ADAPTIVE EXTERIOR LIGHTING

GUIDE FOR IMPLEMENTING ADAPTIVE, ENERGY-EFFICIENT EXTERIOR LIGHTING

Adaptive Induction Area Luminaires
University of California, San Francisco

Adaptive exterior lighting is a relatively new concept recognized by the lighting industry and energy regulators as a potential method to increase energy savings in outdoor applications.

Many adaptive exterior lighting products are being developed and have been introduced into the marketplace, allowing users to implement dynamic lighting designs that offer 30–75% energy savings over traditional systems. These savings are achieved by coupling advanced lighting controls with an efficacious, dimmable source. When a space is unoccupied or has substantially reduced traffic volume, adaptive luminaires deliver lower light levels with substantially reduced power consumption. Full light levels may be achieved by using occupancy sensors that recognize activity in the space, or time schedules may be used to adjust light levels during active periods.

This method of lighting effectively reduces energy use in spaces with low occupancy rates where a minimum light level is required for safety or other reasons, preventing the lights from being completely extinguished.

"Energy-efficient lighting has never been more important or more achievable. We have innovative products for every lighting need that can cut electricity use by up to 50%, which saves consumers money while helping the environment."

Michael Siminovitch, CLTC Director

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BEST PRACTICES FOR ADAPTIVE EXTERIOR LIGHTING

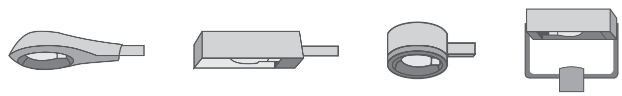
The following characteristics represent the best-practice implementation of an adaptive exterior lighting design:

- Time clocks or fixture-integrated photocontrols should dim and extinguish luminaires when sufficient daylight is available.
- Luminaires should use long-life sources to reduce maintenance and recycling requirements.
- Cutoff or full-cutoff luminaires should be used whenever possible.
- Sources should have correlated color temperatures below 6000 K. Consider 4000 K or below for residential areas.

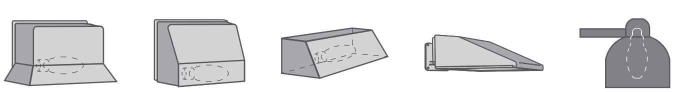
TYPES OF ADAPTIVE EXTERIOR LIGHTING

Many manufacturers offer adaptive exterior luminaires for numerous applications. Fixture styles include street lights, shoebox luminaires, canopy lights, wall packs, bollards, and post-top luminaires. Some luminaires have fixture-integrated occupancy sensors and photocontrols, others use pole- or building-mounted controls, and some use intelligent algorithms to selectively lower light levels based on time of day. A key component of this technology is the inclusion of a dimmable source. Appropriate sources include fluorescent, induction, some ceramic or standard metal halide lamps using electronic ballasts, and LEDs. A dimmable source is necessary to accommodate light level reductions during vacant hours and quick switching between high and low modes.

Full-cutoff roadway & area luminaires



Full-cutoff wallpacks



IS YOUR PROJECT RIGHT FOR ADAPTIVE EXTERIOR LIGHTING?

When implementing an adaptive exterior lighting project, it is important to follow an established procedure to ensure the inclusive evaluation of existing (in retrofit applications) and new lighting designs. This allows for a documented comparison of pre- and post-retrofit light levels, energy consumption, emissions reductions, and economic impacts. One important reason to document multiple lighting comparisons is to enable the project's participation in incentive programs often offered by local governments or utilities. The following procedure outlines steps for implementing a successful adaptive exterior lighting project:

1. Identify areas appropriate for adaptive exterior lighting
2. Evaluate the existing lighting system
3. Evaluate appropriate technologies for project needs
4. Conduct professional lighting layout
5. Perform economic evaluation
6. Choose final product to implement

Adaptive LED Parking Structure Fixtures
University of California, Davis

Identify areas appropriate for adaptive exterior lighting

Areas appropriate for adaptive exterior lighting typically have one or more of the following characteristics:

- Low-to-medium occupancy rate
- Space requires minimum illumination, regardless of occupancy, for safety or wayfinding
- Pole or mounting height for luminaires is less than 30' high
- Pole or luminaire spacing is less than 100' apart
- Landscaping is minimal to reduce sensor obstructions and maintain appropriate light levels

Evaluate the existing lighting system

Pre-retrofit lighting audits can help determine the appropriate adaptive retrofit for the space. For instance, certain existing technologies might undergo only retrofits for controls and the ballast/driver/generator, as opposed to a full fixture replacement. This would apply in a scenario where dimmable sources already have been installed, but lack controls. An audit also allows for an accurate economic evaluation and light level comparison for the pre- and post-retrofit systems. The following list outlines the items to note during an audit.

