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2020 U.S. Lighting Market Characterization

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Disclaimer

Comments

The Energy Department is interested in feedback or comments on the materials presented in this document. Please write to Wyatt Merrill, Solid-State Lighting Technology Manager:

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List of Acronyms and Abbreviations

AEO	Annual Energy Outlook
AHS	American Housing Survey
CBECS	Commercial Buildings Energy Consumption Survey
CFL	compact fluorescent
DOE	United States Department of Energy
EIA	Energy Information Administration
EMS	energy modeling system
EMS	Energy Management System
ft^2	square feet
GWh	gigawatt-hour
HID	high intensity discharge
LED	light-emitting diode
LMC	Lighting Market Characterization
NEEA	Northwest Energy Efficiency Alliance
NEMA	National Electrical Manufacturers Association
OLED	organic light-emitting diode
quad	quadrillion British Thermal Units
RECS	Residential Energy Consumption Survey
SSL	solid-state lighting (capitalized when used to refer to DOE's Solid-State Lighting Program)
TWh	terawatt-hour
U.S.	United States
UL	Underwriters Laboratories
W	watt

Executive Summary

The 2020 U.S. Lighting Market Characterization (LMC) is the fourth LMC released[1] by the U.S. Department of Energy's (DOE's) Solid-State Lighting (SSL) Program, the most recent of which relied on 2015 data. These reports provide summary estimates of the installed stock and energy use of general illumination lighting products operating in the U.S. The objective of this report is to collect and present the technology distribution and 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) of each lighting technology were installed in the U.S. as of 2020, and where were they installed?
- How much energy was consumed by light sources in the U.S. in 2020?
- How did U.S. lighting market characteristics change between 2015 and 2020?

This study groups lighting technologies 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 evaluates subgroups of commonly available lighting products (e.g., reflector lamps, T8 fluorescent tubes, metal halide lamps, LED integrated fixtures/luminaires). In total, 33 lighting product types appear in the analysis, with characterizing information such as average wattage, operating hours, and total installed inventory from the sampled datasets. 0 provides a complete list of the lighting product subgroups found in the report.

The largest sector in terms of number of lamp and luminaire installations (installed units) is the residential sector. In 2020, residences accounted for 80% of all lighting installations nationwide, at 6.5 billion installed units. The report estimates the commercial buildings sector to have 1.6 billion lighting installations, accounting for the remaining 20% of all installations. While this report installment does not analyze the industrial and outdoor sectors, they have historically been smaller, accounting for a combined 5% of installed units in the 2015 LMC.

In both the residential and commercial sectors, the average wattage per installed unit has decreased significantly to approximately 22 watts (W) and 27 W respectively, with much of the reduction attributable to the continuing decline of incandescent, halogen, CFL, and linear fluorescent lamps in favor of high-efficiency LED replacements.

Combined, these inputs resulted in a total annual electricity use of U.S. lighting of 244 terawatt-hours (TWh), or approximately 14% 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 2020

	Total Installed Units	Average Daily Operating Hours	Wattage per Installed Unit	Annual Electricity Use (TWh)
Residential	6,506,275,000	1.6	22	76
Commercial	1,643,002,000	10.1	27	168
Total	**8,149,277,000**	**3.3**	**23**	**244**

Despite relatively fewer installed units, of the 244 TWh of electricity consumed in the U.S. in 2020, approximately 69% was attributable to the commercial sector. This is because commercial buildings have the highest total light output and operating hours. While linear fluorescent lighting continues to be the most

[1] The first three versions of the LMC were released in 2002, 2012, and 2017.

common lighting technology found in this sector at 48% of the installed units, LED installations, driven by both LED lamp replacements and integrated LED luminaires, have increased to approximately the same share of total installed units as linear fluorescent lighting. In many cases for commercial lighting, a single LED luminaire might replace multiple conventional lamps. Although the total number of installed units in the residential sector is much higher than in the commercial sector, the energy consumption of the residential sector only makes up 31%, due to the much lower operating hours of these lights.[2]

There have been significant changes in the lighting stock and energy consumption characteristics since 2010 and 2015 (the baseline years of the previous LMC reports). Section 4.2 details a comparison of the three estimates. Overall, LED lighting penetration has made significant strides in both sectors since 2010. In 2010 and 2015, LED installations represented 1% and 8% of overall lighting inventory, respectively. By contrast, LED installed units represent roughly 48% of the installed base in residential and commercial sectors in 2020.

