An Innovative Approach to Impact Evaluation of Energy Management System Incentive Programs

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Two utility programs in New England provide incentives to encourage installation of energy management systems in non-residential buildings. An unusual approach was taken to evaluate effectiveness of these programs. With the objective of making the DSM effort more credible, the utility and the primary public interest advocate worked as a team to conduct technical analyses underpinning the evaluation. Evaluation credibility was enhanced by embracing very rigorous analytical methods and by providing the public interest advocate equal participation in development of the work plan, and review and endorsement of interim and final results.

The results include both demand and long-term energy impacts. Both types of results vary greatly from site to site, and as compared to preliminary tracking savings estimates. The former can be attributed to the variety of site-specific details. Sources of the latter differences can be attributed to the simplified analysis approaches and assumptions used to determine the preliminary estimates.

The energy management systems reduced electric energy consumption for a typical year by an average of 8% for all sites, with a range from 0% to 30%. On-peak consumption was reduced an average of 6%, with a range of -2% to 50%. Winter demand was reduced an average of 13%, with a range of -1% to 68%. Summer demand was reduced an average of 1%, with a range of -5% to 76%.

BACKGROUND

The utility provided cash incentives for the installation of energy management technology in large commercial and industrial buildings. Qualified applications needed to include EMS systems that implemented any or all of the following capabilities: programmable thermostat setpoints; seven-day time clocks; optimum fan start; direct digital control (DDC) of space temperature; enthalpy economizer control; and duty-cycling to reduce peak loads.

The utility received and processed applications for the incentives from a number of customers. The applications included a description of the intended EMS installation and a calculation of the expected typical annual energy and demand impacts. Over 70 customers received incentives. Of these, 11 sites were sampled by the utility and the primary public interest advocate for site visits and evaluation analysis. The eleven sites include 3 schools, a hotel, a restaurant/night club, 3 industrial plants, a shopping mall and 2 office buildings. The sampled sites were selected by the utility. The evaluation team was not involved in the selection process.

The EMS systems were from a number of venders, and were generally implemented on Windows based personal computers. Most of the sites included programmable thermostats, seven day clocks and DDC temperature control. A few specified enthalpy economizer control.

The utility needed verification that the EMS systems were installed and operating as expected. The utility also needed estimates of the impacts of the EMS installations on building performance for several time periods for a typical year.

ANALYSIS METHODOLOGY

The analysis approach used to determine the energy impacts was based on hourly building simulation using the DOE2.1E program. DOE2 models, calibrated against utility load research meter data, were developed for each site. Generally, the load research data were available for the post-retrofit time period. We developed impact evaluation estimates by modifying the calibrated DOE2 models to represent the pre-retrofit situation, and ran both pre-and post-retrofit cases against weather data representative of long term conditions. Differences in the output from the two cases were used to assemble the energy and demand impacts for each site. All other project activities were designed to support this analysis by improving the accuracy of the DOE2 models.

The public interest advocate was involved in every phase of the evaluation process. This includes providing the calibration criteria, and a constant review of the input assumptions and results. We believe that this is the first time that the public interest advocate and evaluation team cooperated at this level.

Site Visits

The first step involved gathering information on the sites, including their physical characteristics, control strategies, occupancy patterns, HVAC equipment specifications and detailed information on the EMS hardware and software implementation. At the time of the study, all of the EMSs were already installed, so all existing conditions were post-retrofit. Interviews, examination of plans, utility billing records, and other sources were used to determine the pre-retrofit condition of each site.

In order to acquire the detailed information necessary to construct accurate simulation models, a comprehensive survey of each site was conducted. Audits were performed to quantify lighting power densities, plug load densities, process equipment densities, HVAC characteristics, and the number and schedule of building occupants. Interviews were conducted with key on-site personnel to define operating schedules for each of the major building loads and to define the operations and control strategies used in the building. Construction drawings were obtained from which to extract further details of architectural, mechanical, and electrical systems. Budget and time constraints permitted about 2 to 3 days per site. This proved adequate to gather the information needed to develop a good DOE2 model. A great deal of very useful information was gathered through casual conversations with site personnel, sometimes not the key-people that we originally intended to interview. For example, a teacher at one of the schools mentioned that the school had its own sewage treatment plant, a 50 KW load that was on the same meter as the rest of the school. The facility manager and his staff had not previously discussed it with us.

