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ABSTRACT

A study determined the performance levels, energy savings, and occupant acceptance of occupancy sensors that were installed in a Florida small office building and two elementary schools. Performance data was collected in 15-minute intervals. Aggregate time-of-day lighting load profiles were compared before and after the installation and throughout the commissioning period when the sensors were tuned for optimum performance. Data reveal a 10 percent savings in energy usage in one of the two schools where sensors were installed in classrooms, the cafeteria, and administrative offices. Improper sensor installation, set-up, and faulty user operation inhibited energy performance in the other school. Also, sensor malfunctions adversely affected the energy savings in the office building; following their corrections, energy savings improvements were noted. All three case studies suggest that occupancy sensors can provide savings in a variety of building types. However, it is noted that savings will greatly vary due to occupancy patterns, and previous method of control and lighting load. It was determined that savings and user acceptance for areas selected for control by occupancy sensors are influenced by proper sensor selection, location, and controls commissioning. (Contains 19 references, 5 figures, and 1 table.) (GR)

Measured Field Performance and Energy Savings of Occupancy Sensors: Three Case Studies

FSEC-PF309-96

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Abstract

Occupancy sensors have the potential to significantly reduce energy use by switching off electrical loads when a normally occupied area is vacated. While occupancy sensors can be used to control a variety of load types, their most popular use has been to control lighting in commercial buildings. Manufacturers claim savings of 15% to 85 %, although there is little published research to support the magnitude or timing of reductions. Energy savings and performance are directly related to the total wattage of the load being controlled, effectiveness of the previous control method, occupancy patterns within the space and proper sensor commissioning. In an effort to measure performance, energy savings, and occupant acceptance, occupancy sensors were installed in a small office building and two elementary schools. 15-minute data was collected to assess performance. The three sites varied not only in size but also by occupancy patterns, occupant density, and the previous manual control strategies. Aggregate time-of-day lighting load profiles are compared before and after the installation and throughout the commissioning period when the sensors are tuned for optimum performance. For instance, savings on weekdays in the office building were less than 10% prior to the commissioning, although nearly doubled by proper tuning of the time delay setting and correcting false triggering problems. False "ons" during evening hours also affected savings. Occupant acceptance, sensor performance, and commissioning aspects are discussed as well as some recommendations for improved performance.

Introduction

Occupancy sensors (sometimes called motion sensors) replace conventional light switches with automatic controls that turn fixtures on and off based on the presence or absence of occupants in a controlled space. Two primary detection technologies are most common: passive infrared and ultrasonic sensing. Passive infrared sensors (PIRs) detect the difference in long-wave radiation between objects and their background. A compound lens in each fixture divides the coverage area into triangular zones: when the infrared temperature in a zone changes (such as that produced by a persons hand) this is interpreted as movement and the lighting system is kept on. If no motion is sensed over a given time delay (typically adjustable from 30 seconds to 30 minutes) the lighting system is turned off. However, PIR technology requires an open line of sight so partitions and furniture may block proper operation (e.g., they are not generally appropriate to control lighting in bathroom spaces). Multiple sensors must be used in large spaces and ceiling mounting is required for many space configurations for effective sensing. False triggering may occur when units are placed near HVAC vents due to the temperature change of the surroundings in the sensors field of view.

Ultrasonic sensor (US) types emit low intensity inaudible high frequency (20 to 40 kHz) sound waves to detect motion from the changing return echo patterns. When the space "acoustic signature" is altered the device maintains power to the lighting system. However, if no motion is detected over a set time delay, the lights are switched off. US sensors can cover large enclosed area with partitions well, however, they may be sensitive to false triggering from non-human motion (e.g. air motion, ceiling fans, etc.).

A final type of occupancy sensor, so called hybrid or "dual technology" units, use both PIR and ultrasonic sensing to provide more reliable occupant detection. Such devices can nearly eliminate false triggering with greater sensitivity while making it possible to incorporate shorter time delays. These devices, however, have premium prices. Also very short time delays and excessive switching may be distracting to occupants in adjacent spaces and can adversely affect lamp and ballast life. Parasitic power consumption of occupancy sensors is low. Electrical demand is generally 0.2 W per sensor for ultrasonic types and 0.002 W for PIR models (Puleo 1991). Specific control capabilities in terms of coverage sensitivity adjustment, time delays, and user control method vary considerably from one manufacturer to the next. A more complete description of the operational characteristics and performance of specific models of occupancy sensors is contained in a specifier report available from the National Lighting Product Information Program (NLPIP 1992).

