

CALiPER

Snapshot MR16 Lamps

CALiPER last issued an LED Lighting Facts® Snapshot Report covering MR16 lamps on January 1, 2014, making it a good time to examine any progress. Used extensively in retail and display lighting, halogen MR16 lamps deliver focused illumination from a two-inch-diameter aperture, have desirable color quality, are easy to use with controls, and are available with a range of options (e.g., beam angle) and accessories (e.g., spread lenses). Given this combination of features, the conventional halogen MR16 lamp is one of the most difficult lamps for LED technology to successfully replicate. This is especially true for 12 V, 50 W halogen lamps, which are the most commonly used.

While the number of products listed by LED Lighting Facts has approximately tripled in the past two years, the number of listed MR16 lamps has not changed significantly—although many products have been added and others removed. In fact, the share of total listed lamps made up by MR16s has continued to fall, and is now at 7%, down from a high of 25% in the first year of LED Lighting Facts. Performance gains have also been slower for MR16s than for other product types. The 2014 Snapshot on MR16 lamps noted that the lumen output and center beam intensity (CBCP) of LED MR16s had been steadily increasing, but there were still few products that could claim to be truly comparable to a 50 W halogen MR16 lamp. Two years later, the story is still the same. A handful of products have offered higher output and CBCP than the maximum in 2013, but no lamps meet the ENERGY STAR® *expected* CBCP for a given beam angle. Likewise, efficacy increases for MR16s have been slow, with the mean efficacy only increasing from 54 lm/W to 61 lm/W over the past two years.

LED Lighting Facts lists MR16 products operating at 12 V (typically a GU5.3 base) and 120 V (typically a GU10 base). The performance of low-voltage and line-voltage halogen MR16 lamps is not equivalent, even at the same wattage. Thus, it can be difficult for specifiers and consumers to make sense of equivalency claims. About 66% of the currently active MR16 lamps listed by LED Lighting Facts are 12 V lamps, whereas 17% are 120 V; the remainder do not list the voltage, which is an optional metric for the manufacturers to provide.

Note that some of the graphics in this Snapshot vary from those in the previous Snapshot report. Specifically, dated values always refer to the full set of products listed at that point, rather than to just the products added in a given quarter. All yearly values are based on the products listed as of July 1 of that year.



November 20, 2015

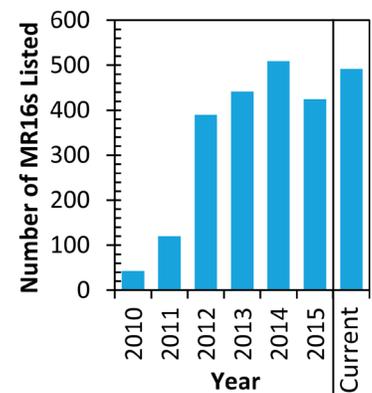
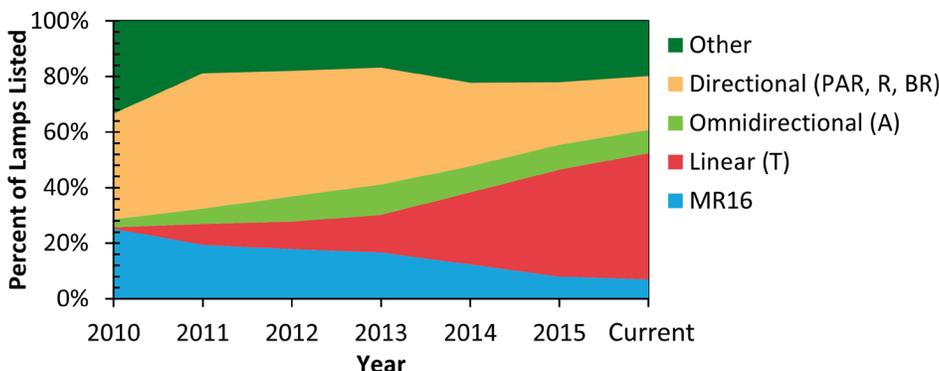
2,283 Partners

