Taitem **TechTip** New York State Homes & Community Renewal

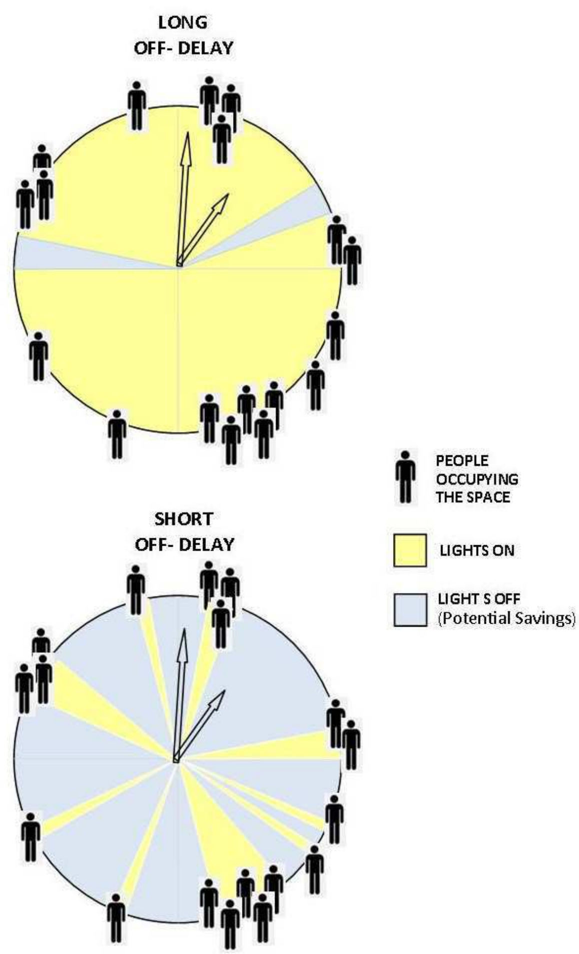
Weatherization Assistance Program

Boosting Energy Savings through Lighting Occupancy Control Settings in Multifamily Buildings

Overview

Very significant energy savings are achieved by converting 24-hour lighting to occupancy controlled lighting. A critical setting is the off-delay, which is the time that the light stays on after occupancy is no longer detected. Significant savings are obtained with an off-delay of 30 minutes, the time suggested in the ASHRAE 90.1-2010 lighting standard. **For most building spaces, there is a potentially large additional energy savings to be gained by further reducing the lighting off-delay and selecting the lowest possible standby lighting level during unoccupied periods.** In the case of corridors, for example, savings can be tripled by using off-delays shorter than 30 minutes.

To estimate the potential savings, three high-rise senior residence buildings were monitored for occupancy patterns in corridors and stairways. Energy savings were modeled using the monitored occupancy patterns and various sensor off-delay times. **More than 50% additional savings are possible by reducing the off-delay time from 30 minutes to 30 seconds in corridors. For stairways, at least an additional 17% savings is possible by reducing the off-delay from 30 minutes to 30 seconds.** Maximum energy savings in both areas exceeded 74% with a 30-second off-delay. For occupancy controls that do not allow such short off-delays, significant savings are achieved by selecting the shortest allowable off-delay setting.



Introduction

Lighting reduction in unoccupied spaces is a well-known energy reduction strategy. ASHRAE 90.1-2010 (Energy Standard for Buildings Except Low-Rise Residential Buildings) requires that lighting in most indoor spaces be reduced or shut off after a period of vacancy. For example, the standard requires that lighting for most indoor spaces be shut off or reduced by at least 50% within 30 minutes after the space becomes unoccupied. The time delay from the end of occupancy until lights are dimmed or shut-off by an occupancy sensor control is called the *off-delay time*.

This Tech Tip focuses on corridors and stairways. These areas are important because stairs and corridors together comprise a significant portion of the common area energy use in high-rise residential buildings. In a survey of energy audits for 40 high-rise residential buildings, lighting in stairs and corridors comprised **60%** of reported common area electric use. Despite this high percentage of energy use, only one of the 40 buildings surveyed reported using occupancy sensor controls on stairway and corridor lights.

A survey of 12 occupancy sensor lighting controls showed that models are available with off-delays ranging from 30 seconds to 30 minutes. The most commonly available off-delay settings are 5, 10, 15, 20, and 30 minutes. We used actual monitored occupancy patterns in this Tech Tip to show the energy savings achieved by selecting the shortest available off-delay times.

