

MEASURING AND VERIFYING SAVINGS FROM LIGHTING RETROFITS AT DOD FACILITIES

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Abstract

In 1993, Southern California Edison initiated a utility ESCo pilot program named ENVEST^{SCE} to provide energy efficiency retrofit solutions to the utility's customers through a combination of incentives, technical project management and long-term financing. The pilot included a measurement and verification (M&V) program that was designed to meet CPUC regulatory guidelines and meet customer savings reporting needs. This M&V activity is delivered within the scope of a customer-financed performance agreement.

This paper will discuss the design of the ENVEST^{SCE} M&V program and implementation of the M&V activities with the customer within the performance contract. A case study of a lighting retrofit project with the United States Department of Defense will be presented, including the difficulties encountered, the lessons learned and the results achieved with the successful execution of the M&V plan.

About the Author

Mark S. Martinez is responsible for Edison ENVEST's engineering activities as the Manager of Technical Services, including measurement and verification. Prior to moving to ENVEST he was manager of Southern California Edison's end-use load research projects, which included over 400 residential and 200 commercial buildings. He also assisted in the development of the California CADMAC M&V protocols and the administration of the M&V program for SCE's DSM bidding pilot, and contributed to the development of the DOE's North American Energy Measurement and Verification Protocol (NEMVP).

ENVEST Overview

General Description

In late 1993, Southern California Edison (SCE) initiated a utility ESCo pilot program named ENVEST^{SCE}. This program was designed to provide energy efficiency retrofit solutions to the utility's customers through a combination of incentives, technical project management and long-term financing. Through ENVEST, Edison acts as a one-stop source that brings together the experts, technology, equipment and support services to create custom-designed energy solution packages for commercial, industrial and public sector customers. ENVEST provides a single point of contact and accountability by coordinating the design, implementation and warranty of the energy solutions through its network of third-party Energy Service Providers and manufacturers who must meet quality control standards.

ENVEST makes the initial capital investment (100 percent) for the customers' energy efficiency solutions. The customers repay the investment over time on their monthly Edison bills. The monthly charge is covered by the savings generated from the energy efficiency measures. Funding for this financing is provided through SCE shareholder investment with ratepayer co-investment.

Services provided to ENVEST customers includes complete energy analysis, engineering and design, installation of solutions, commissioning, monitoring and verification of savings and wrap-around solution warranty. Included in the ENVEST total energy efficiency solution package is a measure-specific measurement and verification (M&V) program to ensure that all CPUC regulatory M&V guidelines were met, retrofit measures met performance criteria and that the long-term persistence of the savings was achieved. This M&V effort differs from traditional utility programs in that it is delivered within the scope of a customer-financed performance agreement between the utility and the customer and is limited only to the direct effects of the specific retrofit measures in the construction project.

Portfolio

The ENVEST pilot program ceased all marketing activities at the end of 1995 and retained 34 customer agreements at year's end for project development. These include 410 sites encompassing over 46 million square feet. In 1996, ENVEST completed or moved towards construction on \$50M in projects with 21 of the 26 public sector customers. Twelve projects, valued at \$21.3M, reached substantial completion. The current portfolio is valued at \$90M. Plans for 1997 include moving to construction for both government and institutional customers with the remainder of the portfolio. Existing projects will be continued and completed through 1998.

When completed, these projects are estimated to reduce annual energy consumption by approximately 145,000 MWh and peak demand by 36 MW. These energy savings will reduce ENVEST participants' annual energy bills by approximately \$14 million.

The government portfolio breakdown by customer is as follows:

General Services Administration	\$5 million
Veterans Administration	\$5 million
United States Postal Service	\$8 million
United States Army	\$6 million
United States Navy	\$18 million
United States Air Force	\$2 million
United States Marines	\$8 million

Although under the jurisdiction of the Administrator of the General Services, the ENVEST contract is specific to each of the military customers. The armed services fall under the jurisdiction of the Department of Defense (DOD), and their agencies.

Measures

The measures financed in the ENVEST program include:

- Lighting system retrofits with controls
- HID dimming systems
- Heating, ventilation and air conditioning (HVAC) package change-outs
- Variable speed drives
- Economizer installations
- EMS installation/upgrade
- Thermostat/controls
- Chiller/boiler central plant replacements
- Thermal energy storage system installation.

