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CADMAC Persistence Subcommittee

Pacific Gas and Electric
San Diego Gas & Electric
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Persistence #3A:
AN ASSESSMENT OF TECHNICAL DEGRADATION FACTORS: COMMERCIAL AIR CONDITIONERS AND ENERGY MANAGEMENT SYSTEMS, FINAL REPORT

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EXECUTIVE SUMMARY

This study, *Persistence 3A: An Assessment of Technical Degradation Factors: Commercial Air Conditioners and Energy Management Systems* (*Persistence 3A*), sponsored by the California DSM Measurement Advisory Committee (CADMAC) Persistence Subcommittee, is the third project to examine the relative technical degradation of demand side management (DSM) measures compared to standard efficiency equipment. This project covers two major DSM measures: commercial direct expansion air conditioners (Comm. DX AC) and energy management systems (EMS).

Commercial DX AC

Research Question

The primary research question is, "Are the efficiencies gained by increasing the number of rows in an air conditioning coil sustainable over time?"

High efficiency commercial package air conditioners can attain efficiency gains through a variety of means: changing to a scroll compressor, changing the metering device, changing motors, adding face area, and adding rows of coils. In *Persistence 1* no relative degradation was likely from the above means except for adding rows to the coils. Due to this, the TDF was determined to have a high degree of uncertainty. There are no technical data available that assist in establishing the differential rate of fouling or efficiency loss.

Research Methodology

Proctor Engineering Group established a time series estimate for condenser and evaporator coil fouling rates. This was derived from available research. Laboratory testing was used to modify the estimated fouling rates and establish a profile for coil fouling. Both high efficiency and standard efficiency coils were tested in a controlled laboratory environment and subjected to continuous fouling. The efficiency of the air conditioner was monitored at various intervals to document the effects of coil fouling on efficiency.

Research Study Results

All of the coils exhibited the same basic fouling behavior. The predominate site of coil fouling was on the face of the coil. The reduction in efficiency was due to the reduction in air flow across the coil. The reduction in air flow on the evaporator coil tended to reduce capacity more than efficiency. The opposite was true for air flow reductions on the condenser coil.

When the air flow was reduced slightly, there was a commensurate reduction in efficiency. As the fouling reached critical proportions, the rate of air flow reduction was greatly accelerated and the efficiency and capacity dropped accordingly. Air flow was reduced 35% on the high efficiency coil with a 2% drop in EER. When air flow was reduced 35% the standard coil had under a 6% drop in EER. The majority (4.6%) of that reduction came in the last two years of the twenty year projection.

Due to the length of time required in the fouling process, it was difficult to control for the amount of contaminants reaching the coils. Physical investigation of the coils and evaluation of the fouling profiles were used to confirm that the number of rows in the coil did not have an impact on the fouling rate.

The efficiencies of both systems were insensitive to low and moderate amounts of air flow reduction due to fouling. However, the high efficiency coils were less susceptible to efficiency loss due to high reductions in air flow.

The condenser fouling data shows that fouling of the condenser coils has a much more dramatic effect on the efficiency. This is particularly true for the standard condenser coil. Although condenser coils have a better chance of being cleaned, fouling them has a more damaging effect on the efficiency and increases the power use of the equipment. A 35% reduction in air flow resulted in a drop in the EER of 24% for the standard unit and 19% for the high efficiency unit. The power use increased 18% and 13% respectively. The data indicate that efficiencies gained by increasing the number of coils are sustainable for up to 18 years, but that significant degradation of these efficiencies is likely after that. Still, the energy cost savings justify the initial extra expense to produce the units with more coils.

The testing shows that the TDF for this measure is greater than one.

Energy Management Systems

Research Question

The primary research question is: “What is the relationship between EMS controlled HVAC system energy usage levels and time from installation?”

Research Methodology

This study consisted of on-site investigations of EMS functioning and continued energy savings as well as billing data analysis (generally for ten years). The buildings in this study were selected so that the most significant space conditioning modification was the EMS system.

The billing data was analyzed in detail. The first analysis was site by site -- a case study approach. The final analysis brought together all the consumption data from all the sites and estimated the persistence of savings over time. The regression process provided statistically significant estimations at the 95% level.

Research Study Results

The research data showed that although there is some EMS savings degradation at some locations, other locations show increasing savings. The billing analysis confirms the field data that little or no degradation (diversified over all units in the study) exists. Some of the causes for this persistence are:

- No instances of disconnected or non-operational EMSs were found.
- The vast majority of EMSs appeared to be operated in a competent and professional manner.
- EMS operators had found that the EMS was a useful tool in performance of their jobs.

Technical Degradation Factors

Establishing Technical Degradation Factors was the primary purpose of this research. A technical degradation factor (TDF) was estimated for each measure. These estimates are displayed in Table ES-1.

Table ES-1 TDF

YEAR	EMS	Comm DX AC
1	1.00	1.00
2	1.00	1.00
3	1.00	1.00
4	1.00	1.01
5	1.00	1.01
6	1.00	1.01
7	1.00	1.01
8	1.00	1.01
9	1.00	1.01
10	1.00	1.02
11	1.00	1.02
12	1.00	1.02
13	1.00	1.02
14	1.00	1.02
15	1.00	1.02
16	1.00	1.02
17	1.00	1.02
18	1.00	1.02
19	1.00	1.06
20	1.00	1.08

1 INTRODUCTION

This study, *Persistence 3A: An Assessment of Technical Degradation Factors: Commercial Air Conditioners and Energy Management Systems* (*Persistence 3A*), is a continuation of the work performed by Proctor Engineering Group (PEG) in the first two Statewide Measure Performance Studies (*Persistence 1*, PEG 1996 & *Persistence 2,* PEG 1998).

1.1. Project Research Objectives

The persistence studies are part of a multi-faceted approach to estimating the persistence of energy savings from demand side management (DSM) programs in California. These studies focused on one aspect of the persistence of savings -- technical degradation. The general research question that these studies are designed to help answer is:

> *How will DSM program savings be affected over time by changes in the technical performance of efficient measures compared to the technical performance of the standard measures they replace?*

Other aspects of savings persistence such as measure life, measure retention, and market effects are being examined through a number of other studies and projects.

The primary study result is a set of Technical Degradation Factors (TDFs). The TDFs are a series of yearly numbers which when multiplied by the first year savings yield an estimate of the energy savings in years subsequent to the first year. Specifically the TDF is defined as: “A scalar to account for time and use related change in the energy savings of a high efficiency measure or practice relative to a standard efficiency measure or practice.” (CADMAC 12/17/97) The base level of performance is the period covered by the first year impact evaluation. The TDF is the ratio of savings in subsequent years to savings in the first year.

This calculation is independent of measure life as determined in the California evaluation protocols. The TDF is calculated for a 20 year period to allow for its independence from changes in the estimates of measure life.

Changes in energy usage that are due to operating conditions, product design or human interaction are included within the scope of the project. The performance of most efficient and baseline measures depend upon installation, and operation & maintenance (O&M) practices. These factors were included within these studies to the extent that they were found to influence relative changes in measure performance over time. The immediate impacts of any initial installation defects are assumed to be accounted for in first year impact studies.

1.2. Background

The two previous projects focused on assessing existing information. The first project (PEG 1996 *Persistence 1*) covered thirteen measures; the second project (PEG 1998 *Persistence 2*) covered an additional twelve measures.

There were two primary stages of work in the previous two studies. The first stage performed an exhaustive search for existing information from published and unpublished sources and synthesized this information into an engineering estimate of technical degradation factors (TDFs). A TDF was estimated for each measure, however, the degree of confidence with which that estimate was made varied greatly. Some TDFs could be estimated with very high confidence while the existing information to substantiate other estimates was weak.

The second stage of the previous studies involved developing research plans for assessing relative technical degradation for those measures where substantial uncertainty was found in stage one. In *Persistence 1& 2*, further research plans were developed for two and five measures respectively, Table 1-1.

Table 1-1 Research Plans for Assessing Relative Technical Degradation

Persistence 1 **Research Plans**	***Persistence 2*** **Research Plans**
Commercial Package Direct Expansion Air Conditioners Oversized Evaporative Cooled Condensers	ASD — Injection Molding Machines Daylighting Controls Variable Air Volume HVAC Systems Energy Management Systems Compressors and Compressed Air Distribution Systems

CADMAC chose to refine the TDF estimate for three of the seven measures:

- Commercial Package Direct Expansion Air Conditioners
- Energy Management Systems
- Compressors and Compressed Air Distribution Systems

CADMAC agreed to accept further TDF research on the three measures included in Persistence 3 studies in lieu of further study of the remaining four measures.

Persistence 3A reports the results of the first two measures: commercial package direct expansion air conditioners and energy management systems.

The third measure, compressors and compressed air distribution systems, will be the focus of *Persistence 3B*. According to CADMAC protocols, performance studies are not required for any measures within the industrial process end use element. (CADMAC, Table 9A) Therefore, performance studies of compressors and compressed air distribution systems are not required. The research is being conducted separately because the TDFs are not required and this allows for a longer research timeline.

1.3. Study Contents and Report Structure

1.3.1. High Efficiency Commercial Package Air Conditioners

The primary research question is: “Are the efficiencies gained by increasing the number of rows in an air conditioning coil sustainable over time?”

High efficiency commercial package air conditioners can attain efficiency gains through a variety of means: changing to a scroll compressor, changing the metering device, changing motors, and /or increasing coil surface area by adding face area or adding rows of coils. *Persistence 1* found no relative degradation was likely from the above means with the possible exception of adding rows to the coils. Due to size limitations of the cabinets, most manufactures increase the surface area by adding rows to the evaporator and condenser coils. Air cooled heat exchangers are widely known to be subject to degradation due to fouling of the coils. It is unknown how adding rows to the coils affects the fouling rate.

The effects of fouling on the indoor evaporator coil are to reduce coil heat transfer by reducing the air flow and heat transfer coefficient. The reduced heat transfer will reduce both the compressor power draw and the capacity. The overall efficiency is reduced because capacity is reduced at a greater rate than the power draw. With both the compressor and the evaporator fan using less energy the connected load of an individual AC unit will decrease from evaporator fouling. However, more energy overall will be used due to increased run time needed to meet the load. Therefore, the diversified load on utility systems will increase due to increased coincidence of air conditioner loads.

Some technical data exist on the rate of coil fouling in conventional package systems. Information on the long term performance of high efficiency package systems is not available. This task will provide a technical evaluation of the relative coil fouling rates and measure the relative efficiency changes due to those changes. Section 2 is the Commercial DX AC methodology section; technical details of the laboratory test procedures and methodology are contained in Appendix A. The study results are reported in Section 3; the data set documentation is contained in Appendices B and C. Recommendations based on the study results are in Section 4. References are listed in Section 8.

1.3.2. Energy Management Systems

The primary research question is: “What is the relationship between EMS controlled HVAC system energy usage and time from installation?”

The term "energy management system" refers to a broad spectrum of control systems. Generally, an EMS is a computer/processor based hardware and software system with sensors, control devices, and all the necessary components that monitor and control conditions related to the use of various forms of energy by HVAC systems. It may also provide information for management and HVAC system maintenance.

PEG has identified two areas where degradation is likely to occur: control point accuracy and human interactions. The sensor/transducer is the primary source of most data inaccuracies. All sensors are subject to drift and need periodic recalibration. Without recalibration the system is likely to respond non-optimally to changing conditions. Human interactions can either improve or degrade the system performance.

The accuracy and reliability of an EMS are dependent on the accuracy and reliability of the process of gathering and transmitting the original information to the operator, the accuracy with which the sensors describe the HVAC process, and the efficacy of the human interface. The human interface provides the greatest opportunity for improvement or degradation of system performance. Whether system performance will degrade, improve, or stay the same depends on the thoroughness of the original commissioning and later maintenance/operation.

Section 5 is the EMS methodology and analysis section. The survey instruments are contained in Appendix E; Appendix G contains analysis details. The study results are reported in Section 6. The dataset documentation is contained in Appendix D, and the survey dispositions are in Appendix F. Recommendations based on the EMS study results are in Section 7. References are listed in Section 8.

A detailed assessment of potential technical degradation mechanisms for this technology is provided in Section 2.9 of the *Persistence 2* report.

1.4. Analytical Approach

1.4.1. High Efficiency Commercial Package Air Conditioners

The estimates of coil fouling were conducted in two stages: 1) evaluating and establishing reasonable bounds for coil contamination, and 2) defining the best fit of the test data to those estimates.

Proctor Engineering Group established a time series estimate for condenser and evaporator coil fouling rates in standard efficiency units. This was derived from available research. Laboratory testing established the differential rates of fouling between standard and high efficiency coil configurations. In order to determine the relative technical degradation, Proctor Engineering Group tested the efficiency of coils undergoing coil contamination. The laboratory testing was completed at the National Research Council, Thermal Technology Centre Laboratories.

Laboratory testing was deemed the most cost effective and reliable approach to estimating degradation. PEG completed a series of efficiency tests, evaluating the efficiency of various coil configurations and fouling rates. All testing was performed in two psychometric rooms simulating American Refrigeration Institute (ARI) standard indoor and outdoor conditions (95°F outdoors, 80°F dry bulb and 67°F wet bulb indoors).

The coil contamination was done with an aerosol duct sealing tool developed by Lawrence Berkeley Laboratory. This tool injects a fine aerosol mist into the air stream. This aerosol tends to build up in areas of significant pressure drop, very similar to dirt deposition. The tool was fitted with special equipment to provide more accurate control of the aerosol injection process.

The experimental variable is the number of rows in the coil. This variable is isolated in the testing by using a high efficiency unit, where both standard and high efficiency coils were alternately installed. Aerosol contaminants were introduced into the return side of the evaporator and intake of the condenser coils. The aerosol injection rate was maintained to provide as constant an injection rate of contaminant as possible. The tests continued until the contamination process resulted in a 35%drop in the air flow rate on the high efficiency coil set. The air flow across the standard efficiency coil was reduced by the same amount. Both coils fouled in the same fashion: there was a small reduction in air flow until the surface of the coil became matted. Once that occurred, the air flow reduction was significant.

The units were tested to determine the efficiency impact of the fouling. Efficiency measurements were made at various steps during the testing. Tests were run to establish the baseline efficiency, efficiency with the evaporator fouled, and with both the evaporator coil and the condenser coil fouled. The coils were then removed and the standard efficiency coils installed. The proper measured charge was reinstalled and the testing repeated.

The data collected provided a profile for each set of coils: the efficiency at a baseline and the efficiency with the various amounts of coil blockage. The results from these tests were compared to other research conducted on the effects of air flow reduction on air conditioning systems.

1.4.2. Energy Management Systems

The complex interactions between EMS control and building operations make an engineering analysis potentially more expensive than a targeted billing analysis with on-site inspections. Changes in the EMS and the settings will have a direct impact on energy use as measured at the meter. An appropriate study is a historical analysis of energy use for the first year and subsequent years. The billing data need to be analyzed for weather dependence and where possible, normalized for weather and significant changes in building use. The buildings in this study were selected so that the most significant space conditioning modification was the EMS system.

The initial sample was drawn from buildings where EMSs were installed as part of utility conservation programs. A phone interview was conducted with operational personnel. Buildings were eliminated if major changes, such as a major change of tenancy, occurred which would compromise the integrity of the historical data. The telephone survey determined:

- The EMS installation date
- End uses connected to the EMS
- EMS energy saving strategies
- Operating personnel experience and opinions about the EMS operation

Almost all sites had on-site inspections to verify EMS operation. Historical monthly utility records were collected for each building.

Forty sites for which billing analysis was successful were used to establish the relationship between EMS controlled HVAC system energy usage and time from installation and to estimate a set of TDFs.

2 METHODOLOGY - COMMERCIAL DX AC

In *Persistence 1*, the TDF developed for Commercial Direct Expansion Air Conditioners (Commercial DX AC) was determined to have a high degree of uncertainty. This research study is designed to provide a more reliable TDF.

2.1. Research Objectives

The main research objective was to determine whether the efficiencies gained by increasing the number of rows in an air conditioning coil are sustainable over time. The second objective was to quantify the relative technical degradation between the standard and high efficiency air conditioning coil. The TDF table was created by projecting, on a yearly basis, the differences in the degradation between the standard and high efficiency coil systems.

2.2. Research Methodologies

High efficiency commercial package air conditioners can attain efficiency gains through a variety of means: changing to a scroll compressor, changing the metering device, changing motors, adding face area, and adding rows of coils. *Persistence 1* found the following:

"PEG concludes that the use of scroll compressors in some efficient units should produce no degradation in energy savings over time."

"PEG concludes that the use of thermostatic expansion valves (TXV's) in some efficient units may lead to some changes in energy savings over time, but the direction of this change is uncertain and the magnitude is likely to be small."

"PEG concludes that energy savings from high efficiency motors will not decline over time due to technical degradation."

"PEG concludes that the differences in condenser coil face areas should produce no degradation in energy savings over time and may actually lead to increases in long-term savings."

The single largest undetermined factor in the degradation is the effect of adding rows of coils to evaporator and condenser coils. Due to size limitations of the cabinets, most manufactures increase the surface area by adding rows to the coils. Air cooled heat exchangers are widely known to be subject to degradation due to fouling of the coils. It is unknown how adding rows to the coils affects the fouling rate.

Evaporator coils are subject to dust, particulates, and vapors from the indoor environment, most of which will pass through or around a typical filter (20-30% particulate arrestance). The coils tend to trap particulates because of the tight fin spacing and the "sticky" nature of both the coil (due to condensation) and the indoor air (cooking and / or tobacco smoke). The rate of dust build-up will depend on a large number of factors. These are: the amount of air passing through the coil, the indoor air quality, the amount and environment of return duct leakage, the filter design and location, maintenance, and the design (coil fin spacing, geometry, and number of rows). The dust may load throughout the coil providing an insulating layer over the fins, or it may primarily build up on the face, reducing the effective coil size.

The impacts of this fouling are: reduced air flow through the coil, and a reduced heat transfer coefficient. The reduced air flow will result in less work being done by the blower. This reduces the amperage required by the blower. Reducing the heat transfer coefficient reduces the number of BTUs that can be extracted from the air stream. Cooler return temperatures result in less work for the compressor. Thus, changes will reduce system capacity while reducing indoor fan power draw and compressor power draw. The overall efficiency is reduced because capacity is reduced at a greater rate than the power draw. More power will be needed, due to increased run time needed to meet the load. The connected load will decrease from evaporator fouling.

Condenser coils are exposed to the outdoor environment and are subject to fouling from dust and dirt much like evaporator coils. In general, the coil fin spacing is tighter than on the evaporator but the surfaces are less sticky (e.g., they are dry and generally subject to fewer aerosols such as smoke and grease). Condensers are also subject to corrosion from salt and pollution that can be a substantial problem in coastal areas (manufacturers tend to use special anti-corrosion coatings or materials to minimize corrosion).

Condensers are generally more accessible and therefore easier to maintain than evaporator coils. Field experience indicates that such maintenance is rarely performed. This is particularly true in commercial rooftop units. A dirty condenser coil will slightly reduce outdoor fan power draw and increase compressor power draw. The dirty coil results in a lower air flow. The condenser fan power draw is consistent with the air flow, although the relationship is not linear. The decrease in heat exchange efficiency will raise the temperature and head pressure. This will result in increasing the power needs of the compressor. The overall effect is to reduce system capacity and efficiency while increasing power draw. In both cases, the run time of the appliance will be extended.

One would expect a greater rate of fouling in a heat exchanger with more rows because it would act as a better filter. However, if the fouling process is dominated by loading at the coil face, then the additional rows may not increase particulate arrestance, although the impact of this equal fouling would be greater. It is not known whether the potential increase in fouling would create a greater proportional decrease in heat exchanger effectiveness for units with more rows. If the decreases are not more than proportional, then no relative degradation should occur.

Laboratory testing was used to determine the relative technical degradation of efficient versus baseline equipment. The pros and cons of performing laboratory testing versus field measurements were examined. Laboratory testing was deemed the most cost effective and reliable approach to estimating degradation. The features that led to that decision are:

- The laboratory offers a controlled setting. Standard and high efficiency equipment can be tested in the same environmental conditions.

- The laboratory allows extensive, real time monitoring of all pertinent parameters. This is virtually impossible in a field setting.

- The accuracy of the sensors available in the lab far surpasses the accuracy of the sensors readily available for field use.

- The control and oversight allows the researchers to determine if the testing is progressing as anticipated and make changes in the testing as needed.

Field measurements offer the ability to see a larger sample of units. Comparing the measured results from these tests presents technical concerns. The field measurements are prone to having numerous factors, other than age, thrown into the equation. Items such as indoor and outdoor air quality; maintenance schedules; refrigerant charge uncertainties; indoor and outdoor conditions at the time of the test; blower and fan motor uncertainties and air flow variations will all have an impact on the test results. These uncontrolled variables make analyzing the data, and making valid conclusions based on the sample, extremely difficult.

2.3. Laboratory Testing

2.3.1. Equipment Selection

Research in Phase 1 of this study analyzed databases of rebated air conditioner makes and models to identify market leading units. Distributors and manufacturers were contacted to confirm this analysis, and identify the most popular models. For the California market these are the Carrier models 48TJE006 and 48HJE006.

These units are comparable five ton, horizontal discharge, rooftop package heating and air conditioning units. Although the exterior dimensions and cabinet are identical, the high efficiency unit has a number of upgraded features. The most notable are the compressor, blower, and the number of heat exchanger rows. Changes in the high efficiency unit result in it being seventy pounds heavier. Other significant features of the units are the same, including the metering device, coil design and construction, coil materials, and nominal air flows. Specific features are listed in Table 2-1. Our original research plan specified a direct comparison between the two units. After more detailed analysis, we concluded that limiting the analysis to the effects of the coils would provide more comprehensive and applicable research results.

In order to isolate the effects of adding rows of coils, PEG purchased a high efficiency unit and tested it with both the standard and high efficiency coils installed. The results of this testing provided the information necessary to make reliable conclusions on the performance of these and other systems.

Table 2-1 Standard & Efficient Unit Characteristics

	Standard Efficiency Unit	**High Efficiency Unit**
CONDENSER COIL		
Number of Rows	1	2
Fin Spacing (per inch)	17	17
Total Face Area (sq.ft.)	13.19	16.5
Coil Type	Copper Tube / Alum. Fins	Copper Tube / Alum. Fins
EVAPORATOR COIL		
Number of Rows	3	4
Fin Spacing (per inch)	15	15
Total Face Area (sq. ft.)	5.5	5.5
Coil Type	Copper Tube / Alum. Fins	Copper Tube / Alum. Fins
COMPRESSOR		
Type	Hermetic	Scroll
EFFICIENCY		
SEER	10	13
EER	8.5	11

2.3.2. Equipment Set-up

PEG purchased one high efficiency air conditioning unit, an additional set of standard efficiency evaporator and condenser coils, and replacement blowers. The test unit was installed in the outdoor side of the psychrometric chamber. Ducts were installed to connect the unit to the indoor chamber. Baseline efficiency tests were run on the high efficiency system and the coils fouled in-situ. The same set of tests was run with the standard efficiency coils installed. The experimental setup utilized the two psychrometric rooms to simulate ARI standard indoor and outdoor conditions (95°F outdoors, 80°F dry bulb and 67°F wet bulb indoors). The air flow rate through the coils was controlled by the standard operating fans. An elaborate fan evacuation system was installed on the supply duct and condenser, to filter, measure and provide adequate pressure compensation. On the evaporator side of the system, the duct pressure was maintained at .4”WC (water column) to simulate a standard duct system. On the condenser side of the system, the control fan was adjusted to compensate for the modifications made to the unit. During the testing, the speed of the control fans was reduced as the fouling occurred. This was done to maintain the established test pressures.

2.3.3. Testing Procedures

PEG and National Research Council staff conducted a battery of tests. Table 2-2 details the minimum efficiency and fouling tests that were planned. The efficiency was tested at different indoor air flow rates. This helped to establish the effects of air flow compared to change in the thermal heat transfer characteristics at the surface of the coil. Essential data were also collected at various points during the coil fouling process. The High efficiency coils were exposed to a consistent concentration of contaminants until the desired flow reduction was reached. The performance of the standard coils was tested with the same air flow reductions. Due to the length of the test procedure, controlling for the amount of contaminant that reached the coil was not possible. The drop in air flow as a function of the exposure time was very close. Once we had established that the fouling characteristics were similar, the loss in air flow was used as the controlling variable. The intermediate test results were used to interpolate the losses across the appropriate range of expected reductions.

Table 2-2 Summary of Tests

Test	**Evaporator Coil**	**Condenser Coil**
Baseline	High Efficiency	High Efficiency
Coil Fouling Rate	**Foul Coil & Replace Blower**	
Evaporator Coil Test	High Efficiency - Fouled	High Efficiency
Coil Fouling Rate		**Foul Coil & Replace Blower**
Combined Coil Test	High Efficiency - Fouled	High Efficiency - Fouled
	Install Standard Coil	**Install Standard Coil**
Baseline Performance	Standard Efficiency	Standard Efficiency
Coil Fouling Rate	**Foul Coil & Replace Blower**	
Evaporator Coil Test	Standard Efficiency Fouled	Standard Efficiency
Coil Fouling Rate		**Foul Coil & Replace Blower**
Combined Coil Test	Standard Efficiency Fouled	Standard Efficiency Fouled

The efficiency of the equipment was established by monitoring the air side of the system, coupled with temperature, pressure and mass flow of the refrigerant. This is verified by measuring temperatures, and energy use of the psychrometric chamber. The monitoring equipment was installed during the first phase of the testing and was cleaned throughout the coil fouling portions of the test. The sensors on the refrigerant system remained in place for the duration of the experiments. When the coils were installed, the refrigerant was removed, the system was evacuated, and the manufacturer’s suggested superheat procedure was used to reestablish the proper charge.

The baseline testing of the unit was compared to the manufactures' specifications. The measured EER was 10.52 at a fan speed of 1914 CFM. The standard rating for this unit shows an EER of 10.9 at an air flow of 2000 CFM. Using the manufacturer’s charging chart, the tested efficiency is slightly above the nameplate rating.

The energy balance of the calorimeter was established during the same baseline test. The energy balance is calculated by comparing the energy that is required to keep the rooms at the desired temperature and humidity to the energy used by the air conditioning unit. The results remained fairly stable throughout the testing. The overall energy balance was off by 6%. This can be due to a variety of assumptions that are programmed into the calculation and is not seen to be an important factor (e.g. the amount of heat gained through the indoor duct system). Variation around the established baseline is the important test variable. The variation was less than 3% for the high efficiency unit. The energy balance for the standard efficiency unit was similar to those run on the high efficiency unit.

Aerosol contaminants were introduced into the return side of the evaporator and subsequently into the intake of the condenser coils. Air flow and contaminant injection rates were continuously monitored. The amount of aerosol was maintained at a constant injection rate. The blower in the package unit was used to provide the pressure drop necessary to pull in the contaminated air. The experiment was set up to emulate the duct pressures that are normal in standard installations. A minimum static pressure of .25"WC is required for standardized testing. A more realistic pressure of .4"WC was used in this test.

All of the exhaust air was run through a filter bank. A single-pass system was used for contamination. The measurement of air flow and the effects of the contamination were very precise. The actual contamination process was less controlled. The test contamination was conducted in California, and went fairly quickly. A 5 Ton AC coil was contaminated over the period of three hours and the air flow was reduced by 37%. Changes were made in the contamination process to reduce the size of the particulates. This, combined with the requirements of the monitoring process in conjunction with fouling, resulted in the fouling in the laboratory taking considerably more time than planned. Coil fouling typically took three to four days of lab time. Cleaning of the equipment and intermediate tests were run during this time as well.

The initial plan called for the contamination to be completed once the indoor coil fouling had resulted in a 30% drop in the air flow rate on the high efficiency coil. The drop in air flow was very sudden close to the end of the fouling process. Over 40% of the reduction in air flow occurred during the last hour of the fouling process

Tests were run to confirm that the drop in air flow was a result of coil fouling, and not simply fouling of the blower wheel. Those tests showed that the reduction in air flow was almost entirely due to the face blockage of the coil and not the contamination of the blower.

The same basic procedure was used for the condenser coil tests. The target flow reduction for the condenser coils was 25%. Intermediate testing was done throughout the fouling for both the high efficiency coils and standard coils.

2.4. Evaluation Methodologies

Environmental conditions are a significant factor in the rate of coil fouling. Changing those conditions will have an enormous impact on the rate of fouling found on the coils. This evaluation is focused on performance degradation differences between standard and high efficiency appliances. The TDFs that are presented reflect the variance between the units. In any specific environment, the effective operational time could be accelerated or reduced. For the purposes of this study, we established a standard deterioration time line. Individual sites may have a higher or lower fouling rate.

We collected all readily available information on coil fouling. We used these data to create engineering estimates of the evaporator and condenser fouling rates over time. Due to the scarcity of the data, we did not attempt to establish bounds for these estimates. These data are representative of standard efficiency coils. The coil fouling process in the laboratory provided us with an accelerated fouling data set. The data collected on the high efficiency coils provided us with a clear time series comparison of fouling rates for standard and high efficiency coils. These new technical data were used to revise the time series estimates.

Once the fouling rates were established, we used both engineering calculations and measured data to evaluate the change in efficiency of the units due to these differential fouling rates. We examined the experimental plan and evaluated the potential measurement errors in the testing. The final TDF was established by applying the efficiency changes to the long term fouling rate of the coils. The standard system was compared with the high efficiency system and the final results are expressed as multipliers for each year of the measure life. We have presented the TDF as a function of the evaporator fouling and as a combination of both the evaporator and condenser fouling.

The nature of the TDF is that there can be a reasonable trend line established for the technology. This trend will provide a conservative estimate of the technical degradation of the technology. It is rare to find a TDF that can be accurately applied to any individual unit. This particular technology has a number of uncontrolled variables. The TDF provides a standard of measure to evaluate the DSM measure. This testing significantly reduced the uncertainty in evaluating the measure.

3 RESULTS - COMMERCIAL DX AC

3.1. Coil Fouling

Fouling of coils was evaluated in terms of the maximum effective reduction in air flow and the probable rate of contamination. Research has shown that the condenser and evaporator coils generally exhibit linear decreases in performance until 50% of the flow is reduced. At that point, performance drops off significantly. If either coil exceeds this fouling rate, the performance and life expectancy of the unit are severely compromised. The coil systems were evaluated separately and the impacts of the fouling were combined to determine the TDF.

3.2. Condenser Fouling

Condenser coils are hot dry coils that are subjected to contamination from the exterior environment. Air flow is created by a single speed fan that is designed to move between 750 and 1000 cfm per ton. Research on the contamination of these coils is sparse. These flows and pressures are difficult to measure in the field. Unit replacement or prescriptive cleaning are the most common efficiency procedures.

3.2.1. Condenser Degradation Limit

PEG estimates that the maximum degradation is 45% condenser face surface loss, resulting in a +10F condensing temperature increase, and a 20% EER decrease in the standard unit. This estimate is based on Jung (1976)

> “Likewise, a change in the heat-transfer coefficient because of a dirty condenser is expected to increase the condensing temperature ~10F. If there is airflow blockage, the temperature could rise higher. These estimated temperature limits do not represent the worst possible case but reasonable expected limits because of reduced airflow or heat transfer. Long before the maximum limits are reached and especially during hot weather, the occupants should be complaining about inadequate cooling, or the unit may malfunction.” (Jung, 1976, Page 20)

Test measurements showed that the standard efficiency had a 15.8F increase in condensing temperature with a 27% reduction in EER. The high efficiency has a 14F increase in condensing temperature with a 24% reduction in EER.

3.2.2. Condenser Degradation Rate

PEG estimates that non-maintained single row condenser coil will lose 50% of the flow over the 20 years. The maximum predicted fouling is not achieved in the estimated 15-year life of the equipment. Jung (1976) states that single row condenser coils are less subject to clogging than multi-row coils:

> “Single-layered condenser coils, although not filtered, are not prone to get dirty if properly installed. Multilayer condenser coils are more likely to clog because of debris becoming trapped between the coils.” (Jung 1976)

Our testing would indicate that face fouling is the predominant means of air flow reduction and would not be different for single or multi-layered coils.

