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An analysis of the energy and cost savings potential of occupancy sensors for academic buildings: An application approach to "Faculty of Natural and Human Sciences" of Korça University

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Abstract:

At colleges and universities, energy consumption has a large impact on both financial and environmental interests. Academic buildings represent a very high energy consumption percentage compared to industry and transportation due to the need of lighting, equipment, heating, cooling and ventilation. Electric lighting is one area where energy savings are possible at reasonable cost in new buildings as well as in retrofit projects. Adding lighting controls is a simple retrofit option than reduce or turn off the lighting when a space is not in use can save a significant amount of energy. Studies conducted on a university campuses found that adding lighting controls can reduce lighting energy use 10% to 90% or more depending on the use of the space in which the sensors are installed. This study explores the importance of energy savings from occupancy sensors. Two academic buildings of "Korça University" were analyzed; their building information, energy consumption data and methods to project energy savings have been analyzed. The results show that an automatic control strategy (using occupancy-based controls) could

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eliminate a significant amount of energy waste in common areas during business hours and also controlling runaway operation after hours and on weekends.

Key words: Energy Efficiency; University building; Office lighting; Occupancy sensors; Lighting control

INTRODUCTION

Throughout the world, there is a powerful shift toward environmentally sustainable thinking and an increased interest in energy efficiency, excited by alarming statistics. At colleges and universities, energy consumption has a large impact on both financial and environmental interests. According to U.S. Energy Information Administration (IEA, 2013), lights are the main source of energy consumption in academic buildings. As a result, there is significant interest in reducing lighting energy use through more efficient lighting systems, including controls, and academic buildings are one of the major targets for energy reduction. In 2016 electricity consumption for lighting was responsible for an energy consumption of around 1/6 to 1/5 of the worldwide electricity production. (Robert K. et al., 2016). An on-site survey of existing university buildings conducted by (Chung and Rhee, 2014) determined the potential for energy conservation in the range 6–29%. Because most of these buildings are not a primary residence, staff members and students do not pay electrical bills, they are not considerate on how to manage their energy usage. In order to conserve energy in academic buildings and commercial buildings, it is important to have a dynamic interaction between the occupants and the building itself, and incorporating occupancy sensors will allow to do that.

As an automatic control strategy, occupancy sensors controls giving building occupants additional opportunities to improve energy savings without compromising lighting service to building owners and operators. Since their introduction more than 30 years ago, occupancy sensors controls for lighting systems have been highlighted as a way to reduce energy consumption in a variety of commercial lighting applications. Originally invented by Kevin D. Fraser of San Francisco, occupancy sensors have gone through several technological advancements since their development due to the continuous demand in the market for energy saving devices. With typical estimated energy savings potential in from ¼ to more than ½ of lighting energy (EPRI 1992), occupancy sensors have frequently been promoted as one of the most cost effective technologies available for retrofitting commercial lighting systems. According to (Zion Market Research report 2016), global motion sensors market was valued at around USD 3.97 billion in 2016 and is expected to reach approximately USD 8.17 billion in 2022, growing at a CAGR (Compound Annual Growth Rate) of slightly above 12.8% between 2017 and 2022.

The primary objective of this study was to explore the importance of energy savings from occupancy sensors. By examining how teachers and students occupy academic building spaces and investigating lighting operation and workspace occupancy patterns, energy and dollars savings potentials are calculated. The model under study is faculty building located in Korça (Albania). The study shows that the majority of energy use (about 80%-90%) occurs for most of space types during the weekdays, with 70%-80% of total energy use occurring during the day. This indicates that an automatic control strategy (using occupancy-based controls) could eliminate a significant amount of energy waste in common areas during business hours and also controlling runaway operation after hours and on weekends. The payback period is calculated to be less than ten years.

