CALiPER

Snapshot **Linear Lamps (TLEDs)**

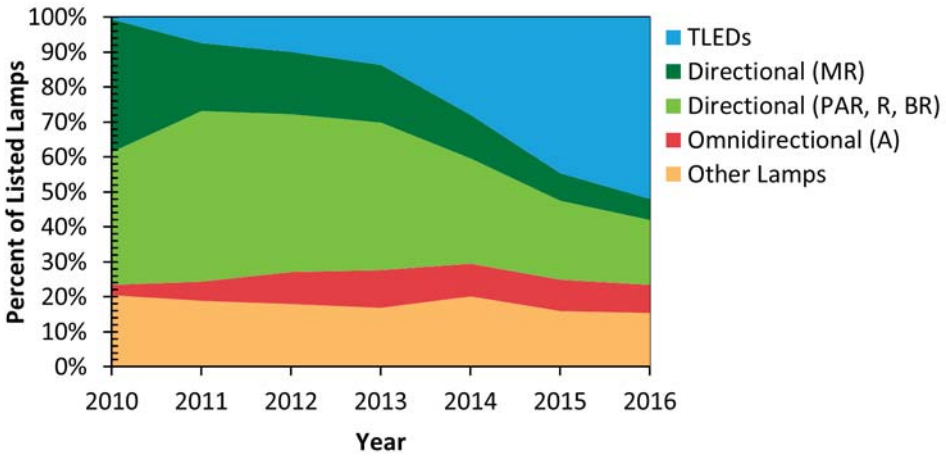
Linear fluorescent lamps—and the "troffers" in which they are often used—are a staple of ambient lighting in offices, classrooms, and other types of commercial spaces. They are energy-efficient, long-lived, and relatively inexpensive. Linear LED lamps, often called TLEDs, are an alternative to linear fluorescent lamps and are mainly used in retrofit situations. Typically drawing about 60% of the power of linear fluorescent lamps, TLEDs are often an intriguing option to achieve energy savings.

As LED Lighting Facts® data show, TLEDs represent a growing share of the LED market, now comprising approximately 52% of the total lamps listed and more than 10% of all products listed. This report compares the basic photometric performance of TLEDs with that of other lamp types, as well as some luminaire types in which TLEDs are often installed, such as troffers. When comparing lumen output and efficacy data for TLEDs versus luminaires, it is important to remember that in almost all cases, TLEDs will be installed in a luminaire that has an efficiency of less than 100%. Based on past CALiPER data, luminaire efficiency for troffers with TLEDs installed is around 75% to 85%; thus, output and efficacy data for TLEDs must be adjusted to make a fair comparison.

There are several types of TLEDs, including those that can operate directly on a fluorescent ballast (UL Type A), those with an integrated driver (UL Type B), those with an external driver (UL Type C), and hybrid models. About 71% of TLEDs listed by LED Lighting Facts supply information about the driver (internal or external) and wiring (plug-and-play or rewire), which has been required for submission for the past year. The distinguishing features of the different types of TLEDs are very important during specification and installation, although there is little difference in photometric performance. Thus, they are not shown separately in this report.

Besides being the dominant form factor among products listed with LED Lighting Facts, TLEDs are at the vanguard of LED efficacy. However, some TLEDs are less efficacious than linear-fluorescent lamps, exemplifying the variety that is a characteristic of all LED product types. It is critical to thoroughly research each individual product in order to make an informed decision, weighing trade-offs between cost and performance, energy savings and appearance, or color and efficacy, as appropriate.