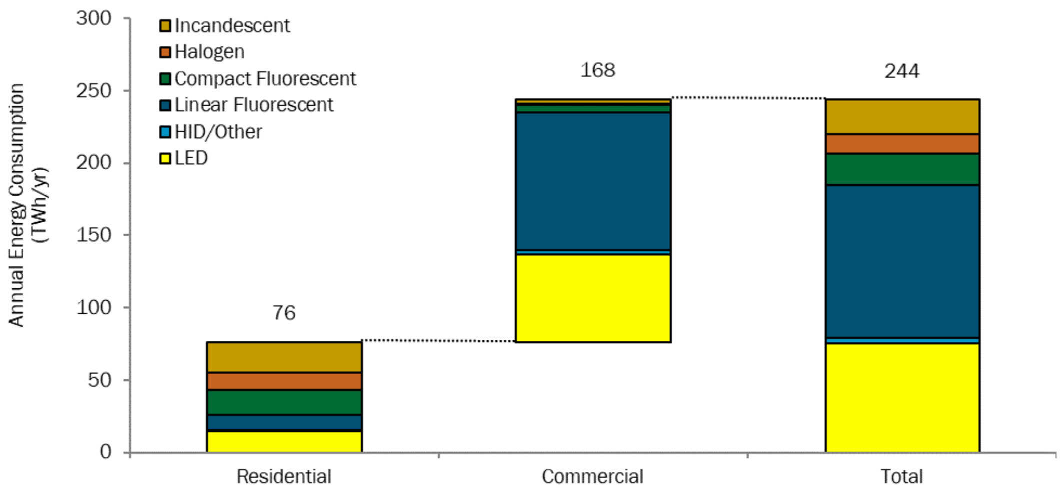

Figure ES.1 U.S. Lighting Electricity Consumption by Sector and Technology in 2020

The continued decline in LED lighting costs and increasing awareness of the performance and energy-savings benefits of LED technology, coupled with federal and state lighting regulations and efficiency incentive programs, have propelled the adoption of LED lamps and luminaires as the premier efficient lighting choice today. In the residential sector, there has been continued replacement of high-energy consuming incandescent and halogen lamps, and even CFLs, with LED lamps. In the commercial sector, many linear fluorescent sources are being replaced by LED lamps and luminaires, which offer greater lifetime, performance, and efficiency.

The report provides results at both a national level and a sector-specific level (residential and commercial buildings). Relative to the 2015 LMC, the scope of this update is narrower due to the availability of up-to-date lighting inventory data, and no longer includes the industrial buildings sector. A future addendum to this report will analyze the outdoor lighting sector. In general, the sample datasets in the residential and commercial sectors are smaller relative to the previous installment of this report. The estimates in this report 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.

[2] The operating hours for the residential sector are based on a 2012 study by DOE (*Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates*). Despite extensive search for more up to date estimates, no data that provided the necessary level of detail could be found. These operating hours do not reflect any lighting use behavior changes due to the Covid-19 pandemic and associated work-from-home trends.

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1 Introduction and Study Scope

1.1 Introduction

In 2002, 2012, and 2017, the U.S. Department of Energy (DOE) published the first three 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, 2010, and 2015. [1, 2, 3] These reports detail technical characteristics of the lighting market while reflecting on drivers of current and future change: new technology development and adoption, national and state government regulations, and energy efficiency programs.

The composition of installed technologies continued its rapid change between 2015 and 2020, with large scale adoption of LED lighting. Given the significant developments in lighting technology, particularly in solid-state lighting (SSL), and sweeping effects of national and state energy policies, DOE has conducted an updated lighting market characterization. Accordingly, DOE presents this report, the fourth 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 (R&D) program. This report answers three main questions:

- How many lighting products (lamps and luminaires) of each lighting technology were installed in the U.S. residential and commercial sectors as of 2020, and where were they installed?
- How much energy was consumed by these light sources in the U.S. in 2020?
- How did U.S. lighting market characteristics change between 2015 and 2020?

This report is sponsored by the SSL R&D subprogram, which is a component of the Emerging Technologies program in the Building Technologies Office (BTO) at DOE. The subprogram focuses on R&D needs for light-emitting diodes (LEDs) and organic LEDs (OLEDs). In addition to its use by BTO, 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 2020 LMC is structured similarly to the 2001, 2010, and 2015 LMC installments. However, this update to the LMC narrows the scope to the residential and commercial sectors based on data availability. Research indicated that the industrial sector lacks up-to-date lighting inventory data. Therefore, this latest report excludes analysis of the industrial sector. A future supplemental installment of the LMC will cover the outdoor lighting sector, as well as updates to efficacy and total lumen output.

1.2 Study Scope

The scope of this LMC installment includes all lighting installed in the U.S. in stationary applications for commercial and residential buildings as of 2020 (the baseline year). This report installment excludes industrial and outdoor lighting sectors, as well as mobile applications, such as automobile headlights.

As in the 2015 LMC, the lighting inventory and energy use estimates are categorized into the residential and commercial sectors. These sectors are 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 sector, the subsectors are based on the principal activity associated with the building. These 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). Table 1.1 lists the sectors and subsectors included in the analysis.

