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Review and Analysis of an Energy Efficiency Incentive Program for Commercial Buildings

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ABSTRACT

A program with 13 participants provided reimbursement for improvements to decrease energy use largely in commercial and not-for-profit buildings but also in two government buildings. Electricity and natural gas savings were determined by modeling the energy use by accounting for changes in weather for the 12 months previous to the improvements, and then predicting energy use for the 12 months immediately after the improvements using the same model.

The threshold for verifiable energy savings resulting from building improvements was a maximum uncertainty of 50% at the 68% confidence level. Improvements involving original furnace or air conditioner replacement resulted in significant and verifiable reductions in energy use. Energy savings due to lighting improvements were verified for only one of seven buildings in which lighting was upgraded. Verifiable results were obtained in buildings with constant usage patterns, hours of operation, and equipment. Significant changes not related to weather, and improvements resulting in less than 10% savings of the total energy measured at the meter led to non-verifiable results.

Other benefits of the program not related to energy cost savings included increasing illumination while maintaining the same electricity use, and improving comfort and noise reduction with additional insulation. The program was very successful in leveraging significant private investment for building improvements. In addition, the program inspired business owners to make further improvements voluntarily after the program ended and also increased interest in similar future programs.

INTRODUCTION

Between 1990 and 2005, the U.S. increased its overall consumption of energy at a rate of 0.7% per year and increased its consumption of electricity at a rate of 2.3% per year (USDOE, 2006). This increased electricity use has narrowed the margin between utility production capacity and demand, particularly in the summertime, and has put a strain on the transmission and distribution systems currently in place (Harrell and Kulkarni, 2004). Consumer energy efficiency and conservation plays an important and cost-effective role in relieving this strain on infrastructure as well as improving health and environmental conditions, especially where electricity is generated from fossil fuels. Major thermal losses in the steam power cycle and further minor losses in plant usage, transmission, and distribution amplify the effects of energy conservation at the point of use. In 2005, the overall conversion efficiency of primary energy to delivered electricity was 31.4%; therefore, on average, for each unit of delivered electricity saved, 3.18 units of primary fuel energy are left unconsumed (USDOE, 2007). These conversion losses are likely to decrease over time as new higher efficiency plants, such as combined or super-critical cycle, are brought online.

Because of the previously-listed disadvantages of using energy from fossil fuels, there have been many incentives or programs created to encourage the conservation of energy. Kinney and Lee (2000) reported on a substantial renovation of a major luxury hotel in Singapore. The renovation included the replacement of an older air conditioning system that had lost capacity and efficiency when it was converted to operate with a different refrigerant. Replacing this system decreased the energy used by 36% from 0.75 to 0.48 kW/ton (4.7 to 7.3 COP). The hotel also removed incandescent bulbs from all light fixtures and lamps and replaced them with compact fluorescent bulbs. The improvements showed that such renovations will pay for themselves within three years.

Höglund (1981) reported on a project to remodel many apartments in Stockholm, Sweden built in the 1930's and 1940's. The apartment buildings were remodeled to determine the specific effects of each modification. Boiler efficiency was improved, windows and doors were weatherproofed, the heating control system in each apartment was augmented, and insulation was added in the attic and on the external walls. The study determined that additional insulation of external walls resulted in the greatest energy savings, and that all the modifications were cost effective, with the additional insulation in the attic being the most economically profitable. The one building in which 100% of the proposed modifications were performed decreased the annual heating oil use per unit of floor area by 47% from 1.5 to 0.79 gal/ft^2·yr (60 to 32 L/m^2·yr).

Wirdzek and Good (1996) presented a project of energy and environmental conservation for the 1 million ft^2 (92,900 m^2) headquarters building of the EPA. The project included efficient lighting, air conditioners, and cooling towers, as well as variable-speed fans, solar hot water, and water-saving sinks and shower heads. The project completed these modifications because they promised a return on the investment of at least the prime rate plus 6%. Energy savings were estimated at more than 9,000,000 kWh of annual electricity consumption.

Horowitz (1989) did a follow-up study of utility-sponsored, low-cost energy audits to commercial buildings in the northeast section of the U.S. The study examined how many and which of the recommended measures from the energy audits were implemented one or two years after the audit. The study found that 33% of the recommendations were implemented within one year after the audit, and another 10% were implemented in the second year. The study concluded that the commercial buildings studied had a slower increase in energy consumption compared to the average, and approximately 20% of the buildings experienced a decline in consumption.

This article presents the analysis and results of a program that encouraged improvements in commercial and not-for-profit organization buildings that would decrease, or slow the increase of, energy use. The article discusses the modifications that were done to each building and the energy and economic savings resulting from the modifications. The results of this article will assist future programs that encourage the reduction of energy consumption by identifying the improvements that noticeably reduce energy use, the improvements that have slight effects, and the improvements that have no noticeable effects or negative effects.

PROGRAM

The program was administered by the Rebuild Carbondale Community Energy Program in Carbondale, IL, and was sponsored by a grant from the Illinois Department of Commerce and Economic Opportunity (DCEO) and the U.S. Department of Energy's (USDOE) Rebuild America program. Under the terms of the grant, funding was allocated to promote energy efficiency and conservation in business and non-profit facilities in Carbondale and also the government facilities of neighboring Union County. The businesses in the city are mainly retail stores, restaurants, hotels, and professional offices. Union County government offices included the courthouse, emergency services, office buildings, and maintenance facilities. $21,500 was allocated for facility improvement grants matching up to 50% of the total project costs. This funding was split: $13,500 for Carbondale facilities, and $8,000 for Union County facilities. The common award was $1,000; however, two participants with large, costly projects in Carbondale received nearly $2,500 each, while one small project received $500. The Union County funds were split between two facilities with one receiving $6,000 and the other $2,000.