AT A GLANCE **LAMPS LISTED BY LED LIGHTING FACTS**



LED lighting facts®

June 17, 2016

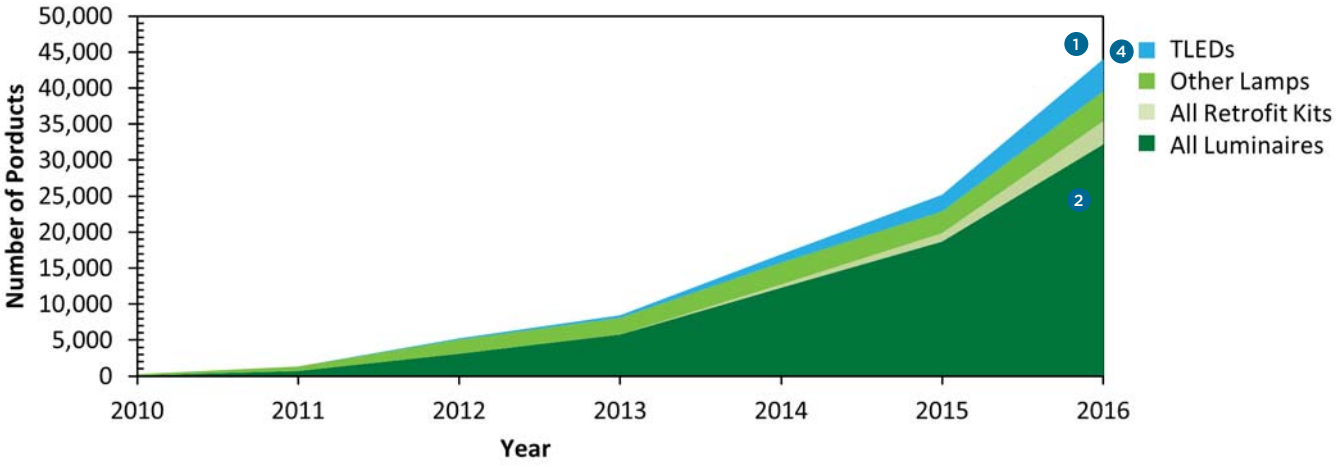
2,462 Partners

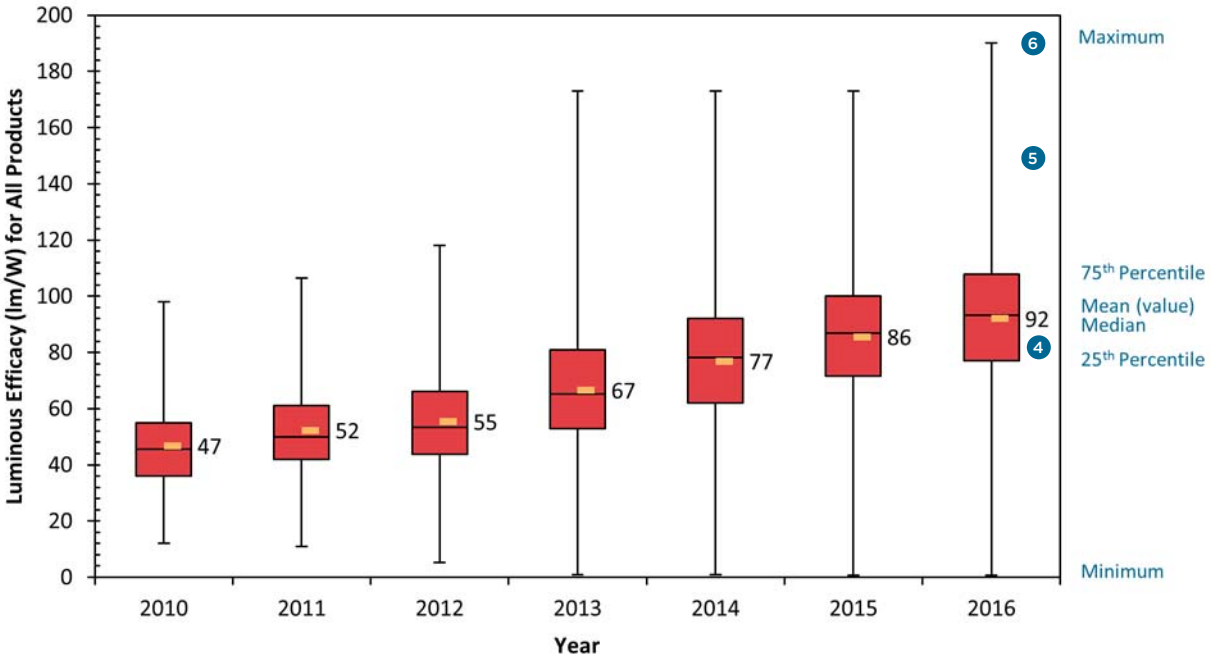
44,091 Total Active Products

Report Highlights

- More than 44,000 products are now listed in the LED Lighting Facts database, with a higher number of new products listed over the past year compared to prior years.
- Across all products, efficacy gains began to slow from the 2012 to 2015 average increase of 10 lm/W per year. From June 2015 to June 2016, average efficacy increased by only 6 lm/W.
- The slowing of increases in average efficacy for the entire LED Lighting Facts database is countered by the fact that overall, products newly listed in 2016 had an average efficacy of 101 lm/W.
- TLEDs now comprise more than 50% of all listed lamps, and more than 10% of all listed products.
- TLEDs offer the highest mean efficacy of any lamp type, and also include the listed product with the highest efficacy (190 lm/W).
- In aggregate, TLED efficacy decreases by 3 lm/W for every 1000 K decrease in CCT. This does not necessarily hold true when comparing specific products.