Table 1.1 Sectors and Subsectors Analyzed

Residential[3]		Commercial[4]
Residence Type	Room Type	Building Activity
Single Family	Basement/Crawlspace	Education
Multifamily	Bathroom	Food Service
Mobile/Manufactured Homes	Bedroom	Food Sales
	Closet	Health Care – Inpatient
	Dining Room	Health Care – Outpatient
	Exterior	Mercantile – Mall & Non-mall
	Garage	Lodging
	Hall/Stair/Entry	Office (Non-medical)
	Kitchen	Public Assembly
	Living Room/Den	Public Order and Safety
	Office	Religious Worship
	Utility	Service
	Other	Warehouse & Storage
	Unknown*	Other

*The “Unknown” room type is included to represent rooms that the source data did not label or describe.

2020 Sector and Subsector Update

The 2020 LMC is focused on the analysis of residential and commercial sectors, and does not include industrial and outdoor sector lighting, which were analyzed in previous LMC installments.

The classification of Residence Type and Room Type remain unchanged from the 2015 LMC for the residential sector. In the commercial sector, the previous classification of “Retail” Building Activity type has now been renamed to “Mercantile” in accordance with changes made in the 2018 Commercial Buildings Energy Consumption Survey (CBECS).

The lighting technologies have been categorized as displayed in Figure 1.1. The categories are based on those used in the 2015 LMC and the categories used in the various 2020 LMC data sources. 0 contains descriptions of each lighting technology and product type.

[3] For definitions of each residential subsector, refer to the linked document. Single-family attached homes as defined by AHS 2021 are included in this report’s “Single Family” category: https://www2.census.gov/programs-surveys/ahs/2021/2021%20AHS%20Definitions.pdf.
[4] For definitions of each commercial subsector refer to: https://www.eia.gov/consumption/commercial/building-type-definitions.php.

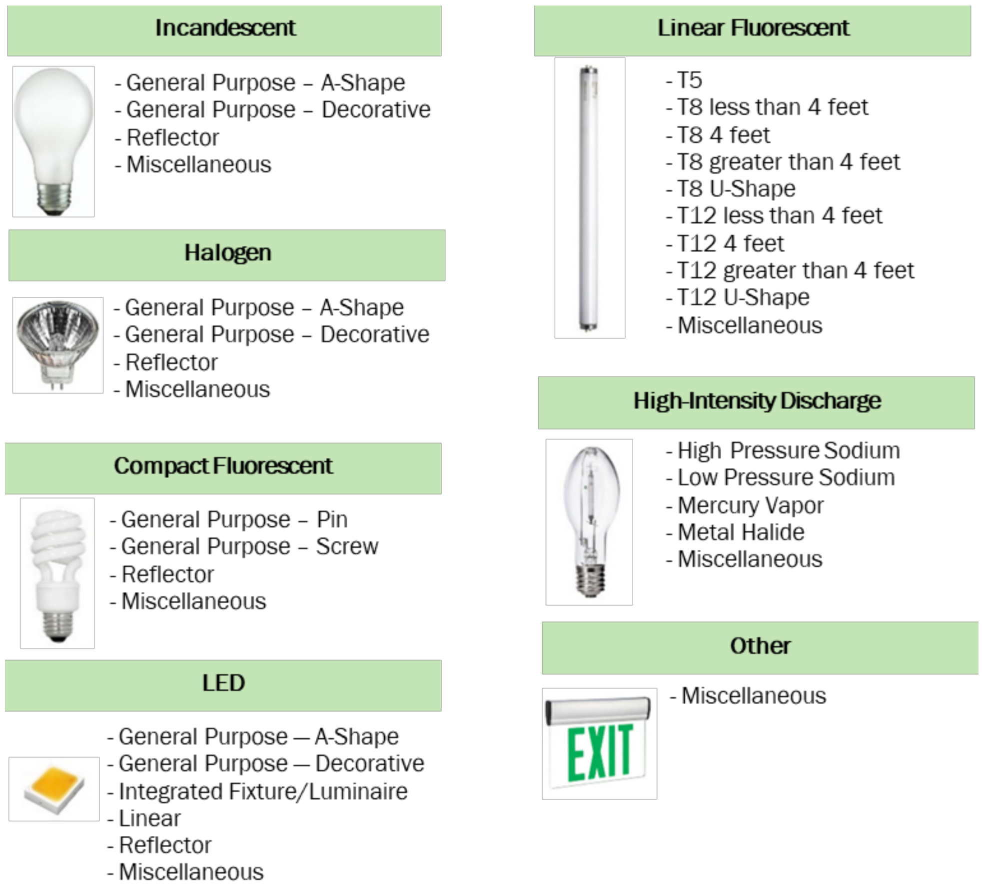

Figure 1.1 Lighting Technology Classification[5]

2020 Lighting Technology Classification Update

"Halogen Reflector – Low Voltage" and "LED Reflector – Low Voltage" classifications from the 2015 LMC have been removed. Low voltage reflectors are no longer analyzed as a separate category from reflectors, based on the data granularity of the data sources used in this update.