Previous Experience and Research

As an inexpensive option and potential retrofit measure, occupancy sensors appeal to building managers. On the other hand, problems with early installations have damaged the reputation of the technology for some users (Puleo 1991). Anecdotal reports suggested that older products failed regularly or turned off lights on occupied classrooms, requiring extra maintenance and/or causing frustration for users. The most frequently cited problems with performance involve false triggering from misinterpretation of space occupancy. This includes "false positives" in which the device triggers on, but no one is present and "false negatives" where lights are turned off when the space is occupied. False positives lead to wasted lighting energy use, while false negatives can greatly reduce the user acceptance of occupancy based lighting controls.

In discussion with educational facilities planners, many questioned the economics of occupancy sensors. They argued that classrooms, which make up the bulk of primary and secondary school facilities, do not remain unoccupied for long periods and that most teachers diligently turn lights off upon leaving rooms. A number expressed the opinion that occupancy sensors would be most appropriate for intermittently used spaces, such as break and copy rooms. However, without empirical evidence, the performance and economics of the technology remained the subject of speculation.

Although occupancy sensors have been used in many commercial facilities over the last decade, published third party performance data is surprisingly sparse (Piette 1995). Both the Electric Power Research Institute (EPRI) and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) estimate an average 30% savings from this technology in generic assessments for commercial buildings (EPRI 1993; ASHRAE 1989). These data are supported by a utility evaluation by Consolidated Edison which found a 30% reduction in average lighting demand for its projects which installed occupancy sensors (Audin 1993).

Measured data from case studies suggest that good performance from occupancy sensor installations can be realized. A retrofit of an office building with passive infrared occupancy sensor controls in South Australia yielded a 40% reduction in lighting energy use with a simple payback of two years (Caddet 1995). Also, several case studies of occupancy sensor installations show savings of 25 to 75% in variety of spaces (EPRI 1994). Finally, a detailed study of occupancy sensors used in a national laboratory found a 31% average lighting energy reduction (Richman et al. 1995) with savings strongly affected both by space type and time delay setting. Savings were highest for mixed ownership spaces (e.g. lunchrooms, copy rooms, restrooms etc.) and lowest for administrative areas. Savings were more than doubled by reducing time delays from the manufacturer recommended settings of 10 to 20 minutes to 2.5 minutes.

Performance data specific to educational facilities is limited. Occupancy sensor manufacturers often claim a 40 to 50% savings in classroom energy use in product literature. A pertinent case study at the University of New Hampshire, showing a reduction in classroom lighting system on-time of some 3 hours per day (EPRI 1994). Researchers at Rensselaer Polytechnic Institute performed field surveys at an elementary school and junior high school to determine classroom occupancy patterns and to estimate wasted lighting energy using a methodology described by Rae and Jaekel (1987). In the elementary school the estimated weekly lighting energy use was 1,694 kWh with some 416 kWh or 25% of the total being wasted when no occupants were present (NLPIP 1992). In the junior high school the wasted lighting energy averaged 15%.

However, prior to this study no evaluation had examined the savings in a Florida classroom environment, and little information existed on potential time-of-use impacts in buildings. In a study of energy end-use intensities in Florida commercial buildings it was estimated that interior lighting energy use accounted directly for 30% of all energy use in office buildings and 32% of all consumption in Florida schools (SRC 1992). Simulation studies indicate that internal lighting is a large portion of the space cooling loads in commercial building, leading to the possibility of indirect HVAC savings (Rundquist et al. 1993). Further, this same study identified advanced lighting controls as a fruitful area for reducing commercial building energy use.

However, in all occupancy lighting control situations, the operation of the lighting by the occupants emerges as the dominant factor in determining potential lighting energy savings. Generally, lighting energy reductions from occupancy sensors will roughly follow room vacancy rates. Savings will be, of course, modified by occupant responsiveness in turning off lights in unoccupied areas. Such behavior is also impossible to evaluate within a laboratory environment. Thus, we desired to conduct a series of tests of the technology using a "before and after" measurement to determine actual potentials.

Building 200: Florida Solar Energy Center

As a first point of evaluation, we chose a small 5,000 ft^2 office building at the Florida Solar Energy Center's (FSEC) Cape Canaveral facility. The lighting system for the entire building was metered, comprising 29 private and suite offices. The building's lighting system consisted of two and four tube fluorescent fixtures with T-12 lamps with magnetic ballasts with an installed power density of 1.95 W/ft^2. Calibrated power transducers on the 277 volt lighting circuits sent watt-hour pulses to the data logger. A multi-channel data logger was used to record the data, with scans taken every ten seconds and integrated averages and totals sent to storage every 15 minutes. The data was automatically relayed to a mainframe computer via modem and dedicated telephone line each evening for plotting and review by the project engineer the following morning.