- While the raw efficacy of TLEDs exceeds that of troffers, the reverse is true if TLED efficacy is adjusted to account for luminaire efficiency. In other words, the efficacy of dedicated LED troffers tends to exceed that of troffers fitted with TLEDs.
- The color and power quality characteristics of TLEDs are generally uniform, with CRI in the low 80s, CCT of 3000 K, 4000 K, or 5000 K, and power factor greater than 0.90.

All Products **Listings & Efficacy Over Time**





1. The growth of the LED Lighting Facts database continues to accelerate. As of June 17, 2016, there were more than 44,000 listed products. Almost 19,000 of those products were added in the last year.

2. The ratio of lamps to luminaires has remained steady for the past two years. Approximately 73% of the database is luminaires, with the remainder split between lamps and retrofit kits.

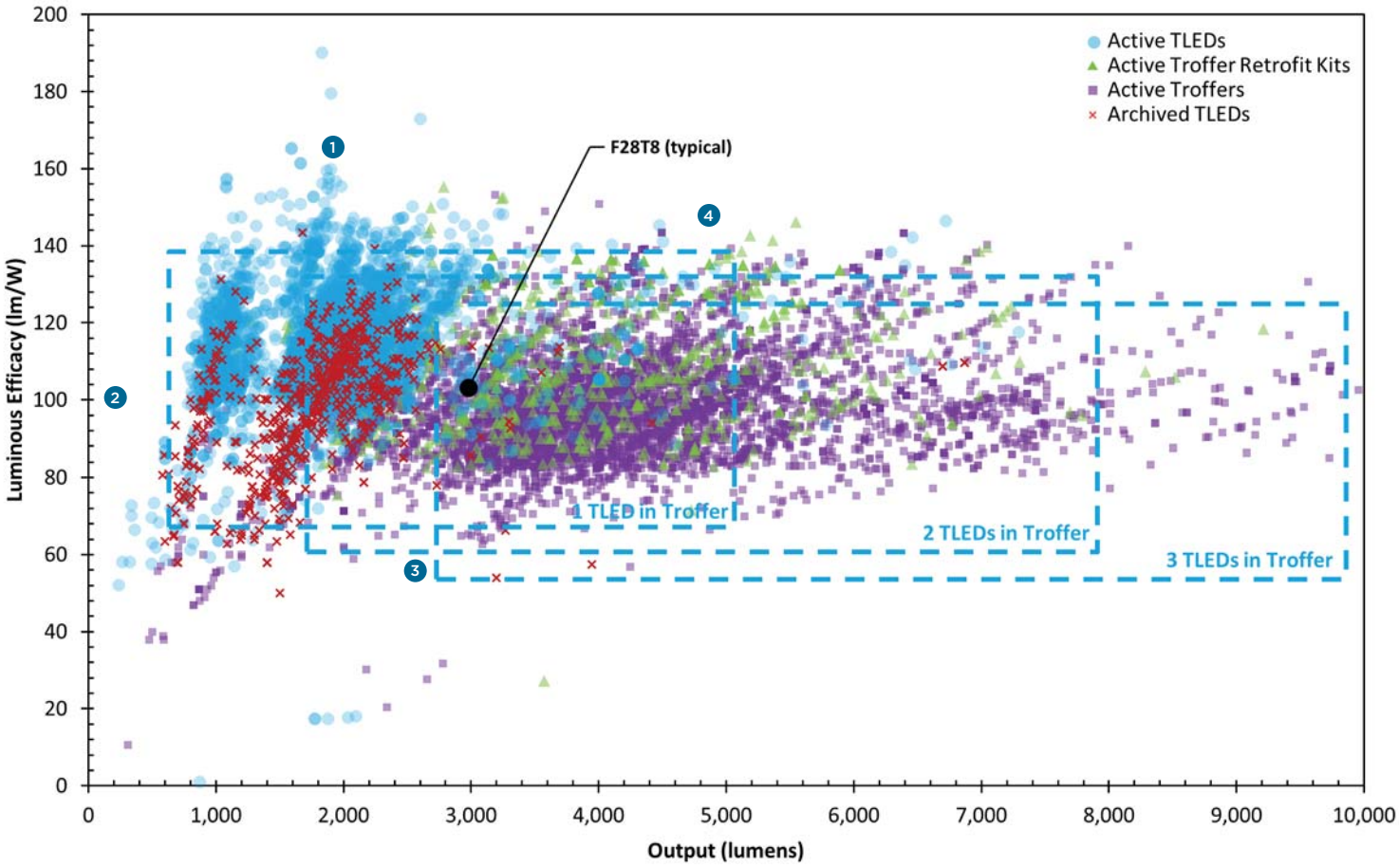
3. As of June 17, 2016, there were 4,523 linear LED lamps (TLEDs) listed by LED Lighting Facts, which is slightly more than 10% of the total products included.