33,622 Total Active Products

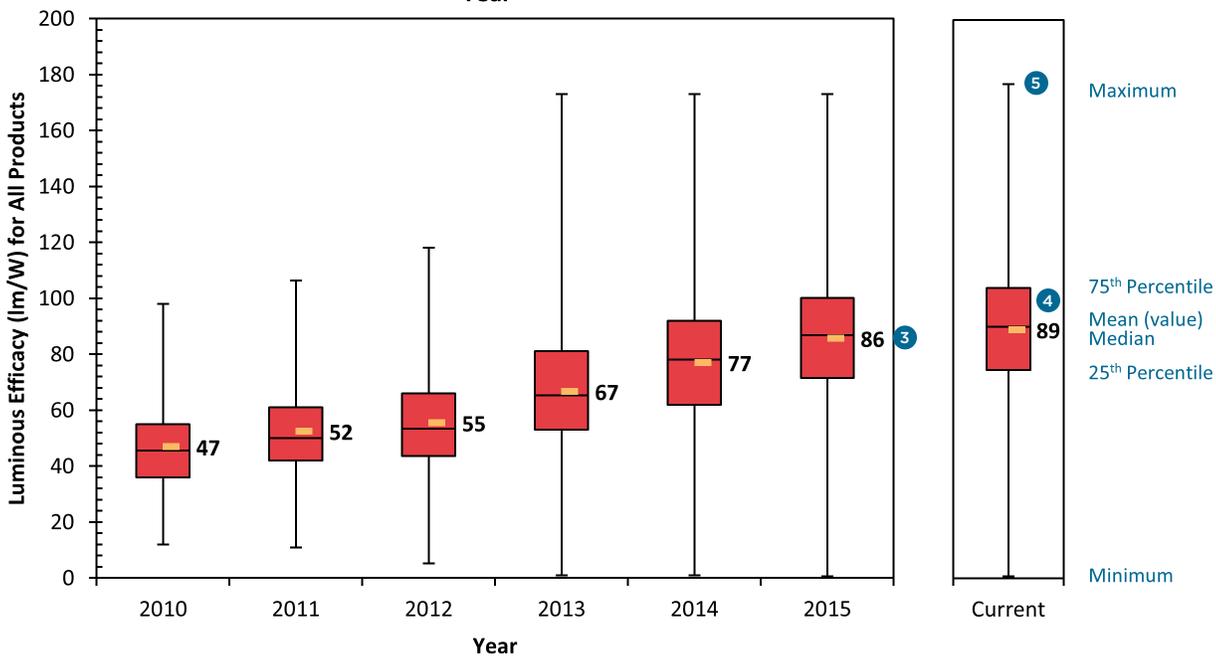
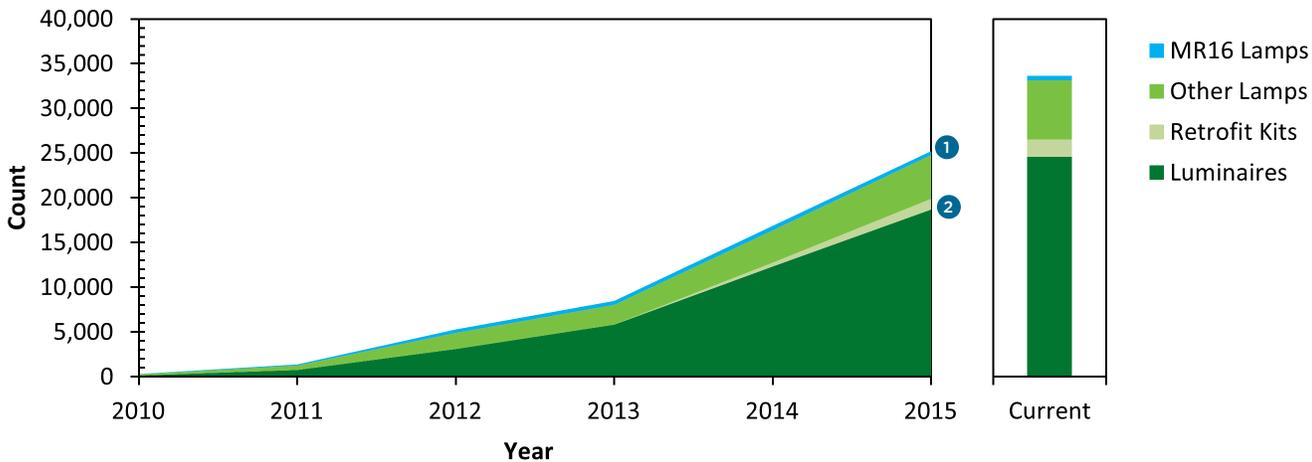
Report Highlights

- Few MR16 lamps currently listed by LED Lighting Facts are comparable to a 50 W (12 V) halogen MR16 lamp. There has been some improvement since the last Snapshot on MR16 lamps (January 1, 2014), but most lamps are still equivalent to 20 W and 35 W (12 V) halogen MR16 lamps.
- While there have been many additions and subtractions, the number of listed MR16 lamps has changed little in the past two years.
- While efficacy and output have increased, the rate of increase has been far slower than for other lamp types.
- The efficacy of MR16 lamps currently is the lowest of any major category of products listed by LED Lighting Facts.
- A greater percentage of MR16 products meet ENERGY STAR criteria for color rendering and color temperature than two years ago.
- There have been small gains made in terms of power factor.

AT A GLANCE LAMPS LISTED BY LED LIGHTING FACTS



All Products Listings & Efficacy Over Time



1 The growth of the LED Lighting Facts database continues to accelerate. As of July 1, 2015, there were more than 25,000 listed products. More than 8,000 products were added in the subsequent five months.