The ENVEST Process

Below are the four key phases of the ENVEST process:

Evaluation of Project Feasibility

- Analyze current gas and electric usage
- Identify potential demand and energy savings
- Propose retrofit solutions
- Develop savings and cost estimates

Design & Project Development

- Manage engineering and design phase
- Refine solution to meet specific customer requirements
- Develop customer specific proposals

Installation

- Procure Service Providers competitively
- Manage construction and installation
- Implement quality control measures
- Record and document all as-built conditions

Post-installation

- Perform commissioning of measures
- Conduct training for operations and maintenance personnel
- Implement M&V program
- Report energy savings

All of the above processes are designed to develop a reasonable assurance that savings estimates are developed in as diligent and accurate method as possible. The ENVEST process is designed to provide a customer not with guaranteed savings, but with guaranteed performance of the measures and a reasonable estimate of the savings generated from the measure performance.

The ENVEST M&V Process

M&V Scope of Work

The objectives for the measurement and verification of savings benefits for the ENVEST customer are as follows:

- To verify as-built kWh and kW savings
- To verify that efficiency measures were installed and commissioned in an effective manner
- To monitor and maintain the persistence of savings

The above objectives are accomplished by developing and delivering a cost-effective, site-specific measurement approach, establishing pre-retrofit operational benchmarks, collecting monitoring data over time and delivering a quarterly project performance report to the customer.

The general approach that ENVEST uses in measuring energy is based on measure-specific load impact measurement protocols. The assignment of the protocol and specific monitoring technique will depend on:

- The nature of the energy-efficiency measure
- The cost-effectiveness of the approach
- The customer's acceptance of the plan
- CPUC regulatory requirements

These measurement protocols, based on industry standards and accepted as guidelines by state regulatory agencies, employ an engineering-based approach to savings estimation, specific to the operating principles of the load under evaluation. The protocols are grouped within the following categories of electric loads:

- Steady-state, with regular schedule and constant performance
- Improved schedule, with constant performance
- Variable load, dependent on weather or operations
- Special process applications

By focusing on the measure-specificity of the savings analysis, the level of uncertainty is minimized when

estimates of savings are calculated to develop a performance verification report for the project.

Deliverables

ENVEST develops a detailed baseline of the operating characteristics of the customer facility with information based on:

- Billing analysis - 3 year historical trend
- Month-to-month rates trend analysis
- Definition of customer operating and utilization schedules
- End-use distribution analysis of the facility
- Temperature-correlated sensitivity analysis

The baseline development tool is in the form of a spreadsheet which includes all of the above and can also be used for the initial rate schedule analysis that occurs in the post-construction phase. This will also establish the 'pre-existing' conditions that will provide a reference point of operations from which the savings will be estimated.

Based on the ENVEST solution, the ENVEST customer has a temporary monitoring system installed to verify the baseline, monitor ongoing operations changes for each of the measures, minimize the variance associated with the savings estimates and track system performance. This system is an aggregation of cost-effective approaches that are specific to the ENVEST project.

The complexity of the lighting circuit design determines the particular method of estimating the baseline operational and usage profile. In the case of the proposed lighting upgrades, a sample of metered data is sufficient to represent the baseline usage and improved efficiency for the population of the facilities lighting circuits. By developing a full-load hours of lighting operation, customer usage can be profiled and used to develop adjustments to the lighting savings estimates.

The savings for the HVAC measures are based on reduced hours of operation and improved performance. Again a sampling approach will verify the engineering algorithms used to determine annual savings estimates. On-site spot metering of retrofitted equipment, combined with a continuous metering of a sample of units by the monitoring system, will verify the operating diversity of the HVAC systems. Adjustment of the facilities' baseline to trend local weather conditions and keep track of the building utilization is also important and is handled using a survey.

After the retrofit project is commissioned and approved by the customer, a periodic performance report is delivered to the customer. This report identifies the customer's savings and accomplishes the following:

- Establishes an adjusted baseline of energy usage
- Correlates the energy bill to the adjusted baseline

- Identifies and explains any variances in the savings estimates
- Notes any additional benefits of the project not captured by the reduction in energy costs

The reporting process will continue for a period of up to two years after the project is substantially completed. The customer, at their discretion, may contract for an extended reporting period or a change in scope of the information included in the report.

Follow-up site visits may be performed to investigate variances in the anticipated savings estimates, but only when mutually agreed upon at the customer's convenience, and at no cost to the customer.

