2010

# Occupancy Based Lighting Control Systems

Nathan Cooper
*Parkland College*

# Occupancy Based Lighting Control Systems

Nathan Cooper
December 2010

## Abstract

The use of occupancy based lighting controls is a proven strategy to reduce energy consumption[1].  With lighting energy costs constituting a large percentage of facility expenses[2] it is prudent to invest in strategies that minimize excess energy consumption and thereby reduce expenses.  The amount of savings that can be realized by occupancy sensors varies greatly.  By logging room occupation and lighting usage statistics for offices and classrooms both before and after sensor installation, the percentage of potential savings can be measured.  The output from those calculations show that the college can see an average potential savings of 40 percent per year in energy used for lighting of unoccupied spaces.  This analysis concludes that Parkland College can realize recovery of investment and further savings over the life of the systems involved.  Further, the utilization of occupancy sensors could keep as much as 412,000lbs of $Co_2$[3] from being emitted annually from needless electrical consumption.

## Overview

With just over $50,000 in funds secured through the Parkland College Innovation Fund for the purchase and installation of lighting occupancy sensors, it is a prime opportunity to evaluate the technology in place at Parkland College and its potential economic and environmental benefits to the school.

Investing in properly designed and integrated energy efficiency strategies is a proven method of controlling facility energy costs.  Organizations that take a strategic approach to energy management can realize both tangible and intangible benefits.  Because of volatile pricing of the commodities that produce our energy, emphasis on measuring and maximizing energy productivity has become crucial.  Energy management is a key element of improving building performance and is an important element of any sustainability policy. One study indicates that a conservative estimate of economic savings potential in existing commercial buildings is between 10 and 20 percent of current energy use. According to that study "If lighting measures alone are considered, the range of economic savings falls in the range of 3 to 12 percent[4]".  Cutting a building's energy use reduces vulnerability to fuel price fluctuations and reduces environmental impact[5].  Energy costs savings put in place today are likely to increase over time. Energy costs are likely to increase.  Since 2000, commercial natural gas

prices have increased 50 percent, with commercial electric prices increasing 39 percent in the same time period[6].

The typical payback for occupancy sensors is between six months and three years[7]. This depends largely on frequency of use of the space and the lighting load controlled. Since the typical lighting control system's useful life is calculated to be at least ten years, the return on investment can be quite high.

Current code requirements prescribe that new buildings over 5,000 ft$^2$ are required to employ lighting control strategies[8]. While there is a requirement for new construction to maximize strategies that reduce energy use, older buildings can often be ignored as having opportunities to become more efficient. It is more likely that deferred maintenance is a major focus as budgets in higher education are strained. However, upgrading systems to become more energy efficient helps to mitigate budgetary constraints, through saving money in reduced energy costs and by maximizing opportunities to keep systems off-line when they are not needed. This effectively lengthens the useful life of building systems and reduces strain on system maintenance.

The largest energy usage in buildings comes from heating, lighting, cooling, and ventilation systems[9]. Nominal electrical costs savings in lighting energy consumption would provide rapid paybacks for investments to control those costs. When looking at Parkland's estimated expenditures for lighting loads[10], which are in-line with the published averages, a modest percentage of energy savings will help the bottom line by saving money.

The purpose of this research is to quantify the potential savings from the installation of occupancy sensors. This report details two types of areas, classrooms and offices. Parkland College has approximately 275 offices and 130 classrooms and laboratories within the confines of the main campus building alone[11]. The main campus utilizes mostly manual control over lighting via standard switch-to-fixture or switch-to-contactor configurations.

Parkland College is a signatory of the American College and Universities Presidents' Climate Commitment (ACUPCC)[12]. The goal of this organization is to significantly lower greenhouse gas emissions of the college through mitigation of pollution sources. This project advances that mission by reducing energy consumption, thereby reducing the amount of greenhouse gases produced.

This research is limited in scope by sample time and size. While it does show actual percentage of savings of the rooms that were subject to data logging and analysis, the extrapolation of the percentage of savings is only an estimate based on the data collected. This analysis is based solely on the percentage of savings only. Without current information on the scope of work to be provided from the grant money, no economic calculations can be derived. While this information can reflect potential savings, further study should be done after installation of the entire project in order to definitively determine the realized savings in energy expenditures. Also, the technology

used in the data logger for monitoring occupancy and lighting control is limited in that it utilizes only passive infrared technology.  This limits the accuracy in certain environments where ultrasonic technology would be a better match.
The temporary installation of the data loggers require close proximity to a light source which may not be within optimal range for the passive infrared sensor, given the unique nature of Parkland's architecture.