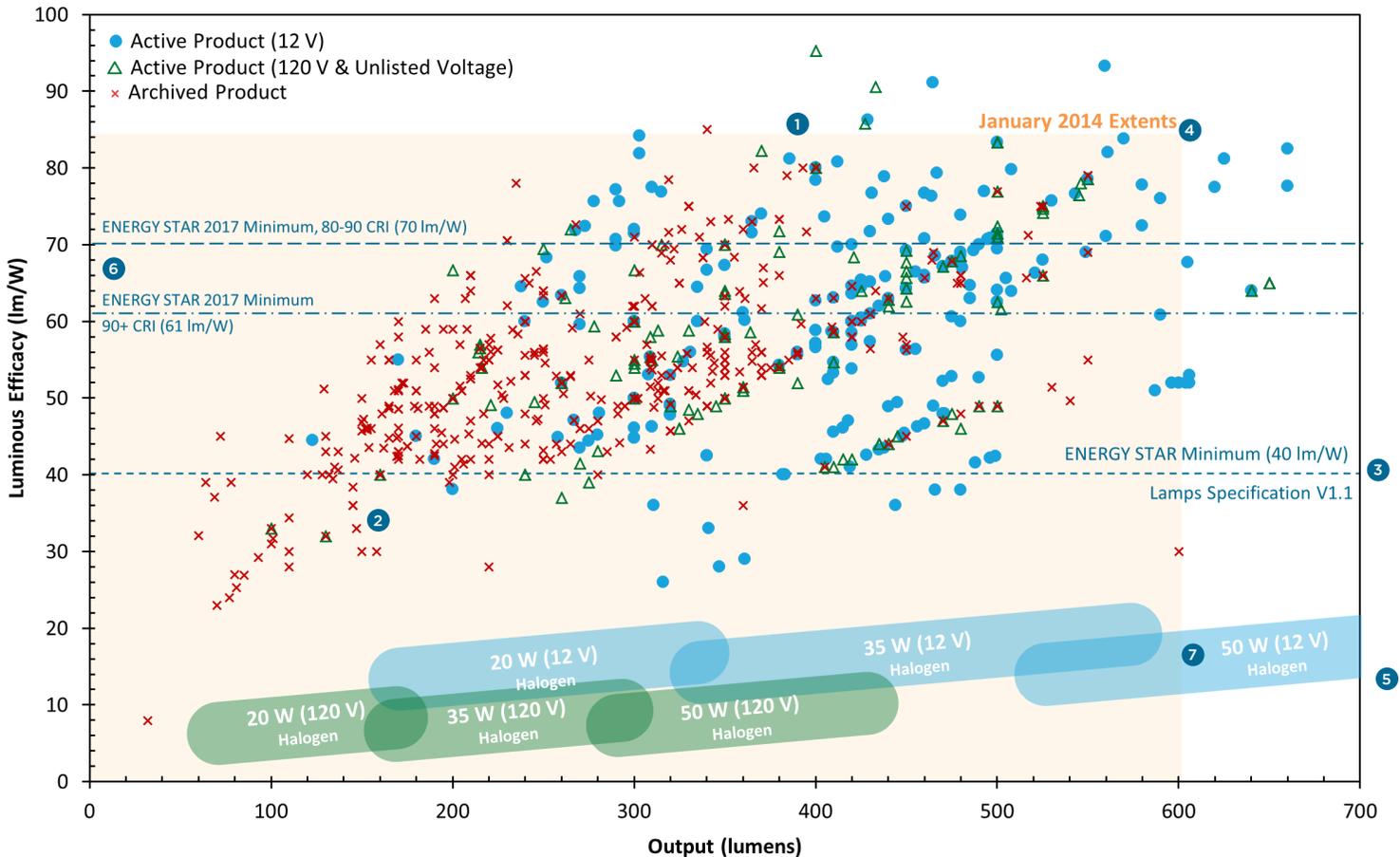
2 The rate of increase in the number of luminaires listed has outpaced lamps and retrofit kits. Luminaires now make up approximately 74% of the LED Lighting Facts database.

3 The mean efficacy for all products continues to grow at a steady rate of approximately 10 lm/W per year. The range for the middle 50% of products is also increasing at a similar rate.

4 Although it is not shown in this chart, the mean efficacy for products listed after July 1, 2015, was 99 lm/W. This value is higher than the current mean listed, because the current mean includes all products still listed, some of which were first added in 2009.

5 While the maximum listed efficacy has not increased in the past two years, the number of very-high-efficacy products has steadily grown. Nearly 50 currently listed products exceed 150 lm/W. These products include industrial fixtures, troffers, linear fixtures, roadway fixtures, and linear lamps. They come from a number of manufacturers, and almost all have a CRI greater than 80 and vary between 3000 K and 5000 K.

MR16 Lamps Efficacy & Output



1 There are few trends or groupings for lumen output or efficacy of LED MR16 lamps. Unlike A lamps, there are no obvious lumen output thresholds for MR16 lamps, in part because specification is usually based on beam angle and center beam intensity.