The degradation rate for multi-row condenser coils is 6.8% / year face surface loss based on Trane(1990) and Braun(1986). Under conditions of accelerated fouling for multi-row coil, Trane found a 27% efficiency loss. This efficiency loss corresponds to a 54% relative condenser area loss. Since this accelerated fouling is equivalent to 8 years of typical operating conditions, yearly fouling would be 6.8% for commercial multi row coils:

> "Trane provided data from an experiment performed in the 1970's where two air conditioners were operated continuously with condenser exposed to a very dirty factory environment for 18 months, equal to perhaps 4-8 years worth of typical operating hours. (Trane 1990). Performance measurements at the end of the test indicated that the air conditioner with the standard plate fin coil had lost 17% of its capacity and 27% of its efficiency." (Persistence 1, 1996)
>
> "An ASHRAE paper noted considerable capacity problems in two 20 ton chillers caused by dirty condensers (Braun 1986). The static pressure across the coils was measured at 2.5 times greater than design after 8 years. Cleaning was not very effective at improving capacity or reducing pressure drop. The author noted that it is extremely difficult to clean a coil more than two rows deep and that coils with tighter fin spacing will tend to foul more quickly." (Persistence 1, 1996)

This maximum estimate is for commercial multi-row coils. The exposures in these cases were to extreme industrial or marine environments. These estimates can be used to evaluate the range of degradation that is possible under varying environmental exposures. This particular test would result in the contamination process being accelerated by 2.7 times. Without maintenance, the coils would reach the condenser degradation limit in seven years. This would hold true for both the standard and high efficiency coils.

Air flow across the condenser coil is more than twice that of the evaporator coil. In response, the standard coil has more than double the face area. The high efficiency condenser coil that was tested had three times the face area of the evaporator coil.

PEG estimates that multiple row condenser coils will lose 50% of the air flow over 20 years. This is consistent with estimates for the standard efficiency flow and contamination ratios as well as the evaporator fouling rates. The maximum predicted fouling is not achieved in the 15 year life of the unit.

3.3. Evaporator Fouling

More information is available on the rate and effects of evaporator coil fouling. The data are still sparse and varied in quality and specificity. The best summary of the phenomenon was provided by O'Neil:

> "Results shows that as evaporator air flow is reduced from a normal amount the electric demand, cooling capacity and EER decrease. Power consumption decrease in a near linear fashion, from 3.54% at 25% reduction in evaporator air flow to 17% at 90% reduction in evaporator air flow. This may imply that as utilities fix degraded air conditioners the demand may go up by 3-17% while usage goes down. Cooling capacity decreases linearly until about 50% evaporator air flow then dropped suddenly." (O'Neal 1992)

The phenomenon has two components: lower power use by the fan and lower compressor power use. The fan amperage increases as a function of air flow. Lower air flow reduces the instantaneous energy use. The lower air flow also lowers the ability of the heat exchanger to transfer heat out of the cooling fluid. Lower return fluid temperatures to the compressor reduce the head pressure and energy use by the compressor.

3.3.1. Evaporator Fouling Limit

The operational limit of fouling for units with thermostatic expansion valves (TXV's) is higher than those with capillary tubes. The limit for capillary tube metering devices is limited by the heat transfer of the coil to prohibit liquid refrigerant from returning to the condenser:

> "As related by one air conditioner manufacturer, flood-back has been observed during tests conducted on their units with a capillary tube and an evaporator airflow reduction to 55% of the unit's rating at an outdoor temperature of 105F..."(Jung 1986)

This resulted in a 5F drop in the evaporator coil temp and a 9% drop in capacity. Although the flood-back condition should not occur in TXV systems, lack of capacity and cycling problems will be noticeable.

Jung conducted a theoretical analysis of reducing the evaporator coil temperature by 10F. This would simulate a reduction of air flow to 30% or a combination of air flow and heat exchange efficiency drop. This calculation was just before ice would be found on the evaporator. The capacity was reduced 19%.

O'Neil et. al. showed that the drop in performance was relatively linear until 50% reduction in air flow was reached. After 50%, the reduction was very dramatic (reduction in EER from -6.51% @ 50% to -34.63% @ 75%).

PEG has established that 50% is a reasonable outside limit for evaporator fouling.

3.3.2. Evaporator Fouling Rate

Research on air filter effectiveness indicates that the decrease in efficiency of coils is due primarily to the decrease in air flow.

"It shows that the COP can drop from 3.12 to 2.76 or 11.5% when only the air flow drops from 1000 to 500 ft3/min (1529 to 850 m3/min), or by 13.2% if the insulation effect of the dust layer is taken into account. This soiling was obtained for a 3-ton heat pump by retaining 600g of a 1000g dust load."(Krafthefer)

The same study estimated that the pressure drop across the coil doubles in 7.4 years. This would be reflective of a drop in air flow of 50% and a drop in capacity of 19%. This study was relatively aggressive in terms of both coil loading and evaluation of the arrestence of the coil.

Another research study showed a 50% reduction of air flow produced a 14.7% reduction in capacity (O'Neil).

Studies that have evaluated the increase in efficiency due to coil cleaning provide an indication of the available efficiencies that are gained in the field. This is an indicator of the efficiency gains that are achievable, and the flip side of the coil fouling evaluations. The total available gain is reflected in the savings and an estimate of the losses that were not recovered. Trane data showed that cleaned condenser coils only recovered 65% of the previous capacity. With this in mind, two additional research studies were reviewed. An evaluation completed by EPRI on the impact of maintenance on packaged unitary appliances showed a 5% average increase in air flow due to coil cleaning on 30 units. A study of 18 units in New England showed 6-11% savings from cleaning coils, adjusting charge, and other measures. Half of the evaporator coils were dirty and all of the condenser coils were clean. Neither of these studies provide a relative time line between cleanings.

All of the data suggests that the drop in evaporator air flow is at or below 50% in typical installations and represents up to 20% reduction in capacity. A conservative estimate of evaporator coil fouling is 40%

over twenty years. The results show only minor differences in the coil fouling rate of the three and four row coil configurations. Although there are differences in efficiency, the coil fouling was within the measurement error and both coils were estimated to lose 40% of their air flow over a twenty year period.

3.4. Testing Results

Fouling of the evaporator coils did not produce a significant deterioration in the performance for either the standard or high efficiency coils. The performance of the fouled coils correlates well with test data on the performance of systems under reduced air flows (O'Neil, et at, 1996). Test results for standard efficiency coils, and the reference test data, are shown in Figure 3-1.

Figure 3-1. depicts the change in performance (EER) as a function of the loss in air flow.

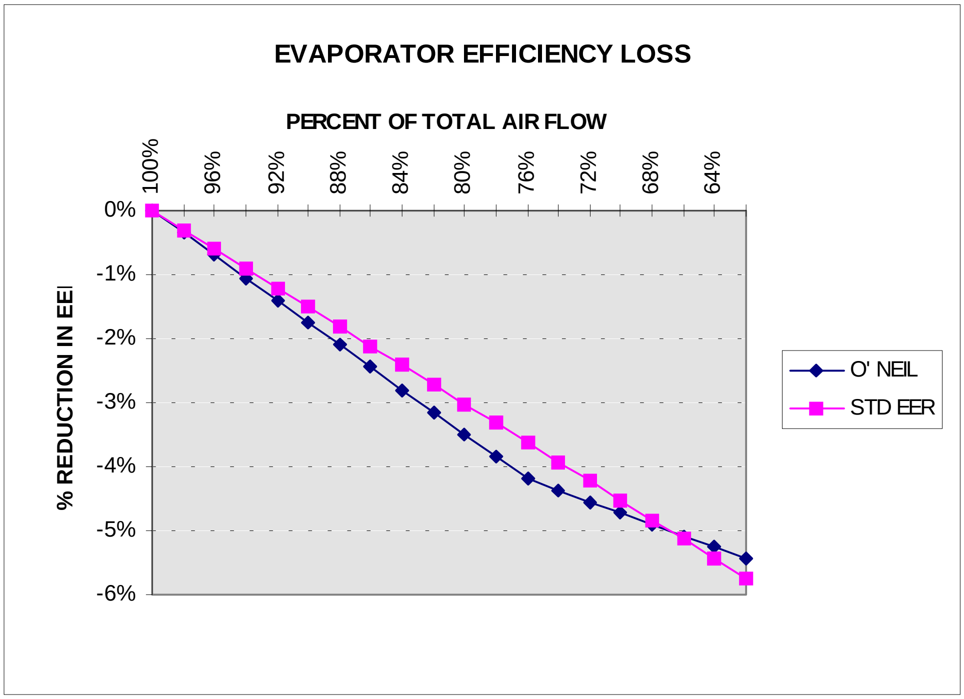

Figure 3-1 Change in efficiency with reduction in air flow

Additional tests were run on the system to determine if the reduction in air flow was due to fouling of the coils or fouling of the blower. The tests showed that the vast majority of the air flow reduction occurred at the coil and not the blower.

The comparison between the high efficiency coils and the standard coils are shown in Figure 3-2.

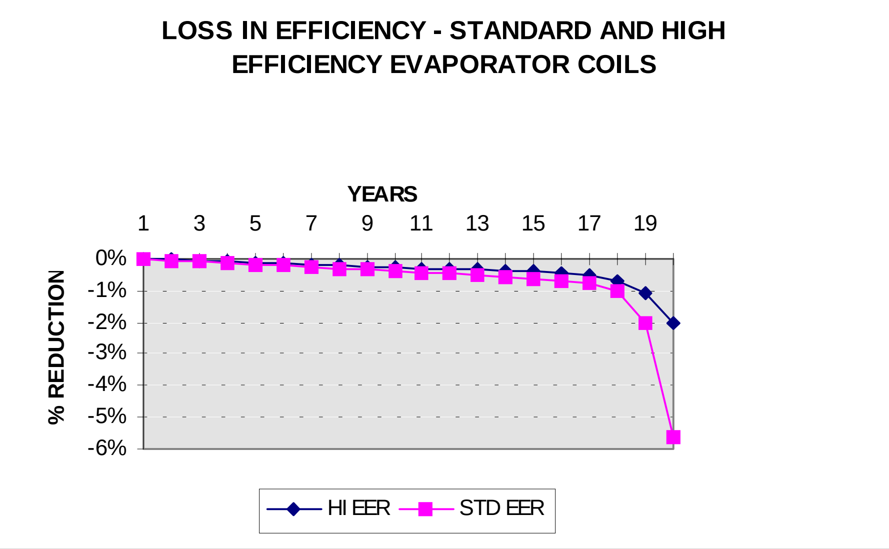

Figure 3-2 - Evaporator coil test results

Tests on the condenser coils demonstrated that the performance of the units was reasonably unaffected by loss of air flow. The combination of evaporator and condenser fouling resulted in the loss of performance due to flood-back of refrigerant to the compressor. As predicted, the efficiency and energy use dropped due to fouling of the evaporator and the efficiency dropped while the energy use increased by fouling the condenser.

The standard efficiency and high efficiency condenser coils have similar fouling characteristics. The high efficiency unit was able to maintain a higher overall efficiency and thus have a longer life expectancy and operating efficiency. Figure 3-3 shows the results of the testing.

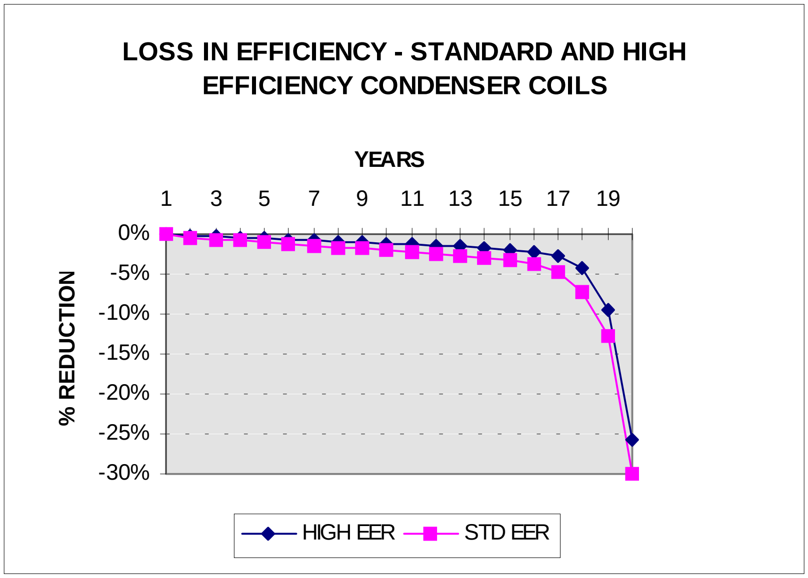

Figure 3-3 - Condenser coil test results

Results - Commercial DX AC

The TDF presented for Commercial DX AC was the evaporator coil fouling profile. The TDF was calculated for both evaporator coil fouling and the combination of the evaporator and the condenser coils fouling. The combined coil fouling projection trended slightly higher, but was within 1% until the last four years. The evaporator profile was chosen to represent the measure for two reasons: the expected life of a Commercial DX AC unit is 15 years and during that time there was little difference and, if any cleaning was done to the condenser coil during those 15 years, there would be no degradation.

It should be noted that the performance of the air conditioners and the TDF are not at all similar. Fouling of each coil produces a profoundly different change in capacity and energy use. This study focused on quantifying the difference between the performance of standard and high efficiency equipment. Considering this data, maintenance programs could be created to meet specific load and performance objectives.

4 RECOMMENDATIONS - COMMERCIAL DX AC

4.1. Commercial DX AC TDFs

Proctor Engineering Group recommends the TDFs in Table 4-1 for commercial DX ACs.

Table 4-1 TDF — Commercial DX AC

YEAR	TDF
1*	1.00
2	1.00
3	1.00
4	1.01
5	1.01
6	1.01
7	1.01
8	1.01
9	1.01
10	1.02
11	1.02
12	1.02
13	1.02
14	1.02
15	1.02
16	1.02
17	1.02
18	1.02
19	1.06
20	1.08

* First year savings are one (1.00) by definition. The TDF modifies the first year savings for subsequent years.

4.2. Equipment Purchase

PEG recommends the purchase of high efficiency commercial air conditioner equipment. The results of the testing showed that the high efficiency coils start with and maintain a higher efficiency than standard efficiency coils. The slower degradation rate will increase the life of the equipment and use less energy over the operational lifetime.

4.3. Coil Cleaning

PEG recommends that the condenser coil be cleaned on a periodic basis or at least after an effective 10 year life. The evaporator coil should also be cleaned if possible. The TDF table for Commercial DX AC is based on the evaporator contamination profile. If the condenser coil is in an uncontaminated location or is cleaned once during its useful life, it will not have significant impact on the efficiency of the unit.

Contamination of coils in the field varies dramatically. Extremely harsh environments or high loading of the equipment will alter the “effective age” of the equipment. The historical data show that the effective age can vary by a factor of three. Both the standard and high efficiency units would be exposed to the same environment. In all cases, the high efficiency unit will continue to perform better than the standard efficiency unit. In all cases, the largest problems occur at high levels of coil contamination.

5 METHODOLOGY - EMS

5.1. *Research Objectives*

The primary research question is: "What is the relationship between EMS controlled HVAC system energy usage and time from installation?"

The answer to this question is presented as a table of TDFs. All of the data collection and analysis are subordinate to the determination of the TDFs, which were calculated from monthly billing data. Data not directly used to calculate the TDFs were collected because 1) they might have revealed hidden confounds, i.e. on-site electricity generation, dual fuel usage, or thermal energy storage which would make the billing data uninterpretable, or 2) they might have helped to interpret the results.

5.2. *Research Methodologies*

5.2.1. Sample Selection

PEG selected an initial sample of buildings where EMSs were installed as part of utility conservation programs. The sample was stratified by utility and building parameters. Buildings from 1995 and earlier program years were utilized because the EMSs had been installed long enough that several years of post installation data were available. The primary samples were: 1995 PG&E and 1994 SCE. (SDG&E sites were not included in the study per SDG&E's request and CADMAC agreement.) These samples were supplemented by an additional sample of earlier installations from each utility. The required number of facilities was readily obtained.

The primary target facilities were office buildings and K-12 schools. Within the K-12 category were district offices and corporate yards as well as school facilities. A third group of diversified building types was also selected; this group included branch banks, fast food restaurants, and city facilities.

Some facility types were deemed potentially to have such large non-HVAC fluctuations in energy usage that analysis would be compromised. These facilities included hospitals, industrial and manufacturing facilities, grocery stores, colleges, and hotels/motels. Other facility types were eliminated because of low frequency of occurrence or to increase the number of sites within the selected classes. See Section 6.1.4 for a discussion of potential site selection bias.

5.2.2. Data Requirements

The analysis required site identification, billing data, and rebate information.

<u>Site Identification</u> Site identification data were used to correlate all other data. In most cases this information was straightforward. In some cases site identification was more complex. Rebate information for schools was often listed under the district office rather than the installation site. Some facilities had multiple meters. Service addresses were sometimes different from building addresses, i.e. the side street on which the electric service entered was used rather than the frontage street. In one case, the service address street no longer even existed; it had been paved over with a freeway.

The master account number or premise number was used as the primary identifier. This number does not change and is tied to the physical facility. Account numbers changed when reading or billing cycles changed. During the On-Site Survey, the electric meter number was recorded. In several cases this was very helpful in resolving identification conflicts. A positive identification of all sites was made.

Important site identification data included:

- Name of rebate recipient
- Address of installation
- Service address
- Contact person for customer account
- Master control number / Premise number
- Electric meter number

All of this information is held confidential. In this report, sites are identified by a three part identifier: 1) utility, 2) organization, and 3) site (if multi-site.) For example, PG&E 1.1 refers to the first of two sites of the organization labeled “1” among PG&E’s rebate recipients. Appendix F gives a brief description of each site.

<u>Energy Data</u> The primary energy data are historical monthly utility records for buildings with an uninterrupted period of comparable operation for an extended period post-EMS installation. Each utility supplied these data for the selected survey sites. In addition, historical weather files were needed for each site in order to test for weather dependency in energy usage fluctuations. These files were obtained from NOAA (National Oceanic and Atmospheric Administration).

In order to be analyzable, the facility operation had to be relatively stable post-EMS installation. This was screened for in the telephone survey. Common reasons for failing the screen were large changes of occupancy, major changes in the HVAC system, or gross changes in operation.

The first year savings were obtained from rebate applications when available. In a few cases this number was not available and was estimated, see Appendix F. This number was used to convert the gross change in energy usage to a TDF ratio.

The date of EMS installation separated the pre and post periods. It was usually obtained from the telephone survey. In those cases where the interviewee could not give the installation date, the installer was contacted. If even this was unsuccessful, rebate application data were used.

During the telephone survey, the major electrical end uses were determined. The seasonal usage patterns were expected to depend on the end uses; i.e., whether heating was gas or electric, etc.

Important energy data included:

- kWh usage in period
- kW demand in period
- Type of reading (Regular, estimated, etc.)
- Reading Date
- Date of EMS installation
- End uses of electricity at site
- Rebated first year savings
- Verification of EMS operation

- Daily temperature data at a nearby weather station

Rebate information The primary data obtained from the rebates were the initial identification of sites that had had rebated EMS installations and the first year savings estimates. Additionally, the rebate application information was sometimes used for date of installation.

Important rebate information included:

- Identification of rebated EMS systems
- Calculation of estimated first year savings

Supplemental information Supplemental information was not used directly in the TDF calculation. EMS control information was obtained to determine if unsuspected confounds were present. The operator interview was helpful in explaining the obtained results.

5.2.3. Survey Design

The purposes of the telephone surveys were to:

- Obtain agreement to participate in the study.
- Screen for changes in occupancy, equipment, or operation that would invalidate historical energy usage comparisons.
- Determine if potential confounds existed due to equipment configuration or control patterns.
- Interview operating personnel.

The purposes of the on-site surveys were to:

- Ascertain that the EMS is present and operating.
- Double-check site identification by obtaining the meter number

The surveys were kept as simple as possible to shorten the interview. The primary research question is the TDF; all other data were subordinate to an accurate TDF calculation. It was not necessary to exactly or exhaustively describe the HVAC systems, only to determine if potential confounds existed and needed to be addressed. Differences such as centrifugal versus reciprocating chillers were not important. Changes in the use of the EMSs were expected and part of persistence.

Survey Construction: The original design contained two surveys. The Telephone Qualification Survey was to determine if minimum data quality existed for the site. The Site Participation Survey, which collected the database information, was to be conducted later. In actuality, once the proper person was found, it was faster and easier to complete both surveys in the same phone call. These two surveys were consolidated into a single Telephone Survey. The on-site information was collected in a separate On-site Survey. The survey forms in Appendix E reflect this final format. The changes in survey format did not involve changes in the data collected; they only involved changes in the question sequencing and elimination of some duplicated questions.

5.2.4. Telephone Surveys

The telephone surveys were started in August. An initial batch of prospective sites was chosen from the original databases. Before any site was contacted, the utility service representative was contacted. This insured that existing relationships were not disrupted. The service rep sometimes facilitated the initial contact.

The telephone survey generally took only about 10-15 minutes for a single installation site. The survey of organizations with multiple sites took about 5-10 minutes per additional site. In about half of the cases some follow-up work was needed. The time for this varied greatly depending on how accessible the information was.

The majority of time and effort in the telephone survey was spent identifying who the proper person to interview was and scheduling a convenient time to talk with them. Often this person had many responsibilities and contacting them at a convenient time might take well over a dozen phone calls.

5.2.5. On-Site Surveys

A total of 45 on-site surveys were conducted. Thirty-five of the 40 analyzed sites had on-site surveys, see discussion in Appendix D.

Survey Procedure The on-site survey time varied depending on whether there were multiple sites or a single site, on the complexity of the site, and how busy the contact person was. At the shortest end, the on-site survey of a branch bank often only took 5-10 minutes. The survey of a school district with multiple installations could take several hours. Generally, the person who met the on-site surveyor was not the same person who answered the telephone survey. As the on-site survey required less knowledge, it was usually handled by a maintenance worker or clerk rather than the facilities manager.

The surveyor asked to see the EMS equipment and recorded whether it was working or not. The surveyor also viewed the electric meter, and, if present, wrote down the meter number. If easily accessible, the HVAC equipment was observed.

On-site Survey Personnel: Table 5-1 details the on-site survey personnel. The majority of on-site surveys were conducted by George Peterson of Proctor Engineering Group — 33 on-site surveys. Two site surveys were conducted by Tom Downey of PEG. The remaining ten on-site surveys were conducted by Conservation Services Group[1] (CSG) personnel.

Table 5-1 On-site Surveyors

Organization	On-Site Surveyor	Number of EMS Installations Surveyed
PEG	George Peterson	33
PEG	Tom Downey	2
CSG	Darryl Daniels	9
CSG	Mike Sims	1
Total		45

5.3. Evaluation Methodologies

The Evaluation included data preparation, model building, and final TDF determination.

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[1] Since 1993, CSG has performed over 10,000 residential energy surveys per year for SCE.

Billing data was obtained from 1990 to late 1998 for most sites. This billing data included kWh and kW as well as meter read dates. The initial data cleaning included correcting high low pairs (misreads) and calculating the kWh use per day. Each site was matched with daily average temperature data for the nearest NOAA weather site.

5.3.1. Case Study Models

Each site was analyzed with multiple models. The data are somewhat complicated time series. The data were analyzed for long term trends, seasonality, outdoor temperature dependence, month of year dependence, and changes in each of these items at the time of the retrofit. A number of analysis methods were used. These individual case study models are detailed in Appendix G.

5.3.2. Pooled Data Model

A basic model was developed with consists of three primary components: the change in energy consumption at the time of the installation of the EMS (kwh / day), the rate of energy consumption <u>change</u> over the long term (kwh / day per day), and how this rate of energy consumption <u>change</u> is effected by the installation of the EMS system. This basic conceptual model is shown in Figure 5-1.

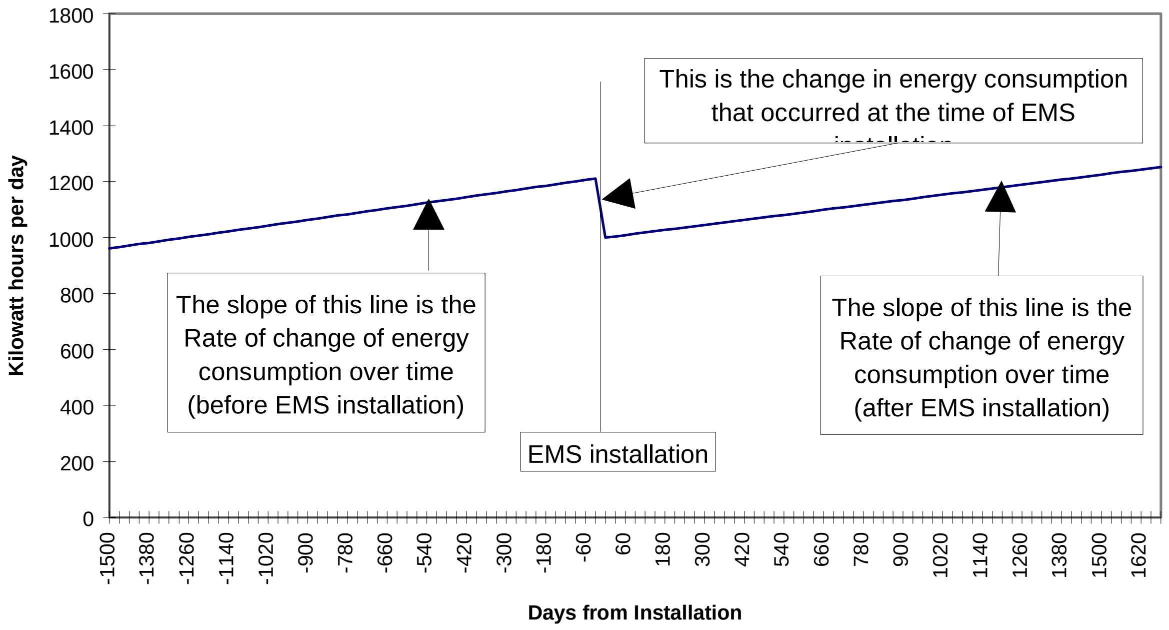

Figure 5-1 Conceptual Model: Energy Consumption vs. Days from EMS Installation

This model allows there to be a long term change in load, a change in the energy consumption at the time of the EMS installation (initial savings), and a new load change rate. If the pre installation rate grows less than the post installation rate, there is degradation of savings. If the pre installation rate grows more than the post installation rate, there is an increase in savings.

The model makes no assumption as to whether the pre and post installation slopes are positive, 0, or negative.

In order to estimate this basic model the following steps were used:

1. The electrical energy consumption rate (kilowatt hours per day) at each site was calculated for each billing period.

2. The average energy consumption rate over the year immediately preceding the EMS installation was calculated.

3. The billing period electrical consumption rate calculated in step 1 was divided by the average rate calculated in step 2. This provided an energy consumption factor normalized to each building's average pre-EMS consumption. We refer to this factor as the Normalized Energy Consumption (NEC). A NEC of 1 is equivalent to a consumption equal to the pre-EMS average, while a NEC of .75 is 75% of the pre-EMS average.

A number of regression techniques were used to estimate the values in the basic model. These regression techniques are listed in Section 6.2. Preferred model is detailed in that section.

5.3.3. Graphical Representation of Data

The NEC for all units for all billing periods is shown in Figure 5-2.

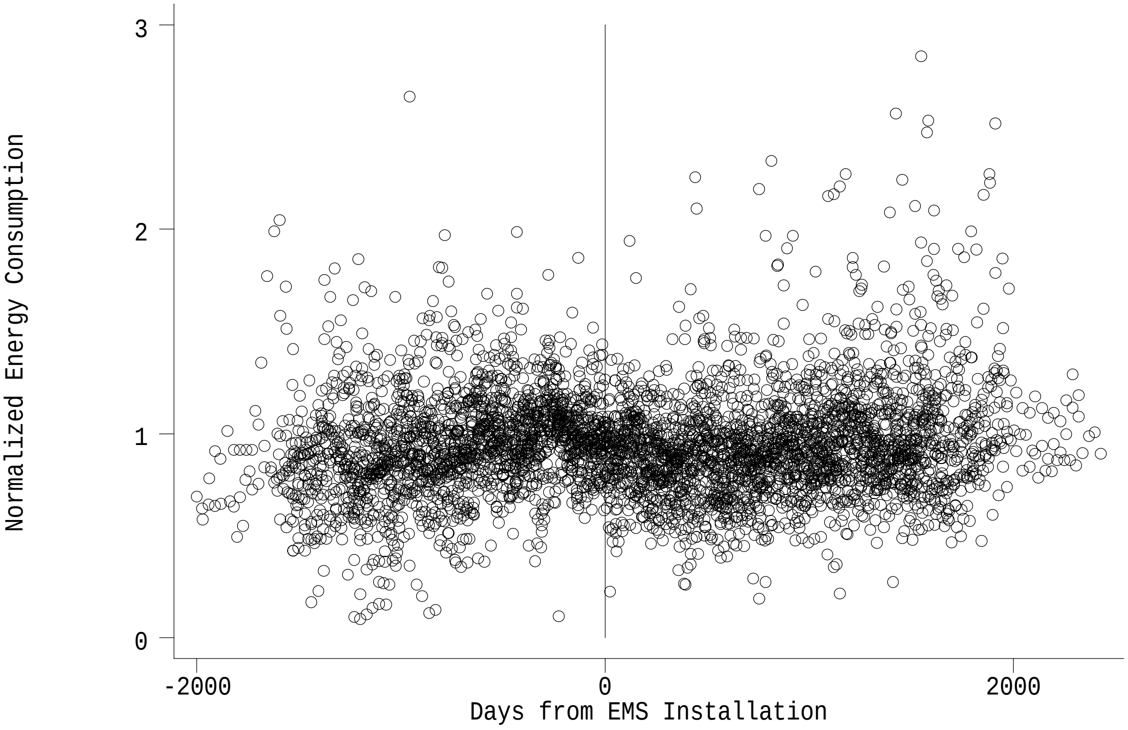

Figure 5-2 Normalized Energy Consumption vs. Days from EMS Installation

The regression fit for the data in Figure 5-2 is shown in Figure 5-3.

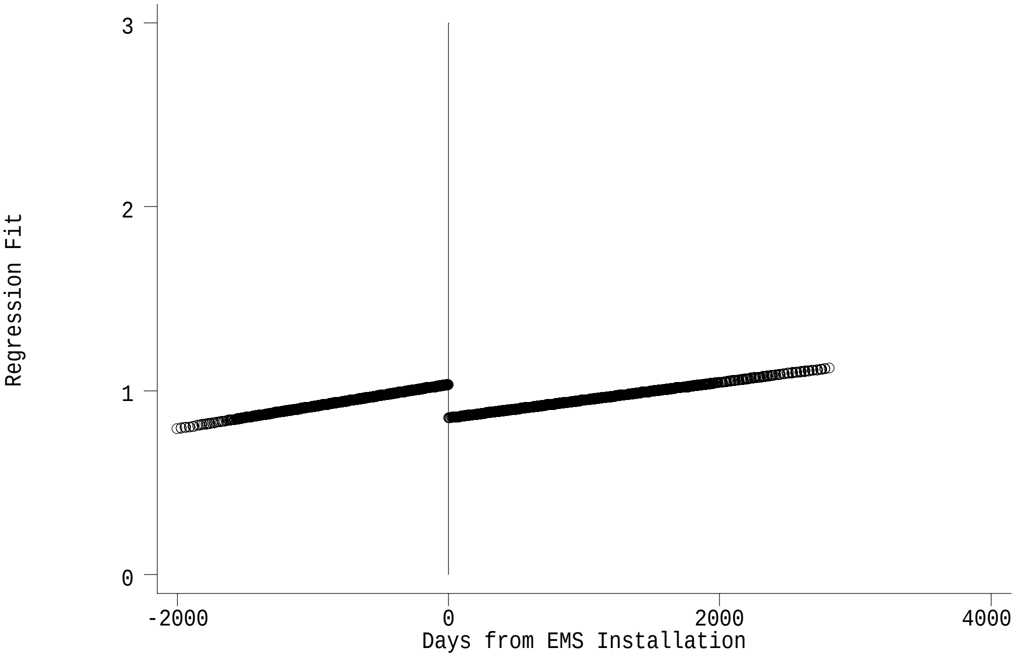

Figure 5-3 Linear Regression Fit to Normalized Energy Consumption

6 RESULTS - EMS

6.1.1. Site Participation

The initial dataset for analysis included a total of 51 EMS installations from 16 participating organizations. All participating organizations except four had multiple EMS installations. Eleven of the installation from the initial dataset were dropped from analysis, see Appendix G. The finished analysis included 40 EMS installations from 15 participating organizations, Table 6-1. This exceeds the minimum of 25 EMS installations required in the research plan.

