Field Test DELTA Snapshots

SENSOR-CONTROLLED LIGHTING IN MULTI-FAMILY CORRIDORS

Demonstration and Evaluation of Lighting Technologies and Applications & Lighting Case Studies

Saving lighting energy in multi-family corridors is becoming more feasible. LED luminaires can easily dim light output when corridors are vacant, rather than turning off entirely. This is referred to as "bi-level" or "adaptive" lighting. Sensors can be mounted in each luminaire, or can be wirelessly linked to multiple luminaires. This guide shows results from a field demonstration of bi-level corridor lighting. Occupants had positive feedback, and considerable energy savings were achieved.¹ Monitoring results from 14 other apartment buildings enabled energy savings calculations comparing market rate vs. below market rate buildings. As energy codes² move toward increased adoption of sensor-controlled lighting, these results show how to use bi-level lighting to improve energy efficiency without occupant dissatisfaction.

Site Demonstration

Lincoln Square Two is a below market rate apartment building in Albany, New York. The building is part of a complex of high-rise apartments built in the 1960s. In 2017, Albany Housing Authority (AHA) collaborated with the researchers, Taitem Engineering and the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, to upgrade³ 60 corridor lights (6 floors, 10 per floor) for this project.

Previous lighting consisted of linear T8 fluorescent lamps⁴ in surface-mounted luminaires spaced typically 13 feet (4 m) apart. Although lamps were in good working order,⁵ plastic cube louvers had yellowed with age, thus distorting colors and reducing luminaire light output. Before the retrofit, average illuminance on the floor was 106 lux (10 fc).

For this research, each of the previous fluorescent luminaires were replaced one-for-one with LED⁶ luminaires controlled by integrated ultrasonic occupancy sensors. Luminaires were rotated to orient parallel to the corridor to improve light distribution on the walls. Each of the new luminaires were set to operate at 100% output when occupied (average 303 lux at floor level); when vacant, luminaires dimmed independently to 20% of full output. Twenty of the new luminaires were set for each of the three delay time settings: 5, 10, or 15 minutes.

- For more information about the methodology and results of the field demonstration, see Brons, Jennifer. "Sensor-controlled Corridor Lighting in a High-Rise Residential Tower: Occupancy Patterns, Dimming Energy Savings, and Occupant Acceptance." LEUKOS. 2018; in press.
- U.S. Department of Energy (DOE). Building Energy Codes Program. Status of State Energy Code Adoption. https://www.energycodes.gov/status-state-energy-codeadoption
- 3. AHA purchased the luminaires from Lamar Lighting, Inc., who also supported this research.
- In the corridors, two 3-ft. T8 fluorescent lamps (2100 lumens per lamp, initial) ran perpendicular to the corridor; in elevator lobbies, two 4-ft. T8 lamps (2900 lumens per lamp, initial).
- Taitem Engineering reported in April 2017 that only three out of 120 T8 lamps had burned out. Lamps were a mix of 3500K and 4100K.
- 6. Lamar Lighting VOL48A FA 40AS, with rated output 2600+ lumens, initial.



Lincoln Square Two, Albany, New York





After



Questionnaire

The LRC administered a questionnaire to compare occupant acceptance to the conventional, fixed-output fluorescent lighting in use before the retrofit. Despite the higher light levels with the new lighting, most occupants did not consider the hallways too bright after retrofit. Over three-quarters (78%) of the occupants approve of the new bi-level lighting. More of the occupants had positive ratings after retrofit than before retrofit.

The occupants also offered very positive comments about the retrofit. Multiple people commented that they like how the individuallycontrolled luminaires ramp-up light output successively as they walk through the corridor. One person likes that the sensors act as a notification that others are present. Several people simply prefer having more light in the corridors, independent of sensor features. There were no negative comments about the sensors.