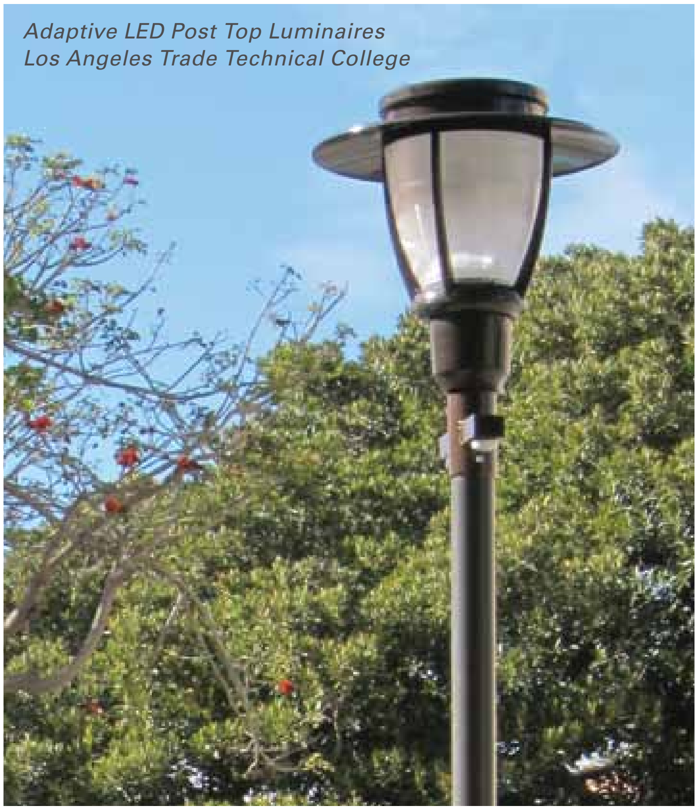
- Condition of the existing fixtures. Items to note: age, location (including height and spacing), lens coloration, fixture cleanliness, environment (e.g., dry, wet, humid), color rendering ability of lamps, surrounding landscape
- Model and manufacturer of existing fixtures; this allows for photometric files to be obtained for comparative modeling
- Lamp and ballast type, including wattages
- Typical usage patterns, including:
  - Hours of business operation for commercial or industrial spaces
  - Hours of operation for the lighting system, including schedules for existing controls such as time clocks, energy management systems, or photocells
- Light levels at grade, measured with an illuminance meter
- Recommended practices provided by the Illumination Engineering Society (IES) for various applications

Evaluate appropriate technologies for project needs

After the audit, evaluate adaptive exterior lighting technologies that will address the project's needs and determine which will offer the best set of benefits for the application. First, identify the project's needs:

- What are the color temperature and color rendering requirements?
- What are the national and local code requirements? (e.g., cutoff, glare reduction, pole height)
- What distribution type best fits the space?
- What user patterns are typical of the space being retrofitted?
- What type of adaptive strategy is best for the project? (e.g., occupancy or schedule-based dimming)
- What type of occupancy/vacancy controls best suit the space? (e.g., passive infrared, ultrasonic, dual-technology)
- What is the geometry of the space being retrofitted? Will the design incorporate daylight?
- What are the budget restrictions?

Based on the answers, the most appropriate technologies for the space should be determined. It is helpful to use the iterative economic evaluation step in conjunction with determining the technology to ensure that the project will produce the anticipated savings from the retrofit.



Adaptive LED Post Top Luminaires
Los Angeles Trade Technical College

Sensor integration

An appropriate occupancy/vacancy sensor is required for many types of adaptive exterior lighting retrofits to effectively trigger high and low light levels. Each sensor has a maximum distance in which it can detect movement. The distance between fixtures and mounting height will be predetermined by the existing poles in the space and will affect the type of sensor chosen for the space.

- **Passive Infrared Radiation (PIR)**: Detects changes in heat by comparing background heat to the heat emitted by new occupants in a space.
- **Ultrasonic (US)**: Detects changes in high-frequency waves and measures the distance to the nearest object by timing the wave's return to the sensor.
- **Dual Technology (DT)**: Detects movement through both PIR and US technologies.
- **Microwave**: Detects changes in ultra-high frequency radio waves, also known as microwaves, when new occupants enter the space.
- **Audio-Based (Microphonics)**: Detects audible sounds made by new occupants in the space.