2 Methodology

The methodology used to develop the national lighting inventory 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 data collected in this step provide information 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 2.1 and Section 2.2, respectively.

The second step involved weighting the datasets 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., building types), as well as to scale sample building counts to the national level.

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

Because the data sources used in the first step were collected in various years prior to 2020, 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 2020. 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 shipment data analysis can be found in Section 2.2.1.1.

Figure 2.1 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 step.

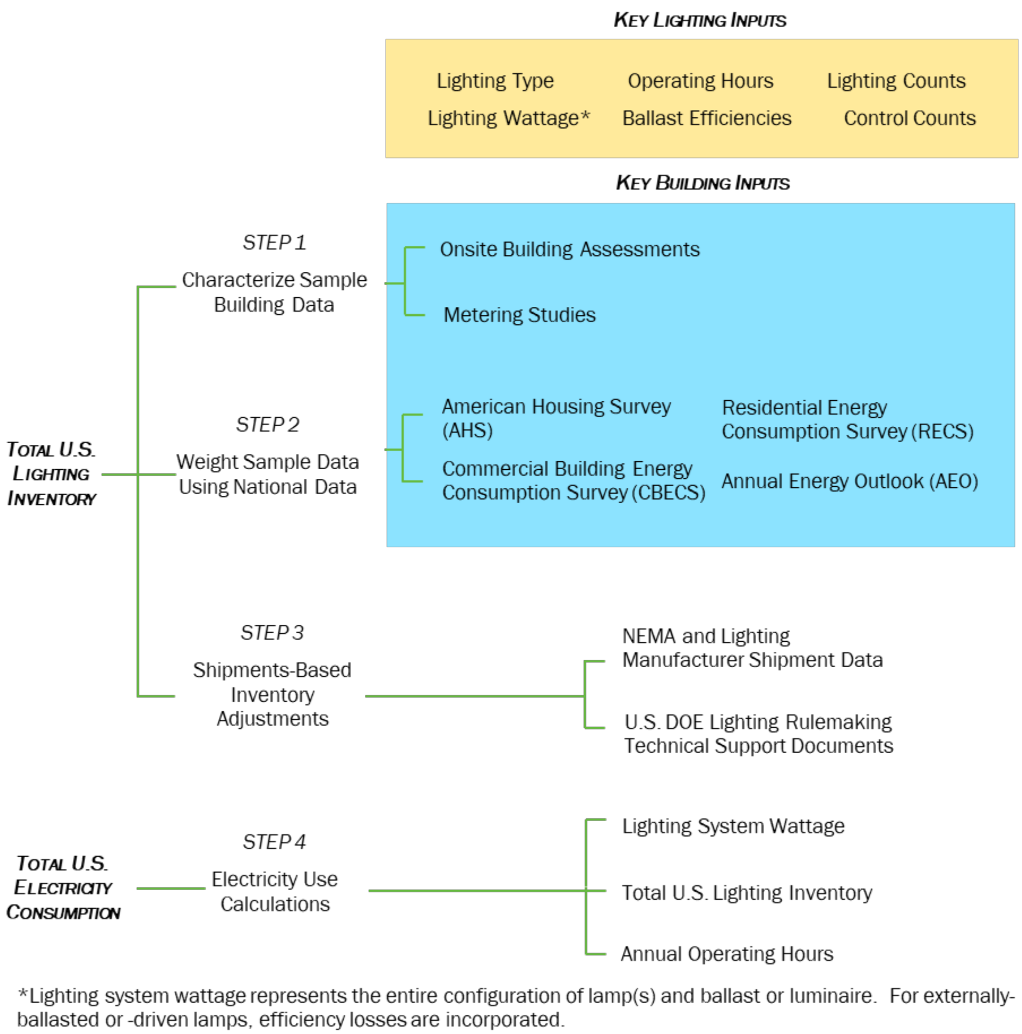
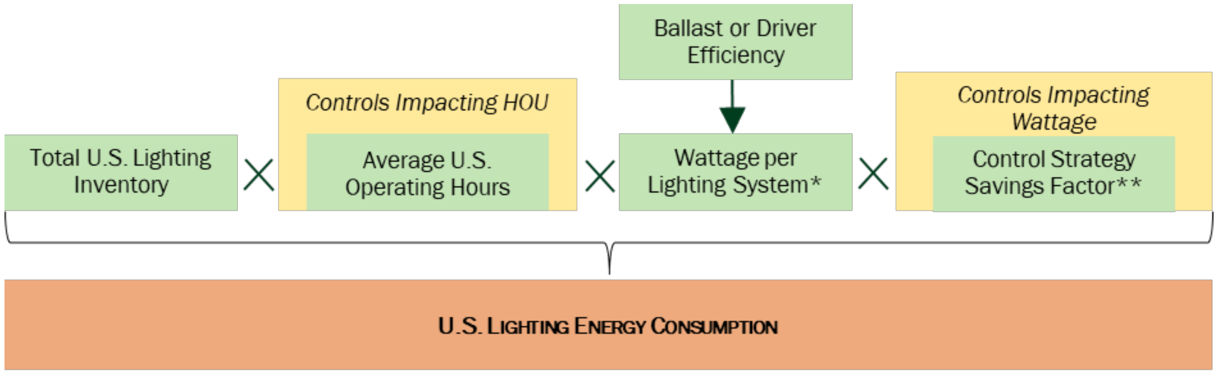