4. The rate of increase for mean efficacy of all listed products has slowed in the last year. Previously averaging an increase of 10 lm/W per year for the past four years, the increase in 2016 was only 6 lm/W.

5. More than 100 currently listed products exceed 150 lm/W. These products include industrial fixtures, troffers, linear fixtures, roadway fixtures, and TLEDs. They come from a number of manufacturers, and almost all have a CRI greater than 80 and vary in CCT between 3000 K and 5000 K.

6. The most efficacious product currently listed by LED Lighting Facts (190 lm/W) is a TLED.

TLEDs **Efficacy & Output**



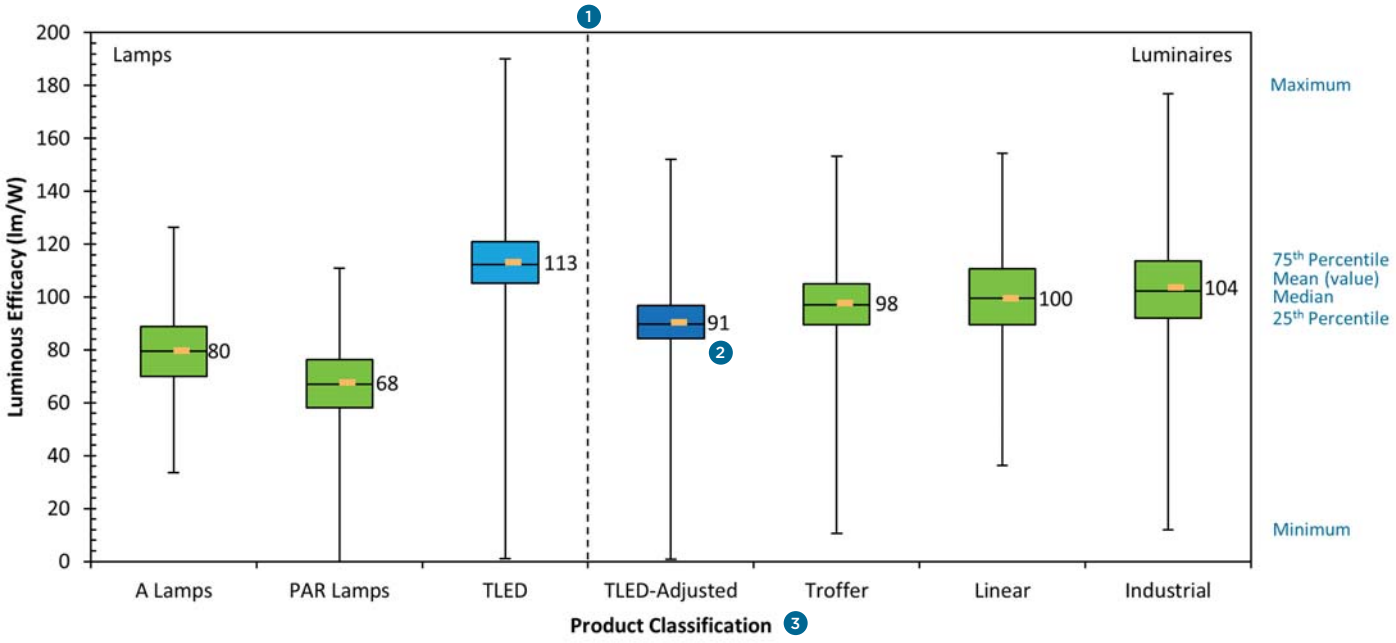
1. Nearly 90% of the currently listed TLEDs (which include 2′- and 4′-long products) emit between 1,000 and 3,000 lumens. This is generally less than the emission of a typical 4′ linear fluorescent lamp. Of the more than two-thirds of TLED products that are identified as having a 4′ length, the mean output is 2,094 lumens.