Exterior sensors should use PIR or microwave technology because ultrasonic and audio-based sensors can be triggered by small animals or weather.

Conduct professional lighting layout

Once the potential technologies have been identified, a lighting designer should conduct a professional lighting layout for the space. Qualified designers—typically employed by electrical contractors, architectural firms, and design firms—can perform accurate lighting layouts. It is important to request a list of the professional's previous designs as reference material; local spaces are preferred so the sites can be evaluated.

An experienced lighting professional will take all of the space parameters into consideration when modeling the new lighting system. This includes photosensor location if applicable and confirmation of appropriate light levels when fixtures are mounted at the specified height. If needed, the lighting designer also should provide a pre-existing lighting system design from the audit information.

The lighting layout step is best approached as an iterative process, evaluating each potential technology and determining which option offers the right combination of distribution and light intensity for the needs of the space.

Perform economic evaluation

Using the information from the previous steps, perform an economic evaluation of the proposed retrofit. From this evaluation, determine the life-cycle cost of potential technologies. A life-cycle analysis takes all costs and benefits into consideration, from production to destruction.

TABLE 1 - EXTERIOR LIGHTING: SOURCE TECHNOLOGIES						
Lamp type	**Demand (W)***	**Source efficacy (LPW)*****	**CCT (K)**	**CRI**	**Lifetime (hours)**	**Price**
HIGH PRESSURE SODIUM	70–400	80–120	1,900–2,200	22–70	15,000–40,000	$$
LOW PRESSURE SODIUM	55–180	130–170	1,700–1,800	–	16,000–18,000	$$
CERAMIC METAL HALIDE	70–400	75–110	3,000–4,200	80–94	10,000–24,000	$$ – $$$
METAL HALIDE	70–400	40–70	3,000–4,200	60–80	10,000–20,000	$$
MERCURY VAPOR	75–1,000	20–40	3,200–6,700	15–50	16,000–24,000	$$
CFL	20–70	80–85	2,700–5,000	80–85	6,000–20,000	$
INDUCTION	70–250	50–85	3,500–5,000	80–85	100,000	$$– $$$
LED	40–250**	Up to 130	2,700–10,000	50–80	35,000–50,000	$$$–$$$$

NOTE: The numbers in this chart were compiled when this guide was created and continue to change as technology improves.
* Typical size of lamps used in exterior applications.
** Typical size of LED luminaires used in exterior applications; luminaire contains multiple LEDs.
*** Based on initial lumens, system efficacy should be determined and is dependent on the specific fixture style, ballasts, and drivers employed.

PIER SOLUTIONS FOR PARKING LOTS AND GARAGES

The California Energy Commission's Public Interest Energy Research (PIER) program compiled a catalog of products used in PIER demonstrations in parking lots and garages. Download the catalog at **cltc.ucdavis.edu/content/blogcategory/118/437**

This includes additional savings beyond energy that the retrofit will provide, compared to the typical system. Usual reduced costs are derived from the following items:

- **Reduced materials cost**: Reduced equipment replacements based on extended life of new technologies plus savings due to reduced hours of operation of the lighting system. See Table 1 for technology lifetime breakdown. Use low end of lifetime expectancy for life-cycle cost analysis. Use the manufacturer specified lifetime of existing and new technologies to determine savings.
- **Reduced labor costs**: Reduced costs associated with fixture cleaning, relamping, and reballasting over the course of the evaluation period.
- **Reduced recycling costs**: Reduced storage and recycling costs from transition to sustainable and/or long-life sources.
- **Rebates and incentives**: Specific funding sources offer different levels of savings. Cash flows should be evaluated to determine which options offer greater impact when multiple sources are being assessed for the project.

The IES provides RP-31, the Recommended Practice for the Economic Analysis of Lighting, which outlines multiple approaches for completing an economic evaluation. Worksheet 2: Life-Cycle Cost/Benefit Analysis provides one method for performing a comprehensive economic analysis. In addition, consider costs to bring the existing system up to "new" operating levels. Costs include cleaning and relamping existing fixtures. This exercise should be included to allow for an accurate comparison between two "new" systems, rather than comparing a new system to a depreciated baseline.

Choose final product for implementation

After evaluating the potential technologies for the space undergoing a retrofit, the final product should be chosen based on the general needs of the project, professional lighting layout, and the economic analysis of the potential technologies. Additional funding requirements should be considered to ensure compliance with grant or rebate programs.