2 The cloud of data for archived products demonstrates that lower-efficacy products are the ones being removed from the database. Almost 50% of the currently listed lamps emit between 400 and 500 lumens.

3 The minimum efficacy requirement for ENERGY STAR qualification of MR16 lamps is 40 lm/W. Notably, only 14 MR16 products currently listed by LED Lighting Facts fall below that threshold. This is an improvement, compared to the 36 products that were less than 40 lm/W in 2013.

4 The approximate extents of products available in 2013 is indicated by the orange shaded area. A handful of products now offer either higher efficacy or higher lumen output, although no products offer both. In other words, the highest-output products are not the most efficacious products, and vice versa.

5 The typical output ranges for halogen MR16 lamps, shown in green for 120 V products and blue for 12 V products, are estimated by CALiPER from surveys of manufacturer data.

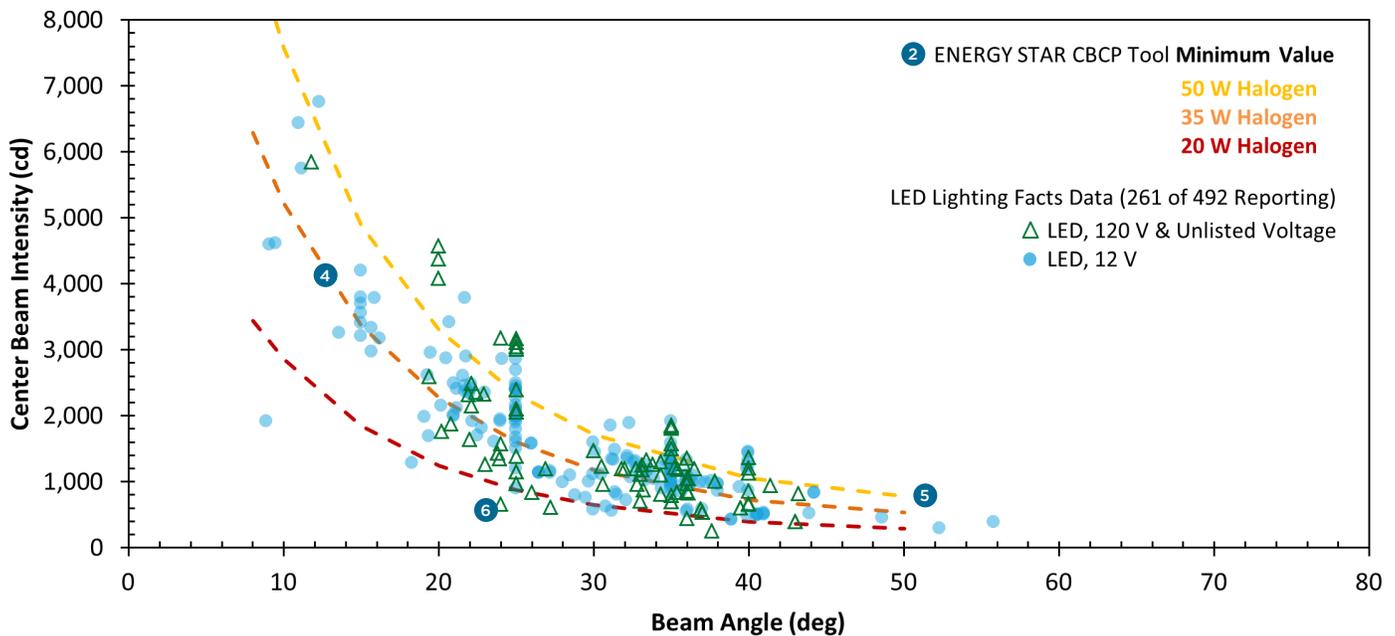
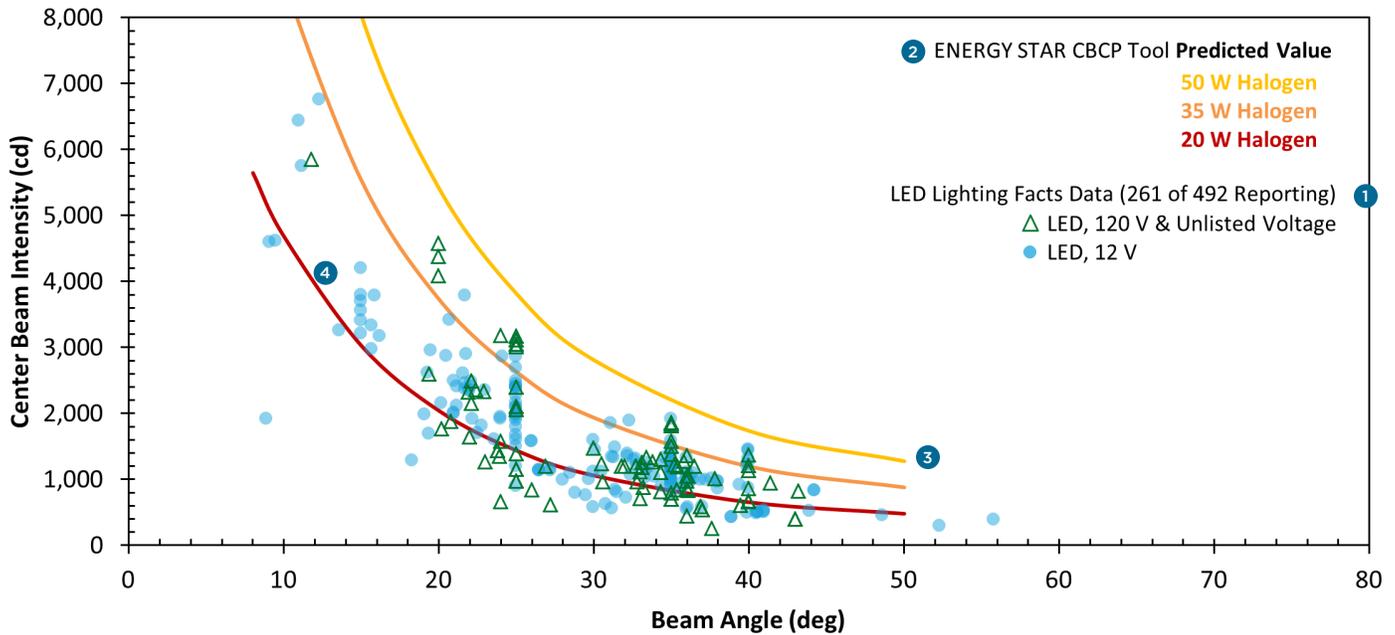
6 Beginning in 2017, the ENERGY STAR minimum efficacy requirements will be substantially higher, with tiers dependent on CRI. Only 25% of the currently active products will meet the new criteria when it takes effect. Over 97% of active products meet the current criteria.

