Energy Savings Forecast of Solid-State Lighting in General Illumination Applications

Prepared for DOE's Lighting R&D Program by Guidehouse, Inc.

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Introduction

The US Department of Energy (DOE) report, "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications," provides predictions of LED market penetration and energy savings compared to conventional lighting sources (i.e., incandescent, halogen, fluorescent, and high-intensity discharge) in all general illumination applications from present day through 2035. The findings present a thorough overview of where the lighting market is currently and where it is forecast to go. This report is of use to manufacturers, suppliers, and other stakeholders in the lighting industry as the transition to solid-state lighting (SSL) technology moves forward. Figure 1 describes the three scenarios considered in this iteration of the study: No-SSL, Current SSL Path, and DOE SSL Program Goals. Also included in this study is the analysis of lighting controls, and in particular connected lighting, as a contributor to energy savings.

Figure 1. Lighting Market Model Scenarios

No-SSL: A hypothetical scenario that assumes LED technology never entered the lighting market. LED lamps and luminaires are not available for competition, only conventional incandescent, halogen, fluorescent, and high-intensity discharge sources. The No-SSL scenario is used as the reference condition from which LED lamp and luminaire energy savings are calculated.

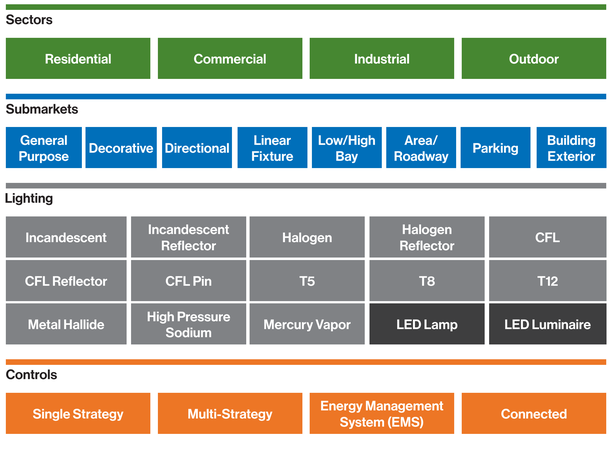
Current SSL Path The expected future path for LED lamps and luminaires given the continuation of current levels of SSL investment and effort from DOE and industry stakeholders.

DOE SSL Program Goals The future path for SSL given the DOE goals outlined in the annual SSL R&D Plan are met, representing the ultimate potential of what DOE has determined is technically feasible in the given timeframe.

Methodology & Analytical Approach

- **Step 1: Calculate national lighting inventory and service**
  Use the lamp installations, average efficacies, average lumen output, and operating hours to estimate a national lighting inventory of installed lighting systems for each sector. In this report, the initial lighting stock was calibrated based on stock from the 2015 Lighting Market Characterization (LMC) to further inform growth trends by technology, whereas in previous years it was based on the 2010 LMC.
- **Step 2: Develop arenas for competition**
  The lighting market model examines eight submarkets across four sectors where a total of 15 technology categories and four different control options may compete. These are shown in Figure 2.

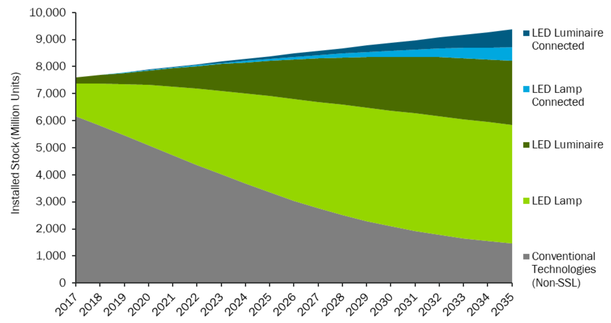
Figure 2. Lighting Market Competition Arenas