Results of Occupancy Monitoring

In order to estimate energy savings for occupancy controlled lighting, various assumptions are made in energy audits about the frequency of occupancy. For this project, we set out to gather actual occupancy data in order to improve the accuracy of the assumptions and resultant energy savings predictions. We monitored three high-rise senior housing buildings for actual occupancy events using occupancy sensors paired with data loggers. All three buildings are almost fully occupied. One stairway and one corridor elevator waiting area were monitored in each building on a floor mid-way between ground level and the highest floor. The buildings were monitored for 4 weeks. Results for corridors and stairways are summarized below.

Corridors

Table 1 summarizes the monitored occupancy data for corridors in the three buildings. Differences between buildings may be attributed to various factors, e.g., apartment density per floor, speed of elevators affecting waiting time, and building-specific resident patterns of movement. However, the overall pattern of more than 97% vacancy in these spaces holds across the three buildings.

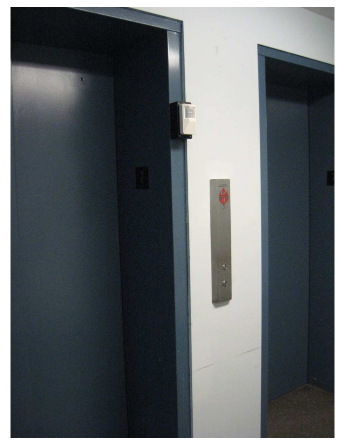


Figure 1: Typical Elevator Corridor Location

	Number of Floors	Apartments per floor	Number of Occupancies per Day	Average Occupancy per Day in minutes	Percent Vacant
Building 1	15	12	83.0	30.4	97.9%
Building 2	6	14	92.9	29.8	97.9%
Building 3	5	18	64.5	7.3	99.5%

Table 1: Monitored Occupancy Summary for Corridors

Stairways

Table 2 summarizes the monitored occupancy data for stairways in the three buildings. With so few occupancy events, differences between buildings may be influenced by just a few individuals with specific and personal patterns of stairway use. Apart from these small differences, vacancy dominates even more strongly than in corridors, with 3 minutes or less of occupancy time per day.

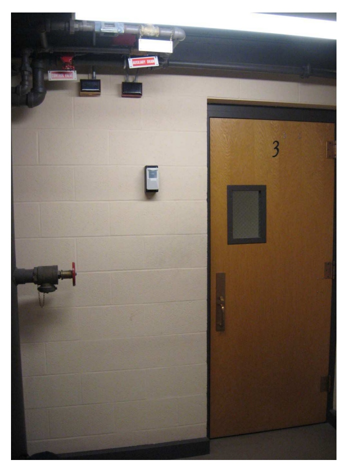


Figure 2: Typical Stairway Location

	Number of Floors	Apartments per floor	Number of Occupancies per Day	Average Occupancy per Day in minutes	Percent Vacant
Building 1	15	12	14.9	3.0	99.8%
Building 2	6	14	3.1	0.8	99.9%
Building 3	5	18	7.9	1.3	99.9%

Table 2: Monitored Occupancy Summary for Stairways

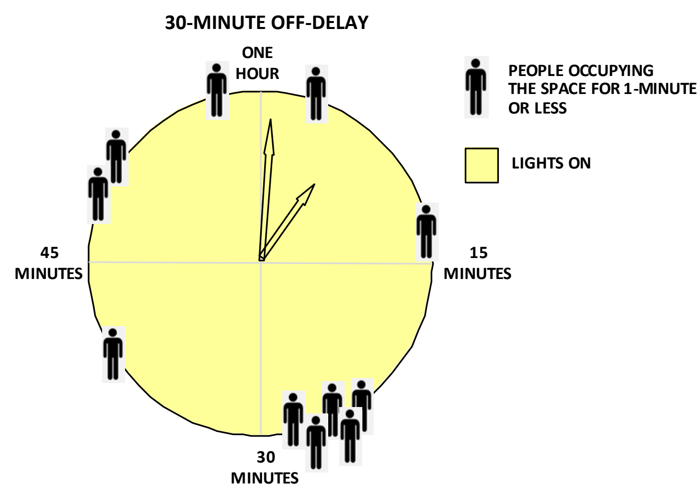
Energy Savings Model

We modeled potential energy savings for various off-delay times using the actual vacancy intervals logged for each building, 24 hours per day for 4 weeks. (See Appendix A. for experimental setup.) The savings were calculated in the following way. For a given off-delay time, each vacant interval throughout the day was compared to the off-delay time. If the off-delay time was shorter than the vacant interval, then a potential savings equal to the difference was recorded. If the off-delay time was greater than the vacant interval, no potential saving was recorded.