2. About 91% of the currently listed TLEDs exceed 100 lm/W, which is roughly the efficacy of a bare linear fluorescent lamp as well as the qualification threshold for the DesignLights Consortium™ Qualified Products List.

3. When evaluating TLEDs, it's important to consider their efficacy when installed in a luminaire. This chart shows approximate performance ranges for the majority of listed TLEDs when installed in a one-, two-, or three-lamp troffer. As the number of lamps increases, the luminaire efficiency is slightly reduced.

4. Both LED troffer retrofit kits and LED troffer luminaires tend to have lower efficacies compared to bare TLEDs, but when luminaire efficiency is considered, the retrofit kits and troffers are comparable to the high end of TLED efficacy.

TLEDs **Current Efficacy Versus Other Product Types**

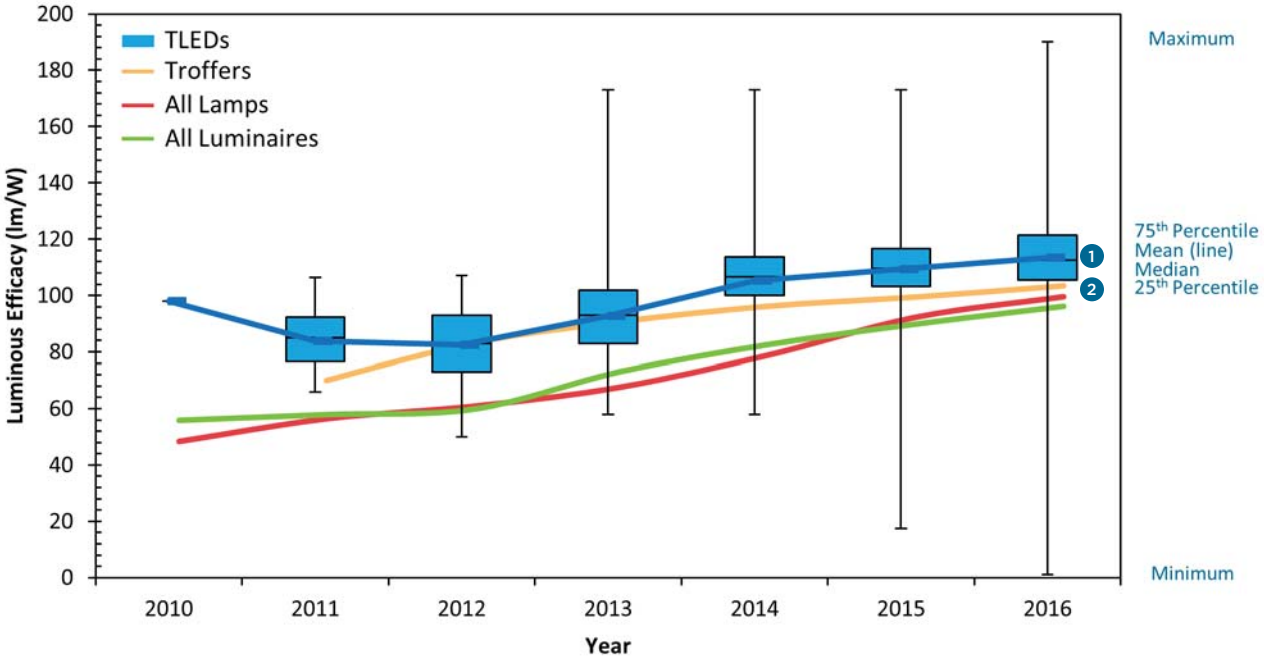


1. This chart compares the efficacy of TLEDs to other product categories. Lamp categories are shown on the left, and luminaire categories are shown on the right. The typical efficacy of TLEDs substantially exceeds the efficacy of A lamps and PAR lamps.