For the purposes of persistence analysis, annual verification of the site conditions will be confirmed with a site audit and collection of operating information from the customer.

Budget

M&V is budgeted for the ENVEST project at a fixed cost over the contract period. ENVEST is responsible for the installation, maintenance, and removal of all pre- and post-construction metering, and for the cost of the pre- and post-metering activity.

The costs are estimated based on the nature of the measures and the applicability of the CPUC protocol guidelines in verifying the as-built (ex-post) energy estimates for the project.

If a cost-effectiveness risk analysis approach based on the annual savings estimates is applied to the cost of the M&V service for the project, the following guidelines are applied:

Pre-retrofit annual energy savings estimate =
(to be determined at feasibility study stage)

Assuming +/- 10 percent confidence in engineering estimates for savings, then the amount of possible uncertainty without M&V over two years = 20 percent of annual energy savings

Two year M&V budget guideline = 20 percent of one year's annual energy savings

The above budgeting criteria is adjusted for the complexity of the project and the measures (multiple sites, many billing accounts, schedule and temperature sensitivity) and also for the customer's requirements (detailed savings analysis, or simple billing comparison). However, the basis of the budget provides a minimum funding to meet the CPUC regulatory requirement, as set for site-specific verification of hours of operation.

Project Management

ENVEST is responsible for managing and directing all M&V activities, and may include subcontractors to accomplish specific tasks.

The DOD Case Study

Background

Edison ENVEST signed an agreement with the General Services Administration that allowed for the pro-

curement of certain energy-related tasks and services by the utility for the United States Government and its agencies and departments through a service charge arrangement. The overall purpose of such an agreement was to facilitate energy efficiency strategies that would enable the Government to comply with Executive Order 12902, as well as other energy-specific needs. This agreement is an amendment to the Areawide Public Utilities Contract.

Table 1
Proposed Equipment Retrofit

Existing Technology	New Technology	Quantity	Estimated Annual Savings (kWh)
Building 3500			
2x2 2-F20 lamps	2-F17 lamps, electronic ballast	1	244
2x2 2-FB40 lamps	2-F17 lamps, electronic ballast, reflector	11	1,407
1x4 1-F40 lamp	1-F32 lamp, electronic ballast	3	178
1x4 1-F40 lamp	1-F32 lamp, tandem wire .5 electronic ballast	2	119
400 watt HPS fixture	2-8ft. 4-F32 lamps, electronic ballast wrap fixtures	11	23,338
2-F40 lamp fixtures	2-F32 lamps, electronic ballast	137	5,129
2-F40 lamp fixtures	2-F32 lamps, tandem wire .5 electronic ballast	4	150
2-F40 fixture	4 ft. 2-F32, electronic ballast wrap fixture	1	37
2x4 3-F40 lamps	2-F32 lamps, electronic ballast, reflector	24	4,643
2x4 3-F40 lamps	3-F32 lamps, electronic ballast	5	530
2x4 4-F40 fixture	Remove	1	530
2x4 4-F40 lamps	2-F32 lamps, electronic ballast	19	6,640
2x4 4-F40 lamps	2-F32 lamps, High Bright electronic ballast, reflector	504	176,118
2x4 4-F40 lamps	2-F32 lamps, tandem .5 electronic ballast, reflector	18	6,458
2x4 4-F40 lamps	4-F32 lamps, electronic ballast	24	4,493
2-F96 lamp fixture	Remove	1	540
2-F96 lamp fixture	8 ft. 2-F32 lamp, electronic ballast wrap fixtures	7	2,511
2-F96 lamp fixture	8 ft. 2-F32 lamp, electronic ballast industrial strip fixtures	2	718
2-F96 lamp fixture	8 ft. 4-F32 lamp, electronic ballast wrap fixtures	12	2,347
4-F96 lamp fixture	8 ft. 4-F32 lamp, electronic ballast wrap fixtures	6	4,418
250 MV fixture	175 MH lamp, transformer	7	2,184
		TOTAL	242,732
		BUILDING	

The successful establishment of this contract resulted in a specific customer agreement with a military base located in SCE's service territory. The base, a DOD facility, contracted Edison ENVEST for the identification, development and implementation of energy efficiency tasks, as outlined in a specific master customer agreement. The first such task that ENVEST undertook was a preliminary audit, which was conducted at no cost to the customer and consisted of a listing of recommended Energy Conservation Measures (ECMs) with estimated cost savings.