## Methodology

There are three types of occupancy sensors that react to human presence.  They are passive infrared (PIR), ultrasonic and a hybrid combination of the PIR and ultrasonic technologies.  Infrared sensors react to the motion of a heat source in its range.  The sensor creates multiple patterns of beams, and when a heat source moves from one beam to another, the sensor is triggered.  This method of detection has several drawbacks.  It will not activate if the heat source does not move, small movements may not be detected, and the heat source must be within direct line of site to the sensor.  In other words, someone sitting quietly may not trigger the sensor.  Ultrasonic sensors emit a frequency that is well above the range of the human ear.  The sound waves reflect off of all the hard surfaces in a space and create a pattern that the sensor can see.  The sensor, regardless of the location of the movement, detects any movement within the space, as line of sight is not necessary.  Careful calibration of ultrasonic sensors is required during installation as they can be very sensitive, and can be triggered by air movement.  The dual-technology sensor is a combination of both technologies that requires both types of sensors to activate, and then only requiring the action of a single sensor to continue to keep the lights on.  Often, these sensors will also have the capability to learn the typical patterns of occupancy, helping avoid false activation of the sensors.

In order to gather data for this project, two occupancy and light loggers were supplied to Parkland College.  The units, model # IT-200 IntelliTimer Pro are manufactured by Watt Stopper[13].  These units include a passive infrared sensor, and a light pipe.  The data logger utilizes proprietary software for quick analysis of recorded data, and raw datasets can be exported into a spreadsheet program for detailed comparative analysis, which is how the data for this research was processed.  Data was tracked via unit serial numbers, identification of room placement in the data logger software, and through dates of use.

A basic test was devised to check the calibration of the two units.  Both units were placed in the same space, and a log kept of every occupancy cycle, its length and whether or not lights were on or off.  This was done for a period of twenty-four hours.  After this time, the data collected from the data loggers was retrieved from both units and compared against the written log and each unit's data set compared to the other.  The initial findings were that one unit matched the log exactly, and the other was within 10 percent of the first.  Based on the precision of the first unit, the second unit's sensitivity was increased slightly in an attempt to have it reproduce more accurate

results.  The test was run again, this time for a shorter frequency of four hours.  The results on this test came with 6.5 percent, which was deemed acceptable for the purposes of this analysis.

A schedule was devised to monitor two classrooms and two offices in the time allotted for this research to be completed.    The schedule allowed for two weeks of data gathering before and after sensor installation.  The data loggers were first installed in two classrooms.  Both of the classrooms were in the L wing, room numbers 123 and 238.  Room L123 is a natural sciences classroom, with no windows to the exterior.  There is a large area of windows on the entrance wall to the corridor, allowing for borrowed natural light from the opposite side of the hall.  Within the classroom, there is a partial wall divider towards the entrance side of the room, which contains a desk and computer.  The ceiling is flat in this classroom.  Because of the divider wall, this layout requires thoughtful layout of an occupancy sensor.  For this project, the data logger was placed into the open classroom area in order to take advantage of the highest probability of triggering the sensor in a larger area.  For the fall 2010 semester, room L123 was scheduled for classes for a total of 15.5 hours a week.  These classes occur on Wednesday, Thursday and Friday[14].  Room L238 is a nursing laboratory, with no window area whatsoever.  The laboratory is laid out with a station and supply area in the center section at the entrance, and two small wings on either side with hospital beds.  The ceiling slopes up from the wall opposite of the entrance.  The data logger was placed opposite of the entry door towards the back of the room next to the supply area.  The scheduled use for this Classroom was for 12 hours a week, with classes occurring on Monday, Wednesday, and Thursday[15]. It should be noted that these schedules do not necessarily reflect true usage of these spaces, as real occupancy rates can be much higher than the scheduled times.

