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2015 U.S. Lighting Market Characterization

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Disclaimer

Comments

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SSL Municipal Street Lighting Consortium
Stadium Managers Association
Unitil Corporation
West Penn Power Company
Western Massachusetts Electric Company
Wireless Infrastructure Association

List of Acronyms and Abbreviations

AEO	Annual Energy Outlook
AHS	American Housing Survey
BR	Bulged Reflector
C&I	Commercial and Industrial
CBECS	Commercial Buildings Energy Consumption Survey
CFL	Compact Fluorescent Lamp
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EIA	Energy Information Administration
EMS	Energy Modeling System
ER	Elliptical Reflector
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
ft^2	Square feet
HID	High Intensity Discharge
HPS	High Pressure Sodium
HVAC	Heating, ventilation, and air conditioning
IPI	International Parking Institute
kWh	Kilowatt-hour
LED	Light Emitting Diode
lm	Lumen
LMC	Lighting Market Characterization
LPS	Low Pressure Sodium
MAPC	Metropolitan Area Planning Council
MECS	Manufacturing Energy Consumption Survey
MH	Metal Halide
MSSLC	Municipal Solid-State Street Lighting Consortium
MV	Mercury Vapor
MW	Megawatt
NAICS	North American Industry Classification System
NEEA	Northwest Energy Efficiency Alliance
NEMA	National Electrical Manufacturers Association
NFDC	National Flight Data Center
NYSERDA	New York State Energy Research and Development Authority
OAAA	Outdoor Advertising Association of America
OLED	Organic Light Emitting Diode
PAR	Parabolic Aluminized Reflector
PG&E	Pacific Gas & Electric Company
PNNL	Pacific Northwest National Laboratory
Quad	Quadrillion British Thermal Units
R	Reflector
SSL	Solid State Lighting
Tlm-hr	Teralumen-hour

TWh	Terawatt hour
UL	Underwriters Laboratories
W	Watt
WIA	Wireless Infrastructure Association

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Executive Summary

The 2015 U.S. Lighting Market Characterization (LMC) is the third report released[1] by the U.S. Department of Energy's (DOE's) Solid-State Lighting (SSL) Program that provides summary estimates of the installed stock, energy use, and lumen production of all general illumination lighting products operating in the U.S. The objective of this report is to collect and present in one document the fundamental energy consumption information that DOE needs to plan an effective lighting research and development program. This report answers three main questions:

- How many lighting products (lamps and luminaires, where applicable) of each lighting technology were installed in the U.S. as of 2015, and where were they installed?
- How much energy was consumed by light sources in the U.S. in 2015?
- How did U.S. lighting market characteristics change between 2001 and 2015?

The results in this report are provided at both a national level and a sector-specific level. The four sectors represented are three building sectors – residential, commercial, industrial – and one outdoor sector. The estimates are based on both public and confidential sources of information including building lighting audits, industry surveys, national lighting product shipment data, and interviews with lighting professionals and subject matter experts. A variety of sources were used to ensure all data inputs are reinforced and to improve the accuracy of the analysis.

Lighting technologies in this study are grouped into seven broad categories: incandescent, halogen, compact fluorescent (CFL), linear fluorescent, high intensity discharge (HID), light-emitting diode (LED), and other. Within each of these categories, the analysis evaluated subgroups of commonly available lighting products (e.g., reflector lamps, T8 fluorescent tubes, metal halide lamps, LED integrated fixtures/luminaires). In total, 35 lighting product types were carried through the analysis, extracting information like average wattage, operating hours, and total installed inventory from the sampled datasets. A complete list of the lighting product subgroups can be found in Table A.1 of the report.

Section 5.1 presents a summary of U.S. lighting characteristics in 2015. More detailed results on the lighting characteristics of each sector analyzed can be found in Section 4 of the main report. The largest sector in terms of number of lamp and luminaire installations is the residential sector. In 2015, residences accounted for 71 percent of all lighting installations nationwide, at 6.2 billion. The commercial buildings sector was the second largest sector with 2.1 billion lighting installations, 24 percent of all installations. The industrial and outdoor sectors were significantly smaller, each accounting for roughly 2 and 3 percent of all installations, 172 million and 258 million, respectively. While over 99 percent of all lighting installations in 2015 were lamp products, LED luminaires – which represent a holistic change-out of the existing lamp, ballast (if applicable), and fixture system – had begun to penetrate the lighting market.

With regard to average daily operating hours, while lighting in the commercial, industrial, and outdoor sectors were typically used for approximately half the day (working hours for the commercial and industrial sectors and nighttime hours for the outdoor sector), residential lights were only used for a couple hours per day, on average. As for average wattage characteristics, the residential sector average wattage of 38 watts (W) per installation represents a balanced mix of higher wattage, lower efficacy incandescent and halogen lamps and lower wattage, higher efficacy CFLs, and LED lamps and luminaires. The commercial, industrial, and outdoor sectors' average wattages are reflective of the high installed base of linear fluorescent lamps, the high wattages of HID lamps, and an increasing presence of LED lamps and luminaires.

[1]The first and second versions of the LMC were released in 2002 and 2012, respectively.

Combined, these inputs resulted in a total annual electricity use of U.S. lighting of 641 terawatt-hours (TWh), or approximately 16 percent of total U.S. electricity use. Figure ES.1 presents the lighting electricity use by sector and technology type.

Table ES.1 Summary of Lighting Market Characteristics in 2015

	Total Lamps and Luminaires	Average Daily Operating Hours	Wattage per Lamp (or Luminaire)	Annual Electricity Use (TWh)
Residential	6,218,969,000	1.9	38	149
Commercial	2,076,460,000	8.9	36	237
Industrial	171,682,000	12.1	65	53
Outdoor	257,546,000	13.4	166	202
Total	**8,724,657,000**	**4.1**	**42**	**641**

Approximately 40 percent of total lighting electricity was consumed in the commercial sector, which also represents the sector responsible for producing the most lumens on an annual basis. Linear fluorescent is the predominant lighting technology found in this sector. In 2015, the outdoor sector was the second largest lighting electricity consumer, at 32 percent of the overall lighting electricity consumption. The residential sector had the third highest lighting electricity consumption, at 23 percent of the overall total. Ranked by technology, HID lighting represents the overall highest electricity consumer at 34 percent of all lighting electricity, followed closely by linear fluorescent lighting at 33 percent. This is trailed by incandescent, halogen, compact fluorescent, and then LED lighting.

Overall, LED lighting penetration into all sectors has made significant strides since 2010, and in 2015 represented 8 percent of overall lighting inventory. LED penetration ranked highest in the outdoor sector, at 22 percent of lighting inventory. This was followed by the commercial, residential, and industrial sectors at 10 percent, 7 percent, and 4 percent of the respective sectors' inventory distribution.

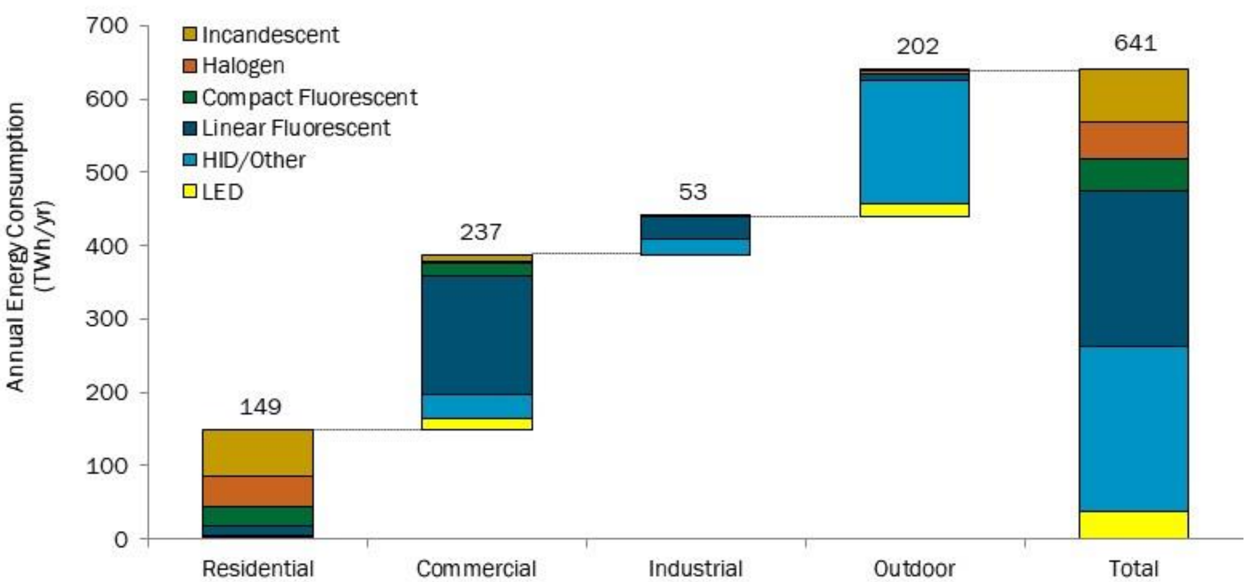

Figure ES.1 U.S. Lighting Electricity Consumption by Sector and Technology in 2015

There have been significant changes in the lighting stock and energy consumption characteristics since 2001 and 2010 (the baseline years of the previous LMC reports). A detailed comparison of the three estimates can be found in Section 5.2. Two notable trends include:

- **The continued growth of lighting inventory.** The total number of lamps and luminaires installed in U.S. stationary applications grew from just under 7.0 billion in 2001 to over 8.2 billion in 2010, and to 8.7 billion by 2015. The vast majority of the growth occurred in the residential sector, primarily due to the increase in number of households. However, the number of lighting products per household, which rose from 43 in 2001 to 51 in 2010, has remained steady since 2010 at 52 lighting products per household in 2015.

- **The continued push towards higher efficacy lighting, resulting in decreased electricity consumption.** Investment in more energy efficient lighting technologies, federal- and state-level lighting regulations, and public awareness campaigns were effective in shifting the market towards more energy efficient lighting technologies, evidenced by, for example, the substantial rise in LED lighting market penetration. Across all sectors, the average system efficacy of installed lighting increased from 36 lumens per watt in 2001, to 40 lumens per watt in 2010, and to 51 lumens per watt by 2015.[2] This rise in efficacy is largely due to two major technology shifts: the shift from incandescent lamps to halogen lamps, CFLs, and LED lighting in the residential sector, and the shift from T12 to higher-efficiency fluorescent lamps and LED lighting in the commercial, industrial and outdoor sectors.

[2] The 2001 and 2010 efficacies are different than those reported in the 2010 LMC. Please see Section 5.2 for discussion regarding the update of 2001 and 2010 lighting efficacies.

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1 Introduction

In 2002 and 2012, the U.S. Department of Energy (DOE) published the first and second installments of the U.S. Lighting Market Characterization (LMC). These publications provide detailed estimates of lighting inventory and energy consumption for the U.S. in the baseline years of 2001 and 2010, respectively (1; 2). These reports detail technical characteristics of the lighting market while reflecting on drivers of current and future change: new technology development, national and state government regulations, and energy efficiency programs.

Between 2010 and 2015, the lighting market experienced a period of continued transformation. Due to significant developments in lighting technology (particularly in solid-state lighting) and sweeping effects of national and state energy policies, DOE found it pertinent to conduct an updated lighting market characterization. Accordingly, DOE presents this report, the third installment of the LMC.

The objective of this report is to collect and present in one document the fundamental energy consumption information that DOE needs to plan an effective lighting research and development program. This report answers three main questions:

- How many lighting products (lamps and luminaires, where applicable) of each lighting technology were installed in the U.S. as of 2015, and where were they installed?
- How much energy was consumed by light sources in the U.S. in 2015?
- How did U.S. lighting market characteristics change between 2001 and 2015?

This report is sponsored by DOE's Solid-State Lighting (SSL) Program. The SSL Program focuses on research and development concerning light-emitting diodes (LEDs) and organic LEDs (OLEDs). This report provides the baseline DOE needs to plan an effective program and against which to measure progress. In addition, the LMC is intended to be used by both governmental and non-governmental organizations for planning and evaluating lighting opportunities, forecasting the direction of the lighting market, and additional research efforts.

For ease of use and comparison, the 2015 LMC is structured similarly to the 2001 and 2010 LMC installments. However, this update to the LMC builds upon the previous efforts by utilizing expanded data sources, enhanced methodologies, and incorporating additional input from a technical review committee.[3] This installment also further examines topics of particular interest to the lighting community, such as the continued and rapid penetration of LED lighting technology and the penetration of and energy savings associated with lighting controls.

3 The methodologies and results found in this report were presented to a technical review committee in the spring and summer of 2017. The committee consisted of 23 members representing government, national labs, lighting manufacturers, utilities, and other non-government organizations. This final report incorporates their suggestions and insights.

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2 Study Scope

The scope of the LMC includes all lighting installed in the U.S. in stationary applications as of 2015 (the baseline year). Mobile applications, such as automobile headlights, are excluded from this report. As in the 2010 LMC, the lighting inventory and energy use estimates are categorized into four sectors: residential buildings, commercial buildings, industrial buildings, and outdoor. Each of these sectors is further divided into several subsectors. For the residential building sector, the subsectors are based on the type of construction of the residence and the room type in which the lamp or luminaire is located. For the commercial and industrial building sectors, the subsectors are based on the principal activity associated with the building. For the building sectors, the subsector classifications are based on those used by the Energy Information Administration (EIA) in its end-use consumption surveys and by the U.S. Census Bureau in its American Housing Survey (AHS).

The outdoor stationary sector accounts for lamps and luminaires installed on the exterior of commercial or industrial buildings,[4] as well as the remainder of lamps and luminaires not installed inside buildings. The outdoor subsectors are based on lighting application, such as railway and airfield lighting. Of note, the outdoor sector includes communication tower lighting, which was not previously analyzed in the 2001 and 2010 LMC installments. Table 2.1 lists all the sectors and subsectors included in the analysis.

[4] Unlike commercial and industrial building exterior lighting, which is classified as outdoor sector lighting, residential building exterior lighting is included as part of the residential building sector analysis and results. These classifications are consistent with those presented in the 2010 LMC.

Table 2.1 Sectors and Subsectors Analyzed

Residential[5]		Commercial[6]	Industrial[7]	Outdoor
Residence Type	Room Type	Building Activity	Manufacturing Activity	Application
Single Family	Basement	Education	Food	Airfield
Multifamily	Bathroom	Food Service	Beverage & Tobacco Products	Billboard
Mobile Home or Trailer	Bedroom	Food Store	Textile Product Mills	Building Exterior – Commercial & Industrial
	Closet	Health Care – Inpatient	Wood Products	Communication Tower
	Dining Room	Health Care – Outpatient	Paper	Parking
	Exterior	Lodging	Printing & Related Support	Railway
	Garage	Offices (Non-medical)	Petroleum & Coal Products	Roadway
	Hall	Public Assembly	Plastics & Rubber Products	Sports Field
	Kitchen	Public Order and Safety	Nonmetallic Mineral Products	Traffic Signal
	Laundry/Utility Room	Religious Worship	Primary Metals	
	Living/Family Room	Retail – Mall & Non-mall	Fabricated Metal Products	
	Office	Services	Machinery	
	Other/Unknown	Warehouse & Storage	Computer & Electronic Products	
		Other	Electrical Equipment, Appliances & Components	
			Transportation Equipment	
			Furniture & Related Products	
			Miscellaneous	

[5] For definitions of each residential subsector refer to: https://www2.census.gov/programs-surveys/ahs/2015/2015%20AHS%20Definitions.pdf.
[6] For definitions of each commercial subsector refer to: https://www.eia.gov/consumption/commercial/building-type-definitions.php.
[7] For definitions of each industrial subsector refer to the North American Industry Classification System (NAICS). For further information on the NAICS refer to: http://www.census.gov/eos/www/naics/.

2015 Sector and Subsector Update

For single family residences, the sample data used for this analysis do not comprehensively classify single family residences as attached or detached. Therefore, a combined "single family" subsector is used in the 2015 LMC. This differs from the 2010 LMC, in which single family attached and single family detached were broken out into separate subsectors.

Additionally, for the 2015 LMC, the outdoor sector includes communication tower lighting, a subsector which was not previously analyzed in the 2001 and 2010 LMC installments.

The lighting technologies have been categorized as displayed in Figure 2.1. The categories are based on those used in the 2010 LMC, the categories used in the various 2015 LMC data sources, and input from members of the technical review committee. Descriptions of each lighting technology and product type can be found in Appendix A.

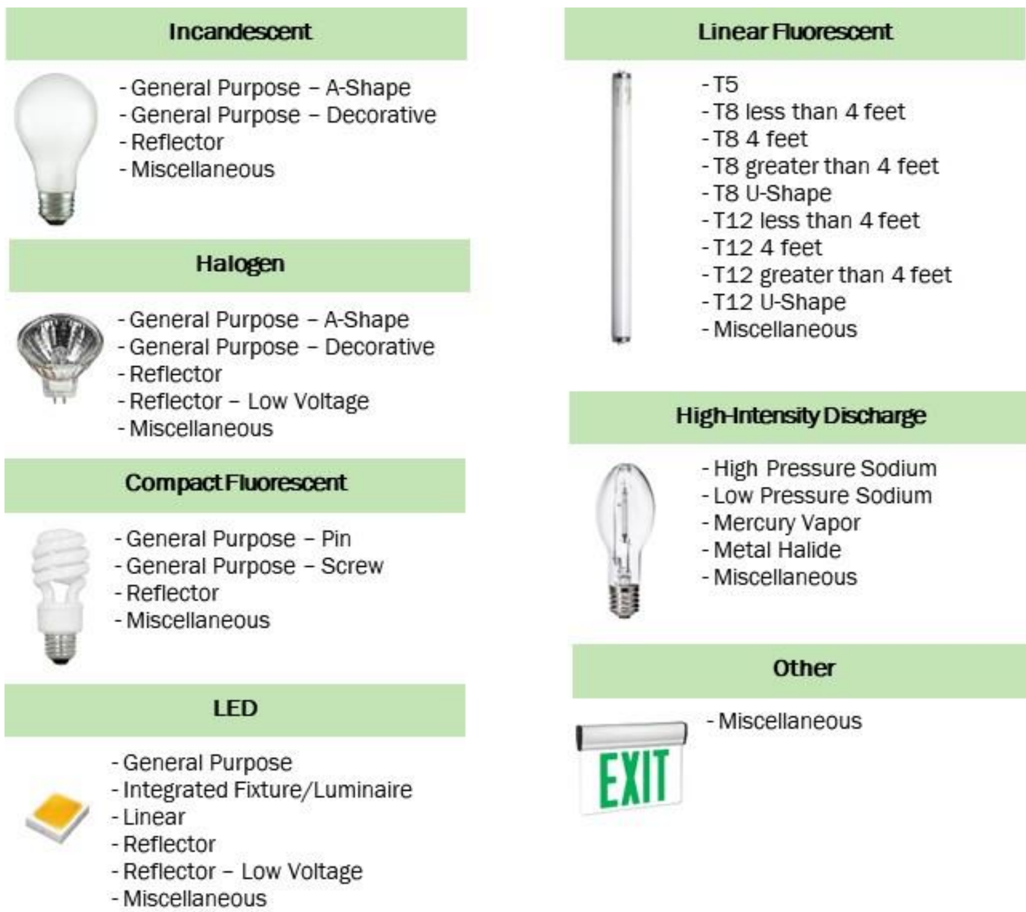


Figure 2.1 Lighting Technology Classification[8]

[8] Low-pressure sodium is a discharge lamp, but not a high-intensity discharge lamp. It has been classified as such for presentation purposes.

2015 Lighting Technology Classification Update

New to the 2015 LMC is the inclusion of LED lighting products as a separate classification group. This differs from the 2010 LMC, in which LED lighting is included within the "Other" technology classification group.

3 Methodology

The methodology used to develop the national lighting inventory for the building sectors (residential, commercial, and industrial) involved three major steps. The first step entailed aggregating sets of sample building data, including lighting characteristics, which were collected by various entities through on-site building assessments. The initial building lighting data collected in this step provide data on the lighting products installed in each building, including details such as quantities, wattages, and operating hours. More information on the data used in this step and the method of aggregation can be found in Section 3.1 and Section 3.2, respectively.

The second step involved weighting the sample datasets in order to make sample data reflective of national conditions. This step was used to adjust for differences in the proportions of certain characteristics between sample data and national inventory (e.g., regional distribution of buildings), as well as to scale sample building counts to the national level.

Because the data sources used in the first step were collected in various years (some prior to 2015), the third step of the analysis involved adjusting the initial inventory estimates so that the final estimates are representative of U.S. conditions in the year 2015. To do so, historical national lighting product shipment data obtained from the National Electrical Manufacturers Association (NEMA) and LED lighting manufacturers were utilized. Additional detail on the shipments analysis can be found in Section 3.2.1.1.

The analysis for the outdoor sector was developed in a slightly different manner than that of the building sectors due to a lack of audit and survey data. Due to the varying formats of the data sources utilized, each subsector analysis in the outdoor sector was developed in a unique way based on the available data. In general, the characteristics of the outdoor subsectors are based on interviews with experts, inventory data collected from trade associations or relevant organizations, and the shipment data mentioned in the preceding paragraph. The data sources used for each outdoor subsector are discussed in Section 3.1.4.

Figure 3.1 illustrates the basic structure of the methods used to estimate total U.S. lighting inventory, as well as the data sources and key inputs for each methodology step.

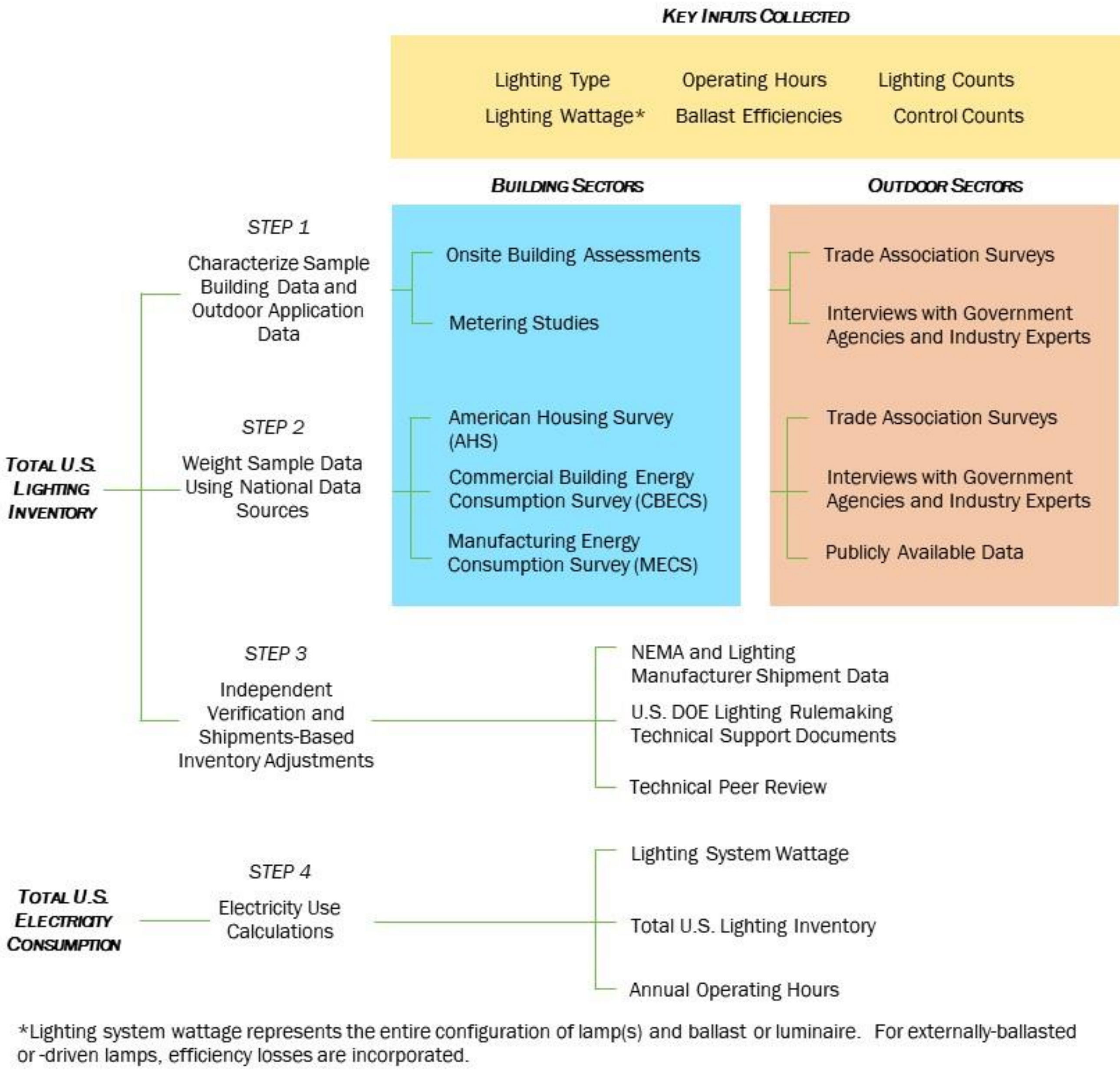
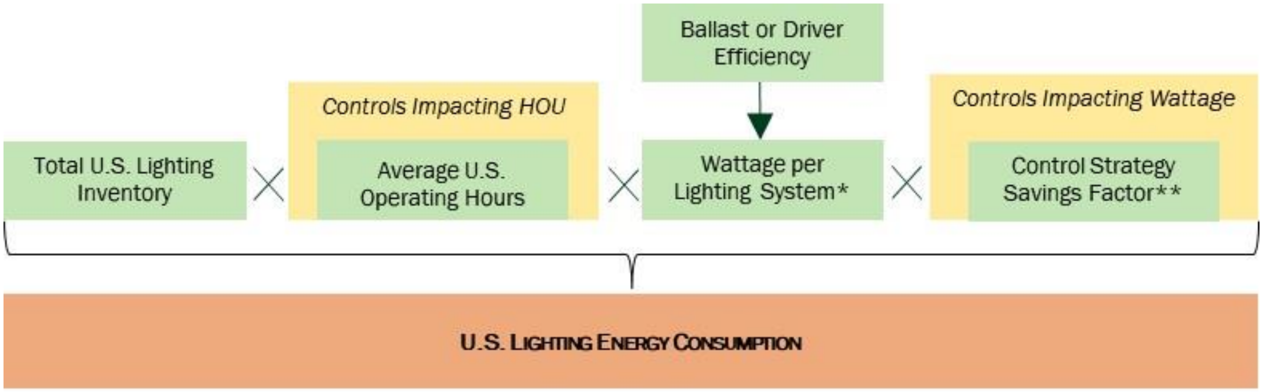


Figure 3.1 National Lighting Inventory and Electricity Consumption Calculations – Sources, Inputs, and High-Level Methodology

As seen in Figure 3.2 below, using the total 2015 U.S. lighting inventory, the energy use for each technology was determined by multiplying the number of installed lamps or luminaires by the associated average wattage and operating hour estimates.

In contrast to the 2010 LMC, for the building sectors, the energy use calculation was made at the lamp or luminaire level (as opposed to at the subsector level). This method achieves greater accuracy in results by preserving the relationship between the installed lamp or luminaire wattage and the hours of use.

Similar to the 2010 LMC, for the outdoor sector, energy use was calculated at the subsector level (i.e., per application) and summed across the outdoor subsectors to determine the total outdoor sector electricity use estimates.



*Lighting system wattage represents the entire configuration of lamp(s) and ballast or luminaire. For externally-ballasted or -driven lamps, efficiency losses are incorporated.

**Operating hours data for all sectors are assumed to include impacts of controls used for reducing operating hours (e.g., occupancy sensors and timers). For the building sectors, energy savings associated with controls that lower wattage are presented in Section 4.3. To maintain consistency with the 2010 LMC, the impacts of controls affecting wattage are not incorporated into cumulative results (Section 4.1) or sector-specific results (Section 4.2). Finally, for the outdoor sector, there were not enough data available on controls impacting wattages to include an analysis of energy savings due to such controls.

Figure 3.2 Energy Use Calculation Components[9]

3.1 Data Collection

The LMC relies primarily on existing data sources. Primary data collection was not conducted for this study, apart from the interviews and surveys for outdoor subsectors that were conducted where insufficient existing data sources were available. The reliance on existing data sources allows the LMC to utilize data on a greater number of buildings, covering a wider variety of geographies, than if all data had to be collected in the field.

Because the LMC relies on existing data sources, the quality of the analysis is dependent on the quality of the source data. Thus, collecting high quality data – objective, accurate, and recent – was a primary concern in the development of this report. In order to do so, data were drawn from several different sources, including:

- **National data sources** include surveys conducted by the EIA and the U.S. Census Bureau that provide the total number and square footage of buildings in the U.S.
- **On-site sources** consist of lighting inventories and characteristics obtained through on-site audits and metering studies, and associated with a random sample of buildings in specific regions of the U.S.
- **Off-site sources** include inventory and operating hour data collected through mail, telephone, and online surveys, as well as additional data collected through interviews.
- **Shipment sources** provide the quantity of annual shipments from manufacturer groups for specific lamp and luminaire types.

The following sections provide more detail on the key data sources used in this analysis.

[9] Throughout the report, average values are weighted by the inventory of each relevant category.

3.1.1 National Data Sources

National data were drawn from the U.S. Census Bureau's AHS for the residential sector and from EIA energy consumption surveys for the commercial and industrial sectors.

The EIA releases multiple studies for which a randomly selected sample of building owners are interviewed in order to estimate basic energy use characteristics for U.S. buildings. The 2015 LMC utilizes two of these studies: the Commercial Buildings Energy Consumption Survey (CBECS) and the Manufacturing Energy Consumption Survey (MECS) (1; 2). The population estimates for the commercial and industrial sectors were derived from these studies. In the commercial and industrial sectors, the building population is defined by the total floorspace per building type.

The residential sector population was developed from the AHS, a bi-annual survey conducted by the U.S. Census Bureau that collects household and demographic data on the nation's housing units. Similar to the 2010 LMC, the residential building population includes both permanently and seasonally occupied houses.[10] Building counts and square footage associated with non-stationary type residences (including boats, RVs, vans, etc.) were excluded from national totals for this report.

The AHS provided U.S. building population and floorspace estimates for 2015, while CBECS and MECS provided U.S. building population and floorspace estimates for 2012 and 2010, respectively. For the commercial sector, estimates of building stock growth from the EIA's Annual Energy Outlook (AEO) 2016 were used to adjust the values to reflect the 2015 base year. For the industrial sector, the MECS estimate of total buildings floorspace was projected to the 2015 base year using the 2010 to 2015 growth in manufacturing employment by North American Industry Classification System (NAICS) code (as reported by the U.S. Bureau of Labor Statistics) as a proxy for the growth in industrial buildings (3). Table 3.1 summarizes the building characteristics of the national surveys used in this report (shown in white), as well as the adjusted 2015 values used in the LMC (shown in green) (4; 1; 2). For the residential sector, 2015 values are shown in both cases since AHS data are representative of 2015.

Table 3.1 U.S. Building Population and Floorspace Summary

Data Source	Sector	Survey Year		Estimated Building Count		Estimated Floorspace	
			2015		Scaled to 2015		Scaled to 2015
AHS	Residential	2015	2015	119,968	119,968	254,552	254,552
CBECS	Commercial	2012	2015	5,263	5,370	83,838	85,537
MECS	Industrial	2010	2015	347	370	11,101	11,855

3.1.2 Residential Lighting Data Sources

The residential sector analysis incorporates data from six existing building audit studies that contain lighting data from 11 states located in the West, Midwest, Northeast, and South. Most of these studies were originally conducted to gain a quantitative understanding of the impacts of different utilities' demand side management

[10] In the 2015 LMC, the calculation of national lighting inventory in the residential sector is based on both permanently and seasonally occupied homes. However, because lamps in seasonally occupied homes are not used in the same manner as the majority of the lighting stock, the calculation of energy consumption in the residential sector considers permanently occupied houses only.

programs. In total, these sources, which contain lighting inventory data for more than 2,900 separate residences and 280,000 lighting products, were used to construct the residential lighting inventory database for the 2015 LMC. Some buildings were removed from this database due to missing data, and data from onsite assessments conducted prior to 2013 were excluded from the analysis.

The building audit studies were selected for this analysis because they utilized the appropriate data collection methodologies and they contain the most up-to-date information on the residential lighting sector.

Table 3.2 outlines the key characteristics of the residential data sources used in this report. Below is a brief summary of each study utilized.

- *Focus on Energy 2013 Baseline Market Study* (5)*:* This study is an assessment to determine the saturation of energy-efficient technologies and the potential for future energy-efficient upgrades and installations in the state of Wisconsin. Included in the analysis is a lighting audit study, for which onsite audits were conducted for 62 residences to determine the existing technologies installed in a representative customer sample.
- *Pennsylvania Statewide Act 129: 2014 Commercial & Residential Light Metering Study* (6)*:* This study represents an effort to detail the existing commercial and residential lighting load profile in the state of Pennsylvania to inform demand and energy savings calculations for lighting energy efficiency programs. Field technicians completed detailed surveys of lighting sockets while onsite, compiling information on lighting inventory by room type, product type, control type, and wattage.
- *Northeast Residential Lighting Hours-of-Use Study* (7)*:* This study represents a collective effort of multiple energy efficiency programs in the Northeast to provide data for demand and energy savings calculations associated with various lighting programs. Onsite audits focused on collecting hours of use and lighting inventory data to aid in overall load planning and savings calculations.
- *Focus on Energy Residential Longitudinal Lighting Study* (8): The data collected for this analysis are a result of a building audit survey in the state of Wisconsin during 2015. Data provided include detailed lighting product types, installed quantities, wattages, residence types, room types, and other building characteristics.
- *Pacific Gas & Electric Company (PG&E) Home Energy Use Study* (9)*:* The data provided with this study are a result of an ongoing home energy use study, which is primarily an effort to collect data on residential lighting control types. In addition to control types, collected data include building type, room type, fixture type, lighting product type, and total installed quantity. Preliminary results from this effort were presented as a comment response to DOE's Notice of Proposed Rulemaking for General Service Lamps (81 FR 14528).
- *EmPOWER 2016 Inventory Analysis and Hours-of-Use Study* (10)*:* The data collected for this analysis are also a result of an ongoing building audit and hours-of-use study in the state of Maryland. Data provided include detailed lighting product types, installed quantities, wattages, residence types, room types, and other building characteristics.

Table 3.2 Residential Data Source Key Characteristics

Source	Geographic Region(s)	Building Count – All	Building Count – Exterior	Year(s) of Data Collection
EmPOWER Inventory Analysis and Hours-of-Use Study	Maryland	95	37	2016
Focus on Energy 2013 Baseline Market Study	Wisconsin	62	3	2013
Focus on Energy 2015 Building Audit Data	Wisconsin	124	43	2015
Northeast Residential Lighting Hours-of-Use Study	Connecticut, New York, Georgia, Kansas, Massachusetts, Maine, Rhode Island	1,428	900	2013-2016
Pennsylvania Statewide Act 129: 2014 Commercial & Residential Light Metering Study	Pennsylvania	203	65	2013
PG&E Home Energy Use Study	California	1,000	479	2015
	All Sample Regions	**2,912**	**1,527**	**2013-2016**

3.1.3 Commercial and Industrial Lighting Data Sources

The commercial and industrial data sources are presented together in this section as most include data on both types of buildings. The 2015 LMC utilizes nine recent studies for these sectors, which cover a total of 20 states and over 3,000 buildings and are used to construct the commercial and industrial lighting inventory databases for the 2015 LMC. Some buildings have been removed from these initial databases as they do not to contain complete lighting inventories.