An applicant was allowed to be the owner or tenant of the building, so long as they were paying the energy bills and would be able to capture any energy savings. Many building owners applied because the program helped them to purchase new equipment and reduce utility costs. One tenant applied because they had secured an economically favorable, long-term lease of the building if they paid for substantial remodeling, including energy-efficient improvements. Other tenant applicants were not-for-profit organizations, such as churches.

PARTICIPANTS AND IMPROVEMENTS

The participating organizations encompassed a wide variety of buildings types, including retail stores, manufacturing, professional and government offices, service businesses such as hotels and restaurants, and not-for-profit organizations such as churches and a student faith center. No applicants were rejected for this program; however, two applicants chose not to participate in the program when it was learned that the improvements must have a greater efficiency than the minimum requirements. Another applicant never installed a high efficiency air conditioner as intended; therefore, they received no funds and were considered a non-participant.

Improvements were classified into three categories: (1) lighting, (2) heating and cooling, and (3) building envelope. The lighting category included the remodeling of older fixtures using T-12 fluorescent bulbs with T-8 fluorescent bulbs, or the replacement of regular incandescent bulbs with compact fluorescent bulbs. In addition, one participant installed light tubes which brought in natural daylight from the roof into the building. Improved heating and cooling systems included the addition of high efficiency furnaces or air conditioners and HVAC control systems, such as set-back thermostats or electronic controls. Improvements to the building envelope included double pane windows, insulated doors, or additional insulation.

Table 1 shows all the participants of the program, the types of improvements made, the total cost of the improvements, and the amount of funds reimbursed by the program. As shown, there were five non-county participants who completed major renovations that incurred significant cost. These participants were likely intending to make improvements to the building independent of the program. However, the program encouraged the significant remodeling of these buildings, including renovations that resulted in greater gains in energy efficiency than in a typical remodeling project. In addition, the off-campus student faith center was required to obtain funds from a regional governing body to perform large improvements on their HVAC system. The funds were more easily obtained when the regional governing body was informed of matching funds coming from this program.

Table 1. Participants, Projects, and Grants

Participant	Floor Area (ft^2)	Energy-Related Improvements	Total Project Costs ($)	Grant Award ($)
Student Faith Center	13,260	Modulated boiler, improved ventilation, and replace pneumatic controls with electric controls	$ 183,800	$ 2,494
Grocery Store	12,000	High efficiency furnace and air conditioner, insulation below roof, light tubes, high efficiency lighting	$ 126,924	$ 2,494
Hardware Store	28,000	Replace T-12 with T-8 fluorescent lighting and LED exit signs	$ 75,991	$ 1,000
Orthodontist	3,050	New lighting, high efficiency air conditioner, and programmable thermostats	$ 38,749	$ 1,000
Psychologist	2,000	Double pane windows, insulation in walls, high efficiency furnace	$ 26,189	$ 1,000
County Building 1	8,752	Replace T-12 with T-8 fluorescent lighting and repaired steam system insulation, condensate receiver, and traps	$ 12,255	$ 6,000
County Building 2	1,504	Replaced old furnace with 92% eff. Gas furnace and new 3-ton A/C. Replaced supply duct with insulated duct.	$ 5,948	$ 2,000
Restaurant	1,520	Double pane window, insulated door, attic insulation	$ 5,755	$ 1,000
Light Industrial	8,750	Replace T-12 with T-8 lighting and programmable thermostats	$ 2,690	$ 1,000
Attorney	4,600	Replace T-12 with T-8 fluorescent lighting	$ 2,200	$ 1,000
Church 2	19,819	Instantaneous, point-of-use hot water heaters and compact fluorescent bulbs	$ 2,121	$ 1,000
Church 1	27,169	Compact fluorescent bulbs and delamping of classrooms	$ 2,092	$ 1,000
Hotel	95,840	Compact fluorescent bulbs immediately outside and in the foyer and in rooms as incandescent bulbs burn out	$ 1,996	$ 500
Totals	226,264		$ 486,710	$ 21,488
Investment per unit area ($/ft^2$)			$ 2.151	$ 0.095
Investment Ratio, Total-to-Grant			22.65	

DETERMINATION OF ENERGY SAVINGS

Terminology and methodology for the measurement of energy savings resulting from energy efficiency projects is presented in the International Performance Measurement and Verification Protocol (IPMVP) (EVO, 2007) and by ASHRAE Guideline 14 (ASHRAE, 2002). Each describes a method for determining whole-building energy savings using monthly utility billing information. When calculating savings by comparing energy use before and after an energy conservation measure (ECM) is implemented, the effects of influential factors such as weather, occupancy, or process output must be included in order to have reasonable certainty in the results. To account for weather effects, the energy use (electricity and natural gas) during a 12-month, pre-retrofit baseline period was described in terms of daily mean outdoor air temperature using a statistical model fitted by a least-squares linear regression. Air temperature data was obtained from the local airport weather station where the daily mean value used was calculated from hourly observations. The error of each modeled data point was weighted by the length in days of the utility billing period. Next, the baseline energy use was projected forward by feeding the model with the daily mean air temperature associated with a 12-month post-retrofit period. Avoided energy use due to the ECMs was then estimated by subtracting the actual energy use during the post-retrofit period from this projected baseline energy use. In order to avoid misleading results, any determination of energy savings was accompanied by an estimate of the associated uncertainty, which was quantified at the 68% confidence level from the model's goodness-of-fit to the baseline data. Sources of uncertainty include baseline model error and changes to building usage patterns between the baseline and post-retrofit periods. These changes could include building operating hours, occupancy level, or unknown new equipment. Adherence to ASHRAE Guideline 14 requires that the maximum uncertainty be 50% of the estimated savings at the 68% confidence level. Both ASHRAE Guideline 14 and the IMPVP recommend that anticipated energy savings should exceed 10% of whole-building baseline energy use in order to be able to determine savings with reasonable certainty using this method. Because outdoor temperature was a significant factor in energy use, the baseline and post-retrofit periods each extended over one full years in order to avoid statistical bias in the results.

