is the same as the predicted.) The higher the index value, the farther the project is from the typical savings. This index was used to identify outliers in each dataset. In the energy saved per dollar invested analysis, a total of 29 outliers were excluded from the dataset. In the simple payback dataset, a total of 95 outliers were excluded.

Outliers were excluded from the dataset for a variety of reasons. A total of 29 projects were excluded from the energy saved per dollar invested dataset and ninety five projects were excluded from the simple payback dataset. But for newer projects, an investigation of the outliers was conducted to understand why the project data was outside the typical ranges. These reasons are summarized below along with key observations that were made through the investigation:

- Projects funded with exclusively appropriated funds sometimes have low cost and energy savings. Appropriated projects are not driven by a simple payback of 10 years, rather are required to life-cycle cost effective. This typically allows for longer payback terms.
- Some inaccuracies were found in the database while researching outliers. It was discovered that some projects were canceled⁶, while other projects were actually duplicates. These corrections were made in the database.
- Several projects had very short paybacks, but were verified as accurate because they were lighting projects in California that utilized public purpose programs funding. These projects had short paybacks because of high electricity prices and public purpose funding that drove down the project's capital cost. This verifies that intent of public purpose programs to help "buy down" the up front cost of the project to make it more economical for the site.
- Individual ECMs that were part of an overall larger project or delivery order often had uncharacteristic savings – sometimes showing atypically high savings, while others were considerably lower than one might expect. In a few cases, data was available on cost and savings data for individual ECMs installed as part of a larger delivery order. In these cases, these individual ECMs did not meet typical simple payback and energy saved per dollar invested value; therefore, they showed up as outliers if they were considered an

⁶ It was uncovered that a large number of small projects that were in line to receive funding from a public benefit fund did not secure their funding and therefore the projects were canceled or put on hold. These projects were small in terms of capital cost, so the impact on total capital investment was less influential.

individual project by themselves. However, the entire bundled delivery order typically had savings information that fell in the normal range. This “bundling” of ECMs is standard practice for alternatively financed projects. It allows longer term payback ECMs to be bundled with lower term payback measures to reach the required 10-year simple payback.

- Some technologies were shown to have atypical savings because of unique circumstances. For example, some projects were driven by only demand savings, so total energy savings was low, but the cost savings was high. Thus, a 10-year payback could be achieved because of the high demand savings.
- Infrared (IR) heating showed unusual savings and were excluded from the analysis. IR heating savings is very dependent upon the existing heating system and its effectiveness. Ineffective systems (e.g., inefficient equipment or distribution, high infiltration rates, minimal building insulation) can be replaced by IR heating and have large energy savings, while more effective systems can be cost-effectively replaced with IR heating but not save nearly as much energy. Another future approach might be to move IR heating projects into their own category to be analyzed separately, to avoid confusion with other heating system retrofits.

APPENDIX C

Determining Prediction Values and Bounds for Excluded Categories

APPENDIX C: Determining Prediction Values and Bounds for Excluded Categories

Three ECM categories, Distributed Energy, Insulation/Envelope, and Water Conservation were excluded from the regression June 2006 analysis because there were a small number of projects in these categories. However, values are still needed to help predict savings and to help identify outliers for these categories, which is described in this appendix. Similar methods were used when possible to find these values for the small categories, with caution and some overriding factors.

The prediction values, used for projects with unknown savings (as shown in Tables 1 and 2), could not be found using the same method as for larger projects because these categories were too small to have reasonable regression analyses conducted. Therefore median and average values were used instead of the regression for all three categories. For simple payback, the average was used because it was higher than the median and therefore a more conservative estimate. For annual energy per dollar invested, the median was used because it was lower than the average and therefore more conservative.

The upper and lower bounds, used to identify outliers (as shown in Table 3), followed the same principle of 5th and 95th percentiles used for the larger categories. For simple payback for all three categories, using the 5th percentile as the lower bound appeared to be reasonable – the lower bounds did not differ substantially from the lower bounds of the larger categories. For simple payback upper bounds, 10 years was used instead of the 95th percentile to make a more conservative assumption until more data can be collected to calculate a more accurate upper bound.

Choosing the Btu per dollar invested bounds required consideration of more factors, partly because many of these values appeared to be outliers. Insulation/Envelope values varied from 1,551 to 166,629 Btu/dollar. The larger values found in this group were much higher than is typically expected in any type of energy efficiency project, and so were not considered when determining the screening bounds. Instead of examining the entire group to determine percentiles, the lower bound was found by averaging the two lowest values. The upper bound used was determined by taking the 95th percentile of the group.

Distributed Energy and Water Conservation both used the 95th percentiles as upper bounds, and 0 as lower bounds. Water conservation projects are not required to save energy if the cost savings still result in a 10-year payback, so 0 Btu/dollar is an acceptable lower bound. Distributed Energy projects include a wide variety of projects, including fuel conversion, which can result in a negative energy savings with a positive dollar savings. However, any project with negative savings should still be verified as accurate and so the lower bound used is 0 Btu/dollar.

It should be noted that all of these values will be periodically reviewed and readjusted as more projects are added to the database. Using more data points as a basis will result in more accurate prediction values and bounds.