Site surveys included both spot measurements and time series data acquisition of selected end-use electric loads and HVAC system characteristics. These measurements were taken to support two activities. The first is the development of site specific end use load and HVAC system performance data to improve the accuracy of the DOE2 models. Time series metering of zone air temperatures or currents on selected circuits also supported verification of the EMS operation. They provided, for example, independent evidence that night setbacks and other EMS functions operated properly. A variety of instrumentation was used during the site visits. True RMS multimeters and power probes were used to make accurate power measurements. Differential pressure gauges and tachometers were used to make fan system measurements. Battery-powered data loggers were used to record time-series measurements of selected currents and temperatures. Data loggers provided temperature histories to verify that night setback of thermostats was occurring. Current transducers were used at a few sites to verify EMS functions that turn lighting systems on and off. Independent measurements to verify other EMS functions were not practical due to limited on-site time. Verification of these functions was accomplished by visual confirmation of the presence of pertinent hardware and/or visual observation of the presence of the control functions in the EMS software.

DOE2 Analysis

The analysis included the processing of the utility meter 15 minute load research data, the acquisition and processing of appropriate weather data, and the actual development and calibration of the site specific DOE2 building models.

Load Research Data Processing. The utility provided 15-minute-interval long-term whole-premise power measurements for ten of the eleven sites. These data were not available for the restaurant/ night club. For this site, the only utility data available were the monthly customer billing records of electric energy consumption and billing demand for each monthly billing period.

The interval load research data are the basis for calibration of the DOE2 models. Calibration involves comparing the DOE2 output with target load shapes, derived from the actual load research data. The DOE2 models are driven with actual weather from a nearby weather station for the same time period as the load research data. The target load shapes were defined in collaboration with technical representatives of the public interest advocate. Eight day-types were defined for which target load shapes were to be developed: winter peak weekday, winter average weekday, winter average weekend day/holiday, summer peak weekday, summer average weekday, summer average weekend day/holiday, spring average weekday, and fall average weekday. Standards for comparison between the DOE2 output and the target load shapes were also developed in conjunction with the public interest advocate. These constitute a pass/fail test for the calibration process. The public interest advocate required passes for all eight load shapes for the DOE2 models to be considered calibrated. For five of the ten analysis sites, circumstances conspired to prevent implementation of the full calibration procedure In three of these cases, load research data were used in an abbreviated fashion similar to that described below. Full calibration involved development of target load shapes for all eight day types. Abbreviated calibration settled for fewer than eight target shapes due to lack of sufficient actual weather data to drive the calibration process, lack of sufficient load research data, or changing and difficult to define internal loads in the building. Continuously changing internal loads, such as the result of rapid expansion of a manufacturing process, are an example of ill-behaved loads that recommended an abbreviated calibration process. The third calibration process employed in this project involved only monthly billing records due to a total lack of appropriate load research data.

The load data, consisting of 15-minute-interval power measurements, were processed into hourly power data. Depending on the circumstances of a particular site, a period of time before or after the EMS installation was selected as the calibration period. The target time periods for the calibration process are defined as:

- Winter peak weekday. The five coldest non-holiday weekdays during December, January, and February were identified using actual weather data for the calibration period. An average hourly load shape was defined by averaging the five days of hour by hour load data.

- Winter average weekday. The loads of all non-holiday weekdays during December, January, and February, but not including the peak weekdays identified previously, were averaged on an hour by hour basis.

- Average winter weekend day/holiday. The hour by hour average of the loads for all December, January, and February weekends and holidays.

The summer peak weekday, average summer weekday, average summer weekend day/holiday, and spring average weekdays and fall average weekdays were derived in a similar fashion.

All of the time periods and calibration criteria were developed by the technical representatives of the public interest advocate.