RESULTS AND DISCUSSION

Summary of results

Table 2 summarizes the savings in electrical and natural gas usage, where applicable, with positive values representing savings and consequently a decrease in usage. Bold values represent verifiable results indicating a maximum of 50% uncertainty in the savings at the 68% confidence level. Nominal values not bold are shown for completeness but are not verifiable results; i.e., the uncertainty was greater than 50% of the estimated savings. The baseline period data shown are actual usage values, while the post-retrofit period data shown are estimated savings calculated by subtracting the actual usage during the post-retrofit period from the *projected* baseline usage.

Table 2. Energy and cost savings sorted descending by total cost savings (verifiable results in bold, negative results in parentheses)

Participant	Actual Baseline Period Usage			Calculated Post-Retrofit Period Savings & Uncertainty		
	Natural Gas	Electricity	Total Cost	Natural Gas	Electricity	Total Cost
	($thm/ft^2 \cdot yr$)	($kWh/ft^2 \cdot yr$)	($\$/ft^2 \cdot yr$)	($thm/ft^2 \cdot yr$ $\pm U_{@68\%C}$)	($kWh/ft^2 \cdot yr$ $\pm U_{@68\%C}$)	($\$/ft^2 \cdot yr$ $\pm U_{@68\%C}$)
County Building 2	0.663	7.741	$ 1.258	**0.307 ± 0.043**	**2.446 ± 0.354**	**$ 0.838 ± 0.096**
Psychologist	0.741	7.277	$ 1.595	**0.337 ± 0.069**	0.554 ± 0.355	**$ 0.371 ± 0.073**
Student Faith Center	0.353	5.361	$ 0.904	0.012 ± 0.032	0.798 ± 0.637	$ 0.125 ± 0.124
Attorney	0.272	11.409	$ 1.440	**0.049 ± 0.016**	(0.278) ± 0.502	$ 0.040 ± 0.024
Hotel	#N/A	4.804	$ 0.313	#N/A	0.335 ± 0.179	$ 0.023 ± 0.012
County Building 1	0.229	12.729	$ 0.868	(0.020) ± 0.013	**0.497 ± 0.218**	$ 0.017 ± 0.073
Light Industrial	0.112	2.721	$ 0.455	(0.002) ± 0.019	(0.235) ± 0.200	$ (0.027) ± 0.052
Church 1	0.385	6.028	$ 0.512	0.019 ± 0.024	**(0.338) ± 0.157**	$ (0.053) ± 0.173
Restaurant	0.290	2.598	$ 0.843	0.017 ± 0.053	**(1.246) ± 0.180**	$ (0.108) ± 0.225
Church 2	0.224	3.377	$ 0.664	0.000 ± 0.020	(0.607) ± 0.440	$ (0.109) ± 0.134
Hardware Store	0.113	15.967	$ 1.307	**(0.087) ± 0.007**	(0.532) ± 0.327	**$ (0.178) ± 0.022**

County Building 2

County Building 2 made significant improvements by installing a high efficiency air conditioner and natural gas furnace, replacing the original equipment. The results of the model, shown in Figures 1 and 2, showed significant, verifiable savings of natural gas and electricity from the improvements. This reduction is particularly noticeable during the height of the heating and cooling seasons when the new equipment was heavily utilized, while the other months, utility usage remained approximately the same as previous.