The potential savings for various off-delay times are reported below. The savings are compared to a baseline of 24-hour lighting operation, since the survey of energy audits shows that the vast majority of high-rise residential buildings are not yet equipped with occupancy lighting controls. Savings are reported for Building 1 only, but occupancy patterns are consistent enough across the monitored buildings to suggest that the results should be representative of similar building types. See below for recommendations for different building areas and resident populations.

Duration of Occupancies

According to the data, 95% of all corridor occupancies were under 20 seconds in duration and 95% of all stairway occupancies were under 60 seconds. Therefore in the great majority of instances, an off-delay of 30 minutes will result in lights remaining on *far* longer than actually needed. In spaces like corridors and stairways, imagine that the light comes on for only 30 seconds while someone walks by and then stays on for another 30 minutes **unnecessarily lighting an entirely empty space**. For busy times of the day, the occupancy sensor is likely to be re-triggered before the 30 minute off-delay expires, resulting in almost continuous lighting.

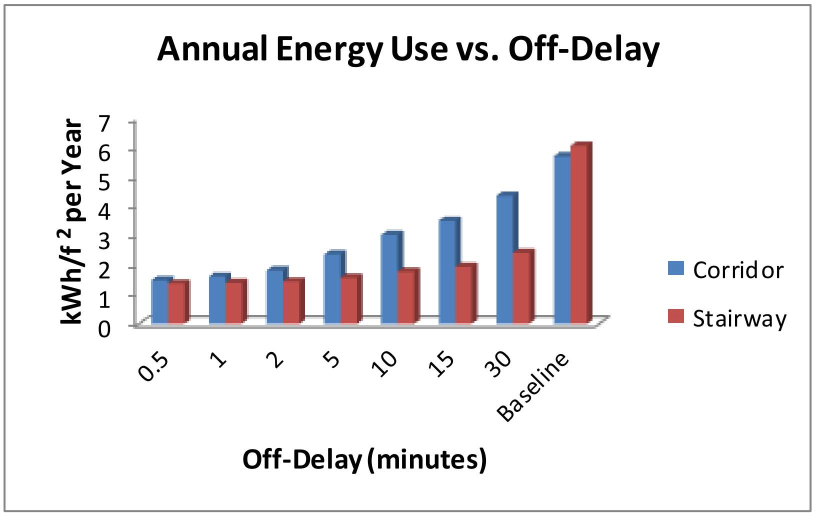


Off-Delay and Standby Lighting Controls for Corridors and Stairways

There are an increasing number of bi-level occupancy controls available, allowing various combinations of off-delay times and standby lighting levels used during unoccupied periods. One popular bi-level fixture allows a minimum standby lighting level of 5% of full fixture output for each fixture, enough to provide a basic level of safety lighting for the instant before the occupancy controlled lighting turns on. We chose this configuration for our analysis of energy savings although other common lighting control scenarios may include an occupancy sensor for every other fixture or for two out of three fixtures.

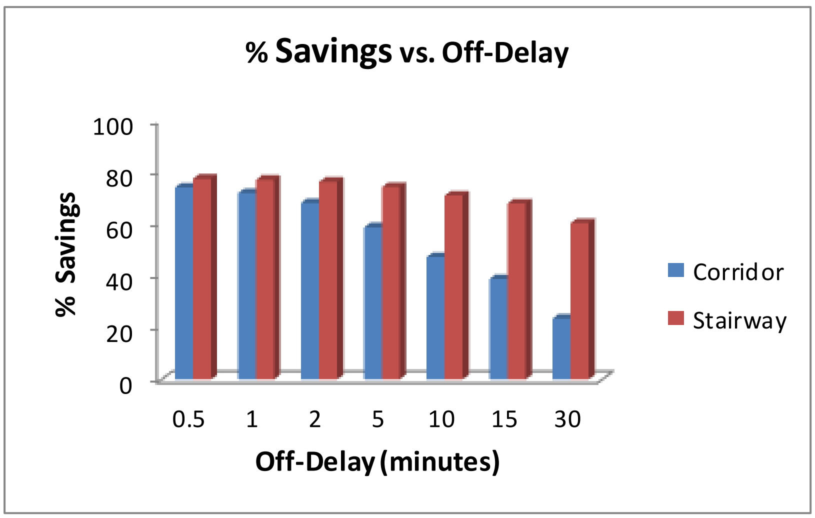
On the following page, Table 3 and Table 4 show the energy use in kWh/f^2/yr and percent energy savings of bi-level occupancy control with various off-delay settings, compared against a baseline of 24-hour lighting operation at full intensity with no occupancy controls. For a standby lighting level of 5% full output (95% reduction), we used a corresponding 78% input-wattage reduction which is typical of the non-linear relationship between input wattage and output when fixtures are dimmed.