Weather Data Acquisition and Processing. Numerous sets of weather data were required for this project. Each analysis site is located in its own micro-climate. Since the detailed weather data required by DOE2 are collected in relatively few locations, most of the analysis sites had to be assigned a nearby weather site, generally an airport location, as an approximation of local weather.

For each weather site, two sets of weather data were required. A set of actual weather data corresponding to a particular site's calibration period was required to drive the DOE2 model during the model calibration process. After achieving calibration, a weather data set representing long-term average weather was required to drive the pre-retrofit and post-retrofit models.

Long-term average weather data were acquired from SAIC/The Fleming Group. Actual weather data for specific time periods were acquired from the Northeast Regional Climate Center (NRCC) at Cornell University. The NRCC data required extensive processing in order to enable the creation of data sets readable by DOE2. Weather data from NRCC consisted of hourly dry bulb temperature, dewpoint temperature, wind speed, wind direction, and total global horizontal solar radiation. The data sets required by DOE2 include wet bulb temperature rather than dewpoint and direct normal solar radiation in addition to global horizontal. To generate these data, a computerized psychrometric routine was used to calculate hourly values for wet bulb temperature. The latest correlation algorithm relating direct normal solar radiation to total global horizontal radiation was acquired from the National Renewable Energy Laboratory. A computer routine was written to calculate an hourly estimate of direct normal radiation from the hourly global horizontal data provided by NRCC. Once the wet bulb and direct normal data were generated, the complete set of required data were placed into a format readable by DOE2.

For this project, the weather site options available for long-term average and actual data included Boston; Providence; Windsor Locks, Connecticut; Worcester; and Concord, New Hampshire. The decisions on which weather to use for the Boston metropolitan area and Providence metropolitan area building sites were obvious. Local weather statistics for the remaining sites were compared with similar statistics for Windsor Locks, Worcester and Concord. In all of these cases the Worcester weather is most similar to the specific site data, and Worcester weather was used in the analysis for these sites.

Long-term average weather data are available for Boston and Providence as Typical Meteorological Year (TMY) data sets. We were advised by SAIC/The Fleming Group that 1993 actual weather data for Worcester are a good approximation of long-term average data for that site.

Simulation Model Calibration. We developed initial DOE2 models for each site. These models included information from the site visit, interviews, building plans and other pertinent sources.

To facilitate calibration, the loads generated by the computer models had to be compared to the actual loads. This was accomplished by extracting the necessary output data from DOE2 to develop hourly simulated load shapes corresponding to the target load shapes. These simulated load shapes were for the same dates for which the target load shapes had been developed.

The DOE2 models were calibrated to the target load shapes developed from the load research data. This was typically accomplished by fine-tuning thermostat setpoints and/or internal load profiles. All adjustments were consistent with site-specific information regarding reasonable ranges of values. In most cases, models of post-retrofit building conditions were calibrated. After achieving a calibrated model (defined as having met the set of specific criteria outlined below), the pre-retrofit model was created by removing the pertinent EMS control functions from the calibrated model. In the other cases, post-retrofit data was not available at all or in sufficient quantity to support post-calibration. For these sites, models of pre-retrofit conditions were calibrated and then the EMS functions were added to the calibrated model to create the post-retrofit model. If the data was available, the post-retrofit DOE2 and real performance data were compared. In all cases, they compared favorably, giving confidence to the approach.

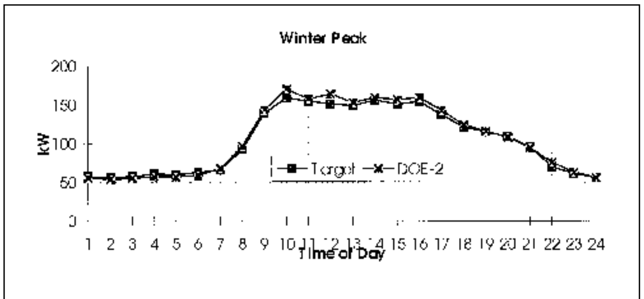
The calibration criteria which the models were required to satisfy tested model accuracy on three levels. First, each calibration load shape derived from the DOE2 output had to be within 20% of the corresponding target load shape, on an hourly basis, for 20 out of the 24 hours. Second, each calibration load shape derived from the DOE2 output had to come within 10% of the daily total kWh for the corresponding target day type. Finally, the models could not exceed a 5% variance from the actual monthly total kWh for winter months (December, January, February) and summer months (June, July, August). These calibration criteria were presented by technical representatives of the public interest advocate. The evaluation team was not involved in their development. It is not known how these criteria compare to those developed for other evaluation efforts. A graph of the Winter Peak day type for one site is shown in Figure 1. Numerical results for the day type and monthly calibrations for the same site are shown in Tables 1 and 2.