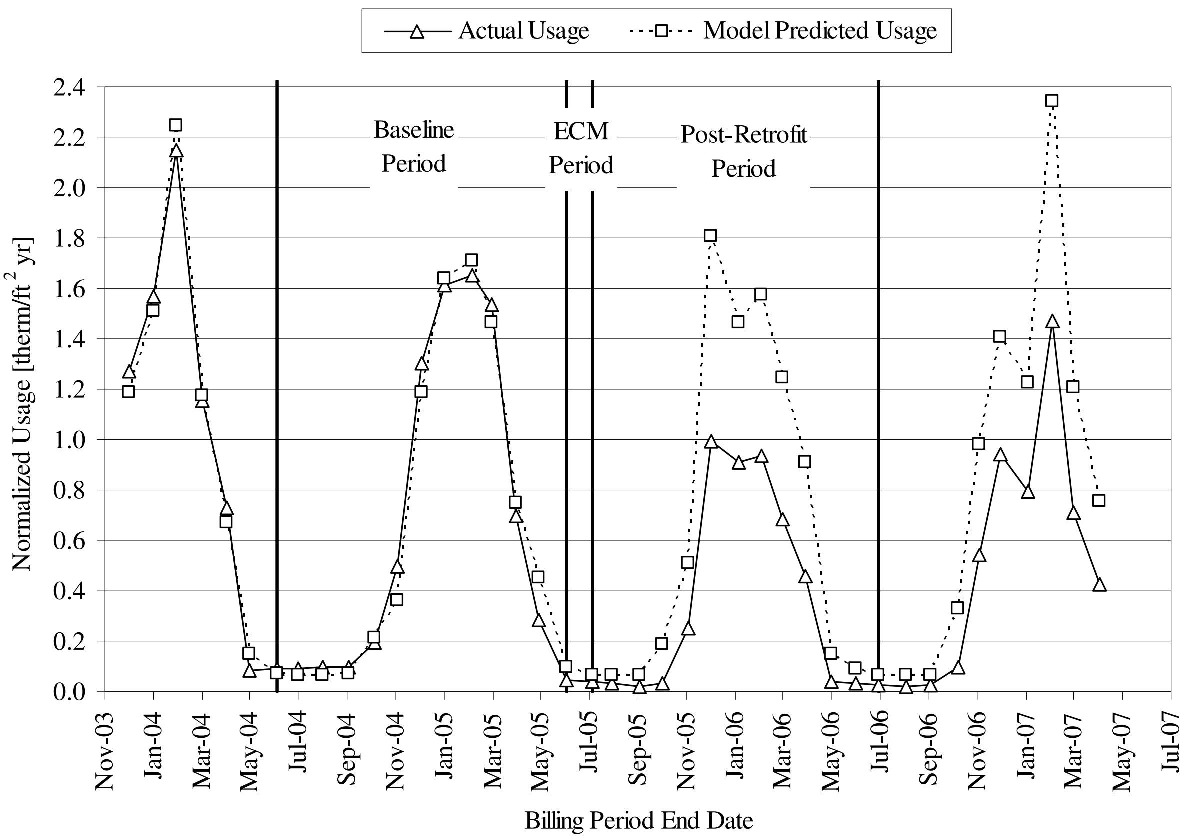

Figure 1. Actual and predicted natural gas usage rates of County Building 2

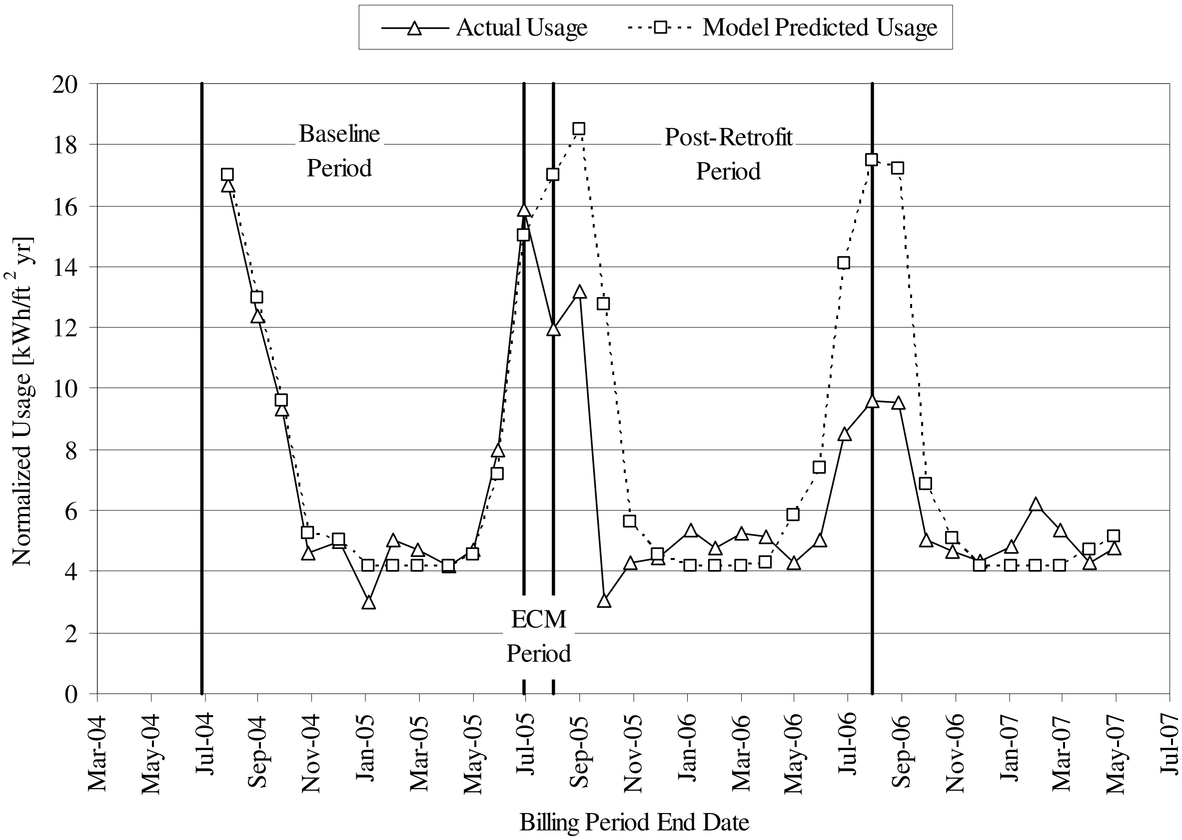

Figure 2. Actual and predicted electric usage rates of County Building 2

Psychologist

Improvements to the psychologist's building were made in two stages: first, a 93% high efficiency furnace and set-back thermostats were installed in October 2005, and then wall insulation and double-pane windows were installed in April 2006. Figure 3 shows the decrease in natural gas use compared to that predicted by the model. Table 2 shows verifiable savings in natural gas usage resulting from all improvements done, particularly the high efficiency furnace. The insulation and double pane windows decreased electrical use from air conditioning, but due to fluctuations in electrical use of the baseline data, the nominal electrical savings were not verifiable.