Table 3.3 and Table 3.4 outline the key characteristics of the commercial and industrial studies used in this report. Below is a brief summary of each study utilized.

- *Assessment of Energy-Efficiency and Distributed Generation Baseline and Opportunities* (11)*:* This report analyzes energy efficiency and distributed generation resources for Maine in the commercial and industrial sectors. For the commercial and industrial sectors, field data were collected to characterize building equipment inventory and assess the saturation of efficient equipment. For lighting measures, this included recording characteristics such as wattage, lighting product type, control type, and building type.
- *California Commercial Saturation Survey* (12)*:* This survey was designed to collect baseline information about energy consuming measures in commercial buildings in California. One primary objective of the study was to examine the saturation of energy efficiency measures in California's commercial sector. Over 1,000 on-site assessments were conducted between 2011-2013 to determine the full inventory of technologies (including those of lighting measures) installed across the state.
- *Commercial Building Stock Assessment: Final Report* (13)*:* This Northwest Energy Efficiency Alliance (NEEA) study was developed to inform the Northwest Power and Conservation Council's 7^{th} Power Plan conservation targets and provide insights for energy efficiency planning and programming across the commercial sector in the Northwest. As part of this analysis, an extensive database was developed that included numerous data fields and key building characteristics.
- *Industrial Assessment Center Data* (14)*:* This source consists of data collected in Industrial Assessment Centers around the country which provide eligible small- and medium-sized manufacturers no-cost energy assessments. These assessments included lighting product counts and characteristics for all sockets and fixtures.
- *Industrial Facilities Site Assessment: Report & Analytic Results* (15)*:* This NEEA study's goal was to obtain end-use energy consumption data for a representative sample of the Northwest industrial facilities. The assessment team categorized energy consumption for the major end-uses applicable to the Northwest, focusing data collection on space conditioning (HVAC), space lighting, motor systems, process cooling and heating systems, steam systems, and cogeneration.
- *Market Characterization and Assessment Study* (16)*:* This data source stems from a 2015 Request for Proposals by the Vermont Department of Public Service. Surveys were ultimately conducted as on-site assessments of existing businesses and newly constructed buildings in Vermont. The project's primary goals are to characterize Vermont's existing and newly constructed commercial and industrial buildings' energy use and to document heating, ventilation, and air conditioning (HVAC), installed lighting, and other equipment.
- *Massachusetts Commercial and Industrial Customer On-site Assessments* (17)*:* These on-site inventory assessments were conducted at non-residential facilities in Massachusetts to provide detail on major energy-consuming end-uses, including lighting, HVAC, motors, and others. Key data collection efforts of the study were to gather information on installed equipment, including age, condition, efficiency level, and other general identifying characteristics to present the saturation of different equipment types.

- *Michigan Statewide Commercial and Industrial Lighting Hours-of-Use Study* (18)*:* This study was designed to collect, analyze, and report representative data samples of metered commercial and industrial lighting to inform energy and demand calculations of lighting measures in the state of Michigan. The primary focus of this work was to determine lighting hours of use estimates, but the team also collected inventory data for other lighting characteristics useful to the LMC.
- *Pennsylvania Statewide Act 129: 2014 Commercial & Residential Light Metering Study* (6)*:* This study represents an effort to detail the existing commercial and residential lighting load profile in the state of Pennsylvania to inform demand and energy savings calculations for lighting energy efficiency programs. Field technicians completed detailed surveys of lighting sockets while onsite, compiling information on lighting inventory by room type, product type, control type, and wattage.

Table 3.3 Commercial Data Source Key Characteristics

Source	Geographic Region(s)	Building Count – All	Building Count – Exterior	Year(s) of Data Collection
Assessment of Energy-Efficiency and Distributed Generation Baseline and Opportunities	Maine	77	19	2012
California Commercial Saturation Survey	California	1,374	74	2011-2013
Commercial Building Stock Assessment: Final Report	Idaho, Montana, Oregon, Washington	1,251	N/A	2014
Industrial Assessment Center Data	Nebraska, Oregon, Alaska, Washington, Alabama, Kentucky, South Carolina, Georgia, Tennessee, Ohio, Maryland, West Virginia	14	NA	2014-2017
Industrial Facilities Site Assessment: Report & Analytic Results	Idaho, Montana, Oregon, and Washington	1	N/A	2014
Market Characterization and Assessment Study	Vermont	193	132	2015-2016
Massachusetts Commercial and Industrial Customer On-site Assessments	Massachusetts	312	30	2014-2015
Michigan Statewide Commercial and Industrial Lighting Hours-of-Use Study	Michigan	123	N/A	2014
Pennsylvania Statewide Act 129: 2014 Commercial & Residential Light Metering Study	Pennsylvania	448	101	2013-2014
	All Sample Regions	**3,793**	**356**	**2011-2017**

Table 3.4 Industrial Data Source Key Characteristics

Source	Geographic Region(s)	Building Count – All	Building Count – Exterior	Year(s) of Data Collection
Assessment of Energy-Efficiency and Distributed Generation Baseline and Opportunities	Maine	14	3	2012
California Commercial Saturation Survey	California	21	1	2011-2013
Industrial Assessment Center Data	Nebraska, Oregon, Alaska, Washington, New Jersey, New York, Pennsylvania, Alabama, Kentucky, South Carolina, Georgia, Tennessee, Ohio, Maryland, West Virginia	103	29	2009-2016
Industrial Facilities Site Assessment: Report & Analytic Results	Idaho, Montana, Oregon, Washington	43	N/A	2014
Market Characterization and Assessment Study	Vermont	11	8	2015-2016
Massachusetts Commercial and Industrial Customer On-site Assessments	Massachusetts	26	3	2014-2015
Michigan Statewide Commercial and Industrial Lighting Hours-of-Use Study	Michigan	5	N/A	2014
Pennsylvania Statewide Act 129: 2014 Commercial & Residential Light Metering Study	Pennsylvania	13	4	2013-2014
	All Sample Regions	**236**	**48**	**2009-2016**

3.1.4 Outdoor Lighting Data Sources

The outdoor sector covers nine applications of outdoor stationary lighting: airfield, billboard, commercial and industrial building exterior, communication tower, parking, railway, roadway, sports field, and traffic signal. Communication towers are a new addition to the 2015 LMC and were not previously evaluated in the 2010 LMC. The following sections provide an overview of these outdoor applications, as well as the sources and methods used to develop the inventory and energy use estimates for each. Where appropriate, the current analysis uses the same information sources as the 2010 LMC in an effort to maintain consistency between the two reports.

In contrast to the inputs for commercial and industrial building exterior application, which are based on sample building inventory data described in Section 3.1.3, inputs for the remaining outdoor applications were collected through a wide variety of sources, including interviews with government and industry representatives, trade association surveys and datasets, and web research.

For each of the outdoor lighting applications, Table 3.5 provides the sources used for estimating the components of energy consumption – namely overall inventory, technology mix, average operating hours, and average wattages. Definitions of each outdoor subsector are included in Section 3.3.

Table 3.5 Outdoor Data Sources

Outdoor Subsector	Source(s)
Airfield Lighting	ADB Safegate (19) Airport Cooperative Research Program (20) Federal Aviation Administration (21; 22; 23; 24; 25; 26) National Electrical Manufacturers Association (27)
Billboard Lighting	Lamar Advertising Company (28; 29) National Electrical Manufacturers Association (27) Outdoor Advertising Association of America (30)
Building Exterior – C&I	See Section 3.1.3
Communication Tower	Dialight plc (31) Federal Communications Commission (32) Flash Technology (33) National Electrical Manufacturers Association (27) Wireless Infrastructure Association (34)
Parking	International Parking Institute (35) National Electrical Manufacturers Association (27) Pacific Northwest National Laboratory (36) Walker Parking Consultants (37)
Railway	Bureau of Transportation Statistics (38) Federal Railroad Administration (39; 40; 41) General Electric (42) Lindsay Corporation for Railway Signals (43) National Electrical Manufacturers Association (27)
Roadway	Department of Transportation (44; 45; 46; 47; 48; 49; 50; 51; 52; 53) (54) Federal Highway Administration (55) Local Government Interviews (56) National Electrical Manufacturers Association (27)
Sports Field	Homeland Infrastructure Foundation (57) Spark Lighting (58) Stadium Managers Association (59; 60; 61)
Traffic Signal	Federal Highway Administration (55; 62; 63) General Electric (42) Institute of Transportation Engineers (64) Navigant (65)

3.1.5 Data Sources Comparison: 2010 LMC vs. 2015 LMC

One of the primary purposes of conducting periodic updates to the LMC is to capture important trends in lighting installed stock caused by technology development, national and state government regulations, and the increasing prevalence of energy efficiency programs. The estimates of national lighting inventory and energy consumption presented in this report provide a good indication for how the lighting market has changed from 2010 to 2015. However, differences in data sources and methodology between the 2010 LMC and the 2015 LMC inevitably influence the results. This section provides an overview of the differences in the underlying data collected for the 2015 LMC, as compared to the 2010 LMC, while departures in methodology for the 2015 LMC relative to the 2010 LMC are discussed in Section 3.2.

3.1.5.1 Building Sectors Data Source Comparison

As seen in Figure 3.3, residential building sample data collected for the 2010 LMC went back 6 years prior to the baseline year of 2010. Additionally, data were highly concentrated in the West. For the 2015 LMC, building data collected in years prior to 2013 have been removed from the analysis due to concerns that older data would skew results. Additionally, sample building data collected for the 2015 LMC are less concentrated in the West, but they contain a more limited data sample for residences located in the Midwest and South.

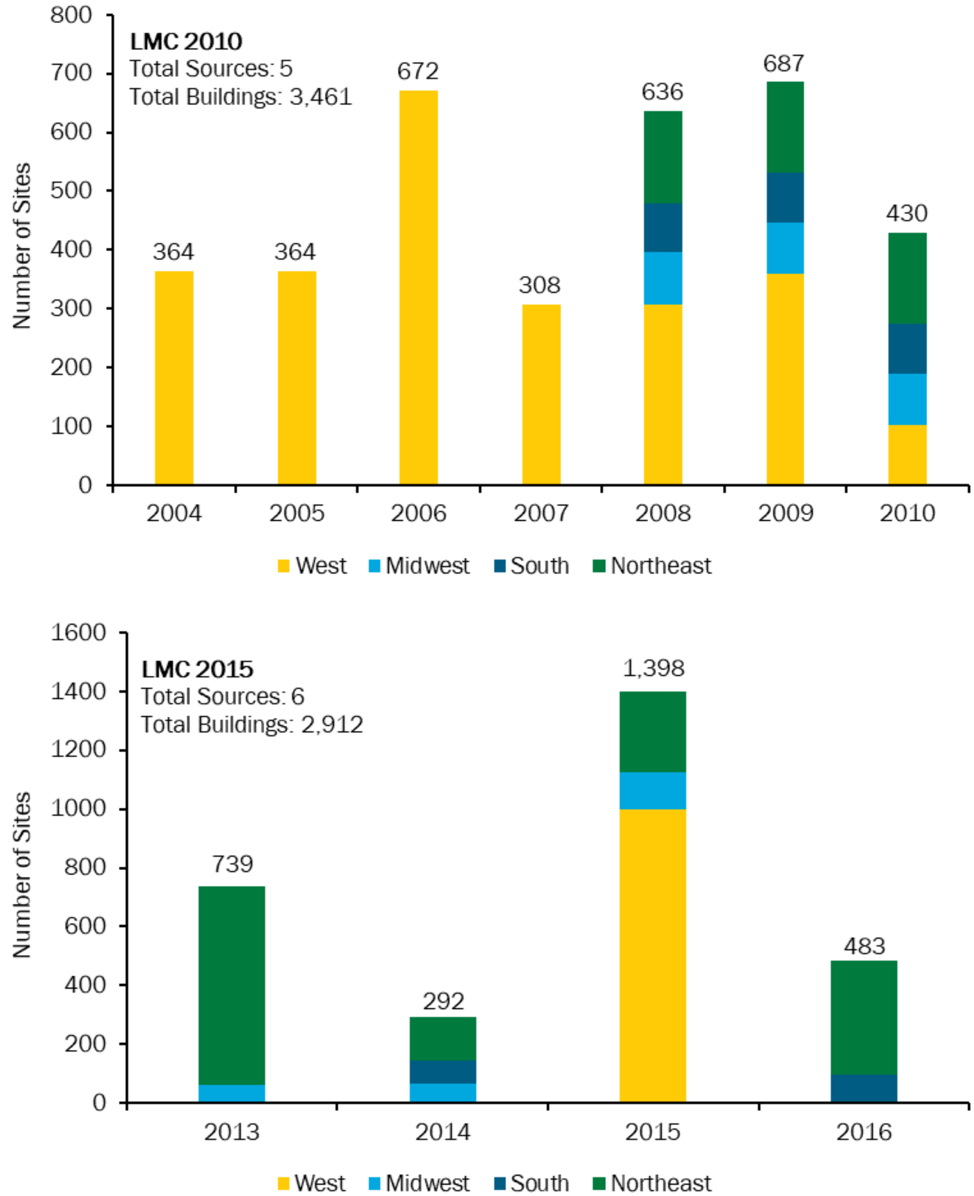


Figure 3.3 Residential Sector Buildings by Year and Region: 2010 LMC vs. 2015 LMC

Figure 3.4 provides a comparison between commercial building sample data collected for the 2010 and 2015 LMC studies. Similar to the residential sector, the 2010 LMC commercial buildings had a high geographic concentration in the West. Additionally, the majority of sample data was collected 6 to 8 years prior to the LMC baseline year of 2010. In contrast, the 2015 LMC draws from a greater number of data sources, which results in a more regionally distributed sample (though still concentrated in the West and Northeast). For the 2015 LMC, the majority of sample data was collected in 2014, the year prior to the baseline year.

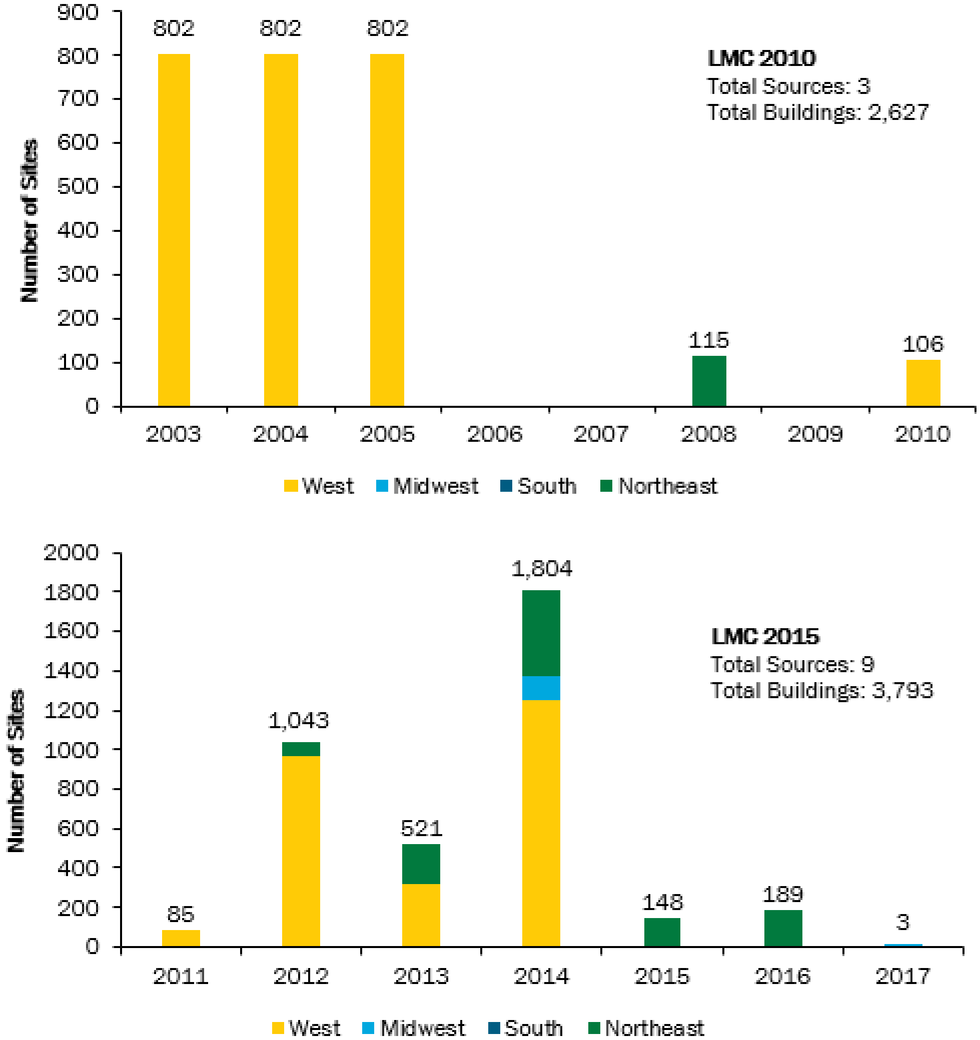


Figure 3.4 Commercial Sector Buildings by Year and Region: 2010 LMC vs. 2015 LMC

Figure 3.5 provides a comparison between industrial sample building data collected for the 2010 and 2015 LMC studies. Again, compared to the 2010 LMC, the 2015 LMC leverages sample data collected in years closer to the LMC baseline year. In addition, the number of sample buildings for which lighting data was collected doubled from the 2010 LMC.

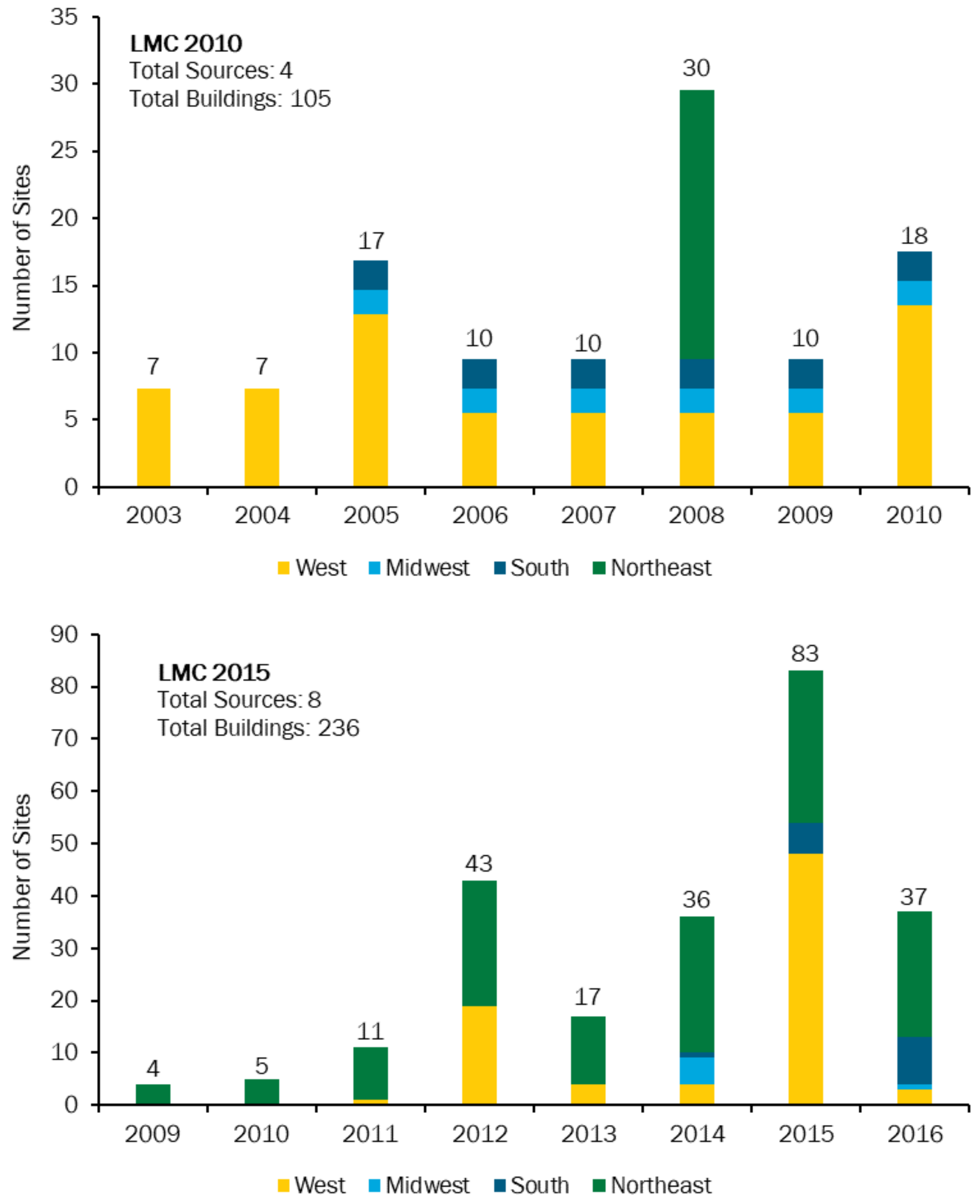


Figure 3.5 Industrial Sector Buildings by Year and Region: 2010 LMC vs. 2015 LMC

3.1.5.2 Outdoor Sector Data Source Comparison

The 2015 LMC analysis of the outdoor lighting sector utilized data provided in 36 industry expert interviews, 77 responses to four trade association surveys, 27 publicly-available third-party studies, and lighting inventory data from 19 participants. In some cases, sources and data leveraged for the 2010 LMC were also recycled, particularly for inputs that are unlikely to have changed over time, such as operating hours and conventional lighting wattages. Major differences in data sources are discussed below for each of the outdoor lighting applications.[11]

Airfield In the analysis of airfield lighting, the majority of installed base data correspond to a national-level database of runways. A previous version of the same database was leveraged for the 2010 LMC analysis, which allows for congruency between the 2010 and 2015 approaches. However, for the 2015 LMC, a new data resource was utilized for the hours of use estimate. The 2015 LMC analysis utilized data on hours of use by runway light function (e.g., approach, runway, taxiway, etc.), whereas the 2010 LMC used average values for all airfield lighting, which were provided in industry expert interviews. For estimating conventional lamp wattage and lighting technology mix, new data provided by recent interviews and external studies are used alongside results gathered for the 2010 LMC.

Parking The 2015 LMC analysis leveraged substantially more data than the 2010 LMC. While the 2010 LMC analysis utilized lighting inventory data for about 100 parking sites (both lot and garage), nearly 3,000 database entries were evaluated for the 2015 LMC. Results of surveys conducted for the 2010 LMC were used alongside more recent sources to estimate the total lighting inventory (derived from the number of lamps per parking space) and the wattages of some conventional lighting technologies.

Railway Similar to parking lighting, the number of data sources and the granularity of data inputs increased compared to the 2010 LMC analysis. Most significantly, for the 2015 LMC, the publicly-available Federal Railroad Administration (FRA) database of railway crossings was leveraged. The database provides details – including the number of lights per crossing – on nearly 430,000 railway-highway crossings. In addition, operating hours are, in part, based on average train traffic data provided for each crossing (train traffic data are useful since many signals operate only when trains are nearby). In contrast, since the crossings database had not been published at the time of the 2010 LMC, it instead made use of simplified estimates from industry experts.

Roadway The approach to analyzing roadway lighting for the 2015 LMC is largely consistent with that of the 2010 LMC. In each case, highway and street lighting were analyzed separately, and then results were aggregated to determine an overall roadway lighting estimate. However, data availability has increased compared to the 2010 LMC analysis. For the 2015 LMC, three times more cities (a total of 61) provided street lighting data, and more than twice as many (a total of 11) state-level Department of Transportation (DOTs) provided data concerning highway lighting in their state.

Sports Unlike the 2010 LMC, sports lighting was analyzed in two separate categories based on the type of field or stadium. For the 2015 LMC analysis, sports lighting end-uses are categorized either as professional and college or as community and high school. This modified approach to sports lighting analysis enhances sensitivity to the differences in lighting technology mix, wattage, fixtures per field/stadium, and hours of use between these two types of sport locations. Analysis of the technology mix for sports lighting leveraged data sources similar to those of the 2010 LMC.

Billboard and Traffic Signals In the case of both billboard lighting and traffic signals, data sources used for the 2010 and 2015 LMC analyses are similar. However, for billboard and traffic signal lighting, the 2015 LMC analysis leveraged a total of six additional industry expert interviews, which help to update estimates for the installed base and technology mix in each category.

3.2 Building Sector Inventory and Energy Use Calculation

The inputs to this calculation are discussed below for the building sectors. As discussed in Section 3.1, these inputs were primarily derived from building survey and audit data, as well as shipment data provided by NEMA and various lighting manufacturers noted in the Acknowledgements section.

[11] Communication tower lighting is not discussed in this section as this is a new application evaluated for the 2015 LMC.

3.2.1 Total U.S. Lighting Inventory

Representing a total of 26 states and 6,969 buildings, the lighting inventory sample database was checked for quality issues such as reporting errors and outliers and subsequently scaled to represent the 2015 U.S. population of buildings. To accomplish this, both a building classification and regional weighting factor were used to reflect the total U.S. building inventory and the lighting installed within, ultimately creating nationally-weighted lighting inventory databases for each building sector.

The sample weight is unique to each sample building. For the residential sector, the sample weight reflects the number of homes in the U.S. that the sample home represents. For the commercial and industrial sectors, the sample weight reflects the square footage of building space in the U.S. that the sample building represents. In addition to scaling the lighting inventory sample data to the national population, sample weights were used to adjust for the under and over representation of certain segments of the building population in the sample dataset.

For the residential sector, data from the 2015 AHS were used to determine the characteristics of the U.S. population of homes in 2015. Over 119 million residences existed in the U.S. in 2015, not including homes that were considered vacant.[12] The sample weight is based on the residence type and U.S. Census region, which are statistically significant indicators of the number of lamps in a residence. The calculation for the basic weight is:

$$Sample\ Weight\ = \frac{\sum Residences\ in\ U.S.of\ type(x)\ \&\ region(y)}{\sum Residences\ in\ Dataset\ of\ type(x)\ \&\ region(y)}$$

Where:
x = type categories (single-family; multifamily; mobile or trailer)
y = region categories (Northeast, Midwest, South, West)

Total floorspace, age of the residence, and other demographic characteristics were not used in the weighting due to inadequate sample data relating to these characteristics. Ownership status was considered as a weighting factor – as it was found to be a statistically significant predictor of lamp quantity – but was ultimately excluded due to the fact that only a subset of sample data contained this information, and the lighting inventory sample data distribution was very similar to national residential building stock distribution for this characteristic. See Appendix B for comparisons of sample and national data distributions for select building characteristics.

The lighting inventory sample data does not include any lighting data for mobile or trailer homes located in the South, and included lighting data for a very small number of mobile or trailer homes in the Midwest. Therefore, lighting data for mobile or trailer homes were averaged over all U.S. Census regions for inclusion in the nationally-weighted lighting inventory database.

[12] The sample weight used to determine the national inventory of residential lighting excludes homes that were considered vacant but includes homes categorized as seasonally-occupied. The sample weight used to determine the energy consumption of national residential lighting stock was adjusted slightly to exclude seasonally-occupied homes.

2015 Residential Weighting Factor Update

For the 2015 update, sample data are geographically diverse enough to allow for inclusion of region in the weighting factor. This differs from the 2010 LMC, in which adjustments to account for the regional bias of sample data were made prior to weighting.

Additionally, the 2015 LMC sample data does not contain robust data on residence square footage. Therefore, unlike the 2010 LMC, this factor was not used for weighting.

The above-mentioned differences in weighting methodology likely account for some of the differences between national residential inventory estimates presented in the 2015 LMC.

For the commercial and industrial sectors, the 2012 CBECS and the 2010 MECS were used to determine the characteristics of the U.S. population of these buildings.

The building population and floorspace of commercial buildings were adjusted from a 2012 baseline to a 2015 baseline using growth estimates from the EIA's AEO 2016 (66). Using this methodology, the 2015 LMC estimates total U.S. commercial floorspace of 88.9 billion ft^2.

To estimate the 2015 building population and floorspace of industrial buildings, the 2010 to 2015 growth in manufacturing employment by NAICS code was used as a proxy for the growth in buildings. The advantage of this method is that it allows for the estimate of 2015 industrial floorspace by both sub-industry and region. However, this analysis assumes a constant ratio of labor to manufacturing floorspace by sub-industry. Because of increases in automation in the industrial sector (which may have resulted in a decrease in the ratio of labor to floorspace for certain sub-industries), this assumption may have underestimated national industrial floorspace in 2015. Using this methodology, the 2015 LMC estimates total U.S. industrial floorspace of 11.8 billion ft^2.

2015 Commercial and Industrial Floorspace Update

The sources of data used to develop estimates of national commercial and industrial building stocks have been updated compared to the 2010 LMC.

- **Commercial Floorspace** – Based on the latest 2012 CBECS, the 2015 LMC estimates 88.9 billion ft^2 in total U.S. commercial floorspace for 2015. This represents an approximate 10 percent increase from the 2010 LMC. However, the 2010 LMC underestimated 2010 commercial floorspace relative to the subsequently published 2012 CBECS (published in April 2015), which has the effect of artificially inflating the growth rate of commercial floorspace between the 2010 and 2015 LMC studies.
- **Industrial Floorspace** – The 2015 LMC estimates a total U.S. industrial floorspace of 11.8 billion ft^2. This represents a 7 percent increase in industrial floorspace compared to the reported 2010 MECS and a 20 percent increase from the 2010 LMC estimate. Similar to the commercial floorspace estimates, the 2010 LMC underestimated 2010 industrial floorspace (and overestimated total building count) relative to the subsequently published 2010 MECS. Again, this has the effect of artificially inflating the growth rate in industrial floorspace between the 2010 and 2015

The sample weight for each building is based on the use type of the building, U.S. Census region, and the total U.S. floorspace dedicated to that use type. Due to the relatively low number of sample buildings in the South and Midwest, these regions were combined for the purposes of weighting. Additionally, due to the small sample of buildings associated with certain end-use category and region combinations, regional and end-use type weights were calculated separately and sequentially-applied to the sample data.

The calculation for weighting commercial and industrial building interior lighting is as follows:

Sample weight 1: adjust the regional proportions of the sample

$$Sample\ Weight\ 1 = \frac{\%\ Floor\ space\ in\ the\ U.S.of\ region\ (x)}{\%\ Floor\ space\ in\ the\ sample\ dataset\ of\ region\ (x)}$$

Where:
x = region categories (Northeast, Midwest and South, West)

Sample weight 2: adjust the building end-use proportions of the sample and scale sample to national level

$$Sample\ Weight\ 2 = \frac{\sum Floor\ space\ in\ U.S.of\ type(y)}{\sum Regionally\ adjusted\ floor\ space\ in\ sample\ dataset\ of\ type(y)}$$

Where:
y = type categories (retail, lodging, machinery manufacturing, etc.)

The lighting inventory sample dataset did not include any information on three industrial building types: apparel manufacturing facilities, leather and allied product manufacturing shops, and petroleum and coal products manufacturing facilities. The average calculated lighting characteristics over the entire industrial sector were used to approximate the lighting characteristics in these building subsectors for use in the nationally-weighted lighting inventory dataset.

2015 Commercial and Industrial Weighting Factor Update

Similar to the 2015 LMC residential sector sample data, the regional distribution for the commercial and industrial sample data allows for inclusion of region in the weighting factor. This differs from the 2010 LMC, which applied adjustments to account for the sample regional bias prior to weighting.

This difference in weighting methodology used likely accounts for some of the differences between commercial and industrial national inventory estimates presented in the 2010 LMC and those presented in the 2015 LMC.

Exterior building lighting was reported for only a subset of the buildings contained in the lighting inventory sample databases.[13] For this reason, weights were applied separately to the portion of sample buildings with initial exterior lighting inventory.

For residential building exterior lighting, the same weighting methodology was used as for residential building interior lighting (described in Section 3.2). However, for commercial and industrial building exterior lighting, weighting to adjust for regionality was not feasible since no sample data were available for the South or Midwest regions. Therefore, only building type was used to weight the commercial and industrial building exterior sample.

3.2.1.1 Inventory Validation and Adjustments Using Shipments Data

Initial estimates of building lighting inventory for the entire U.S. based on the weighting process described above were validated and adjusted, if necessary, using historical shipments data from NEMA and LED lighting manufacturers. This process of verification and adjustment is necessary since a portion of the lighting inventory sample data were collected in years prior to the 2015 baseline year. For each building sector, Table 3.6 below shows the percentage of sample data collected in each year.

[13] All buildings in the lighting inventory sample databases had interior lights reported.

Table 3.6 Building Sectors Lighting Inventory Sample Data – Distribution by Collection Year

Sample Collection Year	Residential	Commercial	Industrial
Pre-2013	0%	29%	27%
2013	25%	14%	7%
2014	10%	48%	15%
2015	48%	4%	35%
Post-2015	17%	5%	16%
Total number of sample sites	2,912	3,822	236

The five-step process used to validate and adjust (if necessary) the nationally-weighted lighting inventory that leveraged lighting product shipments data is summarized in Figure 3.6 and described in detail below.

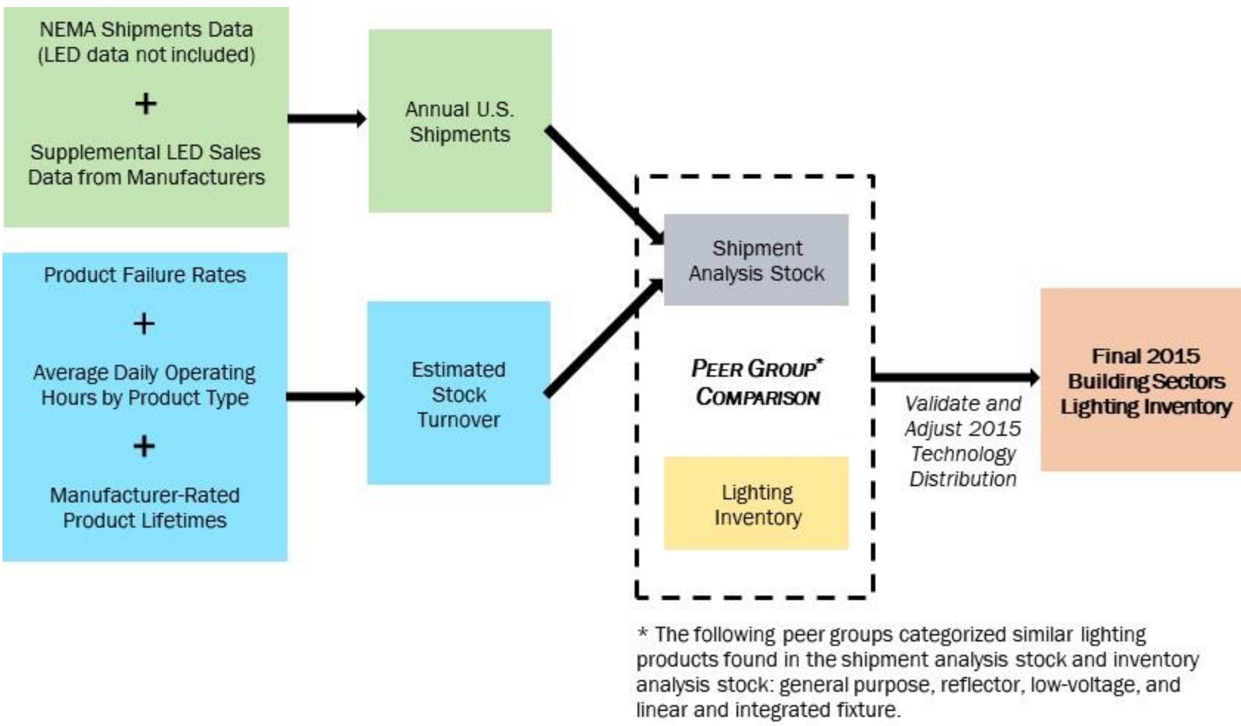


Figure 3.6 National Building Sectors Lighting Inventory Validation Methodology

Step 1 – Estimate Annual U.S. Shipments NEMA provided historical U.S. lighting shipments data by product type for 2001 through 2015 (excluding LED lamps and luminaires). Additionally, lighting manufacturers provided historical U.S. LED lamp and luminaire sales data. Using these data, in combination with market share and sales channel estimates, historical U.S. shipments were estimated for each building sector by each lighting technology classification.