The results for the comparison of monthly loads is shown in Table 2. The DOE2 results meet the $\pm 5\%$ criteria for all winter and summer months (in bold type), except for January at 5.6%.

Strategies for Modeling EMS Functions. We developed specific strategies to model EMS functions, including:

Seven-day clock and night offset of thermostat setpoints: These strategies can be directly implemented in DOE2. The

Figure 1. *Typical Hourly Calibration Graph*



modeling of these control strategies requires only changes in the appropriate schedules in the program inputs.

Optimal start: Optimal start is used to reduce transient peaks associated with the morning start-up of a heating or cooling system. The optimal start strategy can use any of a variety of algorithms to change the timing of heating or cooling relative to the scheduled load. There is an algorithm in DOE2 to model an optimal start strategy. This DOE2 strategy 'learns' about how the building reacts, and adjusts the algorithm accordingly. Implementation of the DOE2 optimal start routine at one site produced a large start-up spike in the hourly demand. We could not explain this behavior.

DDC temperature control: DDC temperature control uses electronic, solid-state sensors to replace traditional mechanical or pneumatic temperature sensors and thermostats. The theory is that energy savings are achieved through better control of zone and selected system temperatures. Presumably, the traditional temperature sensors are not biased, but rather have a wider tolerance around the same mean as the DDC sensors. If this is true, then the pre-retrofit and baseline cases can be modeled with the following steps:

(1) Determine or estimate the measurement uncertainty, or the standard deviation around the mean, of the traditional sensors.

(2) Determine an appropriate number of zone or system sensors to group at convenient temperature settings, say 1 and 2 standard deviations above and below the mean and at the mean.

(3) Modify the DOE2 input files to adjust the setpoint control strategies accordingly. This approximates the normal distribution curve.

This analysis was carried out for one of the office building sites. There were negligible differences in energy performance as compared to analysis with constant setpoints. In cases where no bias exists among the thermostats, it appears that DDC control of zone air temperatures has little impact on energy savings. DDC temperature control of system temperatures was not investigated.

Duty cycling: Duty cycling involves turning selected loads off for a period when they would normally be operating. This strategy is implemented when the overall facility electric load exceeds some specified value. This aims to avoid additional demand charges during periods of high demand. When the facility electric load approaches the specified KW value, the EMS system would shed some load by turning off or cycling selected loads, logically proceeding from lowest priority loads to higher priority loads. Water heaters may be eliminated first, then selected pumps, HVAC equipment,

Table 1. *Typical Hourly and Daily Calibration Results*

Calibration Criteria and Results

Day Type	Hourly Values: # Hours within 20%	Hourly Values: Pass / Fail	Day Type Total: Target KWh	Day Type Total: DOE2 KWh	Day Type Total: Delta	Day Type Total: Pass/Fail (Delta ± 10%)
Summer Peak	22	Pass	4273	3992	−6.6%	Pass
Summer Weekday	24	Pass	3684	3502	−4.9%	Pass
Summer Weekend	23	Pass	2245	2210	−1.6%	Pass
Winter Peak	24	Pass	2495	2549	2.2%	Pass
Winter Weekday	24	Pass	2437	2523	3.5%	Pass
Winter Weekend	24	Pass	1531	1601	4.6%	Pass
Spring Weekday	24	Pass	2813	2861	1.7%	Pass
Fall Weekday	22	Pass	2750	2893	5.2%	Pass

and so forth. Duty-cycling was not implemented at any site, and was not include in the DOE2 analysis.