Figure 2.1 National Lighting Inventory and Electricity Consumption Calculations – Sources, Inputs, and High-Level Methodology

As seen in Figure 2.2 below, using the total 2020 U.S. lighting inventory, the energy use for each technology was determined by multiplying the number of installed units (lamps or luminaires) by the associated wattage and operating hour estimates.

In contrast to the 2010 LMC, both the 2015 and 2020 LMC calculate the energy use at the lamp or luminaire level (as opposed to 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.



*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 and 2015 LMC, the impacts of controls affecting wattage are not incorporated into cumulative results (Section 4.1) or sector-specific results (Section 4.2).

Figure 2.2 Energy Use Calculation Components[6]

2.1 Data Collection

The LMC relies primarily on existing data sources. Primary data collection was not conducted for this study. Thus, the quality of the analysis is dependent on the quality of the source data.

For this study, on-site sources were used to estimate lighting inventory. This contrasts with studies that use modeled data like the EIA's Annual Energy Outlook and the SSL subprogram's adoption and forecast reports.

Collecting high quality data – objective, accurate, and recent – was a primary concern in the development of this report. To do so, data were drawn from several 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 obtained through on-site audits and metering studies, and associated with random samples of buildings in specific regions of the U.S. These studies are usually conducted by utilities or regional energy efficiency organizations.
- **Shipment sources** provide the quantity of annual shipments from manufacturer groups for specific lamp and luminaire types.

2020 On-site Data Availability

In both the residential and commercial sector, there was an overall decrease in the number of available primary studies and data collection efforts for lighting on-site assessments (compared to the 2015 LMC), thereby reducing the total sample size, number of buildings, and geographical diversity available for this updated analysis. The following sections provide more detail on the key data sources used in this analysis.

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

2.1.1 National Data Sources

National building data were drawn from the U.S. Census Bureau's AHS and EIA building energy consumption surveys. The EIA's Annual Energy Outlook (AEO) was used to scale commercial building square footage estimates to the 2020 base year and as a data source for total U.S. energy consumption in 2020.

The EIA releases multiple studies for which a randomly selected sample of building owners are interviewed to estimate basic energy use characteristics for U.S. buildings. The 2020 LMC utilizes two of these studies: the Commercial Buildings Energy Consumption Survey (CBECS) and the Residential Energy Consumption Survey (RECS). [4, 5] The population estimate for the commercial sector was derived from CBECS. In the commercial sector, the building "population" is defined by the total floorspace per building type.

The residential sector population was primarily 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. RECS was used in concert with AHS to determine total floorspace of occupied units.

The AHS provided U.S. housing unit population estimates for 2019 and 2021, while CBECS provided U.S. building population and floorspace estimates for 2018. For the residential sector, an adjusted 2020 value for building population was derived from the 2019 and 2021 AHS publications. For the commercial sector, estimates of building stock growth from the EIA's AEO 2021 were used to adjust the building square footage values from the 2018 CBECS to reflect the 2020 base year. Table 2.1 summarizes the building characteristics of the national surveys used in this report (shown in white), as well as the adjusted 2020 values used in the LMC (shown in green) [6, 4, 5, 7].

Table 2.1 U.S. Building Population and Floorspace Summary

Data Source	Sector	Survey Year	Analysis Year (2020)	Estimated Building Count (thousands)	Scaled to 2020	Estimated Floorspace (million sqft)	Scaled to 2020
AHS	Residential	2021	2020	128,442	126,289	235,822	231,868
CBECS	Commercial	2018	2020	5,710	5,846	94,810	97,070

2.1.2 Residential Lighting Data Sources

The residential sector analysis incorporates data from two existing building audit studies that contain lighting data from seven states located in the West and Northeast of the United States. These studies were originally conducted to gain a quantitative understanding of the impacts of different utilities' demand side management programs and to plan for future programs and spending. In total, these sources, which contain lighting inventory data for more than 3,300 separate residences and 110,000 lighting products, were used to construct the residential lighting inventory database for the 2020 LMC. Data from onsite assessments conducted prior to 2016 were excluded from the analysis.