Step 2 – Estimate Stock Turnover Data on average daily operating hours by technology, product type and building sector were aggregated from the lighting inventory sample data (using onsite audit and metering data sources). Data on average product lifetimes (in hours) were collected from databases developed for DOE lighting energy conservation standard rulemakings. Using both sets of data, average product lifetimes (in years) were estimated, by building sector, for each technology and product type. Finally, product failure rates were incorporated, allowing for the calculation of stock turnover by lighting type.

Step 3 – Estimate Installed Stock in 2015 Stock turnover estimates were applied to annual shipments data to estimate installed stock in 2015 for each building sector by lighting technology and product type.

Step 4 – Define Peer Groups for Comparison Lamps and luminaires were categorized into four lighting peer groups according to end-use application. These peer groups are general purpose lamps, reflector lamps, low-voltage lamps, and linear lamps/integrated fixtures.

Step 5 – Validate and Adjust 2015 Technology Distribution For each lighting peer group (e.g., general purpose, reflector, low-voltage), the 2015 technology distribution estimated from sample inventory data (using the weighting methodology described in Section 3.2.1) was compared against the 2015 technology distribution estimated using shipments data. Where the sample inventory technology mix was weighted too heavily for years prior to the 2015 baseline, or misrepresented due to low inventory counts for a specific lighting type (e.g., MR16 halogen lamps), the shipments-based technology distribution was used. However, the total inventory for each peer group based on sample inventory data was not adjusted. This process was conducted separately for each building sector and indoor/outdoor location (e.g., residential interior lighting, residential exterior lighting, commercial interior lighting, etc.). Shipments-adjusted inventory estimates were provided to a technical review committee for feedback. Comments were received from 21 industry stakeholder organizations, including governmental organizations, utilities, utility partnership organizations, national laboratories, manufacturers, and lighting industry consultants. Comments received from stakeholders resulted in further refinement of the shipments-based adjustments.

In cases where the shipments-based inventory estimates were not used to adjust the technology mix within lighting peer groups, the shipments model was used only for validation purposes.

3.2.2 Operating Hours

The daily hours of operation for lamps and luminaires in the residential sector are based on end-use metering and analysis conducted from 2008 to 2014 according to protocols described in the DOE's 2012 Residential Lighting End-Use Consumption Study (67). As part of the Residential Lighting End-Use Consumption Study effort, lighting metering data were collected in California and, subsequently, in Tennessee and the mid-Atlantic, through lighting loggers that used photosensors to record when lamps were turned on or off. The California metering sample includes more than 1,200 homes (and more than 8,000 lighting installations). Metering was conducted for these homes for several months during the 2008 and 2009 timeframe. For the Tennessee sample, end-use metering data were collected for 62 homes using 419 lighting loggers. Data collection for this sample spanned 1 year, from March 2013 to April 2014. The mid-Atlantic sample includes end-use metering for 183 households (1,281 lighting installations) for over 6 months in late 2012. The sample covered urban, suburban, and rural counties in NY, NJ, and PA.

Although the metering data used for the Residential Lighting End-Use Consumption Study were collected only for certain regions, data on household and lighting inventory characteristics were collected for many regions throughout the country and were used in the study's statistical model with the purpose of estimating average U.S. lighting operating hours.

The Residential Lighting End-Use Consumption Study provides national average daily operating hours by technology and room type. For the LMC, these average values were applied to the residential sample building lighting inventory data at the lamp or luminaire level.

For the commercial and industrial sectors, operating hours are based on surveys with building owners and operators. Although operating hour data were not collected for every lighting installation in the building audits and surveys, many of the studies provided some survey information on estimated operating hours. Operating hours were drawn from multiple geographies, and they were provided as average estimates of use over the entire year, so no adjustment factors were applied to them.

Using the sample operating hour data, average daily operating hours were calculated by building type and lighting technology. Average values were then applied to sample inventory data at the lamp level according to the building end-use and lighting technology combination of each lamp- or luminaire-level observation.

For a small number of building end-use and lighting technology combinations, the size of the sample with associated operating hour data is too small to provide a reliable estimate of average daily operating hours for the building type and lighting technology in question. In these cases, the average value across lighting technologies for that building end-use was used.

For building exterior lighting, due to the limited sample of exterior lighting data containing estimates of daily hours of use, sample operating hour data in the commercial and industrial sectors were combined and average daily operating hours were calculated by lighting technology only.

3.2.3 Lighting System Wattage

The metric of average lighting system wattage includes the wattage (as provided by building audit and survey data) associated with a lamp or luminaire, combined with ballast or driver assumptions for relevant lighting types. For incandescent, halogen, screw-based compact fluorescent lamps (CFLs), general purpose LED lamps, Underwriters Laboratories (UL) 1993 Type B linear LED lamps, [14] and LED luminaires, the wattage per lighting system is represented solely by the reported lamp or luminaire wattage. Pin-based CFLs, linear fluorescent lamps, high-intensity discharge (HID) lamps, and UL 1993 Type A and Type C linear LED lamps were assumed to be operated by an external ballast or driver. These lighting systems consume additional energy due to the losses in the ballast or LED driver. As some ballasts also operate lamps at levels other than their rated wattage, this can significantly affect overall system wattage.

In order to estimate these effects on externally-ballasted (or -driven) lamps, databases of typical ballast and driver input wattages and their associated rated lamp wattages were developed using manufacturer data and the DOE’s Fluorescent Lamps Ballast Standards Rulemaking (68). Only systems with rated lamp wattages similar to the average lamp wattage as provided in the LMC data sources were included in this manufacturer data. The average (system) wattage per lamp for the product categories presented in Figure 2.1 was calculated by multiplying the reported lamp wattage by the average ratio of system input power by lamp rated wattage from the manufacturer catalog data for characteristic lamp-and-ballast (or lamp-and-driver) systems.

$$W_{sys} = W_{lamp}\ x\ \frac{P_{out}}{P_{in}}$$

Where:

W_{sys} *= System wattage reported in LMC*

W_{lamp} *= Lamp wattage provided in data sources*

P_{out} *= Rated output power to the lamp from the ballast (or driver) (values determined from manufacturer data and include ballast factor effects)*

P_{in} *= Rated input ballast (or driver) power from power supply (values determined from manufacturer data)*

Further information on system wattage assumptions is provided in Appendix C.

3.2.4 Building Sector Controls

The data sources considered for the 2015 LMC building sector inventory often specify lighting control types at the lamp or luminaire level. The availability of controls inventory in sample data facilitated the calculation of

[14] Two types of linear LED lamps were assumed to have ballast or driver losses that should be directly accounted for in this analysis. UL 1993 Type A linear LED lamps have integrated drivers and are operated directly on an existing linear fluorescent lamp ballast, thus enduring system efficiency losses. UL 1993 Type C linear LED lamps operate on an external driver, requiring electrical modification to an existing linear fluorescent lamp fixture and will also lead to some system efficiency losses. Reported wattages for UL 1993 Type B linear LED lamps (that operate directly on line voltage) were assumed to be total system wattages. Additional information on linear LED lamp types can be found at: http://energy.gov/sites/prod/files/2017/03/f34/led_troffer_retrofit_guide.pdf.

the energy savings due to the presence of controls in the building sectors. For this calculation, the reported control types that impact wattage were standardized to align with the control strategies detailed in the DOE SSL Program's 2016 Energy Savings Forecast Report (69). These strategies include dimming, daylighting, energy management systems (EMS), connected lighting (for LED), and multi (where a combination of strategies is used), and the strategies are further reported by building sector. Because average operating hours utilized for this study already reflect the presence of certain control types, control types associated with reducing operating hours (i.e., occupancy sensors and timers) were not included in energy savings calculations.

After the standardizing the controls inventory, energy savings discounts based on baseline load profiles[15] (shown in Table 3.7) were applied to the annual electricity consumption calculations. These lighting installation-level results were weighted and scaled to the national level using the same method detailed in Section 3.2.1. To more accurately compare energy consumption estimates with those reported in the 2010 LMC, which did not incorporate control energy savings that impact wattage, control energy savings are presented as a separate results section in this report (see Section 4.3).

Table 3.7 Energy Savings Potential for Control Strategies Analyzed in 2015 LMC (69)

	Dimmer	Daylighting	Multi	EMS
Commercial – Office	6%	15%	19%	19%
Commercial – Warehouse	3%	14%	17%	17%
Commercial – Retail	7%	15%	21%	21%
Commercial – Lodging	4%	9%	12%	12%
Commercial – Health	10%	13%	22%	22%
Commercial – Education	5%	14%	18%	18%
Residential – All	4%	10%	14%	14%
Industrial – Factory	25%	5%	29%	29%

3.3 Outdoor Inventory and Energy Consumption Calculation

As with the building sectors, energy consumption for each outdoor sector application was determined by multiplying lighting inventory by average wattage and average operating hours. However, the inputs were derived in different manners based on data availability. The following sections provide detail on how the outdoor data sources were used to develop the inventory and energy use estimates.

3.3.1 Airfield Lighting

For the purposes of this report, airfield lighting includes all the runway and taxiway lighting used to direct airplane traffic at airfields nationwide. Airfield apron lighting is not included due to a lack of data availability. The Federal Aviation Administration's (FAA's) National Flight Data Center (NFDC) runways database provided the data used to determine the total number of lit runways. The database provides specifications for every registered civil or joint-use (civil/military) airport.

The FAA's Advisory Circular 150/5340-30H details the regulations for airport visual aids, which were used to determine the typical spacing of lighting on runways. The installed base of lamps and luminaires – except those used in taxiway lighting – was calculated using these light spacing regulations in conjunction with runway dimensions and other runway-specific data provided in the NFDC database. Sufficiently detailed information regarding taxiway lighting, however, is not included in the NFDC database. Accordingly, a separate method was used to determine the installed base for these lighting systems.

[15] In the Forecast Report, 24-hour baseline lighting profiles are based on various data inputs for three day types: weekdays, weekends, and holidays. These profiles account for the probability that a lamp or luminaire would be turned on and thus could achieve energy savings from added controls.

Taxiway edge lighting is required by the FAA for all 14 CFR Part 139 certified airports. [16] This analysis assumes that only those certified airports – about 530 – have taxiway lighting.

For the 2010 LMC, the Metropolitan Washington Airports Authority provided the number of taxiway edge lights installed in its two major commercial airports – Washington Dulles International Airport and Ronald Reagan National Airport. This light count was normalized based on the size of the airports, and the resulting value was scaled to all Part 139 certified airports. This 2010 light count was then scaled to 2015 based on the growth rate of the airfield light types resulting from an analysis of the NFDC database.

The NFDC database was also used to determine typical operating hours. In the database, each airport reports which hours it is open. The hours of operation are calculated under the assumption that airfield lights are only illuminated during the non-daytime hours that the airport is open. The duty cycle of typical flash patterns is also included in the calculations.

Lastly, input from the FAA and industry experts was used to estimate the technology mix and typical lamp wattages for each type of lighting system.

3.3.2 Billboard Lighting

The billboard lighting category is composed of the lamps and luminaires that illuminate advertising billboards typically found alongside roads. Digital billboards are not considered because the LMC characterizes lighting used for illumination. The main purpose of displays such as digital billboards is not to illuminate, and thus they are excluded. The billboard lighting category also excludes internally-illuminated signage.

The Outdoor Advertising Association of America (OAAA) confirmed that no national inventory of billboard lights currently exists. However, Lamar Advertising Company and OAAA each provided national-level inventory estimates used to determine the total number of billboards in 2015, broken down by billboard size. Estimates of technology mix, operating hours, and lighting wattages were also based on input from OAAA and Lamar Advertising Company.

Digital Billboard Trends

Digital billboards, which are becoming increasingly common, often take the place of traditional billboards in order to create a more attention-grabbing display. However, the increased utility comes at the price of consuming dramatically more electricity as a result of higher wattages and hours of use. Also, traditional billboards operate only during non-daylight hours, whereas digital billboards typically operate 24 hours per day.

A recent study indicates that digital billboards consume between 29,000 kilowatt-hours (kWh) and 94,000 kWh annually (76). Assuming operation 24 hours per day, the wattage of these billboards is typically between 3,000 W and 11,000 W. These digital billboards consume between 20 and 60 times more electricity than the traditional billboards studied in the LMC.

3.3.3 Commercial and Industrial Building Exterior Lighting

As discussed in Section 3.2.1, inventory and associated energy use for commercial and industrial building exterior lighting were calculated using a method similar to that used for building sector interior lighting. However, for commercial and industrial building exterior lighting, weighting to adjust for regionality of the sample was not possible because no data were reported for the South or Midwest. Accordingly, only building type was used to weight the commercial and industrial building exterior sample buildings to the national level.

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[16] A Part 139 certified airport adheres to the regulations contained in 14 CFR Part 139. This includes most large residential airports that serve scheduled and unscheduled flights with more than 30 seats. Additional information on this certification can be found at: http://www.faa.gov/airports/airport_safety/part139_cert/

3.3.4 Communication Tower Lighting

Communication tower lighting, an application new to the 2015 LMC, encompasses the beacons and indicator lights used on communication towers nationwide. The FAA sets forth requirements for tower lighting standards in Advisory Circular 70/7460-1K[17] (70), which are largely dependent upon tower height. The Federal Communications Commission (FCC) also maintains an Antenna Structure Registration database that includes specifications for each registered tower, including its lighting scheme.[18] The count of each type of tower light was determined by applying Advisory Circular lighting style definitions to each tower in the FCC database.

Standards for operating hours are also set forth by the Advisory Circular document as a function of tower lighting scheme. Given that communication tower lights often flash, data about flash patterns and typical duty cycles were gathered from interviews with industry leaders. The duty cycle is accounted for in the operating hours provided in the report.

Specifications for typical system wattage and an average mix of lighting technologies were determined through feedback from industry experts. In addition, a survey of Wireless Infrastructure Association (WIA) members provided data on the majority of communication towers nationwide (34). Data and feedback from interviews with experts at Dialight plc and Flash Technology were aggregated with the survey data to create a wide-reaching analysis.

3.3.5 Parking Lighting

The parking lighting subsector includes lighting that illuminates parking lots and parking garages, and there are separate estimates for each. In this analysis, the total number of lighting installations is based on the estimated number of total parking spaces. Industry experts estimated that in 2011 there were approximately 610 million parking lot spaces and 85 million parking garage spaces. It is assumed that, between 2011 and 2015, the growth of these quantities is directly proportional to the growth of total vehicle registrations nationwide – approximately 0.9 percent annually (63). By averaging over 1,800 survey and interview responses, it was determined that there are approximately 13.0 parking lot spaces per lighting system and 2.5 parking garage spaces per lighting system.

The mix of lighting technologies is an aggregate of a dataset from Pacific Northwest National Laboratory (PNNL) and responses to an International Parking Institute (IPI) member survey. System wattages were determined from data provided by PNNL and product specification sheets.

3.3.6 Railway Lighting

There are two general types of railway signals considered in this analysis: wayside signals and roadway-railway crossing signals. Wayside signals are colored control signals, similar to roadway traffic signals, and are used to control railway traffic. Roadway-railway crossing signals are located where roadways and railways cross at the same grade; their purpose is to alert and halt roadway traffic when trains are approaching.

The number of wayside signals is based on the FRA estimate of just over 100,000 signaled track miles nationwide (41). Given one standard wayside station every 2 miles and one wayside control station every 12.5 miles, there are an estimated nearly 59,000 wayside stations nationwide (40). The number of signaled crossings was gathered from the FRA's Highway-Rail Crossing Inventory database.[19]

The operating hours were calculated using railway traffic data presented in the FRA's Highway-Rail Crossing Inventory database and an understanding of signal operation patterns provided by railway lighting experts at

[17] More recent Advisory Circular documents have been released since Advisory Circular 70/7460-1K. However, the LMC analysis uses solely this version because it was active from February 2007 to December 2015 – the time period most relevant to the 2015 LMC.
[18] The Antenna Structure Registration database is publicly available and can be downloaded here: http://wireless2.fcc.gov/UlsApp/AsrSearch/asrRegistrationSearch.jsp
[19] The Highway-Rail Crossing Inventory database is publicly available and can be downloaded here: http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/downloaddbf.aspx

GE Lighting (42). Technology mix and wattage data were gathered from similar sources and from lighting product specification sheets.

3.3.7 Roadway Lighting

Roadway lighting is broken into two categories: street and highway. Street lights are mostly found in urban and suburban settings where pedestrian traffic, residences, or commercial properties lie adjacent to the roadway. Therefore, these lights are responsible for illuminating the roadway and the nearby walkways and building fronts. Lighting dedicated solely to pedestrian areas, including walkways, is not included in the analysis. Highway lights are found on roadways that independently serve transportation purposes and are only responsible for illuminating the roadway.

The national inventory of street lighting was modeled using data from 61 cities in 25 states. The data were collected from a wide variety of sources, including interviews with transportation-related city officials, a member survey conducted by the Municipal Solid-State Street Lighting Consortium (MSSLC), and many publicly-available reports and datasets. The national inventory of highway lighting is based on estimates from the Federal Highway Administration (FHWA) that include the total miles of lighted highway and an average spacing of 200 feet between light poles. The mix of technologies for highway lighting was determined through interviews and lighting inventory data provided by the DOT in 11 states.

The remaining inputs were calculated from responses provided in interviews with industry experts, questionnaires from state DOTs, and surveys of organizations including MSSLC, PG&E, Metropolitan Area Planning Council (MAPC), and New York State Energy Research and Development Authority (NYSERDA). In most categories, the result is an average of these inputs.

3.3.8 Sports Lighting

The sports lighting application encompasses the lights used to illuminate outdoor sports fields and stadiums. Retractable-roof stadiums are also included. The analysis of sports lighting was split into two categories: professional (including collegiate) and non-professional (largely municipal, community, and high school). Lights installed in indoor stadiums or fields are included in the commercial sector lighting analysis.

An inventory of professional fields and stadiums nationwide was gathered from a publicly-available Department of Homeland Security dataset.[20] According to industry experts, however, a database of non-professional locations does not exist. Instead, the analysis relies on input from sports lighting industry experts who estimate there is a total of approximately 5,000 stadiums and fields (both professional and non-professional) nationwide. This analysis assumes that all professional fields are illuminated and that half of non-professional fields are illuminated. The resulting inventory is approximately 700 professional and 2,150 non-professional illuminated fields.

The Stadium Managers Association, a trade association dedicated to efficient management of stadiums throughout the world, conducted a survey of its members to collect lighting data. The data from professional stadiums include the total number of lights, operating hours, and lighting technologies installed. These responses are the main source of inputs to the analysis of professional locations.

The number of lights per non-professional field was calculated based on an average of typical four-to-seven pole field lighting schemes provided by lighting vendors. The analysis determined that an average conventionally lit, non-professional sports field uses approximately five poles and 50 lamps.

Typical hours of operation were determined from interviews with experts at Spark Lighting and responses to the Stadium Managers Association's member survey. The lighting wattage used to illuminate both professional and non-professional fields was determined by a compilation and analysis of product specification sheets.

[20] The publicly-available DHS dataset of major sports venues can be downloaded here: https://hifld-dhs-gii.opendata.arcgis.com/datasets/698ba396e1ef412b9ac12ea4e2853936_0

3.3.9 Traffic Signal Lighting

The traffic signal lighting application is composed of the lights that illuminate street signals, such as stop lights and pedestrian road crossing signals. Three types of stop lights are considered in this analysis: tri-colored balls, turn arrows, and bimodal arrows. In addition, three types of pedestrian crossing signals are considered: walking person, stop hand, and countdown.

The number of signalized traffic intersections is an aggregate of multiple models. The outputs of these models range anywhere from 311,000 to 373,000. One frequently cited estimate is that there is one signalized intersection per 1,000 people nationally (71). Another recent estimate from an industry expert is one intersection per 860 people. Given the U.S. population in 2015, those models correspond to roughly 321,000 and 373,000 signalized intersections nationwide, respectively. Yet another model, recommended by industry experts at the FHWA, is a growth of 1.5 percent annually (55). Linear and exponential forecasting of the intersection approximations presented in the National Traffic Signal Report Card Technical Reports from 2005, 2007 and 2012 correspond to approximately 337,000 signalized intersections. The average of these seven models leads to the estimated 331,000 intersections used in this report.

The number of each type of signal per signalized intersection was revised downward approximately 18 percent from the previous LMC edition and 2008 DOE analysis based on input from industry experts at the FHWA. The resulting inputs are an estimated 8.0 colored ball signals, 2.5 arrow signals, 6.6 walking person and hand signals, and 0.2 countdown signals per intersection.

Finally, in order to determine the total installed base, the number of signalized intersections – approximately 331,000 – was multiplied by the total count of each signal type per intersection.

The technology mix of traffic signals is largely affected by The Energy Policy Act of 2005, which required all traffic signals manufactured after January 1, 2006 meet or exceed ENERGY STAR performance criteria. This effectively requires all new signals to use LED technology. Prior to this mandate, traffic signals were predominantly lit by incandescent lamps. Based on the turnover rate of incandescent traffic signals and interviews with experts, it is estimated that in 2015 approximately 79 percent of signals were LED lights. A complete conversion has not yet occurred because some incandescent lamps previously in stock or manufactured before 2006 remain in use today. It is believed that the estimated LED penetration provided in the 2010 LMC is too high.

The wattages of LED traffic signals were determined by compiling product specification sheet data. The wattage of incandescent signals is assumed to have remained constant since the 2010 LMC since no new incandescent signals have been introduced into the market.

Lastly, the hours of operation for traffic signals are based on estimates provided by the FHWA. For colored ball signals, only one of the three bulbs is illuminated at any given time. Thus, on average, the bulbs operate approximately 8 hours per day. The other types of signals range anywhere from 7 percent to 60 percent utilization for the arrow and hand signals, respectively.

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4 Lighting Inventory and Energy Consumption Estimates

The objectives of the LMC analysis are to develop an accurate depiction of the nation's lighting inventory and lighting electricity consumption for the baseline year of 2015. The remainder of this report provides detailed results related to these objectives (Sections 4 and 5) and compares the findings to the 2001 and 2010 LMC results (Section 5.2), as well as to other comparable energy use estimates (Section 6).

Section 4.1 provides the cumulative results for all lighting technologies by sector. Section 4.2 provides detailed results for each sector. Lastly, Section 4.3 examines the prevalence of lighting controls and their associated energy savings.

4.1 Cumulative Results

Table 4.1 presents the estimate of the installed lighting inventory in the U.S. by technology, product type, and sector. The total installed base of lighting products in the U.S. for 2015 is estimated to be 8.7 billion, with 98.7 percent representing lamp products and 1.3 percent representing integrated fixtures or luminaires. This represents an overall growth of 25 percent relative to 2001's estimate of nearly 7.0 billion lighting installations, and a growth of 6 percent relative to 2010's estimate of 8.2 billion lighting installations. High-level trends of lighting in 2001, 2010, and 2015 are detailed in Section 6.

As discussed in Section 2, for this report all outdoor lighting associated with commercial and industrial buildings (e.g., parking lot lighting and building exterior lighting) is classified under the outdoor sector; this is in contrast to the 2001 report in which some outdoor lighting was classified under the commercial and industrial sectors. In addition, the 2015 estimates for the outdoor sector include the communication tower subsector, which was not previously analyzed; however, the addition of communication towers constitutes a low percentage of the total outdoor sector lighting inventory.

In addition, new data have been made available that enable a revision of some outdoor lighting applications. For example, the FAA's NFDC maintains a publicly-available database of airports, which allows for significant increases in precision from 2010. Similarly, the FRA maintains a publicly-available data on highway-rail crossings. Therefore, the estimates of 2010 outdoor lighting have been updated as a result of data that were not previously available. Updated outdoor sector tables are presented in Appendix E.

Since the 2010 LMC, the majority of inventory growth has been in the residential sector, which accounts for more than double the number of lighting installations in the remaining sectors combined. Compared to 2010, the lighting inventories in the residential and commercial sectors have increased by 7 percent and 0.3 percent, respectively. The industrial sector saw a 19 percent increase in lighting inventory, which is attributable, in part, to the estimated 20 percent increase in industrial floorspace since the 2010 LMC.[21] The outdoor sector has seen a significant inventory growth of 25 percent from 2010 to 2015. The vast majority of this increase is attributable to the growth in building exterior lighting in the commercial and industrial sectors.

[21] As outlined in section 3.2.1, the 2010 LMC underestimated 2010 industrial floorspace (and overestimated total industrial building count) relative to the subsequently published 2010 MECS. This has the effect of artificially inflating the growth rate in industrial floorspace between the 2010 and 2015 LMC studies.

Table 4.1 Estimated Inventory of Lamps [22,23,24] in the U.S. by End-Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**2,153,340,000**	**27,496,000**	**33,000**	**8,099,000**	**2,188,968,000**
General Purpose - A-Shape	777,210,000	3,082,000	14,000	-	780,306,000
General Purpose - Decorative	905,110,000	6,026,000	2,000	-	911,138,000
Reflector	430,821,000	4,799,000	3,000	-	435,623,000
Miscellaneous	40,199,000	13,589,000	14,000	8,099,000	61,901,000
Halogen	**1,047,505,000**	**15,415,000**	**34,000**	**5,939,000**	**1,068,893,000**
General Purpose - A-Shape	692,595,000	2,120,000	30,000	-	694,745,000
General Purpose - Decorative	38,885,000	128,000	-	-	39,013,000
Reflector	211,274,000	861,000	2,000	-	212,137,000
Reflector - Low Voltage	62,808,000	11,086,000	-	-	73,894,000
Miscellaneous	41,943,000	1,220,000	2,000	5,939,000	49,104,000
Compact Fluorescent	**2,067,668,000**	**165,255,000**	**409,000**	**11,121,000**	**2,244,453,000**
General Purpose - Pin	30,022,000	80,125,000	184,000	-	110,331,000
General Purpose - Screw	1,813,981,000	63,303,000	36,000	-	1,877,320,000
Reflector	178,453,000	6,009,000	120,000	-	184,582,000
Miscellaneous	45,212,000	15,818,000	69,000	11,121,000	72,220,000
Linear Fluorescent	**512,315,000**	**1,622,321,000**	**154,111,000**	**54,682,000**	**2,343,429,000**
T5	17,892,000	92,700,000	30,469,000	-	141,061,000
T8 Less than 4ft	978,000	19,978,000	452,000	-	21,408,000
T8 4ft	207,324,000	1,149,860,000	87,125,000	-	1,444,309,000
T8 Greater than 4ft	5,775,000	16,557,000	11,925,000	-	34,257,000
T8 U-Shaped	-	35,464,000	424,000	-	35,888,000
T12 Less than 4ft	1,629,000	1,491,000	72,000	-	3,192,000
T12 4ft	255,262,000	266,927,000	11,917,000	-	534,106,000
T12 Greater than 4ft	21,254,000	24,739,000	10,123,000	-	56,116,000
T12 U-Shaped	-	7,917,000	-	-	7,917,000
Miscellaneous	2,201,000	6,688,000	1,604,000	54,682,000	65,175,000
High Intensity Discharge	**755,000**	**24,662,000**	**9,855,000**	**106,731,000**	**142,003,000**
Mercury Vapor	278,000	200,000	37,000	1,694,000	2,209,000
Metal Halide	179,000	22,805,000	7,421,000	46,350,000	76,755,000
High Pressure Sodium	298,000	605,000	2,397,000	57,747,000	61,047,000
Low Pressure Sodium	-	-	-	940,000	940,000
Miscellaneous	-	1,052,000	-	-	1,052,000
LED	**417,779,000**	**217,639,000**	**6,900,000**	**58,779,000**	**701,097,000**
General Purpose	239,923,000	61,480,000	126,000	-	301,529,000
Integrated Fixture/Luminaire	29,859,000	80,153,000	4,276,000	-	114,288,000
Linear	724,000	22,143,000	2,435,000	-	25,302,000
Reflector	126,419,000	24,005,000	63,000	-	150,487,000
Reflector - Low Voltage	3,381,000	8,305,000	-	-	11,686,000
Miscellaneous	17,473,000	21,553,000	-	58,779,000	97,805,000
Other	**19,607,000**	**3,672,000**	**340,000**	**12,195,000**	**35,814,000**
Miscellaneous	19,607,000	3,672,000	340,000	12,195,000	35,814,000
Total	**6,218,969,000**	**2,076,460,000**	**171,682,000**	**257,546,000**	**8,724,657,000**

[22] There was no inventory in the residential sector for U-shaped T8 or T12 lamps. For the purposes of this analysis, it is assumed that the Linear Fluorescent – Miscellaneous category included a small portion of these lamps.
[23] For the 2015 LMC, LED integrated fixtures and luminaires are also included.
[24] The other category is comprised of illuminated exit signs and other lamps that do not fall into any of the previous categories, such as fiber optic lights, induction lamps, xenon lamps, as well as lamps of unknown characteristics.

Table 4.2 presents the distribution of lamps by end-use sector. This table presents essentially the same information as Table 4.1 but instead portrayed as percentages so as to more easily depict technological trends by sector. Relative to updated 2010 values, the results across all sectors for 2015 show a lower percent distribution of incandescent, linear fluorescent, and HID lamps, with a corresponding shift to halogen, CFL, and LED technologies. Linear fluorescent maintained the largest percentage of the installed base in 2015, followed closely by CFL and incandescent technologies, while HID maintained a small percentage.

In the residential sector, the most distinct trend is the continued decrease in saturation of general purpose incandescent lamps (decreasing from 52 percent in 2010 to 27 percent in 2015), and the transitioning to screw-base general purpose CFLs (increasing from 19 percent in 2010 to 29 percent in 2015), general purpose halogen lamps (increasing from less than 1 percent in 2010 to nearly 12 percent in 2015), and general purpose LED lamps (increasing from less than 1 percent in 2010 to nearly 4 percent in 2015). In addition, there has been continued movement toward directional lamps (such as incandescent reflector, halogen reflector, halogen low voltage reflector, CFL reflector, and LED reflector), which, by 2015, comprised over 16 percent of the residential installed base (up from roughly 13 percent in 2010).

In the commercial sector, the most evident trend is the migration from T12 linear fluorescent lamps to T8 linear fluorescent lamps and LED lamps and integrated fixtures/luminaires. In 2010, T8 lamps comprised approximately 60 percent of the commercial installed base of linear fluorescent lamps, and in 2015 this value increased to 75 percent. Additionally, a key development in the commercial sector since 2010 has been the rapid adoption of LED lamps and integrated fixtures/luminaires, which, by 2015, composed approximately 10 percent of the commercial installed base. These trends are likely attributable to federal regulations,[25] utility-based incentive programs, more functionally-advanced technologies (i.e., SSL and its associated capabilities), and a further societal interest in energy conservation and financial savings.

The industrial sector did not experience large technological shifts from 2010 to 2015. Trends include a decrease in HID lamps (from approximately 10 percent in 2010 to 6 percent in 2015) and an increase in linear LED lamps (approximately 1 percent in 2015) and LED integrated fixtures/luminaires (approximately 2 percent in 2015). Although this shift is small, it does show tangible market progress of LED lighting products serving high-lumen applications commonly found in the industrial sector.

The outdoor sector groups all incandescent lamps, halogen lamps, CFLs, linear fluorescent lamps, and LED lamps and integrated fixtures/luminaires in the category of each respective technology. This is because many of the data sources used for the outdoor sector do not provide inventory detail beyond the general lighting technology level. The primary trend evident in this sector is a movement from HID lamps (approximately 58 percent in 2010 to approximately 41 percent in 2015) to LED lamps and integrated fixtures/luminaires (approximately 8 percent in 2010 to 23 percent in 2015). Additionally, the linear fluorescent distribution increased from approximately 13 percent to 21 percent, primarily attributable to the building exterior subsector.

[25] Further information on federal energy conservation standards for fluorescent lamps and ballasts can be found at: https://energy.gov/eere/buildings/appliance-and-equipment-standards-program

Table 4.2 Distribution of Lamps [26] (%) by End Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**34.6%**	**1.3%**	**0.0%**	**3.1%**	**25.1%**
General Purpose - A-Shape	12.5%	0.1%	0.0%	-	8.9%
General Purpose - Decorative	14.6%	0.3%	0.0%	-	10.4%
Reflector	6.9%	0.2%	0.0%	-	5.0%
Miscellaneous	0.6%	0.7%	0.0%	3.1%	0.7%
Halogen	**16.8%**	**0.7%**	**0.0%**	**2.3%**	**12.3%**
General Purpose - A-Shape	11.1%	0.1%	0.0%	-	8.0%
General Purpose - Decorative	0.6%	0.0%	-	-	0.4%
Reflector	3.4%	0.0%	0.0%	-	2.4%
Reflector - Low Voltage	1.0%	0.5%	-	-	0.8%
Miscellaneous	0.7%	0.1%	0.0%	2.3%	0.6%
Compact Fluorescent	**33.2%**	**8.0%**	**0.2%**	**4.3%**	**25.7%**
General Purpose - Pin	0.5%	3.9%	0.1%	-	1.3%
General Purpose - Screw	29.2%	3.0%	0.0%	-	21.5%
Reflector	2.9%	0.3%	0.1%	-	2.1%
Miscellaneous	0.7%	0.8%	0.0%	4.3%	0.8%
Linear Fluorescent	**8.2%**	**78.1%**	**89.8%**	**21.2%**	**26.9%**
T5	0.3%	4.5%	17.7%	-	1.6%
T8 Less than 4ft	0.0%	1.0%	0.3%	-	0.2%
T8 4ft	3.3%	55.4%	50.7%	-	16.6%
T8 Greater than 4ft	0.1%	0.8%	6.9%	-	0.4%
T8 U-Shaped	-	1.7%	0.2%	-	0.4%
T12 Less than 4ft	0.0%	0.1%	0.0%	-	0.0%
T12 4ft	4.1%	12.9%	6.9%	-	6.1%
T12 Greater than 4ft	0.3%	1.2%	5.9%	-	0.6%
T12 U-Shaped	-	0.4%	-	-	0.1%
Miscellaneous	0.0%	0.3%	0.9%	21.2%	0.7%
High Intensity Discharge	**0.0%**	**1.2%**	**5.7%**	**41.4%**	**1.6%**
Mercury Vapor	0.0%	0.0%	0.0%	0.7%	0.0%
Metal Halide	0.0%	1.1%	4.3%	18.0%	0.9%
High Pressure Sodium	0.0%	0.0%	1.4%	22.4%	0.7%
Low Pressure Sodium	-	-	-	0.4%	0.0%
Miscellaneous	-	0.1%	-	-	0.0%
LED	**6.7%**	**10.5%**	**4.0%**	**22.8%**	**8.0%**
General Purpose	3.9%	3.0%	0.1%	-	3.5%
Integrated Fixture/Luminaire	0.5%	3.9%	2.5%	-	1.3%
Linear	0.0%	1.1%	1.4%	-	0.3%
Reflector	2.0%	1.2%	0.0%	-	1.7%
Reflector - Low Voltage	0.1%	0.4%	-	-	0.1%
Miscellaneous	0.3%	1.0%	-	22.8%	1.1%
Other	**0.3%**	**0.2%**	**0.2%**	**4.7%**	**0.4%**
Miscellaneous	0.3%	0.2%	0.2%	4.7%	0.4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

[26] For the 2015 LMC, LED integrated fixtures and luminaires are also included.

