TECHNOLOGY

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LED Luminaires Are Reaching End of Life—Now What?

The earliest days of commercial LED luminaires brought many questions regarding color quality, distribution of light, lifetime, and serviceability. After initial fears were mostly allayed, promises of longevity and energy savings (with incentives!) fueled the adoption of LED technology—and early generation products largely met those promises. Yet, a decade into widespread adoption, a new question emerges: What happens when LED products reach their end of life?

Various groups are asking this question. Homeowners may be living with a failing LED fixture installed by a prior owner. Professional facilities staff can no longer ignore early LED failures that left a few areas slightly dimmer and others more colorful, as the failures are mounting. Lighting specifiers who asked the hard lifetime questions 10 years ago, including requesting TM-21 data, now face an increasing number of clients who are calling to ask what they should do as their LED systems are failing.

Given that LEDs now dominate the architectural lighting market, it can be hard to believe that the notable adoption of LED products started only 10 years ago. The latest *U.S. Department of Energy* (DOE) *Lighting Market Characterization* (LMC) report compares lighting inventories of installed units since 2010 (**Figure 1**), highlighting the considerable adoption that happened between 2015 and 2020.

Back in 2010, 50,000- to 100,000-hour lifetimes seemed like forever; however, for many applications, that span equates to roughly five to 11 years (**Figure 2**). A product with a lifetime of 50,000 hours installed in a residential location where it is turned on an average of a few hours a day means it will hopefully last until the owner moves out—and maybe even until the next owner moves out—while that same product would be expected to last only 5.7 years if it was on 24/7.

When accounting for adoption and expected product lifetimes, it makes sense that more people are facing the question of what to do at the end of life. During a recent lighting conference presentation, specifiers in the room were asked how many of their clients were having issues maintaining their LED luminaires, with the majority responding that about 40% or more of clients were experiencing issues.

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The struggle to maintain LED systems cropped up as a repeated issue as Pacific Northwest National Laboratory researchers spoke with school facility managers across the U.S. in 2024. While schools may not be the target of most product development roadmaps due to their restricted budgets, as noted in the latest LMC report, the educational facilities sector was nearly 14 billion sq ft in 2020, with 78% of that floorspace fluorescent. Facility managers across the country are making decisions about what to install, with day-to-day maintenance often top of mind.

Owners and managers of offices, hospitality, and residential properties face a similar conundrum. What happens when products start failing, especially after the five-year warranty? Are managers and owners prepared to pay for all new luminaires after years of just maintaining lighting with lamp

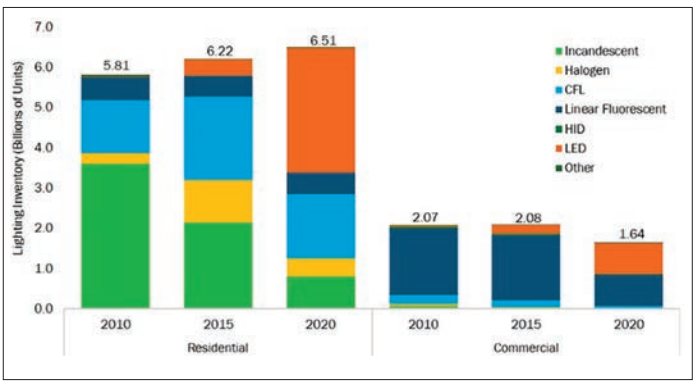

Figure 1. U.S. lighting inventory in 2010, 2015, and 2020 by sector and technology from the latest *U.S. DOE Lighting Market Characterization* (published in April 2024).

replacements? From a design perspective, helping to fix maintenance problems and address unexpected failures is not nearly as much fun as new designs, and designers are often not paid for the time spent.

Recently, a law firm was unsure what to do because the downlights in its Class A office space started to fail a few months after the warranty period ended. Some failures were catastrophic, while others were parametric, including color shift that harkened back to the days of metal halide. The law firm reached out to the original lighting designer, and after plenty of discussion with the original manufacturers and their representatives, the law firm installed a new solution. When the cost to pay a designer, buy new products, and pay an electrician are added up, the total cost to maintain the system can be twice as expensive as that if the law office just relamped their downlights and 15 times more expensive if replacing linear LED cove lighting rather than fluorescent tubes—no designer or electrician needed, no new luminaires needed.

With energy efficiency incentives fading and original manufacturers potentially acquired or gone, the reality many face is that most end-of-life issues mean a completely new fixture—this time without any incentives or promises of a two-year payback. The new mode of swapping out luminaires instead of lamps raises questions of sustainability in every sense of the word, from sustaining design intent to throwing away whole fixtures, and even in some cases needing new ceilings and flooring.

Several products on the market address the issue of serviceability and maintainability in unique ways. Some aim to simplify driver replacement while others use magnets or plastic connectors to make it easy to swap out LED modules and other luminaire components. One manufacturer has even leveraged an old solution: developing a troffer that uses lamps with E26 bases. Yes, you read that right. Eight standard light bulbs in a 2-ft by 4-ft troffer. While it may cause a double-take, the manufacturer is likely responding to market demands.

There has been some movement in Europe driven in part by the Zhaga Consortium, which is helping to standardize the interfaces of LED luminaire components, although Zhaga has yet to gain much traction in the U.S. The question is, will a similar movement take hold domestically?

The lifetime and maintainability requirements of future specifications are likely to be determined by the application and client. There is an assumption that many offices and retail spaces change over every 10 years or less, so why bother worrying about maintenance? However, this all may shift in the coming years, reflecting some of the major disruptions occurring in both office and retail spaces.

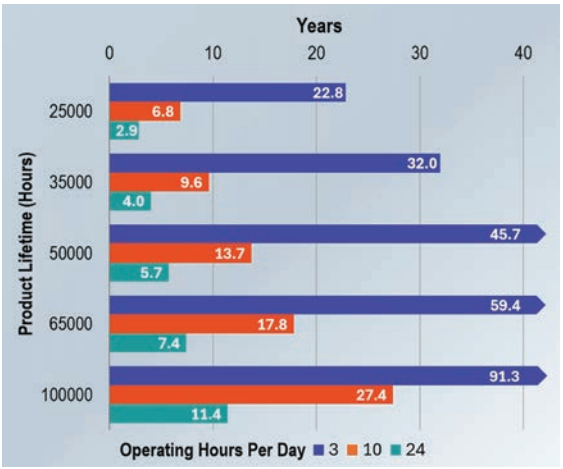

Figure 2. The years of operation for varying product lifetimes and operational hours per day.

Additionally, more owners and clients may be driven by circularity and sustainability goals, while others will just want to keep the lights on.

For many residential, small business, house of worship, corporate, municipal, and educational buildings, luminaires being maintained for 30 years or more is the norm. What sustainable solutions will help these buildings and critical institutions keep the lights on? We hope to continue this conversation, so if you have further thoughts or suggestions you want to share, please reach out at *andrea.wilkerson@pnnl.gov*.

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