2. In order to appropriately compare the efficacy of TLEDs to that of other LED luminaires, a multiplier of 0.8 was applied, representing the efficiency of a typical troffer luminaire in which a TLED might be operated. When this is done, TLEDs tend to have lower efficacies than the dedicated LED luminaires against which they might compete.

3. Products listed by LED Lighting Facts are classified by the submitting manufacturer. There is some ambiguity between categories, and the variation within any given category may be substantial.

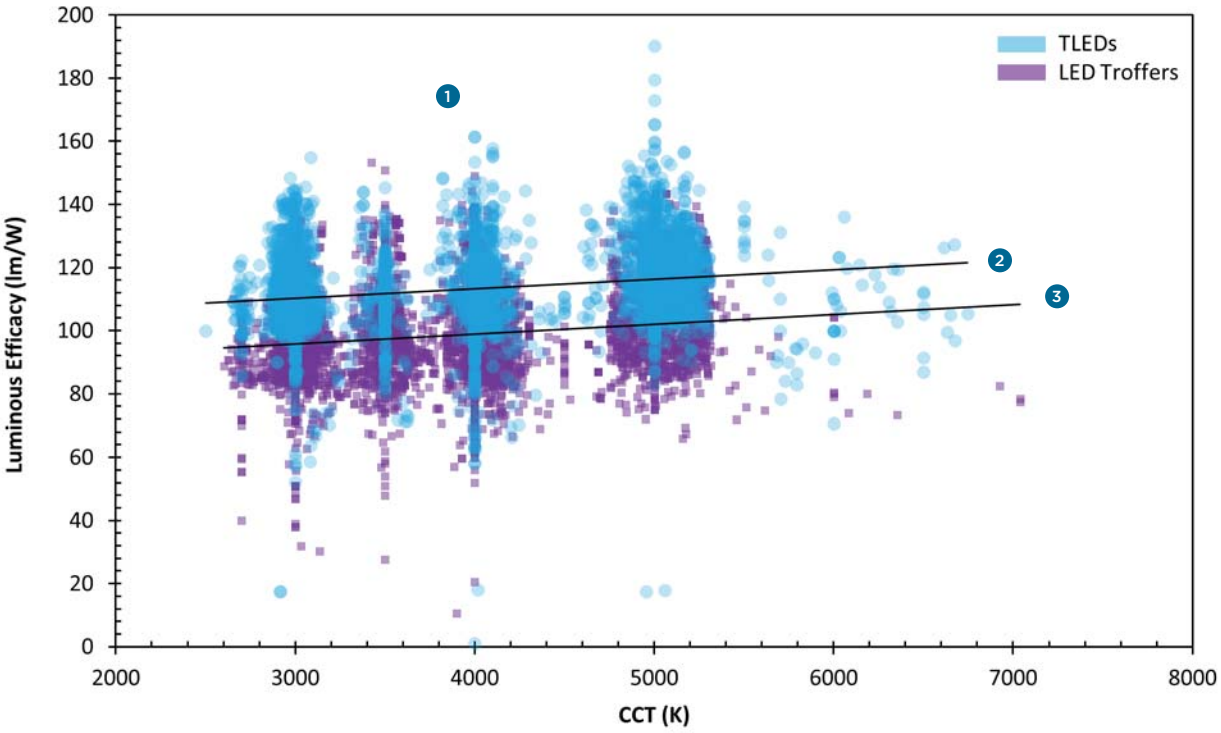
TLEDs **Efficacy Trends Versus Other Product Types**



1. The mean efficacy for listed TLEDs (blue line) has been increasing by about 5 lm/W per year for the past two years, which is comparable to the rate of increase for LED troffers. The value in a given category and year represents all products that were listed in June of that year, not just products newly added in that year.

2. The rate of increase in mean efficacy for both TLEDs and LED troffers has been less than the overall rate of increase for lamps and luminaires listed by LED Lighting Facts.