Table 4.3 lists the average number of lamps (and integrated fixtures/luminaires for LED lighting) in a typical building within each building sector. For residences, a "building" is a single housing unit, even if part of a multifamily structure. For the commercial and industrial sectors, a building is a single stand-alone building. Outdoor is not shown because the data are not shown on a per building basis.

As seen in Table 4.3, the average residence in 2015 is estimated to have 52 lamps or luminaires installed, which is roughly equivalent to the average number of lamps or luminaires installed per residence in 2010. In the commercial sector, the 2015 results estimate an average of 389 lamps or luminaires per building, a small (3 percent) increase from 2010. However, in the industrial sector, the average lamps or luminaires per building increased by approximately 46 percent from 2010 to 2015. The magnitude of this increase in number of lighting installations per building is at least partly attributable to the decrease in estimated total industrial building count relative to total industrial floor space between the 2010 and 2015 LMCs.[27]

In each building sector, the 2015 analysis shows a decline in average number of installations per thousand square feet. Although the differences are not by a wide margin (i.e., each of the declines are by less than three lamps per 1,000 ft^2), this finding may be a result of a move to higher lumen output lighting products, the increase of integrated LED fixtures/luminaires, or it may be within the uncertainty of the 2010 and 2015 estimates.

Table 4.4 lists the average number of lamps per thousand square feet using the inventory counts from Table 4.1 and the floorspace estimates from Table 3.1. In 2010, there were approximately 27 lighting installations per thousand square feet in the residential sector, 25.5 lighting installations per thousand square feet in the commercial sector, and 14.6 lighting installations per thousand square feet in the industrial sector. The corresponding values in 2015 were 24.4, 24.3 and 14.5, respectively.

[27] As previously noted, the 2010 LMC underestimated total industrial floor space and overestimated total building count relative to the subsequently published 2010 MECS, upon which industrial building count and floor space for the 2015 LMC are based. Accordingly, readers should take caution when comparing the number of lighting installations per building between the 2010 and 2015 LMCs, as part of the apparent growth is artificial.

Table 4.3 Average Number of Lamps [28] per Building by End-Use Sector in 2015

	Residential	Commercial	Industrial
Incandescent	**17.9**	**5.1**	**0.1**
General Purpose - A-Shape	6.5	0.6	0.0
General Purpose - Decorative	7.5	1.1	0.0
Reflector	3.6	0.9	0.0
Miscellaneous	0.3	2.5	0.0
Halogen	**8.7**	**2.9**	**0.1**
General Purpose - A-Shape	5.8	0.4	0.1
General Purpose - Decorative	0.3	0.0	-
Reflector	1.8	0.2	0.0
Reflector - Low Voltage	0.5	2.1	-
Miscellaneous	0.3	0.2	0.0
Compact Fluorescent	**17.2**	**30.8**	**1.1**
General Purpose - Pin	0.3	14.9	0.5
General Purpose - Screw	15.1	11.8	0.1
Reflector	1.5	1.1	0.3
Miscellaneous	0.4	2.9	0.2
Linear Fluorescent	**4.3**	**302.1**	**416.0**
T5	0.1	17.3	82.2
T8 Less than 4ft	0.0	3.7	1.2
T8 4ft	1.7	214.1	235.2
T8 Greater than 4ft	0.0	3.1	32.2
T8 U-Shaped	-	6.6	1.1
T12 Less than 4ft	0.0	0.3	0.2
T12 4ft	2.1	49.7	32.2
T12 Greater than 4ft	0.2	4.6	27.3
T12 U-Shaped	-	1.5	-
Miscellaneous	0.0	1.2	4.3
High Intensity Discharge	**0.0**	**4.6**	**26.6**
Mercury Vapor	0.0	0.0	0.1
Metal Halide	0.0	4.2	20.0
High Pressure Sodium	0.0	0.1	6.5
Low Pressure Sodium	-	-	-
Miscellaneous	-	0.2	-
LED	**3.5**	**40.5**	**18.6**
General Purpose	2.0	11.4	0.3
Integrated Fixture/Luminaire	0.2	14.9	11.5
Linear	0.0	4.1	6.6
Reflector	1.1	4.5	0.2
Reflector - Low Voltage	0.0	1.5	-
Miscellaneous	0.1	4.0	-
Other	**0.2**	**0.7**	**0.9**
Miscellaneous	0.2	0.7	0.9
Total	**51.8**	**386.7**	**463.4**

[28] For the 2015 LMC, LED integrated fixtures and luminaires are also included.

Table 4.4 Average Number of Lamps [29] per Thousand Square Feet by End-Use Sector in 2015

	Residential	Commercial	Industrial
Incandescent	**8.5**	**0.3**	**0.0**
General Purpose - A-Shape	3.1	0.0	0.0
General Purpose - Decorative	3.6	0.1	0.0
Reflector	1.7	0.1	0.0
Miscellaneous	0.2	0.2	0.0
Halogen	**4.1**	**0.2**	**0.0**
General Purpose - A-Shape	2.7	0.0	0.0
General Purpose - Decorative	0.2	0.0	-
Reflector	0.8	0.0	0.0
Reflector - Low Voltage	0.2	0.1	-
Miscellaneous	0.2	0.0	0.0
Compact Fluorescent	**8.1**	**1.9**	**0.0**
General Purpose - Pin	0.1	0.9	0.0
General Purpose - Screw	7.1	0.7	0.0
Reflector	0.7	0.1	0.0
Miscellaneous	0.2	0.2	0.0
Linear Fluorescent	**2.0**	**19.0**	**13.0**
T5	0.1	1.1	2.6
T8 Less than 4ft	0.0	0.2	0.0
T8 4ft	0.8	13.4	7.3
T8 Greater than 4ft	0.0	0.2	1.0
T8 U-Shaped	-	0.4	0.0
T12 Less than 4ft	0.0	0.0	0.0
T12 4ft	1.0	3.1	1.0
T12 Greater than 4ft	0.1	0.3	0.9
T12 U-Shaped	-	0.1	-
Miscellaneous	0.0	0.1	0.1
High Intensity Discharge	**0.0**	**0.3**	**0.8**
Mercury Vapor	0.0	0.0	0.0
Metal Halide	0.0	0.3	0.6
High Pressure Sodium	0.0	0.0	0.2
Low Pressure Sodium	-	-	-
Miscellaneous	-	0.0	-
LED	**1.6**	**2.5**	**0.6**
General Purpose	0.9	0.7	0.0
Integrated Fixture/Luminaire	0.1	0.9	0.4
Linear	0.0	0.3	0.2
Reflector	0.5	0.3	0.0
Reflector - Low Voltage	0.0	0.1	-
Miscellaneous	0.1	0.3	-
Other	**0.1**	**0.0**	**0.0**
Miscellaneous	0.1	0.0	0.0
Total	**24.4**	**24.3**	**14.5**

[29] For the 2015 LMC, LED integrated fixtures and luminaires are also included.

Table 4.5 lists the average wattage per lamp or luminaire for each end-use sector. The average wattages for externally-ballasted or -driven lamps account for ballast and driver losses and operation at ballast factors less than one. See Section 3.2.3 for further detail on the calculation of average wattage per lamp or luminaire. In general, relative to the 2010 characteristics, each building sector has seen shifts to more efficacious, and therefore often lower wattage, light sources. Technological trends that contributed to this decrease in overall wattage per lamp or luminaire include a migration from incandescent lamps to halogen lamps, CFLs, and LED lamps and luminaires, and from T12 linear fluorescent lamps to T8 linear fluorescent lamps. In the outdoor sector, the overall average wattage decreased (based on the updated 2010 results) from 2010 to 2015, likely due to an increased presence of LED lamps and integrated fixtures/luminaires. The average LED integrated fixture/luminaire wattage is especially low because it contains many lower lumen products, such as downlight retrofit kits. These trends are discussed in more detail in the sector-specific results presented in Section 4.2.

Table 4.5 Average[30] Wattage per Lamp [31] by End-Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**55**	**67**	**48**	**107**	**55**
General Purpose - A-Shape	63	68	60	-	63
General Purpose - Decorative	41	39	60	-	41
Reflector	67	96	67	-	67
Miscellaneous	56	69	30	107	65
Halogen	**58**	**60**	**52**	**113**	**58**
General Purpose - A-Shape	53	60	43	-	53
General Purpose - Decorative	45	48	40	-	45
Reflector	67	62	80	-	67
Reflector - Low Voltage	42	53	-	-	44
Miscellaneous	125	123	160	113	124
Compact Fluorescent	**16**	**24**	**26**	**25**	**17**
General Purpose - Pin	22	26	36	-	25
General Purpose - Screw	16	22	17	-	16
Reflector	16	20	15	-	16
Miscellaneous	17	26	23	25	20
Linear Fluorescent	**38**	**34**	**43**	**38**	**35**
T5	18	35	54	-	37
T8 Less than 4ft	19	21	17	-	21
T8 4ft	33	31	31	-	31
T8 Greater than 4ft	59	63	65	-	63
T8 U-Shaped	-	31	30	-	31
T12 Less than 4ft	23	27	28	-	25
T12 4ft	41	39	41	-	40
T12 Greater than 4ft	73	84	82	-	79
T12 U-Shaped	-	35	-	-	35
Miscellaneous	40	70	45	38	41
High Intensity Discharge	**173**	**361**	**447**	**314**	**331**
Mercury Vapor	213	284	441	207	219
Metal Halide	88	372	462	382	386
High Pressure Sodium	187	332	399	266	272
Low Pressure Sodium	-	-	-	108	108
Miscellaneous	-	160	-	-	160
LED	**10**	**19**	**26**	**70**	**18**
General Purpose	8	10	10	-	9
Integrated Fixture/Luminaire	9	30	25	-	25
Linear	15	19	28	-	20
Reflector	12	13	12	-	12
Reflector - Low Voltage	4	9	-	-	7
Miscellaneous	9	13	-	70	47
Other	**55**	**17**	**55**	**93**	**64**
Miscellaneous	55	17	55	93	64
Average	**38**	**36**	**65**	**166**	**42**

30 Throughout the report, average values are weighted by the inventory of each relevant category.
31 For the 2015 LMC, LED integrated fixtures and luminaires are also included.

Table 4.6 presents the distribution of installed wattage across lamp and luminaire types within each sector. The installed wattage was calculated by multiplying the lighting inventories in Table 4.1 by the wattages per lamp or luminaire in Table 4.5. While on an inventory basis HID lamps have relatively low market shares, they account for nearly 13 percent of the total installed wattage across all sectors. This is largely due to their use in applications that require high lumen output. This is in contrast to CFLs, which represent nearly 26 percent of all installed base of lamps, but their relatively low lumen output and high efficacy results in their accounting for only 10 percent of total installed wattage.

Table 4.6 Distribution (%) of Installed Wattage by End-Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**49.9%**	**2.5%**	**0.0%**	**2.0%**	**33.0%**
General Purpose - A-Shape	20.8%	0.3%	0.0%	-	13.5%
General Purpose - Decorative	15.9%	0.3%	0.0%	-	10.4%
Reflector	12.2%	0.6%	0.0%	-	8.0%
Miscellaneous	1.0%	1.3%	0.0%	2.0%	1.1%
Halogen	**25.8%**	**1.2%**	**0.0%**	**1.6%**	**17.1%**
General Purpose - A-Shape	15.5%	0.2%	0.0%	-	10.0%
General Purpose - Decorative	0.7%	0.0%	-	-	0.5%
Reflector	6.0%	0.1%	0.0%	-	3.9%
Reflector - Low Voltage	1.1%	0.8%	-	-	0.9%
Miscellaneous	2.2%	0.2%	0.0%	1.6%	1.7%
Compact Fluorescent	**14.1%**	**5.4%**	**0.1%**	**0.6%**	**10.3%**
General Purpose - Pin	0.3%	2.8%	0.1%	-	0.8%
General Purpose - Screw	12.2%	1.9%	0.0%	-	8.3%
Reflector	1.2%	0.2%	0.0%	-	0.8%
Miscellaneous	0.3%	0.5%	0.0%	0.6%	0.4%
Linear Fluorescent	**8.3%**	**73.3%**	**58.7%**	**4.8%**	**22.7%**
T5	0.1%	4.4%	14.7%	-	1.4%
T8 Less than 4ft	0.0%	0.6%	0.1%	-	0.1%
T8 4ft	2.9%	47.8%	24.5%	-	12.4%
T8 Greater than 4ft	0.1%	1.4%	7.0%	-	0.6%
T8 U-Shaped	-	1.5%	0.1%	-	0.3%
T12 Less than 4ft	0.0%	0.1%	0.0%	-	0.0%
T12 4ft	4.4%	13.8%	4.4%	-	5.8%
T12 Greater than 4ft	0.7%	2.8%	7.4%	-	1.2%
T12 U-Shaped	-	0.4%	-	-	0.1%
Miscellaneous	0.0%	0.6%	0.7%	4.8%	0.7%
High Intensity Discharge	**0.1%**	**12.0%**	**39.4%**	**78.6%**	**12.9%**
Mercury Vapor	0.0%	0.1%	0.1%	0.8%	0.1%
Metal Halide	0.0%	11.4%	30.7%	41.5%	8.1%
High Pressure Sodium	0.0%	0.3%	8.5%	36.0%	4.6%
Low Pressure Sodium	-	-	-	0.2%	0.0%
Miscellaneous	-	0.2%	-	-	0.0%
LED	**1.7%**	**5.5%**	**1.6%**	**9.6%**	**3.4%**
General Purpose	0.8%	0.8%	0.0%	-	0.7%
Integrated Fixture/Luminaire	0.1%	3.3%	1.0%	-	0.8%
Linear	0.0%	0.6%	0.6%	-	0.1%
Reflector	0.6%	0.4%	0.0%	-	0.5%
Reflector - Low Voltage	0.0%	0.1%	-	-	0.0%
Miscellaneous	0.1%	0.4%	-	9.6%	1.3%
Other	**0.5%**	**0.1%**	**0.2%**	**2.7%**	**0.6%**
Miscellaneous	0.5%	0.1%	0.2%	2.7%	0.6%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Table 4.7 presents the average daily operating hours for each lighting product type in each sector. The operating hours displayed represent the average daily hours throughout the year. See Section 3.2.2 for details on the methodology for calculating operating hours. It is important to note that though the operating hour estimates presented below are considered to be the best estimates for the purposes of this report, operating hour data vary widely from source to source depending on building types considered, occupant habits, geographies covered, and other factors.

The 2015 average operating hour estimates for the residential sector are similar to those in 2010. Some technologies have slightly different operating hour estimates, but the sector-weighted average is roughly equivalent. Compared to the 2010 LMC, average operating hours estimated for the commercial and industrial sectors in 2010 are 21 percent lower and 7 percent lower, respectively. Due to the magnitude of change, especially in the commercial sector, these estimates may be due to an increased presence of controls that reduce operating hours. Outdoor operating hour estimates have increased 11 percent since 2010. As both the 2010 and 2015 LMC utilized industry expert interviews to develop the average use characteristics for these sectors, this variation could indicate slight changes in lighting use, or it could be within the uncertainty of the estimates due to varying data sources. One key distinction between the 2010 LMC and the 2015 LMC is the designation of LED exit signs. In an attempt to avoid skewed results for the rest of the LED categories, LED exit signs are included in the Other – Miscellaneous grouping for this report and are the primary reason operating hours estimates for this grouping are higher for the commercial and industrial sectors.

Table 4.7 Average Daily Operating Hours by End-Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**1.5**	**10.6**	**11.9**	**9.8**	**1.6**
General Purpose - A-Shape	1.4	11.0	11.1	-	1.4
General Purpose - Decorative	1.5	11.6	12.5	-	1.5
Reflector	1.7	10.4	12.0	-	1.8
Miscellaneous	1.6	10.2	12.7	9.8	4.5
Halogen	**1.9**	**10.9**	**11.6**	**13.2**	**2.1**
General Purpose - A-Shape	1.7	11.2	11.6	-	1.7
General Purpose - Decorative	2.3	13.4	11.7	-	2.3
Reflector	2.4	11.1	11.8	-	2.4
Reflector - Low Voltage	1.9	10.7	-	-	3.2
Miscellaneous	2.5	11.2	11.7	13.2	4.0
Compact Fluorescent	**2.2**	**12.3**	**13.0**	**9.0**	**3.0**
General Purpose - Pin	2.2	12.2	13.0	-	9.5
General Purpose - Screw	2.1	13.0	13.0	-	2.5
Reflector	2.5	10.2	13.0	-	2.8
Miscellaneous	2.2	11.2	13.0	9.0	5.2
Linear Fluorescent	**2.0**	**8.1**	**12.0**	**9.8**	**7.1**
T5	2.6	8.7	12.0	-	8.6
T8 Less than 4ft	1.9	9.2	12.0	-	8.9
T8 4ft	2.1	8.0	12.0	-	7.4
T8 Greater than 4ft	1.5	8.4	12.0	-	8.5
T8 U-Shaped	-	8.2	12.0	-	8.3
T12 Less than 4ft	2.0	11.9	12.0	-	6.9
T12 4ft	1.9	8.4	12.0	-	5.4
T12 Greater than 4ft	1.6	9.1	12.0	-	6.8
T12 U-Shaped	-	8.2	-	-	8.2
Miscellaneous	1.8	7.8	12.0	9.8	9.4
High Intensity Discharge	**3.3**	**10.3**	**14.2**	**12.0**	**11.8**
Mercury Vapor	3.3	10.1	14.2	9.5	8.8
Metal Halide	3.3	10.3	14.2	11.6	11.5
High Pressure Sodium	3.3	9.9	14.2	12.4	12.4
Low Pressure Sodium	-	-	-	11.8	11.8
Miscellaneous	-	9.8	-	-	9.8
LED	**1.9**	**11.1**	**12.0**	**11.8**	**5.7**
General Purpose	1.8	13.5	12.2	-	4.2
Integrated Fixture/Luminaire	2.0	9.4	11.9	-	7.5
Linear	1.6	9.7	12.1	-	9.7
Reflector	2.0	11.8	12.2	-	3.6
Reflector - Low Voltage	1.9	12.4	-	-	9.4
Miscellaneous	2.1	10.5	-	11.8	9.8
Other	**2.1**	**16.2**	**13.4**	**16.3**	**8.5**
Miscellaneous	2.1	16.2	13.4	16.3	8.5
Average	**1.9**	**8.9**	**12.1**	**13.4**	**4.1**

Table 4.8 presents the electricity consumed in 2015 by lighting technology, calculated by summing the inventory-weighted electricity consumption values by lighting product type and technology. Total electricity consumed by lighting in the U.S. in 2015 is estimated to be 641 terawatt-hours (TWh), or roughly 6.8 quadrillion British thermal units (quads) of primary energy. HID and linear fluorescent lamps consumed the greatest amount, constituting 34 percent and 33 percent, respectively, of total lighting electricity consumption.

Similar to 2010, lighting in the commercial sector in 2015 consumed more electricity than other sectors, approximately 37 percent of the total, due to its high operating hour characteristics and large lighting inventories. The outdoor sector is the second greatest consumer (approximately 32 percent of the total), caused by typically long operating hours and high lighting system wattages in that sector. The residential sector was the third greatest consumer of lighting electricity; its large inventory is the primary contributor for driving its electricity consumption to 23 percent of the total lighting electricity consumption in the U.S. Lastly, the industrial sector was the smallest in terms of electricity use, comprising 8 percent of the national total.

Table 4.8 Annual Lighting Electricity Consumed (TWh) by End-Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**63**	**7**	**0**	**3**	**73**
General Purpose - A-Shape	25	1	0	-	26
General Purpose - Decorative	20	1	0	-	21
Reflector	17	2	0	-	19
Miscellaneous	1	4	0	3	8
Halogen	**42**	**3**	**0**	**3**	**49**
General Purpose - A-Shape	22	0	0	-	23
General Purpose - Decorative	1	0	0	-	1
Reflector	13	0	0	-	13
Reflector - Low Voltage	1	2	-	-	3
Miscellaneous	5	0	0	3	9
Compact Fluorescent	**26**	**17**	**0**	**1**	**44**
General Purpose - Pin	1	9	0	-	9
General Purpose - Screw	22	6	0	-	29
Reflector	3	0	0	-	3
Miscellaneous	1	2	0	1	3
Linear Fluorescent	**14**	**162**	**29**	**7**	**212**
T5	0	10	7	-	18
T8 Less than 4ft	0	1	0	-	1
T8 4ft	5	104	12	-	121
T8 Greater than 4ft	0	3	3	-	7
T8 U-Shaped	-	3	0	-	3
T12 Less than 4ft	0	0	0	-	0
T12 4ft	7	31	2	-	41
T12 Greater than 4ft	1	7	4	-	11
T12 U-Shaped	-	1	-	-	1
Miscellaneous	0	1	0	7	9
High Intensity Discharge	**0**	**31**	**23**	**162**	**217**
Mercury Vapor	0	0	0	1	2
Metal Halide	0	30	18	81	129
High Pressure Sodium	0	1	5	79	85
Low Pressure Sodium	-	-	-	1	1
Miscellaneous	-	1	-	-	1
LED	**3**	**15**	**1**	**19**	**38**
General Purpose	1	3	0	-	4
Integrated Fixture/Luminaire	0	8	0	-	9
Linear	0	1	0	-	2
Reflector	1	1	0	-	2
Reflector - Low Voltage	0	0	-	-	0
Miscellaneous	0	1	-	19	20
Other	**1**	**0**	**0**	**6**	**8**
Miscellaneous	1	0	0	6	8
Total	**149**	**237**	**53**	**202**	**641**

Finally, Table 4.9 presents the total lumen production for the U.S. in each sector in 2015. These values are the result of multiplying together lighting inventory, wattage per lamp or luminaire/integrated fixture, and system efficacy (including ballast losses, where appropriate). These lumen production estimates were then summed to calculate the total lighting service for each lighting technology in each sector. Potential fixture losses are not included in these values. The efficacy assumptions used for lumen output calculations are discussed in Appendix C.

Light production is presented in teralumen-hours (Tlm-hr). For sense of scale, 1 Tlm-hr is the amount of light used by approximately 35,000 homes each year. As seen in Table 4.9, in 2015, the commercial sector accounts for the majority of lumen production because of long operating hours and large lighting inventory. This is followed by the outdoor sector, which also has long operating hours and high wattage lighting installations, resulting in relatively high lumen production. The industrial sector uses the least amount of light of all sectors analyzed, which differs from 2010 due to an increase in residential inventory (which is now estimated to produce the third most lumen-hours) and a decrease in estimated industrial sector operating hours. Relative to 2010, the overall 2015 estimate of lumen production increased approximately 8 percent, which is likely attributed to overall building and population growth.

Table 4.9 Annual Lumen Production (Tlm–hr) by End-Use Sector in 2015

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**581**	**67**	**0**	**36**	**685**
General Purpose - A-Shape	249	8	0	-	258
General Purpose - Decorative	175	9	0	-	183
Reflector	146	15	0	-	160
Miscellaneous	12	36	0	36	84
Halogen	**689**	**44**	**0**	**50**	**783**
General Purpose - A-Shape	382	9	0	-	391
General Purpose - Decorative	19	0	0	-	20
Reflector	195	3	0	-	198
Reflector - Low Voltage	9	24	-	-	33
Miscellaneous	83	8	0	50	141
Compact Fluorescent	**1,545**	**1,150**	**3**	**59**	**2,758**
General Purpose - Pin	37	623	2	-	662
General Purpose - Screw	1,350	399	0	-	1,749
Reflector	120	20	0	-	141
Miscellaneous	38	108	0	59	205
Linear Fluorescent	**1,113**	**14,582**	**2,608**	**618**	**18,920**
T5	23	1,072	676	-	1,772
T8 Less than 4ft	1	113	3	-	117
T8 4ft	465	9,754	1,123	-	11,342
T8 Greater than 4ft	18	301	330	-	648
T8 U-Shaped	-	292	5	-	297
T12 Less than 4ft	2	12	1	-	14
T12 4ft	530	2,329	157	-	3,016
T12 Greater than 4ft	70	540	286	-	896
T12 U-Shaped	-	59	-	-	59
Miscellaneous	5	110	27	618	760
High Intensity Discharge	**12**	**2,830**	**1,429**	**12,812**	**17,082**
Mercury Vapor	3	9	4	52	68
Metal Halide	2	2,690	812	3,618	7,121
High Pressure Sodium	7	85	613	9,046	9,751
Low Pressure Sodium	-	-	-	95	95
Miscellaneous	-	46	-	-	46
LED	**203**	**1,264**	**68**	**1,712**	**3,247**
General Purpose	104	242	0	-	346
Integrated Fixture/Luminaire	15	675	38	-	728
Linear	1	152	30	-	182
Reflector	73	82	0	-	156
Reflector - Low Voltage	1	19	-	-	20
Miscellaneous	9	94	-	1,712	1,815
Other	**53**	**18**	**6**	**431**	**508**
Miscellaneous	53	18	6	431	508
Total	**4,195**	**19,955**	**4,114**	**15,718**	**43,983**

4.2 Sector Specific Results

The following four sections examine the cumulative results for all lighting technologies by sector focusing on the subsector-level results. Specifically, details on the installed base, average system wattage, and operating hours are evaluated for the defined subsectors within the residential, commercial, industrial, and outdoor sectors.

As discussed in Section 3, the data populating tables for the residential, commercial, and industrial sectors are based on sample building inventory data. The sample data were scaled to a national level based on census region and residence type for the residential sector and based on building size, census region, and end-use type for the commercial and industrial sectors. The data were then adjusted using shipments data in order to accurately characterize the lighting market in 2015, accounting for the fact that some sample data was collected in years prior to 2015. The subsector results for the outdoor sector were developed in a slightly different manner due to a lack of audit and survey data. Each subsector in the outdoor sector was developed in a unique way based on the available data. For a detailed discussion of the sector methodologies, see Section 3.

4.2.1 Residential Results

The numbers of residential households considered in this analysis by residence type and census region are provided in Table 4.10. As discussed in Section 3.1.1, the values are drawn from the 2015 AHS. Each residency represents a single housing unit, even if part of a multifamily structure.

Table 4.10 Estimated Number of Residences by Census Region and Type in 2015

	Single Family	Multifamily	Mobile Home	Total
Northeast	13,994,408	7,294,548	526,825	21,815,781
Midwest	20,092,088	5,639,808	1,021,069	26,752,965
South	31,734,528	8,748,952	3,983,514	44,466,994
West	18,570,805	6,789,594	1,572,536	26,932,935
Total	**84,391,829**	**28,472,902**	**7,103,944**	**119,968,675**

Table 4.11 presents the average number of lamps or luminaires by residence type and room type in 2015. It is important to note that the values represent the total number of lamps or luminaires in a typical residence in all rooms of each room type. Thus, bedrooms, living rooms, bathrooms, and kitchens are estimated to contain the most number of lamps among all residence types. As seen below, in general, the average number of lamps or luminaires per household is in line with the size characteristics of each of the home types (meaning larger residence types have more installations than smaller residence types). The average number of lamps or luminaires per mobile home decreased compared to 2010 estimates, which is likely due to limited sample data for this residence type for both LMC installments.

Table 4.11 Average Number of Lamps per Household by Residence and Room Type in 2015

	Single Family	Multifamily	Mobile Home	Average
Basement(s)	3.4	0.6	0.3	2.5
Bathroom(s)	8.7	4.8	4.1	7.5
Bedroom(s)	9.2	4.8	4.3	7.9
Closet(s)	3.5	1.3	1.1	2.8
Dining Room(s)	3.4	1.6	1.4	2.9
Exterior(s)	6.0	2.3	2.9	4.9
Garage(s)	3.6	0.2	0.8	2.6
Hall(s)	4.1	1.7	1.1	3.4
Kitchen(s)	7.4	4.1	3.6	6.4
Laundry / Utility Room(s)	1.1	0.2	0.2	0.8
Living / Family Room(s)	9.2	3.9	4.3	7.6
Office(s)	1.4	0.4	0.9	1.1
Other	1.4	0.2	0.8	1.1
Total	**62.3**	**26.2**	**25.9**	**51.6**

Table 4.12 presents the lighting technology distribution by room type. Appendix D presents this same information in a more disaggregated form (distinguishing each lighting technology separately). As seen below, there is significant variation between room types. However, the proportion of most rooms' incandescent lighting has shifted some to a combination of halogen, CFL, and LED products. Lighting in dining rooms, halls, and bathrooms have the highest percentages of incandescent lighting, largely due to the high volume of decorative lamps and fixtures in those applications. While CFLs are common in almost every room type, linear fluorescent lamps appear to only have significant penetration in select applications, namely garages, laundry/utility rooms, and kitchens. The presence of LED products increased in each room type, ranging from 3 percent distribution in garages to 10 percent distribution in kitchens.

Table 4.12 Lighting Technology Distribution of Residences by Room Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Total
Basement(s)	32%	15%	36%	11%	0%	6%	0%	100%
Bathroom(s)	45%	16%	31%	3%	0%	6%	0%	100%
Bedroom(s)	32%	19%	41%	1%	0%	7%	0%	100%
Closet(s)	31%	20%	42%	4%	0%	4%	0%	100%
Dining Room(s)	53%	17%	23%	0%	0%	7%	0%	100%
Exterior(s)	32%	27%	32%	2%	0%	6%	1%	100%
Garage(s)	11%	5%	12%	69%	0%	3%	0%	100%
Hall(s)	46%	11%	34%	0%	0%	7%	0%	100%
Kitchen(s)	28%	14%	29%	19%	0%	10%	0%	100%
Laundry / Utility Room(s)	17%	14%	41%	22%	0%	4%	1%	100%
Living / Family Room(s)	36%	16%	39%	1%	0%	7%	0%	100%
Office(s)	33%	11%	41%	6%	0%	9%	0%	100%
Other	37%	12%	31%	11%	0%	9%	0%	100%
Average	**35%**	**16%**	**33%**	**8%**	**0%**	**7%**	**0%**	**100%**

Table 4.13 presents the average lighting wattage by residence type and room type. As discussed earlier, the wattages presented include ballast or driver effects, where appropriate. Because these numbers represent average wattages across the different lighting technologies in each room, the variations in wattage are fairly small. Higher lumen applications, such as exteriors and garages, tend to have higher wattages. Appendix D presents this information in a more disaggregated form (distinguishing each lamp or luminaire type separately).

Table 4.13 Average Lamp[32] Wattage by Residence Type and Room Type in 2015

	Single Family	Multifamily	Mobile Home	Average
Basement(s)	42	36	13	41
Bathroom(s)	37	37	33	37
Bedroom(s)	35	34	29	35
Closet(s)	36	33	43	36
Dining Room(s)	38	34	29	38
Exterior(s)	51	40	84	51
Garage(s)	41	39	43	41
Hall(s)	36	34	28	35
Kitchen(s)	34	35	31	34
Laundry / Utility Room(s)	34	36	30	34
Living / Family Room(s)	37	35	39	37
Office(s)	34	39	28	34
Other / Unknown	41	50	42	42
Average	**38**	**35**	**39**	**38**

[32] For the 2015 LMC, LED integrated fixtures and luminaires are also included.

Table 4.14 presents the average operating hours per day by residence type and room type. As seen below, for every residence type, exterior lighting represents the application which has the highest operating hours. This is followed by lighting found in kitchens and living rooms. The applications which have the lowest operating hours include halls, bathrooms, bedrooms, and closets. The daily operating hours overall and by residence type remain largely unchanged since 2010, aside from slight increases to multifamily and mobile homes operating hours.

Table 4.14 Average Daily Operating Hours by Residence Type and Room Type in 2015

	Single Family	Multifamily	Mobile Home	Average
Basement(s)	1.5	1.6	1.8	1.5
Bathroom(s)	1.4	1.4	1.4	1.4
Bedroom(s)	1.4	1.5	1.5	1.4
Closet(s)	1.4	1.4	1.4	1.4
Dining Room(s)	1.7	1.8	2.0	1.8
Exterior(s)	3.1	3.0	3.2	3.1
Garage(s)	1.5	1.5	1.5	1.5
Hall(s)	1.2	1.3	1.3	1.2
Kitchen(s)	2.8	2.8	2.7	2.8
Laundry / Utility Room(s)	1.5	1.4	1.5	1.5
Living / Family Room(s)	2.0	2.1	2.0	2.0
Office(s)	1.7	1.7	1.9	1.7
Other / Unknown	1.5	1.5	1.6	1.5
Average	**1.8**	**1.9**	**2.0**	**1.9**

Table 4.15 presents the lighting electricity use by room type. Lighting in building exterior, kitchen, and living room applications consume the most electricity. Building exteriors have the longest operating hours and typically have high-wattage lighting installations for high-lumen applications. Kitchens and living rooms have two of the highest totals of lamps or luminaires per residence. Bathroom lighting, another high-lamp quantity room type, shifted from the number 1 ranked electricity consumer in 2010 to the number 4 ranked consumer in electricity use. As in 2010, laundry/utility room(s), with the lowest average quantity of installations, consumed the least amount of electricity in 2015 at only 13 kilowatt-hours (kWh) per year in the typical house.

Table 4.15 Lighting Electricity Use by Room Type in 2015

	Operating Hours per Day	Average Lamps per Residence	Electricity Use per Room (kWh/yr)	Electricity Use Rank
Basement(s)	1.5	2.5	53	8
Bathroom(s)	1.4	7.5	138	4
Bedroom(s)	1.4	7.9	133	5
Closet(s)	1.4	2.8	49	9
Dining Room(s)	1.8	2.9	67	6
Exterior(s)	3.1	4.9	264	1
Garage(s)	1.5	2.6	55	7
Hall(s)	1.2	3.4	44	10
Kitchen(s)	2.8	6.4	208	2
Laundry / Utility Room(s)	1.5	0.8	14	13
Living / Family Room(s)	2.0	7.6	191	3
Office(s)	1.7	1.1	23	11
Other / Unknown	1.5	1.1	22	12
Total	**1.9**	**51.6**	**1,260**	**N/A**

Table 4.16 provides both electricity consumption and electricity use density by residence type. As expected, there is a direct correlation between the size of a home and the amount of lighting electricity consumed per building on an annual basis. When comparing the density of electricity use across residence types, single-family homes rank the highest and mobile homes rank second.