Measure Impact Analysis

The objective of this project was to quantify the impact of EMS installation at each of the analysis sites. The difference in demand and electric energy consumption between the pre-retrofit model and the post-retrofit model, each driven by long-term average weather, provided the estimate of the EMS impact at each site.

The analysis results also included average demand reductions for three so-called ‘‘super peak’’ periods, and reductions for total annual kWh usage and total annual on-peak kWh usage. The KW demand of each super peak period was calculated as the average KW occurring during the period.

The summer super peak period consists of non-holiday weekday hours 10 AM through 3 PM during June, July, August, and September. The winter super peak period consists of 5 PM through 7 PM during December, January, and February non-holiday weekdays. The shoulder super peak period comprises 9 am until noon during non-holiday weekdays of March, April, May, October, and November. The on-peak energy usage period consists of the hours 8 AM to 9 PM, non-holiday weekdays, every month of the year.

Additional results also included energy savings for the summer on-peak energy period, the summer off-peak energy period, and the on-peak and off-peak energy periods of the winter and shoulder seasons. Off-Peak energy hours are 9 PM to 8 AM on non-holiday weekdays, and all hours of holidays and weekends.

RESULTS

Results from this project include verification of the EMS installations, numerical estimates of their energy and demand impacts and other types of useful information discovered during the work.

Verification

The EMS installations generally followed the information supplied to the utility on the program applications. However, a few exceptions are noteworthy.

Site visit interviews at one site established that the EMS installation was a replacement for an earlier version from the same vender. Further, the earlier version implemented duty cycling for load shedding, which resulted in frequent on/off cycling of the compressors in several roof-top air conditioners. This resulted in expensive failures in these compressors. In order to reduce the chance of compressor failure, the software in the new EMS did not implement the duty cycling. Thus the new EMS actually produced negative energy and demand savings as compared to the earlier system.

Table 2. *Typical Monthly and Annual Calibration Results*

Monthly and Annual Calibration Results			
Month	Load Research Data	DOE2	Delta %
Jan	64986	68600	**5.6%**
Feb	61686	62400	**1.2%**
Mar	68794	73800	7.3%
Apr	72601	76900	5.9%
May	85618	86600	1.1%
Jun	93664	90000	**−3.9%**
Jul	97312	96500	**−0.8%**
Aug	108072	103400	**−4.3%**
Sep	85897	87800	2.2%
Oct	69257	75500	9.0%
Nov	65200	70100	7.5%
Dec	65872	68600	**4.1%**
Annual	938958	960200	2.3%

Table 3. *Percent Total Site Energy and Demand Savings*

Site	Type	Percent Savings			
		Summer KW	Winter KW	Annual KWh	On-Peak KWh
1	Manuf.	N/A	N/A	N/A	N/A
2	School	0%	34%	16%	12%
3	Rest.	5%	−1%	4%	2%
4	School	5%	68%	30%	14%
5	Manuf.	9%	3%	9%	6%
6	Mall	−5%	−1%	3%	−2%
7	Office	2%	3%	1%	2%
8	Manuf.	4%	7%	9%	6%
9	Office	1%	3%	12%	4%
10	Hotel	76%	41%	18%	50%
11	School	0%	29%	13%	12%
TOTAL		**1%**	**13%**	**8%**	**6%**

Several of the sites indicated that the EMS systems would implement enthalpy economizer cycles. While economizers operated at several sites, each was based on the existing HVAC equipment, and did not rely on the EMS for operation. Therefore, the economizer cycles were not given credit during the energy impact calculations.

One site indicated load shedding as part of the EMS capabilities. The hardware to monitor the electric loads through the EMS was not installed at the time of the site visit. The load shedding was not given credit in this evaluation.

Energy Impacts and Realization Rates

Percent Total Site Energy Savings due to the EMS installations are presented in Table 3. Sites 1, 5, and 8 are manufacturing, sites 2, 4 and 11 are schools, sites 7 and 9 are office buildings, site 3 is a restaurant/night club, site 6 is a shopping mall and site 10 is a hotel. Site 10 does not involve a traditional EMS. It has occupancy sensors in the guest rooms that disable the room HVAC equipment during unoccupied periods. The occupancy information for the hotel was developed through staff interviews of typical occupancy rates. A probability based Microsoft Visual Basic(program that we developed translated this information into DOE2 schedules for people and equipment internal gains and HVAC system operations.