- "I like it because it lets you know when someone enters."
- "I like the new lights. They follow you down the hall, ahead of you though."
- "I like how it's bright, and the sensor goes off."
- "I like the way the light dims down. Couldn't ask for more."



Maintenance

There were no failures of the bi-level lighting during the study. However, the LRC noted some maintenance issues in regard to insect accumulation. At this site, windows were left open continuously, especially during summer. Window screens were missing in a few areas, so even at dim output, insects accumulated inside the luminaires. When window screens were inserted, luminaires stayed cleaner.



When I enter this hallway, the light levels change. In my opinion I...



Overall, compared to other multi-family hallways, the lighting in this area is...





Estimated Annual Energy Use

Energy impacts were studied for the three delay time settings. Luminaires programmed with the shortest sensor delay time (5 minutes) operated at high output for less time (22%) compared to those programmed with longer (15 minute) delay times (31%). This resulted in 14% less annual energy use for the short delay time setting compared to the long delay time setting.

Proximity to elevator lobbies increased the amount of time luminaires were at high output, and therefore reduced energy savings in these areas, compared to the remainder of the corridors. However, even in busy elevator lobbies, bi-level lighting used about half as much energy as only upgrading to fixed-output LEDs.

The LRC calculated annual energy use for 48 luminaires comparing the previous T8 fluorescent luminaires to two conditions: LED luminaires without sensors, and bi-level lighting programmed with a 5-minute time delay. At this high-rise residential site, use of sensors to create bi-level lighting more than doubled energy savings compared to upgrading to fixed-output LEDs.





Annual Energy Estimate for 16 Luminaires



Annual Energy Estimates for 48 Luminaires Before and After Retrofit



As suming six floors with six 3-foot T8 luminaires (34.5W each), and two 4-foot luminaires (48W each), operated 24 hours per day. Two additional 4-foot luminaires were excluded from a nalysis of each floor due to extraneous switching.



Relative Time at High vs. Low Output Averaged for Each Delay Time Condition



How Often Will Bi-Level Corridor Lighting Operate at Full Output?

At Lincoln Square, bi-level lighting operated at full output an average of 22% of the time, when set at a 5-minute delay. To compare savings results with other populations, the research team used monitoring equipment⁷ for two weeks at 14 additional sites. The luminaires were not changed, but occupancy patterns were studied at these sites. Up to five monitoring devices were used on each floor, with a minimum of two floors per building.

Occupancy results from five market rate sites were compared to four below market sites and five properties that serve the elderly and/or persons with disabilities (PwD). The results show that below market rate sites and those for elderly/PwD do not have a statistically significant⁸ difference in occupancy rates; therefore, the LRC combined these, for an average occupancy rate of 21%. This is similar to the results at Lincoln Square (22%). Market rate sites had lower occupancy rates (average 9%).

Even if bi-level, sensor-controlled lighting is used in busy locations such as elevator lobbies, it would operate at full output less than a third of the time. Energy savings further increase as traffic decreases toward the extremities of corridors.

Bi-level Sensor Payback Estimates

At the time of publication, the LRC estimates an incremental payback period of about 5 years, assuming an integral sensor and dimming driver would add about \$100 to the cost of the LED luminaire.⁹ As shown at right, the higher the utility rate, the shorter the payback period. When bi-level lighting operates less time at full ("high") output, the payback period would also shorten.

Dim Settings and Energy Savings

Using data from the 14 monitoring sites, the LRC calculated relative impact of light output settings¹⁰ when corridors are vacant. In general, the lower the dim level, the greater the energy savings. This analysis also showed extremely low dim levels (≤10%) may not provide much power reduction advantage compared to more moderate dimming (e.g., 20%). Extremely low light levels may impact how comfortable occupants feel when entering the space in regard to perceptions of safety.