Table 6-1 Participating Organizations

Utility	Number of Participating Organizations	Number of EMS Installations Surveyed
Pacific Gas & Electric	7	12
Southern California Edison	8	28
TOTAL	15	40

The primary target participants were schools and office buildings. There is some overlap in these categories as a school system corporate yard was included in the school category. The "Other" category includes branch banks, a fast food restaurants, and several city facilities, Table 6-2.

Table 6-2 Participating Organizations

Class of Participating Organization	Number of Participating Organizations	Number of EMS Installations Surveyed
School Districts	6	10
Office Buildings	5	11
Other	4	19
TOTAL	15	40

Figure 6.1 details the EMS installations used to calculate the TDF. The column of shaded boxes shows the division of sites between the two utilities: Pacific Gas and Electric and Southern California Edison. The column of rectangles shows the different participating organizations; they are numbered corresponding to the database. In ten cases more than one EMS installation was analyzed per organization. The column of rounded rectangles shows the individual EMS installation sites that were used in the TDF calculation.

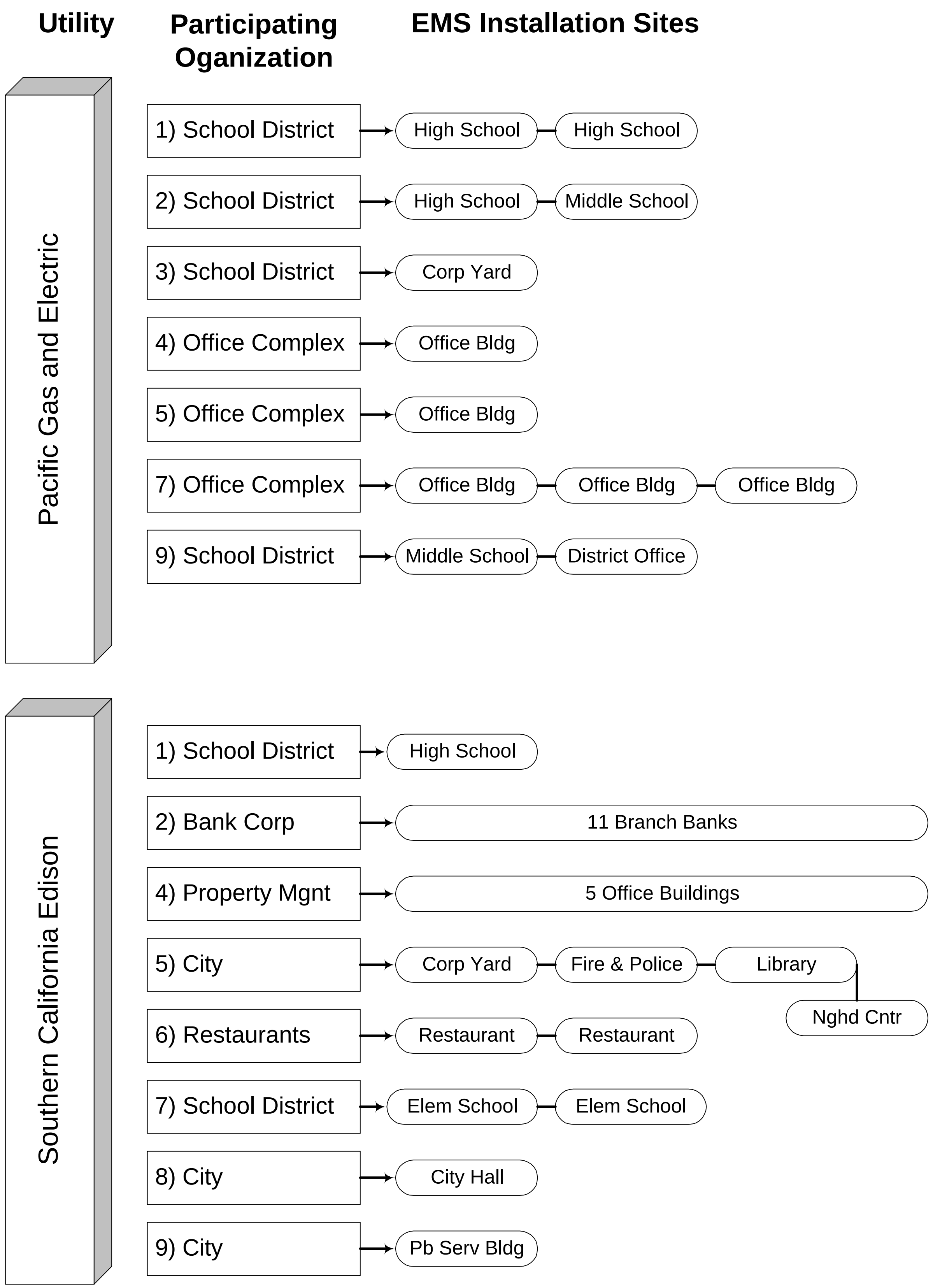

Figure 6-1 Structure of Site Participation

6.1.2. On-Site Surveys

All of the EMS were found to be present and operational during the On-site Surveys. One system was unable to connect to its modem. The maintenance person reported that this was a new problem, and it was reported fixed during a follow-up phone call.

The On-site Survey provided a valuable opportunity to discuss EMS operation with operating personnel and gain subjective impressions of their operation. In general, operating personnel were found to understand and be competent at running the EMS systems. They appreciated that the EMS made the rest of their job easier. The overall impression was that the EMSs surveyed were considered to be important tools, were well maintained, and were professionally operated.

In many multi-site installations the EMS was an integral part of the maintenance program. Maintenance personnel monitored the sites, consulted the EMS readout whenever a complaint was received, and determined the appropriate action based on the EMS readings. For example, if a "too cold" complaint was received in the winter, the operating person would check the boiler operation. If the EMS indicated that the boiler was not operating, a maintenance person would be dispatched immediately; if the problem appeared to be the caller's personal preference, the response would be less immediate.

Varieties of EMS management or operational styles were found. This information was not part of the research plan nor was it formally surveyed; it is included as an informal observation. Table 6-3 identifies the management styles.

Table 6-3 EMS Management Styles

EMS Management Style	Number of Participating Organizations
Single internal manager	7
Many maintenance staff with knowledge to operate	5
External contractor operates under contract	2
Facility is under ESCO contract	2
Total	16

6.1.3. Screening Process

Sixteen organizations were contacted and participated in some portion of the initial telephone interview that were not included in the final database. No sites were eliminated because of non-functional EMSs.

The reason for screening-out varied though several themes predominated. Almost all elementary schools were eliminated because portable classrooms had been added due to classroom size reduction legislation. In some of these cases, the district office or corporate yard was used but not the elementary schools. Some office buildings had significant changes in occupancy that invalidated the longitudinal energy use comparison. For example, in one office building the EMS was installed as part of a building upgrade when the sole tenant moved to new headquarters. Over the next three years occupancy gradually went from 0% to 80%. Even though the owner was eager to participate, this data would have been uninterpretable. A number of other sites were eliminated for other reasons such as not returning phone calls after numerous attempts. Table 6-4 itemizes the screened-out organizations by class of reason for elimination.

Table 6-4 Screened-out Organizations

Reason for Elimination from Study	Number of Organizations Eliminated
Too busy	2
Don’t participate in surveys	2
Change of Occupancy	2
Change of Physical Structure	4
Knowledge of EMS installation not readily available due to change of ownership, personnel, other.	4
HVAC equipment not analyzable (solar, ice storage, etc.)	2
Total	16

6.1.4. Potential Site Selection Bias

The sample was not designed as a statistical representation proportional to resource value claimed for several reasons:

1. Some facility types were inappropriate for a monthly billing analysis.
2. Some facility types had a low frequency of occurrence.

Potential site biases include:

- The survey may not include facilities that have problem EMSs.
- The survey may not include smaller, perhaps less well managed, facilities.
- The survey does not include some large facilities with large resource values
- The survey does not include facilities with highly variable HVAC operation.
- The survey does not include facilities in which HVAC usage is a small part of the total energy use.

Facilities with Problem EMSs: The EMSs in the database sample were all operating and were receiving ongoing attention. Other studies have found sites where the EMS systems were ignored, disabled, or sabotaged. (Liu 1994) We found none of that in this study. It is possible that the sites that agreed to participate did so because they are happy and proud of their EMS systems. If this was true, the degradation in the sample may be less than that experienced in the population. However, no sites, neither participant nor non-participant, reported problem EMSs. This does not appear to be a source of sample bias.

Smaller Facilities: Smaller facilities represent only a small fraction of total resource value. If included proportionally, their inclusion would have little effect on the final TDF.

Large Facilities: The largest resource value facilities were hospital and manufacturing facilities. These facilities are difficult to analyze because the majority of energy is consumed by non-HVAC end uses. Because they tend to have highly qualified professional facility managers, elimination of these facilities is likely to lower the TDF and make the estimate more conservative.

Variable Use Facilities: Facilities with highly variable HVAC operation are not analyzable through monthly billing analysis alone. For example, to analyze a hotel/motel the guest occupancy by day would be needed. Such complex analysis was not part of the study. Variable HVAC operation may complicate EMS operation, and by eliminating these facilities, the TDF may be over-estimated. However, EMS operation of these facilities is often kept simple; the EMS may only function to turn room equipment on/off; and therefore, this probably does not have a large effect.

Small HVAC energy use: Facilities with a small HVAC load compared to overall energy use are not analyzable through monthly billing analysis alone. For example, the refrigeration load on grocery stores is highly weather dependent, and, the refrigeration system interacts with the HVAC system; the refrigerated cases provide most of the summer cooling needs without additional AC operation. As the HVAC load is small, the resource value and effect on final TDF calculation are also likely to be small.

PG&E 1995 EMS database was analyzed for rebate recipient facility classes. Table 6-5 shows the resulting disposition.

Table 6-5 Site Selection by Class of Facility

SIC Code	SIC Code Text	Count	%Count	mWh Save	%mWhS	Reason Del*
212	Cigars	1	1.2%	180	1.47%	2
283	Drugs	1	1.2%	378	3.09%	2
366	Communication equipment	1	1.2%	146	1.19%	1
367	Electronic components and accessories	5	6.2%	1,300	10.62%	1
382	Measuring and controlling devices	2	2.5%	488	3.99%	1
504	Professional & commercial equipment	1	1.2%	5	0.04%	1, 2
541	Grocery stores	5	6.2%	284	2.32%	1
615	Business credit institutions	1	1.2%	198	1.62%	2, ⊗
653	Real estate agents and managers	2	2.5%	1,984	16.20%	⊗
655	Subdividers and developers	1	1.2%	102	0.83%	2
701	Hotels and motels	2	2.5%	339	2.77%	1
737	Computer and data processing services	2	2.5%	1,062	8.67%	2
738	Miscellaneous business services	1	1.2%	99	0.81%	2
799	Misc. amusement, recreation services	1	1.2%	9	0.07%	2
801	Offices & clinics of medical doctors	2	2.5%	57	0.46%	2
806	Hospitals	6	7.4%	2,138	17.46%	1
809	Health and allied services, n.e.c.	1	1.2%	22	0.18%	1, 2
821	Elementary and secondary schools	34	42.0%	2,715	22.17%	⊗
822	Colleges and universities	3	3.7%	607	4.95%	1
823	Libraries	1	1.2%	95	0.77%	2, ⊗
913	Executive and Legislative Combined	1	1.2%	39	0.32%	⊗
	Real Estate, not classified	7	8.6%	925	7.55%	⊗
	TOTAL	81	100.0%	12,248	100.00%	

* Reason Deleted

(1) Inappropriate for a monthly billing analysis.
(2) Low frequency of occurrence.
(⊗) Used in analysis

Count: Number of rebates in class
Count%: Percent of rebates in class
mWh Save: Annual mWh resource value
%mWhS: Percent of resource value in class

The majority of resource value is within facility classes that were surveyed in the study. PEG estimates potential site selection bias as small and that site selection bias is not a major source of study error.

6.1.5. Operating Personnel Interview

For each participating organization, the person who provided the survey information was interviewed about their role and opinions about the EMS operation. In several cases, more than one person provided survey information and two interviews were performed for the same organization. A total of 19 interviews was performed.

The purpose of the "Operating Personnel Interview" was to determine general attitudes towards the EMSs and to seek information that might help explain observed differences in EMS performance. The interview results do not affect the TDF calculation and are not primary data. The interview is included in the survey as questions 90-99 in Appendix E.

Respondents were given a choice of six responses to each questions, three levels of agreement and three of disagreement. An average response was also calculated by assigning a value of 1 for strongly disagree to 6 for strongly agree, Table 6-6. The questions and average responses are listed in Table 6-7. Further details of the interview results are presented in Appendix D.

Table 6-6 Index Values of Interview Responses

Response	Index Value	Response	Index Value
strongly agree	6	disagree somewhat	3
agree	5	disagree	2
agree somewhat	4	strongly disagree	1

Table 6-7 Operating Personnel Interview Questions

Survey Question #	Survey Question	Average Response
1)	Lowering energy costs is an important part of my job responsibilities	5.3
2)	I was adequately trained to understand the operation and capabilities of the EMS.	4.9
3)	Over time I learned how to use the EMS to best advantage. The EMS is now working much better than it did initially	4.4
4)	Over time, different people have run the EMS and its operation has changed considerably.	2.9
5)	We have increased our usage of the EMS over time; it now controls more of the facility.	3.3
6)	Reducing complaints from occupants is an important part of my job responsibilities.	5.7
7)	The EMS is operating well.	5.2
8)	The EMS makes controlling energy costs easier	4.9
9)	The EMS makes operating the buildings HVAC system easier.	5.1

The greatest agreement found among respondents was that reducing occupant complaints was an important part of their job responsibility — average 5.7. All respondents agreed with this question with

79% strongly agreeing. Respondents also said that lowering energy costs was an important part of their job responsibility — average 5.3. All respondents agreed that the EMS was operating well — average 5.2. Most respondents agreed that the EMS made controlling energy costs easier — average 4.9, and most respondents agreed that the EMS made controlling the facilities HVAC system easier — average 5.1. The perceived usefulness of the EMS is discussed in Section 6.3.

6.2. Billing Analysis

The on-site inspections of the EMS systems showed no apparent causes for degradation of energy savings. The operators were using the systems regularly, knew how they functioned, and very few savings mechanisms had been abandoned that were used in the first year of operation. In fact there were sites where the EMS was utilized to a larger extent over time, controlling more equipment, or being utilized more fully for the connected equipment.

The site visits indicated that the appropriate TDF would be near unity. The case studies showed conflicting results, with some sites showing increasing savings, others with savings losses over time. The most powerful analysis is the billing analysis with the combined data from all units.

The following regression techniques were used to estimate the model described in Section 5.3.2:

- Ordinary Least Squares
- Weighted Least Squares - This allows us to weight the data by the average energy consumption of each building.
- Regression with Robust Standard Errors - This produces White-corrected standard errors in the presence of heteroscedasity.
- Regression with Clustered Data and Robust Standard Errors - This is able to relax the assumption of independence. This addresses the fact that only the observations on different buildings are truly independent.
- Robust Regression - This regression addresses data with outliers and high leverage points. It first estimates the regression, calculating Cook’s D and excludes any observation for which D>1. Thereafter it works iteratively performing the regression, calculates the case weights based on absolute residuals, and regresses again using those weights. Weights derive from one of two weight functions, Huber weights and biweights are used until convergence.
- Cross Sectional Time Series Regression of Panel Data - this technique was used to estimate both fixed effects and random effects models.

All of these methods shared this common basic structure. The analysis regresses the NEC against three predictors: days from retrofit, pre-EMS, and days prior to retrofit (this is equal to 0 after the retrofit).

For all but the Time Series Cross Sectional Regression, the model is of the form:

$$NEC_{it} = \alpha + x_{it} * \beta + \varepsilon_{it}$$

For the Time Series Cross Sectional Regression, the model is of the form:

$$NEC_{it} = \alpha + x_{it} * \beta + \nu_i + \varepsilon_{it}$$

where:

NEC_{it} is the Normalized Energy Consumption in time period t for building i

t is the time variable (elapsed days)

i is the unit variable (building)

α is the intercept (constant)

x_{it} is the value of the independent variable in time period t for unit i

the independent variables are indate, pre, and pindate

indate is the number of days from EMS installation (- if before installation, + if after installation)

pre is an indicator variable (1 if prior to EMS installation, 0 if after installation)

pindate is the number of days from EMS installation (- if before installation, 0 after installation) ; pindate is pre * indate

β is the coefficient of x in the model

ν_i is a case specific residual, this is a constant for each unit

ε_{it} is the general residual

In lay person's terms:

The Initial Savings Coefficient (β pre) from the model is the change in energy consumption that occurs at the time of the EMS installation. The savings are in terms of a fraction of the average electrical consumption over the year prior to the EMS installation. The first year savings can be estimated from this coefficient and the Persistence Coefficient. The first year savings would be:

S_1: Savings in year 1 (as a percentage of pre-EMS consumption) = $\beta_{pre} + \beta_{pindate} * (0.5) * 365$

The Persistence Coefficient (β pindate) from the model is the net change in energy consumption growth that occurs at the time of the EMS installation. This factor captures the change in growth that occurs at the time of the EMS installation. If the coefficient is positive, there is increasing savings. If the coefficient is negative there is degradation of savings. In Table 6_8, the Persistence Coefficient is annualized (multiplied by 365). The savings for any year can be estimated from:

S_y: Savings in year y (as a percentage of pre-EMS consumption) = $\beta_{pre} + \beta_{pindate} * (y - 0.5) * 365$
Where y can be 1 through 20.

Each of the models produced very similar estimates of the coefficients. The purpose of the regressions was to estimate the Persistence Coefficient and, if necessary, the savings in each year. The estimated coefficients and their standard errors were the focus of this investigation.

Table 6-8 presents the results of these analyses. In all cases the coefficients support a TDF of 1 or more. The preferred estimates are shown in bold and the results are detailed below the table.

Table 6-8 Billing Analysis Results

Data Population	Initial Savings Coefficient (+ denotes energy savings)	Significantly (95%) different from 0	Persistence Coefficient (+ denotes savings growth) [annualized]	Significantly (95%) different from 0
Data limited to periods later than 1500 days before retrofit and earlier than 1700 days after retrofit				
OLS regression All Data 40 Buildings	+0.184	yes	+0.009	no
OLS only for units with first year savings 25 Buildings	+0.224	yes	+0.035	yes
Data weighted by average pre-EMS consumption 40 Buildings	+0.190	yes	+0.022	yes
Regression with Robust Standard Errors 40 Buildings	+0.184	yes	+0.008	no
Regression with Clustered Data and Robust Standard Errors **40 Buildings**	**+0.184**	**yes**	**+0.009** **(-0.021 to +0.038)**	**no**
Robust Regression 40 Buildings	+0.167	yes	+0.027	yes
Fixed Effects Cross Sectional 40 Buildings	+0.183	yes	+0.011	no
Random Effects Cross Sectional 40 Buildings	+0.183	yes	+0.011	no

All the regression analyses point to a Persistence Coefficient of 0 or larger. The standard errors and confidence intervals are most appropriate where robust standard errors are used. For this reason, the regression with clustered data and robust standard errors was chosen as the primary analysis, with support from the other regressions.

Results - EMS

The following is the results table from the preferred regression.

```
reg NEC indate pre pin if indate>-1500&indate<1700,cluster(ii)

Regression with robust standard errors          Number of obs = 3690
                                                F( 3, 39) = 19.91
                                                Prob > F = 0.0000
                                                R-squared = 0.0390
Number of clusters (ii) = 40                    Root MSE = .25731

---------------------------------------------------------------------------
                        Robust
 NEC        Coef.       Std. Err.    t          P>|t|      [95% Conf. Interval]
---------------------------------------------------------------------------
indate       .0001085   .0000272    3.996       0.000      .0000536   .0001634
pre          .1837449   .0267534    6.868       0.000      .1296311   .2378587
pindate     .000024     .0000404    0.594       0.556     -.0000578   .0001058
_cons       .851312     .0205937     41.339     0.000      .8096574   .8929666
```

The preferred regression has a low R squared because the largest variation in energy consumption has been removed through the normalization process. A regression of post-retrofit energy consumption on average pre-retrofit consumption shows an R squared of .85. The important statistic here is the confidence interval on the Persistence Coefficient (365* pindate).

The billing data clearly show that while there are load increases after the EMS is installed, those increases are equal to or less than the load increases that occurred prior to EMS installation. Based on the billing analysis and the field site visit results, Proctor Engineering recommends a consistent TDF of 1 for all years.

The recommended TDF are shown in Table 6-9.

Table 6-9 Recommended TDFs

Year	1	2	3	4	5	6	7	8	9	10
TDF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Year	11	12	13	14	15	16	17	18	19	20
TDF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

6.3. Discussion of Results

The TDFs estimated in this report, *Persistence 3A*, are significantly higher than those estimated in *Persistence 2*. Among the possible reasons for this are:

- Evidence of disconnection
- Focus on failures
- Perceived usefulness to building operators
- Retrofit versus new
- Load growth versus degradation

- Professional management
- Less complex systems

There is evidence to support each of these hypotheses

Evidence of disconnection All EMSs were found to be operational and in use. The lower TDF in Persistence 2 was strongly influenced by reports of large numbers of EMSs being disconnected. (A potentially operational but disconnected EMS that is physically present is considered to be retained but have no persistence of saving according to CADMAC protocols.) Liu et al (1994) reported EMCS controls had been disabled in over 100 schools in Texas.

Focus on failures Problematic EMSs may be over-represented in the literature because they come to the attention of experts who are called in to fix them. Haberl (1999) reports working on numerous problem systems.

Perceived usefulness The findings from the operator interview support the hypothesis that the operators of the surveyed EMS systems generally found them functioning well and useful for fulfilling important job responsibilities, Section 6.1.5 and Appendix D. Given this hypothesis, it is not surprising that the study found them in operation, well maintained, and understood by operating personnel.

Retrofit versus new A number of the EMSs reviewed in *Persistence 2* had been installed on new buildings. (Diamond et al. 1992, Koran 1994) In a new building the EMS is installed and then the operators get involved with a pre-existing EMS system. *Persistence 3A* reviewed only retrofit installations. In a retrofit, the operations and maintenance staff are in place. If they do not agree to the EMS installation, it is unlikely to happen. Their input during the design phase may help insure that the system operates according to the building's needs. One of the reports reviewed for *Persistence 2* (Tanaka and Miyasaka 1994) found that after fifteen month five of eight new building had yet to reach stable operation. Retrofit EMS installations may be better designed and better accepted by operations staff.

Load growth versus degradation Increasing load appears identical to EMS savings degradation in monthly billing analysis. In several cases in this study what appeared to be savings degradation turned out to be load growth that had previously been unreported. One of the reports used in *Persistence 2* (Diamond et al. 1992) noted that some of the reported energy use increase was probably due to increased occupancy.

Professional management Most of the EMSs reviewed in Persistence 3A were installed for large organizations with multiple facilities and professional management. These recipients may differ from those in *Persistence 2*, but there is inadequate data to determine this. Haberl (1999) identified professional management as a highly significant factor in savings persistences.

Less complex systems Many of the EMS systems in the literature were complex systems. They often controlled large office buildings with VAV HVAC systems. (Claridge et al. 1991, Koran 1994, Tseng et al. 1994) While some of the rebated systems fit this description, most were much less complex. Often the EMSs functioned as a "glorified timeclock;" they only turned the packaged HVAC systems on/off. The lower complexity may result in higher persistence.

7 RECOMMENDATIONS - EMS

7.1. EMS TDFs

Proctor Engineering Group recommends a constant TDF of one (1.00) for EMSs.

7.2. EMS Functionality

The Energy Management Systems at the sites investigated were working as designed. Unfortunately they lacked a primary component of a management system. They did not report the energy consumption. EMS as they were used at these sites look very closely at individual items, “the trees”. These systems did not put longer term energy consumption trends in front of the operator. As a result there was no attention called to increasing energy consumption “in the forest”.

Proctor Engineering Group recommends that EMS systems be tied into the building meter and designed to display a 12 month running average of energy consumption.

7.3. Demand Reductions

The analysis of the historical billing data shows that in the majority of the cases the installation of the EMS resulted in a drop in kW billing demand even in the peak cooling months. While billing kW may not be the same as system peak kw, they are generally related.

No resource value was claimed for demand reduction. The source of the billing demand reduction was not investigated, however, it was clearly present.

Proctor Engineering Group recommends that this be investigated. It may be appropriate for a demand reduction resource value to be claimed for the installation of EMS systems.

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APPENDIX A LABORATORY TEST PROCEDURES AND METHODOLOGIES

Laboratory Test Procedures

Laboratory Facilities

Proctor Engineering Group conducted the experimental testing at the National Research Council's Thermal Technology Center. NRC's facilities, research staff, and availability made it the preferred location for conducting the tests. Measurements at the laboratory are made with calibrated instruments that are NIST (National Institute of Science and Technology) traceable. The laboratory is certified to meet ARI (American Refrigeration Institute) standards.

The psychrometric rooms that were used in the testing can maintain "indoor" and "outdoor" conditions over a wide range of desired temperature and humidity levels. The psychrometric rooms were built in accordance with ARI specifications and were designed for testing units with capacities up to 10 tons. In each of the psychometric rooms, steam humidification valves, duct heaters, cooling coils, and dehumidification coils are computer controlled to maintain the room environments to design specifications. These super insulated rooms are housed within a two story bay at the Thermal Technology Center. The control center is on the upper level and overlooks the rooms.

The room temperatures are controlled by overhead air handling units containing chilled water coils and electric resistance heaters. The cooling coils are supplied with a highly responsive brine-based cooling system. Room air is moved through the rooftop conditioning area and reintroduced into the room through a perforated wall delivery system.

Figure A-1 shows the laboratory engineer in the control room. The panel to his left controls all of the equipment settings and environmental conditions.

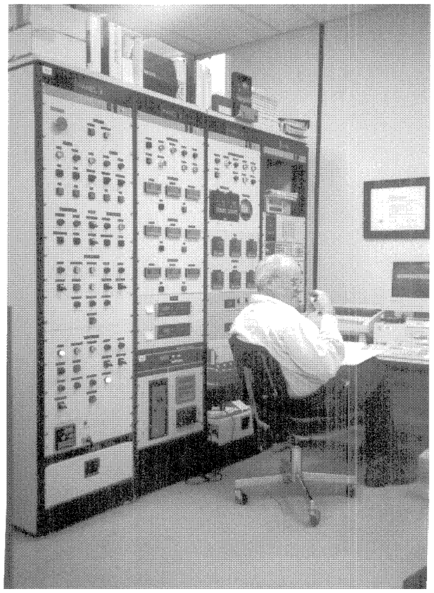


FIGURE A-1 CONTROL ROOM

Steam from an electric boiler is fed into the supply air to raise the humidity. Dehumidification coils in the supply duct remove moisture from the air when necessary.

The individual environmental conditions are operated by a wall mounted controller that allows the operator to view and modify the environmental parameters. It displays the ambient air temperatures and humidities in each room and provides output signals to control the cooling coil valves, the heater relays, and the steam valves. The controller is connected to a personal computer enabling the operator to display and record all measurements. The temperatures in the rooms are maintained within ± 0.2°F of the desired values.

Both the indoor and outdoor rooms are outfitted with a calibrated Brandt air measurement system. The system includes a fixed orifice, air flow straightening vanes and a pitot tube array. The measurement system is coupled with a variable speed fan control system. This allows the operators to measure and adjust the amount of air flow through the system being tested. The flow rate can be controlled to ±1% of reading for any given test.

Equipment Setup

The air conditioning unit was moved into the outdoor unit by forklift and placed on blocks. All of the electrical components were rewired through the sensors and a remote control panel. The refrigerant mass flow meter and the pressure sensors were installed in the refrigerant system, and the system evacuated.

Supply and return ductwork was manufactured to connect the air conditioning unit to the indoor room. The return air duct was installed under the unit, sealed and insulated. The supply air system was mounted on the side discharge flange and was ducted back to the indoor room. In the indoor room, the duct was connected to a filter bank and the air flow measurement fan. All of the ducts were tightly sealed to prevent air from leaking into the outdoor room. A damper was installed on the supply system, and adjusted to simulate standard operating pressure. Three sets of average static pressure taps were installed on the duct system: one set on the return duct, and two sets on the supply duct, before and after the damper. After the installation of the system, a wall was built between the rooms and was sealed in place. The larger “outdoor” room holds the equipment. The “indoor” room is connected by ducts. Both air handling fans are connected to independent air measurement systems.

Figure A-2 shows the basic layout of the testing facility.

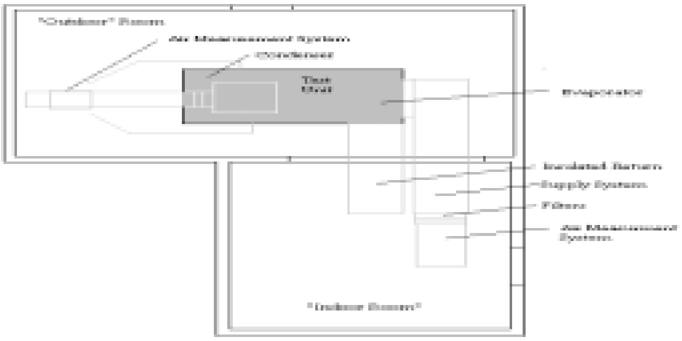


Figure A-2 Equipment Layout

Figure A-3 shows the supply ducting, pressure measurement devices and the return system extending through the wall that separates the two psychrometric rooms.

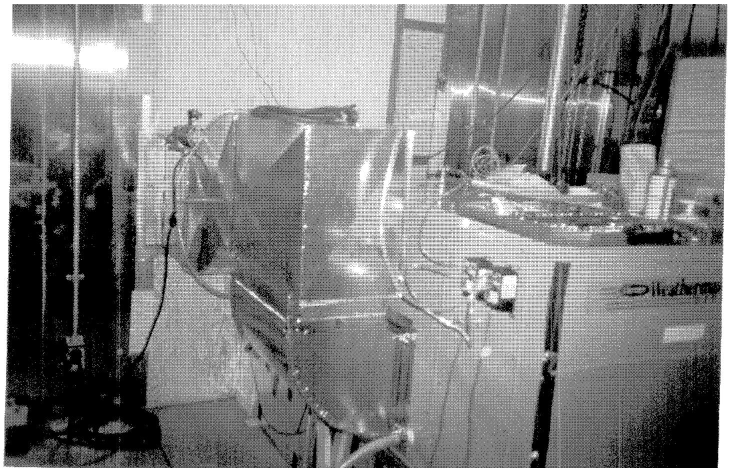


FIGURE A-3 SUPPLY AND RETURN DUCTS

The condenser side of the air conditioning unit was outfitted with specially designed air flow devices. The standard louvered panels on the inlet side of the coil were replaced with a directional enclosure. This design allows access to the entire coil while providing a single location for the input of contaminants. A collection hood was built for the exhaust side of the condenser. The hood was connected to a filter bank and the air flow measurement fan. The fan system was used to offset the pressures created by the modifications. Plexiglas panels were installed around the coil to allow for observation of the fouling process.

Figure A-4 shows the condenser side of the air conditioning unit.

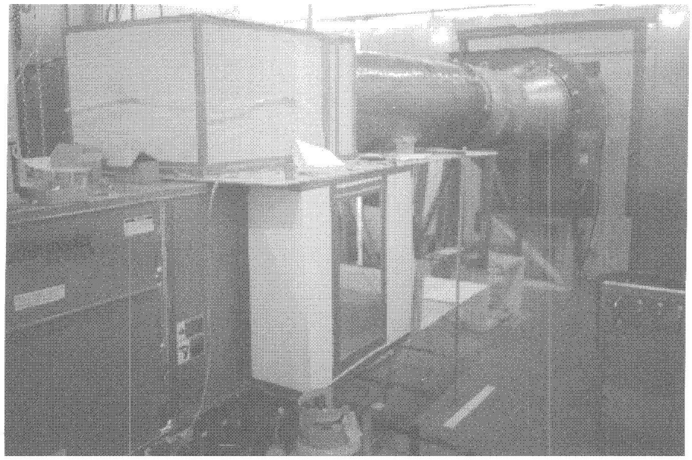


FIGURE A-4 CONDENSER MODIFICATIONS

Coil Fouling

The coil fouling equipment consists of three major components: the computer control system, the heater/injector system, and the delivery system. The delivery system is an 8' long inflatable duct, 36 " in diameter. For this experiment we installed a pressure plate on the exhaust end of the duct to ensure that the tube will remain inflated during the testing. The inflatable duct is attached to the injector system. The injector system contains the fluid flow pump, injector fan, and supplemental heaters. The fluid flow pump was a variable speed peristaltic pump installed specifically for this experiment. This aerosol material is pumped from a pre-measured container into the injector system. The injector tube serves as a preheater for the liquid material. Supplemental heaters are located around the injector and are used to enhance the evaporation of moisture from the minute aerosol particles. The heated air is blown through the injector tube and directly into the duct.