7 Almost 20% of MR16 lamps listed by LED Lighting Facts offer comparable lumen output to typical 12 V 50 W halogen MR16 lamps (> 500 lumens). Lower wattage categories are well represented, however. A vast majority of LED MR16 products that listed voltage were 12 V, which is typical for most applications.

8 At a given wattage, line-voltage halogen MR16 lamps (120 V) typically have lower lumen output than their low-voltage counterparts. Many of the MR16 lamps listed by LED Lighting Facts offer comparable output to all three types of line-voltage products, but only about 16% of products were listed at 120 V.

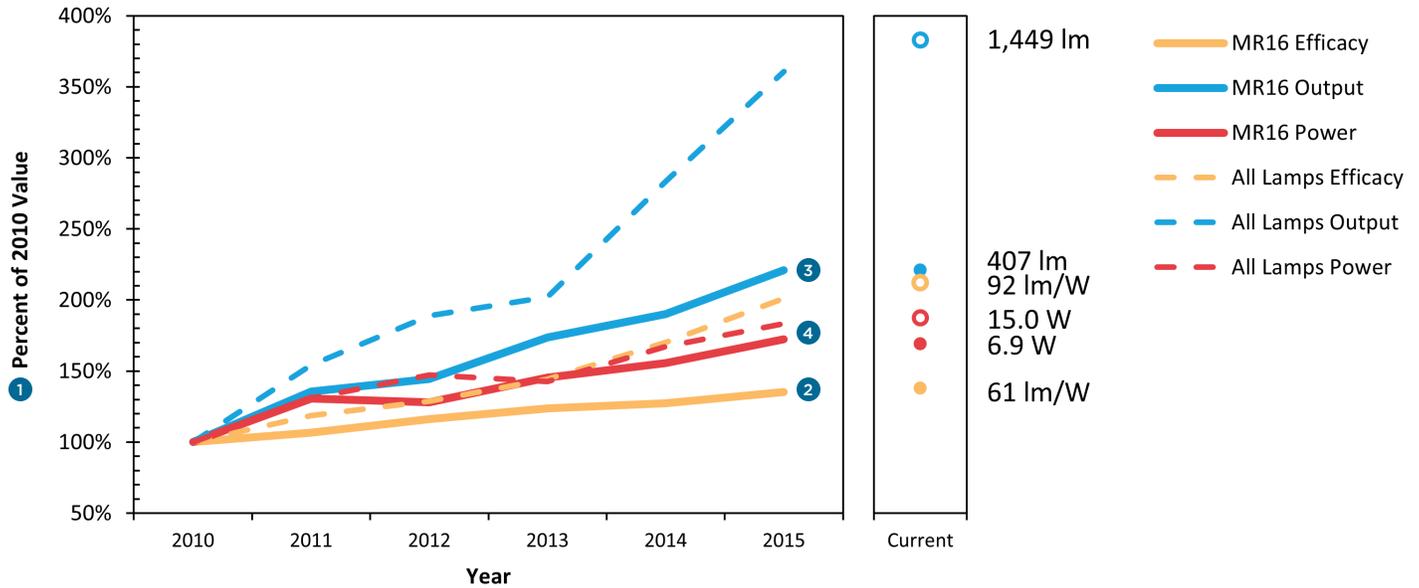
Regardless of voltage, LED MR16 lamps offer superior efficacy compared to their halogen counterparts.