Adaptive Induction Parking Garage Luminaires
University of California, Davis

Adaptive LED Bollard
California Department of Public Health, Richmond, CA

WORKSHEET 1 – LIGHTING SYSTEM POWER AND ENERGY USE ESTIMATION

1. Compute the total power (kW) used by the existing system.

EXISTING LAMP OR LUMINAIRE WATTAGE		NUMBER OF LAMPS		TOTAL POWER CONSUMED
______ W	×	______ lamps	=	______ W

2. Compute the total energy (kWh) consumed annually by the existing system.

TOTAL POWER CONSUMED BY SYSTEM LUMINAIRE		HOURS OF USE PER DAY		DAYS OF USE PER WEEK		WEEKS OF USE PER YEAR		TOTAL ENERGY CONSUMED
______ W	×	______ hrs/day	×	______ days/wk	×	______ wks/yr	=	______ kWh/yr

3. Compute the total energy cost (dollars) annually to operate the existing system.

TOTAL ENERGY CONSUMED		ENERGY RATE		TOTAL COST
______ kWh/yr	×	______ $/kWh	=	______ $/yr

WORKSHEET 2 – LIFE-CYCLE COST / BENEFIT ANALYSIS

INITIAL COSTS	SYSTEM 1	SYSTEM 2
1. Lighting system — initial installed costs, all parts and labor (dollars) An estimate is prepared for material and labor of the installation.		
2. Total power used by lighting system (kW) Connected load of the lighting system, including ballasts and transformers, if any.		
3. Utility rebates (enter a financial incentive as a negative number) (dollars) To reduce peak demand, electric utility companies in the United States may offer incentives for end users who retrofit or install energy-efficient lighting equipment in their buildings.		
4. Other first costs generated by the presence of the lighting systems (dollars) Include any other differential costs, such as insulation, solar power, or tax credits.		
5. Initial taxes (dollars) Usually 6–8% of the initial cost (Line 1).		
6. Total costs (dollars) The sum of lines 1, 3, 4, and 5.		
7. Installed cost per square foot (dollars) The installed cost per square foot.		
8. Watts of lighting per square foot (w/ft²) Watts per square foot, also known as the power density.		
9. Residual (salvage) value at end of economic life (dollars) The amount the system will be worth at the end of its economic life (as scrap, for example). Use the same life for each system under comparison. Note that this value is negative if money is received for the salvage; it is positive if a cost is incurred to dispose of the system at the end of its life.		

ANNUAL POWER AND MAINTENANCE COSTS	SYSTEM 1	SYSTEM 2
1. Luminaire energy (operating hours × kW × $/kWh) (dollars) The number of operating hours and cost per kWh depends on occupancy schedules and local power rates. Ten hours a day, five days a week, 52 weeks per year represents 2,600 hours. In the United States, the average energy cost for commercial, institutional, and industrial customers is $0.08 to $0.09 per kWh.		
2. Other annual costs generated by the lighting system (dollars) Other costs may include costs to maintain the lighting system.		
3. Cost of lamps annually (dollars) The cost of lamps per year depends on the relamping strategy. If spot relamping is used, then the lamp cost per year is figured from this formula: $\text{lamp cost per year} = \frac{\text{(labor and lamp cost for spot replacement of one lamp)} \times \text{(number of lamps in the system)}}{\text{(lamp life) / (annual burning hours)}}$		
4. Other annual costs generated by the lighting system (dollars) To annualize ballast costs, use: $\text{ballast cost per year} = \frac{\text{(cost to replace one ballast)} \times \text{(number of ballasts in the system)}}{\text{(ballast life) / (annual burning hours)}}$		

Adaptive HID Wall Pack
California State University, Chico

Adaptive Induction Area Luminaire

Adaptive LED Parking Structure Luminaire

Through the California Energy Commission's Public Interest Energy Research (PIER) Program, demonstrations of adaptive exterior lighting technologies have been implemented for parking garages, street and parking areas, pathways, building perimeters, and security lighting. These studies demonstrate that adaptive lighting technologies are effective in reducing energy consumption while maintaining appropriate light levels for each application.

More information on these studies can be found at:
cltc.ucdavis.edu/content/view/665/351

Scan this QR code with your smartphone for more information about CLTC's demonstrations:

For more information about CLTC's PIER lighting demonstrations, visit:

www.pierpartnershipdemonstrations.org
www.terradex.com/PublicPages/CIEE/PIER_01.aspx