The system is controlled by a laptop computer. The software controls the operation of the system and continuously monitors the air flow and temperature of the duct sealer. The injector was set up approximately 8 feet from the return duct, in the “inside” room. Contaminated air from the injection system is mixed with additional indoor air before going into the return ductwork.

Figure A-5 shows the computer control system (top) and the injector system attached to the evaporator side of the air conditioning system (bottom).

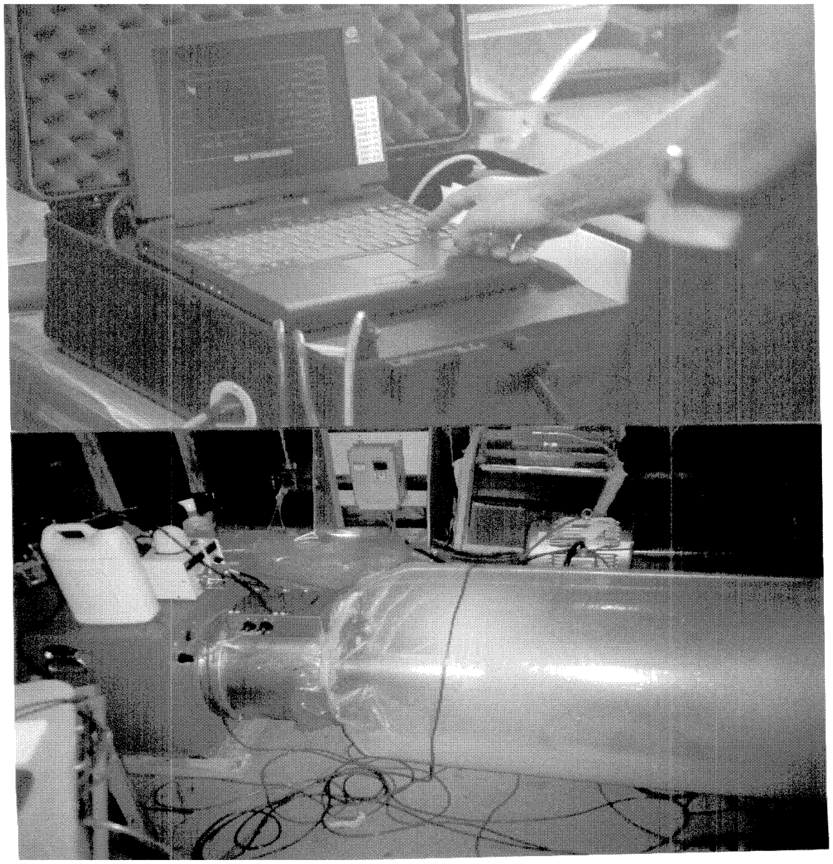


FIGURE A-5 CONTAMINATION SYSTEM AND CONTROLS

In order to foul the condenser, this equipment was moved over to the "outside" room and installed at the inlet to the condenser coil shown in Figure A-3.

Instrumentation

There are two sets of instrumentation used in the project:

- The sensors that are hard-wired and used to monitor and control the calorimeter.
- The temporary sensors that were specifically installed to monitor the performance of the air conditioning unit.

In some cases, the computer software is used to convert or combine test measurements into the desired engineering units. The air conditioning unit was rewired and repiped to allow individual measurement and control of each component of the system.

The data acquisition system was specifically reconfigured to provide sensors for collecting data on flow, humidity, pressure, and temperature of the air streams, power measurements for the condenser fan, the compressor, and the evaporator blower, and refrigerant temperature, pressure and flow measurements.

In addition to the basic measurements on the air conditioner, measurements were made of all calorimeter functions so an energy balance could be calculated. These measurements documented the amount of conditioning needed to maintain the test conditions. The test instrumentation required hundreds of connections to be field installed.

Figure A-6 shows the field connections made at the terminal block, directly above the refrigerant mass flow meter.

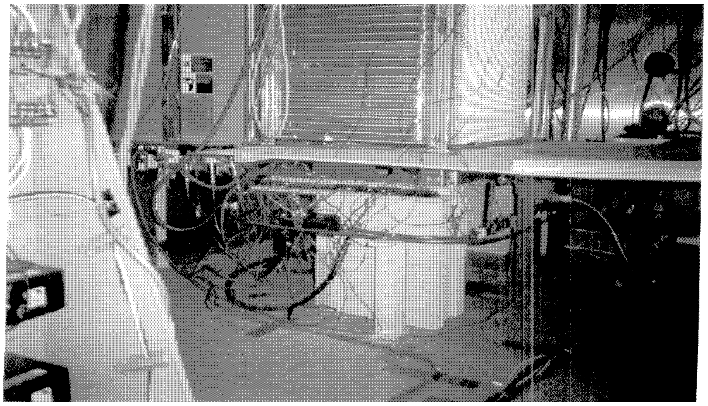


FIGURE A-6 FIELD CONNECTIONS OF THE MONITORING EQUIPMENT

Accurately monitoring the electric consumption of all the devices is an essential component of the testing. Output from these sensors allowed the laboratory engineers to establish an energy balance. This energy balance is the basis for establishing the efficiency of the appliance.

Figure A-7 shows the electric control system for the psychrometric room (left) and the special sensor panel for monitoring the air conditioning system (right).

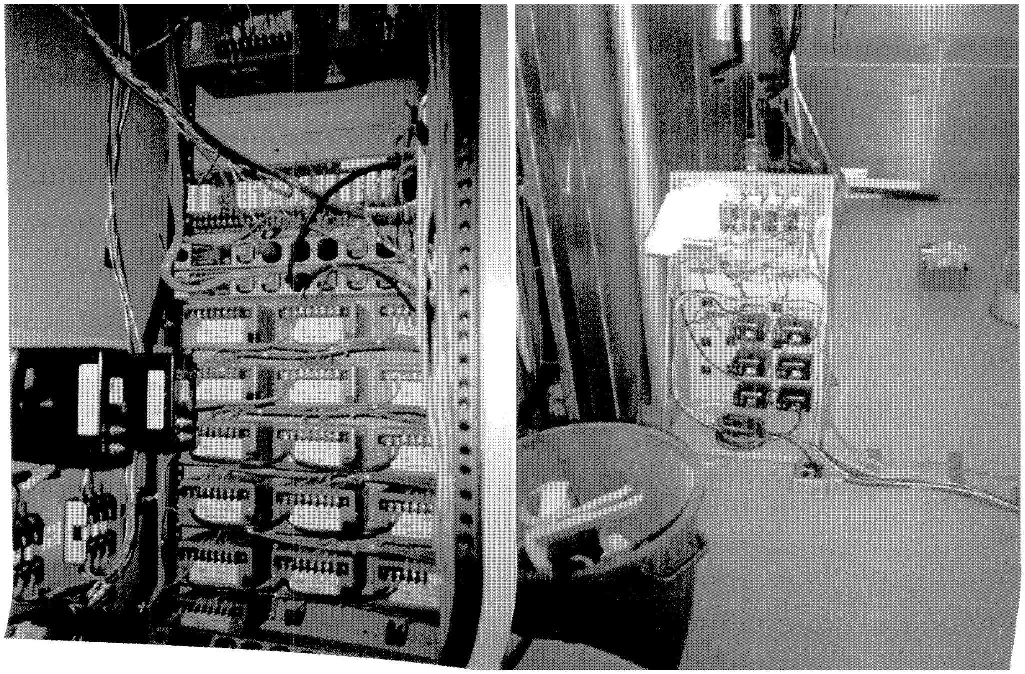


FIGURE A-7 ELECTRICAL CONTROLS AND MONITORING SYSTEMS

The field-installed monitoring system consisted of 19 basic physical parameters. These measurement points can accurately describe the energy flows throughout the system.

Table A-1 - details the basic data acquisition points and sensor types.

Table A-1. Data Acquisition

LOCATION	**PARAMETER**	**INSTRUMENT**
Evaporator coil air inlet	Dry bulb temperature	Thermocouple grid (~0.2^{0}F)
Evaporator coil air inlet	Wet bulb temperature	Chilled mirror dew point sensor (~0.2^{0}F)
Evaporator coil air discharge	Dry bulb temperature	Thermocouple grid (~0.2^{0}F)
Evaporator coil air discharge	Wet bulb temperature	Chilled mirror dew point sensor (~0.2^{0}F)
Condenser coil air inlet	Dry bulb temperature	Thermocouple (~1^{0}F)
Condenser coil air inlet	Relative humidity	Chilled mirror dew point sensor (~0.2^{0}F)
Condenser coil air discharge	Dry bulb temperature	Thermocouple (~1^{0}F)
Evaporator coil air inlet	Pressure	Pressure transducer (~0.1%)
Evaporator coil air discharge	Airflow	Pitot-Static Array (~0.5 % of reading)
Condenser coil air inlet	Pressure	Pressure transducer (~0.1%)
Condenser coil air discharge	Airflow	Pitot-Static Array (~0.5 % of reading)
Refrigerant liquid line	Dry bulb temperature	Thermocouple (~1^{0}F)
Refrigerant liquid line	Pressure	Pressure transducer (~0.25 psi)

Refrigerant vapor line	Dry bulb temperature	Thermocouple (~1^0F)
Refrigerant vapor line	Pressure	Pressure transducer (~0.25 psi)
Refrigerant liquid line	Refrigerant flow	Mass flow meter (~0.2% of reading)
Evaporator fan power	Watts	Watt Transducer (~0.25% or reading)
Condenser fan power	Watts	Watt Transducer (~0.25% or reading)
Compressor power	Watts	Watt Transducer (~0.25% or reading)

An air sampling station was used in the outdoor room near the condenser unit to measure outdoor room ambient temperature and relative humidity. Thermocouples were suspended around the condenser coil to measure average inlet and exhaust air temperatures.

Customized pressure transducers were used to measure the pressure drop through the air flow sensor systems. Externally mounted pressure transducers were used to record the average duct static pressure. A static pressure of 0. 4” H_20 was maintained across the unit during the testing. Atmospheric air pressure was also measured, and used to adjust the calculated air flow.

Chilled mirror humidity sensors were used to measure the dew point temperature of the air in the rooms and in the air flow after the evaporator coil. This allowed us to maintain the humidity levels and determine the amount of moisture taken out of the system by the evaporator. The latent and sensible capacity of the system was calculated using these measurements.

Power measurements were taken using electrical watt transducers. These instruments measured current draw and voltage, calculated true power, and supplied an output voltage signal to the data acquisition system. Power measurements were made for the outdoor fan, the compressor, and the indoor fan.

Data Acquisition System

All measurement points were sampled every 5 seconds by an HP 3497A data acquisition system.

The voltage signals from the sensors were collected using an electronic data logger. The input boards on the data logger accepted thermocouple inputs and voltage inputs from the sensors. The data logger was connected to a personal computer where the signals were converted into engineering units.

For each capacity test, the air conditioner was allowed to run 15 minutes to reach steady state, then data were collected on all channels and stored to disk. The data file was then processed using an analysis program developed by the Thermal Technology Center. The output from this analysis program is documented in summary form in Appendix B, and the complete database is in Appendix C.

Methodology

Coil Comparison

The original research plan was very tightly controlled and had alternative means of verifying the measured results. Changes during the testing required changes in the research plan. The largest change was due to the inability to maintain tight controls on the fouling process. The extended periods of time required to foul the coils resulted in numerous cleanings, and adjustments. As a result the absolute amount of material deposited on the coils is not known. We have established the fouling profiles for each of the coils based on exposure time. This fouling profile is used to adjust rate of fouling in the TDF. The profiles are very similar and are consistent with field experience.

Coil Fouling

The coil contamination process was done with an aerosol duct sealing tool developed by Lawrence Berkeley Laboratory. This tool injects a fine aerosol mist into the air stream. This aerosol tends to build up in areas of significant pressure drop, very similar to dirt deposition. There are a variety of technical reasons that this approach was selected:

- A pumped liquid aerosol is inherently more controlled than adding ASHRAE dust into the system.
- The time required to contaminate the system is significantly reduced.
- The ability to control the contamination process, lowers or eliminates the importance of measuring the dust contaminant levels pre and post coil to attempt to determine the coil fouling rate.
- The aerosol is “lab friendly” and does not have a propensity to migrate. (One major concern of the laboratory staff was the contamination of the lab with errant dust and fibers.)

The technical differences between “common coil contaminants” and ASHRAE dust or vinyl polymer are indeterminate. With this in mind, ASHRAE dust and the vinyl polymer affect the fouling in two major areas: particle size and the resistance to heat flow. We concentrated our theoretical design efforts on providing a contaminant that has a fairly small particle size.

We have evaluated the differences between ASHRAE filter dust and the polymer used in the experiment. The development of the aerosol fouling machine was focused on sealing holes. For this purpose, it is best to have a sampling of particles, but the predominately larger in size. We have modified the equipment and protocol to create smaller sized particles. In addition to physical testing of the equipment, we reviewed the basic research to modify the test contaminants to approximate the ASHRAE test dust profile. We used a number of techniques to modify the standard system in order to minimize the particle size: lowered the injection rate of material, increased the fluid temperature, reduced the air flow, and developed a specialized impacter to further reduce the particle size. In order to eliminate the largest particles, we lowered the air flow rate through the injection apparatus. Based on previous testing, this dropped the 30 micron size particles to under 50% penetration and the 20 micron size particles to under 75% penetration. The particles that are 10 micron and below stayed at over 90% penetration. The testing time required to foul the coil was significantly extended due to these modifications.

The initial testing was done with the air conditioning system running.. This lead to inaccuracies in calculating the energy balance. Increased moisture from the contamination process, coupled with minor contamination of the chilled mirror dew point sensor, created errors. Subsequent benchmark tests were completed with the air conditioner running at steady state conditions, but with the injector system off and clean sensors.

The polymer’s resistance to heat flow is slightly lower than the ASHRAE test material. Although the predominant heat transfer mechanism was not the thermal resistance of the heat exchanger, we have estimated the difference.

> “Standardized air cleaner dust (fine) is classified from dust in a desert area in Arizona. It is predominately silica and has a mass mean diameter of 7.7um.” ASHRAE 52.1

The acrylic polymer is suspended in a liquid to be atomized, and entrained in a heated air stream to evaporate the water. The resulting solid material has an estimated R-value of 2.3/inch. The ASHRAE dust has an estimated R-value of 2.54/inch. This results in the under-prediction of degradation by this heat transfer method. Studies by Trane have documented only small reductions in the overall efficiency of the coils due to coating the fins with material. This testing was done to evaluate the various options to protect coils from corrosion. The reduction in heat transfer due to the increased resistance of the coils was not measurable . Due to the low estimated heat loss from this heat transfer method, the differences are not material to the final outcome.

The injector system was field tested and calibrated in California before being shipped to the Laboratory. The duct-mounted injector system was attached to the return air side of the system (evaporator fouling test). Air flow was measured at the filter bank on the supply side of the system. Pressure measurements were monitored continuously using and Automated Performance Testing (APT) system. Results from the APT were used to determine when the injection equipment needed to be cleaned. The injector nozzle and pressure plate have a tendency to build up solid material. These areas were cleaned approximately every two hours of injection time. The test results show that the coil had a clean, even deposition of material across the entire coil face. The length of time necessary to foul the coil and the clean deposition are additional indications that the particle size of the contaminants was appropriate.

The condenser side of the system was configured with a mixing box connecting all three sides of the coil. The injection device was attached at the inlet of the mixing box. Even with free access to the entire coil, the contamination tended to build up more quickly on the front face of the coil. The coil fouling profile was similar to the evaporator: The air flow reduction was drastically accelerated at the end of the fouling process. Relatively low air flow reductions are observed even when the coil appears to be fouled. At a certain point in the fouling process the flow can no longer be maintained and the air flow reduction is accelerated.

Calculation of the TDF

The air flow profiles and fouling rates for the standard and high efficiency units are very similar. The most important remaining variable is the energy efficiency. The efficiency of the units over a range of fouling conditions is well documented. We established the long-term fouling profiles based on the historical data. These profiles were modified based on test results.

PEG created a mathematical model based on the coil fouling rate and applied this to the measured change in efficiency. The result was a year-by-year projection of coil fouling and efficiency for each system. The analysis was done on each set of coils.

The efficiency of the appliances for each year needed to take into account both the loss in performance of the system due to the evaporator and the condenser fouling. PEG used the evaporator system efficiency as the baseline and reduced the efficiency by the measured change in performance found by fouling the condenser coil. The evaporator fouling produced relatively little change in the refrigerant pressures. The condenser fouling did effect the refrigerant pressures.

The combined changes in efficiency based on reduction in air flow were matched with the projections of fouling. The results were then combined to create the TDF.

APPENDIX B DATA SUMMARY - COMMERCIAL DX AC

Data Summary

Test Results

Test results that served as the benchmarks have been recorded on disk. For each of the coils tested there were a different number of these tests taken. They required the calorimeter to be stabilized and the equipment running for at least 15 minutes. These benchmarks extended the time necessary to foul the coils. Interim tests were performed reasonably often and printed to examine the fouling and air flow effects. These results have been saved as text. Both data sets are included in Appendix C.

Summary of Manual Test Results

The manual data set was printed as the testing was in progress. These data points are valuable for examining the fouling profile. The data summary page provides the calculated values for many of the air conditional load components. This includes both latent and sensible capacity.   A sample copy of the data recording sheet is show in Figure B-1. The summary sheet is shown in Figure B2.

Table B-1 SAMPLE DATA COLLECTION SHEETS - COMMERCIAL AC

NRC CALORIMETER HEAT PUMP TEST FACILITY

REFRIGERANT PROPERTIES BY REFPROP

File: check4-DAl'	Scan No: 101	Project: STD-26	COIL FOULING
Temperatures (deg C)	Methanol: 0%	Batet 1998:12:15	Time: 11:25:29

Chan	Temp	Chan	Temp	Chan	Temp	Chan	Temp	Chan	Temp
1	34.90	21		41		61	19.03	81	
2	34.84	*22*		42		62	20.28	82	
3		23		43		63	19.42	83	
4	34.89	24		44		64	20.99	84	16.00
5	48.70	25		45		65		85	
6	46.42	26		46		66		86	37.02
7	37.52	*27*		47		67		87	
8	46.29	28		46		68		88	
9		29		49		69		89	83.64
10		30		5 a		70		90	
11		31		51		71		91	
12		32		52		72		92	20-92
13		33	26.59	53		73	48.76	93	20.25
14		34		54		74	35.38	94	10.45
15		35		55		75		95	11.29
16		36		56		76		96	
17		37		57		77		97	
18		38		58		*78*	34.80	98	34.04
19		39	23.58	59		79	4.017	99	25.20

Chan	Value	Chan	Value	Chan	Value	Chan	Value
100		125		150		175	
101	3.0559 In H20	126		151		176	
102	1.2040 In H20	127		152		177	
103	.05299 ln H20	128		153		178	
104	98.905 kPa	129		154		179	
105		130		155		180	
106		131		156		181	
107		132		157		182	1757.3 kPa
108		133		158		163	
109		134		159		184	656.91 kPa
110		135		160		185	
111	15.658 Deg C	136	.33500 in H20	161		186	
112	12.465 Deg C	137	0.01736 In H20	162		187	3.7337 Watts
113	-.00440 Volt5	138	.24076 In H20	163	6.9128 kg/min	188	
114		139	.12555 In H20	164		189	1966.5 kPa
115		140	4.8071 kwatts	165		190	
116		141	2,2953 kVAr	166		191	
117		142		167		192	
119		143		168		193	
119		144		169		194	
120		145	.12024 kVAr	170		195	
121		146	.29323 kwatts	171	8.7798 Deg C	196	
122		147	.8166 kwatt	172		197	
123		140	.69265 KVAR	173		198	

Table B-2 Test Results Summary Sheet - Commercial AC

Refrigerant(s): R22 100.0% Date: 1998:12:15 Time: 11.25:29,

			Enthalpy(kJ/kg)(Btu/hr)	
Comp Inlet Sat Temp (PI84):	8.8C	47.9*F	260.1	111
Comp Inlet Superheat (T84):	7.2*C	13.O F		
Compressor Outlet Sat Temp (PI99):	50.4'C	122.7 F	294.5	126
Compressor Outlet Superheat (T99)-	33.2'C	59.8 F		
Condenser Inlet Sat Temp (PI89):	50.4'C	122.7 F	294.5	126
Condenser Inlet superheat (T89):	33.20 C	59.8 F		
Cond Outlet **sat** 'Temp (PI82):	45.6 C	114.0 F	90.1	38
Cond Outlet Subcooling (T86):	8.50C	15.4 F		
Liquid at TXV. Sat Temp (Pl82):	45.6 C	114.0 F	90.8	39
Liquid at TXV, Subcooling (T7):	8.0 C	14.5 F		
Evap Suction, Sat Temp(Pl84):	8.8 C	47.9 F	260.1	111
Evap Suction, Superheat (T84);	7.2'C	13.0 F		
Outdoor Room Drybulb Temperature (T78):	34.810C	94.65'F		
Outdoor Room Wetbulb Temperature (TI71)	18.66'C	65.58,F		
Air on to Cond Temperature-e ([TI+T2+T4+T74/4)	35.01C	95.01-'F		
Static Press Difference Across 18 in Brandt:		1.204 In H20		
Pressure at Nozzle Throat (PlO4+PI37):	98.91kpa	397.49 In H20		
Actual Airflow rate into outdoor room coil:	1.9541m:'/5	4140.5 ft3/min		
Actual Airflow rate out outdoor room coil:	2.0349m:3/s	4311.6 ft3/Min		
Standard Airflow rate for 18 in Brandt:	1.8079M3/S	3830.7 ft3/min		
Indoor Room Drybulb Temperature (T201):	26.64'C	79.96OF		
Indoor Room Wetbulb Temperature (T211):	19.324C	66-77:F		
Wetbulb Temperature leaving unit (TI12):	13.28'C	55190,F		
Temperature leaving unit (from thermopile):	14.50,C	58.10'F		
Relative humidity:	50.93%			
Humidity Ratio:	0.01144			
Specific Heat of air/water in room	1.0223 @J/kg'C 4.280 Btu/Ib'F			
Static Press Difference Across 10 in Brandt:	3.056 In H20			
Effective Area:	0.27500 ft2			
Temperature at Nozzle Throat (T202):	15.490C	59.89'F		
Pressure at Nozzle Throat (PlO4+PIQ3):	98.89 kPa	-197.42 In H20		
Specific Volume of air in room (dry):	0.8861 M3/kg	14-193 ft:-'/lb		
Specific Volume of air at Brandt (dry):	0.8474 m:3/kg	13.574 ft3/lb		
Actual Airflow rate into indoor room coil:	0.8815 m3/s	1867.9 ft,'/min		
Actual Airflow rate out indoor room coil:	0.8449 m3/s	1790.2 ft3/min		
Standard Airflow rate:	0.8357 m3/s	@l 770.7 ft-"/min		
Enthalpy entering duct (per kg dry air):	55.960 kJ/kg	24.075 Btu/ibm		
Enthalpy leaving duct (per kg dry air):	38.038 kJ/kg	16.364 Btu/Ibm		
'('temp difference across indoor coil: (DeltaT)	-12.143'C	-21.858'F		
Heat gained through indoor duct:	0.245 kW			
Indoor unit n sensible capacity:	-12.376kW	-42257Btu/hi,		
Indoor unit sensible capacity (corrected);	-12.622kW	-43095Btu/hr		
Indoor unit latent capacity: -	-5.316kW	-18150Btu/hr		
Indoor unit total capacity (corrected):	-18.113kW-	-61847Btu/hr		
indoor capacity 'from refrigerant:	19-503IkW	65590Btu/hr		
Condenser capacity from refrigerant,	23-54kW	80378Btu/hr		
Compressor Power Requirement:	4.807 kW			
Indoor fan power: (added to Tot Cap for HB)	0.81@,-Kw			
I)Outdoor fan power requirement:	0.293			
Total power requirement:	0.000 kW			
Coil refrigerant air heat Balance	3. 027%			

APPENDIX C DATA SET - COMMERCIAL DX AC

Summary of Computer Test Results

The computer database will consist of the tests listed in Table C-1. These files contain three sets of data: thermocouple data, pressure and flow data, and calculational data. The calculations provide the engineering calculations necessary to evaluate the performance characteristics of the unit.

Table C-1 - Computer Test Results on Commercial DX AC

	High Efficiency		Standard Efficiency	
Number of Tests	Evaporator	Condenser	Evaporator	Condenser
1	Check 6	Check 30	Check b2	Check b8
2	Check 14	Check 56	Check b4	Check b10
3	Check 30	Check 63	Check b5	Check b17
4			Check b7	Check b22
5			Check b8	Check b28
6				

Each of the data files contain the 8-10 readings on every channel. This includes those that were used to calculate the average performance of the unit over that sampling period. The sample readings are typically 4 seconds apart . Figure C-1. shows a sample plot of the compressor power usage for test CHECK30.

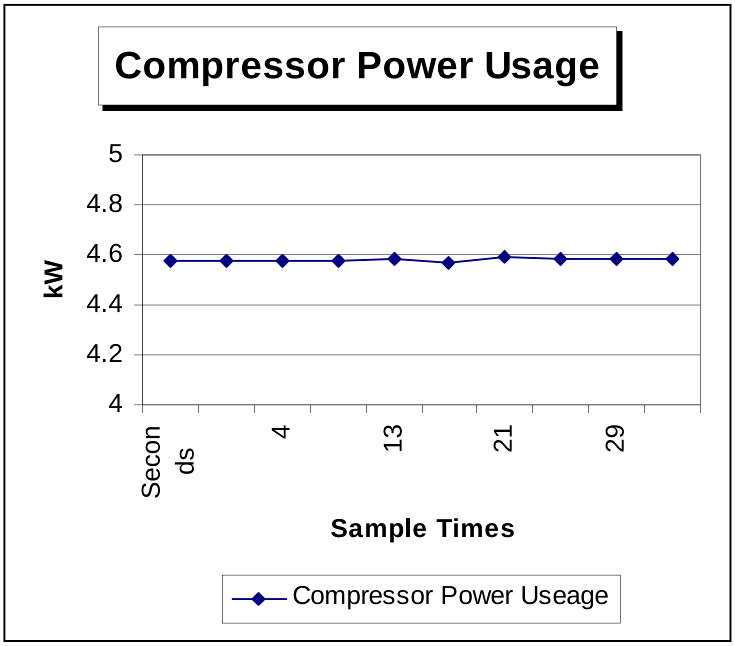


Figure C-1 Compressor Power Usage - Test # CHECK30

Each file is recorded in an EXCEL format. The files are placed in the appropriate test folders.

APPENDIX D EMS DATASET DOCUMENTATION

EMS Control Points and Energy Saving Mechanisms

Cooling

Table D-1 Cooling System Questions

Question #	Question	Database Field
	EMS controlled?	(45)
	Building or facility cooling system is electrically based?	(46)
1	Central system with air distribution	(47)
2	Central system with chilled water distribution	(48)
3	Rooftop DX units	(49)
4	Individual window ACs	(50)
5	Evaporative cooling	(51)
6	Thermal Energy Storage	(52)
7	District Chilled water	(53)
8	Other	(54)

Table D-2 Cooling Questions Database

5	45	46	47	48	49	50	51	52	53	54
PG&E/ SCE	**Cool: Controlled**	**Cool: Electric**	**Cool: Type1**	**Cool: Type2**	**Cool: Type3**	**Cool: Type4**	**Cool: Type5**	**Cool: Type6**	**Cool: Type7**	**Cool: Type8**
PG&E1.1	yes	yes	no	yes	yes	yes	yes	no	no	yes
PG&E1.2	yes	yes	no	yes	yes	yes	no	yes	no	no
PG&E2.1	yes	yes	no	no	yes	no	no	no	no	no
PG&E2.2	yes	yes	no	no	yes	yes	no	no	no	no
PG&E3.1	yes	yes	no	no	yes	yes	no	no	no	no
PG&E3.2	yes	yes	no	no	yes	no	yes	no	no	no
PG&E4.1	yes	yes	no	yes	no	no	no	no	no	yes
PG&E5	yes	yes	no	no	yes	no	no	no	no	yes
PG&E6.1	yes	yes	no	no	yes	no	no	no	no	no
PG&E6.2	yes	yes	yes	no	no	no	no	no	no	no
PG&E6.3	yes	yes	yes	no	no	no	no	no	no	no

PG&E7.1	yes	yes	no	no	yes	no	no	no	no	no
PG&E7.2	yes	yes	no	no	yes	no	no	no	no	no
PG&E7.3	yes	yes	no	no	yes	no	no	no	no	no
PG&E9.1	yes	yes	no	yes	no	no	no	no	no	no
PG&E9.2	yes	yes	no	no	yes	no	no	no	no	no
SCE1.1	yes	yes	no	no	yes	no	no	no	no	yes
SCE1.2	yes	yes	no	yes	no	no	no	no	no	yes
SCE4.1	yes	yes	no	no	yes	no	no	no	no	no
SCE4.2	yes	yes	no	no	yes	no	no	no	no	no
SCE4.3	yes	yes	no	no	yes	no	no	no	no	no
SCE4.4	yes	yes	no	no	yes	no	no	no	no	no
SCE4.5	yes	yes	no	no	yes	no	no	no	no	no
SCE4.6	yes	yes	no	no	yes	no	no	no	no	no
SCE4.7	yes	yes	no	no	no	no	no	no	no	yes
SCE8	yes	yes	no	no	yes	no	no	no	no	no
SCE6.1	yes	yes	no	no	yes	no	no	no	no	no
SCE6.2	yes	yes	no	no	yes	no	no	no	no	no
SCE5.1	yes	yes	no	no	yes	no	no	no	no	yes
SCE5.2	yes	yes	no	no	yes	no	no	no	no	yes
SCE5.3	yes	yes	no	no	yes	no	no	no	no	yes
SCE5.4	yes	yes	no	no	yes	no	no	no	no	yes
SCE2.01	yes	yes	no	no	yes	no	no	no	no	no
SCE2.02	yes	yes	no	no	yes	no	no	no	no	no
SCE2.03	yes	yes	no	no	yes	no	no	no	no	no
SCE2.04	yes	yes	no	no	yes	no	no	no	no	no
SCE2.05	yes	yes	no	no	yes	no	no	no	no	no
SCE2.06	yes	yes	no	no	yes	no	no	no	no	no
SCE2.07	yes	yes	no	no	yes	no	no	no	no	no
SCE2.08	yes	yes	no	no	yes	no	no	no	no	no
SCE2.09	yes	yes	no	no	yes	no	no	no	no	no
SCE2.10	yes	yes	no	no	yes	no	no	no	no	no
SCE2.11	yes	yes	no	no	yes	no	no	no	no	no
SCE2.12	yes	yes	no	no	yes	no	no	no	no	no
SCE2.13	yes	yes	no	no	yes	no	no	no	no	no
SCE7.1	yes	yes	no	no	yes	no	no	no	no	yes
SCE7.2	yes	yes	no	no	yes	no	no	no	no	yes
SCE7.3	yes	yes	no	no	yes	no	no	no	no	yes
SCE7.4	yes	yes	no	no	yes	no	no	no	no	yes
SCE7.5	yes	yes	no	no	yes	no	no	no	no	yes
SCE9	yes	yes	no	no	yes	no	no	no	no	yes

Heating, Pools, DHW, Ventilation, Lighting, & Other

Table D-3 Heating, etc. Questions

Database Field	Question	Key
(55)	Heating EMS controlled?	
(56)	Building or facility heating system is electrically based?	
(57)	Heating system type:	1 = CAV 2 = VAV 3 = Circ hot water 4 = Individual heaters 5 = Heat Pumps 6 = Other
(58)	Heating fuel type	1 = Electric Resistance 2 = Heat Pump 3 = Gas / Oil 4 = Steam ~~5 = Not heated~~ 6 = Other
(59)	Does this facility have a swimming pool or spa?	
(60)	Pool/spa heating fuel type:	1 = Electric Resistance 2 = Heat Pump 3 = Gas / Oil 4 = Steam ~~5 = Not heated~~ 6 = Other
(61)	Pool/Spa EMS controlled?	
(62)	DHW heating fuel type:	1 = Electric Resistance 2 = Heat Pump 3 = Gas / Oil 4 = Steam 5 = No DHW 6 = Other
(63)	DHW EMS controlled	
(64)	Ventilation type:	1 = Forced fan 2 = With heat-cool system 4 = Not fan based 5 = Other
(65)	Ventilation EMS controlled?	
(66)	Lighting EMS controlled?	
(67)	Other EMS controlled?	