Explanations of Table 3:

Site 1. There are no savings for site 1 because the new EMS operates in essentially the same manner as the older one it replaces.

Site 2. This is a school, which allows the night setback to occur during the winter on-peak period. The school had generally poor thermostat control before the EMS.

Site 4. Same as Site 2.

Site 6. This is the only new construction site, so good practice was assumed for the base case. It is a shopping mall, and its 10 AM occupancy start-up occurred during the Summer on-peak period. Since the baseline assumed no night setback, the start-up loads of the actual building produce a demand spike.

Site 7. The base case had good control practice, including time clocks for lights, and an essentially manual optimum fan system start time determined by the operators. Since the EMS does little to improve operations, only small savings were realized.

Site 10. This site is not a traditional EMS, but uses guest room occupancy sensors in a hotel to disable HVAC during unoccupied periods. It is clearly an energy saving technology.

Site 11. This is a school. The operator manually adjusts the EMS to achieve savings, particularly demand. There is no air conditioning, so there is little impact summer impact.

The Totals in this and the following Table are based on the total savings for all of the sampled sites.

Realization rates are the ratio of the savings calculated in this study to the savings calculated in the original application to the utility. Realization rates for the 11 EMS installations are presented in Table 4.

Table 4. *Realization Rates*

Site	Type	Realization Rate			
		Summer KW	Winter KW	Annual KWh	On-Peak KWh
1	Manuf.	0	0	0	0
2	School	0	2.05	0.41	0.75
3	Rest.	1.06	1	0.20	0.16
4	School	N/A	N/A	0.90	0.61
5	Manuf.	4.70	1.55	2.55	2.19
6	Mall	− 2.40	− 0.59	0.52	− 0.99
7	Office	2.00	N/A	0.41	1.87
8	Manuf.	2.18	13.59	1.12	1.84
9	Office	0.95	N/A	1.23	0.65
10	Hotel	0.22	1.88	0.93	0.86
11	School	1.05	7.63	1.25	3.04
TOTAL		**0.78**	**4.23**	**0.83**	**1.09**

Explanations of Table 4:

Site 1. See Energy Savings above.

Site 2. The tracking estimates overestimated the heating capacity controlled by the EMS, and included load shedding which was not implemented at the time of the study. Even so, an impressive winter kW realization rate resulted from taking advantage of thermostat setbacks during non-school hours.

Site 3. The tracking estimates are based on percentages of the total expected site loads, but the basis for the percentages are not presented in the utility application. Therefore, the validity of the tracking estimates cannot be evaluated. However, they take credit for optimal start and economizers which are not appropriate for this site, since the former was not implemented and the latter is independent of the EMS operation.

Site 4. The tracking estimates were performed with a bin method, suitable for energy calculations, but inadequate for demand estimates.

Site 5. The tracking estimates are based on percentages of the total expected site loads, but the basis for the percentages are not presented in the utility application. These percentages appear to underestimate the typical savings.

Site 6. The negative demand savings result from morning start-up from set-back loads which are not calculated in the tracking estimates. The -0.99 on-peak annual kWh savings result from the morning start-up hours being included in the on-peak period.

Site 7. Differences in demand and energy savings result from erroneous assumptions for HVAC operation schedules in the tracking estimates.

Site 8. The tracking estimates include constant multipliers for each EMS measure. Discussions with the EMS contractor could not provide a basis for the values used in the calculation. The approach does not accurately account for time-of-day effects, weather, dynamic interactions, or a range of other important thermal mechanisms and operational details. Despite inclusion in the savings estimates of inappropriate EMS features, the constant multipliers significantly underestimated savings.

Site 9. The analysis approach used to develop the tracking estimates is not presented in the application.

Site 10. The tracking estimates were calculated using a bin method approach, which are inappropriate for calculating demand savings. There are also significant differences in the assumptions used in the tracking system and performance review analyses.

