Field Test DELTA Snapshots

SENSOR-CONTROLLED BI-LEVEL LIGHTING FOR PARKING LOTS

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

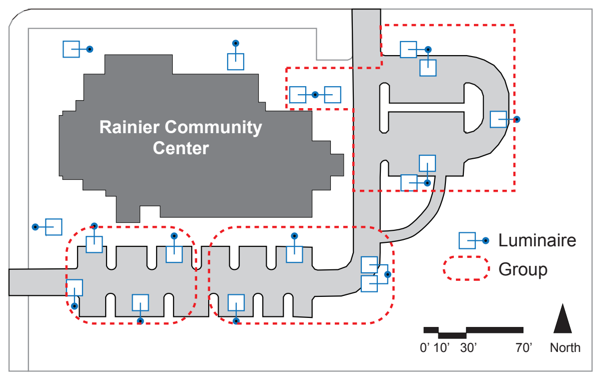
With market transformation to LED luminaires, more options are available for control of outdoor lighting at night. Model energy conservation codes encourage dimming outdoor lighting when parking lots are unoccupied.[1] Some municipalities have also adopted light pollution ordinances requiring light level reductions late at night. Occupancy sensors are therefore increasingly important for meeting both energy and light pollution requirements for outdoor lighting. Sensor-controlled, bi-level lighting dims to a pre-set, low level when unoccupied, then returns to full output when the sensor detects occupancy. There are many options for how to program sensor-controlled, bi-level lighting, which impact energy and, potentially, occupant comfort. This guide summarizes results[2] from Lighting Research Center (LRC) field demonstrations of several sensor-based dimming strategies: various delay times for dimming onset, various dim levels, and grouped vs. independent control of parking lot luminaires. It also provides guidance on how to select and set up these types of systems.

Rainier Community Center, Seattle, Washington, after retrofit

Site Demonstration

The Rainier Community Center is located in the Columbia City neighborhood of southeast Seattle, Washington. The facility was built in 1996 to serve the recreational needs of the local community. The building is open until midnight on Friday and Saturday, until 9 p.m. Monday to Thursday, and is usually closed on Sunday.

The building is surrounded by trees, plants, and flowers, and two parking lots. The previous lighting consisted of 400-watt, metal halide luminaires mounted on 30-ft. concrete poles. In spring 2019, the 18 existing luminaires were replaced on a one-for-one basis with dimmable LED luminaires, operating at 94 watts.[3] Sensors were external to the luminaires, mounted on the poles at 15-ft. height. At maximum output, the LRC measured an average of 22 lux in the parking lots. The luminaires use a dimming driver that receives a 0-10 volt signal from the sensors. For several experiments, the lighting control settings were re-programmed using a wireless signal between the central control computer and each luminaire.



Parking lot lighting plan, with Experiment 3 control groups

1. ASHRAE-IES 90.1 2016 "Energy Standard for Buildings Except Low-Rise Residential Buildings" and IECC 2018 "International Energy Conservation Code."
2. For more information about the methodology and results of the field demonstration, see final report "Field Demonstration of Sensor-controlled Parking Lot Luminaires" submitted to Bonneville Power Administration, September 2019.
3. Cree Lighting OSQ-A-K-40K rated at 130W; due to a power-limiting device, luminaires actually operated at 94W.

Experiment 1

Several bi-level conditions were demonstrated to groups of volunteers in summer 2019. On pathways and streets outside the parking lots, each experimenter waited for the lights to dim down to the low level (with a 1-minute sensor time delay), then led each group toward one of four viewing areas. Participants observed the sensor-controlled lighting, then completed a brief questionnaire for each condition. The LRC tested four conditions in Experiment 1:

- Dim to 26% when unoccupied, with each luminaire controlled independently
- Dim to 50% when unoccupied, with each luminaire controlled independently
- Dim to 26% when unoccupied, luminaires grouped by area
- Non-controlled, 100% continuous output

In Experiment 1, participants rated sensor-controlled lighting conditions as significantly more noticeable than the non-controlled condition. All conditions were rated as safe, not annoying, and allowing visibility of dropped items. There were mixed reactions whether the bi-level lighting gives the impression that the building was open for business. Several participants commented that the sensors did not react until they were near the luminaire (<1 pole height).

Rainier Community Center, Seattle, Washington, after retrofit

Experiment 2

A focus group of lighting decision-makers also gave feedback about bi-level lighting on one night, as well as general feedback about the use of sensors with parking lot lighting. The LRC tested three conditions in Experiment 2, all of which dimmed to 26% when unoccupied:

- Each luminaire controlled independently, 1-minute delay time
- Luminaires grouped by area, 1-minute delay time
- Each luminaire controlled independently, 5-minute delay time

Decision-makers agreed that they felt safe in all conditions and did not find the sensor control annoying. The decision-makers' highest-ranked concerns about bi-level, sensor-controlled parking lot lighting was occupant acceptance, programming challenges, and price. Secondary concerns were liability, and lack of information about energy savings and payback.