These studies were selected for this analysis because they utilized appropriate data collection methodologies and they contain data on the categories relevant to weighting this analysis. They contain the most up-to-date information on the residential lighting sector. Table 2.2 outlines the key characteristics of the residential data sources used in this report. Below is a brief summary of each study utilized.

- *Residential Building Stock Assessment II Final Report (2016-2017)* [8]: This 2020 Northwest Energy Efficiency Alliance (NEEA) report examines unique regional buildings data regarding the energy and technology characteristics of residential facilities throughout the Pacific Northwest region for the base years of 2016-2017. The study is an update to the previously completed analysis in 2011-2012. It is aimed as a database to be used by energy planners, energy efficiency program designers, and researchers.

- *NMR Onsite Lighting Data 2016-2020* [9]: This data contains detailed information about lighting installations in 945 participants' homes. The survey was conducted by NMR Group, Inc. for various utilities in the New England and Mid-Atlantic area. This data is not publicly available.

Table 2.2 Residential Data Source Key Characteristics[7],[8]

Source	Geographic Region(s)	Building Count – All	Year(s) of Data Collection
Residential Building Stock Assessment II Final Report	Idaho, Montana, Oregon, Washington	2,368	2016-2017
NMR Onsite Lighting Data 2016-2020	Massachusetts, New York, Rhode Island	945	2016-2020
	All Sample Regions		**2016-2020**

2.1.3 Commercial Lighting Data Sources

The 2020 LMC commercial analysis is primarily built utilizing primary data from three recent studies that examined on-site lighting inventory, technology, wattage, hours of use, and/or control strategy used. The studies encompass five states and roughly 1,300 buildings. Some buildings have been removed from these initial databases as they do not to contain complete lighting inventories.

Table 2.3 outlines the key characteristics of the commercial studies used in this report. Below is a brief summary of each study.

- *Commercial Building Stock Assessment 4 (2019) Final Report* [10]: This 2020 Northwest Energy Efficiency Alliance (NEEA) report examines unique regional buildings data regarding the energy and technology characteristics of commercial facilities throughout the Pacific Northwest region for the base year of 2019. The study is an update to the previously completed analyses in 2003, 2009, and 2014. It is aimed as a database to be used by energy planners, energy efficiency program designers, and researchers.
- *Massachusetts 2018 and 2019 C&I Lighting Inventory Studies* [11] [12] : These studies collected measure lifetimes, lighting characteristics, and analyzed technology saturation and market share for the commercial and industrial facilities in Massachusetts. These on-site assessments included both program participants and non-participants from the lighting programs within Massachusetts.
- *Massachusetts C&l Upstream Lighting Net-to-Gross Study, Final Report* [13]: This study focused on an analysis of the net-to-gross ratios associated with the Upstream Lighting Initiative for commercial and industrial customers in Massachusetts. The study included on-site lighting assessments alongside tracking of program data.

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[7] NYSERDA data for New York state was also collected but was ultimately excluded as it did not include information about bulb shape, only technology type.

[8] NMR data for Vermont was collected as well, but was ultimately excluded because it lacked information about home type for the surveyed locations.

Table 2.3 Commercial Data Source Key Characteristics

Source	Geographic Region(s)	Building Count – All	Year(s) of Data Collection
Massachusetts 2018 and 2019 C&I Lighting Inventory Studies	Massachusetts	296	2018-2019
Massachusetts C&I Upstream Lighting Net-to-Gross Study, Final Report	Massachusetts	76	2018
Commercial Building Stock Assessment 4 Final Report	Idaho, Montana, Oregon, Washington	932	2019
	All Sample Regions	**1,304**	**2018-2019**

2.1.4 Data Sources Comparison: 2015 LMC vs. 2020 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 2015 to 2020. However, differences in data sources and methodology between the 2015 LMC and the 2020 LMC inevitably influence the results. This section provides an overview of the differences in the underlying data collected for the 2020 LMC, as compared to the 2015 LMC, while departures in methodology for the 2020 LMC relative to the 2015 LMC are discussed in Section 2.2.

As seen in Figure 2.3, 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 were 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. Data collected for the 2020 LMC were concentrated in the West and Northeast census regions. No residential or commercial lighting inventory data representing the Midwest or the South regions could be obtained.