Table D-4 Heating & Other Database

5	55	56	57	58	59	60	61	62	63	64	65	66	67
PG&E /SCE	**Heat: EMS**	**Heat: Elect?**	**Heat: Type**	**Heat: Fuel**	**Pool?**	**Pool: Fuel**	**Pool: EMS?**	**DHW: Fuel**	**DHW: EMS?**	**Vent: Type**	**Vent: EMS?**	**Light: EMS?**	**Other: EMS?**
PG&E1.1	yes	no	3	3	yes	3	no	3	yes	1	yes	yes	no
PG&E1.2	yes	no	3	3	no		no	1	no	1	yes	part	yes
PG&E2.1	yes	no	2	3	no	0	no	3	yes	1	yes	part	no
PG&E2.2	yes	no	3	3	no	0	no	3	yes	1	yes	yes	no
PG&E3.1	yes	no	1	3	no	0	no	3	no	1	yes	no	no
PG&E3.2	yes	no	1	3	no	0	no	3	no	1	yes	no	no
PG&E4.1	yes	yes	3	3	no	0	no	1	no	1	yes	yes	no
PG&E5	yes	yes	1	2	no	0	no	3	no	1	yes	no	no
PG&E6.1	yes	no	1	3	no	0	no	3	no	1	yes	part	no
PG&E6.2	yes	no	3	3	no	0	no	3	no	1	yes	part	no
PG&E6.3	yes	no	3	3	no	0	no	3	no	1	yes	part	no
PG&E7.1	yes	no	1	3	no	0	no	3	no	1	yes	yes	yes
PG&E7.2	yes	no	1	3	no	0	no	3	no	1	yes	yes	yes
PG&E7.3	yes	no	1	3	no	0	no	3	no	1	yes	yes	yes
PG&E9.1	yes	no	3	3	no	0	no	3	yes	1	yes	part	no
PG&E9.2	yes	no	3	3	no	0	no	3	no	1	yes	part	no
SCE1.1	yes	part	1	3	no	0	no	3	no	1	yes	no	no
SCE1.1	yes	part	3	2	no	0	no	3	part	1	yes	part	no
SCE4.1	no	yes	2	1	yes	0	no	?	no	1	yes	no	no
SCE4.2	no	yes	2	1	yes	0	no	?	no	1	yes	no	no
SCE4.3	no	yes	2	1	yes	0	no	?	no	1	yes	no	no
SCE4.4	no	yes	2	1	yes	0	no	?	no	1	yes	no	no
SCE4.5	no	yes	2	1	yes	0	no	?	no	1	yes	no	no
SCE4.6	part	no	2	3	no	0	no	3	no	1	yes	no	no
SCE4.7	yes	yes	5	6	no	0	no	3	no	1	yes	yes	no
SCE8	yes	no	2	3	no	0	no	3	no	1	yes	no	no
SCE6.1	yes	no	1	3	yes	0	no	3	yes	1	yes	yes	yes
SCE6.2	yes	no	1	3	yes	0	no	3	yes	1	yes	yes	yes
SCE5.1	yes	yes	1	3	no	0	no	3	no	1	yes	part	no
SCE5.2	yes	yes	1	3	no	0	no	3	no	1	yes	part	no
SCE5.3	yes	yes	1	3	no	0	no	3	no	1	yes	part	no
SCE5.4	yes	yes	1	3	no	0	no	3	no	1	yes	part	no
SCE2.01	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.02	yes	yes	1	1	no	0	no	1	no	1	yes	yes	yes
SCE2.03	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes

SCE2.04	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.05	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.06	yes	yes	1	1	no	0	no	1	no	1	yes	yes	yes
SCE2.07	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.08	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.09	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.10	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.11	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.12	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE2.13	yes	no	1	3	no	0	no	1	no	1	yes	yes	yes
SCE7.1	yes	yes	1	2	no	0	no	3	no	1	yes	no	no
SCE7.2	yes	yes	1	2	no	0	no	3	no	1	yes	no	no
SCE7.3	yes	yes	1	2	no	0	no	3	no	1	yes	no	no
SCE7.4	yes	yes	1	2	no	0	no	3	no	1	yes	no	no
SCE7.5	yes	yes	1	2	no	0	no	3	no	1	yes	no	no
SCE9	yes	yes	5	2	no	0	no	1	no	1	yes	no	no

Equipment Scheduling and Control

Energy Savings Mechanism EPRI lists the following uses of an EMCS to save energy. (EPRI 1993). This list formed the basis of questions 74-93 of the site participation survey.

Equipment Scheduling and Control

- Temperature Setback / Forward Thermostat
- Schedules On / Off controls — turn off HVAC equipment and lights during unoccupied times
- Occupant Overrides — override scheduled off times for intermittent after-hours occupancy
- Tenant Billing — billing of tenants for system override
- Optimum Start / Stop — optimize the time a building is conditioned
- Night Purge — using night air for cooling
- Economizer Control — using outside air for cooling when possible
- Enthalpy Control — use outside air for cooling based on total heat content, sensible and latent
- Indoor Air Quality Control — use minimum outside air and maintain indoor air quality by active control

Utility Rate Structure Response

- Load Shedding — shed loads at a preset demand limit
- Load Cycling — cycling of shed loads to maintain comfort
- Temperature Scheduling — reset temperature during peak demand periods
- Generation — generate electricity on-site to reduce utility demand
- Dual Fuel — switching to alternative fuels to reduce demand
- Thermal Storage — production and storage of coolness at night for daytime use
- Cogeneration — capture and use of heat from electric generation
- Chiller Heat Capture — service hot water heating from rejected chiller heat
- Closed-Loop Water Source Heat Pumps — transfer of heat from interior to exterior zones

Coordinating Central HVAC Equipment

- Duty Cycling — sequencing loads to limit demand
- Sequencing Boilers / Chillers — using the minimum number of modules required
- Resetting Chiller / Boiler Temperatures — resetting delivery temperatures to minimum required
- Cooling Tower Control — minimize energy use and prevent freeze up
- Free Cooling — using a heat exchanger rather than chiller for cooling at low ambient temperatures

Controlling Lights

- Schedule Lights On and Off — timer / scheduler for lighting
- Override Time-out — automatic end to override control
- Occupancy Sensing — lights controlled by sensing occupancy
- Illumination Level Control — daylighting and dimming of artificial lighting

Table D-5 Equipment Scheduling and Control Questions

Question #	Question	Database Field
1)	Space Temperature Control	(68)
2)	Temperature Setback / Forward Thermostat	(69)
3)	Schedules On / Off controls — turn off HVAC equipment during unoccupied times	(70)
4)	Optimum Start / Stop — optimize the time a building is conditioned	(71)
5)	Night Purge — using night air for cooling	(72)
6)	Economizer Control — using outside air for cooling when possible	(73)
7)	Indoor Air Quality Control — use minimum outside air and maintain indoor air quality by active control	(74)

Table D-6 Equipment Scheduling and Control Database

5	68	69	70	71	72	73	74
PG&E/SCE	**Equip 1**	**Equip 2**	**Equip 3**	**Equip 4**	**Equip 5**	**Equip 6**	**Equip 7**
PG&E1.1	yes	yes	yes	yes	no	yes	no
PG&E1.2	no	no	yes	yes	no	no	no
PG&E2.1	yes	no	yes	no	yes	yes	no
PG&E2.2	no	no	yes	no	no	no	no
PG&E3.1	yes	yes	yes	no	no	no	no
PG&E3.2	yes	yes	yes	no	no	no	no
PG&E4.1	no	yes	yes	yes	yes	yes	no
PG&E5	yes	no	yes	yes	no	no	no
PG&E6.1	yes	yes	yes	yes	yes	yes	no
PG&E6.2	yes	yes	yes	yes	yes	yes	no
PG&E6.3	yes	yes	yes	yes	yes	yes	no
PG&E7.1	no	no	yes	yes	no	no	no
PG&E7.2	no	no	yes	yes	no	no	no
PG&E7.3	no	no	yes	yes	no	no	no
PG&E9.1	yes	yes	yes	no	no	yes	no
PG&E9.2	yes	no	yes	no	no	no	no
SCE1.1	yes	yes	no	yes	no	no	no
SCE1.1	yes	yes	no	yes	no	no	no
SCE4.1	no	yes	yes	yes	yes	yes	no
SCE4.2	no	yes	yes	yes	yes	yes	no
SCE4.3	no	yes	yes	yes	yes	yes	no
SCE4.4	no	yes	yes	yes	yes	yes	no

SCE4.5	no	yes	yes	yes	yes	yes	no
SCE4.6	no	yes	yes	yes	yes	yes	no
SCE4.7	yes	yes	yes	yes	no	no	yes
SCE8	yes	yes	yes	yes	no	yes	no
SCE6.1	yes	yes	yes	no	no	no	no
SCE6.2	yes	yes	yes	no	no	no	no
SCE5.1	yes	no	yes	yes	no	yes	no
SCE5.2	yes	no	yes	yes	no	yes	no
SCE5.3	yes	no	yes	yes	no	yes	no
SCE5.4	yes	no	yes	yes	no	yes	no
SCE2.01	no	no	yes	yes	no	no	no
SCE2.02	no	no	yes	yes	no	no	no
SCE2.03	no	no	yes	yes	no	no	no
SCE2.04	no	no	yes	yes	no	no	no
SCE2.05	no	no	yes	yes	no	no	no
SCE2.06	no	no	yes	yes	no	no	no
SCE2.07	no	no	yes	yes	no	no	no
SCE2.08	no	no	yes	yes	no	no	no
SCE2.09	no	no	yes	yes	no	no	no
SCE2.10	no	no	yes	yes	no	no	no
SCE2.11	no	no	yes	yes	no	no	no
SCE2.12	no	no	yes	yes	no	no	no
SCE2.13	no	no	yes	yes	no	no	no
SCE7.1	no	no	yes	no	no	no	no
SCE7.2	no	no	yes	no	no	no	no
SCE7.3	no	no	yes	no	no	no	no
SCE7.4	no	no	yes	no	no	no	no
SCE7.5	no	no	yes	no	no	no	no
SCE9	no	no	no	no	no	no	no

Utility Rate Structure Response

The EMS system generally does not reduce demand. None of the resource value claimed by the utilities was for demand reduction. The site did not report any demand limiting mechanisms.

Table D-7 Utility Rate Structure Response Questions

Question #	Question	Database Field
1)	Load Shedding — shed loads at a preset demand limit	(75)
2)	Temperature Scheduling — reset temperature during peak demand periods	(76)
3)	Generation — generate electricity on-site to reduce utility demand	(77)
4)	Dual Fuel — switching to alternative fuels to reduce demand	(78)
5)	Thermal Storage — production and storage of coolness at night by daytime use	(79)
6)	Cogeneration — capture and use of heat from electric generation	(80)
7)	Chiller Heat Capture — service hot water heating from rejected chiller heat	(81)
8)	Closed-Loop Water Source Heat Pumps — transfer of heat from interior to exterior zones	(82)

Table D-8 Utility Rate Structure Response Database

5	75	76	77	78	79	80	81	82
PG&E /SCE	**UtilRt 1**	**UtilRt 2**	**UtilRt 3**	**UtilRt 4**	**UtilRt 5**	**UtilRt 6**	**UtilRt 7**	**UtilRt 8**
PG&E1.1	no	no	no	no	no	no	no	no
PG&E1.2	no	no	no	no	yes	no	no	no
PG&E2.1	no	no	no	no	no	no	no	no
PG&E2.2	no	no	no	no	no	no	no	no
PG&E3.1	no	no	no	no	no	no	no	no
PG&E3.2	no	no	no	no	no	no	no	no
PG&E4.1	no	no	no	no	no	no	no	no
PG&E5	no	no	no	no	no	no	no	no
PG&E6.1	no	no	no	no	no	no	no	no
PG&E6.2	no	no	no	no	no	no	no	no
PG&E6.3	no	no	no	no	no	no	no	no
PG&E7.1	no	no	no	no	no	no	no	no
PG&E7.2	no	no	no	no	no	no	no	no
PG&E7.3	no	no	no	no	no	no	no	no
PG&E9.1	no	no	no	no	no	no	no	no

PG&E9.2	no	no	no	no	no	no	no	no
SCE1.1	no	no	no	no	no	no	no	no
SCE1.1	no	no	no	no	no	no	no	no
SCE4.1	no	no	no	no	no	no	no	no
SCE4.2	no	no	no	no	no	no	no	no
SCE4.3	no	no	no	no	no	no	no	no
SCE4.4	no	no	no	no	no	no	no	no
SCE4.5	no	no	no	no	no	no	no	no
SCE4.6	no	no	no	no	no	no	no	no
SCE4.7	no	no	no	no	no	no	no	yes
SCE8	no	no	no	no	no	no	no	no
SCE6.1	no	no	no	no	no	no`	no	no
SCE6.2	no	no	no	no	no	no`	no	no
SCE5.1	no	no	no	no	no	no	no	no
SCE5.2	no	no	no	no	no	no	no	no
SCE5.3	no	no	no	no	no	no	no	no
SCE5.4	no	no	no	no	no	no	no	no
SCE2.01	no	no	no	no	no	no	no	no
SCE2.02	no	no	no	no	no	no	no	no
SCE2.03	no	no	no	no	no	no	no	no
SCE2.04	no	no	no	no	no	no	no	no
SCE2.05	no	no	no	no	no	no	no	no
SCE2.06	no	no	no	no	no	no	no	no
SCE2.07	no	no	no	no	no	no	no	no
SCE2.08	no	no	no	no	no	no	no	no
SCE2.09	no	no	no	no	no	no	no	no
SCE2.10	no	no	no	no	no	no	no	no
SCE2.11	no	no	no	no	no	no	no	no
SCE2.12	no	no	no	no	no	no	no	no
SCE2.13	no	no	no	no	no	no	no	no
SCE7.1	no	no	no	no	no	no	no	no
SCE7.2	no	no	no	no	no	no	no	no
SCE7.3	no	no	no	no	no	no	no	no
SCE7.4	no	no	no	no	no	no	no	no
SCE7.5	no	no	no	no	no	no	no	no
SCE9	no	no	no	no	no	no	no	no

Coordinating Central HVAC Equipment & Controlling Lights

Table D-9 Coordinating Central HVAC Equipment Questions

Question #	Question	Database Field
1)	Duty Cycling — sequencing loads to limit demand	(83)
2)	Sequencing Boilers / Chillers — using the minimum number of modules required	(84)
3)	Resetting Chiller / Boiler Temperatures — resetting delivery temperatures to minimum required	(85)
4)	Cooling Tower Control — minimize energy use and prevent freeze up	(86)
5)	Free Cooling — using a heat exchanger rather than chiller for cooling at low ambient	(87)

Table D-10 Controlling Lights Questions

Question #	Question	Database Field
1	Schedule Lights On and Off — timer / scheduler for lighting	(88)
2)	Illumination Level Control — daylighting and dimming of artificial lighting	(89)

Table D-12 Coordinating Central HVAC Equipment & Lighting Database

5	83	84	85	86	87	88	89
PG&E/SCE	**Coord 1**	**Coord 2**	**Coord 3**	**Coord 4**	**Coord 5**	**Lights 1**	**Lights 2**
PG&E1.1	no	no	no	no	no	yes	no
PG&E1.2	no	no	no	no	no	yes	no
PG&E2.1	no	no	no	no	no	yes	no
PG&E2.2	no	no	no	no	no	yes	no
PG&E3.1	no	no	no	no	no	no	no
PG&E3.2	no	no	no	no	no	yes	no
PG&E4.1	no	no	yes	yes	no	yes	no
PG&E5	no	no	no	no	no	no	no
PG&E6.1	no	no	no	no	no	yes	no
PG&E6.2	no	no	no	yes	no	yes	no
PG&E6.3	no	no	no	yes	no	yes	no
PG&E7.1	no	no	no	no	no	yes	no
PG&E7.2	no	no	no	no	no	yes	no

PG&E7.3	no	no	no	no	no	yes	no
PG&E9.1	no	no	yes	yes	no	yes	no
PG&E9.2	no	no	no	no	no	yes	no
SCE1.1	no	no	no	no	no	no	no
SCE1.1	no	no	yes	no	no	yes	no
SCE4.1	no	no	no	no	no	no	no
SCE4.2	no	no	no	no	no	no	no
SCE4.3	no	no	no	no	no	no	no
SCE4.4	no	no	no	no	no	no	no
SCE4.5	no	no	no	no	no	no	no
SCE4.6	no	no	no	no	no	no	no
SCE4.7	no	no	yes	yes	no	yes	no
SCE8	no	no	no	no	no	no	no
SCE6.1	no	no	no	no	no	yes	no
SCE6.2	no	no	no	no	no	yes	no
SCE5.1	no	no	no	no	no	yes	no
SCE5.2	no	no	no	no	no	yes	no
SCE5.3	no	no	no	no	no	yes	no
SCE5.4	no	no	no	no	no	yes	no
SCE2.01	no	no	no	no	no	yes	yes
SCE2.02	no	no	no	no	no	yes	yes
SCE2.03	no	no	no	no	no	yes	yes
SCE2.04	no	no	no	no	no	yes	yes
SCE2.05	no	no	no	no	no	yes	yes
SCE2.06	no	no	no	no	no	yes	yes
SCE2.07	no	no	no	no	no	yes	yes
SCE2.08	no	no	no	no	no	yes	yes
SCE2.09	no	no	no	no	no	yes	yes
SCE2.10	no	no	no	no	no	yes	yes
SCE2.11	no	no	no	no	no	yes	yes
SCE2.12	no	no	no	no	no	yes	yes
SCE2.13	no	no	no	no	no	yes	yes
SCE7.1	no	no	no	no	no	no	no
SCE7.2	no	no	no	no	no	no	no
SCE7.3	no	no	no	no	no	no	no
SCE7.4	no	no	no	no	no	no	no
SCE7.5	no	no	no	no	no	no	no
SCE9	no	no	no	no	no	no	no

On-site Surveys

PG&E/SCE	Site identification number
On-site Date	Date of on-site survey
On-site Surveyor	On-sire surveyor
EMS_active	Is the EMS operational and active
Mnfg	Manufacturer of main unit
Model	Main unit model number
CPU_location	Location of main control unit
EMS_Op#1, 2, & 3	Observations that confirm that the EMS is operating
#Meters	Number of electric meters controlled by the EMS

On-site Surveys A total of 45 on-site surveys were conducted. The database of sites submitted for analysis had 51 sites. Of these, 40 had on-site surveys. The analysis was able to utilize 35 sites with on-site surveys and 5 without.

Analyzed Sites without On-site Surveys

In the case of two participating organizations, a sampling technique was used rather than conducting on-site surveys at every site.

One large bank had numerous branch banks (SCE 2) which all received exactly the same EMSs, about 50 total. Twelve of these were installed under SCE's rebate program. The database included thirteen site — nine rebated sites and four non-rebated sites. A total of 8 on-site surveys were performed on branches of this bank. Not all sites received on-sites for two reasons: 1) some were too busy or had scheduling conflicts; and 2) we wanted to reasonably limit the inconvenience and time required of the bank personnel and operations. Ten SCE 2 branch bank sites were used in the calculation of the TDF. Of these 10, six had on-site and four did not; eight were rebated and two were not.

Since all eight on-sites confirmed that the same EMS was operating in the same fashion, the probability that additional on-site would discover anything else was considered vanishingly small. Therefore, it was decided to qualify all sites by sampling.

A similar sampling technique was used with SCE 5, where three out of four analyzed sites had on-site surveys.

Table D-13 On-site Survey Database

PG&E/SCE	On-site Date	On-site Surveyor	EMS_active	Mnfg	Model	CPU_location	EMS_ Op#1	EMS_ Op#2	EMS_ Op#3	#Meters
PG&E1.1	9/11/98	Downey, T	yes	Trane	EMT1000AAC0210014	Boiler Rm	yes	na	na	1
PG&E1.2	9/11/98	Downey, T	yes	Trane	EMT1000AAC0210014	Boiler Rm	yes	na	na	1
PG&E2.1	11/5/98	Peterson, G.	yes	Barbar Coleman	na	Maintenance Bldg	yes	na	na	??
PG&E2.2	11/5/98	Peterson, G.	yes	Barbar Coleman	na	Maintenance Bldg	yes	na	na	??
PG&E3.1	11/24/98	Peterson, G.	yes	Kelar	na	Yard front office	yes	na	na	1
PG&E3.2	11/24/98	Peterson, G.	yes	Honeywell	na	Closet under stairway	yes	na	na	1
PG&E4	10/2/98	Peterson, G.	yes	Barrington Sys	LanStar	6th fl mech rm	yes	yes	yes	3
PG&E5	1/21/99	Peterson, G.	yes	Honeywell	Building Mngt	2nd fl electrical room	yes	yes	yes	1
PG&E6.1	12/29/98	Peterson, G.	yes	Johnson Controls	x	1st fl electrical room	yes	yes	na	1
PG&E6.2	12/29/98	Peterson, G.	yes	Johnson Controls	x	2nd fl mech room	yes	yes	yes	1
PG&E6.3	12/29/98	Peterson, G.	yes	Johnson Controls	x	2nd fl mech room	yes	yes	na	1
PG&E7.1	10/5/98	Peterson, G.	yes	Robertshaw	DSM35	Hallway Elect closet	yes	yes	na	1
PG&E7.2	10/5/98	Peterson, G.	yes	Robertshaw	DSM35	Hallway Elect closet	yes	yes	na	1
PG&E7.3	10/5/98	Peterson, G.	yes	Robertshaw	DSM35	Hallway Elect closet	yes	yes	na	1
PG&E9.1	11/24/98	Peterson, G.	yes	Landis & Gyr	System 600	HVAC yard enclosure	yes	yes	yes	1
PG&E9.2	11/24/98	Peterson, G.	yes	Landis & Gyr	System 601	Roof	yes	yes	na	1
SCE1.1	11/10/98	Peterson, G.	yes	Landis & Gyr	System 600	Telephone Equip Rm	no	na	na	1
SCE1.2	11/10/98	Peterson, G.	yes	Landis & Gyr	System 600	Library Rm	yes	yes	na	1
SCE4.1	11/9/95	Daniel, D	yes	Robertshaw	#2604	1st fl elect rm	yes	na	na	1
SCE4.2	11/9/95	Daniel, D	yes	Robertshaw	#2604	1st fl elect rm	yes	na	na	1
SCE4.3	11/9/95	Daniel, D	yes	Robertshaw	#2604	1st fl elect rm	yes	na	na	1

SCE4.4	11/9/95	Daniel, D	yes	Robertshaw	#2604	1st fl elect rm	yes	na	na	1
SCE4.5	11/9/95	Daniel, D	yes	Robertshaw	#2604	1st fl elect rm	yes	na	na	1
SCE4.6	11/9/95	Daniel, D	yes	Landis & Gyr	System 600	2nd fl elect rm	yes	na	na	1
SCE4.7	11/12/95	Daniel, D	yes	Landis & Gyr	System 600	2nd fl elect rm	yes	yes	na	4
SCE8	11/10/98	Peterson, G.	yes	Carrier	Prog controller	Equipment rm	yes	yes	na	1
SCE6.1	12/13/98	Peterson, G.	yes	So Ca Enrgy Sys	na	Rear of store	yes	na	na	1
SCE6.2	12/13/98	Peterson, G.	yes	Integ Ener Contrls	na	Manager's office	yes	yes	yes	1
SCE5.1	11/9/98	Sims, M	yes	Honeywell	#7505	Power rm	yes	na	na	1
SCE5.3	2/9/99	Peterson, G.	yes	Honeywell	Bldg Mngt	Power rm	yes	yes	na	1
SCE5.4	2/9/99	Peterson, G.	yes	Honeywell	Bldg Mngt	Interior closet	yes	yes	na	1
SCE2.01	11/9/98	Peterson, G.	yes	Methodyne	ATI	Utilities rm	yes	na	na	1
SCE2.02	11/10/98	Peterson, G.	yes	Methodyne	ATI	Utilities rm	yes	na	na	1
SCE2.06	11/9/98	Peterson, G.	yes	Methodyne	ATI	Gnd fl elect rm	yes	na	na	1
SCE2.07	12/14/98	Peterson, G.	yes	Methodyne	ATI	Outside utilities rm	yes	yes	na	1
SCE2.08	12/14/98	Peterson, G.	yes	Methodyne	ATI	Telephone rm	yes	yes	na	1
SCE2.09	12/14/98	Peterson, G.	yes	Methodyne	ATI	Storage rm	yes	yes	na	1
SCE2.12	12/17/98	Daniel, D	yes	Methodyne	ATI	1st fl supply rm	yes	yes	yes	1
SCE2.13	12/17/98	Daniel, D	yes	Methodyne	ATI	1st fl break rm	yes	yes	yes	1
SCE7.1	11/9/98	Peterson, G.	yes	Robertshaw	DSM35	Custodial storage	yes	na	na	1
SCE7.2	11/9/98	Peterson, G.	yes	Robertshaw	DSM35	Offices	yes	na	na	1
SCE7.3	11/9/98	Peterson, G.	yes	Robertshaw	DSM35	Offices	yes	na	na	1
SCE7.4	11/9/98	Peterson, G.	yes	Robertshaw	DSM35	Offices	yes	na	na	1
SCE7.5	11/9/98	Peterson, G.	yes	Robertshaw	DSM35	Offices	yes	na	na	1
SCE9	10/10/98	Peterson, G.	yes	Honeywell	#7505	Power rm	yes	na	na	1

Operating Personnel Interview

A survey of experiences and opinions consisting of nine questions was taken of personnel with responsibilities for EMS operation. The level of responsibilities varied from direct and full responsibility to a distant supervisory role. The purpose of the survey was to gather supplemental information that might be helpful in explaining the obtained results; it was not designed to be a statistically rigorous survey.

Table D-14 Operating Personnel Interview Questions

Survey Question #	Survey Question	Database Index
1)	Lowering energy costs is an important part of my job responsibilities	(91)
2)	I was adequately trained to understand the operation and capabilities of the EMS.	(92)
3)	Over time I learned how to use the EMS to best advantage. The EMS is now working much better than it did initially	(93)
4)	Over time, different people have run the EMS and its operation has changed considerably.	(94)
5)	We have increased our usage of the EMS over time; it now controls more of the facility.	(95)
6)	Reducing complaints from occupants is an important part of my job responsibilities.	(96)
7)	The EMS is operating well.	(97)
8)	The EMS makes controlling energy costs easier	(98)
9)	The EMS makes operating the buildings HVAC system easier.	(99)

Respondents were given a choice of six responses to each questions, three levels of agreement and three of disagreement. An average response was also calculated by assigning a value of 1 for strongly disagree to 6 for strongly agree, Table D-15.

Table D-15 Index Values of Interview Responses

Response	Index Value	Response	Index Value
strongly agree	6	disagree somewhat	3
agree	5	disagree	2
agree somewhat	4	strongly disagree	1

Table D-16 Operating Personnel Interview Results

PG&E/ SCE	Interview _1	Interview _2	Interview _3	Interview _4	Interview _5	Interview _6	Interview _7	Interview _8	Interview _9
PG&E1.1	agree	agree	agree somewhat	disagree	agree somewhat	agree	agree	agree somewhat	agree
PG&E2	strongly agree	agree	agree	disagree	agree	strongly agree	agree	agree	strongly agree
PG&E2	strongly agree	strongly agree	agree	disagree	agree	strongly agree	agree	agree	strongly agree
PG&E3	agree	disagree	agree somewhat	strongly agree	disagree	strongly agree	agree	agree	disagree
PG&E4	strongly agree	strongly agree	strongly agree	strongly agree	strongly agree	strongly agree	strongly agree	agree	strongly agree
PG&E5	agree somewhat	agree	disagree	disagree	disagree	strongly agree	agree	agree	disagree
PG&E6	agree	agree	agree	disagree	disagree	strongly agree	agree	agree	agree
PG&E6	strongly agree	strongly agree	agree	strongly agree	disagree somewhat	strongly agree	agree	agree	agree
PG&E7	agree somewhat	disagree somewhat	agree somewhat	agree somewhat	agree somewhat	strongly agree	agree	agree somewhat	agree
PG&E9	agree	agree	agree somewhat	disagree	strongly disagree	strongly agree	agree	agree	agree
SCE1	agree	agree	strongly agree	strongly disagree	strongly disagree	strongly agree	agree somewhat	disagree somewhat	agree
SCE2.06	strongly agree	strongly agree	disagree	strongly disagree	agree	strongly agree	strongly agree	strongly agree	agree
SCE4.1	agree	disagree	agree somewhat	disagree	disagree somewhat	agree somewhat	agree somewhat	disagree somewhat	agree somewhat
SCE4.7	agree	agree somewhat	disagree	agree somewhat	strongly agree	strongly agree	strongly agree	agree	strongly agree
SCE5.1	strongly agree	strongly agree	strongly agree	strongly disagree	strongly agree	strongly agree	strongly agree	strongly agree	strongly agree
SCE6.1	agree	strongly agree	agree somewhat	agree somewhat	disagree	strongly agree	agree	strongly agree	strongly agree
SCE7.1	agree	agree	agree somewhat	disagree	disagree	agree	agree	agree	agree
SCE8	strongly agree	strongly agree	strongly agree	strongly disagree	strongly disagree	strongly agree	strongly agree	strongly agree	strongly agree
SCE9	strongly agree	agree	agree	agree	disagree	agree	strongly agree	strongly agree	strongly agree

All respondents reported that lowering energy costs was an important part of their job responsibilities, Figure D-1. The mean of the responses was 5.3.

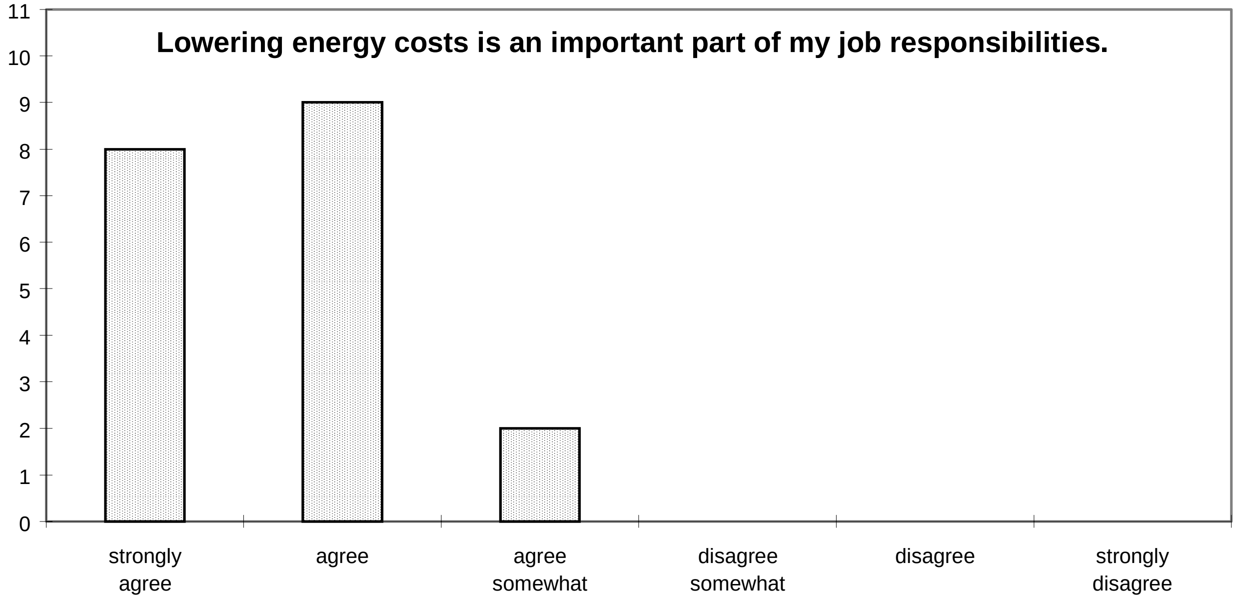


Figure D-1: Lowering Energy Costs

Most respondents agreed that they had been adequately trained in the EMS operation, but the degree of training varied considerably, Figure D-2. At one extreme, the operator of a facility that had been sold during the S&L bankruptcies had received no training whatsoever. He found the EMS dysfunctional and taught himself how to use it. At the other extreme, some respondents were the professionals who installed and maintained the EMS equipment as their full-time jobs. The mean of the responses was 4.9.

