Adaptive Lighting in Outdoor Security Applications

Today, adaptive lighting, which is lighting controlled by occupancy sensors or schedules that adjust light levels based on actual site conditions, is considered best practice for numerous outdoor applications. Adaptive lighting has been adopted as part of some commercial energy standards and the strategy is now included in many outdoor lighting specifications and design guides. Outdoor areas with heightened security requirements, however, are often excluded from adaptive lighting control requirements and these areas remain lit with high, uniform levels of static illumination.

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Common practice follows the principle that more light equals more safety and security at night. For many of these areas, however, few people have site access and few visitors, if any, are ever present in the space, making them prime spots for use of occupancy-controlled lighting. First, when the space is vacant, use of low light levels cuts unnecessary energy use, costs and light pollution, while still providing adequate lighting by which to view the area from a distance for monitoring and periodic security checks. Second, when an occupant enters the space, sensors automatically detect their movement and immediately shift the lighting to full output, which alerts security personnel to activity in the area while also making the area bright for occupants.

However, even with these apparent benefits, many organizations feel the perceived risks associated with use of adaptive lighting in security applications outweigh the benefits. Research on the use and impacts of adaptive lighting is often noted as a critical need for moving the strategy from concept to reality.

The California Lighting Technology Center (CLTC) at UC Davis partnered with the Office of Naval Research to evaluate the energy-savings potential and end-user acceptance of adaptive lighting for outdoor security applications. The project focused on design and demonstration of an outdoor, adaptive lighting system at the Naval Facilities Engineering Systems Command Hawaii. CLTC designed and installed outdoor, adaptive, security lighting at two military locations with heightened security requirements: 1) an office building and 2) a guard shack.

Current guidance on security lighting design is provided by both the Illuminating Engineering Society (IES) and the U.S. Department of Defense (DOD). The IES publication *Guide for Security Lighting for People, Property, and Critical Infrastructure (IES G-1-16)* provides design guidance for security lighting. Generally, for critical checkpoints and inspection stations such as those found on military bases, the recommended light level is the greater of 1) 10 footcandles at grade, or 2) twice the light level of the immediate surrounding area. Additionally, IES G-1-16 recommends that these applications have light levels of at least 2 fc extending from the critical area towards the roadway for at least 50 ft. The DOD design standards include additional requirements pertaining to security lighting of buildings and area perimeters. A summary of the U.S. DOD building lighting requirements for outdoor security applications is provided in **Table 1**.

At the time of this research, no published findings were identified that specifically evalu-

APPLICATION TYPE	AREA	WIDTH FEET	LOCATION TO LIGHT	MINIMUM LIGHT LEVEL (FC)	MAXIMUM UNIFORMITY (MAX: MIN)
PERIMETER	Inner Clear Zone	20-30	Outer edge fence	0	0:1
PERIMETER	Outer Clear Zone	30	Outer edge	0.2-0.4	10:1
PERIMETER	Isolation Zone	30	Between fence lines	0.5 -1.0	6:1
BUILDING	Low Level of Protection (LLOP)	--	Building entry and exits	0.2 - 4, see *UFC 3-530-01 pp. 110-111*	20:1
BUILDING	Medium Level of Protection (MLOP)	--	Same as LLOP plus exterior walls	0.2-0.5	15:1
BUILDING	High Level of Protection (HLOP)	30	Same as MLOP and area around facility	0.5-1.0	10:1
ENTRY CONTROL FACILITY	Pedestrian	--	Entry	2-21	3:1
ENTRY CONTROL FACILITY	Vehicular	50	Pavement and sidewalk	1	4:1
ENTRY CONTROL FACILITY	ID Verification	--	Guard Station	10-100	3:1
ENTRY CONTROL FACILITY	Search Areas	--	Pavement	10-100	3:1

Table 1. U.S. DOD building lighting requirements for security applications.

ated a person's ability to detect a relative change between the low light levels and high light levels provided by an adaptive, outdoor lighting system. Some research exists for indoor lighting. One lighting study conducted in an office environment showed that at least a 20% reduction in light levels was required by most study participants to detect a light level change.[1] Fifty percent of study participants could not detect illuminance reductions less than 15% when doing paper tasks and this value jumped to 20% when working on the computer, regardless of the initial illuminance or dimming function. In addition, reductions of 30-40% were deemed acceptable even though they were noticeable to participants.