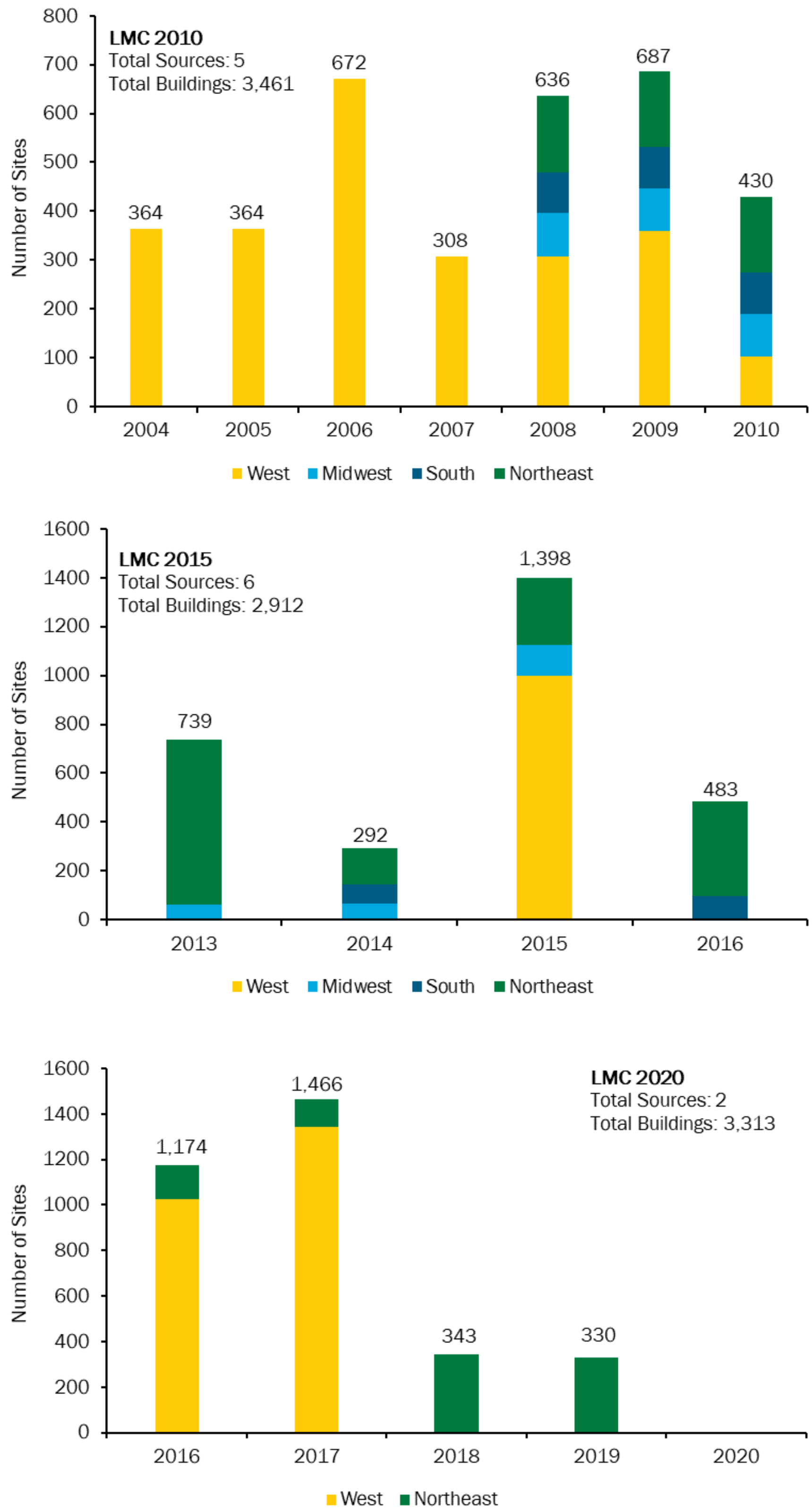

Figure 2.3 Residential Sector Buildings by Year and Region: Previous LMC Reports vs. 2020 LMC

Figure 2.4 provides a comparison between commercial building sample data collected for the 2010, 2015, and 2020 LMC studies. Similar to prior analyses, the 2020 LMC commercial buildings dataset had a high geographic concentration, with data from the West and Northeast census regions, and the majority of the data from the year prior to the baseline year. As discussed above, a key difference from the 2015 LMC is that the 2020 LMC does not contain geographic data from the Midwest or South region.