- 7. Onset HOBO UX90-005 mounted on or near the ceiling.
- 8. Minitab (version 16) Test of Equal Variances.
- 9. Other assumptions: 25W at high output, 6W at (nominal) 20% output.
- Power demand at the nominal outputs was calculated assuming the luminaire type demonstrated at Lincoln Square: 10% output = 5W, 20% output = 6W, 30% output = 8W, 40% output = 10W, 100% output = 25W.

Average Time Sensor-Controlled Lighting Would Operate at Full Output



Elevator Proximity: Average Time at Full Output (Assuming 5-minute Delay)



Estimated Payback Period in Years Assuming ~\$100 Incremental Cost of Integral Sensor & Dimming Driver



Impact of Light Output Settings on Energy Use





Key Findings

The Lincoln Square bi-level lighting demonstration showed:

- Over three-quarters (78%) of the occupants approved of the new bi-level lighting.
- 5-minute delay time was not objectionable.
- Dimming to 20% light output when vacant was not objectionable.
- Use of sensors to create bi-level lighting more than doubled energy savings compared to upgrading to fixed-output LEDs.
- The lower the dim setting when vacant, the greater the energy savings due to bi-level lighting.

Monitoring of 14 other apartment corridors showed:

- Below-market sites had similar average occupancy rates (21%) as Lincoln Square (22%).
- Market-rate apartment corridors had lower occupancy rates (9%).
- Payback period was estimated as approximately 5 years for incremental cost of sensors and dimming drivers.





Guidance for Sensor-Controlled Lighting in Corridors

- Replace existing lighting with dimmable LED luminaires. Occupants like when light levels increase before
 they are under the luminaire; ultrasonic sensors may be needed if corridors turn and block line of sight for
 approaching traffic. Sensors may be integrated in new luminaires or mounted remotely.
- Even busy locations are suitable for sensor-controlled lighting. Spaces such as elevator lobbies do experience slow-downs, especially late at night, thus benefiting from bi-level lighting. Corridor extremities show even more savings.
- Short delay times. To maximize energy savings, reduce delay times; this research showed that occupants accepted 5-minute delay times, thus it is not necessary to keep corridor lights at full output for longer durations after vacancy.
- **Consider light output when vacant**. When a corridor is vacant, it is possible to dim to low output (20%) without annoying occupants. However, extremely low levels (10%) may not provide much power reduction advantage compared to more moderate dimming (e.g., 20%). Consult manufacturer information about light output vs. power demand when programming bi-level lighting. Extremely low light levels (when vacant) may also impact how comfortable occupants feel when entering the space.
- Meet egress lighting requirements even when vacant. Even when dimmed, bi-level corridor lighting can meet minimum light levels (10 lux [1 fc]) required by fire-safety codes.
- Consider light output when occupied. As with any lighting retrofit, consider whether present light levels are suitable before duplicating with a new lighting system. An over-lighted corridor would see energy benefits from reduced illuminances even when occupied. While occupants at the demonstration site liked having high light levels (300 lux [30 fc]) when walking through the corridor, even higher light levels are not necessary. Conversely, illuminances less than 50 lux (5 fc) may be considered too dim, especially if there are no windows, and if the population is older, uses mobility aid devices, etc. Bi-level lighting can increase occupied light levels without increasing overall energy use.
- **Typical vacancy rates, by sector**. For below market rate properties and those that serve the elderly and/or persons with disabilities, expect bi-level corridor lighting to operate at dim output 75% to 80% of the time, when set at a 5-minute delay. For market-rate apartments, expect bi-level corridor lighting to operate at dim output about 90% of the time.
- Occupants liked bi-level lighting. There were no complaints about sensor-controlled lighting. Occupants
 had positive comments about perception of safety and comfort. Part of the positive feedback was due to
 increased light levels and improved distribution and uniformity.

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- Demonstration Luminaires: Lamar Lighting

Field Test DELTA evaluates new energy-efficient lighting products to independently verify field performance claims and to suggest improvements. A primary goal of the Field Test DELTA program is to facilitate rapid market acceptance of innovative energy-efficient technologies.

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