Table 4.16 Lighting Electricity Use by Residence Type in 2015

	Average Floorspace	Installed Wattage (W/ft^2)	Electricity Use per Building (kWh/yr)	Intensity ($kWh/yr/ft^2$)	Intensity Rank
Single Family	1,957	1.21	1,525	0.78	1
Multifamily	951	0.98	602	0.63	2
Mobile	1,220	0.83	757	0.62	3

4.2.2 Commercial Results

Fourteen commercial building space types were examined for the 2015 LMC. Table 4.17 displays the number of buildings, total square footage, and average floorspace per building for each space type on a national level. As mentioned in Section 3.2.1, these sector characteristics were collected from the 2012 CBECS database and scaled to a 2015 baseline by using the total square footage estimates from the EIA's AEO 2015.

Table 4.17 Estimated Number and Floorspace of Commercial Buildings in 2015

	Average Square Feet	Number of Buildings	Total Square Feet
Education	31,463	397,000	12,487,083,000
Food sales	7,073	181,000	1,277,378,000
Food service	4,787	388,000	1,855,871,000
Health care - Inpatient	237,400	10,000	2,422,121,000
Health care - Outpatient	12,116	150,000	1,817,101,000
Lodging	36,873	161,000	5,944,092,000
Offices (Non-medical)	15,763	1,033,000	16,275,345,000
Other	16,016	128,000	2,042,580,000
Public assembly	15,793	359,000	5,671,680,000
Public order and safety	17,143	86,000	1,469,189,000
Religious worship	11,061	420,000	4,649,370,000
Retail - Mall & Non-Mall	18,821	614,000	11,559,657,000
Services	7,480	632,000	4,723,849,000
Warehouse and storage	16,428	812,000	13,342,069,000
Average/Total	**15,930**	**5,371,000**	**85,537,385,000**

Table 4.18 illustrates the distribution of technologies across the commercial sector by space type. For the entire commercial sector, linear fluorescent lighting technology is by far the most prevalent at 78 percent of lighting inventory, and it represents over half of installations for all subsectors except lodging. In addition, of note is the slight decrease in distribution of each technology and cumulative shift to LED lighting, which is estimated to account for 10 percent of overall commercial sector lighting.

Table 4.18 Lighting Technology Distribution by Commercial Building Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Total
Education	0%	0%	4%	88%	1%	7%	0%	100%
Food sales	0%	1%	2%	78%	5%	13%	0%	100%
Food service	10%	4%	8%	60%	0%	18%	0%	100%
Health care - Inpatient	3%	1%	17%	67%	0%	11%	0%	100%
Health care - Outpatient	1%	2%	5%	79%	0%	12%	0%	100%
Lodging	4%	1%	43%	30%	0%	21%	0%	100%
Offices (Non-medical)	1%	1%	4%	87%	1%	7%	0%	100%
Other	1%	1%	16%	71%	1%	11%	0%	100%
Public assembly	2%	1%	12%	67%	2%	16%	0%	100%
Public order and safety	3%	3%	12%	72%	1%	10%	0%	100%
Religious worship	3%	1%	13%	70%	1%	12%	1%	100%
Retail - Mall & Non-Mall	1%	1%	4%	80%	2%	11%	0%	100%
Services	2%	0%	2%	82%	1%	13%	0%	100%
Warehouse and storage	0%	0%	1%	89%	2%	7%	0%	100%
Average	**1%**	**1%**	**8%**	**78%**	**1%**	**10%**	**0%**	**100%**

Table 4.19 shows the average wattage by technology for each commercial space type. The wattages displayed account for any ballast or driver effects, where relevant. In general, the wattage values do not vary significantly across space types for each lighting technology. Three building types of note – lodging, health care (inpatient), and food service – have the lowest average wattages, due to their higher LED penetration (shown in Table 4.18). For most building types, overall average wattages decreased compared to 2010 estimates, due to the shift to more-efficient lighting types.

Table 4.19 Average Lighting[33] Wattage by Commercial Building Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Average
Education	118	154	29	34	410	25	6	36
Food sales	82	57	27	35	141	21	8	38
Food service	30	35	21	35	85	10	27	29
Health care - Inpatient	53	72	22	30	222	14	50	28
Health care - Outpatient	102	70	20	33	132	16	4	32
Lodging	62	35	21	32	144	10	11	24
Offices (Non-medical)	63	52	24	33	369	22	10	34
Other	104	80	30	33	397	12	10	33
Public assembly	61	58	30	34	299	21	27	37
Public order and safety	214	51	29	36	175	15	6	40
Religious worship	92	96	26	34	333	12	6	34
Retail - Mall & Non-Mall	75	63	26	36	330	16	42	41
Services	64	59	24	36	393	14	5	39
Warehouse and storage	48	54	29	32	457	40	15	42
Average	**67**	**60**	**24**	**34**	**361**	**19**	**17**	**36**

33 For the 2015 LMC, LED integrated fixtures and luminaires are also included.

The average operating hours by lighting technology for each commercial building space is provided in Table 4.20. The average operating hours for each space type are directly influenced by the dominant technology: linear fluorescent. The "other" category is mainly populated by LED exit signs, which are characterized by high daily operating hours. The commercial sector-wide average daily operating hours decreased by over 2 hours since 2010. The shift can be attributed to a greater prevalence of occupancy sensor controls or to variations in sampled datasets, which sourced data on operating hours from different regions of the U.S.

Table 4.20 Average Daily Operating Hours by Commercial Building Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Average
Education	6.8	8.6	7.4	7.3	8.4	8.0	17.3	7.4
Food sales	15.1	18.0	15.9	16.8	19.1	19.0	23.0	17.2
Food service	12.4	12.7	13.0	12.8	13.2	13.0	19.9	12.8
Health care - Inpatient	12.2	12.5	11.2	10.6	15.6	12.4	12.4	11.0
Health care - Outpatient	7.2	9.1	8.7	8.4	8.2	7.2	22.8	8.3
Lodging	17.3	18.0	17.3	15.9	18.6	19.1	20.0	17.3
Offices (Non-medical)	7.7	8.2	8.6	7.4	8.8	9.3	14.8	7.6
Other	7.7	7.3	11.6	9.3	10.7	9.3	18.9	9.6
Public assembly	9.7	11.1	10.6	7.6	11.7	12.4	14.5	8.9
Public order and safety	16.8	13.1	16.2	14.2	8.3	18.3	21.0	14.8
Religious worship	4.2	5.4	5.3	4.5	5.8	5.4	16.2	4.8
Retail - Mall & Non-Mall	7.2	11.1	11.0	10.3	11.4	11.3	12.2	10.4
Services	7.6	7.6	6.4	6.9	9.9	8.5	23.5	7.1
Warehouse and storage	7.3	9.3	8.2	7.0	8.1	8.0	22.1	7.2
Average	**10.6**	**10.9**	**12.3**	**8.1**	**10.3**	**11.1**	**16.2**	**8.9**

Table 4.21 depicts the consumption of annual lighting electricity per building and per square foot for each space type. The installed wattage, which includes ballast or driver effects, represents weighted averages across all lighting technologies for each building type subsector. As in 2010, inpatient health care buildings consume the largest amount of lighting electricity per building due to their substantial area footprint. The final column in Table 4.21 provides a ranking of electricity use per floorspace to compare all subsectors by a common metric. Based on this ranking, food sales buildings have the most energy-intense lighting characteristics.

Table 4.21 Lighting Electricity Use by Commercial Buildings in 2015

	Average Lamps per 1,000 ft^2	Installed Wattage (W/ft^2)	Electricity Use per Building (kWh/yr)	Intensity ($kWh/yr/ft^2$)	Intensity Rank
Education	38	1.4	117,100	3.7	3
Food sales	29	1.1	48,900	6.9	1
Food service	24	0.7	15,700	3.3	6
Health care - Inpatient	17	0.5	471,200	2.0	11
Health care - Outpatient	19	0.6	22,700	1.9	12
Lodging	25	0.6	138,000	3.7	2
Offices (Non-medical)	19	0.6	27,900	1.8	13
Other	24	0.8	44,900	2.8	8
Public assembly	21	0.8	40,400	2.6	9
Public order and safety	17	0.7	60,500	3.5	4
Religious worship	30	1.0	19,500	1.8	14
Retail - Mall & Non-Mall	20	0.8	59,700	3.2	7
Services	33	1.3	25,300	3.4	5
Warehouse and storage	20	0.8	37,200	2.3	10

4.2.3 Industrial Results

The MECS database provides data for the 21 subsectors shown below in Table 4.22. As discussed in Section 3.2.1, the total floorspace is based on the 2010 MECS and has been adjusted to a 2015 baseline using manufacturing employment growth as a proxy for floorspace growth. Because of increases in automation in this sector, this assumption may have underestimated national industrial floorspace in 2015. However, the results presented in this section reflect the best estimates of 2015 industrial building counts and floorspace available at this time.

Table 4.22 Estimated Number and Floorspace of Industrial Buildings in 2015

	Average Square Feet	Number of Buildings	Total Square Feet
Apparel	18,734	3,000	49,755,000
Beverage and Tobacco Products	35,764	7,000	234,122,000
Chemicals	17,760	49,000	866,089,000
Computer and Electronic Products	52,880	9,000	501,517,000
Electrical Equip., Appliances, and Components	43,622	7,000	283,977,000
Fabricated Metal Products	31,451	46,000	1,443,100,000
Food	33,435	35,000	1,176,594,000
Furniture and Related Products	43,792	11,000	497,587,000
Leather and Allied Products	28,794	1,000	14,944,000
Machinery	40,205	24,000	974,502,000
Miscellaneous	22,721	16,000	371,025,000
Nonmetallic Mineral Products	15,885	34,000	543,228,000
Paper	47,947	12,000	565,288,000
Petroleum and Coal Products	7,217	13,000	95,085,000
Plastics and Rubber Products	59,410	15,000	912,899,000
Primary Metals	36,790	17,000	619,469,000
Printing and Related Support	24,480	14,000	331,462,000
Textile Mills	75,888	3,000	206,332,000
Textile Product Mills	30,888	4,000	137,385,000
Transportation Equipment	68,943	22,000	1,517,571,000
Wood Products	17,747	29,000	512,964,000
Total	**31,999**	**371,000**	**11,854,895,000**

It is important to note that facility lighting characteristics – including inventory, wattage, and operating hours – for apparel, leather and allied products, and petroleum and coal products were not available within the industrial building lighting sample database. To address this issue and estimate overall inventory *including* these three missing subsectors, the total weighted inventory of the remaining 17 subsectors was divided by the combined percentage of total industrial floorspace associated with the missing subsectors. The additional inventory estimated using this approach was then allocated to each of the three missing subsectors using their relative square footage proportions. To determine other lighting characteristics (e.g., energy consumption, operating hours, etc.), the average lighting distributions of the remaining 17 subsectors were assumed to be representative for building types where survey data were unavailable.

Table 4.23 provides the distribution of lighting technologies in industrial buildings for 2015. The industrial buildings database represents a limited sample size, and therefore, representative lighting characteristics for some building types have greater levels of uncertainty. Similar to the 2010 results, this is most evident when considering the incandescent, halogen, and CFL results per building type. It is likely that these technologies are used to some extent within each industrial building subsector; however, the vast majority of the installed stock are linear fluorescent installations, followed by HID and LED technologies.

Table 4.23 Lighting Technology Distribution by Industrial Building Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Total
Apparel	0.0%	0.0%	0.2%	91.3%	5.6%	2.5%	0.3%	100%
Beverage and Tobacco Products	0.0%	0.0%	0.0%	98.1%	0.0%	1.9%	0.0%	100%
Chemicals	0.1%	0.0%	0.9%	63.0%	24.5%	6.4%	5.1%	100%
Computer and Electronic Products	0.1%	0.0%	0.0%	93.3%	0.0%	6.6%	0.0%	100%
Electrical Equip., Appliances, and Components	0.0%	0.0%	0.6%	95.7%	1.9%	1.8%	0.0%	100%
Fabricated Metal Products	0.0%	0.0%	0.0%	75.4%	13.4%	11.2%	0.0%	100%
Food	0.0%	0.0%	1.1%	94.1%	2.4%	2.4%	0.0%	100%
Furniture and Related Products	0.0%	0.0%	0.0%	93.2%	5.4%	1.4%	0.0%	100%
Leather and Allied Products	0.0%	0.0%	0.2%	91.3%	5.6%	2.5%	0.3%	100%
Machinery	0.0%	0.0%	1.4%	94.2%	2.0%	2.3%	0.0%	100%
Miscellaneous	0.1%	0.3%	0.1%	88.8%	1.2%	9.5%	0.0%	100%
Nonmetallic Mineral Products	0.0%	0.0%	0.0%	98.2%	0.0%	1.8%	0.0%	100%
Paper	0.0%	0.0%	0.0%	97.9%	0.2%	1.9%	0.0%	100%
Petroleum and Coal Products	0.0%	0.0%	0.2%	91.3%	5.6%	2.5%	0.3%	100%
Plastics and Rubber Products	0.0%	0.0%	0.0%	80.5%	10.9%	8.6%	0.0%	100%
Primary Metals	0.0%	0.0%	0.0%	98.2%	0.0%	1.8%	0.0%	100%
Printing and Related Support	0.0%	0.0%	0.0%	97.4%	1.1%	1.5%	0.0%	100%
Textile Mills	0.0%	0.0%	0.0%	98.3%	0.4%	1.3%	0.0%	100%
Textile Product Mills	0.0%	0.0%	0.0%	94.7%	3.9%	1.4%	0.0%	100%
Transportation Equipment	0.0%	0.0%	0.0%	80.1%	13.7%	6.2%	0.0%	100%
Wood Products	0.0%	0.0%	0.0%	83.1%	15.4%	1.5%	0.0%	100%
Average	**0.0%**	**0.0%**	**0.2%**	**89.8%**	**5.7%**	**4.0%**	**0.2%**	**100%**

The average system wattage by lighting technology for industrial buildings is provided in Table 4.24. These wattages account for ballast or driver effects for lamps that operate on external ballasts or drivers. Compared to 2010, there are some differences in the overall weighted averages of each technology, but this is likely due to the underlying variance in the limited industrial sample datasets for each analysis.

Table 4.24 Average Lighting Wattage by Industrial Building Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Average
Apparel	48	52	26	43	447	26	55	65
Beverage and Tobacco Products	-	-	-	89	-	25	-	88
Chemicals	25	-	18	40	411	25	56	130
Computer and Electronic Products	20	-	-	52	-	25	-	50
Electrical Equip., Appliances, and Components	58	-	20	48	447	25	-	55
Fabricated Metal Products	75	40	-	39	503	18	2	99
Food	40	50	16	47	454	21	-	56
Furniture and Related Products	40	-	-	46	458	25	-	68
Leather and Allied Products	48	52	26	43	447	26	55	65
Machinery	60	88	41	33	461	23	-	42
Miscellaneous	61	49	23	39	454	44	2	44
Nonmetallic Mineral Products	-	-	-	35	-	25	-	35
Paper	75	90	15	53	472	25	-	54
Petroleum and Coal Products	48	52	26	43	447	26	55	65
Plastics and Rubber Products	91	-	-	42	411	25	-	80
Primary Metals	-	-	-	31	-	22	-	31
Printing and Related Support	-	-	-	46	334	25	-	49
Textile Mills	-	-	-	32	345	25	-	33
Textile Product Mills	-	-	-	40	465	25	-	56
Transportation Equipment	-	-	27	49	454	25	-	103
Wood Products	-	-	20	46	417	25	-	103
Average	**48**	**52**	**26**	**43**	**447**	**26**	**55**	**65**

Table 4.25 presents the average daily operating hours per building type. Operating hours are based on annual estimates and thus account for seasonal periods of high and low lighting use. The average across the industrial sector is greater than any other building sector largely due to the long business hours associated with many manufacturing facilities.

Table 4.25 Average Daily Operating Hours by Industrial Building Type in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Average
Apparel	12.6	11.7	13.0	12.0	14.2	12.2	12.6	12.1
Beverage and Tobacco Products	-	-	-	12.0	-	12.2	-	12.0
Chemicals	12.6	-	13.0	12.0	14.2	12.2	13.5	12.6
Computer and Electronic Products	12.9	-	-	12.0	-	12.2	-	12.0
Electrical Equip., Appliances, and Components	12.5	-	13.0	12.0	14.2	12.2	-	12.0
Fabricated Metal Products	13.0	11.7	-	12.0	14.2	12.2	24.0	12.4
Food	13.0	11.7	13.0	12.0	14.2	12.2	-	12.1
Furniture and Related Products	12.5	-	-	12.0	14.2	12.2	-	12.1
Leather and Allied Products	12.6	11.7	13.0	12.0	14.2	12.2	12.6	12.1
Machinery	12.1	11.9	13.0	12.0	14.2	12.1	-	12.1
Miscellaneous	11.0	11.6	13.0	12.0	14.2	11.9	24.0	12.0
Nonmetallic Mineral Products	-	-	-	12.0	-	11.9	-	12.0
Paper	12.5	11.7	13.0	12.0	14.2	12.2	-	12.0
Petroleum and Coal Products	12.1	11.7	13.0	12.0	14.2	12.1	12.5	12.1
Plastics and Rubber Products	13.2	-	-	12.0	14.2	12.3	-	12.2
Primary Metals	-	-	-	12.0	-	12.2	-	12.0
Printing and Related Support	-	-	-	12.0	14.2	12.1	-	12.0
Textile Mills	-	-	-	12.0	14.2	12.2	-	12.0
Textile Product Mills	-	-	-	12.0	14.2	12.2	-	12.1
Transportation Equipment	-	-	13.0	12.0	14.2	12.2	-	12.3
Wood Products	-	-	13.0	12.0	14.2	12.2	-	12.4
Average	**11.9**	**11.6**	**13.0**	**12.0**	**14.2**	**12.1**	**13.6**	**12.1**

Table 4.26 displays the lighting electricity consumption for the industrial sector in 2015. The metrics are the same as those discussed for the commercial sector in Section 4.2.2. While operating hours do not vary significantly across the subsectors, wattage is slightly more variable. The final column in Table 4.26 provides a ranking of electricity use per floorspace in order to compare all subsectors by a common metric. Wood product facilities are ranked as the greatest electricity consumer based on this metric, while computer and electronic products ranked as the lowest.

Table 4.26 Lighting Electricity Use by Industrial Buildings in 2015

	Average Lamps per 1,000 ft^2	Installed Wattage (W/ft^2)	Electricity Use per Building (kWh/yr)	Intensity ($kWh/yr/ft^2$)	Intensity Rank
Apparel	14	1.0	74,400	4.0	13
Beverage and Tobacco Products	17	1.5	222,500	6.2	6
Chemicals	7	1.0	86,000	4.8	9
Computer and Electronic Products	7	0.3	85,200	1.6	21
Electrical Equip., Appliances, and Components	19	1.1	194,300	4.5	11
Fabricated Metal Products	12	1.2	178,700	5.7	8
Food	12	0.6	98,100	2.9	15
Furniture and Related Products	19	1.3	276,400	6.3	5
Leather and Allied Products	14	1.0	67,100	2.3	18
Machinery	10	0.4	80,600	2.0	19
Miscellaneous	29	1.3	133,700	5.9	7
Nonmetallic Mineral Products	25	0.9	60,300	3.8	14
Paper	11	0.6	125,400	2.6	17
Petroleum and Coal Products	14	1.0	32,800	4.5	10
Plastics and Rubber Products	7	0.5	160,000	2.7	16
Primary Metals	13	0.4	65,900	1.8	20
Printing and Related Support	41	2.0	209,100	8.5	3
Textile Mills	58	1.9	581,500	7.7	4
Textile Product Mills	33	1.8	292,000	9.5	2
Transportation Equipment	8	0.9	292,000	4.2	12
Wood Products	23	2.3	201,600	11.4	1

4.2.4 Outdoor Results

As discussed in Section 3.3, the outdoor sector covers nine applications of outdoor stationary lighting: airfield, billboard, commercial and industrial building exterior, communication tower, parking, railway, roadway, sports field, and traffic signal. To enable the discussion and comparison with 2015 results, the 2010 LMC outdoor sector results have been updated based on increased data availability since the previous analysis.[34] Those updated 2010 results are presented in Appendix E and discussed below alongside the 2015 results.

Table 4.27 provides the inventory of lighting installations in each outdoor application in 2015. In total, these applications represent 258 million lamps and luminaires. In 2010, the (updated) inventory of lighting products in these applications was approximately 206 million lamps and luminaires.

Table 4.27 Inventory of Lamps[35] by Outdoor Application (1,000s) in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Total
Airfield	338	599	-	-	-	-	-	-	304	-	1,242
Billboard	-	-	-	-	-	487	-	-	114	-	601
Building Ext.: C&I	3,044	2,524	11,121	49,124	1,361	17,414	8,435	-	13,701	1,189	107,914
Comm. Tower	139	2	-	-	-	-	-	-	101	108	350
Parking	1,250	2,790	-	5,558	58	27,076	13,785	-	23,498	9,502	83,519
Railway	376	-	-	-	-	-	-	-	545	-	921
Roadway	59	-	-	-	272	1,073	35,484	940	9,003	1,396	48,227
Sports Field	-	23	-	-	3	300	43	-	85	-	453
Traffic Signal	2,891	-	-	-	-	-	-	-	11,429	-	14,320
Total	8,099	5,939	11,121	54,682	1,694	46,350	57,747	940	58,779	12,195	257,546

The majority of lamps and luminaires are installed in commercial and industrial building exterior, parking, and roadway applications. Together, these three applications comprise over 93 percent of outdoor lighting. The smallest five applications – communication tower, sports field, billboard, railway, and airfield – together amount to less than 2 percent of the total outdoor lighting installed base.

The installed base in these outdoor lighting applications increased by approximately 25 percent since 2010, though most of this growth is attributed to the building exterior application. For both the 2010 and 2015 LMC installments, lighting inventory sample databases for the commercial and industrial sectors contain a relatively small number of buildings with exterior lighting data reported (compared to interior lighting data). For this reason, differences in building exterior sample data unrelated to actual trends may have been exaggerated.

The installed base increased for all outdoor lighting applications, with the exception of railway. The installed base of railway lighting remained nearly constant. This is related to the total length of railroad in the U.S., which has slightly decreased since 2010 (38). Billboard lighting quantities remained essentially constant, likely due to the transition towards digital billboards, which are excluded from this study. Despite increases in road mileage and thus potential display space, many marketers are switching to the more attention-grabbing digital options, according to interviews with industry experts.

In 2015, the most common lighting technologies were LED, high-pressure sodium (HPS), and linear fluorescent – making up 23, 22, and 21 percent, respectively, of the outdoor lighting inventory in these applications. LED lighting is the only technology consistently used across all studied outdoor applications.

[34] To enable a consistent comparison between 2010 and 2015, an analysis of communication tower lighting corresponding to 2010 was completed – even though communication towers were not included in the 2010 LMC – and the results are included in any reference to 2010 LMC outdoor results.
[35] For the 2015 LMC, LED integrated fixtures and luminaires are also included.

Table 4.28 shows the extent to which LED lighting had penetrated the outdoor lighting inventory in 2010 and 2015. As might be expected, the applications with the highest average wattages – billboard and sports field – have seen the most significant growth in LED lighting. In outdoor applications requiring high-lumen output lighting, LED lighting has only recently become cost-effective, which has caused it to grow in commonality at a rapid pace in the past 5 years.

Table 4.28 LED Penetration by Outdoor Application in 2010 and 2015

	LED Penetration	
	2010	2015
Airfield	20%	24%
Billboard	1%	19%
Building Exterior: C&I	0%	13%
Comm. Tower	24%	29%
Parking	4%	28%
Railway	53%	59%
Roadway	5%	19%
Sports Field	0%	19%
Traffic Signal	73%	80%
Average	**8%**	**23%**

The mix of lighting technologies can vary dramatically within a lighting application. For example, in the case of highway lighting, the dominant technology is largely polarized between states. In nine of the 11 surveyed states, one lighting technology is used for over 95 percent of highway lights. However, based on the sample data collected, once states begin to adopt LED lighting, they typically convert nearly all highway lights statewide (46; 52; 45; 50).

Table 4.29 provides the average system wattage of outdoor sector lighting. In the case of externally-ballasted or -driven lamps, ballast or driver effects are included in the provided wattages.

Table 4.29 Average Lighting Wattage by Outdoor Application in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Average
Airfield	105	97	-	-	-	-	-	-	15	-	79
Billboard	-	-	-	-	-	400	-	-	129	-	348
Building Ext.: C&I	69	87	25	38	200	333	183	-	18	19	97
Comm. Tower	403	114	-	-	-	-	-	-	14	131	205
Parking	130	113	-	35	307	407	215	-	105	98	216
Railway	24	-	-	-	-	-	-	-	8	-	15
Roadway	164	-	-	-	211	250	305	108	134	120	262
Sports Field	-	3,478	-	-	1,000	1,421	955	-	770	-	1,357
Traffic Signal	134	-	-	-	-	-	-	-	9	-	34
Average	**107**	**113**	**25**	**38**	**207**	**382**	**266**	**108**	**70**	**93**	**166**

The outdoor lighting applications can be split into two categories based on the intended use of the light: indicators and illuminators. In airfield, communication tower, railway, and traffic signal applications, the light is used as an indicator or signal to convey a message. The remaining applications – billboard, building exterior, parking, roadway, and sports field – use high lumen output lamps to illuminate larger spaces. As expected, lights used as indicators typically have low wattages compared to those used as illuminators. The only exception is communication tower lighting, which must be visible from significant distances.

LED lighting installations represented the lowest-wattage option in all applications except linear fluorescent lamps in parking garages and low-pressure sodium (LPS) and "other" category lamps in roadway applications. The exceptions in roadway lighting are a byproduct of the way the data are aggregated. Street and highway lighting are analyzed separately, and the results are combined into the overall roadway application. LPS and "other" (largely induction) lights are mostly used in street lighting as opposed to highway lighting because of various lighting characteristics. The result is that the overall wattages for LPS and "other" lamps are lower than the wattage of LED lighting installations because they are used in areas requiring less illumination.

Table 4.30 presents the average daily operating hours as a function of application and lighting technology. The operating hours account for flashing as applicable. For example, in the case of a light flashing (at a 50 percent duty cycle) for 12 hours per day, the light operates 6 hours per day. This makes the hours of use appear lower than might be expected for applications in which lights are used as indicators (as opposed to illuminators).

Parking lighting installations, especially those used inside structures, operate the longest because they are often illuminated during both day and night, unlike many other applications. According to industry experts, an increasing number of parking garages have begun installing motion-activated lighting systems, which can dramatically decrease operating hours. Fixtures in open-air parking lots are assumed to be equipped with a photocell and thus operational only during non-daylight hours.

On average, railway lighting installations are illuminated fewer hours than those in other outdoor applications because the majority of signals are activated for only a brief period of time when a train is nearby. Some wayside signals are illuminated all day, but they are becoming less common (40; 42).

Sports field lighting is also used only a few hours per day. This is because field illumination is typically necessary only when the field is being used during non-daylight hours.

Intuitively, it seems that traffic signals are operated 24 hours per day. However, given that only one of each signal's three lamps – red, yellow, and green – is illuminated at any given time, each light is illuminated an average of 8 hours daily. Operating hours of pedestrian and arrow signal vary by type, but the average for those types of signals is approximately 8.2 hours per day.

Table 4.30 Average Daily Operating Hours by Outdoor Application in 2015

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Average
Airfield	4	4	-	-	-	-	-	-	3	-	4
Billboard	-	-	-	-	-	10	-	-	10	-	10
Building Ext.: C&I	8	8	9	9	9	9	9	-	9	22	9
Comm. Tower	10	10	-	-	-	-	-	-	10	4	8
Parking	20	20	-	20	13	14	16	-	16	16	16
Railway	3	-	-	-	-	-	-	-	1	-	1
Roadway	12	-	-	-	12	12	12	12	12	12	12
Sports Field	-	2	-	-	2	2	2	-	2	-	2
Traffic Signal	8	-	-	-	-	-	-	-	8	-	8
Average	**10**	**13**	**9**	**10**	**9**	**12**	**12**	**12**	**12**	**16**	**13**

Table 4.31 provides the electricity consumption of each of the outdoor applications. Parking and roadway lighting – with their high prevalence and high wattages – together consumed 82 percent of the outdoor sector's electricity. Commercial and industrial building exterior lighting consumed 16 percent of the total. Less than 2 TWh per year was consumed by each of the remaining outdoor applications. Across all outdoor applications,

metal halide and HPS lighting consumed 40 percent and 39 percent, respectively, of the total outdoor electricity consumption.

Table 4.31 Lighting Electricity Consumption by Outdoor Application in 2015 (TWh/yr)

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Total
Airfield	0	0	-	-	-	-	-	-	0	-	0
Billboard	-	-	-	-	-	1	-	-	0	-	1
Building Ext.: C&I	1	1	1	6	1	18	5	-	1	0	33
Comm. Tower	0	0	-	-	-	-	-	-	0	0	0
Parking	1	2	-	1	0	61	19	-	13	6	103
Railway	0	-	-	-	-	-	-	-	0	-	0
Roadway	0	-	-	-	0	1	55	1	5	1	63
Sports Field	-	0	-	-	0	0	0	-	0	-	1
Traffic Signal	1	-	-	-	-	-	-	-	0	-	1
Total	**3**	**3**	**1**	**7**	**1**	**81**	**79**	**1**	**19**	**6**	**202**

4.3 Lighting Controls

In recent years, lighting controls have become the focus of building codes and design as a potential method of more intelligently operating lighting systems to save energy. Lighting controls – which include various dimming and sensor technologies used separately or in conjunction with other systems, such as timers and daylighting – can yield significant energy savings because they use feedback from the lit environment to provide adequate lighting only when needed.

Lighting controls can save energy by either reducing input wattage or limiting hours of operation. The average operating hours presented in this report account for the use of certain controls, such as timers and occupancy sensors, because they are based on building surveys and metering data. However, there are other controls, such as dimmers, that reduce light levels and therefore also reduce wattages.

For the 2015 LMC, the prevalence and energy savings of lighting controls in the residential and commercial sectors were estimated based on the available controls data in the various sampled datasets, spanning several geographic regions. These data were scaled to a national level using the same methodology as described in Section 3.2.1. The industrial and outdoor sectors were not included in this part of the analysis due to insufficient data, and, based on expert surveys, controls were assumed to be included in most of the operating hours assumptions in the outdoor sector. It is important to note that the control estimates presented in the following tables are reflective of sampled inventories that prioritized additional lighting characteristics (e.g., number of lighting installations, wattage, etc.) during compilation. The actual saturation of controls is higher than the estimates presented in this report.

As discussed in Section 3.2.4, only control strategies that impact wattage were considered for energy savings estimates in this results section. The energy savings of these strategies were estimated by using values determined for the DOE SSL Program's 2016 Energy Savings Forecast Report (69). The energy savings allocated to each control strategy were applied at the lamp or luminaire level in the inventory so that the energy savings were then scaled to a national level based on inventory weightings. The following discussion provides a brief description of each of the lighting control strategies[36] examined in this study:

- **Dimmers** allow users of conventional lighting technologies to manually regulate the level of lighting in a building by adjusting the voltage reaching the lamp. As voltage input is reduced, either by way of a step function or a continuous function, the lumen output of the system is proportionally decreased. For LED lamps or luminaires, dimming is achieved by pulse width modulation or constant current reduction. Pulse width modulation dimming enables LED lamps or luminaires to dim by switching current at a frequency from zero to the rated output current. Constant current reduction dimming modifies lumen output by reducing or increasing the current that is continuously flowing through the LED, which is proportional to the lighting level of the LED.
- **Daylighting** utilizes photosensors and daylight harvesting to dim or cycle (on/off) lighting in response to detected natural light levels. Daylighting regulates light output to supplement available daylight with an optimized level of artificial light output.
- **Occupancy sensors**, or motion detectors, switch the lamp or luminaire on for a set period of time in response to detected motion and are useful in areas that are sporadically occupied. This control type saves energy by reducing hours of operation of lighting.
- **Timers** provide lighting service on a preset schedule, without the need for manual operation. This control type also saves energy by reducing hours of operation.

[36] Connectivity, where energy savings are optimized and there is the ability to communicate between lamps and luminaires, is an additional strategy emphasized in the SSL Program's Energy Savings Forecast Report. However, the weighted results in this analysis do not register significant values for any of the building sectors.

- **Energy management systems** are information and control systems that monitor occupancy and lighting in the built environment in order to provide centralized lighting control. They often combine several of these control technologies to reduce energy consumption.
- **Multi-strategy systems** are any combination of two, three, or four of the above-mentioned control strategies (e.g., occupancy sensors and dimming) implemented together on the same lamp or luminaire. However, it is assumed that there is no communication between different lamps and luminaires within the space.

As depicted in Table 4.32, lighting controls are more frequently installed in the commercial sector than in the residential sector, with an estimated 18 percent of lamps in the commercial sector being used in conjunction with lighting controls. This is in contrast to only 10 percent of residential lighting installations being used with lighting controls.

Control Penetration Trends

It is important to note that the results of this analysis show that control saturation has decreased since the 2010 LMC analysis. This trend is unlikely. Nearly all evidence suggests that control usage has increased over the past 5 years due to growing attention on controls in state and municipality building code requirements. One possible explanation for the difference between the 2010 and 2015 results is the (difference in) geographical bias within the sampled datasets. The 2010 LMC was primarily based on data sourced from California or nearby states, which have shown more progressive steps than other regions to integrate energy efficiency (including an early adoption of controls) into the built environment. The 2015 LMC sample data has a relatively lower proportion of data sourced from California.

Although the 2015 LMC presents a decrease in overall control saturation, there is a noticeable increase in occupancy sensor saturation, particularly in the commercial sector. This increase in occupancy sensors could be a primary factor for lower operating hours in the commercial sector, discussed in Section 4.2.2, compared to the 2010 LMC.

Table 4.32 Prevalence of Lighting Controls by Sector

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Residential	89%	8%	0%	1%	0%	0%	1%	100%
Commercial	82%	1%	1%	10%	1%	5%	1%	100%

Table 4.33 presents the prevalence of lighting controls in the residential sector by lighting type. Even though incandescent lamps have a longer history of control compatibility, they are not the technology most likely to be used with lighting controls in the residential sector. Instead, the analysis indicates that LED lamps and luminaires are more likely to be used in conjunction with lighting controls, mostly with dimmers. However, because incandescent lamps represent a much larger share of the residential sector inventory than other lamp types, the 12 percent of incandescent lamps used with dimmers represent the vast majority of residential lamps used with lighting controls.