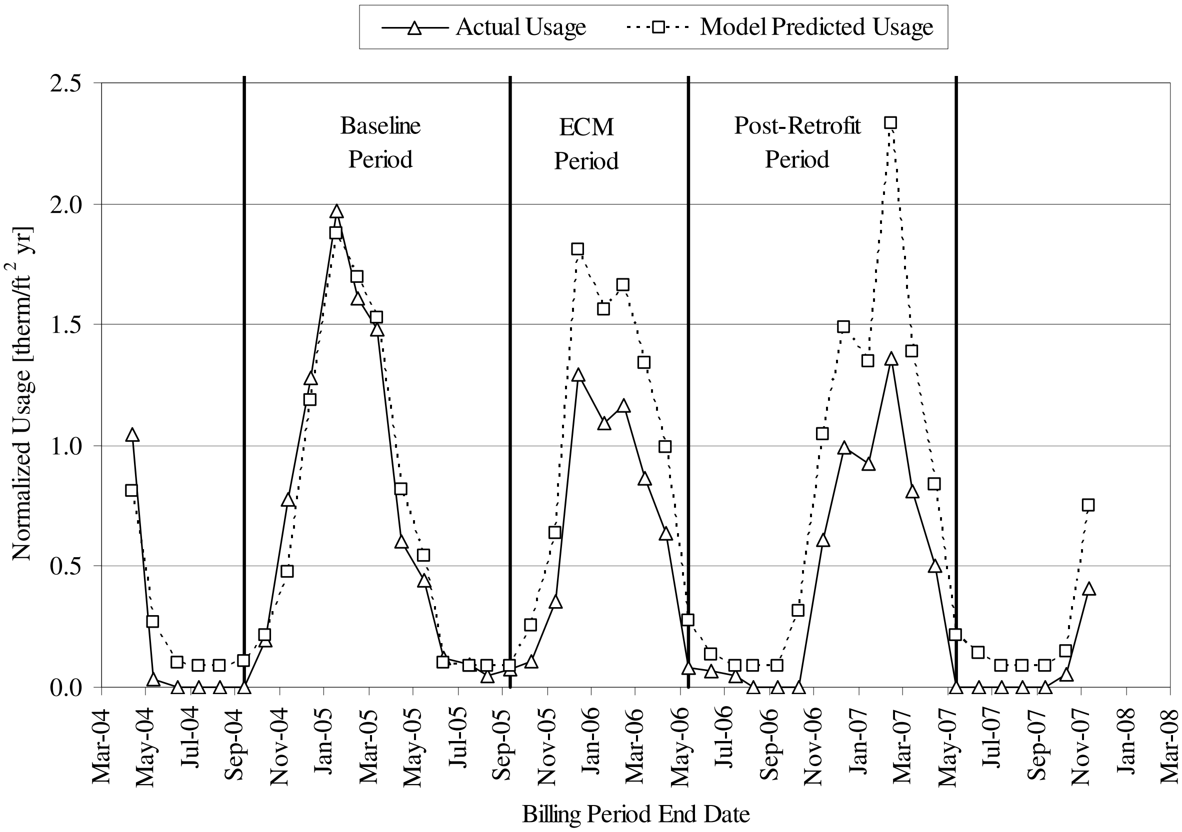

Figure 3. Actual and predicted natural gas usage rates of psychologist building

This participant was likely to make improvements without receiving funds from the program; however, the program strongly encouraged the choice of a high efficiency furnace and additional wall insulation when the old furnace and siding was replaced. In addition, the building is now much quieter with less noise from the cars outside. It is also quieter between rooms in the building, there was no insulation installed in interior walls, but the insulation in the exterior walls greatly reduced reverberations and therefore the noise exiting the rooms, improving patient/client confidentiality. The setback thermostat reduced the additional tasks needed to be done by the employees opening and closing the building.

Student Faith Center

The student faith center differs from churches in that the building has more occupants during normal business hours, such as students stopping by between classes. It also has more activities during the evenings and weekends, in addition to regular religious services on Sundays.

The original heating and control system needed to be replaced. Two new modulated boilers comprised less than one-fourth of the floor area of the original boiler, which they replaced. To utilize the same exhaust flue, the two new boilers were higher efficiency than required by energy codes but were not highest efficiency, condensing boilers which utilize PVC pipes for the flue. During the initial meeting with the director of the building, the pneumatic control system could be heard leaking air and it was determined that the 1.25 hp (0.93 kW) motor of the air compressor operated constantly; consequently, a new electronic control system was installed.

Nominally, there was a very small natural gas and relatively significant electricity savings. However, energy use of the building was noticeably related to the university class schedule, not accounted for in the model, the model did not as accurately predict baseline energy use as in other buildings, particularly when class was not held. This variability resulted in savings that were not verifiable.

Attorney

The attorney building also made lighting improvements through removal of magnetic ballasts and T-12 bulbs in favor of electronic ballasts and T-8 bulbs. The model results showed a nominal but unverifiable increase in electrical usage. It also predicted a decrease in natural gas usage that was verifiable, but not possible to explain from improvements of this project since it only involved items using electricity.

Hotel

The hotel replaced all the incandescent bulbs with compact fluorescent bulbs (CFLs) in the foyer and outside. CFLs were installed in hotel rooms as incandescent bulbs burned out. The lights in the foyer were left on almost constantly while the outside lights were left on all night; therefore, the greatest potential for electrical savings occurred with these lights. Another advantage was that these bulbs were difficult to change because of their height above the ground; the longer-lasting CFLs require less frequent changing. Table 2 shows a noticeable savings that was not verifiable for electrical usage. The primary difficulty in the analysis of the energy data resulted from no available occupancy data before or after improvements. Gas usage data was not collected for this facility.