TLEDs **Efficacy Versus CCT**

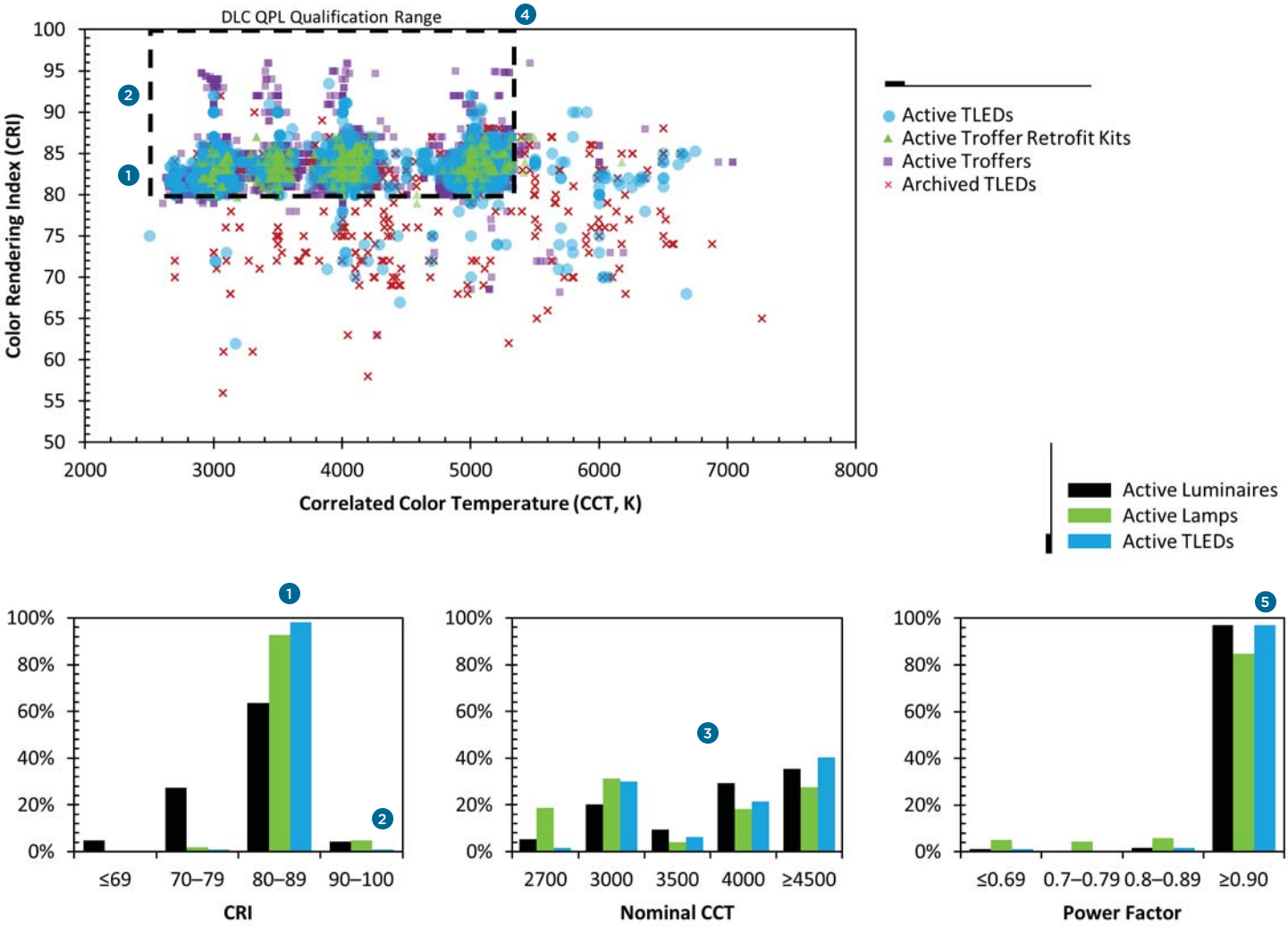


1. Examining the CCT of TLEDs and troffers, four groups emerge, corresponding to nominal CCTs of 3000 K, 3500 K, 4000 K, and 5000 K. At any given CCT, there is a wide range of efficacy. Importantly, average trends should not be applied when comparing a small number of products. The relationship between efficacy and CCT is predicated on all other factors being the same, or else being averaged over large datasets.

2. On average, a decrease of 1000 K in CCT for TLEDs equates to a decrease of 3 lm/W in luminous efficacy.

3. The relationship between efficacy and CCT for LED troffers is very similar to that for TLEDs. In fact, this relationship is fairly consistent across lighting product types, which is not surprising because it originates at the LED package level.

TLEDs **Color Quality & Power Quality**



1. Almost all (98%) of TLEDs listed by LED Lighting Facts have a CRI in the 80s, with most between 80 and 85.

2. Only 1% TLEDs listed by LED Lighting Facts have a CRI in the 90s, which is somewhat lower than other product categories.