Six months of pre-retrofit lighting energy consumption data were taken. The base line data indicated that annual lighting energy use in Building 200 was approximately 12,509 kWh. Twenty three PIR and US occupancy sensors were installed in the facility on September 16, 1994. Each occupancy sensor was mounted to provide good coverage of the controlled zone--both wall and ceiling mount devices were used. The lighting controls were installed and configured using approximately 40 man-hours of labor. Time delays were initially set to 15-minutes. Figure 1 compares two representative week day lighting demand profiles before and after the occupancy sensor retrofit. The influence of lights accidentally left on is apparent in the pre-retrofit energy data as is the switching during the lunch hour in the post installation period.

We then compared the long term pre-retrofit data to post-retrofit data through January 1995 to assess energy savings as well as changes in the daily pattern of consumption. Preliminary analysis of the weekday lighting power data revealed moderate savings from 11 AM to 1 PM during the lunch hour and from 5 PM to 7 AM. As shown in Figure 2, average daily weekday savings totaled approximately 7% (3.0 kWh/Day). However, review of the data on individual days revealed power use at odd late evening and early morning hours when the building was believed to be unoccupied (see Figure 1). We suspected that this consumption was due to false positives from malfunctioning occupancy sensors. The manufacturer then suggested replacement of the three rogue sensors with models less prone to false triggering.

After this was done, the problem was significantly reduced. However, one puzzling bank of hallway fixtures continued to turn on during early morning hours. At first a phantom 3 AM office visitor was suspected, but after surveillance efforts failed to capture the culprit, suspicion moved to a laser printer in the hallway. Apparently, the nightly movement of paper from the printer was enough to trigger an ultrasonic sensor in the same space. A reduction in the sensitivity setting and relocation of the device solved the problem. However, the metering information we had available for trouble-shooting makes our case unique and we suspect that in most installations such problems can go undetected. After solving these difficulties, metered average savings rose to approximately 10%.

We then reset the time delays in the occupancy sensors to seven minutes on April 19th, 1995 and continued to record lighting energy use data for another three months from April 20th to July 7th. As shown by Figure 2, the average daily energy savings on work days were nearly doubled to approximately 19% (8.25 kWh/Day) by correction of false triggering and decrease of the sensor time delay.

Unexpectedly, we found weekend power consumption to be slightly greater after the retrofit. This was primarily due to the extra time the lights stayed on after the room was vacated, while before the retrofit, weekend visitors probably switched off lights immediately upon exit. Also, weekend workers moving through the building were found to activate many more lights than they would have turned on with manual controls. However, impact on annual energy use was negligible since non-work day lighting energy use was only a small fraction of the annual total.

The project had a final direct lighting energy savings of approximately 2,060 kWh per year and approximately 2,580 kWh when HVAC cooling savings were added (Rundquist et al. 1993). Estimated cost savings were approximately $129 per year. This matches against the $2,354 spent on the sensors and their installation. The project did not show attractive economics (a 18.2 year payback), but was not intended to be cost effective, but rather to allow study of the factors that affect occupancy sensor retrofit performance on a small scale installation. The loads being controlled by each sensor were fairly small; obviously it is advantageous to control the largest possible load with each device. Also, energy researchers are likely more vigilant in their operation of lighting than typical office personnel so that savings from this installation were not expected to reflect a typical installation.