MR16 Lamps Beam Angle and Center Beam Intensity



- 1** Beam angle and center beam intensity (CBCP) are now required metrics for listing with LED Lighting Facts, but they were not always. Of the 492 MR16 products that are currently active, 261 provide data for both beam angle and CBCP (66 at 120 V, 171 at 12 V).
- 2** ENERGY STAR provides a tool for calculating the predicted CBCP for a given wattage and beam angle halogen MR16, as well as the minimum for claiming equivalency. It is available at: <http://www.energystar.gov/LampsCBCP>.
- 3** None of the 276 LED MR16 lamps that provided distribution data to LED Lighting Facts could provide the predicted CBCP for a 50 W halogen MR16 at its listed beam angle. However, many exceeded the CBCP that ENERGY STAR predicts for a 35 W halogen MR16.
- 4** There are now nine MR16 products listed with a beam angle less than or equal to 15°. Three listed MR16s have a beam angle less than 10°.
- 5** Many lamps met ENERGY STAR's lower-limit threshold for claiming equivalency to a 50 W halogen MR16, a marked improvement over the one product meeting that criterion in 2013. The lower limits are two standard deviations below the predicted value at a given beam angle.
- 6** A handful of the 276 lamps that listed distribution data failed to meet the minimum CBCP value for a 20 W halogen MR16 lamp.

MR16 Lamps versus All Lamps Efficacy, Output, and Power Trends



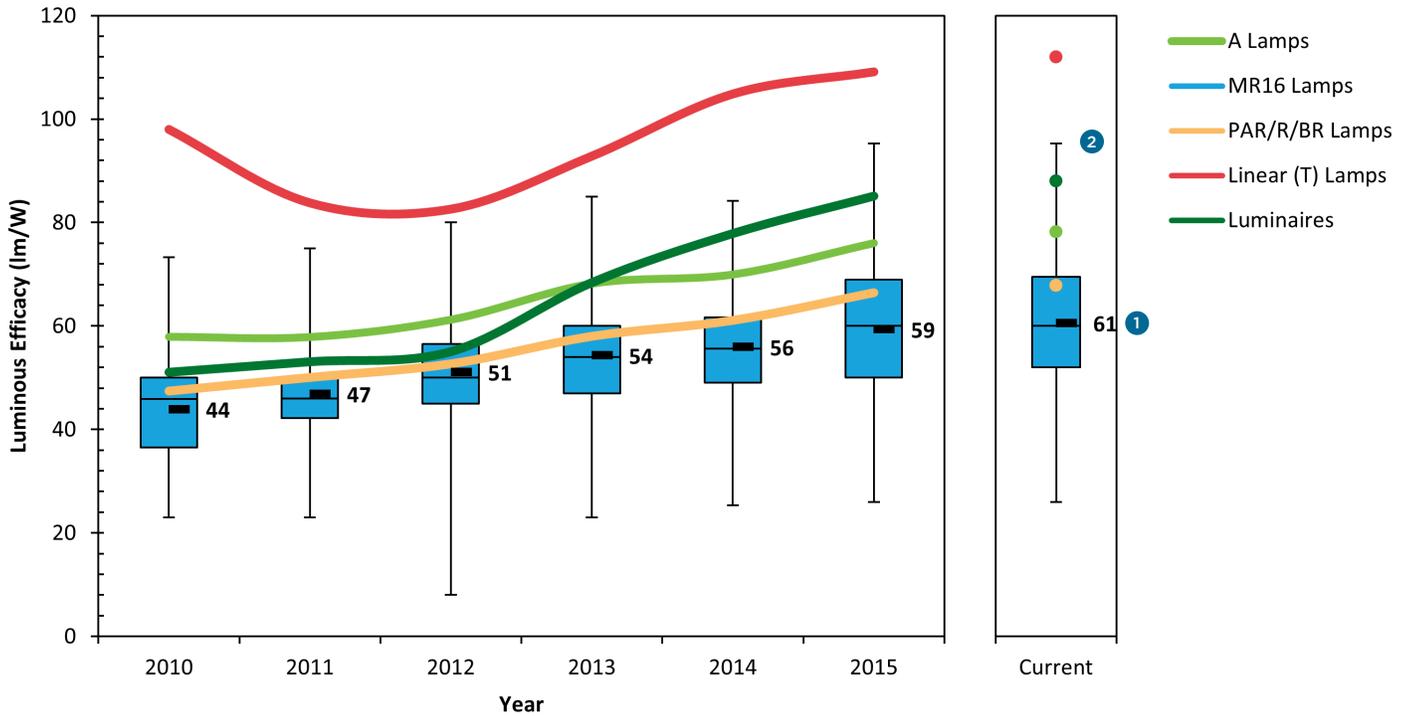
1 For this chart, all values have been normalized to the 2010 datapoint. At that point, the efficacy for MR16s and all lamps listed by LED Lighting Facts was the same (44 lm/W). There was, however, a substantial difference in input power (8.0 W for all lamps versus 4.1 W for MR16s) and lumen output (378 lumens versus 184 lumens).