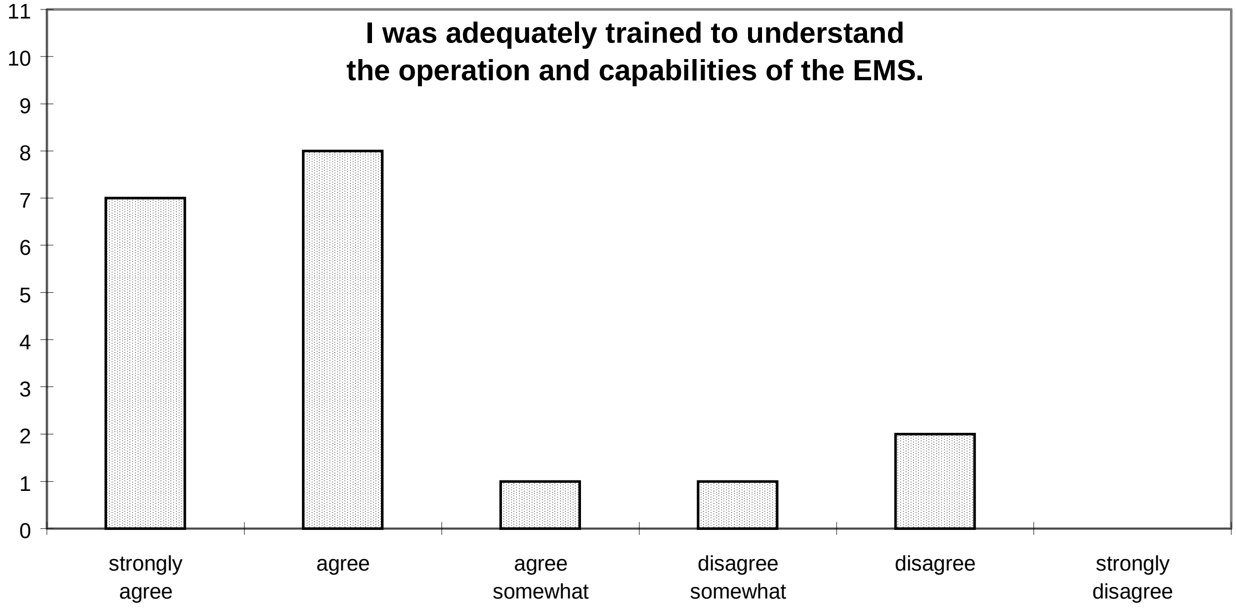


Figure D-2: Adequate training

Most respondents agreed that EMS operation had improved over time, Figure D-3. Those who disagreed said that the EMS operation had not changed. The mean of the responses was 4.4.

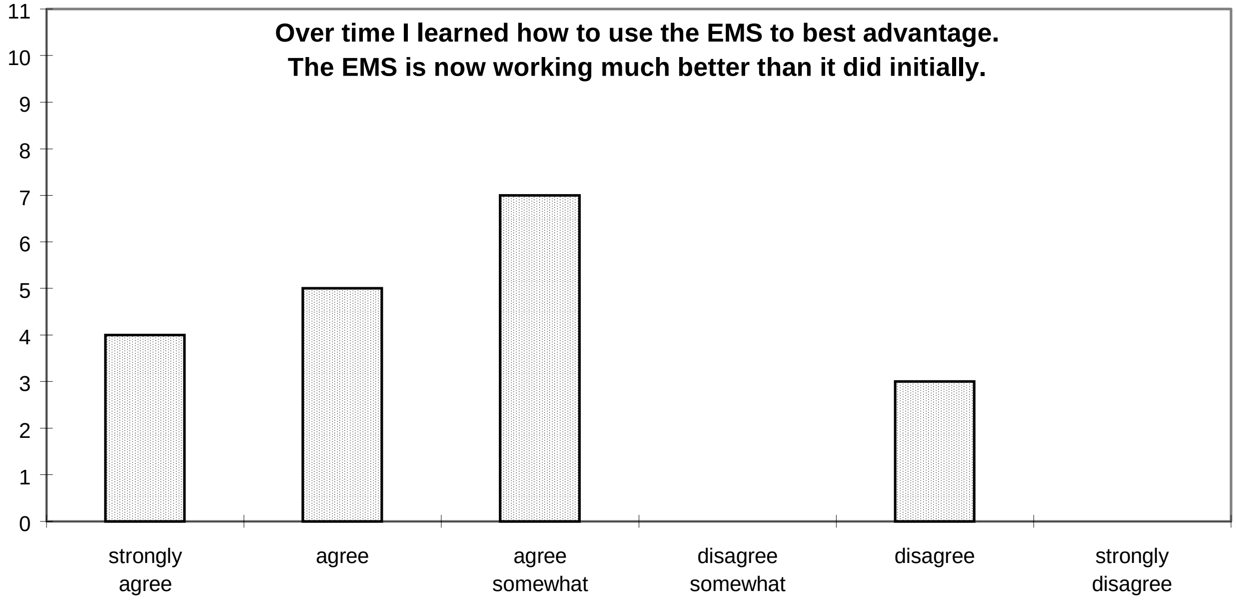


Figure D-3: Improvement of EMS functioning

A wide variation was found about whether the people responsible for EMS operation and EMS operation itself had changed over time, Figure D-4. The mean of the responses was 2.9.

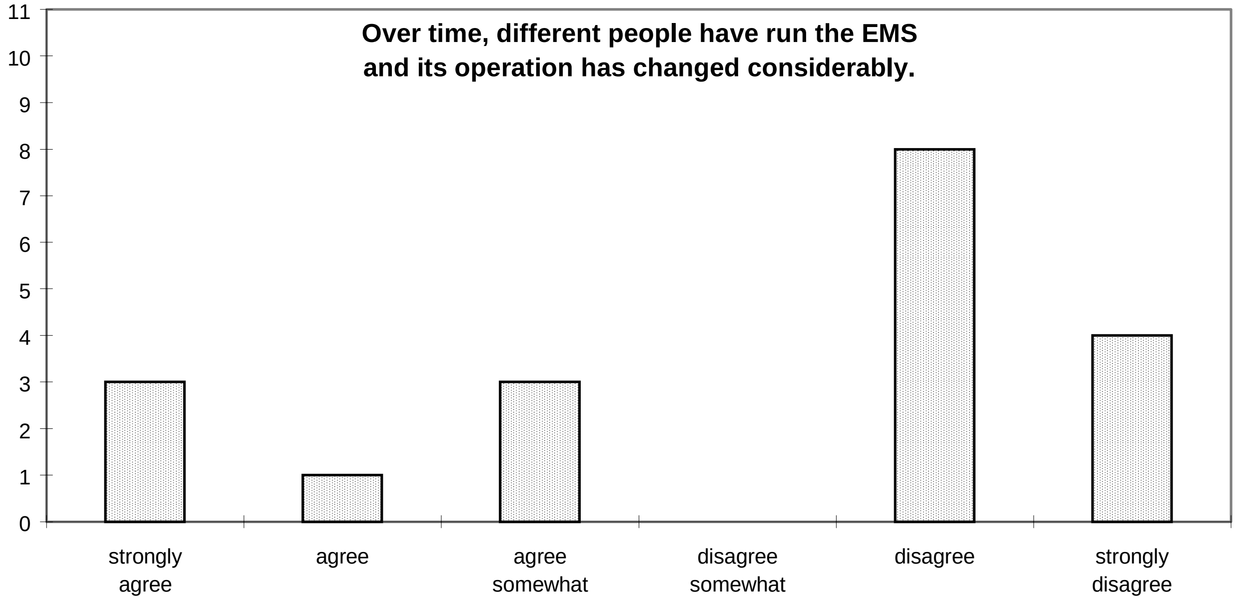


Figure D-4: Stability of operation and personnel

A wide variation was found about whether the EMS capabilities and usage had been expanded or not, Figure D-5. The mean of the responses was 3.3.

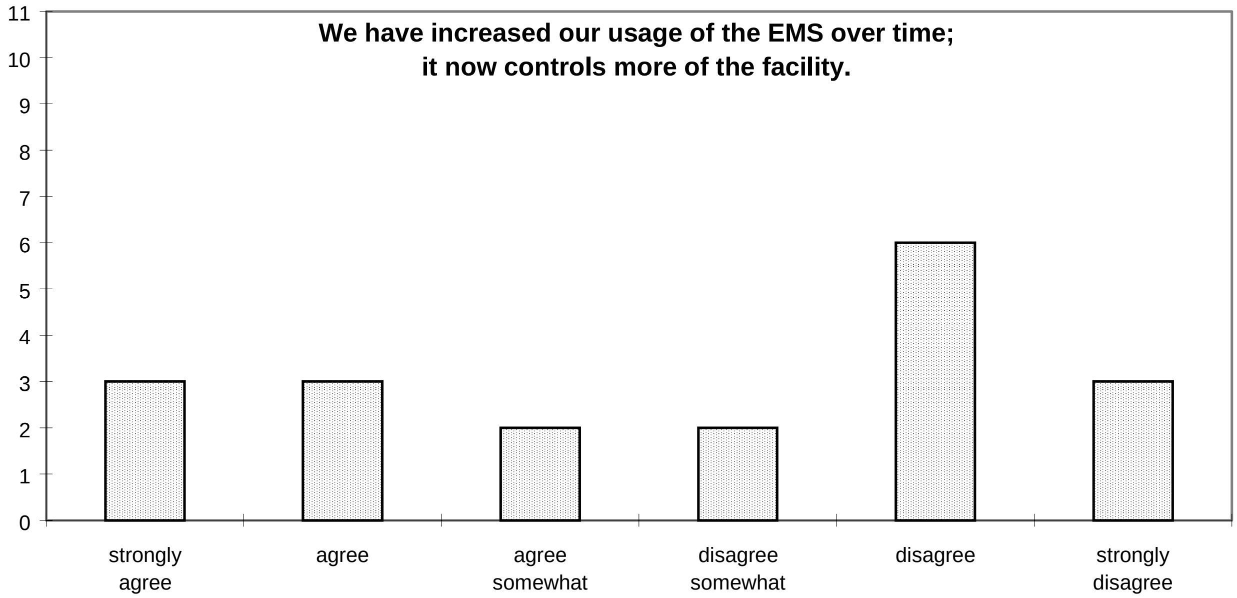


Figure D-5: Expansion of EMS control

The greatest agreement was found among respondents that reducing occupant complaints was an important part of their job responsibility, Figure D-6. All respondents agreed with this question with 79% strongly agreeing. The mean of the responses was 5.7.

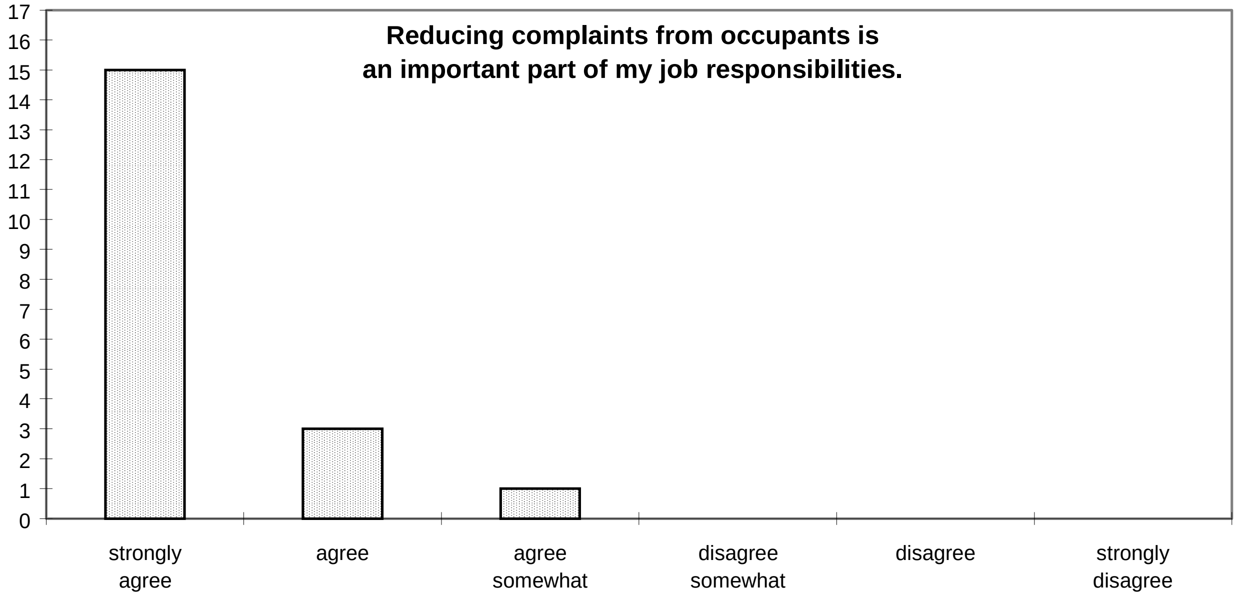


Figure D-6: Reducing complaints

All respondents agreed that the EMS was operating well, Figure D-7. The mean of the responses was 5.2.

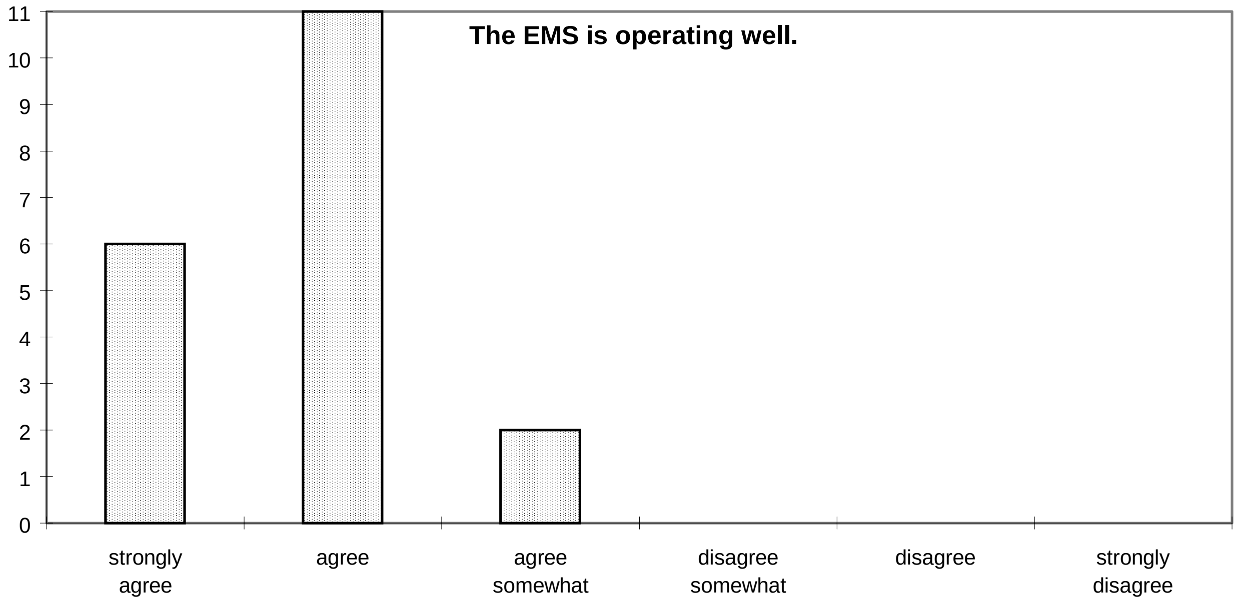


Figure D-7: EMS operating well?

Most respondents agreed that the EMS was made controlling energy costs easier, Figure D-8. The mean of the responses was 4.9.

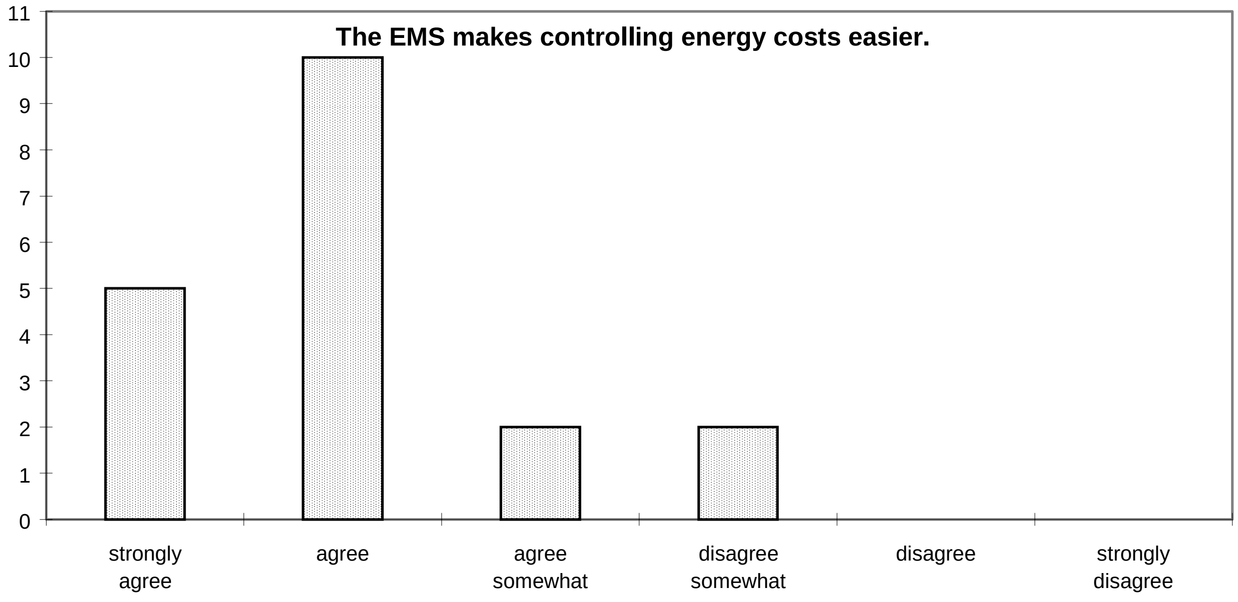


Figure D-8: Controlling energy costs easier?

Most respondents agreed that the EMS was made controlling the facilities HVAC system easier, Figure D-9. The mean of the responses was 5.1.

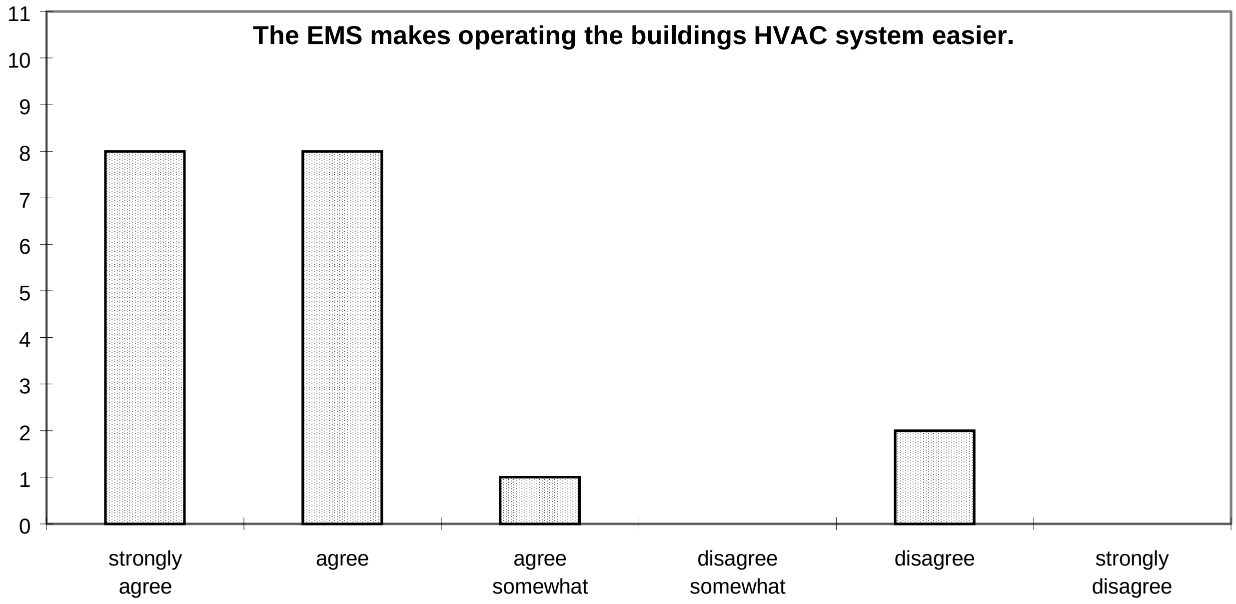


Figure D-9: Controlling HVAC system easier?

APPENDIX E SURVEY INSTRUMENTS

This Appendix contains the Phone Survey and the On-Site Survey

TELEPHONE SURVEY

Site Identification

(1) Master Cntl # / Premise #: ________________

(2) Rebate Coupon #: ____________________

(3) Program Year: __________________________

(4) Account #: __________________________

(5) PG&E / SCE Survey #: ____________________

(6) Meter #: ____________________________

(7) Date: ______________________________________

(8) Surveyor: ___________________________________

(9) Account Name: ______________________________

(10) Address: ______________________________________

____

⇒ Proctor Engineering is under contract with [PG&E, SCE] to evaluate the quality and effectiveness of Energy Management Systems. Utility records show that you received assistance from [PG&E, SCE] in installing an Energy Management System in 1992-95.

Are you the correct person to talk to? (If not), who should we speak to, please?

(if asked for clarification,…"person who might know about the EMS, or who would decide whether your company would participate in our evaluation and learn how much the EMS may have affected your energy bills."

Contact person: (11) ____

Telephone # (12) __________________________

⇒ Did you receive funding or a rebate from [PG&E, SCE] to install an EMS?

(13)	Yes	No

⇒ We are only choosing twenty-five sites to perform a detailed analysis of how EMSs affect energy usage. Participants in this analysis will be asked to supply physical site data, and assist with an on-site inspection. As a benefit from participation, you will receive an analysis of how EMS operation has affected your energy bills This telephone survey will take about 20 minutes. The on-site audit is expected to take about an hour of your time. Would your organization be willing to participate in this analysis phase?

(14)	Yes	No

⇒ In order to make the final selection of the sites for analysis we would like to talk to the person or persons most familiar with the physical operation of the potential site. Who would that person(s) be?

Contact person: (15) ____________________________________

Telephone # (16) ______________________________________

Fax # ____ E-mail: ______________________________

⇒ Is the EMS physical present now? (17)

Yes	No

⇒ If No, Why was the EMS removed:

Why? ____ (End Survey)

⇒ In order to obtain the best energy analysis results, we are looking for sites that as much as possible, only had an EMS installed and had stable use patterns.

⇒ Did your building have any other retrofits?

(18)

Yes	No

Describe briefly: ____

⇒ Did your building have any large change in use or occupancy?

(19)

Yes	No

Describe briefly: ____

⇒ Did your building have any large change in physical structure or operation?

(20)

Yes	No

Describe briefly: ____

⇒ What type of business use or operation occurs at this building / facility?

Business use: ___________________________________{Compare to SIC code description}

Our records indicate that this is a _______ establishment. Does this designation make sense to you? Y/N

Utility / rebate SIC classification (21) ___________ Final SIC designation: (22) ___________

Building square footage from rebate application (23) ___________

Building square footage used in analysis (24) ___________

Rebate saving paid for: kWh / year (25) _______________ kW (26) _________________

Analysis saving: kWh / year (27) _______________ kW (28) _________________

Comment (29) ____

⇒ Approximate building square footage? (30) ___________

Number of buildings controlled by EMS: ? (31) ___________

Number of stories: ? (32) ___________ (1, 2, 3, …, M = multiple buildings)

⇒ Who designed the EMS:

EMS Designer: (33) ____

Was a pre-installation analysis done that predicted the potential savings and benefits from the installation of an EMS. Yes / No Is this available to us for review?

(34)

Yes	No

⇒ Who installed the EMS:

EMS Installer: (35) ____

⇒ When was the EMS installed:

Start of installation: (36) ________________________

Installation complete: (37) ______________________

Start of EMS operation of building: (38) _________________________

⇒ If the EMS were to malfunction, who would be called to repair it.

EMS Service Personnel: (39) ____

Date rebate application (40) ___________

Date rebate field inspection (41) ___________

Date rebate paid (42) ___________

Analysis start installation date (43) ___________

Analysis finish installation date (44) ___________

EMS Control Points and Energy Savings Mechanism

⇒ What building or facility functions are controlled by the EMS?; Saving Strategies

Cooling:

EMS controlled? (45)

Yes	No	Partial

____

Building or facility cooling system is electrically based: (46)

Yes	No	Partial

Cooling system type: Describe: ____

1 = Central system with air distribution	(47)	Yes	No	Partial
2 = Central system with chilled water dist	(48)	Yes	No	Partial
3 = Rooftop DX units	(49)	Yes	No	Partial
4 = Individual window ACs	(50)	Yes	No	Partial
5 = Evaporative cooling	(51)	Yes	No	Partial
6 = Thermal Energy Storage	(52)	Yes	No	Partial
7 = District Chilled water	(53)	Yes	No	Partial
8 = Other	(54)	Yes	No	Partial

Heating:

EMS controlled? (55) Yes | No | Partial ______________________________

Building or facility heating system is electrically based :(56) Yes | No | Partial

Heating system type: (57) ____________

- 1 = CAV
- 2 = VAV
- 3 = Circ hot water
- 4 = Individual heaters
- 5 = Heat Pumps
- 6 = Other
-

Heating fuel type: (58) ________

- 1 = Electric Resistance
- 2 = Heat Pump
- 3 = Gas / Oil

4 = Steam
~~5 = Not heated~~
6 = Other

Swimming Pool / Spa:

Does this facility have a swimming pool or spa? :(59) Yes | No | Partial

Pool/spa heating fuel type: (60) _____________

- 1 = Electric Resistance
- 2 = Heat Pump
- 3 = Gas / Oil

4 = Steam
5 = Not heated
6 = Other

EMS controlled? (61) Yes | No | Partial ______________________________

Domestic Hot Water:

DHW heating fuel type: (62) __________

- 1 = Electric Resistance
- 2 = Heat Pump
- 3 = Gas / Oil

4 = Steam
5 = No DHW
6 = Other

EMS controlled? (63) ☐ Yes ☐ No ☐ Partial ______________________________

Ventilation:

Ventilation type: (64) __________

- 1 = Forced fan
- 2 = with heat-cool

4 = Not fan based
5 = Other

EMS controlled? (65) ☐ Yes ☐ No ☐ Partial ______________________________

Lighting & Other:

EMS controlled? (66) ☐ Yes ☐ No ☐ Partial ______________________________

Other:_______________(67) ☐ Yes ☐ No ☐ Partial ______________________________

Equipment Scheduling and Control

1) Space Temperature Control	(68)	Yes	No	N/A
2) Temperature Setback/Forward Thermostat	(69)	Yes	No	N/A
3) Schedules On/Off controls — turn off HVAC equipment during unoccupied times	(70)	Yes	No	N/A
4) Optimum Start/Stop — optimize the time a building is conditioned	(71)	Yes	No	N/A
5) Night Purge — using night air for cooling	(72)	Yes	No	N/A
6) Economizer Control — using outside air for cooling when possible	(73)	Yes	No	N/A
7) Indoor Air Quality Control — use minimum outside air and maintain indoor air quality by active control	(74)	Yes	No	N/A

Utility Rate Structure Response

1) Load Shedding — shed loads at a preset demand limit	(75)	Yes	No	N/A
2) Temperature Scheduling — reset temperature during peak demand periods	(76)	Yes	No	N/A

3) Generation — generate electricity on-site to reduce utility demand	(77)	Yes	No	N/A
4) Dual Fuel — switching to alternative fuels to reduce demand	(78)	Yes	No	N/A
5) Thermal Storage — production and storage of coolness at night by daytime use	(79)	Yes	No	N/A
6) Cogeneration — capture and use of heat from electric generation	(80)	Yes	No	N/A
7) Chiller Heat Capture — service hot water heating from rejected chiller heat	(81)	Yes	No	N/A
8) Closed-Loop Water Source Heat Pumps — transfer of heat from interior to exterior zones	(82)	Yes	No	N/A

Coordinating Central HVAC Equipment

1) Duty Cycling — sequencing loads to limit demand	(83)	Yes	No	N/A
2) Sequencing Boilers/Chillers — using the minimum number of modules required	(84)	Yes	No	N/A
3) Resetting Chiller/Boiler Temperatures — resetting delivery temperatures to minimum required	(85)	Yes	No	N/A
4) Cooling Tower Control — minimize energy use and prevent freeze up	(86)	Yes	No	N/A
5) Free Cooling — using a heat exchanger rather than chiller for cooling at low ambient	(87)	Yes	No	N/A

Controlling Lights

1) Schedule Lights On and Off — timer/scheduler for lighting	(88)	Yes	No	N/A
2) Illumination Level Control — daylighting and dimming of artificial lighting	(89)	Yes	No	N/A

Operating Personnel Interview

Date: ______________________________

Interviewee: (90) ____________________

Account #: ________________________________

Account Name: ____________________________

1) Lowering energy costs is an important part of my job responsibilities

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(91)

2) I was adequately trained to understand the operation and capabilities of the EMS.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(92)

3) Over time I learned how to use the EMS to best advantage. The EMS is now working much better than it did initially

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(93)

4) Over time, different people have run the EMS and its operation has changed considerably.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(94)

5) We have increased our usage of the EMS over time; it now controls more of the facility.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(95)

6) Reducing complaints from occupants is an important part of my job responsibilities.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(96)

7) The EMS is operating well.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(97)

8) The EMS makes controlling energy costs easier.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(98)

9) The EMS makes operating the buildings HVAC system easier.

Strongly Agree	Agree	Agree Somewhat	Disagree Somewhat	Disagree	Strongly Disagree

(99)

ON-SITE SURVEY

Date: (100.) ________________________________

Surveyor: (101.) ____________________________

Account #: _______________________________________

Account Name: ___________________________________

Address: ____

____

Site contact person

Contact person: (102.) ____

Telephone # (103.) ________________________

Appt: Date ___________________ Time ___________________

EMS Basic Data

Is the EMS operational and active? (104.)

Yes	No	Partial

(105.) Mnfg: ____

(106.) Model Number: ____

(107.) CPU Location: ____

Nameplate Info: ____

Check of EMS Operation

Point #1: ____________________________________

EMS reading: ____________________Spot-check reading: ______________________________

Reading verification (108.)

Yes	No

Point #2: ____________________________________

EMS reading: ____________________Spot-check reading: ______________________________

Reading verification (109.)

Yes	No

Point #3: ____________________________________

EMS reading: ____________________Spot-check reading: ______________________________

Reading verification (110.)

Yes	No

Metering and Control Verification

Number of Electric Meters: (111.) _________________

Electric meter number: (112.) _______________

End uses: ____

Electric meter number: (113.) _______________

End uses: ____

Electric meter number: (114.) _______________

End uses: ____

APPENDIX F SURVEY DISPOSITION

Site Identifiers

In this report, sites are identified by a three part identifier: 1) utility, 2) organization, & 3) site (if multi-site.) For example, PG&E 1.1 refers to the first of two sites of the organization labeled "1" among PG&E's rebate recipients.

First Year Savings Estimates

The estimate of first year savings is an important parameter in the calculation of the TDF. The absolute variation of annual kWh energy usage is divided by the first year savings to obtain the TDF as a dimensionless ratio. The rebated first year savings was used for 31 of the 40 analyzed installations. For nine of the installations, the first year savings was estimated, Table F-1.