Experiment 3

The luminaires at Rainier Community Center were set to operate for one week in each of four bi-level conditions, each with a 2-minute sensor time delay:

- Dim to 26% when unoccupied, with each luminaire controlled independently
- Dim to 26% when unoccupied, luminaires grouped by area (see lighting plan, page 1)
- Dim to 50% when unoccupied, with each luminaire controlled independently
- Dim to 70% when unoccupied, with each luminaire controlled independently

On a weekly basis in summer 2019, energy and sensor/luminaire behavior data were gathered, as well as questionnaires from users of Rainier Community Center. The users did not show significant preferences for any of the four conditions; all were considered equally acceptable. Using the sensor/luminaire behavior data, the LRC calculated occupancy patterns use at various sensor delay times, ranging from 5 to 30 minutes.

Key Findings

"The light change is cool."

Occupant feedback was generally positive:

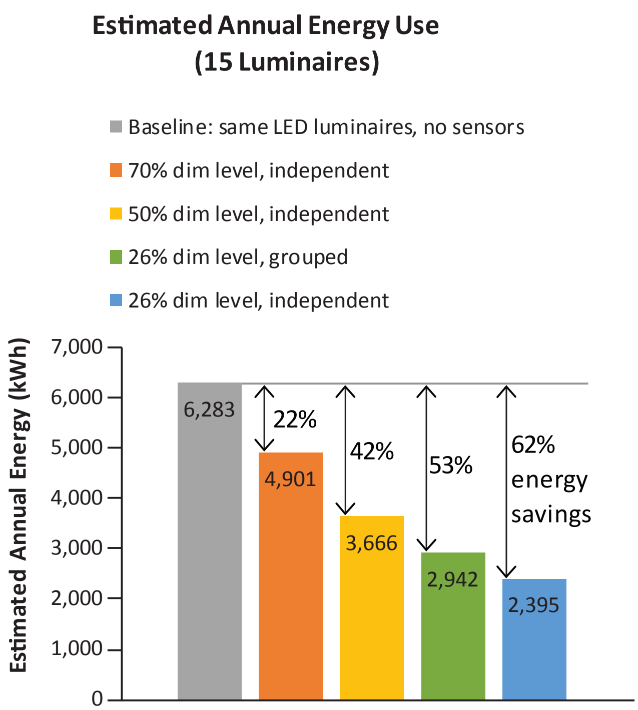
- For all test conditions, most occupants agreed they felt safe.
- Sensor time delay of 2 minutes was acceptable to occupants.
- Dimming to low levels (26% of full light output) when unoccupied was equally acceptable as dimming less aggressively (70% of full light output).
- Despite positive laboratory tests, in the field, some sensors did not respond to pedestrians until they stood close to the sensors. Occupants expressed some concerns that sensors required close proximity (<1 pole height) before the luminaire would increase to full output.

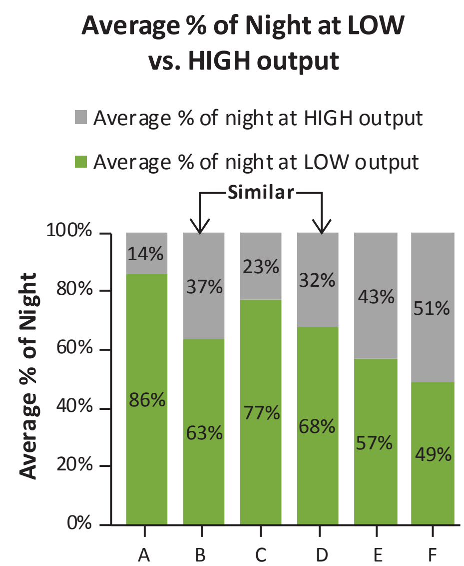
Occupancy patterns:

- Luminaires near the building entrance had higher activity patterns than those far from the entrance.
- When the luminaires were grouped, more time was spent at high output compared to programming with independent sensor control; the average percentage of the night at low output was 86% when independently controlled, and 63% when grouped. Using summer monitoring, grouped function with a 2-minute delay was similar to estimates for a 10-minute time delay with independent operation.
- The longer the sensor delay time, the greater the percentage of the night at high output, thus reducing energy savings.