Table 4.33 Prevalence of Lighting Controls in the Residential Sector by Lighting Technology

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Incandescent	86%	12%	0%	0%	0%	-	1%	100%
Halogen	83%	11%	0%	1%	0%	-	4%	100%
CFL	96%	3%	0%	0%	0%	-	1%	100%
Linear Fluorescent	99%	0%	0%	1%	0%	-	0%	100%
HID	-	-	-	-	-	-	-	-
LED	80%	15%	0%	1%	1%	-	2%	100%
Other	71%	6%	0%	22%	0%	-	0%	100%

Table 4.34 presents the estimated prevalence of lighting controls in the residential sector by room type. As seen below, interior lighting controls are most likely to be found in the dining room and living room, with dimmers being the predominate lighting control strategy. The most predominant application employing multiple control strategies is the exterior application, which is typically a combination of daylighting and occupancy (motion) sensors.

Table 4.34 Prevalence of Lighting Controls in the Residential Sector by Room Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Basement(s)	91%	8%	0%	0%	0%	-	0%	100%
Bathroom(s)	95%	3%	0%	1%	0%	-	1%	100%
Bedroom(s)	93%	6%	0%	0%	0%	-	0%	100%
Closet(s)	100%	0%	0%	0%	0%	-	0%	100%
Dining Room(s)	70%	30%	0%	0%	0%	-	0%	100%
Exterior(s)	81%	0%	1%	4%	2%	-	12%	100%
Garage(s)	97%	0%	0%	1%	0%	-	1%	100%
Hall(s)	93%	6%	0%	0%	1%	-	0%	100%
Kitchen(s)	88%	12%	0%	0%	0%	-	0%	100%
Laundry / Utility Room(s)	98%	1%	0%	0%	0%	-	0%	100%
Living / Family Room(s)	84%	15%	0%	0%	0%	-	0%	100%
Office(s)	88%	11%	0%	0%	0%	-	0%	100%
Other	90%	9%	0%	1%	1%	-	0%	100%

Table 4.35 presents the prevalence of lighting controls by residence type. As seen below, single family homes are the most likely to have controls installed, with dimming being the predominant control strategy used.

Table 4.35 Prevalence of Lighting Controls in the Residential Sector by Residence Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Single Family	89%	8%	0%	1%	0%	-	1%	100%
Multifamily	91%	8%	0%	1%	0%	-	1%	100%
Mobile Home	99%	-	-	-	-	-	1%	100%

Table 4.36 shows the likelihood of finding lighting controls in the commercial sector. These results show that approximately 18 percent of all lamp types are used in conjunction with lighting controls. Energy management systems and occupancy sensors are often the most prevalent control strategies used in the commercial sector.

Table 4.36 Prevalence of Lighting Controls in the Commercial Sector by Lamp Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Incandescent	87%	8%	0%	1%	2%	2%	0%	100%
Halogen	90%	4%	0%	2%	0%	4%	0%	100%
CFL	86%	1%	0%	5%	3%	5%	1%	100%
Linear Fluorescent	83%	0%	0%	10%	1%	4%	1%	100%
HID	82%	0%	0%	2%	1%	15%	0%	100%
LED	69%	2%	4%	12%	1%	10%	2%	100%
Other	96%	0%	0%	0%	1%	2%	0%	100%

The choice of lighting controls also depends on the building type and the application of the space being used. As seen in Table 4.37, commercial lighting controls are most popular in warehouse and storage applications, with occupancy sensors being the most common control strategy. Controls are also commonly used in public assembly, public order, and retail applications.

Table 4.37 Prevalence of Lighting Controls in the Commercial Sector by Building Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Education	83%	0%	2%	8%	1%	4%	2%	100%
Food sales	84%	0%	0%	4%	2%	9%	0%	100%
Food service	92%	2%	0%	3%	2%	0%	0%	100%
Health care - Inpatient	92%	0%	0%	5%	0%	2%	1%	100%
Health care - Outpatient	96%	0%	0%	2%	0%	1%	0%	100%
Lodging	92%	2%	0%	3%	1%	1%	0%	100%
Offices (Non-medical)	83%	0%	0%	8%	4%	5%	1%	100%
Other	88%	0%	0%	5%	0%	5%	2%	100%
Public assembly	77%	1%	0%	11%	1%	9%	1%	100%
Public order and safety	81%	2%	0%	9%	1%	6%	0%	100%
Religious worship	87%	2%	0%	7%	0%	4%	0%	100%
Retail - Mall & Non-Mall	81%	0%	0%	3%	2%	13%	1%	100%
Services	97%	1%	0%	2%	0%	0%	0%	100%
Warehouse and storage	57%	0%	0%	34%	1%	6%	2%	100%

Lighting controls equate to energy savings only if they are used. As mentioned, energy savings discounts are applied to control strategies that impact wattage, based on the energy savings potential of those strategies in various end-use applications compared to baseline (i.e., no controls) load profiles analyzed in the 2016 Energy Savings Forecast Report. Table 4.38 summarizes the energy savings of the control strategies found in this analysis for the residential and commercial sectors, compared to the original electricity consumption estimates (as discussed previously) that do not incorporate the presence of controls impacting wattage.[37] Overall, an estimated 5 TWh is saved in the national inventory considered in this analysis due to the impact of controls.

Table 4.38 Energy Savings of Lighting Controls by Sector (GWh Saved Per Year)

	Dimmer	Daylighting	EMS	Multi	Total
Residential	505	50	-	1,284	1,839
Commercial	66	160	2,525	413	3,163
Total	**571**	**210**	**2,525**	**1,696**	**5,002**

[37] For comparison purposes with the 2010 LMC, which does not incorporate controls impacting wattage into the electricity consumption estimates, Table 4.8 in Section 4.1 does not incorporate the energy savings discussed in this section.

5 Results Summary

In 2015, the total primary energy consumption in the United States was 97 quads, according to the EIA's AEO 2017 (72). Roughly 44 quads (or 45 percent) of this energy was consumed for electricity use. The breakout of the total electricity consumption by each sector is displayed in Figure 5.1 below. Note that this is a breakdown of total electricity consumption and not just lighting.

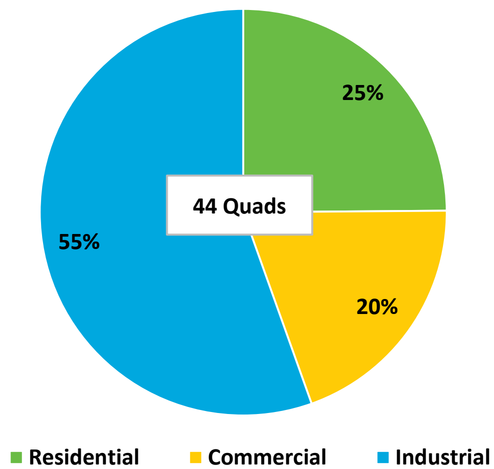

Figure 5.1 U.S. Delivered Electrical Energy Consumption in 2015[38]

In 2015, the total amount of electricity consumed by lighting technologies is estimated to be 641 TWh, or 6.5 quads.[39] Thus, lighting accounted for 7 percent of the total energy and 17 percent of the total electricity consumed in the U.S. in 2015.[40] This is equivalent to the total energy consumed by over 59 million homes and the energy produced by 209 500-megawatt (MW) coal burning power plants (73).

The following section summarizes the results presented in Section 4 of this report.

5.1 Lighting Market Characteristics

Figure 5.2 displays the breakdown of the inventory estimates, total lighting electricity consumption, and the lumens produced by sector. The residential sector accounts for the overwhelming majority of installed lighting at 71 percent of the nationwide installed base. However, in terms of electricity, the sector only consumes 149 TWh, or 23 percent of the national total. Due to the relatively low efficacy of residential light sources (especially incandescent), the residential sector only accounts for 10 percent of the lumens produced.

The commercial sector is the greatest energy consumer, accounting for 37 percent of the total lighting electricity consumption. In addition, the commercial sector represents the sector in which the greatest number of lumens is produced – 45 percent of all lumens produced. This is largely due to the longer operating hours found in the commercial sector as compared to the residential sector. Both the industrial and outdoor sectors make up a relatively small portion of the total installed stock of lighting, each 3 percent or less. However, the use of high lumen output lighting products and high operating hours results in these sectors consisting of proportionally greater shares of total electricity consumption and lumen production.

38 Residential sector includes public street and highway lighting, interdepartmental sales, and other.
39 Conversion to quads from TWh estimates includes site to source electricity conversion of 3.14.
40 Based on a total electricity consumption of 44.1 quads of source energy for residential, commercial, and industrial sectors from AEO.

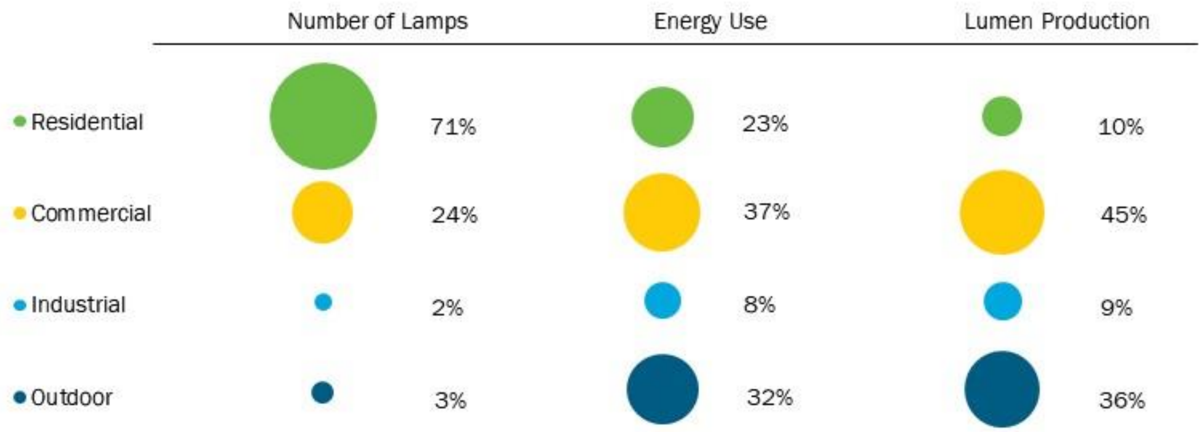

Figure 5.2 U.S. Lighting[41] Inventory, Electricity Consumption and Lumen Production in 2015

Figure 5.3 portrays the same electricity consumption data from Figure 5.2, except this time disaggregated by lighting technology. At 35 percent of the total, HID/Other[42] lighting types consumed the greatest amount of electricity, followed by linear fluorescent lamps at 33 percent of the total, primarily due to their high operating hours in the commercial and industrial sectors. In 2010, fluorescent lamps were the largest consumer of electricity.

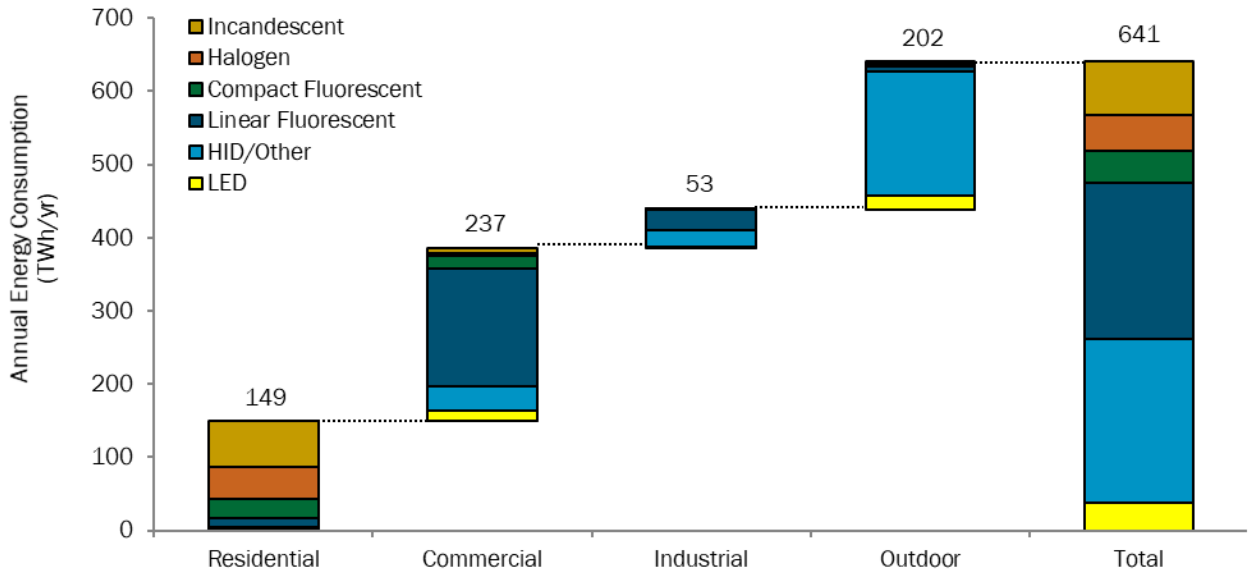

Figure 5.3 U.S. Lighting Electricity Consumption by Sector and Technology Type in 2015

[41] For the 2015 LMC, LED integrated fixtures and luminaires are also included.
[42] The other category is comprised of illuminated exit signs and other lamps that do not fall into any of the previous categories, such as fiber optic lights, induction lamps, xenon lamps, and lamps of unknown characteristics.

In the residential sector, incandescent lamps were the largest consumers of electricity. In 2015, these lamps made up 42 percent of the total sector consumption. This is a dramatic shift from 2010 when incandescent lamps consumed 78 percent of the total sector electricity. In 2015, halogen lamps and CFLs accounted for 28 percent and 18 percent of residential sector lighting consumption, respectively. LED and HID/other technology lamps consumed 2 percent and 1 percent, respectively.

In the commercial sector, fluorescent lamps consumed the most energy, accounting for 76 percent of the sector's lighting electricity consumption. HID lamps were the second largest electricity consumer – approximately 13 percent of the commercial sector total – followed by LED and incandescent technologies at 6 percent and 3 percent, respectively. As was the case in 2010, the industrial sector is dominated by two lamp technologies. Linear fluorescent lamps were the main electricity consumer at 55 percent of the total lighting electricity use, while HID lamps, at 44 percent, make up most of the remaining balance.

Though the technology mix varies widely in the outdoor sector depending on the subsector (e.g., 80 percent of traffic signals are installed with LED lighting, while over 80 percent of billboard applications used metal halide technology), on a sector-wide basis, HID lamps were the most consuming technology, accounting for 80 percent of the sector's total electricity consumption.

To understand the energy use of lighting and the savings that can be realized by switching to more efficient lighting sources, it is important to recognize the relationship between lumens produced and electricity used. Wattage is a measure of power input while lumens produced is a measure of light output. The lumen output per watt of power input defines the efficacy (lm/W) and is the key measure of a lamp or luminaire's energy performance. Figure 5.4 depicts the overall lighting efficacies in terms of sector and technology. Interestingly, the average LED efficacy is lower than fluorescent and HID technologies. This difference can be attributed to the variance in LED lighting performance, as detailed in DOE's 2015 LED Adoption Report (74).

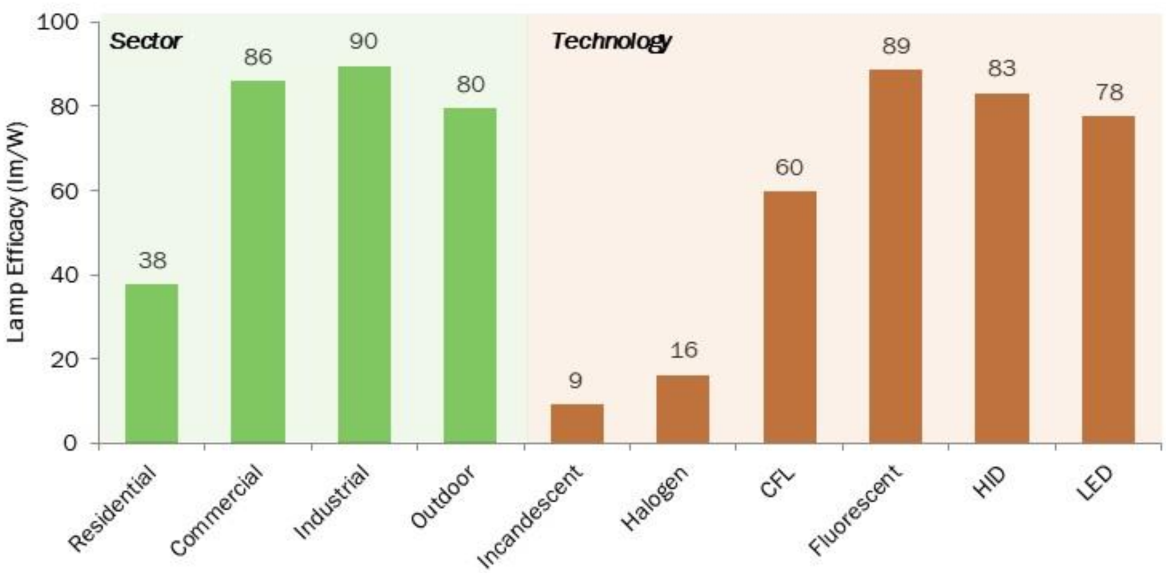

Figure 5.4 Lighting Efficacies as a Function of Sector and Technology Type

Figure 5.5 provides the lumen production for each sector by technology type in Teralumen-hours per year. Annual lumen production is calculated by multiplying the wattage per lamp or luminaire by its average efficacy and its operating hours per year.

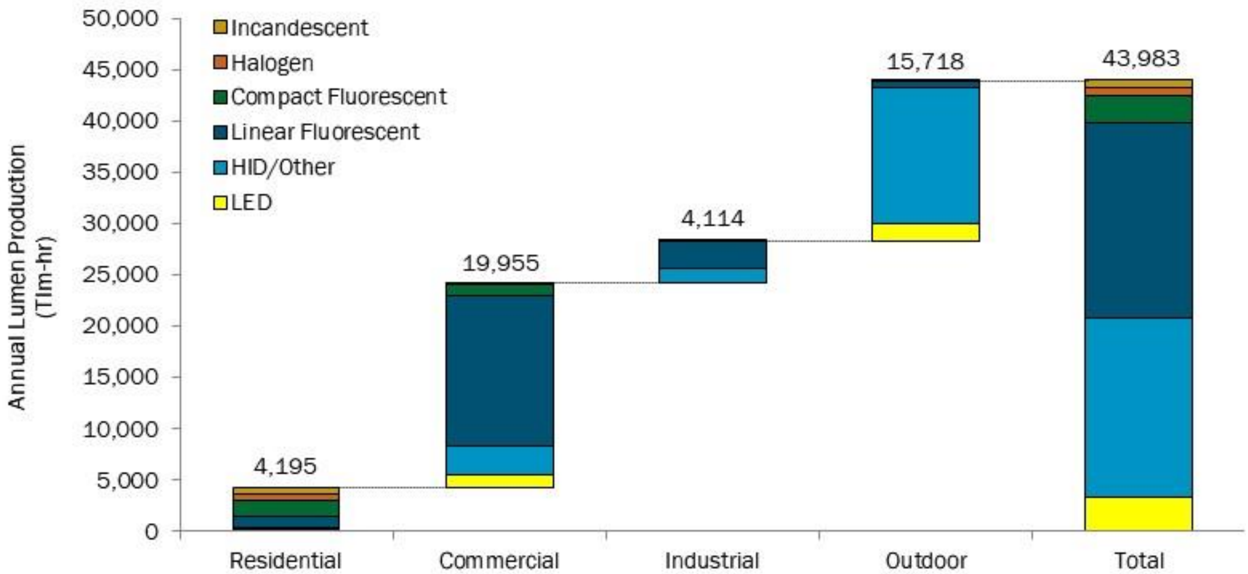

Figure 5.5 U.S. Lumens Production by Sector and Technology Type in 2015

The commercial sector nearly used more light than all the other sectors combined, largely due to its high average operating hours and large volume of floorspace. The outdoor sector produced the second greatest quantity of lumens, also due to the use of high lumen output lighting products for long operating hours (in this case, largely during the night). The residential sector, which houses the largest quantity of installed lighting stock but predominately utilizes low lumen output lighting products for relatively few hours per day, used the third most light. The industrial sector used the least light.

Across all sectors, fluorescent lamps, responsible for approximately 49 percent of annual lumen production nationally, produced the most lumens of all lighting technologies. HID light sources were the second most dominant, producing about 39 percent of the total national light output. LED lighting has begun to play a more significant role than in the past. In 2015, 7 percent of light produced nationwide came from LED lighting sources; in contrast, this value was less than 1 percent in 2010. Because incandescent lamps are most often found in sockets that are turned on relatively infrequently, and given their characteristically low lumen outputs, the total lumen production of the technology accounts for only 2 percent of the total. This is a noteworthy decrease from 5 percent corresponding to 2010.

In summary, Table 5.1 and Table 5.2 present the sectoral lighting energy consumption estimates in terms of both delivered (end-use) and primary (source) energy. They also provide the estimated average annual energy consumption for lighting per building and by technology.

Table 5.1 U.S. Annual Lighting Energy Use Estimates by Sector in 2015

	Electricity Use Per Building (kWh/yr)	Number of Buildings	Total Site Energy Consumption (TWh/yr)	Total Primary Energy Consumption (quads/yr)	Percent of Total
Residential	1,242	119,969,000	149	1.5	23%
Commercial	44,156	5,370,000	237	2.6	37%
Industrial	142,070	370,000	53	0.5	8%
Outdoor	N/A	N/A	202	1.9	32%
Total	**N/A**	**N/A**	**641**	**6.6**	**100%**

Table 5.2 U.S. Annual Lighting Energy Use Estimates by Sector and Lighting Technology in 2015

	Incandescent		Halogen		CFL		Linear Fluorescent		HID		LED		Other		Total	
	TWh	Quad	TWh	Quad	TWh	Quad	TWh	Quad	TWh	Quad	TWh	Quad	TWh	Quad	TWh	Quad
Residential	63	0.65	42	0.44	26	0.27	14	0.14	0	0.00	3	0.03	1	0.01	149	1.54
Commercial	7	0.07	3	0.04	17	0.18	162	1.68	31	0.32	15	0.16	0	0.00	237	2.45
Industrial	0	0.00	0	0.00	0	0.00	29	0.30	23	0.24	1	0.01	0	0.00	53	0.54
Outdoor	3	0.03	3	0.03	1	0.01	7	0.08	162	1.68	19	0.20	6	0.07	202	2.09
Total	**73**	**0.76**	**49**	**0.51**	**44**	**0.46**	**212**	**2.19**	**217**	**2.24**	**38**	**0.39**	**8**	**0.08**	**641**	**6.63**

5.2 Comparison to 2001 and 2010 LMC Results

Section 3 describes departures in the analysis methodology relative to the 2010 LMC. Section 4 presents the detailed results of the 2015 LMC, with references to how characteristics of the installed base of lighting have changed since 2010. Section 5 provides an overall summary of the 2015 LMC results. The following section provides a holistic, but higher-level comparison of installed lighting characteristics between the 2001, 2010, and 2015 LMC installations.

Between 2001 and 2015, the general trend in lighting nationwide has been an increase in lighting inventory and efficacies, while wattages and typical operating hours have decreased (for the building sectors). Table 5.3 provides a sectoral breakdown of these changes.

Table 5.3 Comparison of Lighting Characteristics in 2001, 2010, and 2015

	Lamps (million)			Average Daily Operating Hours			Wattage per Lamp			Electricity Use (TWh)		
	2001	2010	2015	2001	2010	2015	2001	2010	2015	2001	2010	2015
Residential	4,611	5,812	6,219	2.0	1.8	1.9	63	46	38	208	175	149
Commercial	1,966	2,069	2,076	9.9	11.2	8.9	56	42	36	391	349	237
Industrial	327	144	172	13.5	13.0	12.1	65	75	65	108	58	53
Outdoor	73	206	258	10.5	12.0	13.4	205	183	166	58	195	202
Total	**6,977**	**8,231**	**8,725**	**4.8**	**4.6**	**4.1**	**62**	**49**	**42**	**765**	**777**	**641**

Figure 5.6 depicts a summary of the changes in lighting inventory between the 2001, 2010, and 2015 LMC editions.

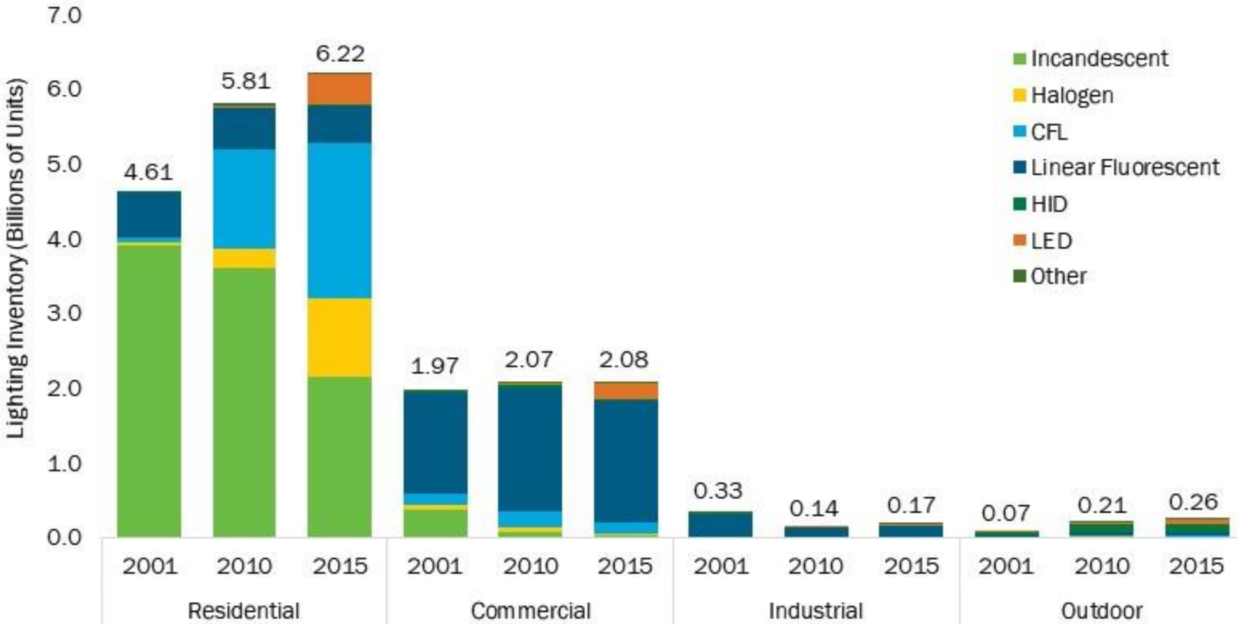

Figure 5.6 Comparison of Lighting Inventories by Sector and Technology Type in 2001, 2010, and 2015

Increases in installed base can be partially attributed to growing floorspace and building counts nationwide, as shown in Figure 5.7.

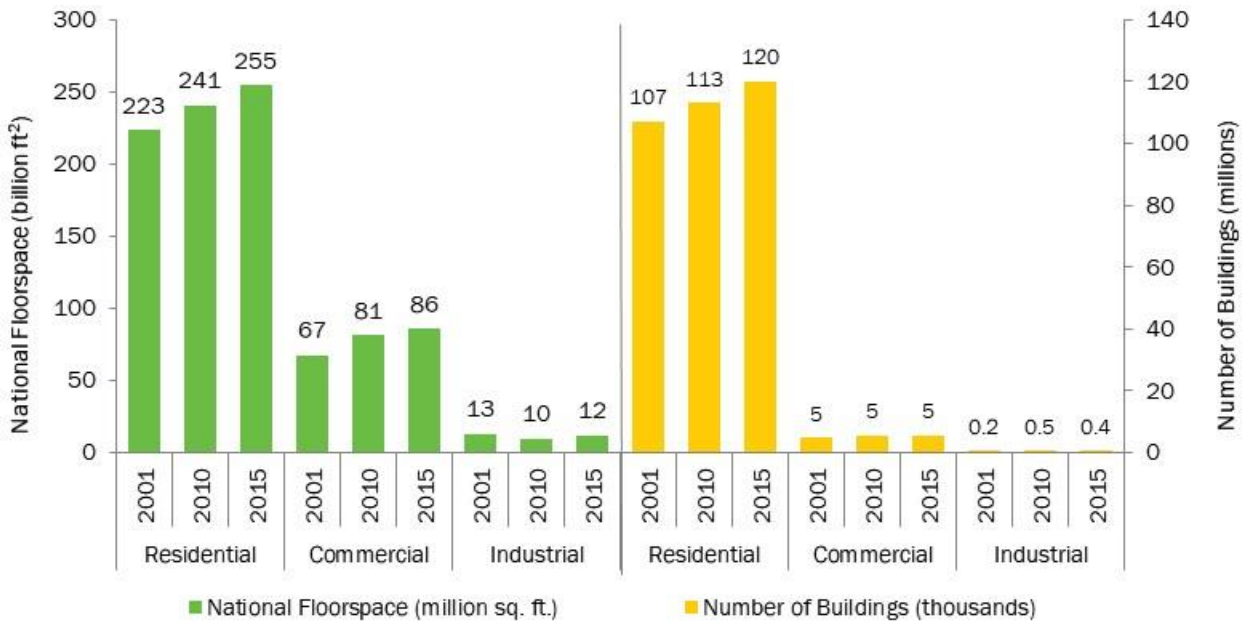

Figure 5.7 Trends in National Floorspace and the Number of Buildings Nationwide[43]

Figure 5.8 provides the corresponding summary of the ways in which electricity consumption has varied by lighting technology and sector.

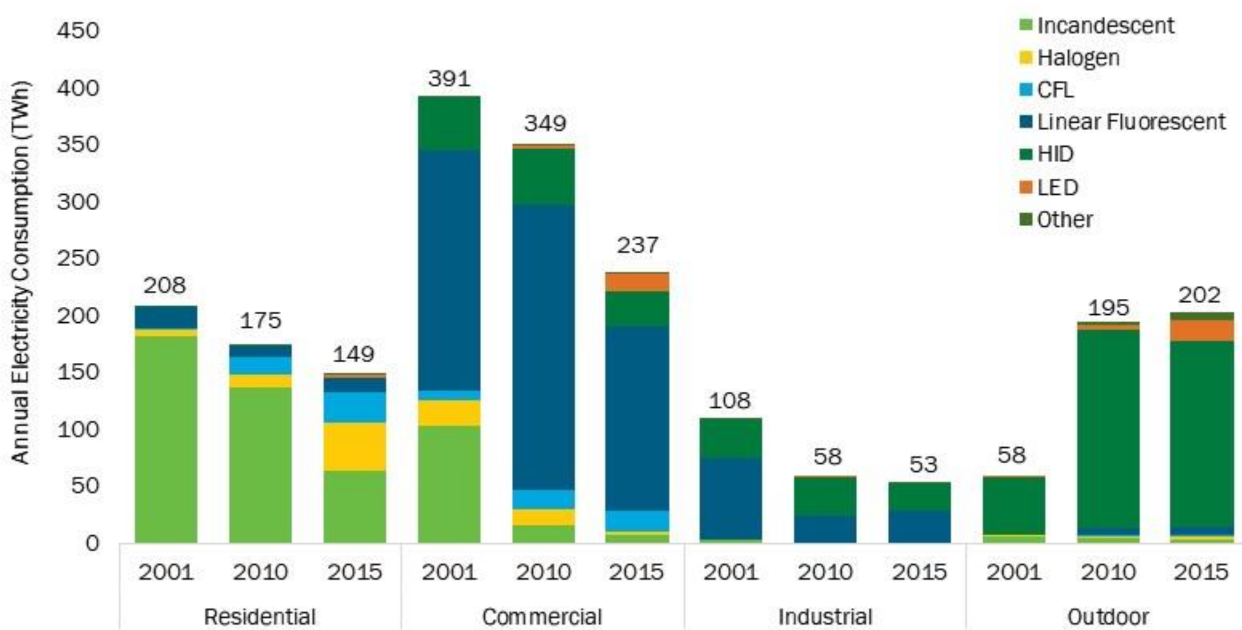

Figure 5.8 Comparison of Electricity Consumption by Sector and Lighting Technology in 2001, 2010, and 2015

Within the residential sector, there was a continual growth of floorspace and number of buildings between 2001 and 2015. However, the increasing prominence of LED, compact fluorescent, and halogen lighting (and

[43] As previously noted, the 2010 LMC underestimated total industrial floor space and overestimated total building count relative to the subsequently published 2010 MECS, upon which industrial building count and floor space for the 2015 LMC are based.

decreased prominence of incandescent lamps) caused a decrease in average wattage, which largely explains the decline in electricity use.

Between 2001 and 2015, the commercial sector installed base increased, but this increase lagged the growth of commercial floorspace. From 2010 to 2015, the installed base grew approximately 0.1 percent annually, whereas commercial floorspace grew approximately 0.8 percent annually. Overall, the commercial sector saw a decrease in electricity consumption, in part the result of decreasing lamp and luminaire wattages and typical operating hours, the latter of which is likely due to the greater prevalence of controls.

In the industrial sector, there was a large decrease in the estimated installed base between 2001 and 2010, which was largely due to differences in estimated industrial floorspaces used by the two studies. This decrease in installed base is also directly responsible for the decrease in electricity consumption between 2001 and 2010. Between 2010 and 2015, the installed base increased by approximately 19 percent, and this growth can be attributed to a growth in overall industrial floorspace compared to the 2010 LMC.[44] Although the installed base increased, the decrease in electricity consumption can be primarily attributed to a shift towards more efficacious lighting installations, as the industrial sector average efficacy increased from approximately 77 lm/W in 2010 to 90 lm/W in 2015.

The outdoor sector experienced the greatest relative increase in lighting inventory from 2001 to 2010 and from 2010 to 2015. This is partially due to new applications considered in the current report, the classification differences between the two reports, and the increasing popularity of outdoor lighting. Commercial and industrial building exterior lighting – which was previously classified in the commercial and industrial sectors in the 2001 LMC, but in the outdoor sector for the 2010 LMC and 2015 LMC – accounted for 42 percent of the outdoor sector's lighting inventory in 2015. Due to building exterior dataset variations and updated methodologies, the lighting inventory in this application increased from 62 million in 2010 to 108 million in 2015. Excluding the building exterior lighting application, the remaining outdoor lighting applications grew approximately 4 percent from 2010 to 2015. As detailed in Section 4.2.4, the penetration of LED lighting increased significantly in many outdoor applications. Based on the adjusted 2010 values (found in Appendix E), LED lighting grew from 8 percent of the installed outdoor inventory in 2010 to 23 percent in 2015.

Much of the reduction in lighting electricity use since 2001 has occurred as a result of the migration toward higher efficacy light sources and an increase in overall stock efficacy. The average efficacy, in lumens per watt, is depicted in Figure 5.9 for each sector in 2001, 2010, and 2015.

Average Efficacy Updates

The lamp efficacies depicted do not account for fixture losses but do include ballast effects. The efficacy values corresponding to 2001 and 2010 reported here are lower than the values reported in the 2010 LMC due to a change in calculation methodology. The efficacy values for specific lighting product categories have not been altered. Rather, the decreased efficacy is the result of standardizing the methodology for calculating the weighted-average efficacy. In past editions of the LMC, the average efficacy was calculated by dividing the total lumens produces by the total electricity consumed. This approach has been updated in order to create a more robust, consistent analysis. The updated calculation methodology weights the efficacy of every lamp and luminaire equally. Each value of average efficacy was determined as an average of lighting type-specific efficacies, which was then weighted by the installed base of that lighting product category. Since the analyses in 2001 and 2010 used different methodologies, the corresponding efficacies have been updated using the new calculation methodology. The efficacy assumptions are presented in Appendix C of this report.