Four of the estimates were derived from two cases where the rebate information combined three installations for one organization into one application and one estimate of first year savings (PG&E4.1, PG&E7.1, PG&E7.2, PG&E7.3). In both cases the buildings were similar, and the individual first year saving estimates were derived by proportioning the rebated savings among the building based on square footage.

In the case of SCE2.02 and SCE2.06, the first year saving were proportioned by square footage based on SCE2.01. PG&E1.2 was based on PG&E1.1, proportioned by square footage. The estimates for PG&E3.1 and PG&E5 were based on a database average of 1 kWh / year / ft².

Table F-1 First Year Savings Estimate Methods

PG&E / SCE	Comment
PG&E1.1	Estimated at based on PG&E1.1
PG&E3.1	Estimated at 1 kWh / yr / ft2
PG&E4.1	Rebate combined 3 bldgs. Savings proportioned by ft2.
PG&E5	Estimated at 1 kWh / yr / ft2
PG&E7.1	Rebate combined 3 bldgs. Savings = 1 / 3 of rebated
PG&E7.2	Rebate combined 3 bldgs. Savings = 1 / 3 of rebated
PG&E7.3	Rebate combined 3 bldgs. Savings = 1 / 3 of rebated
SCE2.02	Estimated based on SCE2.01 (2.5 kWh / yr / ft2)
SCE2.06	Estimated based on SCE2.01 (2.5 kWh / yr / ft2)

Pacific Gas & Electric

PG&E 1

This high school district, located in the foothills of the Sierras, has three schools. Each school has two electrical feeds with separate electric meters. In two schools most of the changes occurred on only one of the two meters, and therefore, the other meter had valid comparative data.

PG&E 1.1 The older main meter had only two portables added since the installation of the EMS. A variety of HVAC systems supply various buildings. The largest is two 50 ton chillers and cooling towers that provide cooling to several buildings; in this system the EMS provides on/off and optimum start, while pneumatic thermostats provide space temperature control. A 40 ton DX unit supplies a VAV system in an office building; the EMS controls space temperatures and system operation including an economizer. Most of the main classroom building does not have cooling; however, the computer room is cooled with a 15 ton DX unit. The EMS also controls some lighting. Eighteen window ACs are not EMS controlled. Heating is supplied from a boiler through circulating hot water.

The facility had an old EMS that was upgraded to a newer EMS in the retrofit. An extensive lighting retrofit was done at the same time as the EMS installation.

PG&E 1.2 The facility has two parts called the upper and lower campus. The usage of the upper campus and science building, which had few changes since EMS installation, was analyzed. A 75 ton chiller and cooling tower provides cooling to three buildings. A 60 ton DX unit with ice storage provides chilled water to a fourth building. The EMS provides on/off and optimum start; pneumatic thermostats provide space temperature control. Cooling to another small area is provided through 4-5 window ACs without EMS control. The EMS also controls exterior lighting.

The facility had an old EMS that was upgraded to a newer EMS in the retrofit. An extensive lighting retrofit was done at the same time as the EMS installation.

PG&E 2

The Unified School District has installed an EMS in each of their schools. This has been done over time, and there are three different systems, each one more modern than the last. One employee’s major task is the operation of the EMS. Each school day he checks the operation of all the schools, adjusts schedules, and issues maintenance work orders. The EMS is used to turn equipment on/off with space temperature control provided by thermostats.

PG&E 2.1 This high school consists of one building with 203,000 sq. ft. The whole building is cooled with eighteen rooftop DX units with gas heating. The EMS schedules equipment on/off and controls the economizers. An extensive lighting retrofit was done at the same time as the EMS installation.

PG&E 2.2 This middle school has 11 buildings enclosing a total of 103,000 sq. ft. The five portables were present before the EMS was installed. Most of the school buildings are not cooled. The music wing is cooled with a rooftop DX unit. The EMS schedules equipment on/off and controls exterior lighting. The administration area and computer room are cooled with window ACs which are not EMS controlled. All heating is gas fired. An extensive lighting retrofit was done at the same time as the EMS installation.

PG&E 3

This large city unified school district installed EMSs throughout the district using rebates. However, every school facility was disqualified from the study due to other physical changes that affected energy use. The Corporate Yard and District Office Building were surveyed. The EMS schedules HVAC on / off, controls the space temperature, and utilizes setback / forward. The shared savings program under which the EMS systems were installed recently ended, and the system operation is being transferred to new operators.

PG&E 3.1 The Corporate Yard has several buildings which are cooled with rooftop DX units. The EMS schedules equipment on / off and limits the thermostat settings within a ±4°F range. In April 1998, the Transportation Building HVAC was upgraded to a more efficient unit; therefore, analysis had to stop on that date. Heating is done with gas.

PG&E 3.2 The school district office building has rooftop DX units and a rooftop evaporative cooling pond. The EMS schedules equipment on / off and controls the space temperatures. Heating is done with gas. The retrofit was installed in April 1994, but the first electric data was from February 1995.

PG&E 4

This office complex has two 6-story and one 2-story office towers with an attached 6 level parking ramp. A single EMS controls the complex providing HVAC control, occupant over-ride capabilities, billing information and maintenance information. In a January 1997 retrofit, stairwell and security lighting was upgraded.

The office complex has had four owners since the EMS was installed. It originally changed hands as part of the S&L bankruptcy soon after the EMS was installed. One maintenance person works full time. The EMS computer is located in his office, which is the rooftop mechanical room. He logs and reviews all of the EMS's operation each month.

PG&E 5

This credit union office encloses 14,600 square feet with two stories. Six rooftop heat pumps provide HVAC functions. The EMS controls the space temperatures, schedule equipment on / off, and optimizes equipment starts. No other retrofits were reported installed.

PG&E 6

This set of three bank branch buildings is located in the SF Bay area. The EMSs were installed in early 1991; they are among the earliest rebated customers and therefore have some of the longest post-installation usage histories. The EMS controls the space temperatures, sets the temperature forward and back, schedule equipment on / off, and optimizes equipment starts, and does night purge and economizer control. The HVAC and EMS operation is handled by a controls contractor.

PG&E 6.1, 6.2 & 6.3 No other retrofits were reported installed at the bank branches.

PG&E 7

7.1, 7.2 & 7.3 This set of three office buildings is located in the East SF Bay area. The management is located on-site with the front end computer software on one of the administrator's PCs. The property ownership was transferred January 1996. The administrator and the single maintenance person both can operate the EMSs. The HVAC system is rooftop DXs with gas heating. The EMS turns the equipment on/off with optimal start. Space temperature are controlled by individual thermostats. The EMS was installed June 1994. Building occupancy was increasing up until 1996.

PG&E 9

The district offices and one middle school were surveyed. As with many school districts, all of the elementary schools were disqualified because they had had significant numbers of portables added due to mandated class size reduction.

PG&E 9.1 The middle school is supplied with cooling from classroom VAV boxes supplied by four large air handlers. Chilled water for cooling is supplied from a chiller and cooling tower, and hot water for heating is supplied by a boiler. The EMS controls the space temperature, resets the temperature forward/back turns HVAC equipment on/off, controls the cooling tower, and resets the chilled water temperature; it also controls exterior lighting. No other retrofits were done at the site.

PG&E 9.2 The school district office building is cooled with three rooftop DX units. Heating is supplied by circulating hot water from a boiler. The EMS controls the space temperature and turns HVAC equipment on/off; it also controls exterior lighting. The Corporate Yard is also on the same meter; it has several smaller non-EMS controlled ACs and electric resistance heating. No other retrofits were done at the site.

Southern California Edison

SCE 1

This unified school district west of Los Angeles has EMSs in all of its buildings. All of the maintenance personnel know at least basic EMS operation. The elementary schools were disqualified because of the addition of portable classrooms. A high school and middle school were surveyed.

SCE 1.1 The EMS installation in the high school was part of a general HVAC upgrade. Heat pumps were added to many of the classrooms. The increased load is clearly seen at the time of the retrofit. Two buildings, the cafeteria, and a classroom wing are cooled with a chiller and cooling tower and supplied with heat from a boiler. The EMS controls the space temperature, resets the temperature forward/back, turns HVAC equipment on/off, resets the chilled water temperature; and controls exterior lighting. The facility had only 1 other recorded rebated retrofit. A timing device was installed that saved a small amount of energy with no kW reduction.

SCE 1.2 The EMS installation was part of a general HVAC upgrade to this 1949 era school. Heat pumps were added to many of the classrooms. The EMS controls the space temperature, resets the temperature forward/back turns HVAC equipment on/off; and controls exterior lighting. The billing dataset was short; it included only a little pre-data.

SCE 2

These sites belong to a large California bank corporation. The original eleven EMS installations were done with SCE rebates. These installations were considered successful and the remaining sites had the same EMS system installed, but SCE rebates were not available that year. The only retrofit was the EMS at all sites.

SCE 2.1, 2.2, …2.11 All of the sites have the same EMS system, which is controlled from the central office. The EMS schedules equipment on/off with an optimum start. Exterior signs are also EMS controlled.

SCE 4

This set of buildings is operated by a large property management firm with headquarters in the Midwest. Each site also has a contracted on-site manager. Building maintenance is handled by an outside firm.

SCE 4.1, 4.2, 4.3, 4.4 & 4.5 The first five buildings are an office park (SCE 4.1-SCE 4.5). The EMSs were installed under an ESCO arrangement in 12/93. Space temperature is controlled by pneumatic thermostats in the spaces. The EMSs limit the space temperatures, schedule equipment on/off, optimize starting times, and control the economizers. Cooling is provided by rooftop DX units with electric resistance heating at the terminal VAV boxes. The only retrofit was the EMS at all sites.

SCE 4.6 This is a 90,000 square foot general office building. Two 45 ton rooftop DX units supply conditioned air to a VAV distribution system. Gas heating is provided from a boiler to a hot deck. In 6/98 the condenser was replaced due to deterioration from corrosion.

SCE 4.7 The HVAC system is a loop of partly conditioned water that supplies water-source heat pumps. The loop water is heated by a boiler or cooled by a cooling tower to maintain moderate loop temperatures. The EMS controls the space temperatures, schedules equipment on/off, optimizes morning starts, controls the cooling tower, and adjusts the supply loop temperature. This building has four electric services which feed different wings of the building. The energy use on all four services is affected by EMS operation and the services were combined for analysis .

SCE 5

This city installed a set of EMSs to control 10 buildings at 6 sites throughout the city. Data were analyzed for four sites: Corporate Yard, Library, Neighborhood Center, and Fire & Police. The EMS controls space temperature, schedules equipment on/off, and controls economizers when present. Exterior lighting is also EMS controlled. The buildings had a combination of lighting retrofits, HVAC upgrades, and EMS installations.

SCE 6

This large fast food restaurant chain has installed EMSs throughout the country. The corporate facility manager estimates that total energy is composed of one-third each for the HVAC, lighting, and prep line. Each restaurant is approximately 2200 square feet. The only retrofit was the EMS at all sites.

SCE 6.1, 6.2 The EMS controls the space temperature, sets the space temperature forward/back, and schedules equipment on/off. Some cooking equipment and some lighting is also controlled. Cooling is provided by rooftop DX units with gas heating.

SCE 7

This school district installed EMSs at all five of their school sites during a general upgrade and remodel that upgraded the lighting and added air conditioning to the classrooms.

SCE 7.1, 7.2, 7.3, 7.4 & 7.5 The HVAC systems are rooftop heat pumps. The EMS schedules equipment on/off; space temperatures are controlled by thermostats. Domestic hot water is gas heated.

SCE 8

This city installed an EMS system in their 12,000 sq. ft. city hall in conjunction with an HVAC system upgrade. The HVAC consists of three 10 ton rooftop DX units with gas heating and a VAV distribution system. The EMS controls the space temperature, sets the space temperature forward / back with optimum start, schedules equipment on / off, and controls the economizers. Control and servicing is provided by the local contractor who installed the system.

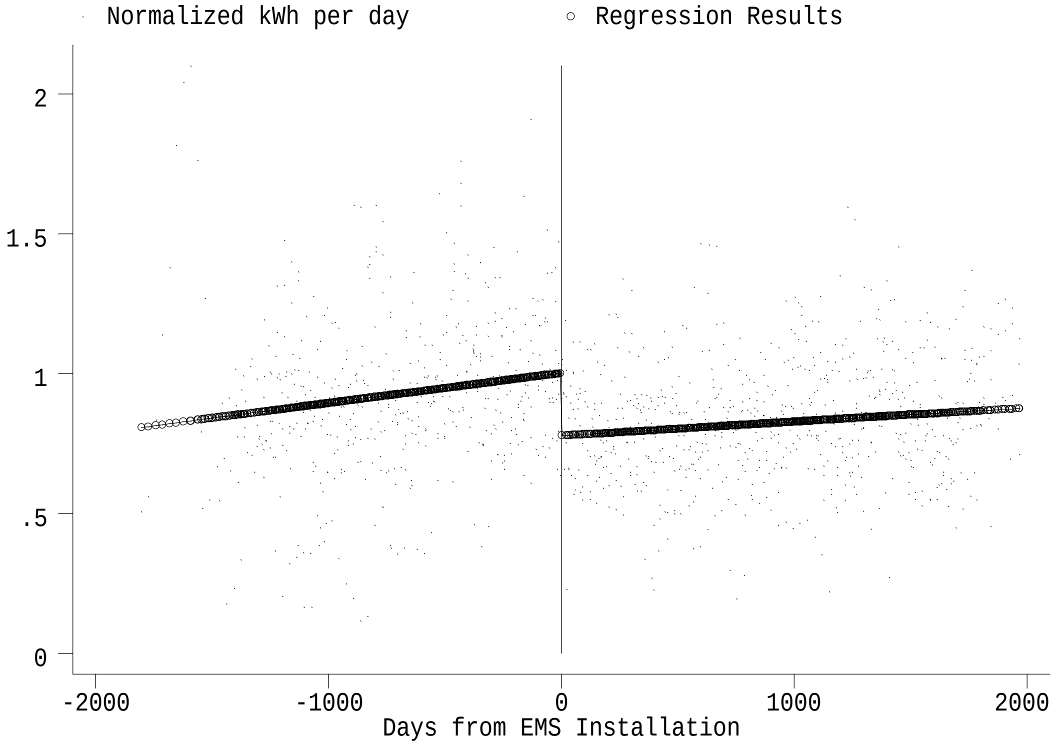
SCE 9

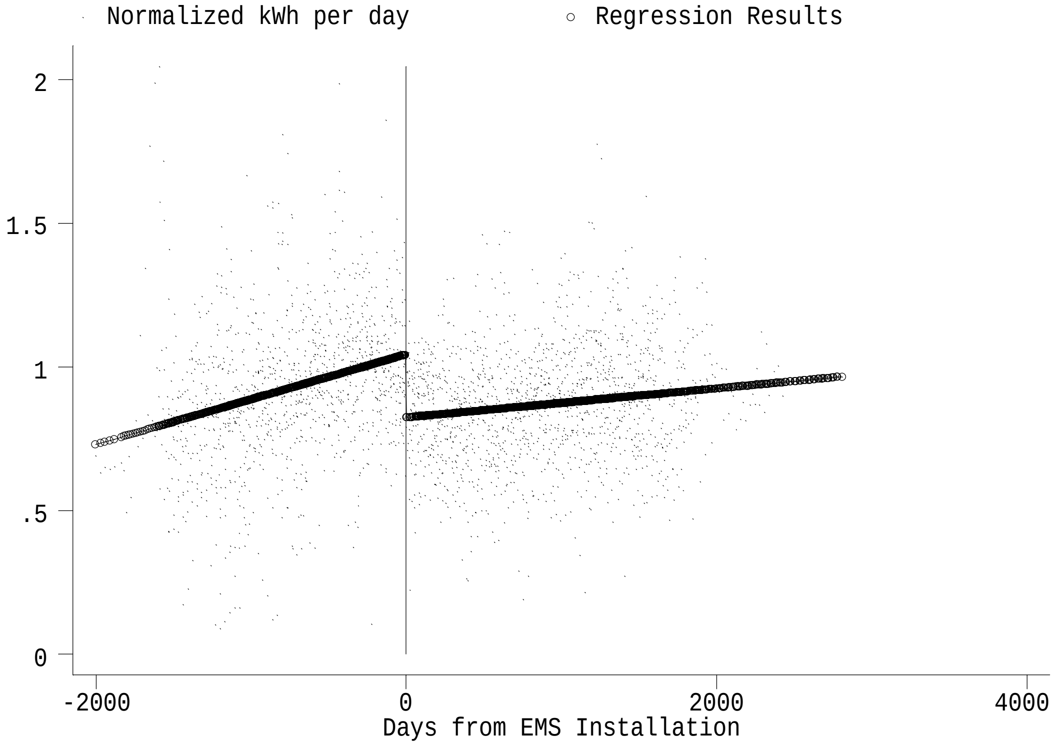
This city installed an EMS system in their 6,500 sq. ft. Public Service Building. The HVAC is a rooftop heat pump. The EMS schedules equipment on / off. Servicing is provided by the national controls manufacturer who installed the system. Lighting retrofit was installed at the same time as the EMS installation.

APPENDIX G DESCRIPTION OF MODELS

Analysis Consistency

Each of the analyses were reviewed for consistency of judgment to ensure that the decisions about data treatment were constant regardless of whether the data showed good or poor persistence. This review took place three times in the course of the analysis.





All units with savings

Models

Moving Average Analysis (ma)

The first, simplest and often best model was based on a twelve month moving average of total building electrical consumption. This running average model has the following characteristics:

- It removes month of year dependence (each data point has all twelve months).
- It removes seasonal dependence (all seasons are included in each data point).
- It shows dependence on outside weather conditions as variability in the long term trend.

In doing this it assumes that:

- The changes in weather are relatively small from year to year.
- Consumption associated with the month of the year or the season of the year are fixed and do not change with the addition of the EMS system.

The simplest case of this model is illustrated in Figure G-1.

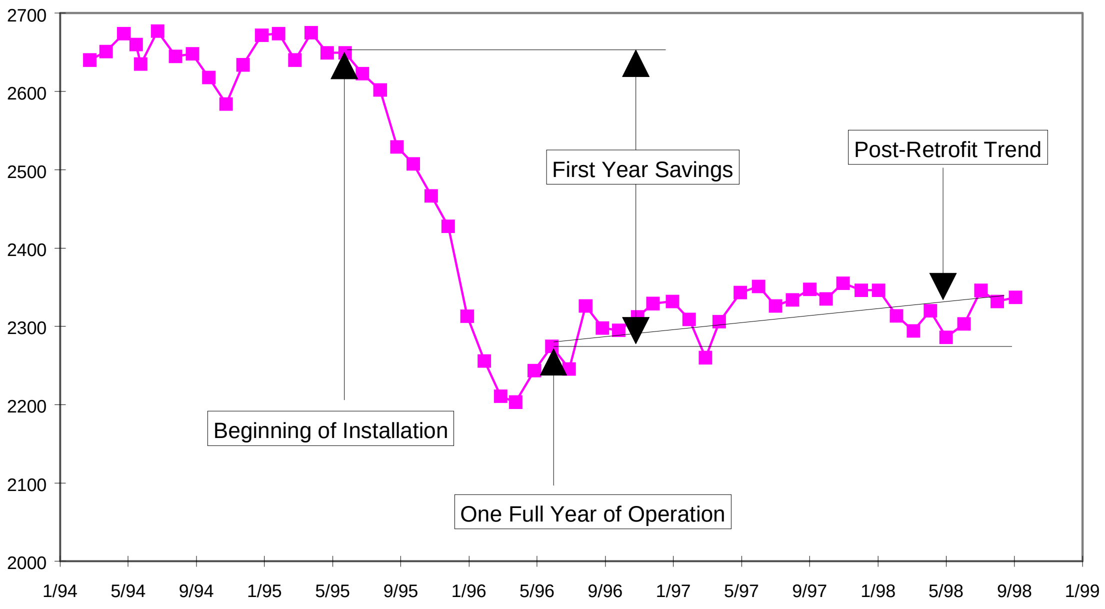


Figure G-1 Illustration of Moving Average Analysis

Each point in this figure is the running 12 month average of electrical consumption (kWh per day). In the case illustrated in Figure G-1 the trend in electrical consumption before the EMS installation is level. The time of the installation is clear because of the inflection point. The full first year savings are shown after 12 months when there are no pre-installation months in the moving average. The degradation rate is within the post-retrofit trend (growth in load) after the first year.

The cases are not usually this simple for the following reasons:

1. There is a long term trend shown in most of the buildings data. This trend is generally an increase in energy consumption over time.

2. Some buildings show a post-retrofit load growth that exceeds the savings within a few years and that trend continues after the total first year savings are exceeded.

3. There is often higher variability in the moving average. This is sometimes due to identifiable changes in how the building was operated or the occupancy situation.

These issues were dealt with in the analysis in the following manner:

1. If there was a pre-EMS long term trend that did not have an identified cause, or did not have an identified end, it was assumed that it would continue into the future if the EMS were not installed.

2. If there was a pre-EMS long term trend that had an identified cause and an identified end with stable consumption thereafter, the analysis was based only on data after stable consumption occurred.

3. Once the post-EMS load growth exceeded the first year savings, the technical degradation was not projected to continue. This assumes that the EMS does not degrade to the point where it increases consumption over the base case.

4. Once the post-EMS load reduction exceeded the first year savings, the negative technical degradation was not projected to continue. This assumes that the EMS does not improve to the point where it increases savings by more than the initial savings.

5. If there were identifiable changes in occupancy or building use, the analysis was confined to time periods when these variables were reported to be constant.

Simple Regression Analysis (reg)

The simple regression analysis regresses the monthly kilowatt hour per day against three predictors: days from retrofit, pre-EMS, and days prior to retrofit.

The reg model is of the form:

$$kpd_{it} = \alpha + indate * \beta_1 + pre * \beta_2 + pindate * \beta_3 + \varepsilon_{it}$$

where:

kpd_{it} is the kilowatt hours usage per day in time period t for unit i

α is the intercept (constant)

indate is the number of days from EMS installation (- if before installation, + if after installation)

pre is an indicator variable (1 if prior to EMS installation, 0 if after installation)

pindate is the number of days from EMS installation (- if before installation, 0 after installation) in

β_1 is the coefficient of indate in the model

β_2 is the coefficient of pre in the model

β_3 is the coefficient of pindate in the model

ε_{it} is the residual

From this regression the following values are estimated:

$\mathbf{S_y}$**:** Savings in post-installation year y = $\beta_{pre} + \beta_{pindate} * (y-0.5) * 365$
[y is 1 thru 20]

Technical Degradation Factor (TDF) = $\mathbf{S_y}/\mathbf{S_1}$**:**

Time Series Regression Analysis (xtday)

The cross sectional time series regression analysis also regresses the monthly kilowatt hour per day against; days from retrofit, pre-EMS, and days prior to retrofit.

The xtday model is of the form:

$$kpd_{it} = \alpha + x_{it} * \beta + \nu_i + \varepsilon_{it}$$

where:

t is the time variable (elapsed date)

i is the unit variable (month of year)

kpd_{it} is the kilowatt hours usage per day in time period t for unit i

α is the intercept (constant)

x_{it} is the value of the independent variable in time period t for unit i

the independent variables are the same as in the reg model (indate, pre, pindate)

β is the coefficient of x in the model

ν_i is a case specific residual, this is a constant for each unit

ε_{it} is the general residual

This model can be estimated in a number of ways. One way is by using the within estimator. The within estimation (also known as the fixed effects estimator) uses ordinary least squares to estimate the following equation:

$$(kpd_{it} - akpd_i) = (x_{it} - ax_i) * \beta + (\varepsilon_{it} - a\varepsilon_i)$$

where:

$akpd_i$ is the average kilowatt hours usage per day for unit i

ax_i is the average value of the independent variable for unit i

$a\varepsilon_i$ is the average general residual for unit i

Another method of estimating the xt model is the random effects estimator with estimates the following equation:

$$(kpd_{it} - \theta * akpd_i) = (1-\theta) * \alpha + (x_{it} - \theta * ax_i) * \beta + [(1-\theta) * \nu_i + (\varepsilon_{it} - \theta * a\varepsilon_i)$$

where

θ is a function of the variances of ν and ε.

See STATA Reference Manual Release 5, Volume 3, xtreg, pp 631-647.

Both the fixed effects and the random effects estimator were investigated to estimate the model. They produced similar results in most cases. The analysis is based on the random effects estimator.

This regression is nearly the same as the simple regression. The difference is that this method takes into account the month of year pattern of consumption. From this regression the same values are estimated:

S_y: Savings in post-installation year $y = \beta_{pre} + \beta_{pindate} * (y-0.5) * 365$
[y is 1 thru 20]

Technical Degradation Factor (TDF) = **S_y/S_1:**

Other Time Series Regression Analyses

Other time series cross sectional analyses were also attempted. These models used weather data variables (heating and cooling degree days to various bases) as additional predictors. None of these models successfully improved the predictive power of the analysis.

PG&E Sites

PG&E 1.1

This unit is a school that shows strong growth trends before and after retrofit. It also shows very strong monthly and seasonal patterns that dwarf any weather patterns. The load growth increases after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analysis produced similar numbers. The analysis used data beginning 4 years before the retrofit. The pre-EMS load growth was 88 kWh per day per year. The savings was 252 kWh per day. The post-EMS load growth was 175 kWh per day per year. The load growth increased by 87 kWh per day per year (potential degradation). The savings was confounded by a lighting retrofit at the same time.

A linear regression based on kWh per day and time (reg) provided these alternative estimates:
Savings=296 kWh per day, Load growth increase 46 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=246 kWh per day, Load growth increase 74 kWh per day per year.

All the regression coefficients in the xtday model are statistically different from 0 (at 95% confidence).

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.65	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The confidence in these estimates is weak because:

- the load growth exceeds the savings in the billing data, which indicates that not all the post-EMS load growth is degradation
- the billing load factor is nearly constant after EMS installation, which suggests that the EMS savings is not degrading.
- the analysis is confounded by a lighting retrofit simultaneous with the EMS installation.

PG&E 1.2

This unit is a school that shows a two year pattern of growth before retrofit. Like PG&E1.1, the load growth increases after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analysis produced contradictory trends. The pre-EMS load increased by 49 kWh per day per year. The post-EMS load increases at 83 kWh per day per year. This produces a net increase in load (potential degradation) of 34 kWh per day per year. The savings was 169 kWh per day. The savings was confounded by a lighting retrofit at the same time.

A linear regression based on kWh per day and time (reg) provided these alternative estimates:
Savings=534 kWh per day, Load growth reduction (potential negative degradation) of 150 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=382 kWh per day, Load growth reduction of 65 kWh per day per year.

Both of the regression based analyses contained coefficients that were not statistically different from 0.

The potential degradation (pindate) coefficient in the xtday regression was not statistically different from 0 (at 95% confidence). This could be interpreted as no potential degradation.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.80	0.60	0.40	0.20	0	0	0	0	0

The confidence in these estimates is weak because:

- the load growth accelerated in the year just prior to the EMS installation, this trend may have extended into the post period. If the analysis used the year prior to installation, no relative load growth would be projected.

- the billing load factor is nearly constant after EMS installation, which suggests that the EMS savings is not degrading.

- the consumption growth after EMS installation is nearly all concentrated in increased billing kW.

- the analysis is confounded by a lighting retrofit simultaneous with the EMS installation.

PG&E 2.1

This unit is a school that shows a two year pattern of load reduction before retrofit. The load growth reduction trend slows after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analysis produced similar trends. The pre-EMS load decreased by 260 kWh per day per year. The post EMS load reductions slow to 68 kWh per day per year. This produces a net increase in load of 192 kWh per day per year. The savings was 1116 kWh per day. The savings was confounded by a lighting retrofit at the same time.

A linear regression based on kWh per day and time (reg) provided these alternative estimates:
Savings=919 kWh per day, Load reduction slowed by 125 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=783 kWh per day, Load reduction slowed by 44 kWh per day per year..

Both of the regression based analyses contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.83	0.66	0.48	0.31	.014	0	0	0	0

The confidence in these estimates is weak because:

- the billing load factor is nearly constant after EMS installation, which suggests that the EMS savings is not degrading.
- the analysis is confounded by a lighting retrofit simultaneous with the EMS installation.

PG&E 2.2

This unit is a school that shows a two year pattern of load reduction before retrofit. The load growth reduction trend slows after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analysis produced similar trends. The pre-EMS load decreased by 28 kWh per day per year. The post EMS load increased by 43 kWh per day per year. This produces a net increase in load of 71 kWh per day per year. The savings was 66 kWh per day. The savings was confounded by a lighting retrofit at the same time.

A linear regression based on kWh per day and time (reg) provided these alternative estimates:
Savings=229 kWh per day, Net load increase of 64 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=61 kWh per day, Net load increase of 68 kWh per day per year

Both of the regression based analyses contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.07	0	0	0	0	0	0	0	0

The confidence in these estimates is weak because:

- the load growth exceeds the savings in the billing data, which indicates that not all the post-EMS load growth is degradation
- the billing load factor is nearly constant after EMS installation, which suggests that the EMS savings is not degrading.
- the analysis is confounded by a lighting retrofit simultaneous with the EMS installation.

PG&E 3.1

This unit is a school corporate complex that shows a long pattern of load increases before retrofit. The load growth continues after the EMS is installed. The EMS was actually put in operation over a year after installation. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analysis produced similar trends. The pre-EMS load increased by 72 kWh per day per year. The post EMS load decreased by 22 kWh per day per year. This produces a net reduction in load of 94 kWh per day per year. The savings was 56 kWh per day.

It may seem unusual that the savings from an EMS would grow. In this case, the first year saw the system not operating properly.

A linear regression based on kWh per day and time (reg) provided these alternative estimates:
Savings=122 kWh per day, Net load reduction of 90 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=127 kWh per day, Net load reduction of 89 kWh per day per year

All the coefficients in the xtday analysis were statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

The confidence in these estimates is moderate because:

- there is very good information from telephone contacts and survey on how this EMS was operated.
- the billing load factor is nearly constant after EMS installation, which suggests that the EMS savings is not degrading.
- the analysis is not confounded by any other simultaneous retrofits with the EMS installation.

PG&E 3.2

This unit had insufficient pre-EMS data to complete an analysis.

PG&E 4.1&4.2

Meter 4.3 had near zero use and was dropped.

This unit is an office complex. The analysis begins one year prior to EMS installation. The load grows after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. One time series analysis produced a similar trend. The other model “blew up”. The pre-EMS load trend was not estimated (one year of data only). The post EMS load increased by 42 kWh per day per year. The savings was 521 kWh per day.

A linear regression based on kWh per day and time (reg) “blew up” and provided these alternative estimates: Increased consumption = 511 kWh per day, Net load increase of 657 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=563 kWh per day, Net load increase of 38 kWh per day per year

Both of the regression based analyses contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.92	0.84	0.76	0.68	0.60	.052	.044	.036	0.27

The confidence in these estimates is weak because:

- the billing load factor is level in the long term (particularly with the new owner), but has many variations after EMS installation.
- the analysis is not confounded by any other simultaneous retrofits with the EMS installation.
- in spite of these pluses, the pre-EMS conditions are not known.

PG&E 5

This unit is an office building. The load is nearly constant both before and after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced similar trends. The pre-EMS load was falling at about 2 kWh per day per year. The post-EMS load was falling at 1 kWh per day per year (a net increase of 1 kWh per day per year. The savings was 77 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 73 kWh per day, Net load decrease of 24 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=106 kWh per day, Net load decrease of 12 kWh per day per year

Both of the regression based analyses contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.99	0.97	0.96	0.95	0.94	0.92	0.91	0.90	0.88

The confidence in these estimates is moderate because:

- the analysis is not confounded by any other simultaneous retrofits with the EMS installation.
- there are two years of stable pre-EMS data

PG&E 6.1

This unit is an office building. The load grows after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced similar trends. The pre-EMS load trend was not determined in the ma analysis (only one year of pre data). The post-EMS load increased at 26 kWh per day per year. The savings was 90 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 13 kWh per day, Net load decrease of 59 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=11 kWh per day, Net load decrease of 61 kWh per day per year

Both first year savings estimates and net load changes are dominated by the slim pre data. Both contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.71	0.49	0.23	0.00	0.00	0.00	0.00	0.00	0.00

The confidence in these estimates is weak because:

- there is only one year of pre-EMS data, which is insufficient to establish a pre EMS trend.
- the load growth exceeds the savings in the billing data, which indicates that not all the post-EMS load growth is degradation

PG&E 6.2

This unit is an office building. The load grows after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced the opposite trend (savings increasing over time). The pre-EMS load trend was not determined in the ma analysis (only one year of pre data). The post-EMS load increased at 29 kWh per day per year. The savings was 54 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 82 kWh per day, Net load decrease of 17 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=82 kWh per day, Net load decrease of 17 kWh per day per year

Both regressions projected higher load increase pre-EMS than post-EMS. This fact is responsible for the growing savings. The ma analysis was for only one pre year, so the pre-EMS load growth was taken as 0. Both regressions contained coefficients that were not statistically different from 0.