OBJECTIVES AND METHODOLOGY

The main objective of this work is study and analysis the energy and cost savings we can obtain by introducing occupancy sensors in academic buildings. Two building from Korça Public University were chosen for study. The first building has three floors, three big halls, nine offices and 15 teaching rooms, while the second building has one floor with two library halls. All spaces contain manual control switches for the lighting systems, with a minimum connected lighting load of at least 350 watts. A one-month monitoring period from 10 January to 10 February 2017 was chosen to represent a typical lighting and occupancy schedule. The minimum lighting level is determined by European Standard EN 12464-1 about Lighting of Workplaces (CEN, 2003), which suggests a maintained average illuminance of 500 lux for normal desk-based office tasks. Data for 29 rooms were collected. The rooms are categorized by primary occupancy type into nine offices for staff members, 15 teaching classrooms, three halls, and two library rooms. Rooms were surveyed for occupancy type, lighting system specification and dimensions. Occupancy patterns and lighting operation data was collected using "HOBO UX90-006" Room Occupancy/Light Data Logger connected with "HOBO Light Pipe UX90-LIGHT-PIPE-1" probe for more accuracy. The logger device recorded the time and state of the light and/or occupancy condition with the relevant time. Each time occupancy or the lighting condition changed, the logger device recorded the time of day and the change in light and/or occupancy condition. The data recorded from the HOBO UX90 device are downloaded in computer and then analyzed in excel program.

It should be noted that there were some cases when the sensor has detected false occupancy. This was considered as a detection error. All physical instruments inherent some instrument error. Since those cases occurred for 0% to 2% of the total events, they were corrected simply by modifying the data set to switch the occupancy condition from occupied to unoccupied for those instances.

Two simple formulas were used to determine lighting energy use and waste. Lighting energy use was calculated by multiplying the total lighting load by the time that the lights were on and the room was occupied, while the lighting energy waste was calculated by multiplying the total load by the time that the lights were on and the room was unoccupied. Total energy savings was determined considering the flat price of ALL14/kWh under each control scenario.

ENERGY SAVINGS POTENTIAL

Occupancy and lighting conditions use in any space will always fall into one of the
following four conditions:

1. Occupied with the lights on
2. Occupied with the lights off
3. Unoccupied with the lights on
4. Unoccupied with the lights off

Of the four conditions, condition one is of interest for collecting information about how frequently occupants use these types of spaces with the lights on. Conditions two and four are very important when considering lighting controls. For example, if occupants occupy a space with the lights off, then a manual lighting control device should be provided in order to allows occupants to turn lights off when needed. Condition three is very important when considering using automatic occupancy sensor control. This condition represents wasted lighting energy by having lights on when spaces are unoccupied.

Table 1. illustrates the average percentage of time each site was occupied with lights on and off, and unoccupied with lights on. It shows that daytime percentage of total occupied time with lights on and off never exceeding 50% for offices and libraries and 80% for classroom and halls. While the daytime average unoccupied time with lights on is about 30%-40% for offices and halls, and about 15% for classes and libraries.

Table 1: Average percentage of time each site was occupied with lights on and off, and unoccupied with lights on and off.

	Weekdays							
	Daytime (work time 08:18)				**Night (after work 18-08)**			
Site	**Occupied with lights on**	**Occupied with lights off**	**Unoccupied with lights on**	**Unoccupied with the lights off**	**Occupied with lights on**	**Occupied with lights off**	**Unoccupied with lights on**	**Unoccupied with the lights off**
Offices	40%	8%	32%	20%	7%	0%	15%	78%
Classrooms	62%	17%	15%	6%	24%	0%	13%	63%
Halls	55%	1%	43%	1%	12%	1%	26%	61%
Libraries	23%	15%	14%	48%	4%	0%	3%	93%
	Weekends							
Offices	16%	6%	7%	71%	12%	0%	5%	83%
Classrooms	12%	4%	7%	77%	4%	0%	2%	94%
Halls	14%	2%	8%	76%	3%	0%	2%	95%
Libraries	7%	5%	4%	84%	1%	0%	1%	98%

The high percentage of wasted lighting energy (unoccupied space with lights on) particularly for offices and halls demonstrates that occupants were not carefully to turn lights off when they vacated spaces. If we look over the data for condition two, they show that occupants rarely occupied spaces with the lights off. Table 2. Below shows the average percentage of lighting energy use for weekdays and weekends for each site, while table 3, shows the average percentage of energy waste.

Table 2: Average percentage of energy use for weekdays and weekends for each site.

	Energy Use (%)					
Site	**Weekdays**				**Weekends**	
	Day	**Night**	**Total**	**Day**	**Night**	**Total**
Offices	65%	13%	78%	12%	10%	22%
Classrooms	80%	11%	91%	8%	1%	9%
Halls	71%	13%	84%	11%	5%	16%
Libraries	79%	14%	93%	6%	1%	7%

Table 3: Average percentage of energy waste for weekdays and weekends for each site.