Off-Delay Energy Savings for Corridors and Stairways



	Corridor	Stairway
ASHRAE LPD Guideline	0.65 W/f^2	0.69 W/f^2
Off delay (min)	*kWh/f^2 per Year*	
0.50	1.47	1.36
1	1.60	1.39
2	1.81	1.43
5	2.35	1.56
10	3.01	1.76
15	3.49	1.93
30	4.35	2.40
Baseline 24 hr.	5.69	6.04

Table 3: Energy use for various off-delay times vs. 24 hour operation, for 95% lighting reduction during vacancy. Note: The Corridor Lighting Power Density (LPD) above is based on the average of ASHRAE's Corridor and Lobby guideline.



	Corridor	Stairway
Off delay (min)	*% Savings*	
0.50	74.1%	77.5%
1	72.0%	77.1%
2	68.2%	76.3%
5	58.8%	74.3%
10	47.1%	71.0%
15	38.7%	68.0%
30	23.5%	60.4%
Baseline 24 hr.	0.0%	0.0%

Table 4: Percent energy savings for various off-delay times vs. 24 hour operation, for 95% lighting reduction during vacancy.

Note in the tables above that the energy use depends on the lighting power density but the percentage savings are independent of LPD.

These comparisons show not only the energy savings that are available by taking the first step to install occupancy controlled lighting, but the very significant additional savings reaped by selecting the shortest possible off-delay times.

Different Areas and Resident Populations

Different resident populations have their own unique occupancy patterns; in fact, the three senior housing buildings we studied had some differences in their occupancy patterns. Other building types and spaces will have greater distinctions. A building of predominantly professionals will likely have fewer occupancy events from 9 AM to 5 PM, with peaks between 7 AM and 9 AM and between 5 PM and 7 PM. Younger professionals may have another peak between 10 PM and 2 AM when returning from socializing. Laundry rooms will have occupancy periods of perhaps 5-20 minutes at a time as residents start and finish and fold laundry loads. To generalize, the frequency and time per occupancy determine the potential savings. A higher frequency of short occupancies, as in corridors, results in a modest savings with a 30 minute off-delay but a large savings with intermediate and short off-delay settings. In spaces with very few, brief occupancies, such as stairways in buildings with elevators, the largest savings is achieved by taking the first step to install occupancy controlled lighting, but additional, modest savings can be achieved as off-delay times are shortened. The contrast between these two areas can be seen in Table 4, where a further 15% savings is gained by reducing corridor off-delays from 5 minutes to 30 seconds, while that same change saves a little less than 3% in stairways. Spaces with few but longer occupancies of perhaps up to 30 minutes will benefit from the shortest off-delay that doesn't create false lighting shut-offs while still occupied. **One trend holds throughout all spaces: regardless of the occupancy pattern, reducing off-delay times to the minimum possible will always achieve an additional energy savings.**

Fixture Life

The energy savings are clear but the picture is not complete without considering that fluorescent lighting life will be reduced by many short on/off or dimming cycles. Recent investigation into this issue did not reveal any clear predictions for very short off-delays. The extent to which fluorescent lighting life is affected by cycles depends greatly on the bulb and ballast types; this data is sometimes provided by the lighting manufacturer but usually for on/off cycles of three hours or greater.

When adding occupancy controls to existing lighting, it is important to replace instant-start electronic ballasts with programmed-start ballasts. Instant-start electronic ballasts start fluorescent lamps in a fraction of a second by providing a voltage that is high enough to start the lamp without pre-heating the lamp electrodes. While energy efficient and fast, these ballasts cause stress on the cold electrodes which results in fewer on/off cycles before lamp failure. Programmed-start ballasts work by first applying, and then maintaining, a precise voltage to heat the lamp electrodes before applying the voltage to ignite the lamp. This minimizes lamp deterioration caused by oxides sputtering off cold surfaces of the electrodes. Therefore, lamps with programmed-start ballasts may survive up to five times the number of cycles of lamps equipped with instant-start ballasts. When choosing new fixtures with integrated controls, be sure to choose those with programmed-start ballasts. Most fluorescent lamps, when used for occupancy controlled applications, will have a recommended burn-in period during which the lamp is continuously lit. Many occupancy sensors will have a built-in feature to accommodate the burn-in period.

As fluorescent fixtures with occupancy controls continue to gain market share, the industry will likely respond with components that are more robust to on/off cycling. For example, most manufacturers already offer extended-life T8 lamps. Bulb and ballast replacement intervals should be monitored to better understand the tradeoff between replacement costs and clear energy savings. With good maintenance and energy records, off-delay times can be adjusted upward if it appears that lighting life is being compromised.