The schedule allocated two weeks of data gathering, after which the units were retrieved, their memories downloaded to a computer, logs reset and then installed in two offices.  The offices selected were X108 and M116.  Room X108 is the Physical Plant office, and contains a window to the exterior, a flat ceiling and a partial wall to divide the space.  The room also contains moveable partitions to help divide the occupant work spaces.  This office has an unusual occupancy schedule in that the night maintenance crew is dispatched from this area.  M116 is typical of many offices in the main building.  It has no windows and the room is long and narrow.  The door is at one end of a long wall.  After the transition was made from the classrooms to the offices, the Parkland electrician installed an occupancy sensor in each classroom by the end of the two-week logging period.  The data loggers were then retrieved; their memories downloaded again, logs reset, and placed back into the classrooms to begin data collection post-sensor installation.  At this time due to procurement conflicts, the electrician was able to install only one occupancy sensor, in office M116.  Another cycle of data logger recovery was invoked, with only a single unit being used for the final two weeks of data recording.

After the final cycle of data collection, the data was compared to usage based on room schedule and usage before and after occupancy sensor installation.  With the data

imported into a spreadsheet program the percentage of potential savings in energy saved by sensor installation could be calculated. An additional component will be calculated; Carbon dioxide emissions mitigated as a function of energy savings. It is important to understand the relationship between energy, which is produced through an array of sources, and greenhouse gases (GHG).


## Results

Taking equal sample lengths of each space allowed for simple extraction of savings in wasted energy. For room L123, an approximate duration of 15 days (360 hours) of data was collected. The logs recorded for 360.05 hours pre-sensor installation and 359.62 hours post-sensor installation. The log difference was less than 1 percent and deemed suitable for comparison. Before sensor installation the logger showed a lights 'on + vacant' time of 34.28 hours, 9.5 percent of total log time, a lights 'on + occupied' of 85.95 hours, 23.9 percent of the total time and an 'off + occupied' time of over 11 hours, 3.1 percent of log time. The rest of the time was shown as 'off + vacant'. After the sensor was installed, a 'lights on + vacant' situation occurred for 20.20 hours 5.6 percent, 'on + occupied' for 80.65 hours, 'off + occupied' for 8.98 hours, and the remainder of time, 249.78 hours, as 'off + vacant'. When comparing before and after occupancy sensor installation data, the higher number divides the difference in time for 'on + room vacant'. In this case, there was an energy savings of 41%. Taking the percentage of time that the room is in a 'lights on + vacant' situation and multiplying it by hours in a year (8,760) gives the total wasted power-on hours annually. The power-on hours in a year can be multiplied by the utility rate (a base rate of $0.11/kWh is used for this report) and the lighting load for the room (825 watts) and then divided by 1000 to derive annual savings in electrical energy costs for that space ($76.00 rounded).

For the laboratory classroom L238, an approximate duration of 14 days (336 hours) of data was obtained. The logs recorded for 335.95 hours pre-sensor installation and 335.35 hours post-sensor installation. The log difference was less than 1 percent and deemed suitable for comparison. Before sensor installation the logger showed a 'lights on vacant' time of 103.55 hours, 30.8 percent of total log time, a 'lights on + occupied' of 39.32 hours, 11.7 percent of the total time and a 'off + occupied' time of 7.22 hours, just 2.1 percent of log time. The rest of the time was shown as 'off + vacant'. After the sensor was installed, a lights 'on + vacant' situation occurred for 16.12 hours 4.8 percent, 'on + occupied' for 43.65 hours, 'off + occupied' for 2.13 hours, and the remainder of time, 273.45 hours, as 'off + vacant'. It should be noted for the pre-sensor data gathering cycle, the data logger tracked an occurrence wherein the lights were left on in the space for an entire weekend, adding three days to the lights on and vacant situation. For the final calculation, the 72-hour overage has been discounted. This provided an energy savings of 49 percent. Using the standard calculation ((814.7)(1,350w)($0.11)/1000), the amount of annual cost savings for L238 was $110.

For office M116, approximately 13 days (312 hours) of data was collected. The logs recorded for 312.00 hours pre-sensor installation and 312.32 hours post-sensor

installation.  The log difference was less than 1 percent and deemed suitable for comparison.  Before sensor installation the logger showed a lights 'on + vacant' time of 47.20 hours, 15.1 percent of total log time, a lights 'on + occupied' of 52.20 hours, 16.7 percent of the total time and a 'off + occupied' time of 4.87 hours, 1.6 percent of log time.  The rest of the time was shown as 'off + vacant'.  After the sensor was installed, a lights 'on + vacant' situation occurred for 13.07 hours 4.2 percent, 'on + occupied' for 70.18 hours, 'off + occupied' for 4.22 hours, and the remainder of time, 224.85 hours, as 'off + vacant'. This provided an energy savings of 72 percent.  Using the standard calculation ((1325.2)(300w)($0.11)/1000), the amount annual cost savings for M116 was $44.