Site 11. The tracking estimates include constant multipliers for each EMS measure. This approach does not accurately account for time-of-day effects, weather, dynamic interactions, or a range of other important thermal mechanisms and operational details.

Anecdotal Results

We investigated the use of the EMS at each site to provide data for the performance verification. Typically the EMSs proved inadequate. They were not designed to take the data points or log the time periods needed for these purposes,. Even when appropriate data was taken, the trend log capabilities of the EMSs generally stored only the previous 24 hours or so of data. They could not, therefore, be used to record schedule changes over weekends. The personal computers used to implement the EMS easily have enough capacity to store large amounts of data. Therefore, this situation could easily be remedied with revisions to EMS control software.

There is a wide range of on-site user expertise with the EMSs. At one site the facilities manager constantly adjusted system operations in response to both existing conditions and occupant complaints. Not coincidentally, this site had by far the greatest demand savings of all of the sites. The EMS at one other site was viewed as a black box, and no one on staff had the expertise to meaningfully monitor or adjust its operation. Our examination of the control software indicated that at least a few control setpoints at the latter location were suspect, and should be modified.

The tracking estimates at several sites applied savings associated with features that were essentially unchanged by the installation of the EMS system. Either the features were independent of EMS operation (economizer control) or were done in some other manner before the EMS. The latter includes lighting control, and HVAC time-clock or thermostat functions.

Information forms were developed for the on-site visits. These were developed in collaboration with the technical representative of the public interest advocate. However, they proved of little use during the on-site visits. The facility managers and staff generally liked to talk, and provided useful information that could not be easily documented by filling out the boxes on a form. The forms did prove useful for a phone call after a visit to help insure that all essential information was collected.

A non-energy advantage of EMS installation was evident at several sites. Users greatly appreciated information provided by their EMS. It allowed them to discover information about the performance of their building they had not previously known.

CONCLUSIONS

The site visits, short-term monitoring and analysis methodology were successfully applied to a range of types of sites and EMS installations. The approach proved to be appropriate for performing the impact evaluation.

The energy and demand savings had large variations from site to site.

- Schools provided consistently high savings.
- The hotel occupancy sensors provided very high savings.
- Sites with poor pre-EMS control practices benefited more than sites with good practices.
- The site occupancy schedule could have a large impact on the energy savings. This is particularly true if the fan system start-up occurs during the peak demand period.

The realization rates had a wide range for the various sites. The tracking estimates were generally based on bin methods, constant rule-of-thumb multipliers of annual energy consumption or undocumented calculations.

- Bin methods are not suitable for demand calculations.
- Constant multiplier methods are impossible to evaluate. Discussions with EMS suppliers provided no evidence to support the constant values used in the calculations.
- Undocumented calculations are impossible to evaluate.

A variety of assumptions were used in the calculation of the tracking estimates.

- Some of the assumptions, such as occupancy or fan schedules, were inaccurate.
- Some assumptions supported EMS features which should not be attributed to the present EMS installation.

This includes existing economizers, an existing comparable EMS system, and EMS features that were not installed at the time of the site visits.

User expertise could have a major impact on the energy savings from the EMS.

The EMS hardware and software at a typical site could probably be upgraded to collect data that would be more useful for evaluation purposes.

Implications for improved program design

The range and groupings of performance savings indicates that not all sites are equally suitable for EMS incentive programs. Issues like site operating schedules in relation to demand periods, the form and quality of the existing control situation, the type of facility, the existence of special opportunities, and the capabilities of on-site personnel should be considered. Poorly operated schools are likely to enjoy good benefit from an EMS installation. The hotel occupancy sensors are a special situation which provided large demand and energy savings. Well operated office buildings showed small improvements due to the EMS. Training of on-site personnel may be a reasonable approach to improve the EMS performance savings.

The range of the realization rates indicates the variety of quality in the tracking estimates. While tracking estimates are not the basis for determining incentive payments in these particular programs, if they are at other utilities, the methods and assumptions used in tracking calculations should be carefully checked for validity and accuracy before payments are made.

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