Researchers at the California Lighting Technology Center (CLTC), with funding provided by the California Energy Commission’s EPIC Program, are addressing this idea as part of a larger project focused on the integration and demonstration of exterior lighting systems with on-board solar generation, battery storage and advanced controls. In other words, “smart and clean” exterior lighting systems. The research emphasizes how to best leverage mature, demand-side technologies to create a fully integrated, easy-to-install, low-maintenance system that reduces strain on California’s electricity grid.

As part of its research, CLTC is developing advanced controls that can optimize battery charging and discharging based on real-time signals like Flex Alerts, dynamic electricity prices, source fuel mix, and Public Safety Power Shutoffs (PSPS), which are temporary, regional cuts in grid-supplied electricity designed to reduce fire risks caused by electric infrastructure.

Today, the majority of California’s exterior lighting is grid-connected and operates from early evening to early morning via stand-alone photocell control. To determine the decarbonization potential of a smart and clean exterior lighting system, it is important to understand the fuel mix of the electric grid supplying the electricity during the operation period.

At 8 p.m. on September 8, CAISO reported that 55% of the grid was fueled by natural gas—a carbon-dense fossil fuel. Figure 1 shows all the energy resources supplying the grid at that point in time. This makes exterior lighting an ideal candidate for onboard distributed energy resources (DERs) and load-shifting technology. By integrating grid-connected exterior lighting with solar generation, battery storage and advanced controls, system owners can reduce their carbon-dense fossil fuel use by replacing it with clean and local solar electricity delivered by an onboard battery. Further increasing its usefulness to the community, the battery provides backup power to the exterior lighting making the system more resilient to power outages.

But is there enough exterior lighting in California to make a difference during critical grid events like those experienced on September 8? Twilight maps (Figure 2) show that on this day, approximately 90% of California reached nautical twilight by 8 p.m.—the typical period when exterior lighting turns on for the night. This period overlapped the September 8 Flex Alert by two hours.

Based on California Energy Demand Forecast data published by the California Energy Commission, California’s commercial exterior lighting accounts for 4,968 GWh energy use annually. (This data does not include...
streetlights, which would add deeper benefit if retrofit.) This equates to approximately 1 GW of exterior lighting demand in California, assuming an average operation of 13 hours per day, 365 days per year.

As a comparison, demand at 8 p.m. on September 8 was 45,537 MW (45.5 GW) in Figure 3. An automated action to run the existing exterior lighting off-grid using onboard batteries (1 GW) would reduce this demand by approximately 2%. Alternatively, an automated action to reduce the grid-connected power of exterior lighting statewide by 20%, a reduction which studies have shown to be imperceptible to humans, would offset demand by just 0.5% (209 MW).

In addition to decarbonization, energy reduction and grid flexibility benefits, the research also focuses on how to implement smart, clean exterior lighting as a community improvement project. Lighting design practices used with this research prioritize engagement with residents and business owners through local community studies and technology demonstrations in priority communities. Pursuing an inclusive, community-focused relighting strategy can increase safety and use of outdoor areas. To do this effectively, CLTC is collaborating with industry partners and local community organizations at seven committed demonstration sites to ensure the systems meet each community’s needs.

In partnership with community-based organizations, CLTC is gathering community feedback on the existing lighting and their goals for its replacement. The project is targeting 700 responses to help refine system designs...
and prioritize system features for each priority community.

At the onset of this project, CLTC conducted an initial assessment to define general system performance targets. Results are summarized in Figure 4. To hit these targets and meet industry standards, a draft California model specification is under development. The model specification identifies specific requirements for each performance target and their associated metrics.

Examples of metrics for the exterior lighting subsystem include system efficacy of 120 lumens per watt to meet DLC Premium v5.1, CCT of 3000K or less, CRI of 80 or greater, BUG ratings that meet International Dark-Sky Association guidance, and dimmable sources down to 10% power.

Metrics that address DERs include PV array efficiencies of 20% or greater, battery duration of three days for low to average PSPS risk areas and eight days for high PSPS risk areas, and battery depth of discharge at 25% maximum.

To enable two-way communication between the lighting network and real-time signal providers like local utilities, the system must be equipped with an application program interface (API). The lighting network must also meet IEEE Standard 2030.5 to enable communication with the grid per California’s Electric Rule 21, which governs interconnection of DERs to California infrastructure.

In addition, the system controller that regulates power from solar panels and the grid to the battery must meet the IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces (1547) and UL Standard 1741 SA for Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources.

Using these performance

CLTC is developing advanced controls that can optimize battery charging and discharging based on real-time signals

Figure 3. The demand on California’s electric grid at 8 p.m. on September 8 was 45,537 MW. Source: CAISO.

Figure 4. Performance targets for smart & clean exterior lighting systems.
targets, CLTC is collaborating with industry partners to customize a suite of technologies that meet California’s needs. Testing focused on integration limitations and subsystem efficiencies is under way to ensure that selected hardware can meet performance targets. In Figure 5, exterior lighting subsystem performance is tested and monitored in local weather conditions at CLTC.

Once testing is complete, exterior lighting systems meeting the California specification will be selected to replace 200 existing luminaires in seven priority California communities. Site-specific characteristics and survey feedback will be incorporated during each site’s design phase to ensure recommended light levels are met and equipment is properly sized.

By evaluating the capabilities of these systems under real world conditions and providing the outcomes to decision makers throughout the state, these smart and clean exterior lighting systems are poised to help California meet its aggressive decarbonization, grid-flexibility and community-improvement policy goals.

Stay up to date on this project by visiting https://cltc.ucdavis.edu/bigidea.

References

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What is a Flex Alert?
A Flex Alert is a call for consumers to voluntarily conserve electricity when there is a predicted shortage of energy supply, especially if the grid operator needs to dip into reserves to cover demand. When consumers reduce electricity use at critical times, it can prevent more dire emergency measures, including possible power outages.

—CAISO, www.flexalert.org