As previously indicated, Office X108 did not get an occupancy sensor installed before this project concluded.  The data logger software analysis on the estimated savings came out to $44 annually without actual savings measured.

| Room | Lights on and Vacant | | % Improvement | Annual kWh savings |
| | Pre-Sensor hours | Post-Sensor hours | | |
| --- | --- | --- | --- | --- |
| L123 | 34.3 | 20.2 | 41 | 688 |
| L238 | 31.55* | 16.1 | 49 | 1100 |
| M116 | 47.2 | 13.1 | 72 | 398 |
| X108 | 8.0 | na | na | na |

Table 1: Percentage of savings
*Actual number 103.55 hours.

To calculate the GHG equivalent necessitated the following procedure.  It was necessary to find the "site" equivalent of greenhouse gas emissions, and then convert it to "source" or point-of-generation quantities through a common multiplier.  For this calculation an average kWh rate made from the three rooms L123, 238, and M116. Is then used with a $CO_2$ multiplier of 1.312, and then converted from a site to source emission using a multiplier of 1.065.  This product is then multiplied by 405 rooms, which is a bulk of the office and classroom space in the main building.  This calculation gives a result of 412,250 lbs of $CO_2$ equivalent.

## Discussion

It was noted that without detailed information on the scope of work of the $50,000 dollar grant, it is not possible to do an economic analysis on the actual project.  Without actual quantities of occupancy sensors to be installed, there is insufficient data to do the necessary calculations for Net Present Value (NPV) and Internal rate of Return (IRR). Additionally, the price used for the electric utility rate is a non-aggregated number.  This means it is not inclusive of transmission and distribution charges, metering charges, line-loss charges, or any other charge that affects true utility rates.  In a typical situation,
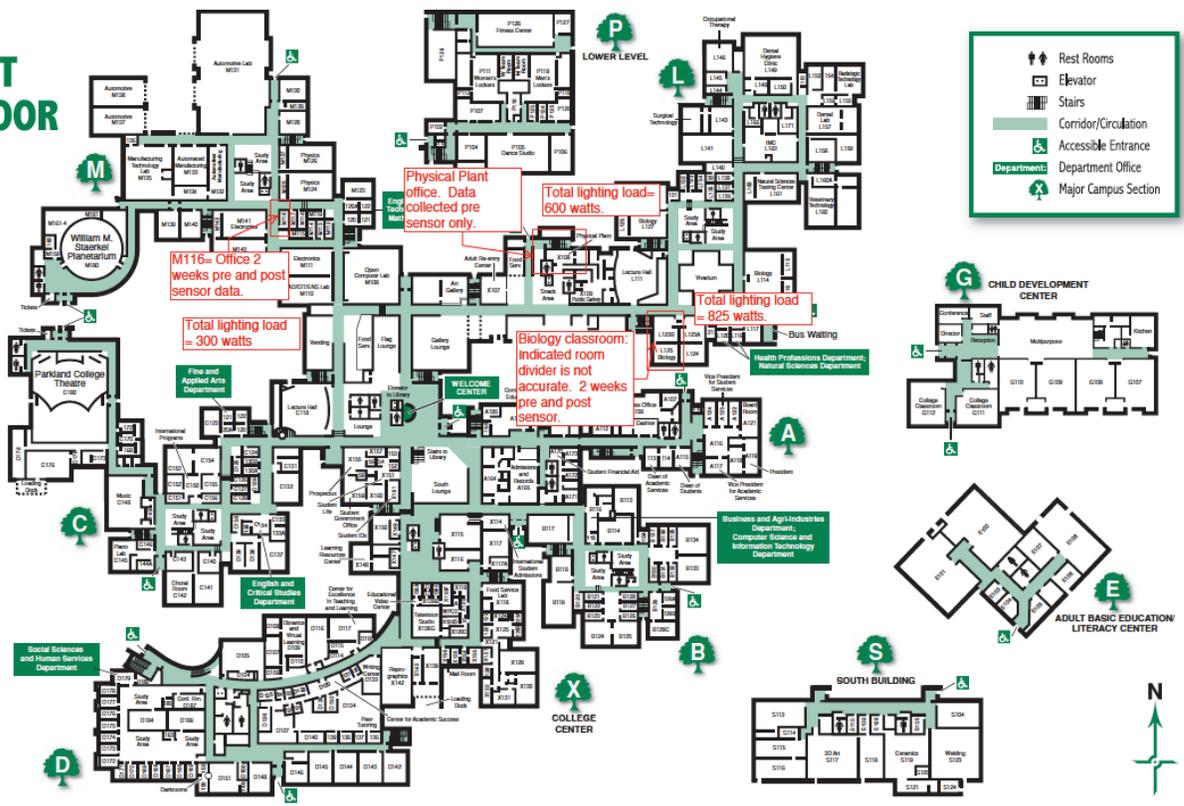
an average would be made of total electrical utility charges, which is more representative of actual costs.  This would increase the savings potential.  Also, these figures represent a full calendar year of savings, which may not be the case for every room.  Summer and winter breaks may affect the occupancy of rooms.  Some offices are occupied year around, while others are not.  This same exception applies to classrooms as well.  Without detailed room usage for the entire campus, it is not possible to infer the percentage of difference between occupied and unoccupied times in a calendar year.