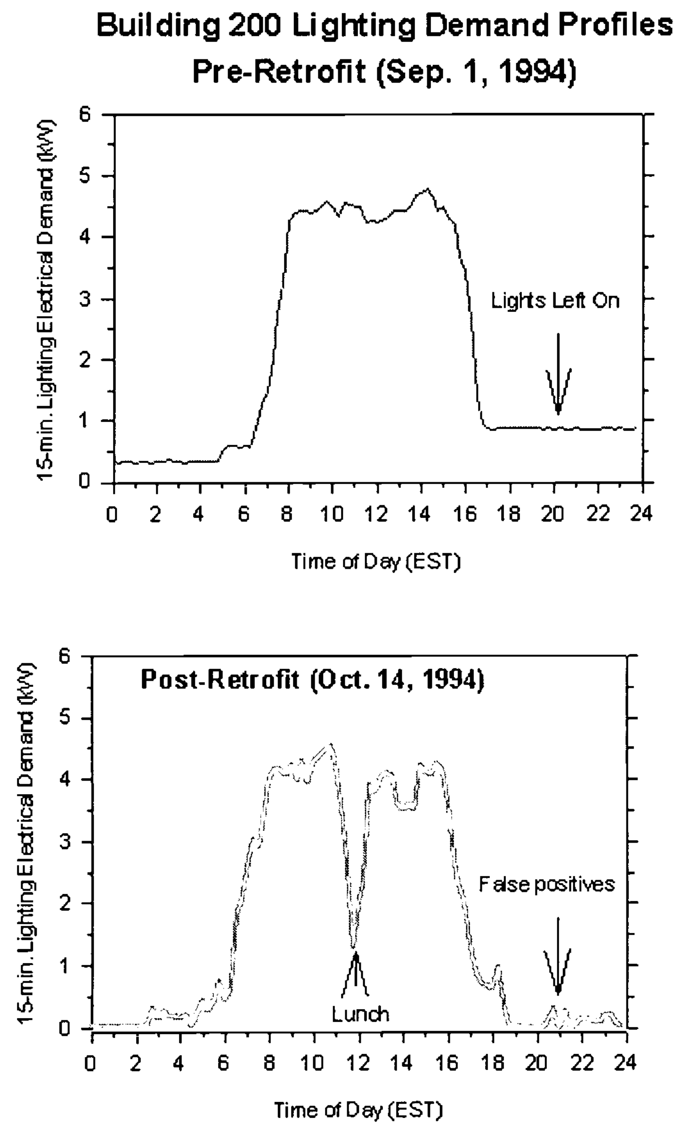

Figure 1. Sample Daily Load Profiles for Building 200

An occupant acceptance survey was administered to those receiving occupancy sensors in the study. The survey revealed good overall acceptance of the sensors throughout the monitoring period with incidences of false negatives. The only drawback observed was a slight increase in the frequency of ballast and lamp failures. However, the ballasts were estimated to be at least twenty years old and many of the lamps were near the end of their useful life. Thus, proper commissioning of occupancy sensors emerged as a key issue in achieving reasonable performance.

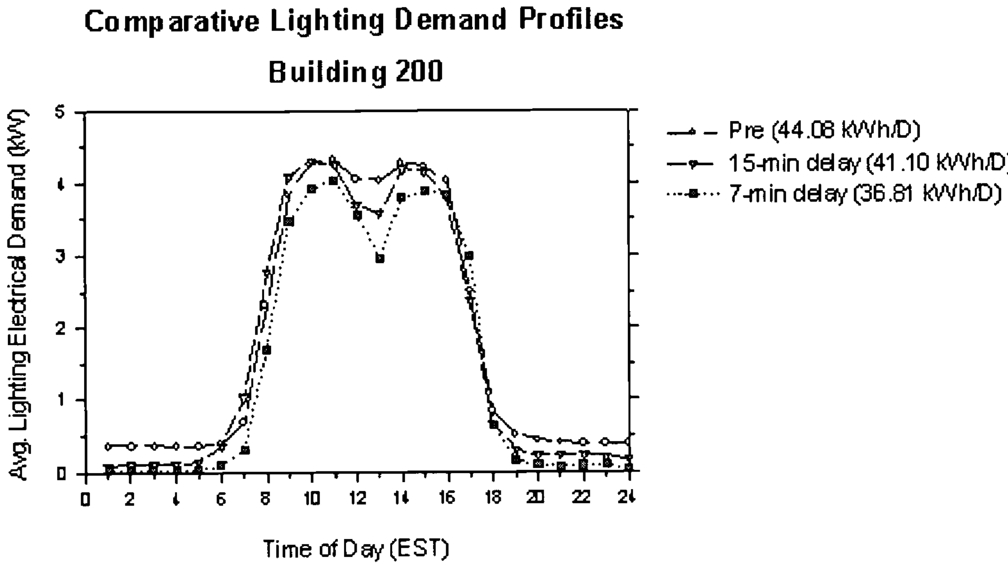

***Figure 2**. Building 200 Pre and Post Period Load Profiles*

Northwest Elementary School, Pasco County, Florida

Northwest Elementary School, located on the west coast of Florida, was the location of the first school site that was evaluated. A 58,000 ft^2 main building, comprised of classroom pods, administrative spaces, a media center, and a cafeteria, became the subject of the study. The work was sponsored by the Florida Department of Education and is more fully described in a source report (Floyd et al. 1995).