From that, a preliminary task proposal was developed that also included estimated service charge payments for the ECM implementation.

The ENVEST Solution

The base received the task proposal, and decided to go forward with design-build implementation of the first recommended task - a lighting retrofit. This consisted of a comprehensive energy-efficient lamp and ballast retrofit of the lighting systems in a number of warehouses, office

buildings, and hangers. The retrofit also included outdoor lighting and sensors in the residential housing areas. ENVEST solicited competitive bids from lighting service providers, and submitted a final construction proposal and schedule to the base along with a service charge payment schedule. The base gave notice to proceed with this Task One as additional tasks related to HVAC and other measures were being developed.

The scope of the work in Task One as proposed by the winning bid was to produce total annual kWh savings of 1,921,751. These savings were to be accomplished by: 1) replacing 60 watt incandescent bulbs with 17 watt outdoor-sensor lights at 2000 residential sites. The as-built savings for this retrofit are estimated at 313,040 kWh; and

2) retrofitting a total of ten commercial sites with electronic ballasts, lower wattage lamps, reflectors and de-lamping (e.g., reducing four unit lamps to two), as needed. The total estimated annual savings for the commercial retrofit were 1,608,711 kWh.

Table 1 provides an example of the proposed equipment retrofit for one of the larger buildings.

The M&V Approach

ENVEST relied on the lighting contractor's fixture by fixture pre-retrofit audit for developing inventory and specification information on the pre-existing lighting conditions, such as lamp counts and hours of operation (see Table 1).

Table 2
Cumulative Building Savings -- Original Sample

CUMULATIVE KWH SAVINGS

Building Number	Total KWh Saved	Total Dollars Saved	Percentage of Total Savings	Percentage of Cumulative Savings
Building 3736	530,098	\$36,047	32.95%	33%
Building 3500	242,732	\$16,506	15.09%	48%
Building 2650A	181,508	\$12,343	11.28%	59%
Building 1820	171,117	\$11,636	10.64%	70%
Building 2800	153,202	\$10,418	9.52%	79%
Building 1810	117,780	\$8,009	7.32%	87%
Building 1	94,124	\$6,400	5.85%	93%
Building 1210	90,699	\$6,168	5.64%	98%
Building 3535	21,905	\$1,490	1.36%	100%
Building 3513	5,546	\$377	0.34%	100%
Address-o-Lites	313,040	\$19,722	NA	NA
Total KWh Savings annually for all retrofits in Phase 1: 1,921,751				
Total Dollars Saved through Phase 1: \$129,116				

Note: Metering of the first five buildings ranked in order of KWh saved will provide nearly 80% of the total savings for the 10 buildings.

$$\text{kWh savings} = (\text{kW number of fixtures} * \text{hours of operation pre-retrofit}) - (\text{kW number of fixtures} * \text{hours of operation post-retrofit})$$

Using this information along with the estimated savings, ENVEST selected a sample for measurement that should represent up to 80 percent of the projected savings. A total of five buildings were selected. Table 2 represents the original projected savings per building as reported by the retrofit contractor.

Monitoring Equipment. In order to verify the hours of operation for as much of the total building lighting load

as possible at the panel, ENVEST through its contractor Quantum Consulting, Inc. planned to install AC data loggers. The advantage of using these type of loggers over photosensitive loggers is that more of the lighting operating profile for the building is captured. Also, with these loggers ENVEST can record current loads for future utilization reference. This meets the overall objective of verifying the operating hours of the retrofit and producing load profiles from the data collected.

Post Retrofit Audit. A post retrofit audit was conducted before installing loggers. The purpose of the audit was to verify the lighting schedules for each building from the lighting contractor's pre-retrofit estimates, verify the

as-built conditions of the number and type of fixtures, verify the specifications of the new lights and assess the lighting loads and suitability for monitoring.

Gaining access to the facility and specific buildings at a military installation is always a challenge. Although escorts were not required for these sites, overall access must be coordinated with the sponsoring group (in this

case, Civil Engineering) and specific access to buildings is controlled by the site facility managers. Even with extensive preparation, access to the building lighting panels initially met with some difficulty. Not all of the military liaisons had keys to the panels. However, this initial audit did provide valuable data on the persistence of the retrofit even at this early stage of the program.