The data logging of L238 illustrates another benefit of lighting occupancy sensors.  It appears as though the lights were left on accidentally on a Friday evening and then left on for an entire weekend when the room is generally not occupied.  While this situation is not the norm, it possibly happens enough to make occupancy sensors a valid alternative to manual control.  The savings for the two classrooms fall in a standard range of potential savings for these types of spaces[16].  While office M116 saw greater returns in reduction of 'lights on + vacant' situation, this is higher than the amount of savings that are typical for private offices.

Also of note: The sensors that were installed were set with a thirty-minute delay to switch off.  This means that without manual override, the lights will stay on for half an hour after occupancy ends.  This may cause a situation wherein an increase in energy use occurs.

[1] An analysis of the energy and cost savings potential of occupancy sensors for Commercial lighting systems http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf

[2] http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.4

[3] Using 1.312 lbs per kWh x site to source electric Transmission and Distribution multiplier of 1.065:
http://homepower.com/article/?file=HP137_pg32_Mail_3_1 accessed 12/15/2010
http://www.carbonfund.org/site/pages/carbon_calculators/category/Assumptions
accessed 12/15/2010

[4] http://www.pnl.gov/main/publications/external/technical.../PNNL-18337.pdf

[5] http://www.epa.gov/cleanenergy/documents/suca/consumer_fact_sheet.pdf

[6] http://www.eia.doe.gov/mer/elect.html Table 9.9

[7] Mechanical and Electrical Equipment for Buildings Eleventh edition pg. 657

[8] http://www.aboutlightingcontrols.org/education/papers/2009/2009_ashrae_04.shtml

[9] http://www.eia.doe.gov/energyexplained/index.cfm?page=us_energy_commercial - tab2
accessed 12/14/2010
http://buildingsdatabook.eren.doe.gov/docs%5CDataBooks%5C2005_BEDB.pdf
accessed 12/12/2010

[10] Information obtained from the Smart Energy Design Assistance Center report:
"Feasibility Report Energy Evaluation and Recommendations, Parkland College"
January 9,2009 pg. 16; Figure 5

[11] http://www.parkland.edu/about/quickfacts.aspx
First and second floor maps used to estimate office counts:
http://www.parkland.edu/about/maps.aspx

[12] http://www.presidentsclimatecommitment.org/about/commitment

[13] http://www.wattstopper.com/products/details.html?id=13 accessed 12/12/2010

[14] Class schedule data retrieved from academic scheduling office. 12/16/2010

[15] Class schedule data retrieved from academic scheduling office. 12/16/2010

[16] http://www.hubbell-wiring.com/press/pdfs/0904bpfhubbell.pdf accessed 12/12/2010

**1ST FLOOR**

Physical Plant office. Data collected pre sensor only.

Total lighting load = 600 watts.

M116= Office 2 weeks pre and post sensor data.

Total lighting load = 300 watts.

Total lighting load = 825 watts.

Biology classroom: Indicated room divider is not accurate. 2 weeks pre and post sensor.

Rest Rooms
Elevator
Stairs
Corridor/Circulation
Accessible Entrance
Department: Department Office
Major Campus Section

Nursing Lab: 2 weeks of data collection pre and post sensor installation.

Total lighting load = 1,350 watts.