3. A vast majority of the listed TLEDs have a nominal CCT of 3000 K, 4000 K, or 5000 K, with substantial representation in each.

4. The DesignLights Consortium qualification program requires TLEDs to have a CRI of at least 80 and a nominal CCT of less than 5000 K. About 97% of the currently listed TLED products meet both criteria.

5. A vast majority (97%) of TLEDs that are currently listed by LED Lighting Facts (and that report this optional metric) have a power factor of 0.90 or greater.

Discussion **How do TLEDs stack up?**

TLEDs seem to be everywhere, and the numbers from LED Lighting Facts back that up. Their presence in the LED Lighting Facts database is growing rapidly, and they now make up more than 10% of all active products and more than 50% of active lamps. Their rise to prominence is indisputable, but TLEDs are not necessarily a clear favorite when evaluating performance.

Data from LED Lighting Facts show that TLEDs consistently draw less power and emit fewer lumens than the linear fluorescent lamps they are intended to replace. On balance, they have somewhat higher efficacies, but the energy savings achieved is in large part due to the lower power draw. Importantly, TLEDs offer more of a directional emission than linear fluorescent lamps, meaning they can make troffers or other luminaires more efficient and thus need fewer lamp lumens to provide equal illuminance at the work plane. Note, however, that sometimes the increased luminaire efficiency cannot balance out the reduced lamp lumens; in such cases, energy savings are derived from reducing the light levels, which may or may not be acceptable. The change in distribution, something that is not obvious in LED Lighting Facts data, also presents another issue: it can change both the appearance of the luminaire and the distribution of light within a space.

Often, TLEDs are compared to other options for replacing fluorescent lighting, such as using retrofit kits or dedicated LED fixtures. At first glance, TLEDs may appear superior, with higher efficacy and likely a lower product cost and installation cost. However, accounting for factors such as luminaire efficiency and the remaining life of existing fluorescent ballasts (if they are to be reused) may tip the balance against TLEDs in some scenarios. Still, viable TLED options are increasingly available, something that could not be said a few years ago. As TLEDs push the efficacy limits for LED products, replacing low-cost fluorescent lamps becomes more compelling, as long as other tradeoffs are appropriately accounted for. Notably, average efficacy did not differ substantially between products identified as internal driver (116 lm/W) or external driver (115 lm/W), or for products identified as plug-and-play (113 lm/W) or rewiring required (119 lm/W).

There are thousands of TLEDs available. As this report shows, there is a great diversity in performance, even when examining only basic attributes. This report does not address the electrical and safety considerations when changing from fluorescent to LED lamps, nor does it examine features such as distribution of light or lifetime. When evaluating TLEDs, it is critical to examine the expected performance of the complete lamp and luminaire system, understand the complexities of installation, and be cautious in considering long-term performance.

The Fine Print **About LED Lighting Facts Snapshot Reports**

Snapshot reports analyze the dataset—or subsets—from DOE's LED Lighting Facts product list. They are designed to help lighting retailers, distributors, designers, utilities, energy-efficiency program sponsors, and other industry stakeholders understand the current state and trajectory of the solid-state lighting market. Product classifications are at the discretion of the manufacturer, and Snapshot reports generally reflect the raw data listed in the LED Lighting Facts database. Minimal action is taken to adjust for inconsistencies.

The LED Lighting Facts database is not a statistical sample of the overall market. LED Lighting Facts is a voluntary reporting program in which manufacturers submit data for products tested in accordance with IES LM-79-08. Within any category, the data may be skewed not only by what is submitted, but also by the reporting practices of different manufacturers (e.g., reporting each small variation of a product). Given the broad nature of some of the predetermined categories, not all individual products may be directly comparable (i.e., the form factor may be substantially different). Despite these limitations, the LED Lighting Facts database is the largest of its kind, and is generally considered indicative of market trends. The product list includes a wide variety of product types, from manufacturers large and small, lighting industry veterans and brand new companies alike.

LED Lighting Facts and the Snapshot reports focus on five core metrics: lumen output, input power, luminous efficacy, color rendering index, and correlated color temperature. Data for other performance metrics can be voluntarily submitted, and all data are available on the LED Lighting Facts website. Specifiers should thoroughly consider all aspects of performance when evaluating different products.

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

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