Table 3
Re-tuned Savings Estimate: New Sample -- Post Audit

Building Number	Total KWh Saved	Total Dollars Saved	Building Number	Rank (Descending)	Percentage of Total
3736	552,867	\$37,594.96	3736	552,867	36%
3500	204,498	\$13,905.86	3500	204,498	50%
2800	193,121	\$13,132.23	2800	193,121	62%
1820	177,465	\$12,067.62	1820	177,465	74%
2650A	167,491	\$11,389.39	2650A	167,491	85%
1210	93,814	6,379.35	1210	93,814	91%
1	87,013	\$5,916.88	1	87,013	97%
3535	41,461	2,819.35	*3535	*41461	99%
3513	6,440	\$437.92	3513	6,440	100%
1810	-42,634	(\$2,899.11)	1810	-42,634	
Address-o-Lites	313,040	\$21,287.00			
* Removed Building					
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Total KWh Savings annually for all retrofits in Phase 1: 1,794,576					
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Total Dollars Saved through Phase 1: \$122,031					
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Note: Metering of the first five buildings ranked in order of KWh saved will provide 85% of the total savings for the 10 buildings of interest.

During this visit it was discovered that one of the buildings in the scope of work had been demolished, one building was no longer occupied, and one building was undergoing renovations and also unoccupied. Also, operating schedules had changed significantly from what was reported by the retrofit contractor for some of the remaining buildings, nearly doubling in schedule from the retrofit conditions in some cases.

On the basis of the above changes, estimates of the post-retrofit savings were re-tuned and a new sample for monitoring was selected (Table 3). With the new sample of buildings, it was estimated that the sample should now be able to verify about 85 percent of the expected savings.

Installation. Armed with the new sample and verified contacts for building access, QC returned to the base to install the current loggers.

The following installation procedure was used:

- Install one current logger in each of the five (5) buildings identified as the top total kWh saved according to the re-tuned savings spreadsheet.

- Conduct a quick survey of each building to re-verify the building's main lighting schedule and any other areas of the building with a lighting schedule that significantly varies from the representative (logged) main.
- Locate the electric panel that encompasses lighting loads best representative of that schedule.
- Place loggers and one or more CTs on phase of the lighting panel that captures most of the building's main lighting circuits. Set to record the average current and kW at 15 minute intervals.
- Loggers remain in place for approximately four weeks.

Logger Removal and Verification of Savings. After removal, QC compiled and analyzed the data to provide:

- Interval data for each lighting panel monitored

- Logger load profiles for each day
- Determination of average annual hours of operation for each building
- Calculation of kWh and/or dollar savings based on logger load profiles

These data were then compared to the as-built or re-tuned savings from the results of the first audit, and provided the basis for the first year's "true-up" of annual savings from the project.

Conclusions

The ENVEST approach to measurement and verification is a necessary component of the site-specific energy-efficiency savings estimation process, and that this process does not follow the standard evaluation models developed for the utility industry. Also, for the M&V to be cost-effective and acceptable to all parties, the process must be both measure- (in this case, lighting retrofit) and customer-specific. The customer's expectations for energy savings must first be managed with a proactive approach to developing, estimating, and verifying the energy benefits of the project, then periodically reported to the customer as a means to feedback the operational and seasonal sensitivity of the savings.

The DOD facilities represent a constantly changing environment that requires a tracking system for as-builts

during construction as well as post-construction activities. The government, as well as the military, is facing reevaluation of mission and budget trimming of utilities. These force the public works organizations to consolidate missions, enact temporary shutdowns, and even eliminate facilities and activities. This leads to an unpredictability in the persistence of the energy savings, requiring that the retrofit be checked on a periodic basis, within the scope of the contractual reporting requirement.

Ultimately, because of the self funding nature of the project and the administrative costs, including M&V, the scope and design of the M&V approach is forced to be cost effective, as demonstrated by this paper. All M&V projects at ENVEST are fixed-price budgeted, with a very dynamic flexibility necessitated by the changing customer information needs and site activities. The verification of savings over the long term enhance the persistence of the measures such that the customer benefits not only from the enhanced infrastructure but also from the benefits of lower utility costs.

The ENVEST pilot was officially ended on December 31, 1995. All projects signed, in development, or in construction were continued into 1996, but no new customer agreements were signed. Project construction, commissioning, and verification activities for the portfolio are expected to continue through 1999, at which time deregulation in California, along with the new public-funded DSM programs, will be in full swing.