Lighting controls are necessary for implementing an

Adaptive Sensor-Based Lighting strategy. The Navy's sequence of operations included three simple requirements for its outdoor lighting systems:

1. On at dusk (low mode)
2. High lighting mode triggered by area activity
3. Off at dawn

To achieve these goals, CLTC evaluated a cross-section of outdoor occupancy sensing products utilizing varying sensing technologies in order to quantify their reliability in detecting activity within the designated demonstration areas. CLTC evaluated one traditional dual-technology (passive infrared + microwave) occupancy sensor and three LiDAR sensors. Results showed that tested LiDAR sensors performed more consistently than a traditional dual-technology sensor in terms of coverage pattern and detection reliability. Furthermore, the mechanically scanning LiDAR sensors outperformed the solid-state LiDAR in terms of reliability by more consistently detecting occupants over time and under various conditions.

What is the difference between these technology types?

Passive Infrared. Infrared sensing is a common technology used for occupancy detection within the lighting industry and is by far the most used by lighting manufacturers. Passive infrared (PIR) utilizes a pyroelectric sensor to detect infrared light within its field of view (FOV), which is translated as a voltage output. Occupants that enter the FOV create a shift in the detected infrared light due to their body temperature, which causes the voltage to change. The sensor translates the change as detection. PIR is a reliable and cost-effective solution, although PIR detection can lose reliability during extreme temperature shifts. PIR is often coupled with a second sensing technology, such as microwave technology, as part of a dual-technology sensor, which can offer increased detection reliability.

Microwave. Microwave detection works by emitting pulsed microwaves and calculating the time it takes for the waves to bounce off a distant object and return to the sensor. The travel time is often referred to as the time-of-flight (ToF). The ToF associated with a specific, stationary object in the sensor's FOV is considered the baseline. When an occupant enters the sensor's FOV, it creates a Doppler shift, or change in wave frequency, due to the introduction of the new object at a different distance from the sensor. A microwave sensor interprets the change in ToF as an occupancy detection. Microwave motion sensors have been mainly utilized in street lighting applications due to their long detection range in narrow fields of view. Although they are less prominent on the market than PIR sensors, they are promising for long-distance motion sensing.

LiDAR. The operating principle of Light Detection and Ranging (LiDAR) is also based on the ToF principle, which refers to the time it takes for IR radiation at specific wavelengths to be sensed at its emission location after it is backscattered by surfaces. Using the constant speed of light, the ToF is used to calculate the distance to the surface that reflected the radiation. During vacancy, the LiDAR signals remain constant. Changes in the LiDAR signals indicate moving objects in the detection area. LiDAR technologies are available with solid-state and mechanical scanning sensing.

CLTC designed a system with 0-10-V bilevel dimming triggered by an external LiDAR sensor coupled with a photocell for dusk-to-dawn operation for the Naval installations. In addition, the Navy required that the system be isolated from any internet-based control or access points to address cybersecurity requirements at its facilities. CLTC evaluated nine product combinations before selecting its final technology package. Selected systems included those with the simplest commissioning process, an intuitive programming interface with a large number of control customization options, and a responsive technical support team available for troubleshooting issues.

Demonstration Results

CLTC collected approximately six months of energy and lighting usage data for the Navy's existing lighting systems and its new adaptive systems to estimate the project's energy impacts. Results show that adaptive systems saved 36-44%. One week of representative data is provided in **Figure 1**.

CLTC also surveyed employees at the Naval Command sites following installation of the new adaptive lighting. All survey participants thought that the use of outdoor adaptive lighting, specifically the change from low to high light levels, helped to identify when and where others were present in the controlled areas. All participants believed this improved the safety of the area. More than 90% cited the new lighting as equivalent to or better than the pre-retrofit lighting in the area.

CLTC continues to research the impact of outdoor adaptive lighting systems in terms of both energy savings potential and end user acceptance. Recent funding from the California Energy Commission's EPIC program focuses on the smart integration of renewable energy and advanced lighting systems for outdoor applications. Learn more at *cltc.ucdavis.edu/bigidea.* ◎

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Figure 1. Instantaneous power for guard shack - seven day comparison.

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References

1. Lighting Research Center. Understanding Light Levels for Load Shedding. 2003.