County Building 1

County Building 1 also made lighting improvements from magnetic ballasts and T-12 bulbs to electronic ballasts and T-8 bulbs. This was done since many lenses on the lights had become discolored and needed to be replaced. Also, the building used steam for heating and insulation of the steam pipes had not been replaced in some locations after repairs to the heating system, thus insulation was added in those locations. The results of the model showed a verifiable savings in electricity use resulting from the lighting improvement and showed a non-verifiable increase in natural gas use. This is the only example of recognizing savings in electrical use, as seen in Figure 4, from modifying lighting from T-12 to T-8. This was only noticeable in a building with very constant operating hours and usage patterns.

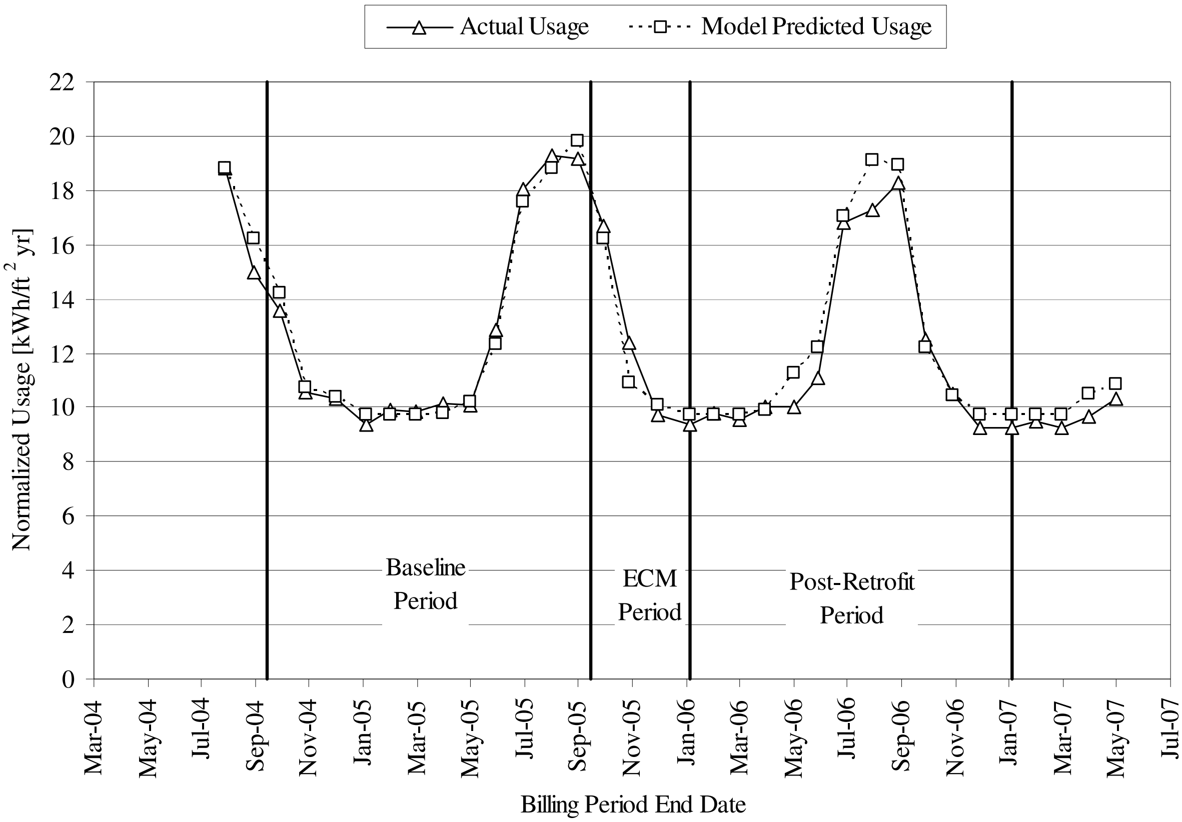

Figure 4. Actual and predicted electricity usage rates of County Building 1

<u>Light Industrial</u>

The light industrial building replaced all the magnetic ballasts and T-12 fluorescent bulbs with electronic ballasts and T-8 bulbs and installed a setback thermostat. The occupants previously turned the thermostat down when the building was unoccupied; consequently, the improvement of a set-back thermostat did not change the natural gas usage, but simplified the opening and closing of the building, and provided warmth at the beginning of the workday. Energy use patterns varied with other factors, likely increases in production, besides weather conditions leading to non-verifiable results, and nominal results showed slight increases in both electricity and natural gas. The building was not fully conditioned or lighted making the baseline usage values low as compared to other buildings as shown in Table 2.

Church 1

Church 1 installed many CFLs and delamped certain classrooms that had light intensity readings nearly twice as high as suggested. The improvements should have only affected electrical use which actually showed a small, verifiable increase, perhaps due to changes in building operation. The results from Church 1 highlight the difficulty in recognizing changes in energy usage after improvements, particularly in buildings where energy usage patterns fluctuate with many factors besides weather.

Restaurant

The restaurant installed replacement, double pane windows, insulated doors, and insulation in the attic, while at the same time making improvements to the exterior of the building. The restaurant changed hours of operation from being only open on the evening weekends for a total of 6 hours per week before improvements to 56 hours per week after improvements and also purchased another freezer during the improvements. The increase in hours of operation resulted in significant increase in electrical use as expected. Gas usage measured only the heating to the building since a separate gas meter was dedicated to the cooking equipment. The double pane windows, insulated door, and attic insulation likely resulted in the small natural gas savings in Table 2, though the result was not verifiable.