Primary lighting for the school was 2 x 4 luminaires with T10 lamps/magnetic ballast or T8 lamps/electronic ballast. The connected facility lighting load is approximately 87 kW. The test building was unusual in that it already contained an efficient lighting system. Pasco County also has one of the most aggressive energy management programs of any district school board in the state. Even before installation of the occupancy senors, lighting was effectively controlled by facility staff so as to prevent waste. Given these factors, it was expected that the evaluation in Northwest Elementary would provide insight into the minimum savings that could be expected from the technology if properly applied in a Florida school.

Technicians audited the school on December 21, 1994 and subsequently drew up a plan for instrumentation to monitor its energy use. The facility was instrumented on February 25, 1995, also using a similar before and after monitoring protocol. Fifteen minute electrical demand data were taken for six months prior to the lighting controls being modified to accommodate occupancy sensors. Data in the baseline period revealed that lighting made up approximately 24% of total electrical energy use at the school (70 $kBtu/ft^2$).

A total of 46 passive infrared (PIR) occupancy sensors were installed and carefully adjusted in terms of location, time delay, and sensing sensitivity from August 7, 1995 to August 15, 1995. The installation was performed by a team of two electricians, a Research Engineer and the Energy Coordinator from Pasco County. Approximately 33 classrooms, seven offices, and a cafeteria were equipped with occupancy sensors. In several offices wall sensors were used. The remainder of the spaces (classrooms, cafeteria, and larger offices) received ceiling mounted sensors. The broad coverage of the ceiling mounted PIR sensors minimized the need for multiple occupancy sensors in all but five areas. Dual technology sensors were considered, but not utilized due to their higher cost.

Classroom occupancy sensors were located in a corner near the teachers desk to minimize false "offs" when only the teacher was in the classroom. All occupancy sensors were set to a 10 minute time delay, which has worked well in most situations. Shorter time delays may improve savings, however, false "offs" may also increase. Past installation experience has shown that unless the occupancy sensors are properly located, aimed, and tested by experienced personnel, poor savings and occupant dissatisfaction will result.

The analysis of the comparative pre- and post-retrofit periods as shown in Figure 3, indicated an average savings of 10.8% (96 kWh) on school days of the pre-retrofit lighting energy with greater reductions to total energy due to reduced load on the air conditioning system. Most of the savings occurred during the evening hours so that monthly peak electrical demand was unaffected. There are some 200 school days per year, not including holidays, weekends and summer recess. The school day extends from 7:00 AM to 3:45 PM, although office and janitorial activities often extend beyond the formal school day schedule when much of the savings were found to accrue.

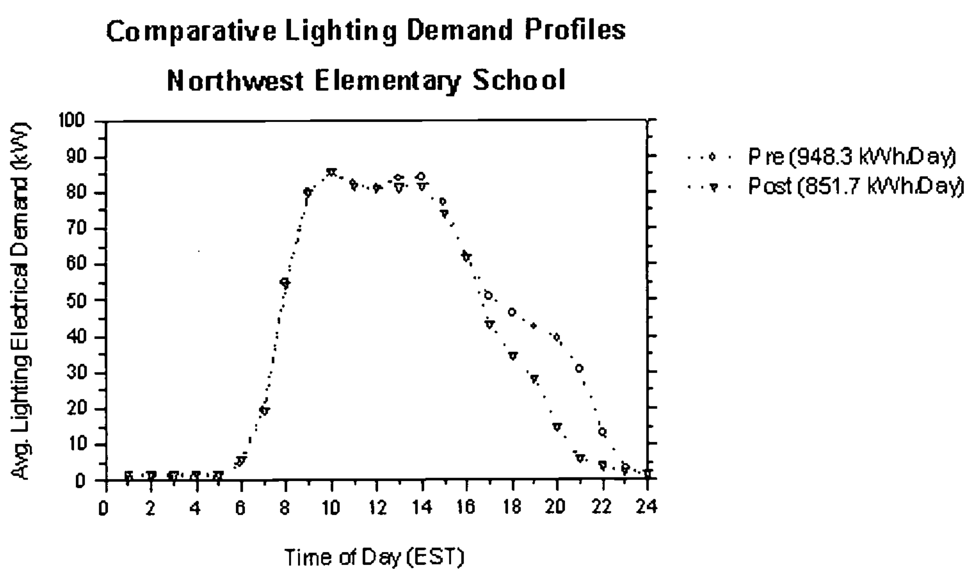

Figure 3. *Northwest Elementary Lighting Load Shapes Before and After the OC Installation*

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Based on the monitoring, an annual direct lighting energy savings of 26,620 kWh was estimated.