Overall Lighting Stock and Energy Savings Results

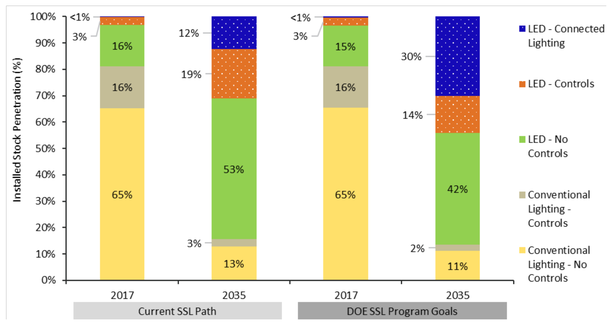
The report provides forecast estimates for the installed base penetration of lighting systems (lamp(s), ballast, and fixture are counted as one unit) from present day to 2035. In 2017, LED lighting installations represented 19% of the installed stock. However, by 2035, LED lamps and luminaires are anticipated to hold the majority of lighting installations in each of the applications examined, comprising 84% of the installed stock across all categories (shown in Figure 3).

Figure 3. Total US Installed Stock Projections for the Current SSL Path Scenario



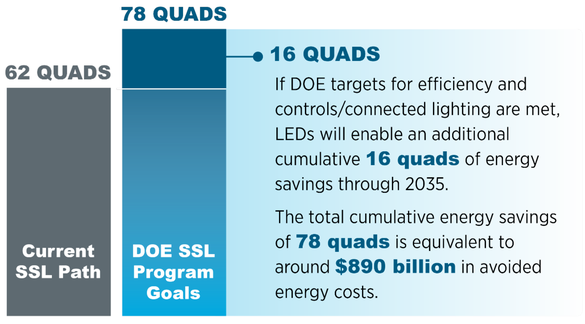
In 2017, connected lighting made up a small portion of the market, but it is projected to grow upward of 30% by 2035 if DOE's goals are met. Figure 4 illustrates both the 2017 and 2035 forecast penetration of these connected LED products relative to the total installed lighting stock for each scenario.

Figure 4. Lighting Controls Installed Penetration for LED vs. Conventional Lighting



In addition to forecasting the installed base, the report provides predictions for future lighting energy consumption and the expected savings from LEDs and controls. Following the Current SSL Path, the installed penetration of LEDs is projected to save 4.8 quads in annual energy consumption by 2035. However, if the DOE SSL Program Goals are met, LED installed penetration is projected to save an additional 1.3 quads annually in 2035, or a total of 6.1 quads. Figure 5 shows the amount of energy that could be cumulatively saved through 2035 if the US DOE SSL Program goals are realized.

Figure 5. US Cumulative Energy Savings Forecast from 2017 to 2035



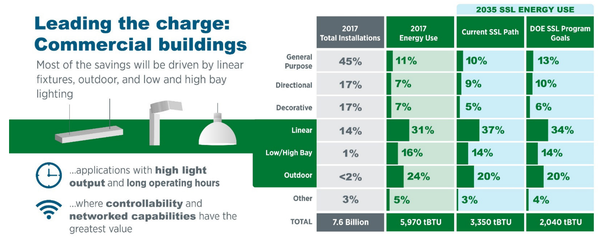
- In 2017, LED lighting already offered 1.1 quads of energy savings.
- By 2035, of the total 6.1 quads in annual energy savings expected from LED lighting if DOE SSL Program Goals are met, 16% is made possible by the penetration of connected LED lighting.
- The reduced consumption in the residential sector alone would save an average household approximately $15 annually in 2017 and $117 annually in 2035 – a cumulative savings of $1,420 over the 18-year forecast period.
- The commercial sector will provide 39% of all energy savings in 2035, despite representing only 17% of all LED installations.
- The outdoor sector has the highest installed penetration of LED lighting for all years between 2017 and 2035.