	Energy Waste (%)					
Site	**Weekdays**				**Weekends**	
	Day	**Night**	**Total**	**Day**	**Night**	**Total**
Offices	47%	26%	73%	17%	10%	27%
Classrooms	52%	34%	86%	8%	6%	14%
Halls	63%	19%	82%	11%	7%	18%
Libraries	76%	18%	94%	5%	1%	6%

As we can see from table 2, the majority of energy use (about 80%-90%) occurs for most of space types during the weekdays, with 70%-80% of total energy use occurring during the day. As well the majority of energy wastes occurs during the weekdays. Since the majority energy waste occurs during the daytime (70%-80%) rather than in the evenings, we can conclude that occupants were not attentive for controlling their lighting during the workday, but were more careful about turning the lights off after work hours and over weekend.

This indicates that an automatic control strategy (using occupancy-based controls) could eliminate a significant amount of energy waste in common areas during business hours and also controlling runaway operation after hours and on weekends. The savings estimates are examined over weekday and weekend over days and evenings.

IMPACT OF TIME-OUT PERIOD ON ENERGY SAVINGS

Almost all occupancy sensors have an integrated variable time relay that can adjust the time interval (ranging from several seconds to more than 30 minutes) between the last detected motion and the switching off of the lamps.

Longer time delays can reduce the incidence of occupant complaints, but also reduce the energy savings, while the shorter time delays increase energy savings and incidence of occupant complaints too.

Adjusting the time delay allows the sensor to be customized to the application to creates a tradeoff between saving energy and avoiding occupant complaints. I have calculated that adjusting time relay to three minutes delay will be the optimal time for studying case.

ENERGY AND COST SAVINGS

Table 4: Average energy savings over one week.

Energy savings weekdays (watt)				
Site	**Total power load (watts per hour)**	**Daytime** (work time 08:00-18:00) **Unoccupied hours with lights on**	**Night** (after work 18:00-08:00) **Unoccupied hours with lights on**	**Total Energy savings (watts per 24 hours)**
Offices	**4536**	3.2	2.1	24040.8
Classrooms	**7776**	1.5	1.82	25816.32
Halls	**2888**	4.3	3.64	22930.72
Libraries	**600**	1.4	0.42	1092
Energy savings Weekends (watt)				
Offices	**4536**	0.7	0.5	5443.2
Classrooms	**7776**	0.5	0.2	6998.4
Halls	**2888**	0.8	0.2	2888
Libraries	**600**	0.4	0.1	300
Total energy savings over one week (watt)				89509.44

If we calculate the current price of energy (ALL 14 /kWh), the total financial savings per year is:

89.5 kWh * 42(school weeks per year) * 14 (ALL/kWh) = ALL 52626

The proposed method for lighting energy saving in the studied case incorporate installing 32 Wireless Ceiling-Mounted Occupancy sensors and 25 Wireless Wall-Mounted Occupancy sensors. If I take in consideration installing a well-known sensor brand, the price per pcs vary from about ALL 2500 to more than ALL 10000. I have proposed a Lutron retrofitting package (MRF2-1S8A-1OC Sensor plus RF Switch) which cost ALL 8500 per package. The total cost involved in all sensor installation and switch replacement is calculated to be about ALL 35000.

If we calculate the current offer price of sensor package (ALL 8500/pc), the total sensor price is: 57* ALL 8500 = ALL 484500

From the above data, we can calculate the payback period.

Payback period = total cost of sensors + labor cost / Financial saving per year.

(ALL 484500 + ALL 35000) / ALL. 52626 = 9.87 years.

If we take into account, the electricity price forecast for the next ten years, the payback period drops far below 9 years.

DISCUSSION AND CONCLUSION

Practically, energy consumption in academic buildings is a very complex organizational issue due to the heterogeneity of activities (for e.g. as lecture halls, laboratories, and offices) (L. Perez & J. Ortiz 2008). To minimize energy consumption through effective organizational energy management, and on the other hand to satisfactorily meet the energy needs of users and maintain comfort standards poses a challenge. Teachers and students do not occupy academic spaces for a large percentage of time, and furthermore they are not attentive about controlling the lighting in their spaces both during the workday, and after hours and weekends. Because occupants do not pay bills, they are not considering on how to manage their energy usage.

Through the analysis of the case studied, occupancy-based controls techniques (using occupancy-based controls) demonstrated they are a feasible option to eliminate a significant amount of energy waste in academic buildings during teaching hours, and also controlling runaway operation after hours and on weekends.

This would be a useful topic of additional research, where introducing specific techniques would yield more economic benefits within academic buildings.

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