Power and energy:

- Maximum power demand (94W) was lower than expected (130W) due to a power limiting device factory-installed in the luminaires, which impacted conditions available for testing.
- At the Rainier Community Center, power factor was 0.65 when luminaires operated at 26% output. While power factor does not impact the user, this could be a concern to the utility's power generation if these luminaires were widespread in the region.
- The most aggressive sensor settings demonstrated at the Rainier Community Center were estimated to save 62% lighting energy annually, compared to the same luminaires without bi-level sensor controls.





Measured: (**A**) 2-minute delay, independent; (**B**) 2-minute delay, grouped; **Calculated:** (**C**) 5-minute delay, independent; (**D**) 10-minute delay, independent; (**E**) 20-minute delay, independent; (**F**) 30-minute delay, independent

Guidance for Sensor-Controlled , Bi-level Lighting in Parking Lots

- **Seek sensor controls with short delay time options**. Some lighting control systems lack options for short sensor time delays (e.g., 2 minutes).
- **Seek bi-level controls with low-level dimming options**. For a building that is closed at night, bi-level, sensor-controlled parking lot lighting will likely spend the majority of the night at dimmed output; the ability to dim to low levels (e.g., 26%) enables the designer to balance occupant acceptability with energy savings. Some bi-level sensor control systems have limited dimming steps, and/or cannot dim to low levels.
- **Seek technical information about luminaire 0–10V dimming characteristics**. Verify with the luminaire manufacturer the relationship between control settings and power demand, including all of the installed electronics in the luminaire.
    - Power-limiting devices in the luminaires at the Rainier Community Center limited the range of dim levels available for testing.
    - Expect power and light output to be closely related, when operated from 1–8V. However, control voltage of 5V should not be expected to correspond to 50% output, for example.
    - Low-end limits: dimming to 10% output may not result in half the power demand of dimming to 20%, for example.
- **Minimize light output when unoccupied**. To promote energy savings, program bi-level controls to dim to 20–30% light output when parking lot is unoccupied.
    - Some building codes may require sensor controls in parking lots, but only require dimming to 70% of full output when unoccupied. Setting dim levels to 20–30% of full light output will improve energy savings without sacrificing comfort of occupants.
- **Expect occupants to experience dim/unoccupied output**. Due to sensor spatial responses, lag time, or obstruction, sensor-controlled parking lot luminaires will sometimes operate at low output while occupants are present. Despite energy advantages to minimizing light output when unoccupied, ensure sufficient light output at low levels for occupant comfort and perceived safety.
    - Expect sensor response only in close proximity to luminaire (<1 mounting height).
    - At the Rainier Community Center, illuminance at maximum output was measured at an average of 22 lux, thus at low output was approximately 6 lux; this was acceptable to study participants.
- **Minimize sensor delay times**. Promote energy savings by maximizing percentage of night spent at low output.
    - At a 2-minute sensor delay (independently controlled), luminaires at the Rainier Community Center spent 86% of the night at low output. At a 5-minute delay, luminaires would have spent 77% of the night at low output. At a 30-minute sensor delay, luminaires would have spent less than half of the night at low output.
    - Unless there is a special geometric condition (e.g., driveway turning a corner around the building) set delay times short (e.g., 2 minutes).
- **Typical occupancy patterns**. Expect sensors near the building entry to have higher rates of occupancy than remote locations. Expect false triggering when sensors are located in proximity to external roadways.
    - Near the entry of the Rainier Community Center, luminaires were at full output 14–17% of the night (with a 2-minute delay). In the rear of the building, luminaires spent only 5–10% of the night at full output.
    - Luminaires near a residential street adjacent to the Rainier Community Center were at high output 23–26% of the night.
- **Grouped operation of luminaires will reduce energy savings**. At the Rainier Community Center, luminaires that were operated in a grouped control mode spent 20% more of the night at full light output compared to individual operation. One luminaire with frequent activity will drive up the output of an entire group. If grouped operation is desired (e.g., driveway turning a corner around the building), minimize the size of groups to facilitate energy savings. Create groups based on similar activity patterns.

Guidance for Sensor-Controlled, Bi-level Lighting, Continued

- **Seek bi-level controls that are easy to install and program**. Installers prefer systems that provide clear confirmation of bi-level settings such as time delay, dim levels, and grouping. If a motorized lift is required to access control settings, they are not likely to be adjusted after installation.

- **Coordinate with trees**. In this summer demonstration, trees and other foliage blocked both light distribution and sensor coverage (image below). Trees may not be represented on a lighting specifier's electrical drawings, thus additional inquiries may be necessary to choose appropriate sensors and groupings.

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Sensor-Controlled Bi-level Lighting for Parking Lots

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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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