- **Step 3: Project annual lighting demand**
  Use annual average growth forecasts of floor space provided in the Energy Information Agency's (EIA's) Annual Energy Outlook (AEO) 2018 to project changes in lighting demand going forward.
- **Step 4: Calculate the available market**
  Lighting market turnover results from (a) new installations due to new construction, (b) units replaced upon failure of existing lamps, and (c) units replaced due to lighting upgrades and renovations.
- **Step 5: Project conventional and LED lighting technology improvement**
  Conventional technology is projected to make some improvements as it competes with new LED lighting products. These improvements are adjusted to account for existing legislative and regulatory energy conservation standards. The LED projection is derived from the performance curves from public LED product databases and from prices of LED products collected systematically since 2010.
- **Step 6: Model the market share of all lighting technologies**
  The lighting market model predicts market share as an aggregate of many individual purchase decisions using three analytic components: an econometric logit model that considers economic factors, a technology diffusion curve that considers existing marketplace presence, and an acceptance factor that considers non-economic biases. Additionally, LED penetration is calibrated by comparing past LED market share values predicted by the model to actual historical values.
- **Step 7: Model the market share and energy savings of lighting controls**
  The lighting market model calculates market share of four groups of lighting controls using an initial stock and calculated shipments in each analysis year. The energy savings are then calculated in the model per control system, accounting for the energy saving effect of the control (turning lights off or reducing wattage) and its utilization (percent of time that each control strategy is used).
- **Step 8: Calculate overall lighting market energy savings**
  Compare the lighting energy consumption projected by the lighting market model to that of a hypothetical No-SSL scenario in which LED products are assumed to have never entered the general illumination market. All other market conditions, such as the energy conservation standards, are unchanged.

Submarket Stock and Energy Savings Results

When considering the scenario results by submarket, several interesting trends emerge. Figure 6 shows several trends with respect to which submarkets offer significant energy savings in 2017 and 2035 for the Current SSL Path and the DOE SSL Program Goals scenarios.

Figure 6. Total US Lighting Installations and Energy Consumption: 2017 and 2035 Current SSL Path and DOE SSL Program Goals



- Although A-type lamps comprised 45% of all lighting installations in 2017, low and high bay fixtures, representing 1% of all lighting installations, contribute more 2017 lighting energy use than A-type lamps.
- Directional lighting applications, an early adopter of LED technology, currently contribute the most to 2017 LED energy savings at 19% of all 2017 LED energy savings. However, it is expected to contribute less to overall LED energy savings than linear and low/high bay applications in 2035.
- Linear fixture, low/high bay, and outdoor applications represent significant portions of 2017 energy use due to high light outputs and long operating hours, and most of the energy savings gained through 2035 will be driven by these applications, where connected capabilities will have the greatest impact on energy use.

Table 1. LED Penetration by Submarket for the Current SSL Path Scenario

Submarket	2017	2020	2025	2030	2035
General Purpose	21%	39%	62%	77%	85%
Decorative	8%	20%	46%	70%	85%
Directional	28%	44%	63%	73%	77%
Linear Fixture	11%	25%	59%	80%	88%
Low/High Bay	12%	28%	61%	82%	90%
Parking	36%	69%	95%	98%	98%
Area/Roadway	37%	64%	92%	99%	100%
Building Exterior	31%	63%	92%	98%	98%
Other[1]	22%	41%	68%	84%	91%
TOTAL LED Installed Stock Penetration	**19%**	**35%**	**60%**	**76%**	**84%**

1. The "other" submarket is included to accommodate lighting products with unknown applications; however, it was not explored in great detail in the report.

Table 1 shows the breakdown of LED installed penetration by submarket from 2017 to 2035.

- In 2017, LEDs had the greatest installed penetration in the outdoor sector, representing 37% of parking applications, 36% of area and roadway, and 31% of building exterior applications.
- In the area and roadway submarket, already a popular area for LED lighting (and one of the submarkets with the highest penetration in 2017 at 36%), LEDs are predicted to exceed 92% installed penetration by 2025 and achieve 100% by 2035.
- Low and high bay LEDs have seen continued growth in adoption – achieving an estimated 12% of all installations in 2017. This is expected to grow to 90% by the end of the analysis period.
- The shift of the general purpose (predominantly A-Type) submarket will occur more slowly, with a projected 62% installed penetration by 2025, but will increase to 85% by 2035.