2 The increase in efficacy for lamps as a whole has outpaced the increase in efficacy for MR16 lamps. This can largely be traced to the increasing prominence of linear LED lamps (TLEDs), which now make up 45% of the listed lamps and have a mean efficacy of 112 lm/W.

3 As with efficacy, lumen output for all lamps has increased rapidly, but has shown relatively modest growth for MR16s. The rapidly growing number of TLEDs after 2013 is the primary driver of this trend; TLEDs require higher output to be comparable to the incumbent linear fluorescent lamps.

4 The relative increase in input power was about the same for LED MR16 lamps and all lamps listed by LED Lighting Facts.

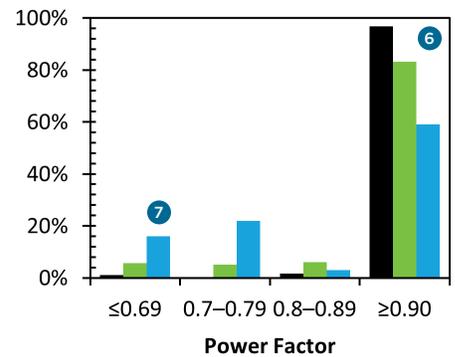
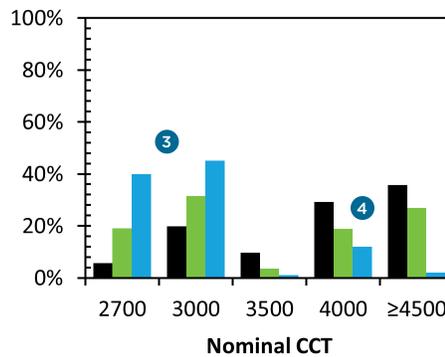
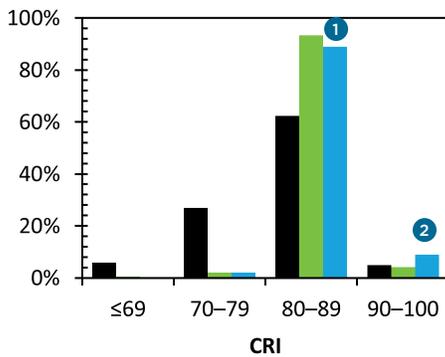
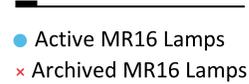
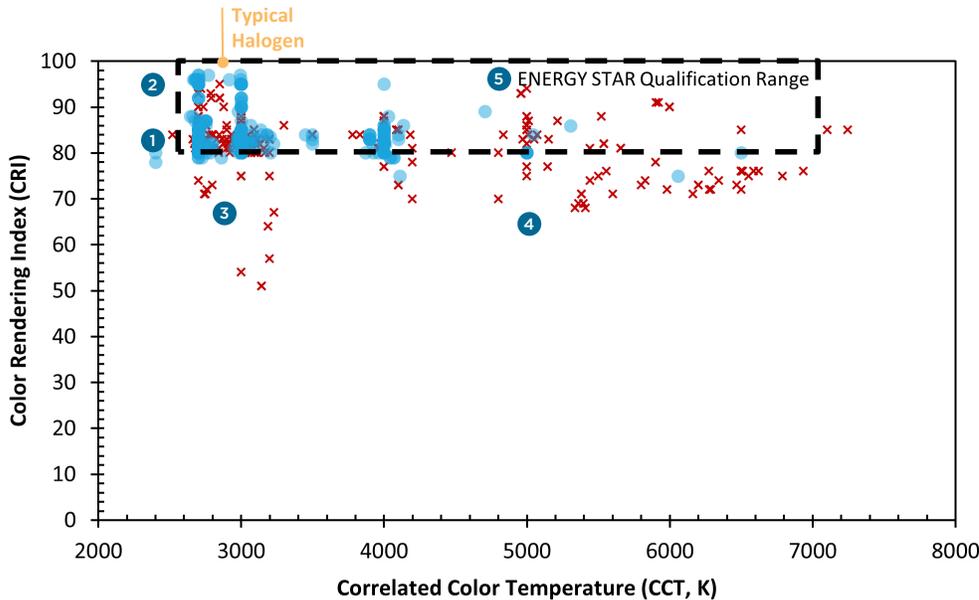
MR16 Lamps Efficacy Versus Other Product Types



1 The mean efficacy for MR16 lamps has increased much more slowly than the mean efficacy for other common lamp categories, including A lamps, PAR/R lamps, and T lamps. With the exception of TLEDs, the rate of increase in efficacy for lamps has generally been slower than the rate of increase for luminaires. TLEDs and LED luminaires are typically used to replace relatively efficient incumbent technologies, such as fluorescent and metal halide.