To this was added an estimated additional 7,260 kWh in reduced HVAC costs (Rundquist et al. 1993). At the facility's electricity rate ($0.05/kWh) annual monetary savings is estimated at $1,694. The data did not evidence any reduction in peak electrical demand from the retrofit, so no credit was taken for this portion of monthly energy costs.

The cost for the sensors, wiring and relay packs for the project was $4,067 or about $88 per control. Installation labor was valued at $2,000 (125 man-hours). Including costs of installation and set-up, the payback of the occupancy sensor retrofit was approximately 3.6 years with a 28% simple rate of return from the investment. This performance is considered excellent given that the building already had an efficient lighting system which was responsibly controlled prior to the occupancy sensor installation. The project results indicate that with proper installation and adjustment (which was found to be critically important to user acceptance and performance) occupancy sensor technology can provide economically attractive returns either in new or existing educational facilities.

Fellsmere Elementary School

The third project in which occupancy sensors were installed is an elementary school in Central Florida which is serving as a pilot project to demonstrate energy savings in public buildings similar to that achieved by the Texas LOANSTAR project (Verdict et al. 1990). Termed FLASTAR (Florida Alliance for Saving Taxes and Resources), the project has entailed the comprehensive metering of a Florida elementary school with which to demonstrate energy savings potential. Over twenty channels of weather and sub-metered energy data has been collected since April 12, 1995.

The facility is composed of the main school building, with an attached new wing and various portable classroom areas. All school lighting circuits are individually sub-metered so that this end-use can be separated. Figure 4 details the proportions of the sub-metered end uses from electricity consumption data from April 12 to December 4, 1995 prior to the installation of the occupancy sensors. Metered lighting energy use has averaged about 17% of total facility energy consumption.

The large "other" end-use category represents refrigeration, kitchen cooking loads and miscellaneous end-uses such as computers, office equipment, and water coolers. Measured electricity consumption has totaled approximately 2,200 kWh on school days and 1,300 kWh on non-school days. On this basis, annual estimated energy consumption for the 35,000 square foot facility is approximately 75 kBtu/ft^2. During the summer of 1995, the first retrofit, replacement of aging chillers was completed with an estimated 10% reduction to measured cooling energy use at the facility (Sherwin et al. 1996).

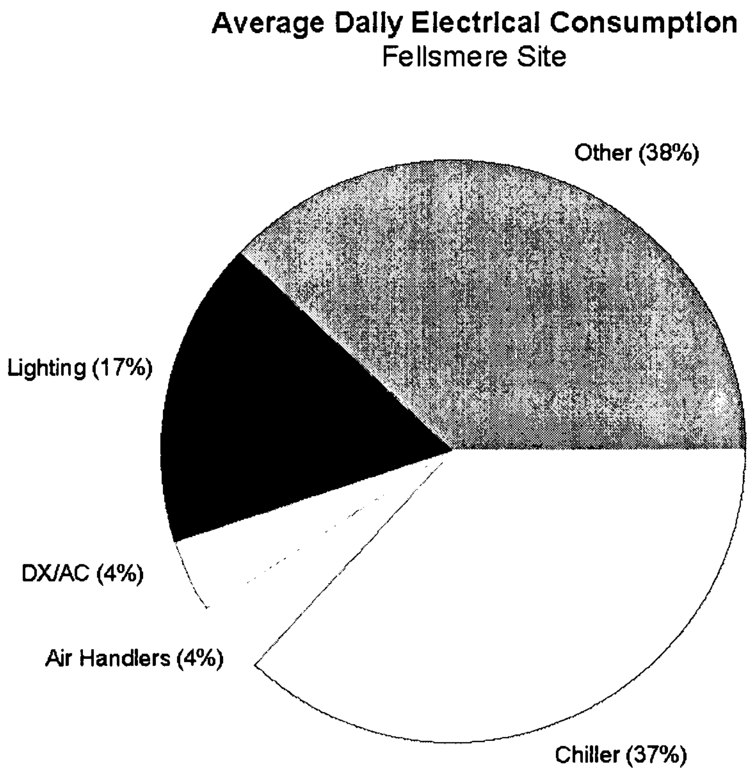

Figure 4. Breakdown of end-uses at Fellsmere Elementary prior to the OC Installation.