The load growth far exceeded the savings. This is an example of the fact that load growth is not necessarily degradation of the EMS system. This is illustrated in Figure G-2.

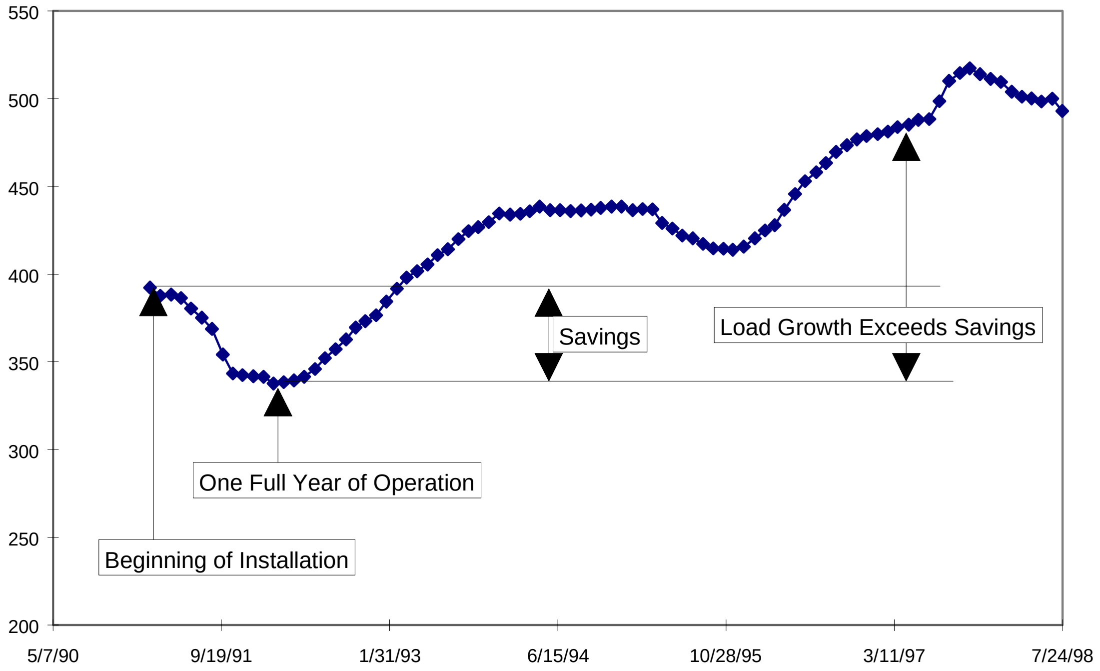


Figure G-2 PG&E 6.2

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The confidence in these estimates is weak because:

- there is only one year of pre-EMS data, which is insufficient to establish a pre-EMS trend.
- the load growth exceeds the savings in the billing data, which indicates that not all the post-EMS load growth is degradation

PG&E 6.3

This unit is an office building. The load grows after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced the opposite trend (growing savings). The pre-EMS load trend was not determined in the ma analysis (only one year of pre data). The post-EMS load increased at 10 kWh per day per year. The savings was 93 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 114 kWh per day, Net load decrease of 17 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=114 kWh per day, Net load decrease of 17 kWh per day per year

Both regressions contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.89	0.78	0.68	0.57	0.46	0.35	0.25	0.14	0.03

The confidence in these estimates is weak because:

- there is only one year of pre-EMS data, which is insufficient to establish a pre-EMS trend.

PG&E 7.1

This unit is an office building. Load growth is evident both before and after the EMS is installed. The occupancy in this building increased up to January of 1996. At that time a new owner took over the building. When the new owner took over the building the new managers started investigated the operation of the EMS system and put it into full use. The moving average (ma) analysis was used to estimate savings based on stable occupancy beginning January 1996. This is illustrated in Figure G-3. The time series analyses produced different results because they projected pre-EMS growth trends without end.

The ma analysis produced the best estimates of savings and persistence. The pre-EMS load increased at 187 kWh per day per year. The post-EMS load growth is projected to be nil. The savings are a constant 304 kWh per day.

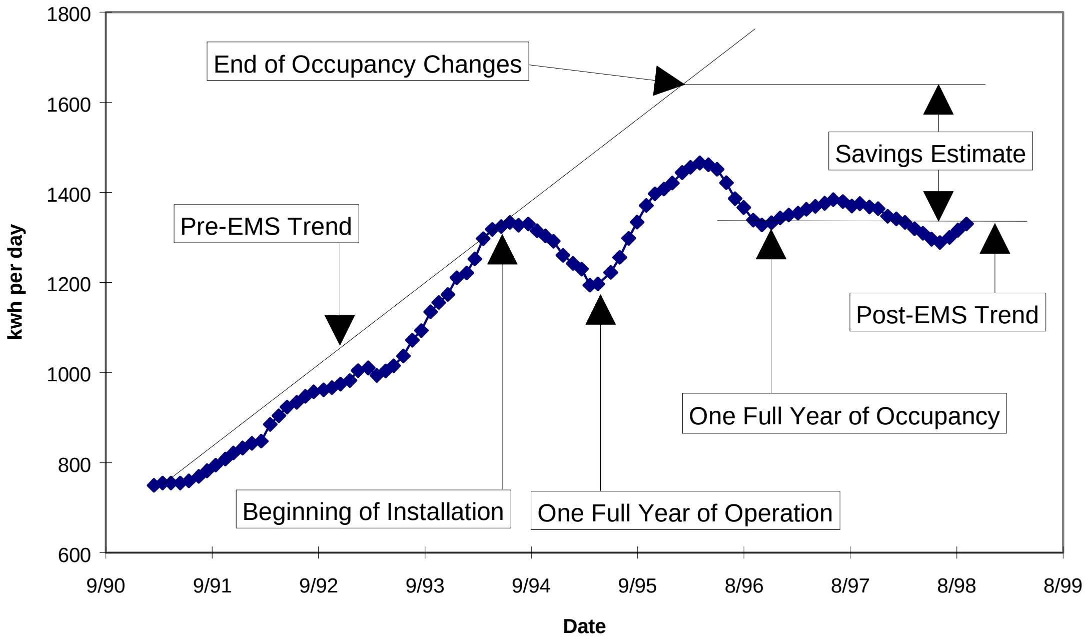


Figure G-3 PG&E 7.1

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 163 kWh per day, Net load decrease of 148 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=187 kWh per day, Net load decrease of 148 kWh per day per year

Both regressions contained coefficients that were not statistically different from 0.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The confidence in these estimates is moderate because:

- there is good institutional memory on the condition when the new owners took over. This includes some information on occupancy trends prior to their acquisition of the building.

- after an impressive excursion in the second year after EMS-installation, there was a nearly constant billing load factor.

- the analysis is not confounded by any other retrofits.

PG&E 7.2

This unit is an office building. Load growth is evident both before and after the EMS is installed. In addition one floor of the building moved out 8 months before the EMS was installed. Full occupancy was present no later than January 1996 when the new owner took over the complex. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced similar savings estimates with net post-EMS load growth. The pre-EMS load increased at 99 kWh per day per year. The post-EMS load growth was 98 kWh per day per year. The net load increase was 1 kWh per day per year. The savings was 814 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 850 kWh per day, Net load increase of 85 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=778 kWh per day, Net load increase of 73 kWh per day per year

Both regressions contained coefficients (pindate) that were not statistically different from 0. These are the coefficients that project a net load growth.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99

The confidence in these estimates is weak because:

- the pre-EMS load projection depends on only a year and a half of data.

PG&E 7.3

This unit is an office building. Load growth is evident both before and after the EMS is installed. The occupancy was known to increase both before and after the EMS installation. The moving average (ma) analysis was used to estimate savings and consumption growth after EMS installation. The other time series analyses produced similar results. The pre-EMS load increased at 82 kWh per day per year. The post-EMS load growth dropped to 30 kWh per day per year. The net load reduction was 52 kWh per day per year. The savings was 208 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 284 kWh per day, Net load decrease of 40 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=301 kWh per day, Net load decrease of 41 kWh per day per year

Both regressions contained only statistically significant coefficients.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.25	1.50	1.75	2.00	2.00	2.00	2.00	2.00	2.00

The confidence in these estimates is weak because:

- the pre-EMS load projection is during a time of rising occupancy.
- the savings increases exceed the savings in the billing data, which indicates that not all the post-EMS load reduction is negative degradation

PG&E 9.1

This unit is a school building. Load growth is evident both before and after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced estimates that showed a net increase in consumption after EMS installation. The pre-EMS load increased at 46 kWh per day per year. The post-EMS load growth dropped to 38 kWh per day per year. The net load reduction was 8 kWh per day per year. The savings was 133 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 189 kWh per day, Net load increase of 30 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=180 kWh per day, Net load increase of 19 kWh per day per year

With both regressions the pindate coefficients were not statistically different from zero.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.06	1.12	1.18	1.24	1.30	1.36	1.42	1.48	1.54

The confidence in these estimates is weak because:

- there is a large variability in the moving average and billing load factor.
- portables were added in the summers of 1996 and 1997

PG&E 9.2

This unit is a school office. Load growth is evident both before the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced estimates that showed greater reductions in consumption after EMS installation. The pre-EMS load increased at 117 kWh per day per year. The post-EMS load dropped at the rate of 61 kWh per day per year. The net load reduction was 178 kWh per day per year. The savings was 375 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 469 kWh per day, Net load reduction of 325 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=437 kWh per day, Net load reduction of 255 kWh per day per year

With both regressions the pre and indate coefficients were not statistically different from zero.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.47	1.95	2.00	2.00	2.00	2.00	2.00	2.00	2.00

The confidence in these estimates is weak because:

- while the data is well behaved, the load increases in the pre-EMS period are not apparent in the post period.
- the savings increases exceed the savings in the billing data, which indicates that not all the post-EMS load reduction is negative degradation

SCE Sites

SCE 1.1

This unit was dropped from the analysis because of a lack of pre-EMS data.

SCE 1.2

This unit was dropped from the analysis because EMS installation coincided with the installation of a new electric heat pump system. No first year savings were discernible.

SCE 2.1

This unit is a branch bank. There is little over one year of pre-EMS data. Some load growth is evident after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. The time series analyses produced estimates that showed similar trends. The pre-EMS load was estimated at 0 kWh per day per year. The post-EMS load growth was 7 kWh per day per year. The net load growth was 7 kWh per day per year. The savings was 49 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 154 kWh per day, Net load increase of 48 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=126 kWh per day, Net load increase of 44 kWh per day per year

With both regressions the pindate coefficients were not statistically different from zero.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.86	0.71	0.57	0.43	0.29	0.14	0.00	0.00	0.00

The confidence in these estimates is weak because:

- there little pre-EMS data to establish a trend.

SCE 2.2

This unit is a branch bank. Large variations in load are evident both before and after the EMS is installed. The moving average (ma) analysis was used to estimate savings and consumption growth. In opposition to the ma analysis the other time series analyses produced estimates with no change in consumption trends. The pre-EMS load growth was estimated at 13 kWh per day per year. The post-EMS load growth was 81 kWh per day per year. The net load growth was 68 kWh per day per year. The savings was 98 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 170 kWh per day, Net load reduction of 1 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings=169 kWh per day, Net load reduction of 1 kWh per day per year

With both regressions the pindate coefficients were not statistically different from zero.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The confidence in these estimates is weak because:

- there is very high variability in electrical use.
- the load growth exceeds the savings in the billing data
- The regression analyses show different trends from the moving average analysis

SCE 2.3

This unit had no discernible savings.

SCE 2.4

This unit is a branch bank. Energy consumption had been rising for four years prior to the EMS installation. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced estimates with similar savings but with nearly flat post-EMS load. The pre-EMS load was increasing 16 kWh per day per year. The post-EMS load growth was 2 kWh per day per year. The net load reduction was 14 kWh per day per year. The savings was 29 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 24 kWh per day, Net load growth of 4 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 15 kWh per day, Net load reduction of 1 kWh per day per year

None of the predictor coefficients were statistically different from zero for either regression model.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.48	1.97	2.00	2.00	2.00	2.00	2.00	2.00	2.00

The confidence in these estimates is weak because:

- the projected savings exceed twice the first year savings.

SCE 2.5

This unit had insufficient pre-EMS data to complete an analysis.

SCE 2.6

This unit is a branch bank. Energy consumption had been rising for two years prior to the EMS installation. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced similar estimate. The pre-EMS load was increasing 57 kWh per day per year. The post-EMS load growth was 13 kWh per day per year. The net load reduction was 44 kWh per day per year. The savings was 158 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 217 kWh per day, Net load reduction of 48 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 222 kWh per day, Net load reduction of 51 kWh per day per year

The indate coefficient was not statistically different from zero for either regression model.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.28	1.56	1.84	2.00	2.00	2.00	2.00	2.00	2.00

The confidence in these estimates is weak because:

- the projected savings exceed twice the first year savings.

SCE 2.7

This unit had no discernible savings.

SCE 2.8

This unit had no discernible savings.

SCE 2.9

This unit is a branch bank. Energy consumption had been nearly stable for three years prior to the EMS installation. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced substantially different estimates. The pre-EMS load was increasing 1 kWh per day per year. The post-EMS load reduction rate was 6 kWh per day per year. The net load reduction was 7 kWh per day per year. The savings was 92 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 26 kWh per day, Net load increase of 16 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 27 kWh per day, Net load increase of 16 kWh per day per year

None of the predictor coefficients were statistically different from zero for either regression model.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.08	1.15	1.23	1.30	1.38	1.46	1.53	1.61	1.68

The confidence in these estimates is moderate because:

- the variability in average is low except for the time of EMS installation.

SCE 2.10

This unit is a branch bank. Energy consumption had been nearly stable for three years prior to the EMS installation. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced similar estimates. The pre-EMS load was increasing 23 kWh per day per year. The post-EMS load increased at 10 kWh per day per year. The net load reduction was 13 kWh per day per year. The savings was 45 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 74 kWh per day, Net load reduction of 10 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 74 kWh per day, Net load reduction of 10 kWh per day per year

The pindate coefficient was not statistically different from zero in the xtday model.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.29	1.58	1.87	2.00	2.00	2.00	2.00	2.00	2.00

The confidence in these estimates is weak because:

- the savings growth exceeds twice the first year savings.

SCE 2.11

This unit had no discernible savings.

SCE 4.1

This unit is an office building. Energy consumption had been nearly stable for little over a year prior to the EMS installation. After EMS installation the occupancy fell. The occupancy has returned to full and the savings are slightly larger than that seen in the first year. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced similar estimates. The pre-EMS load trend is taken as 0. The post-EMS load increased by 7 kWh per day per year. The net load increase was 7 kWh per day per year. The savings was 191 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 79 kWh per day, Net load reduction of 22 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 106 kWh per day, Net load reduction of 35 kWh per day per year

The pindate coefficient was not statistically different from zero in the xtday model.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.96	0.93	0.89	0.85	0.82	0.78	0.74	0.71	0.67

The confidence in these estimates is moderate because:

- there is not a lot of variability once occupancy is stable.
- points of stable occupancy are known from management company and billing data.

SCE 4.2

This unit had no discernible savings.

SCE 4.3

This unit is an office building. It exhibits the same pattern as 4.1. Energy consumption had been nearly stable for little over a year prior to the EMS installation. After EMS installation the occupancy fell. The occupancy has returned to full and the savings are slightly larger than that seen in the first year. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses “blew up” and produced very high estimates of savings. The pre-EMS load trend is taken as 0. The post-EMS load dropped at 9 kWh per day per year. The net load reduction was 9 kWh per day per year. The savings was 180 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 617 kWh per day, Net load reduction of 92 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 557 kWh per day, Net load reduction of 76 kWh per day per year

Neither the pindate nor the indate coefficient was statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45

The confidence in these estimates is moderate because:

- there is not a lot of variability once occupancy is stable.
- points of stable occupancy are known from management company and billing data.

SCE 4.4

This unit is an office building. It exhibits the same pattern as 4.1 and 4.2 except that the savings are eliminated by load growth. Energy consumption had been nearly stable for little over a year prior to the EMS installation. After EMS installation the occupancy fell. The occupancy has returned to full and the savings are no longer seen in the data. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced very high estimates of savings. The pre-EMS load trend is taken as 0. The post-EMS load increased at 137 kWh per day per year. The net load increase was 137 kWh per day per year. The savings was 337 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 524 kWh per day, Net load increase of 97 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 519 kWh per day, Net load increase of 87 kWh per day per year

Neither the pindate nor the indate coefficient was statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.59	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00

In spite of the stability and known occupancy information, the confidence in these estimates is weak because:

- the consumption increases exceed the first year savings.

SCE 4.5

This unit had insufficient billing data for analysis.

SCE 4.6

The ma analysis for this unit is demonstrated by Figure G-4

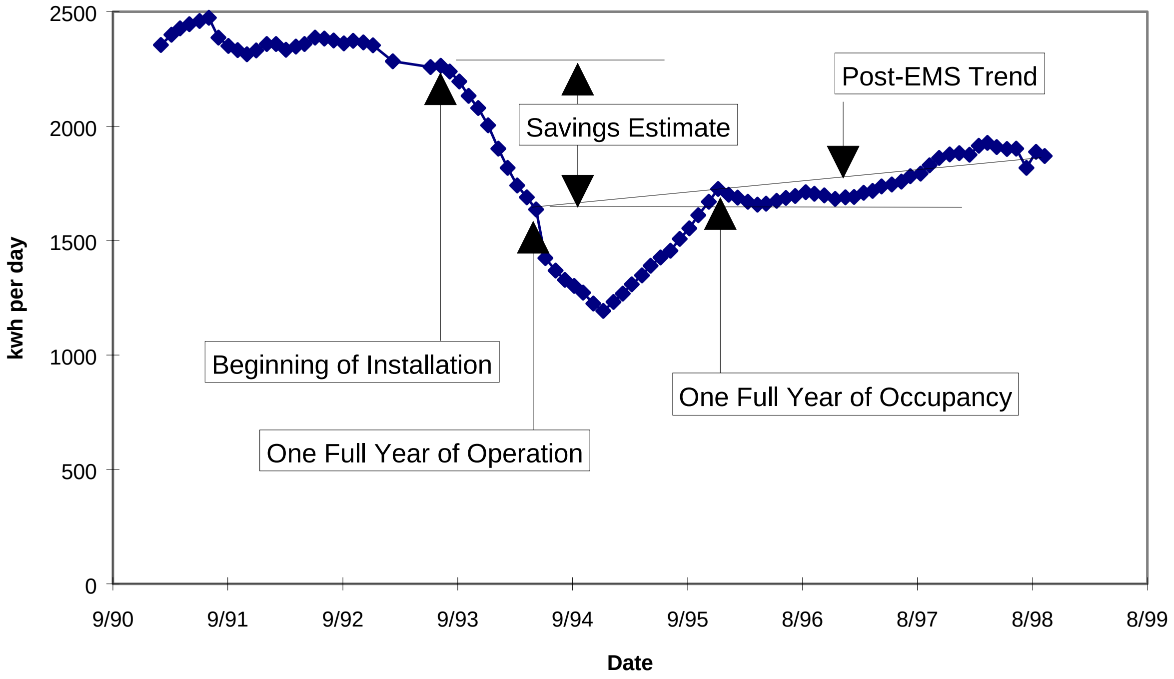


Figure G-4 SCE 4.6

This unit is an office building. It had a major occupancy change in the same time period as the EMS installation. Energy consumption had been nearly stable for a number of years prior to the EMS installation. After EMS installation the occupancy fell. The occupancy has returned to full. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced very high estimates of savings. The pre-EMS load trend is taken as 0. The post-EMS load increased at 53 kWh per day per year. The net load increase was 53 kWh per day per year. The savings was 623 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 1177 kWh per day, Net load increase of 110 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 1117 kWh per day, Net load increase of 113 kWh per day per year

Neither the pindate nor the indate coefficient was statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.91	0.83	0.74	0.66	0.57	0.49	0.40	0.32	0.23

The confidence in these estimates is weak because:

- the details on the occupancy changes are unknown.

SCE 4.7

This unit had insufficient data.

SCE 5.1

This unit is a corporate yard. Energy consumption had been rising for years prior to the EMS installation. After EMS installation the consumption dropped and the apparent savings increased over about 6 months. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced similar estimates. The pre-EMS load trend was increasing consumption at the rate of 15 kWh per day per year. The post-EMS load dropped at 9 kWh per day per year. The net load reduction was 24 kWh per day per year. The savings was 93 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 200 kWh per day, Net load reduction of 31 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 182 kWh per day, Net load reduction of 27 kWh per day per year

Neither the pindate nor the indate coefficient was statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.27	1.54	1.81	2.00	2.00	2.00	2.00	2.00	2.00

The confidence in these estimates is weak because:

- the savings exceed two times the first year savings.

SCE 5.2

This unit is a police and fire station. Energy consumption had fallen for two years prior to the EMS installation. After EMS installation the consumption dropped and remained essentially constant. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced similar estimates. The pre-EMS load trend was dropping consumption at the rate of 49 kWh per day per year. The post-EMS load increased at 4 kWh per day per year. The net load increase was 53 kWh per day per year. The savings was 212 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 332 kWh per day, Net load increase of 31 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 250 kWh per day, Net load increase of 38 kWh per day per year

Neither the pindate nor the indate coefficient was statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.75	0.50	0.25	0.00	0.00	0.00	0.00	0.00	0.00

The confidence in these estimates is weak because:

- the net load growth exceeds the savings in the billing data, which indicates that the pre-EMS load growth would not have continued.

SCE 5.3

This unit is a public library. The old air conditioning system was replaced a year prior to the EMS installation. The analysis begins at that point with the pre-EMS trend taken as 0. After EMS installation the consumption dropped and remained essentially constant. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses produced higher estimates of savings and predicted savings growth. The post-EMS load increased at 7 kWh per day per year. The net load increase was 7 kWh per day per year. The savings was 115 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 457 kWh per day, Net load reduction of 183 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 228 kWh per day, Net load reduction of 50 kWh per day per year

Neither the pindate nor the indate coefficient was statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
0.94	0.88	0.82	0.76	0.70	0.63	0.57	0.51	0.45

The confidence in these estimates is weak because:

- of the confounding factor in the pre-EMS years.

SCE 5.4

This unit is a neighborhood center. The consumption was stable for over a year prior to the installation of the EMS. The analysis begins at that point with the pre-EMS trend taken as 0. After EMS installation the consumption dropped and remained essentially constant. The moving average (ma) analysis was used to estimate savings and consumption growth. The other time series analyses “blew up” and produced excessive estimates of savings and predicted savings growth. The post-EMS load dropped at 2 kWh per day per year. The net load reduction was 2 kWh per day per year. The savings was 236 kWh per day.

A linear regression based on kWh per day and time (reg) provided these alternative estimates: Savings = 1198 kWh per day, Net load reduction of 623 kWh per day per year.

Time series cross sectional analysis (xtday) which includes the monthly effect provided these alternative estimates:
Savings= 710 kWh per day, Net load reduction of 298 kWh per day per year

The indate coefficient was not statistically different from zero in the regressions.

The TDFs for this unit:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10
1.01	1.02	1.03	1.03	1.04	1.05	1.06	1.07	1.08

The confidence in the moving average estimates is moderate because:

- there is low variability in the data.
- pre-EMS changes in the building are known and have settled out by the beginning of the analysis.

SCE 6.1 and 6.2

There are no discernible savings on these units.

SCE 7.1, 7.2, 7.3, 7.4, and 7.5

There are no discernible savings on these units. The data is confounded by a general remodeling and the addition of air conditioning. All these buildings show a trend of load growth after the remodeling.

SCE 8

There is no discernible savings on this unit.

SCE 9

There is no discernible savings on this unit.

Sites Dropped form Final Analysis

The database for analysis included 51 installations. Forty of these were used for the final analysis; eleven were dropped from analysis. Table G-1 presents the reasons these eleven sites were dropped.

Table G-1 Reasons Sites Dropped from Analysis

Site	Reason Site Dropped from Analysis
PG&E 3.2	Insufficient pre-data
PG&E 6.1	Insufficient pre-data
PG&E 6.2	Insufficient pre-data
PG&E 6.3	Insufficient pre-data
SCE 1.1	Insufficient pre-data
SCE 2.05	Insufficient pre-data
SCE 2.12	Usage data not obtained
SCE 213	Usage data not obtained
SCE 7.3	Extensive retrofits
SCE 7.4	Extensive retrofits
SCE 7.5	Extensive retrofits

APPENDIX H SUMMARY OF PERSISTENCE STUDIES

Summary of Persistence Studies

There are five persistence studies. The short titles and abbreviations are: *Persistence 1* (P1), *Persistence 2* (P2), *Persistence 3A* (P3A), *Persistence 3B* (P3B), and *Neg-TDF Supplement* (PNg). Full references are given in Section 8.

Persistence 1 & 2 In *Persistence 1* and *Persistence 2*, an in-depth search of existing information was performed and the results were used to synthesize estimated TDFs. *Persistence 1* covered thirteen measures and *Persistence 2* covered twelve additional measures. The other persistence studies did not introduce any additional measures; they refined the TDFs for these measures. These 25 measures are labeled M01-M25 in this appendix, Table H-1 & Table H-2.

Neg-TDF Supplement Originally the TDFs of measures that were estimated to improve over time relative to the baseline (negative TDFs) were set equal to one (1.00). In *Persistence 1* and *Persistence 2* there were four such measures. In the *Neg-TDF Supplement* report, existing information was used to calculate TDFs for these four measures. The results of this study are included in Table H-2 below.

Persistence 3A The second stage of the first two studies involved developing research plans for assessing technical degradation for those measures where substantial uncertainty was found in stage one. In *Persistence 1& 2*, further research plans were developed for two and five measures respectively. CADMAC agreed to accept further TDF research of the three measures included in Persistence 3 studies in lieu of further study of the remaining four measures. In this report, *Persistence 3A*, new research was conducted and a new TDF based on this research was estimated for two these measures: commercial package direct expansion air conditioners and energy management systems. The results of this research are included in Table H-2 below.

Persistence 3B The third measure, compressors and compressed air distribution systems is the focus of *Persistence 3B*. The study is incomplete, however, the TDF is fixed at 1.00 by the protocols. The TDFs used for resource value calculations will not be changed by the results of this study.

Summary Tables

Table H-1 below lists all 25 measures studied in the Persistence Studies. Table H-2 below displays the TDFs estimated in *Persistence 1* & *Persistence 2* as modified by all subsequent reports.

The summary report of the Persistence Study is: *Summary Report of Persistence Studies: Assessmsnts of Technical Degradation Factors, Final Report*; CADMAC Report #2031P. Those using the Persistence Studies for resource value calculations under CADMAC protocols should refer to this report.

Table H-1 Study Measures

Measure #	High Efficiency Measure	Baseline Technology	Ref. Reports
M01	Residential Central A/C - high efficiency.	Standard SEER A/C	P1, PNg
M02	Commercial A/C - Package DX	Standard efficiency unit	P1, P3A
M03	Oversized evaporative cooled condenser	Air cooled condenser	P1
M04	Refrigerator 10-30% better than std.	Standard efficiency refrigerator	P1, PNg
M05	Electronic Ballast	Efficient magnetic ballast	P1
M06	T8 with electronic ballast	T12 w/efficient magnetic ballast.	P1
M07	Optical Reflector, delamp	Standard fixture	P1
M08	HID interior Metal Halide 250-400W	Mercury vapor 400-1000W	P1
M09	Occupancy Sensor	On/off switch	P1
M10	Motor - high efficiency	Standard efficiency motors	P1
M11	Adjustable Speed Drive for HVAC Fan	Variable inlet vanes or damper	P1
M12	Infra-red Gas Fryer	Standard atmospheric fryer	P1
M13	Residential ceiling insulation	Standard levels attic insulation	P1
M14	LED exit signs	Incandescent exit signs	P2
M15	Process adjustable speed drives — waste water pumps	Inlet vane throttling on waste water pumps	P2, PNg
M16	Process adjustable speed drives — injection molding machines	Standard injection molding machines	P2
M17	Fiberglass batt R-15 wall and R-19 floor insulation	R-13 fiberglass batt wall and floor insulation	P2
M18	Switched or stepped daylighting controls	Standard manual lighting controls	P2
M19	Dimmable daylighting controls	Standard manual lighting controls	P2
M20	Agricultural pump repair or replacement	Existing agricultural pump	P2, PNg
M21	Variable air volume HVAC distribution system	Constant air volume HVAC distribution system	P2
M22	Energy management systems	Manual operation	P2, P3A
M23	New air compressors	Existing air compressors	P2, P3B
M24	High efficiency compressed air distribution system	Standard efficiency compressed air distribution system	P2, P3B
M25	13 watt hard-wired compact fluorescent downlights	Incandescent downlights	P2

Table H-2 Summary of TDFs

M# YEAR	M01 Resid DX AC	M02 Comm DX AC	M03 Oversized Evap Condens	M04 Resid Refrig	M05 Electronc Ballasts	M06 Elect Bal T8 lamps	M07 Optical Reflectrs	M08 HID fixtures	M09 Occupancy Sensors	M10 High Effic Motors	M11 ASD HVAC Fan	M12 Infrared Gas Fryer	M13 Resid Ceiling Insulation
1*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	0.98	1.04	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
3	1.01	1.00	0.96	1.06	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
4	1.01	1.01	0.93	1.07	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
5	1.02	1.01	0.91	1.08	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
6	1.02	1.01	0.89	1.08	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
7	1.03	1.01	0.87	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
8	1.03	1.01	0.84	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
9	1.04	1.01	0.82	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
10	1.04	1.02	0.80	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
11	1.05	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
12	1.05	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
13	1.06	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
14	1.07	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
15	1.07	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
16	1.08	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
17	1.09	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
18	1.09	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
19	1.10	1.06	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
20	1.10	1.08	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00

* First year savings are one (1.00) by definition. The TDF modifies the first year savings for subsequent years.

Table H-2 Summary of TDFs (continued)

M# YEAR	M14 LED exit	M15 ASD Pump	M16 ASD IMM	M17 Wall&Flr Insul	M18 Stepped DLighting	M19 Dimmable DLighting	M20 Ag Pump	M21 VAV	M22 EMS	M23 Cmpr	M24 Cmpr Air Dist Sys	M25 CFL Downlite
1*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	0.98	1.00	1.00	0.73	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	1.00	0.91	1.00	1.00	0.61	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	0.74	1.00	1.00	0.54	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	0.57	1.00	1.00	0.48	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	0.50	1.00	1.00	0.43	1.01	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	0.48	1.00	1.00	0.39	1.01	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	0.47	1.00	1.00	0.36	1.01	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	0.47	1.00	1.00	0.33	1.01	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	0.47	1.00	1.00	0.31	1.01	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	0.47	1.00	1.00	0.29	1.01	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	0.47	1.00	1.00	0.27	1.01	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	0.47	1.00	1.00	0.26	1.01	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	0.47	1.00	1.00	0.24	1.02	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	0.47	1.00	1.00	0.23	1.02	1.00	1.00	1.00	1.00	1.00
16	1.00	1.00	0.47	1.00	1.00	0.23	1.02	1.00	1.00	1.00	1.00	1.00
17	1.00	1.00	0.47	1.00	1.00	0.22	1.02	1.00	1.00	1.00	1.00	1.00
18	1.00	1.00	0.47	1.00	1.00	0.21	1.02	1.00	1.00	1.00	1.00	1.00
19	1.00	1.00	0.47	1.00	1.00	0.21	1.02	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	0.47	1.00	1.00	0.20	1.02	1.00	1.00	1.00	1.00	1.00

* First year savings are one (1.00) by definition. The TDF modifies the first year savings for subsequent years.