[44] As outlined in section 3.2.1, the 2010 LMC underestimated 2010 industrial floorspace (and overestimated total industrial building count) relative to the subsequently published 2010 MECS. This has the effect of artificially inflating the growth rate in industrial floorspace between the 2010 and 2015 LMC studies.

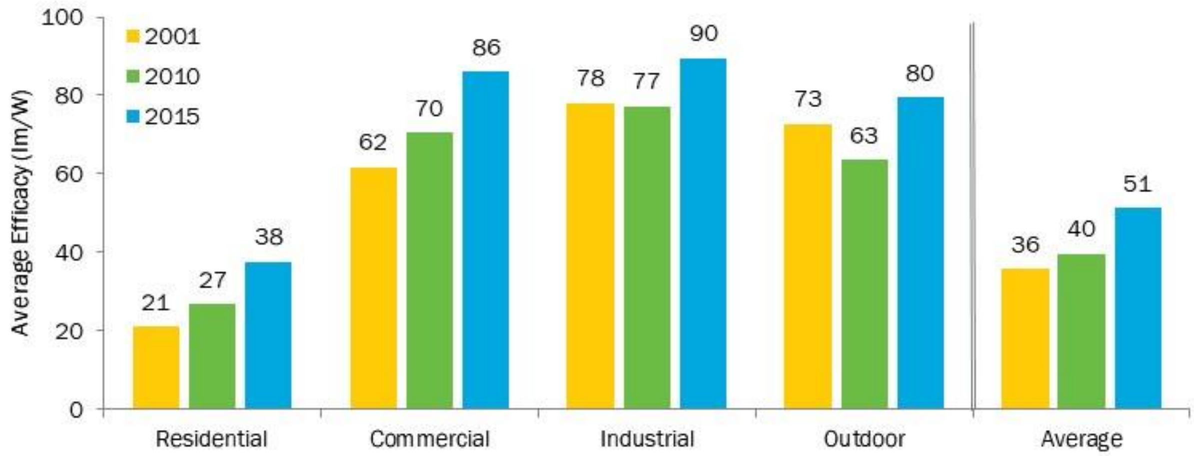

Figure 5.9 Average Efficacy by Sector in 2001, 2010, and 2015

As evident in Figure 5.9, the most inefficient lighting sector in 2015 was the residential sector. This was also true in 2001 and 2010. Despite their decreasing presence, incandescent lamps still accounted for over one third of all residential lighting inventory. The average efficacy of lighting in the commercial and industrial sectors was relatively similar. The relatively high efficacies are the result of significant reliance on primarily fluorescent and, to an increasing extent, LED technologies. These technologies account for 97 percent and 94 percent of the lighting inventory in each the commercial and industrial sectors, respectively. The efficacy of lighting in the outdoor sector is determined mostly by HID, fluorescent and LED technologies, which account for 41 percent, 25 percent, and 23 percent of the installed base, respectively. While the outdoor sector has a much higher concentration of HID lamps than other sectors, it also has the highest percentage of LED lighting. These competing characteristics result in a sector-wide efficacy that is notably higher than the national average. Overall, the national average efficacy has increased by over 40 percent since 2001, marking a significant trend toward more efficient lighting in the U.S.

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6 Comparison of Lighting Electricity Consumption Estimates

The previous sections of this report provide discussion and analysis comparing the 2015 LMC results to those of the 2001 and 2010 LMC installments. Though the 2001 and 2010 LMC values are shown in Section 5.2 for comparison, this discussion focuses on comparing the 2015 LMC results to the results of the other studies listed.

Table 6.1 Annual Lighting Electricity Consumption Estimates

Source	Model Year	Annual Lighting Electricity Consumption (TWh/yr)
Residential		
LMC, 2002	2001	208
LMC, 2011	2010	175
EIA, AEO 2011	2010	208
EIA, AEO 2016	2015	143
LMC, 2015	2015	149
Commercial		
LMC, 2002	2001	391
CBECS, 2003	2003	393
EIA, AEO 2011	2010	299
LMC, 2011	2010	349
CBECS, 2016	2012	212
EIA, AEO 2016	2015	254
LMC, 2015	2015	237
Industrial		
LMC, 2002	2001	108
MECS, 2006	2003	58
LMC, 2011	2010	58
MECS, 2013	2010	48
LMC, 2015	2015	53
Outdoor		
LMC, 2002	2001	87
LMC, 2011	2010	195
LMC, 2015	2015	202

In the residential sector, the estimate of lighting electricity consumption is approximately 5 percent more than the prediction from the EIA's AEO. For the commercial sector, the two estimates are similar, with the EIA AEO prediction at 254 TWh and the 2015 LMC at 237 TWh.

The industrial sector results from the 2015 LMC indicate that lighting consumed approximately 53 TWh in 2015. The 2013 MECS indicated that electricity consumption from industrial lighting was approximately 48 TWh in 2010.

The only comparable studies found that provided lighting energy use for the entire outdoor sector are the 2001 LMC and the 2010 LMC.

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Appendix A Lighting Product Category Descriptions

Table A.1 Lighting Product Category Descriptions

Lighting Product Category		Description
INCANDESCENT	General Purpose – A-Shape	Standard incandescent lamps with an A-shaped bulb of all base types.
	General Purpose – Decorative	Standard incandescent lamps with a globe-, bullet-, candle-, or other decorative-shaped bulb of all base types.
	Reflector	Reflectorized incandescent lamps with an ER-, BR-, PAR-, or other reflector-shaped bulb of all base types.
	Miscellaneous	All other types of incandescent lamps not previously listed, such as night lights, bug lights, as well as incandescent lamps of unknown characteristics.
HALOGEN	General Purpose – A-Shape	Standard halogen lamps with an A-shaped bulb meant as a direct replacement for general service incandescent lamps, including all base types and wattages.
	General Purpose – Decorative	Standard halogen lamps with a globe-, bullet-, candle-, or other decorative-shaped bulb of all base types.
	Reflector	Reflectorized lamps with a tungsten halogen capsule and a parabolic-, elliptical-, or other reflector-shaped bulb of all base types.
	Reflector – Low Voltage	Reflectorized lamps that operate at 24 volts or less, typically multifaceted reflectors and other display lamps, of all base types.
	Miscellaneous	All other types of halogen lamps not previously listed, such as those with a quartz envelope not employing a decorative bulb, tubular-shaped bulbs, and halogens of unknown characteristics.
CFL	General Purpose – Screw	Compact fluorescent lamps with an A-, globe-, spiral-, or other decorative-shaped bulb meant as a direct replacement for general service incandescent lamps having a screw-in base, including all wattages.
	General Purpose – Pin	Compact fluorescent lamps with an A-, globe-, spiral-, or other decorative-shaped bulb having a non-screw-in base, such as a pin base, including all wattages.
	Reflector	Reflectorized compact fluorescent lamps with an R-, PAR-, or other reflector-shaped bulb of all base types.
	Miscellaneous	All other types of CFLs not previously listed, as well as CFLs of unknown characteristics.
LINEAR FLUORESCENT	T5	Bi-pin linear T5 lamps of all wattages and exact metric lengths.
	T8 Less than 4ft	Bi-pin linear T8 fluorescent lamps less than 4 feet in length, predominantly 2 feet.
	T8 4ft	Bi-pin linear T8 fluorescent lamps 4 feet in length.
	T8 Greater than 4ft	Single- and bi-pin linear T8 fluorescent lamps greater than 4 feet in length, predominantly 8 feet.
	T8 U-Shaped	U-shaped T8 fluorescent lamps having medium bi-pin bases
	T12 Less than 4ft	Bi-pin linear T12 fluorescent lamps less than 4 feet in length, predominantly 2 feet.
	T12 4ft	Bi-pin linear T12 fluorescent lamps 4 feet in length.
	T12 Greater than 4ft	Single- and bi-pin linear T12 fluorescent lamps greater than 4 feet in length, predominantly 8 feet.
	T12 U-Shaped	U-shaped T12 fluorescent lamps having medium bi-pin bases.
	Miscellaneous	All other types of linear fluorescent lamps not previously listed, as well as fluorescent lamps of unknown characteristics.
HID	Mercury Vapor	Mercury vapor lamps of all base types.
	Metal Halide	Metal halide lamps, including ceramic metal halide, of all base types.

	High Pressure Sodium	High pressure sodium lamps of all base types.
	Low Pressure Sodium	Low pressure sodium lamps of all base types.
	Miscellaneous	All other types of HID lamps not previously listed, as well as HID lamps of unknown characteristics.
LED	General Purpose	LED lamps with an A-, globe-, bullet-, candle-, or other decorative-shaped bulb of all base types.
	Integrated Fixture/Luminaire	Integrated LED fixtures and luminaires of all shapes and sizes.
	Linear	Linear LED lamps that are meant as direct replacements for linear fluorescent lamps.
	Reflector	Reflectorized LED lamps with an ER-, BR-, PAR-, or other reflector-shaped bulb of all base types.
	Reflector - Low Voltage	Reflectorized LED lamps that operate at 24 volts or less, typically multifaceted reflectors and other display lamps of all base types.
	Miscellaneous	All other types of LED products not previously listed, as well as LED products of unknown characteristics.
OTHER	Miscellaneous	Illuminated exit signs and other lamps that do not fall into any of the previous categories, such as fiber optic lights, induction lamps, xenon lamps, as well as lamps of unknown characteristics.

Appendix B Sample Dataset Characteristics

The following figures provide details of the building sector datasets juxtaposed with details of the national building stock. These figures display the representative quality of the sample datasets. The greatest deviations are found in the geographic distribution plots. For other characteristics, the distribution of the sample datasets is fairly close to the national conditions. As is discussed in Section 3.2.1, lighting inventory sample data were weighted to account for deviations from the geographic and building type distributions of the total U.S. building stock.

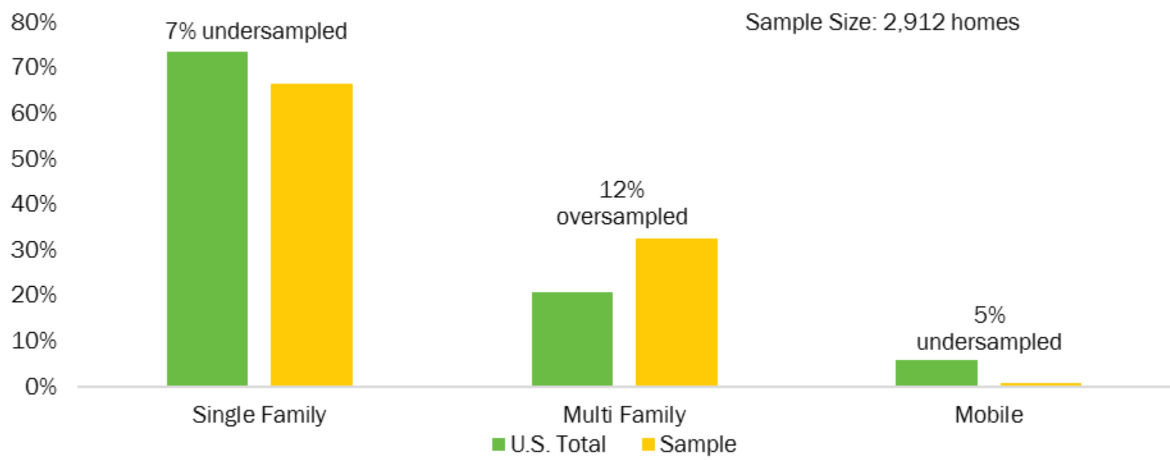

Figure B.1 Residential Sector Building Distribution by Residence Type

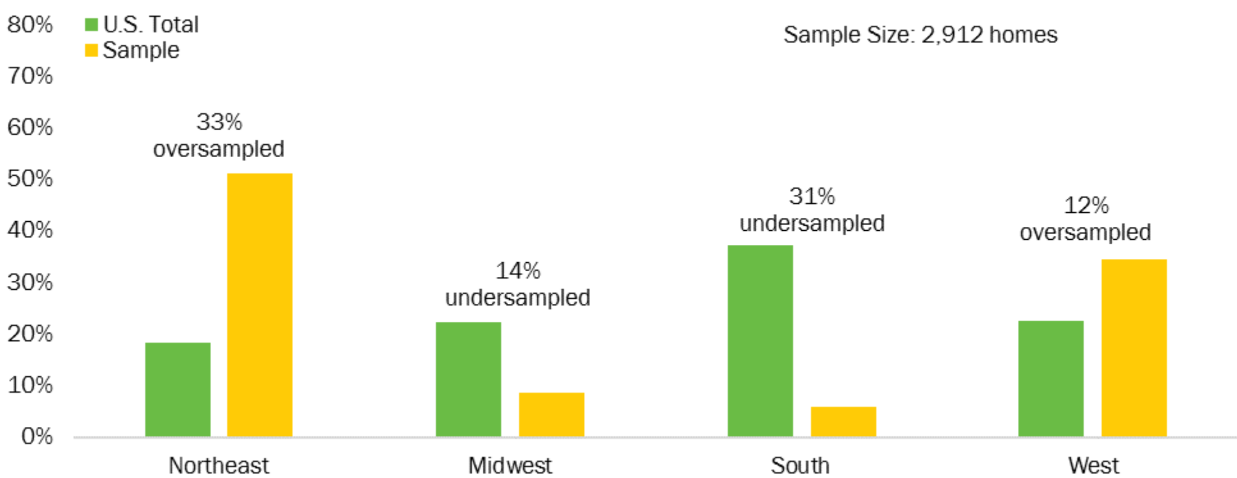

Figure B.2 Residential Sector Building Distribution by Geographic Region

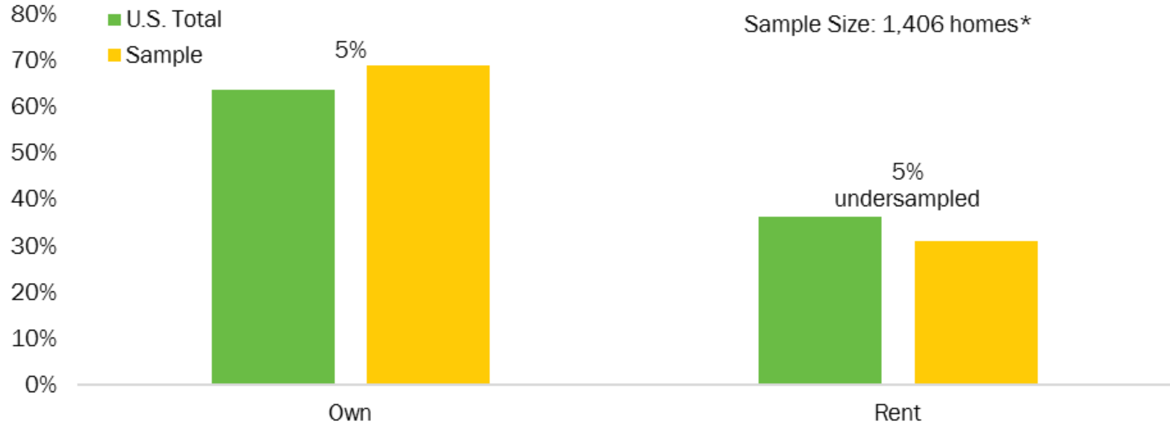

Figure B.3 Residential Sector Building Distribution by Ownership Status

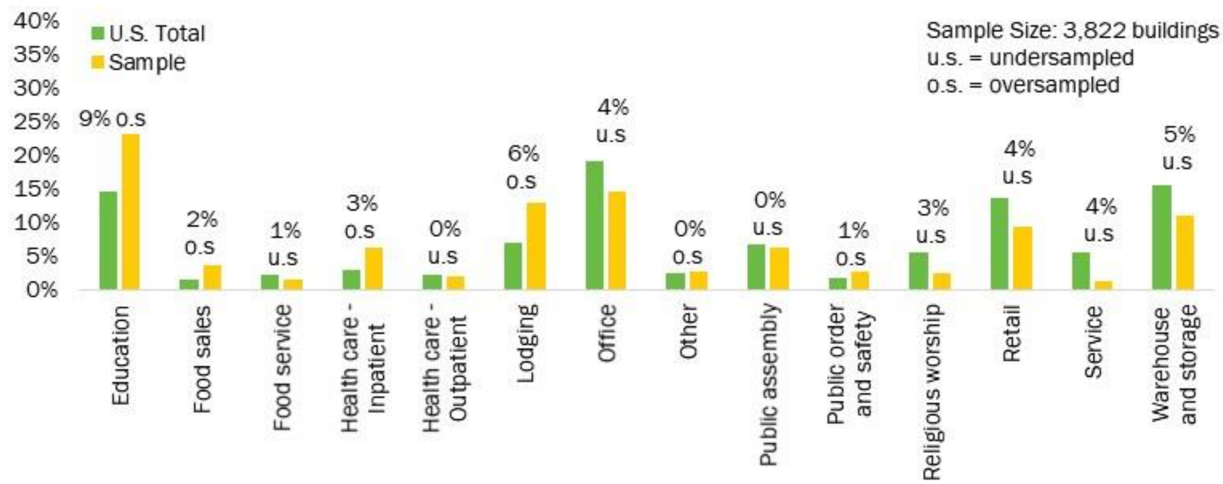

Figure B.4 Commercial Sector Square Footage Distribution by Building Type

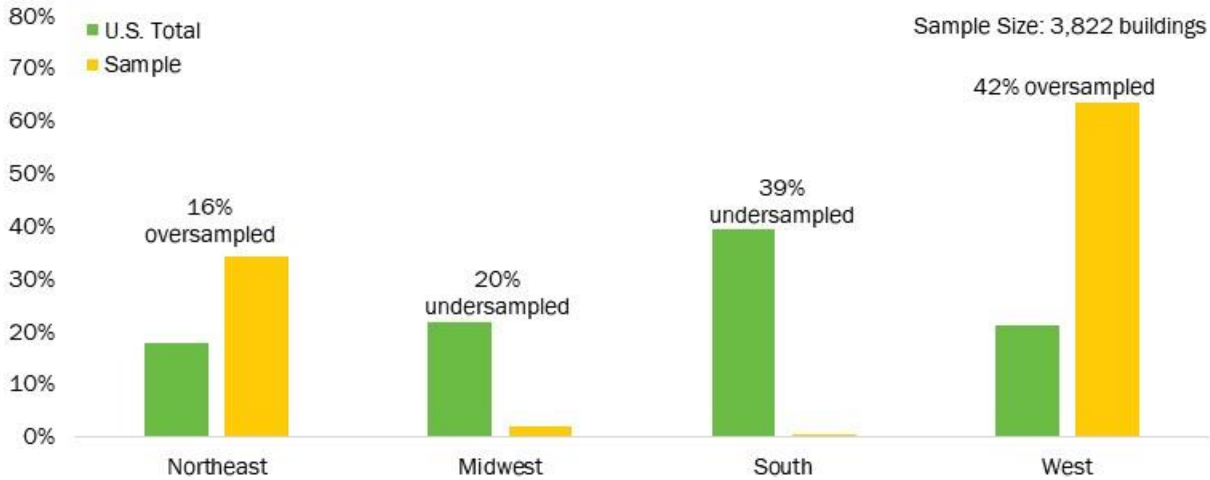

Figure B.5 Commercial Sector Square Footage Distribution by Geographic Region

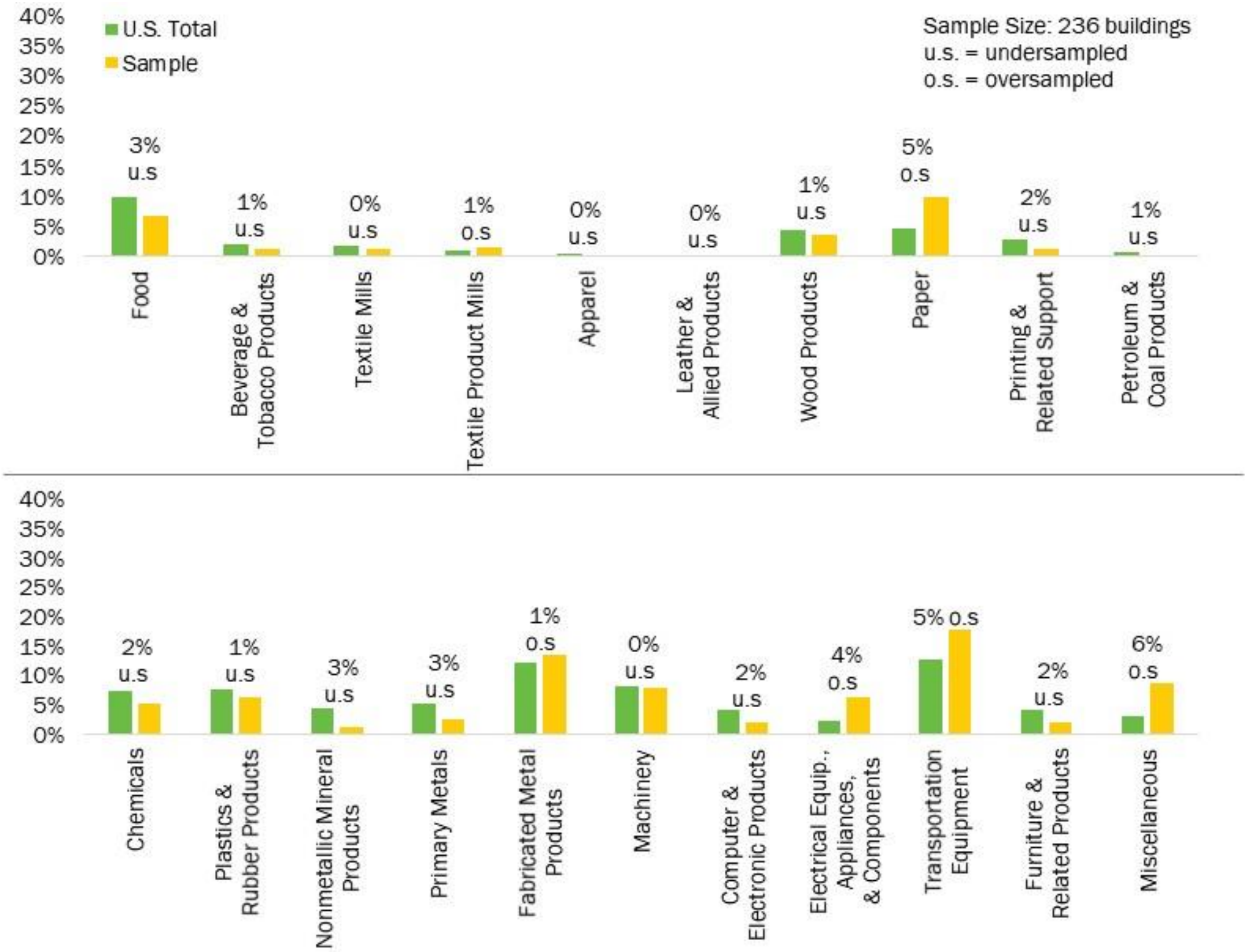

Figure B.6 Industrial Sector Square Footage Distribution by Building Type

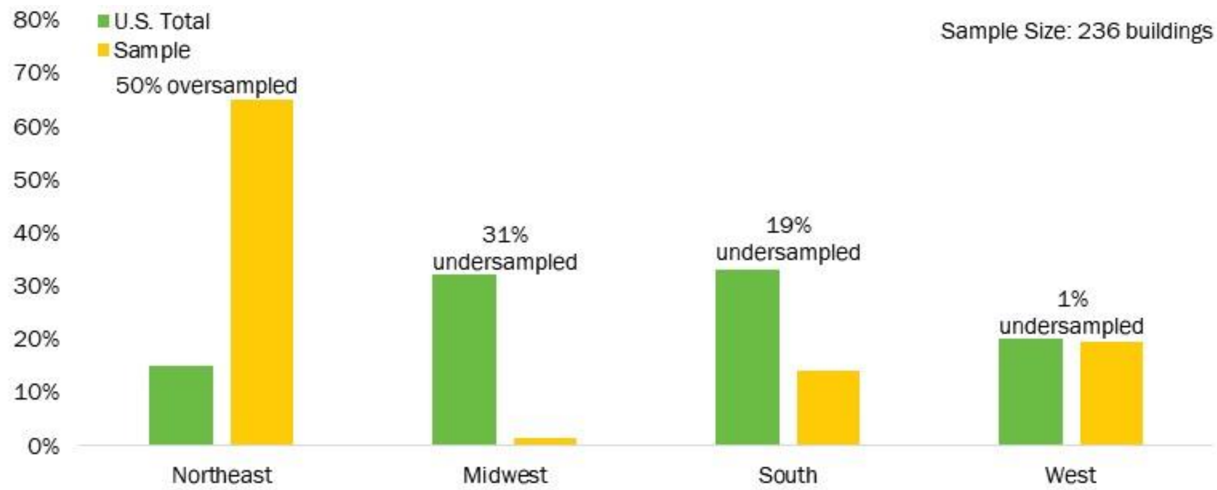

Figure B.7 Industrial Sector Square Footage Distribution by Geographic Region

Appendix C Efficacy and Wattage Assumptions

The total electricity consumption estimate provided in this report accounts for ballast and driver effects for non-integrated lamps. Similarly, the lumen output estimate is dependent on the system efficacies, which were calculated using manufacturer catalog data and a wattage-efficacy curve-fit analysis. Limited ballast data and no efficacy data were provided in the data sources discussed in Section 3.1, so the average ballast values, shown in Table C.1, are based on manufacturer catalog data.

Table C.1 Ballast Prevalence in Non-Integrated Lamps

	Residential			Other Sectors		
	Electronic	Magnetic	Ballast Factor	Electronic	Magnetic	Ballast Factor
CFL - Pin	100%	0%	1.0	100%	0%	1.0
T5	100%	0%	1.0	100%	0%	1.0
T8	100%	0%	0.9	100%	0%	0.9
T12	20%	80%	0.8	90%	10%	0.9
Mercury Vapor	0%	100%	1.0	0%	100%	1.0
Metal Halide	90%	10%	1.0	10%	90%	1.0
High Pressure Sodium	0%	100%	1.0	0%	100%	1.0
Low Pressure Sodium	-	-	-	0%	100%	1.0

As mentioned earlier, there are three types of linear LED lamps considered in this analysis. Although the sampled data does not provide enough detail to project inventories of each type, considerations were made to account for the effect of ballasts (for Type A linear LED lamps) or external drivers (Type C linear LED lamps). Type B linear LED lamps were assumed to operate directly at the rated wattages given, so no external effects were considered for these lamp types. In order to incorporate ballast and driver effects for Type A and Type C linear LED lamps, two steps were taken. First, a database of manufacturer catalog information was compiled to determine the average system efficiency for each type using the same process described in Section 3.2.3. Ballast factors were included for Type A lamps. Next, market saturations were estimated for each of the three types to determine an overall ballast or driver loss factor to apply to the wattages of linear LED lamps in the inventory database. These market saturations, shown below in Table C.2, were determined using data collected for Bonneville Power Administration's lighting market research (75).

Table C.2 Estimated Linear LED Lamp Distribution by Type in 2015[45]

LED Linear Lamp Types	Estimated 2015 LED Linear Lamp Distribution
Type A	38%
Type B	47%
Type C	14%

The lamp or luminaire efficacy values depicted in Table C.3 are individual lighting type efficacy values based on the lamp or luminaire's weighted average wattage and a database composed of lighting manufacturer catalog efficacies. This database was used to construct a curve-fit analysis, which allows the weighted average wattage values to be used to project an efficacy for a given lighting product category. These efficacies were

[45] For additional detail on the different types of LED linear lamps, please see UL 1993: https://standardscatalog.ul.com/standards/en/standard_1993_5.

then used to estimate total lumen production (as displayed in Table 4.9) by multiplying the efficacy by the total electricity consumption for each lamp or luminaire type.

Table C.3 System Efficacy Assumptions

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**9.2**	**9.7**	**9.1**	**11.1**	**9.2**
General Purpose - A-Shape	10.0	10.3	9.9	-	10.0
General Purpose - Decorative	8.8	8.7	9.4	-	8.8
Reflector	8.4	9.2	8.5	-	8.5
Miscellaneous	9.7	10.2	8.4	11.1	10.0
Halogen	**16.2**	**12.3**	**16.2**	**16.3**	**16.2**
General Purpose - A-Shape	17.1	17.5	16.2	-	17.1
General Purpose - Decorative	14.8	15.0	14.3	-	14.8
Reflector	15.2	14.8	16.0	-	15.2
Reflector - Low Voltage	10.6	10.6	-	-	10.6
Miscellaneous	16.5	16.5	17.1	16.3	16.5
Compact Fluorescent	**59.2**	**66.0**	**62.1**	**65.5**	**59.8**
General Purpose - Pin	68.4	70.1	73.4	-	69.6
General Purpose - Screw	60.5	62.4	61.1	-	60.5
Reflector	45.1	47.8	44.0	-	45.1
Miscellaneous	60.5	66.0	64.4	65.5	62.5
Linear Fluorescent	**82.3**	**90.6**	**91.4**	**83.4**	**88.7**
T5	86.3	103.5	94.0	-	99.3
T8 Less than 4ft	76.6	79.6	73.3	-	79.3
T8 4ft	93.1	94.1	93.8	-	93.9
T8 Greater than 4ft	95.7	96.5	96.9	-	96.5
T8 U-Shaped	-	88.8	88.1	-	88.8
T12 Less than 4ft	63.9	66.0	66.1	-	64.9
T12 4ft	73.3	74.0	73.0	-	73.6
T12 Greater than 4ft	80.0	78.9	79.1	-	79.4
T12 U-Shaped	-	70.4	-	-	70.4
Miscellaneous	83.8	89.7	85.2	83.4	84.1
High Intensity Discharge	**76.3**	**90.3**	**64.4**	**83.3**	**83.2**
Mercury Vapor	41.4	43.0	45.3	41.3	41.5
Metal Halide	80.0	90.2	45.5	44.5	58.3
High Pressure Sodium	106.6	119.2	123.2	114.4	114.7
Low Pressure Sodium	-	-	-	159.8	159.8
Miscellaneous	-	84.4	-	-	84.4
LED	**73.8**	**81.1**	**87.5**	**90.2**	**77.6**
General Purpose	77.8	81.3	80.4	-	78.5
Integrated Fixture/Luminaire	72.9	82.2	80.7	-	79.7
Linear	106.8	104.4	100.5	-	104.1
Reflector	66.3	66.6	66.3	-	66.3
Reflector - Low Voltage	62.3	59.4	-	-	60.3
Miscellaneous	74.8	77.4	-	90.2	84.6
Other	**66.3**	**64.6**	**66.3**	**67.2**	**66.4**
Miscellaneous	66.3	64.6	66.3	67.2	66.4
Average	**37.6**	**86.0**	**89.5**	**79.5**	**51.4**

Appendix D Supplementary Residential and Commercial Results

Additional detail is provided on the residential and commercial sectors due to the greater availability of data sources for these sectors. Table D.1 provides the breakdown of lighting installations by residential room type and Table D.2 provides the average lighting wattage of lamps by residential room type. For the commercial sector, Table D.3 provides the breakdown of lighting installations by building type, and Table D.4 provides the average lighting wattage by building type.