The interior lighting system is predominantly from fluorescent fixtures. Two-lamp fixtures based on the T-12 F34CW lamp with magnetic ballasts are most common with 513 of this type and 133 of mixed one, three, and four-tube fixtures. As audited, the connected lighting load is 59.0 kW or about 2.0 W/ft^2. This compares to 1.4 W/ft^2 for more contemporary efficiency lighting systems for schools (McIvaine et al. 1994) and suggests potential for improved controls. Audited classroom desk-top illuminance levels were from 76 to 85 foot candles; each room is outfitted with two wall switches that control one half of the classroom electrical lighting.

Schedules strongly affect lighting energy consumption. The last day of regular school occupancy for the Spring semester at Fellsmere Elementary was on June 6, 1995. However, during the summer, some of the faculty and secretaries were present from Monday to Thursday from 8 AM to 3 PM. Custodians were also on site from Monday to Thursday from 6:30 AM to 3:30 PM. Summer school was not held in the the portion of the building metered in the project. The Fall school schedule resumed on August 21 and continued until December 15 and faculty and staff remained until December 22. Spring session commenced on January 3, 1996.

Since metered data showed lighting accounts for about 17% of electrical end use at this facility, an occupancy sensor retrofit appeared to possess considerable promise. The school staff appears to make efforts to turn off lights after hours; however, there are numerous data to show lights being inadvertently left on after hours and on weekends (Sherwin 1996). A previous technical assistance report (TAR) and analysis for the Institutional Buildings Program (IBP) had estimated a savings for the retrofit of 25,960 kWh per year based on an assumed 20% reduction in daily lighting hours at the facility (Bosek, Gibson and Associates 1995). Estimated project cost was $10,192 with a 4.1 year simple payback.

The occupancy sensors were installed on December 15th. A total of 59 controls were installed in the facility; 39 ceiling-mounted PIR sensors were placed in classrooms and the 20 wall-mounted units were installed in office and administrative locations. The total cost for the sensors and hardware was similar to that at Northwest Elementary $5,154 (or $87/control). However, the cost of labor for installation was much higher at $9,365. The labor cost for the installation is difficult to reconcile since the estimate shown by R.S. Means Mechanical Estimator is only 3.5 hours per sensor installation-- an allowance which already seems liberal given our experience at Northwest Elementary. The TAR estimate for the retrofit labor was $3,803. The large disparity in labor costs for the installation are currently unexplained.

The first analysis of the measured lighting load profile for school days showed an *increase* of lighting electricity consumption of approximately 27% from 16.70 kWh/Day to 21.2 kWh per day, as shown in Figure 5. On the other hand consumption on non-school days dropped by 20% from 6.91 kWh/Day to 5.53 kWh. Based on previous installation experience we suspected that the sensors were poorly installed or improperly adjusted.

On February 22, 1996 the occupancy sensors were tuned in an effort to increase the energy savings. Tuning consisted of reducing the time delay from 12 minutes to approximately 7 minutes in most areas and changing the program selection. The program dictates which technology (ultrasonic and/or infrared) is used to initially turn on the lights and which technology is used to keep the lights on. Prior to tuning, either ultrasonic or infrared would turn the lights on. This was changed to a setting where both technologies must detect movement in order for the lights to come on. As shown in Figure 5, this resulted in an improvement in performance, but still did not produce effective savings.

Although the tuning reduced the light energy use, usage was still greater after the sensors were installed and tuned than with manual switching. We suspect this is due to false positives occurring and inadvertent tripping of the sensors when occupants enter the space momentarily. The reasons for the poor initial performance seem to be a combination of factors recently described by the county energy coordinator (Aiken 1996). The specific controls installed were obtained through a procurement process in which the lowest bidder was selected. The acquired equipment was found to possess characteristics which may have compromised performance. Based on examination of the data, it appears as if a number of the ultrasonic sensors are falsely triggering during evening hours, increasing consumption. Another cited complaint was the long "strike time" of the sensors; once lights were turned off, they would not turn back on for some 11 seconds. This led the installation crew to alter the sensor set time delay in some locations to the maximum available (15 minutes). As described above, both in our studies and those performed by PNL (Richman et al. 1994), proper setting of the device time delay is crucial to achieving potential energy savings.

A further reduction to potential savings at the facility may be behavioral (LaPointe 1996). Prior to installation of the control sensors, all facility staff punctually turned off lights when leaving unoccupied spaces. However, now staff leaves all occupancy sensor switches with the room lights to be triggered on when an occupant enters spaces. Based on observation by facility staff, lights are now on more of the time in the average classroom than they were prior to the retrofit since the typical space is left on for 7-minutes after it is vacated until the occupancy sensor turns off the lighting. Also, even a momentary visit by a single individual to a room or rooms in this configuration will result in the lights being on for 7 minutes, whereas they would likely not be powered at all in this instance under manual control. Regardless, the failure in this case of the addition of occupancy sensors to produce savings as installed, points to the importance of proper specification of equipment, a careful installation and setup, and adequate instruction to users. Such commission is critical to achieving expected energy savings.