2 Even after a recent jump, the maximum efficacy for listed MR16 lamps remains relatively low. It is substantially less than the mean efficacy for TLEDs, at least partially due to the need for greater optical control. Form factor, cost, and incumbent characteristics all likely contribute to this outcome as well.

MR16 Lamps Color Quality & Power Quality



1 A vast majority of MR16 lamps listed by LED Lighting Facts (89%) have a CRI in the 80s, with a majority of those between 80 and 85.

2 About 9% of currently active MR16 lamps have a CRI greater than 90, including products from five different manufacturers. This is notably higher than the percentage for all lamps combined. In general, the currently listed MR16 lamps tend to have higher color fidelity than other lamps.

3 A vast majority of the listed MR16s have a nominal CCT of either 2700 K or 3000 K, with slightly more at 3000 K. These CCTs are the closest to halogen lamps, which often have CCTs around 2800 K to 3000 K.

4 A small number of MR16 lamps currently listed by LED Lighting Facts have a nominal CCT of 3500 K or higher, which is noticeably different from conventional MR16 lamps. Products in this range are archived more frequently, indicating a movement away from this type of performance.

5 ENERGY STAR requires lamps to have a CRI of at least 80 and a nominal CCT between 2700 K and 6500 K. A vast majority of the currently active MR16 lamps (97%) met both criteria.

6 A majority (59%) of MR16 lamps currently listed by LED Lighting Facts (that report this optional metric) have a power factor of 0.90 or greater. However, the percentage is noticeably lower than for all active luminaires (97%) or lamps (83%). Only 34% of currently listed MR16 lamps reported power factor, compared to 46% for all active products. Importantly, the transformer to which low-voltage lamps are connected affects the electrical characteristics of the system, making the manufacturer-provided power factor of low-voltage MR16s an unreliable predictor of actual system performance.

7 About 16% of the currently active MR16 lamps (that report this optional metric) have a power factor below the ENERGY STAR minimum of 0.70—markedly more than for other product categories. The small form factor of MR16 lamps, which leaves little room for a power factor correction circuit, is likely a contributing factor.

Discussion **How do LED MR16 lamps stack up?**

In the past two years, LED technology has progressed rapidly, which is reflected in the data available through LED Lighting Facts. The number of available products is increasing, along with the average efficacy and output performance. For LED MR16s, however, the progress has been much slower. The increase in mean efficacy is about half of that seen for other categories, and lumen output or CBCP have not notably increased in recent years, either. There are still no listed lamps at a given beam angle that meet the expected CBCP values for a 50 W halogen MR16 using the ENERGY STAR calculator—although several now meet the minimum threshold. At the same time, the number of MR16s listed by LED Lighting Facts has not changed much in four years, and the category represents a dwindling percentage of the total number of listed lamps. Yet, the market penetration for LED MR16s is among the highest for any product category.

The MR16 category was an early target for LEDs because their attributes seem well suited for the technology: small size, directional output, and a low-efficacy incumbent (halogen). Now these conditions may be contributing to the stagnant performance. For example, LED MR16s are already much more energy efficient than halogen lamps, and there are no other source types that can match the other features of halogen lamps (i.e., dimmability); thus, there is less incentive to improve the efficacy of LED MR16 lamps, compared to, say, linear lamps (TLEDs), which must compete with high-efficacy linear fluorescent lamps. In contrast with MR16s, the efficacy, output, and number of TLEDs have been growing rapidly. Given the limitations of the MR16 form factor and need for high color quality, the market may be dictating that the energy performance improvements are a secondary consideration to cost-competitiveness, CBCP, and perhaps light output. Still, efficacy improvements can help alleviate thermal-management challenges associated with the small form factor, for example, which may help a true 50 W halogen MR16 equivalent to emerge.

Many performance considerations are not captured in basic photometric data. For example, LED MR16 lamps require an integral driver that must fit into the form factor and, in most applications, must operate at 12 V, necessitating the use of a transformer. This combination may result in compatibility issues, where performance is degraded in one or more areas (e.g., flicker). This is sometimes a result of tradeoffs that must be made, such as between flicker and power quality. More information can be found in the DOE SSL Fact Sheet on MR16 lamps.¹ Long-term performance is another key consideration, and will be the focus of an upcoming CALiPER investigation.

¹ Available at: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_mr16-lamps.pdf

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 is available on the LED Lighting Facts website. Specifiers should thoroughly consider all aspects of performance when evaluating different products.