Church 2

The Rebuild Carbondale personnel suggested to Church 2 to remove an old, natural gas, water heater and install electric, point-of-use water heaters because usually, small amounts of hot water were needed in the kitchen and bathrooms, except for a couple large activities each year. The suggestion intended to stop natural gas use from standby losses of the old, water heater. Church 2 unfortunately only had the funds available to install the electric, water heaters in the bathrooms on the ground floor and the kitchen, thus requiring the natural gas, water heater to remain operational for the bathrooms on the two floors above. This "improvement" unfortunately did not verifiably reduce natural gas usage because the original water heater was still operational, and additional electricity is needed to produce hot water in the kitchens and the bathrooms on the ground floor, increasing electricity use. The nominal results in Table 2 show essentially no change in natural gas use and an increase in electric use, due to fluctuations in addition to weather, none of these results were verifiable.

If this project were proposed again, the program manager would require electric, water heaters be installed in all bathrooms and kitchen, and the natural gas, water heater be removed or made inoperable. The program manager would better explain that a reduction in natural gas usage only results when the existing water heater is inoperable. Now, unfortunately, Church 2 has higher utility bills and therefore even less funds available to make improvements. The only known advantage of this improvement was that previously a long time elapsed for hot water to reach the kitchen or ground floor bathrooms, whereas now hot water is quickly available.

Hardware Store

The hardware store replaced the magnetic ballasts and T-12 bulbs with electronic ballasts and T-8 bulbs, and all incandescent exit signs with LED exit signs. These improvements were done when they consolidated a rental business into the same store. No significant change in natural gas use was expected since improvements only included lighting. However, the natural gas use showed a significant increase. It was determined that the new rental business in the store often left their large door open for loading or unloading equipment. In addition, due to removal of the drop ceiling during renovation a dead air space between the drop ceiling and roof was eliminated, effectively decreasing the insulation of ceiling and roof combination. Both of these modifications likely contributed to the increase in natural gas usage, as shown in Figure 6.

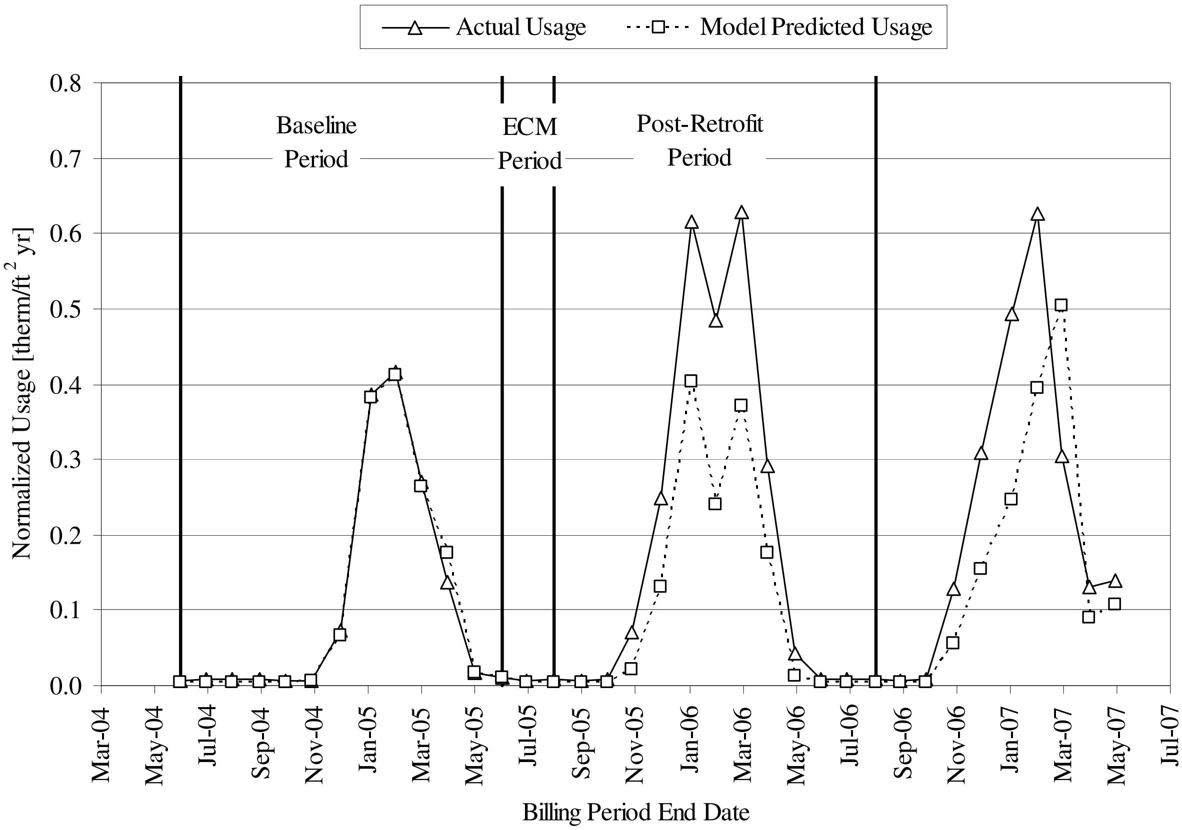

Figure 6. Actual and predicted natural gas usage rates of hardware store

The electric savings expected from the lighting improvements were not realized. However, changes in the structure and operation mentioned above likely increased infiltration and roof heat gain causing increased electric use for air conditioning. In addition, extra light fixtures were installed, lights were reoriented directly over the aisles, the ceiling was painted white, and the flooring was replaced with lighter colored material. These improvements resulted in an increase in light levels from 30 to 70 foot-candles, more than doubling the light level with a small but unverifiable increase in electric usage, as shown in Figure 7.