Summary

When replacement lighting is being evaluated for a project, this analysis shows that it pays to choose occupancy controls that allow off-delay times as short as 30 seconds. For occupancy controls that do not allow such short off-delays, significant savings will be achieved by selecting the shortest allowable off-delay setting. In all common areas, very significant energy savings are realized by using much shorter off-delays than the 30-minute maximum specified in ASHRAE 90.1-2010.

Not surprisingly, the savings achieved with different occupancy control settings depends on occupancy patterns. All savings referred to in this summary are compared to 24-hour operation with full intensity.

In corridors with a larger number of short occupancies, approximately 24% savings are achieved by first introducing occupancy controls with a 30-minute off-delay. A number of vacancies will be less than the 30-minute off-delay, meaning that the lighting is likely to be continually triggered during the higher occupancy periods of the day. This is why very significant savings can be achieved by selecting the shortest off-delays. Setting a 30–second off-delay can provide a total energy savings of approximately 74%.

The occupancy data suggests that very short off-delays of less than one minute should be avoided in an elevator waiting area to prevent unwanted lighting reduction while an occupant is standing still. Some lighting controls allow sensitivity adjustments to minimize these occurrences. However, the possibility of this happening in other corridor areas or stairways will be very small, since practically all occupancies will be a quick passage.

For very low occupancy areas like stairways, the largest energy savings of nearly 70% comes from the first step of installing occupancy controls, even with a 30-minute off-delay time. The vacancy periods are so long that the occupancy sensor will almost always turn off the lights before the next occupancy. Additional savings of about 10% are possible by selecting an occupancy control that allows off-delays as short as 30 seconds, bringing the total savings up to almost 80% compared to 24-hour operation.

Acknowledgement

The Ithaca Housing Authority and the Geneva Housing Authority graciously provided access to their buildings for our occupancy monitoring project.

General Recommendations

- In all areas, an occupancy sensor with a 30-minute off-delay will result in some savings. **However, much greater energy savings can be achieved with shorter delay settings.**
- In corridors and stairways use bi-level lighting with standby lighting during vacancies set to 5% of the fixture output unless site specific safety conditions require greater lighting levels.
- In corridors, set the off-delay to a maximum of 15 minutes, preferably less; off-delays of 1, or even 5, minutes will greatly increase savings. **Reduce the off-delay to 30 seconds to maximize energy savings.**
- In stairways, set the off-delay to a maximum of 15 minutes. Set to shorter off-delays for even greater energy savings.
- At elevator waiting areas, set the off-delay to 1 or 2 minutes to maximize energy savings while reducing the possibility of false shut-offs when residents are waiting.
- In low-rise buildings that do not have elevators, treat stairways the same as corridors for off-delay settings.
- Use only programmed-start ballasts for all lighting controlled by occupancy sensors (dimming, bi-level, and full-shut-off applications.)
- You might want to monitor ballast and lamp life when using off-delays shorter than 5 minutes. Multi-floor buildings provide a perfect setting to make controlled comparisons and adjust off-delays to fit your site conditions. Consider setting hallway controls on two floors at a 5 minute off-delay, or shorter, while the others are set at 30 seconds, and then compare lighting replacement costs over a 2-year period. Balance the replacement costs against your energy saving to find the right strategy for your buildings. And tell us what you find!

Appendix A
Experimental Setup

Figure 1: Motion Sensor and Data Logger Unit

Equipment Overview:

The testing unit is a combination of a **Visonic SRN-2000 C/PC** passive infrared occupancy sensor (OS) being monitored by an **Onset HOBO U9-001** state data logger. The SRN-2000 was chosen because it is capable of being powered by a 9V battery, has a contact closure output suitable for state logging, has adjustments for the detection angle and sensitivity, and has an operating mode which allows instantaneous re-triggering rather than the normal operating mode which suppresses re-triggering for 2 minutes or more. The HOBO U9-001 is a basic data logger which records changes of state, in this case when the OS output contacts open or close.

Methodology:

Occupancy sensors were installed in two locations in each of three multi-story senior citizen housing units. One sensor was installed in a stairwell, about the middle floor. The other sensor was placed near the elevator serving the same floor. All sensors were placed at about 6 feet above the floor and tested for sensitivity.

Data was collected continuously for four weeks at each location. The data was downloaded and patterns of occupancy were analyzed with statistical software to calculate total occupancies and potential energy savings.

Figure 2: Data Logger and Sensor Battery Setup