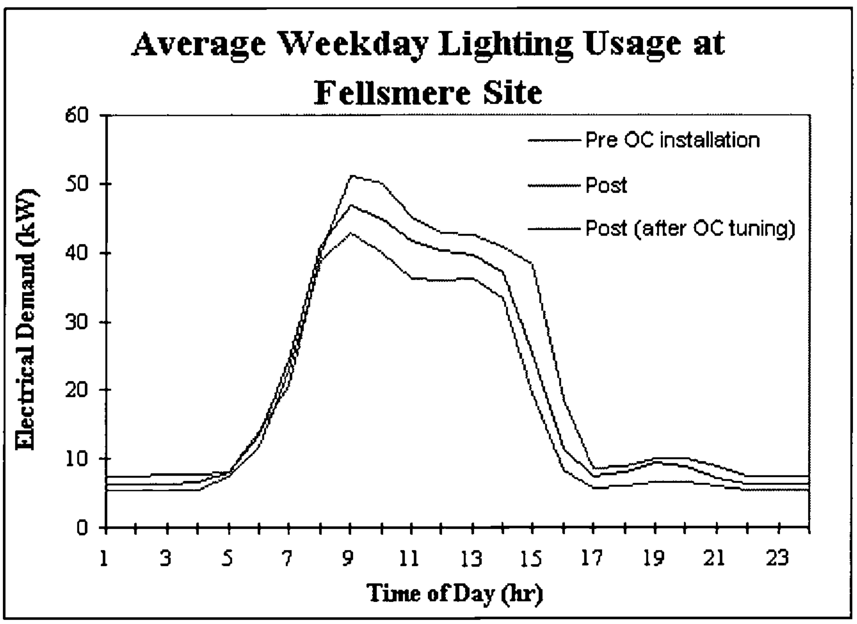

Figure 5. Fellsmere Elementary before and after the OC Installations.

Conclusions

Occupancy sensors are frequently identified as an effective means of controlling lighting energy costs in commercial buildings. However, there are few field studies to support manufacturers estimates of energy reductions. Realized savings depend upon human factors, previous control strategies and proper sensor commissioning which can only be measured in field studies.
In order to measure occupancy sensor performance, three sites were monitored using a before and after monitoring protocol. The results of the three case studies are summarized in Table 1. The first of these case studies involved a small office building where a variety of sensors were installed. Savings were first found to be moderate, but increased significantly when sensor malfunctions were addressed and the time delays were reduced. In the second case study an elementary school was monitored for saving when PIR sensors were installed in classrooms, a

cafeteria, and administrative offices. A 10% savings was realized even though the previous method of manual control was considered effective. We expected the third site to produce similar results as site two since the two schools had similar occupancy patterns. However, initial results showed that the school was actually using more lighting energy in the post period. The increase appears to be the result of poor sensor installation, set-up, and user operation of the devices.

***Table 1.* Summary of Results from Three Case Studies of Occupancy Sensor Retrofit**

Site	**Building 200**	**Northwest Elementary**	**Fellsmere Elmentary**
Building Type	Small office	Elementary school	Elementary school
Floor Area(Ft^2)	5, 000	58,000	35,000
Lighting Load (kW)	9.7	110.0	59.0
Sensor Time Delay (min)	15 minutes (initial) 7 minutes (final)	10 minutes	12-15 minutes (initial) 7 minutes (final)
Baseline Annual Light kWh	12,509 12,509	246,481	108,004
Estimated Annual Savings kWh*	1,084 2,060	26,420	(-15,444)
Installed Cost	$2,354	$6,067	$15,446
Savings	10% 19%	11%	Negative
Payback (Yrs)	34.7 18.2	3.6	None

*** These are direct savings. Total savings are approximately 25% greater since HVAC interactions are included.**

The results of the three case studies suggest that occupancy sensors can provide savings in a variety of building types. However, savings may vary greatly due to differences in occupancy patterns, previous method of control and lighting load. In order to achieve good results, it appears imperative to first determine the appropriateness of occupancy sensors for a specific area over manual control with competing lighting energy efficiency measures. Savings and user acceptance for areas selected for control by occupancy sensors is influenced by proper sensor selection, location and controls commissioning.

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