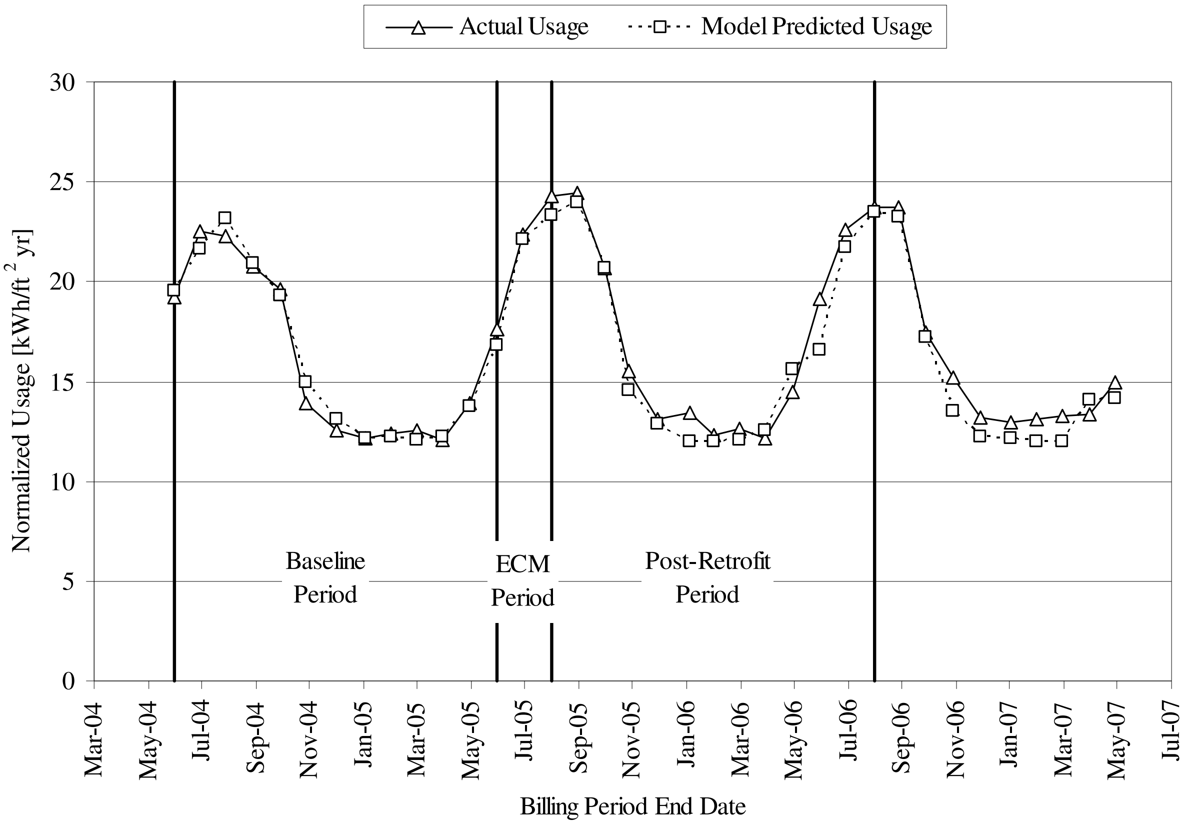

Figure 7. Actual and predicted electricity usage rates of hardware store

CONCLUSIONS

The program successfully leveraged a significant amount of external funding with a relatively small amount of grant funds yielding an overall project-to-grant investment ratio of nearly 23:1. This was helped by including some larger improvements that were likely scheduled regardless of the program; however, the program encouraged these improvements to be very energy efficient. Other smaller improvements likely were being contemplated, and when the participants learned of the program, they were convinced to make the improvements due to the program's offer to reimburse up to 50% of the total cost. Some participants asked if there were additional programs available. Other participants have asked for assistance in making additional improvements entirely on their own. For example, the light industrial facility is considering upgrading the heating systems in both their shop and office areas with more efficient equipment.

Verifiable and significant savings in energy use were seen from the projects that replaced outdated HVAC equipment with new, high efficiency equipment as shown from the psychologist building and County building 2. Lighting improvements were made in many buildings, in particular, installing electronic ballasts and T-8 bulbs. However, it was difficult to verify savings in electricity use in these projects, except for County building 1, which had constant hours of operation and predictable electrical use. Typically, lighting accounts for 20-30% of total building energy use (USDOE, 2007), and improvements can reduce electricity used by lighting by 20%, resulting in a total energy reduction of only 4-6% making it difficult to verifiably distinguish savings in lighting improvements.

The changes in energy usage in many buildings were likely not verifiable for a number of reasons. First, savings were not significant enough to overcome the uncertainty in modeling baseline usage. Both ASHRAE Guideline 14 (2002) and the IPMVP (EVO, 2007) suggest that whole-building energy savings should exceed 10% in order to be verifiable. For future programs, improvement projects than can demonstrably save 10% or more should be given priority or increased funding. Second, the model, which was based only on weather conditions, must predict the baseline energy use with low error. Variations other than weather, such as changes in school schedules, hours of operation, hotel occupancy, or production affect energy use but were not taken into account by the model. For future programs, participants should be required to document any significant changes in building use that affect energy consumption.

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