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Table D.1 Lighting Technology Distribution by Residential Room Type

	Basement	Bathroom	Bedroom	Closet	Dining Rm	Exterior	Garage	Hall	Kitchen	Utility Rm	Living Rm	Office	Other
Incandescent	**32%**	**45%**	**32%**	**31%**	**53%**	**32%**	**11%**	**46%**	**28%**	**17%**	**36%**	**33%**	**37%**
General Purpose - A-Shape	12%	12%	17%	16%	10%	10%	9%	15%	7%	14%	12%	13%	21%
General Purpose - Decorative	2%	29%	11%	11%	39%	10%	1%	24%	8%	2%	12%	13%	9%
Reflector	17%	2%	3%	3%	3%	10%	1%	6%	12%	1%	11%	7%	7%
Miscellaneous	0%	1%	1%	0%	1%	10%	0%	1%	1%	0%	1%	0%	0%
Halogen	**15%**	**16%**	**19%**	**20%**	**17%**	**27%**	**5%**	**11%**	**14%**	**14%**	**16%**	**11%**	**12%**
General Purpose - A-Shape	13%	13%	16%	16%	14%	10%	3%	8%	5%	12%	11%	5%	8%
General Purpose - Decorative	0%	1%	0%	0%	0%	1%	0%	0%	2%	0%	0%	2%	0%
Reflector	2%	1%	2%	3%	2%	14%	0%	3%	4%	1%	4%	2%	1%
Reflector - Low Voltage	1%	1%	0%	0%	0%	-	0%	0%	1%	1%	1%	1%	1%
Miscellaneous	0%	0%	0%	0%	0%	3%	1%	0%	1%	0%	0%	1%	0%
Compact Fluorescent	**36%**	**31%**	**41%**	**42%**	**23%**	**32%**	**12%**	**34%**	**29%**	**41%**	**39%**	**41%**	**31%**
General Service - Screw	0%	1%	0%	0%	0%	0%	0%	1%	1%	1%	0%	0%	0%
General Service - Pin	33%	29%	39%	36%	19%	27%	12%	30%	20%	38%	34%	34%	28%
Reflector	3%	1%	1%	6%	1%	4%	0%	2%	7%	1%	4%	5%	2%
Miscellaneous	1%	0%	1%	0%	2%	1%	0%	1%	1%	1%	1%	2%	0%
Linear Fluorescent	**11%**	**3%**	**1%**	**4%**	**0%**	**2%**	**69%**	**0%**	**19%**	**22%**	**1%**	**6%**	**11%**
T5	0%	0%	0%	0%	0%	-	0%	0%	2%	0%	0%	0%	0%
T8 Less than 4ft	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
T8 4ft	3%	1%	0%	2%	0%	1%	28%	0%	9%	10%	0%	2%	2%
T8 Greater than 4ft	0%	0%	0%	0%	0%	-	1%	0%	0%	1%	0%	0%	0%
T8 U-Shaped	-	-	-	-	-	-	-	-	-	-	-	-	-
T12 Less than 4ft	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
T12 4ft	6%	1%	0%	2%	0%	1%	36%	0%	9%	11%	1%	3%	6%
T12 Greater than 4ft	1%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	2%
T12 U-Shaped	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High Intensity Discharge	**-**	**-**	**-**	**-**	**-**	**0%**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Mercury Vapor	-	-	-	-	-	0%	-	-	-	-	-	-	-
Metal Halide	-	-	-	-	-	0%	-	-	-	-	-	-	-
High Pressure Sodium	-	-	-	-	-	0%	-	-	-	-	-	-	-
Low Pressure Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	-	-	-	-	-	-	-	-	-	-	-	-	-
LED	**6%**	**6%**	**7%**	**4%**	**7%**	**6%**	**3%**	**7%**	**10%**	**4%**	**7%**	**9%**	**9%**
General Purpose	5%	4%	5%	3%	5%	4%	1%	4%	4%	3%	4%	2%	3%
Integrated Fixture/Luminaire	0%	1%	1%	0%	0%	0%	0%	0%	1%	0%	1%	0%	0%
Linear	0%	0%	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%
Reflector	1%	1%	1%	1%	1%	1%	1%	3%	5%	1%	3%	6%	6%
Reflector - Low Voltage	0%	0%	0%	0%	0%	-	0%	0%	0%	0%	0%	0%	0%
Miscellaneous	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
Other	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**0%**
Miscellaneous	0%	0%	0%	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table D.2 Wattages by Lighting Technology and Residential Room Type

	Basement	Bathroom	Bedroom	Closet	Dining Rm	Exterior	Garage	Hall	Kitchen	Utility Rm	Living Rm	Office	Other
Incandescent	**67**	**51**	**54**	**57**	**45**	**64**	**67**	**48**	**54**	**60**	**56**	**53**	**62**
General Purpose - A-Shape	74	59	62	66	58	65	69	58	58	62	66	61	71
General Purpose - Decorative	48	44	40	38	40	46	33	37	42	44	40	40	39
Reflector	64	87	62	80	58	81	86	63	62	59	63	61	62
Miscellaneous	54	71	47	29	46	77	56	57	35	63	67	60	95
Halogen	**59**	**50**	**50**	**52**	**57**	**86**	**65**	**59**	**46**	**49**	**56**	**61**	**60**
General Purpose - A-Shape	58	49	49	48	57	61	57	58	50	49	54	55	57
General Purpose - Decorative	83	47	77	39	55	61	-	60	23	-	55	74	44
Reflector	57	58	50	68	58	84	79	62	55	37	55	56	58
Reflector - Low Voltage	48	36	44	34	41	-	33	45	41	49	43	39	47
Miscellaneous	215	81	83	187	77	202	102	72	36	73	135	84	174
Compact Fluorescent	**16**	**15**	**16**	**15**	**14**	**17**	**19**	**15**	**16**	**17**	**16**	**16**	**18**
General Service - Screw	24	19	24	20	21	20	28	20	25	22	24	24	29
General Service - Pin	16	15	16	16	14	16	19	15	16	17	16	16	18
Reflector	15	16	15	15	14	20	20	17	16	19	16	16	16
Miscellaneous	21	14	18	16	15	20	19	14	17	33	17	18	28
Linear Fluorescent	**41**	**34**	**36**	**36**	**38**	**38**	**40**	**31**	**34**	**37**	**39**	**37**	**48**
T5	62	20	15	40	28	-	41	16	14	18	21	11	-
T8 Less than 4ft	29	19	19	19	18	21	24	30	18	18	15	15	18
T8 4ft	33	32	33	31	-	33	33	27	32	33	33	33	33
T8 Greater than 4ft	-	-	-	-	-	-	59	-	-	59	-	-	-
T8 U-Shaped	-	-	-	-	-	-	-	-	-	-	-	-	-
T12 Less than 4ft	28	24	25	21	21	38	30	21	23	23	37	21	21
T12 4ft	40	40	41	38	41	40	41	41	41	40	41	41	40
T12 Greater than 4ft	67	41	57	63	-	72	76	-	-	55	66	34	85
T12 U-Shaped	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	42	30	33	33	32	42	55	35	30	37	37	35	42
High Intensity Discharge	**-**	**-**	**-**	**-**	**-**	**173**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Mercury Vapor	-	-	-	-	-	213	-	-	-	-	-	-	-
Metal Halide	-	-	-	-	-	88	-	-	-	-	-	-	-
High Pressure Sodium	-	-	-	-	-	187	-	-	-	-	-	-	-
Low Pressure Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	-	-	-	-	-	-	-	-	-	-	-	-	-
LED	**11**	**9**	**9**	**9**	**8**	**9**	**11**	**10**	**10**	**10**	**10**	**11**	**11**
General Purpose	11	9	8	9	7	8	10	8	9	9	9	9	10
Integrated Fixture/Luminaire	12	5	9	8	13	18	9	7	8	13	12	8	19
Linear	15	-	-	-	-	-	-	-	-	-	-	-	-
Reflector	10	11	12	10	12	13	12	13	12	11	12	11	11
Reflector - Low Voltage	-	3	7	-	5	-	-	4	5	-	3	4	8
Miscellaneous	16	7	8	-	12	8	21	9	11	13	9	10	35
Other	**-**	**58**	**58**	**60**	**53**	**63**	**-**	**56**	**32**	**53**	**60**	**60**	**-**
Miscellaneous	-	58	58	60	53	63	-	56	32	53	60	60	-
Average	**41**	**37**	**35**	**36**	**38**	**26**	**41**	**35**	**34**	**34**	**37**	**34**	**42**

Table D.3 Lighting Technology Distribution by Commercial Building Type

	Education	Food Sales	Food Service	Health Care - Inpatient	Health Care - Outpatient	Lodging	Office	Other	Public Assembly	Public Order and Safety	Religious Worship	Retail	Service	Warehouse and Storage
Incandescent	**0.2%**	**0.3%**	**10.3%**	**3.0%**	**0.8%**	**3.9%**	**0.5%**	**0.6%**	**2.3%**	**2.8%**	**2.7%**	**0.5%**	**2.4%**	**0.2%**
General Purpose - A-Shape	0.0%	0.0%	0.5%	0.3%	0.1%	0.6%	0.1%	0.2%	0.4%	0.7%	0.3%	0.1%	0.0%	0.0%
General Purpose - Decorative	0.0%	0.0%	2.3%	1.2%	0.0%	1.2%	0.0%	0.0%	0.7%	0.1%	0.6%	0.1%	0.0%	0.1%
Reflector	0.0%	0.1%	0.5%	0.2%	0.1%	1.2%	0.0%	0.0%	0.1%	0.1%	1.2%	0.1%	0.0%	0.1%
Miscellaneous	0.1%	0.2%	7.0%	1.3%	0.7%	0.9%	0.4%	0.3%	1.0%	2.0%	0.6%	0.2%	2.3%	0.0%
Halogen	**0.0%**	**1.3%**	**3.5%**	**1.4%**	**2.3%**	**0.9%**	**0.6%**	**0.8%**	**1.3%**	**2.8%**	**1.1%**	**1.5%**	**0.4%**	**0.2%**
General Purpose - A-Shape	-	0.0%	0.0%	-	2.2%	0.1%	0.1%	-	0.1%	2.5%	0.0%	0.1%	0.0%	0.0%
General Purpose - Decorative	0.0%	-	0.0%	-	0.0%	0.0%	0.0%	-	0.0%	0.0%	0.0%	0.0%	-	-
Reflector	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%
Reflector - Low Voltage	0.0%	0.9%	3.0%	1.2%	0.1%	0.6%	0.5%	0.8%	1.1%	0.2%	0.7%	1.2%	0.3%	0.2%
Miscellaneous	0.0%	0.4%	0.3%	0.2%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.2%	0.1%	0.0%	0.0%
Compact Fluorescent	**3.5%**	**2.3%**	**8.3%**	**17.2%**	**5.2%**	**43.2%**	**3.8%**	**15.6%**	**11.5%**	**11.7%**	**13.3%**	**4.1%**	**1.8%**	**1.0%**
General Purpose - Pin	1.8%	1.3%	1.9%	8.5%	1.7%	21.6%	2.2%	2.5%	4.6%	8.4%	8.4%	1.6%	0.8%	0.4%
General Purpose - Screw	1.3%	0.4%	4.7%	5.0%	2.5%	19.2%	0.9%	0.8%	6.1%	3.2%	3.2%	2.2%	0.7%	0.3%
Reflector	0.1%	0.4%	1.4%	0.2%	0.1%	0.8%	0.1%	0.0%	0.3%	0.1%	1.1%	0.2%	0.3%	0.1%
Miscellaneous	0.3%	0.2%	0.3%	3.5%	1.0%	1.6%	0.6%	12.3%	0.5%	0.0%	0.6%	0.1%	0.0%	0.2%
Linear Fluorescent	**88.5%**	**78.1%**	**59.9%**	**67.0%**	**79.4%**	**30.1%**	**86.9%**	**71.3%**	**67.3%**	**71.5%**	**69.6%**	**80.4%**	**81.5%**	**89.0%**
T5	2.0%	15.4%	0.1%	7.3%	0.3%	1.9%	1.7%	9.9%	1.2%	4.9%	1.8%	5.7%	5.7%	12.8%
T8 Less than 4ft	1.0%	0.5%	0.2%	7.3%	0.8%	1.7%	1.6%	0.8%	0.7%	0.5%	0.5%	0.3%	0.6%	0.1%
T8 4ft	72.3%	52.8%	25.0%	41.3%	46.5%	20.5%	61.3%	46.9%	39.2%	30.6%	44.7%	44.8%	63.7%	68.3%
T8 Greater than 4ft	2.0%	2.9%	0.8%	0.2%	0.0%	0.1%	0.1%	0.1%	0.1%	0.6%	0.2%	0.7%	0.8%	0.7%
T8 U-Shaped	0.8%	2.7%	2.1%	2.8%	2.5%	1.6%	1.1%	0.1%	0.6%	2.7%	7.7%	2.7%	1.3%	0.5%
T12 Less than 4ft	0.0%	0.2%	0.2%	0.6%	0.1%	0.3%	0.0%	-	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%
T12 4ft	9.9%	2.3%	29.7%	6.7%	28.3%	3.2%	20.2%	11.7%	23.2%	27.0%	13.7%	21.2%	3.1%	4.9%
T12 Greater than 4ft	0.2%	1.0%	1.5%	0.1%	0.5%	0.1%	0.5%	1.3%	1.8%	3.5%	0.3%	4.7%	1.3%	1.5%
T12 U-Shaped	0.2%	0.4%	0.2%	0.2%	0.4%	0.3%	0.3%	0.1%	0.5%	1.4%	0.4%	0.1%	2.0%	0.1%
Miscellaneous	0.0%	0.0%	0.0%	0.5%	0.0%	0.3%	0.2%	0.4%	0.0%	0.1%	0.1%	0.1%	3.1%	0.0%
High Intensity Discharge	**0.8%**	**4.5%**	**0.2%**	**0.1%**	**0.0%**	**0.3%**	**0.6%**	**0.6%**	**1.6%**	**1.0%**	**0.6%**	**2.5%**	**1.2%**	**2.3%**
Mercury Vapor	0.0%	0.0%	0.0%	-	-	0.0%	0.0%	0.1%	0.0%	0.1%	-	0.0%	0.0%	0.0%
Metal Halide	0.7%	4.4%	0.0%	0.1%	0.0%	0.2%	0.5%	0.5%	1.5%	0.7%	0.5%	2.3%	1.2%	2.2%
High Pressure Sodium	0.0%	0.1%	0.0%	0.0%	-	0.0%	0.0%	0.0%	0.0%	0.2%	-	0.0%	0.0%	0.1%
Low Pressure Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	0.1%	0.0%	0.1%	-	-	0.0%	0.1%	0.0%	0.1%	-	0.1%	0.1%	0.0%	0.0%
LED	**6.9%**	**13.4%**	**17.6%**	**11.3%**	**12.1%**	**21.5%**	**7.5%**	**11.2%**	**15.8%**	**10.0%**	**12.2%**	**10.7%**	**12.7%**	**7.2%**
General Purpose	1.0%	1.5%	7.4%	5.3%	2.4%	14.5%	1.1%	1.5%	7.3%	5.5%	4.3%	2.3%	0.8%	0.5%
Integrated Fixture/Luminaire	4.1%	3.7%	1.8%	3.3%	3.1%	1.3%	4.0%	3.7%	2.9%	2.7%	2.7%	3.7%	7.7%	4.4%
Linear	1.2%	1.2%	0.7%	1.1%	1.1%	0.4%	1.1%	1.2%	0.9%	1.1%	-	1.0%	2.2%	1.2%
Reflector	0.2%	0.9%	3.1%	0.7%	0.3%	3.9%	0.3%	0.3%	1.9%	0.2%	3.9%	2.0%	0.4%	0.4%
Reflector - Low Voltage	0.0%	1.2%	2.1%	1.0%	0.3%	0.5%	0.3%	0.7%	1.3%	0.5%	-	0.8%	0.3%	-
Miscellaneous	0.4%	4.9%	2.5%	-	5.0%	0.8%	0.7%	3.8%	1.5%	-	1.3%	0.8%	1.3%	0.8%
Other	**0.1%**	**0.1%**	**0.2%**	**0.1%**	**0.1%**	**0.3%**	**0.1%**	**0.0%**	**0.3%**	**0.2%**	**0.6%**	**0.3%**	**0.1%**	**0.0%**
Miscellaneous	0.1%	0.1%	0.2%	0.1%	0.1%	0.3%	0.1%	0.0%	0.3%	0.2%	0.6%	0.3%	0.1%	0.0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table D.4 Wattages by Lighting Technology and Commercial Building Type

	Education	Food Sales	Food Service	Health Care - Inpatient	Health Care - Outpatient	Lodging	Office	Other	Public Assembly	Public Order and Safety	Religious Worship	Retail	Service	Warehouse and Storage
Incandescent	**118**	**82**	**30**	**53**	**102**	**62**	**63**	**104**	**61**	**214**	**92**	**75**	**64**	**48**
General Purpose - A-Shape	81	73	56	60	71	62	77	78	73	61	70	75	63	53
General Purpose - Decorative	21	56	29	51	52	38	59	48	41	66	41	56	45	27
Reflector	100	127	60	66	66	83	75	95	74	95	132	76	69	52
Miscellaneous	199	69	26	51	110	69	59	126	67	278	80	89	64	111
Halogen	**154**	**57**	**35**	**72**	**70**	**35**	**52**	**80**	**58**	**51**	**96**	**63**	**59**	**54**
General Purpose - A-Shape	-	72	43	-	72	41	66	-	70	53	43	35	38	90
General Purpose - Decorative	70	-	82	-	75	40	53	-	46	50	40	45	-	-
Reflector	142	64	50	75	59	43	52	87	89	48	90	52	55	41
Reflector - Low Voltage	53	55	33	67	31	27	50	80	55	20	54	67	60	47
Miscellaneous	334	60	47	97	123	68	46	35	61	150	300	43	64	86
Compact Fluorescent	**29**	**27**	**21**	**22**	**20**	**21**	**24**	**30**	**30**	**29**	**26**	**26**	**24**	**29**
General Purpose - Pin	33	30	27	22	25	22	26	30	32	34	28	32	21	35
General Purpose - Screw	25	22	20	19	18	20	22	25	30	17	21	22	29	24
Reflector	22	26	17	24	17	18	18	17	19	20	22	20	19	16
Miscellaneous	26	22	20	25	17	18	23	30	26	22	27	22	34	34
Linear Fluorescent	**34**	**35**	**35**	**30**	**33**	**32**	**33**	**33**	**34**	**36**	**34**	**36**	**36**	**32**
T5	51	41	39	32	48	26	40	32	54	43	55	34	49	26
T8 Less than 4ft	19	22	25	19	20	22	24	20	19	28	28	25	18	22
T8 4ft	31	32	31	30	31	32	31	31	31	31	32	31	32	31
T8 Greater than 4ft	69	50	60	58	61	37	53	34	43	35	42	63	62	52
T8 U-Shaped	31	30	31	29	31	31	31	31	30	31	31	31	31	31
T12 Less than 4ft	25	19	28	26	31	29	29	-	26	21	29	27	29	29
T12 4ft	47	43	36	41	36	41	36	36	36	36	41	36	42	38
T12 Greater than 4ft	85	96	84	95	77	116	79	80	80	77	124	80	88	92
T12 U-Shaped	36	36	42	35	38	36	35	42	35	35	34	38	35	41
Miscellaneous	29	43	34	34	23	21	33	27	31	26	31	30	87	41
High Intensity Discharge	**410**	**141**	**85**	**222**	**132**	**144**	**369**	**397**	**299**	**175**	**333**	**330**	**393**	**457**
Mercury Vapor	290	122	268	-	-	293	276	266	403	117	-	190	773	205
Metal Halide	422	134	76	211	132	136	403	417	309	128	347	345	399	462
High Pressure Sodium	440	415	118	296	-	219	299	205	130	319	-	360	177	359
Low Pressure Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	300	138	78	-	-	123	60	124	79	-	250	73	156	469
LED	**25**	**21**	**10**	**14**	**16**	**10**	**22**	**12**	**21**	**15**	**12**	**16**	**14**	**40**
General Purpose	16	26	6	12	12	9	9	11	11	6	10	7	11	12
Integrated Fixture/Luminaire	30	24	13	16	26	19	28	22	50	31	13	28	14	59
Linear	22	24	18	21	20	17	24	15	23	24	-	4	19	16
Reflector	16	15	12	12	9	9	11	10	13	13	16	14	13	16
Reflector - Low Voltage	11	10	13	13	7	7	8	8	7	8	-	7	10	-
Miscellaneous	17	20	13	-	12	13	17	2	35	-	3	15	12	1
Other	**6**	**8**	**27**	**50**	**4**	**11**	**10**	**10**	**27**	**6**	**6**	**42**	**5**	**15**
Miscellaneous	6	8	27	50	4	11	10	10	27	6	6	42	5	15
Average	**36**	**38**	**29**	**28**	**32**	**24**	**34**	**33**	**37**	**40**	**34**	**41**	**39**	**42**

Appendix E Updated 2010 Results

Due to updated data from interviews with industry experts, the outdoor results presented in the 2010 LMC have been updated for this analysis to enable more accurate comparisons between 2010 and 2015. Only results for the outdoor sector have been updated. Table E.1 through Table E.4 provide these updated 2010 outdoor values. Table E.5 through Table E.9 show these results aggregated with the unaltered 2010 residential, commercial, and industrial results from the 2010 LMC.

Table E.1 Inventory of Lamps by Outdoor Application (1,000s) in 2010 – Revised

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Total
Airfield	370	563	-	-	-	-	-	-	233	-	1,167
Billboard	-	-	-	6	6	583	-	-	6	-	600
Building Ext.: C&I	14,775	2,621	12,052	12,468	1,815	9,865	7,919	274	1	294	62,084
Comm. Tower	154	2	-	-	-	-	-	-	81	104	342
Parking	-	781	-	15,283	1,177	30,429	24,545	-	3,518	4,031	79,765
Railway	436	-	-	-	-	-	-	-	490	-	925
Roadway	70	-	-	-	472	1,261	40,005	1,104	2,585	1,537	47,035
Sports Field	-	27	-	-	3	349	50	-	0	-	428
Traffic Signal	3,615	-	-	-	-	-	-	-	9,762	-	13,377
Total	19,420	3,994	12,052	27,757	3,474	42,487	72,519	1,378	16,676	5,966	205,722

Table E.2 Average Lighting Wattage by Outdoor Application in 2010 – Revised

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Total
Airfield	101	97	-	-	-	-	-	-	15	-	82
Billboard	-	-	-	148	400	400	-	-	125	-	395
Building Ext.: C&I	61	74	22	42	79	72	78	74	28	68	55
Comm. Tower	408	116	-	-	-	-	-	-	14	131	228
Parking	-	113	-	35	307	407	215	-	105	105	244
Railway	24	-	-	-	-	-	-	-	9	-	16
Roadway	164	-	-	-	210	248	301	108	131	120	279
Sports Field	-	3,478	-	-	1,000	1,431	955	-	0	-	1,501
Traffic Signal	134	-	-	-	-	-	-	-	9	-	42
Average	**77**	**108**	**22**	**38**	**176**	**333**	**248**	**101**	**48**	**108**	**183**

Table E.3 Average Daily Operating Hours by Outdoor Application in 2010 – Revised

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Total
Airfield	4	4	-	-	-	-	-	-	3	-	4
Billboard	-	-	-	10	10	10	-	-	10	-	10
Building Ext.: C&I	8	8	9	9	9	9	9	9	9	9	9
Comm. Tower	10	10	-	-	-	-	-	-	10	4	8
Parking	-	20	-	20	13	14	15	-	15	20	16
Railway	3	-	-	-	-	-	-	-	1	-	2
Roadway	12	-	-	-	12	12	12	12	12	12	12
Sports Field	-	2	-	-	2	2	2	-	0	-	2
Traffic Signal	8	-	-	-	-	-	-	-	8	-	8
Average	**8**	**10**	**9**	**15**	**11**	**12**	**13**	**11**	**10**	**17**	**12**

Table E.4 Lighting Electricity Consumption by Outdoor Application in 2010 (TWh/yr) – Rev.

	Incandescent	Halogen	CFL	Linear Fluorescent	MV	MH	HPS	LPS	LED	Other	Total
Airfield	0	0	-	-	-	-	-	-	0	-	0
Billboard	-	-	-	0	0	1	-	-	0	-	1
Building Ext.: C&I	3	1	1	2	1	3	2	0	0	0	12
Comm. Tower	0	0	-	-	-	-	-	-	0	0	0
Parking	-	1	-	4	2	67	35	-	2	3	113
Railway	0	-	-	-	-	-	-	-	0	-	0
Roadway	0	-	-	-	1	2	61	1	1	1	66
Sports Field	-	0	-	-	0	0	0	-	0	-	1
Traffic Signal	1	-	-	-	-	-	-	-	0	-	2
Total	**4**	**1**	**1**	**6**	**3**	**73**	**98**	**1**	**4**	**4**	**195**

Table E.5 Estimated Inventory of Lamps in the U.S. by End-Use Sector in 2010 – Revised

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**3,602,809,000**	**77,597,000**	**402,000**	**19,420,074**	**3,700,228,074**
General Purpose - A-Shape	2,028,184,000	42,930,000	387,000	-	2,071,501,000
General Purpose - Decorative	980,054,000	-	-	-	980,054,000
Reflector	433,929,000	19,421,000	15,000	-	453,365,000
Miscellaneous	160,642,000	15,246,000	-	19,420,074	195,308,074
Halogen	**256,990,000**	**47,596,000**	**71,000**	**3,994,063**	**308,651,063**
General Purpose - A-Shape	26,785,000	969,000	3,000	-	27,757,000
General Purpose - Decorative	-	-	-	-	-
Reflector	168,876,000	19,499,000	63,000	-	188,438,000
Reflector - Low Voltage	19,348,000	25,644,000	-	-	44,992,000
Miscellaneous	41,981,000	1,484,000	5,000	3,994,063	47,464,063
Compact Fluorescent	**1,322,525,000**	**216,183,000**	**406,000**	**12,052,000**	**1,551,166,000**
General Purpose - Pin	5,386,000	136,207,000	201,000	-	141,794,000
General Purpose - Screw	1,121,452,000	40,498,000	91,000	-	1,162,041,000
Reflector	114,754,000	39,478,000	114,000	-	154,346,000
Miscellaneous	80,933,000	-	-	12,052,000	92,985,000
Linear Fluorescent	**572,897,000**	**1,654,753,000**	**128,625,000**	**27,757,126**	**2,384,032,126**
T5	3,636,000	108,066,000	9,245,000	-	120,947,000
T8 Less than 4ft	3,020,000	14,090,000	708,000	-	17,818,000
T8 4ft	64,022,000	907,727,000	78,425,000	-	1,050,174,000
T8 Greater than 4ft	1,369,000	27,914,000	3,349,000	-	32,632,000
T8 U-Shaped	1,155,000	45,897,000	546,000	-	47,598,000
T12 Less than 4ft	7,025,000	7,294,000	14,000	-	14,333,000
T12 4ft	331,790,000	410,460,000	24,006,000	-	766,256,000
T12 Greater than 4ft	28,685,000	109,066,000	10,830,000	-	148,581,000
T12 U-Shaped	316,000	10,828,000	1,021,000	-	12,165,000
Miscellaneous	131,879,000	13,411,000	481,000	27,757,126	173,528,126
High Intensity Discharge	**1,434,000**	**34,851,000**	**14,155,000**	**119,857,037**	**170,297,037**
Mercury Vapor	206,000	1,025,000	1,424,000	3,473,618	6,128,618
Metal Halide	45,000	30,422,000	9,407,000	42,486,780	82,360,780
High Pressure Sodium	1,183,000	3,355,000	3,324,000	72,518,739	80,380,739
Low Pressure Sodium	-	49,000	-	1,377,900	1,426,900
Miscellaneous	-	-	-	-	-
LED	**9,175,000**	**38,029,000**	**592,000**	**16,675,608**	**64,471,608**
General Purpose	-	-	-	-	-
Integrated Fixture/Luminaire	-	-	-	-	-
Linear	-	-	-	-	-
Reflector	-	-	-	-	-
Reflector - Low Voltage	-	-	-	-	-
Miscellaneous	9,175,000	38,029,000	592,000	16,675,608	64,471,608
Other	**45,939,000**	**297,000**	**-**	**5,966,305**	**52,202,305**
Miscellaneous	45,939,000	297,000	-	5,966,305	52,202,305
Total	**5,811,769,000**	**2,069,306,000**	**144,251,000**	**205,722,213**	**8,231,048,213**

Table E.6 Distribution of Lamps (%) by End-Use Sector in 2010 – Revised

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**62.0%**	**3.7%**	**0.3%**	**9.4%**	**45.0%**
General Purpose - A-Shape	34.9%	2.1%	0.3%	-	25.2%
General Purpose - Decorative	16.9%	-	-	-	11.9%
Reflector	7.5%	0.9%	0.0%	-	5.5%
Miscellaneous	2.8%	0.7%	-	9.4%	2.4%
Halogen	**4.4%**	**2.3%**	**0.0%**	**1.9%**	**3.7%**
General Purpose - A-Shape	0.5%	0.0%	0.0%	-	0.3%
General Purpose - Decorative	-	-	-	-	-
Reflector	2.9%	0.9%	0.0%	-	2.3%
Reflector - Low Voltage	0.3%	1.2%	-	-	0.5%
Miscellaneous	0.7%	0.1%	0.0%	1.9%	0.6%
Compact Fluorescent	**22.8%**	**10.4%**	**0.3%**	**5.9%**	**18.8%**
General Purpose - Pin	0.1%	6.6%	0.1%	-	1.7%
General Purpose - Screw	19.3%	2.0%	0.1%	-	14.1%
Reflector	2.0%	1.9%	0.1%	-	1.9%
Miscellaneous	1.4%	-	-	5.9%	1.1%
Linear Fluorescent	**9.9%**	**80.0%**	**89.2%**	**13.5%**	**29.0%**
T5	0.1%	5.2%	6.4%	-	1.5%
T8 Less than 4ft	0.1%	0.7%	0.5%	-	0.2%
T8 4ft	1.1%	43.9%	54.4%	-	12.8%
T8 Greater than 4ft	0.0%	1.3%	2.3%	-	0.4%
T8 U-Shaped	0.0%	2.2%	0.4%	-	0.6%
T12 Less than 4ft	0.1%	0.4%	0.0%	-	0.2%
T12 4ft	5.7%	19.8%	16.6%	-	9.3%
T12 Greater than 4ft	0.5%	5.3%	7.5%	-	1.8%
T12 U-Shaped	0.0%	0.5%	0.7%	-	0.1%
Miscellaneous	2.3%	0.6%	0.3%	13.5%	2.1%
High Intensity Discharge	**0.0%**	**1.7%**	**9.8%**	**58.3%**	**2.1%**
Mercury Vapor	0.0%	0.0%	1.0%	1.7%	0.1%
Metal Halide	0.0%	1.5%	6.5%	20.7%	1.0%
High Pressure Sodium	0.0%	0.2%	2.3%	35.3%	1.0%
Low Pressure Sodium	-	0.0%	-	0.7%	0.0%
Miscellaneous	-	-	-	-	-
LED	**0.2%**	**1.8%**	**0.4%**	**8.1%**	**0.8%**
General Purpose	-	-	-	-	-
Integrated Fixture/Luminaire	-	-	-	-	-
Linear	-	-	-	-	-
Reflector	-	-	-	-	-
Reflector - Low Voltage	-	-	-	-	-
Miscellaneous	0.2%	1.8%	0.4%	8.1%	0.8%
Other	**0.8%**	**0.0%**	**-**	**2.9%**	**0.6%**
Miscellaneous	0.8%	0.0%	-	2.9%	0.6%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Table E.7 Average Wattage per Lamp by End-Use Sector in 2010 – Revised

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**59**	**53**	**46**	**77**	**58**
General Purpose - A-Shape	64	58	46	-	64
General Purpose - Decorative	44	0	0	-	44
Reflector	69	79	65	-	70
Miscellaneous	45	7	0	77	45
Halogen	**67**	**68**	**68**	**108**	**67**
General Purpose - A-Shape	50	46	36	-	50
General Purpose - Decorative	-	-	-	-	-
Reflector	68	78	64	-	69
Reflector - Low Voltage	44	60	-	-	53
Miscellaneous	82	99	145	108	85
Compact Fluorescent	**17**	**19**	**31**	**22**	**17**
General Purpose - Pin	22	19	45	-	19
General Purpose - Screw	17	20	17	-	17
Reflector	17	20	16	-	18
Miscellaneous	18	-	-	22	18
Linear Fluorescent	**25**	**37**	**39**	**38**	**35**
T5	19	36	58	-	37
T8 Less than 4ft	16	20	23	-	19
T8 4ft	26	30	30	-	30
T8 Greater than 4ft	41	54	73	-	56
T8 U-Shaped	27	31	30	-	31
T12 Less than 4ft	16	35	33	-	26
T12 4ft	27	43	39	-	36
T12 Greater than 4ft	50	78	84	-	73
T12 U-Shaped	27	42	41	-	41
Miscellaneous	16	31	42	38	21
High Intensity Discharge	**154**	**350**	**403**	**274**	**300**
Mercury Vapor	193	362	451	176	271
Metal Halide	79	349	434	333	350
High Pressure Sodium	150	356	295	248	253
Low Pressure Sodium	-	185	-	101	104
Miscellaneous	-	-	-	-	-
LED	**11**	**12**	**11**	**48**	**21**
General Purpose	-	-	-	-	-
Integrated Fixture/Luminaire	-	-	-	-	-
Linear	-	-	-	-	-
Reflector	-	-	-	-	-
Reflector - Low Voltage	-	-	-	-	-
Miscellaneous	11	12	11	48	21
Other	**54**	**11**	**-**	**108**	**60**
Miscellaneous	54	11	-	108	60
Average	**46**	**42**	**75**	**183**	**49**

Table E.8 Average Daily Operating Hours by End-Use Sector in 2010 – Revised

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**1.8**	**10.4**	**12.6**	**8.2**	**2.0**
General Purpose - A-Shape	1.8	10.5	12.7	-	1.9
General Purpose - Decorative	1.8	-	-	-	1.8
Reflector	1.7	9.8	11.9	-	2.1
Miscellaneous	1.9	10.8	-	8.2	3.2
Halogen	**1.9**	**12.4**	**11.7**	**9.7**	**3.6**
General Purpose - A-Shape	2.0	12.1	11.7	-	2.4
General Purpose - Decorative	-	-	-	-	-
Reflector	1.9	12.4	11.7	-	3.0
Reflector - Low Voltage	1.7	12.6	-	-	7.9
Miscellaneous	2.0	10.1	11.7	9.7	2.9
Compact Fluorescent	**1.8**	**10.4**	**13.1**	**9.0**	**3.1**
General Purpose - Pin	1.9	10.4	13.2	-	10.1
General Purpose - Screw	1.8	10.7	13.0	-	2.1
Reflector	1.8	10.0	13.0	-	3.9
Miscellaneous	1.9	-	-	9.0	2.8
Linear Fluorescent	**1.9**	**11.1**	**12.5**	**14.9**	**9.0**
T5	2.5	11.7	12.6	-	11.5
T8 Less than 4ft	2.1	11.2	12.6	-	9.7
T8 4ft	1.9	11.1	12.6	-	10.6
T8 Greater than 4ft	1.7	11.0	12.6	-	10.8
T8 U-Shaped	2.1	11.0	12.6	-	10.8
T12 Less than 4ft	2.0	11.3	12.0	-	6.7
T12 4ft	1.9	11.1	12.4	-	7.1
T12 Greater than 4ft	1.7	11.1	12.5	-	9.4
T12 U-Shaped	1.9	11.0	12.5	-	10.9
Miscellaneous	2.1	11.0	12.3	14.9	4.9
High Intensity Discharge	**2.5**	**11.1**	**16.8**	**12.4**	**12.4**
Mercury Vapor	2.4	11.1	16.5	10.6	11.8
Metal Halide	2.1	11.1	16.5	12.4	12.4
High Pressure Sodium	2.5	11.0	17.9	12.5	12.5
Low Pressure Sodium	-	11.2	-	11.3	11.3
Miscellaneous	-	-	-	-	-
LED	**2.1**	**20.8**	**22.3**	**9.9**	**15.3**
General Purpose	-	-	-	-	-
Integrated Fixture/Luminaire	-	-	-	-	-
Linear	-	-	-	-	-
Reflector	-	-	-	-	-
Reflector - Low Voltage	-	-	-	-	-
Miscellaneous	2.1	20.8	22.3	9.9	15.3
Other	**1.4**	**14.8**	**-**	**17.1**	**3.3**
Miscellaneous	1.4	14.8	-	17.1	3.3
Average	**1.8**	**11.2**	**13.0**	**12.0**	**4.6**

Table E.9 Annual Lighting Electricity Consumed (TWh) by End-Use Sector in 2010 – Rev.

	Residential	Commercial	Industrial	Outdoor	All Sectors
Incandescent	**136**	**15**	**0**	**4**	**156**
General Purpose - A-Shape	84	9	0	-	94
General Purpose - Decorative	28	0	0	-	28
Reflector	19	5	0	-	24
Miscellaneous	5	0	0	4	10
Halogen	**12**	**15**	**0**	**1**	**28**
General Purpose - A-Shape	1	0	0	-	1
General Purpose - Decorative	-	-	-	-	0
Reflector	8	7	0	-	15
Reflector - Low Voltage	1	7	0	-	8
Miscellaneous	2	1	0	1	4
Compact Fluorescent	**15**	**16**	**0**	**1**	**32**
General Purpose - Pin	0	10	0	-	10
General Purpose - Screw	13	3	0	-	16
Reflector	1	3	0	-	4
Miscellaneous	1	0	0	1	2
Linear Fluorescent	**10**	**250**	**23**	**6**	**289**
T5	0	16	2	-	19
T8 Less than 4ft	0	1	0	-	1
T8 4ft	1	111	11	-	123
T8 Greater than 4ft	0	6	1	-	7
T8 U-Shaped	0	6	0	-	6
T12 Less than 4ft	0	1	0	-	1
T12 4ft	6	71	4	-	81
T12 Greater than 4ft	1	35	4	-	40
T12 U-Shaped	0	2	0	-	2
Miscellaneous	2	2	0	6	9
High Intensity Discharge	**0**	**49**	**35**	**175**	**260**
Mercury Vapor	0	1	4	3	8
Metal Halide	0	43	25	73	141
High Pressure Sodium	0	5	6	98	110
Low Pressure Sodium	0	0	0	1	1
Miscellaneous	-	-	-	-	0
LED	**0**	**3**	**0**	**4**	**7**
General Purpose	-	-	-	-	0
Integrated Fixture/Luminaire	-	-	-	-	0
Linear	-	-	-	-	0
Reflector	-	-	-	-	0
Reflector - Low Voltage	-	-	-	-	0
Miscellaneous	0	3	0	4	7
Other	**1**	**0**	**0**	**4**	**5**
Miscellaneous	1	0	0	4	5
Total	**175**	**349**	**58**	**195**	**777**

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