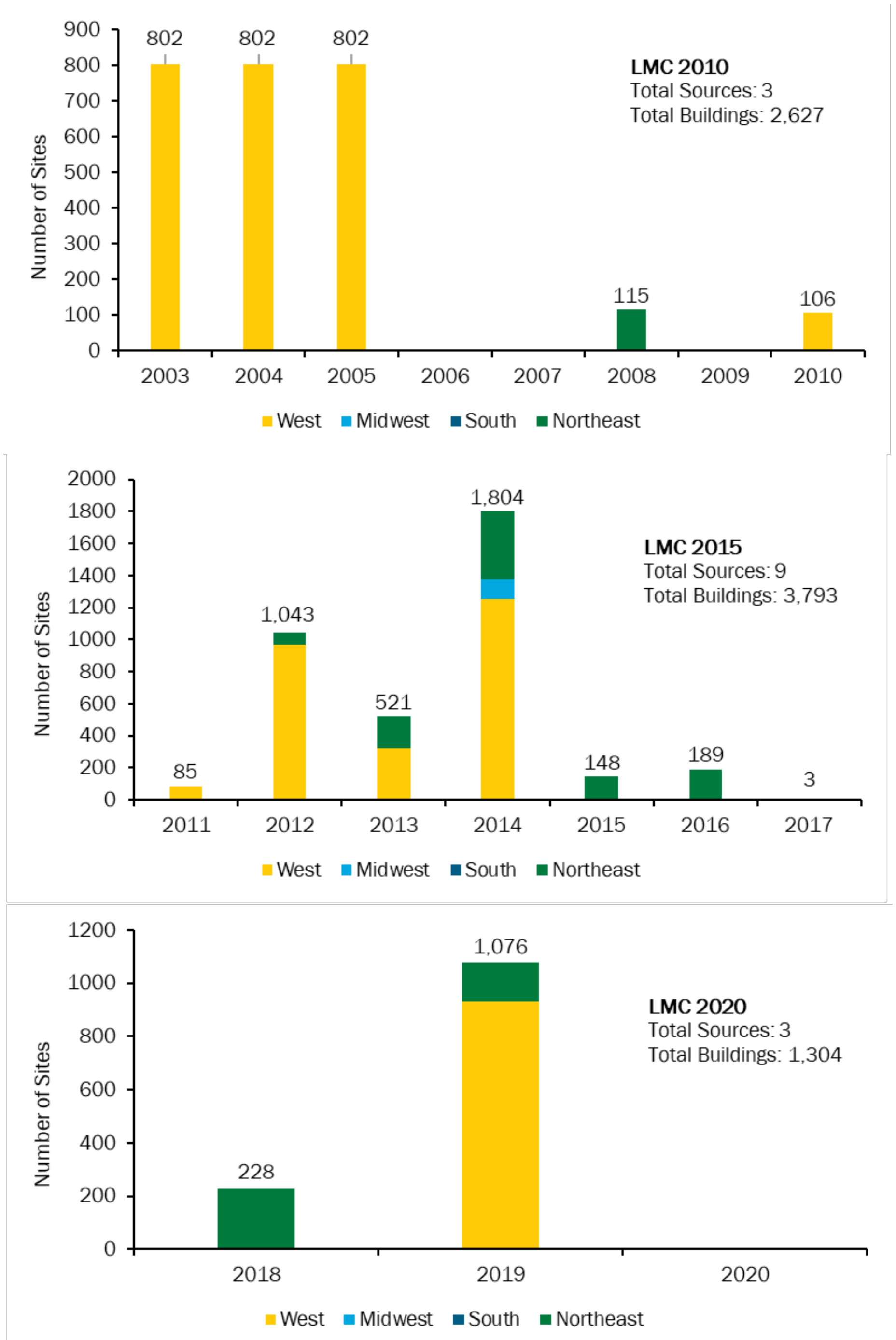

Figure 2.4 Commercial Sector Buildings by Year and Region: Previous LMC Reports vs. 2020 LMC

2.2 Building Sector Inventory and Energy Use Calculation

The inputs to this energy use calculation are discussed below for the building sectors. As discussed in Section 2.1, these inputs were primarily derived from building survey and audit data, as well as shipment data provided by NEMA.

2.2.1 Total U.S. Lighting Inventory

Representing a total of seven states and 4,617 buildings, the lighting inventory sample database was checked for quality issues such as reporting errors and outliers and subsequently scaled to represent the 2020 U.S. population of buildings. To accomplish this, building classifications 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.

Sample weights were calculated for 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 sector, 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 types of buildings in the sample dataset.

For the residential sector, data from the 2019 and 2021 AHS were used to determine the characteristics of the U.S. population of homes in 2020. Over 126 million residences existed in the U.S. in 2020, not including homes that were considered vacant. The sample weight is based on the residence type. The calculation for the basic weight is:

$$Sample\ Weight_{Res} = \frac{\sum Residences\ in\ U.S.of\ type(x)}{\sum Residences\ in\ Dataset\ of\ type(x)}$$

Where:
x = type categories (single-family; multifamily; mobile or trailer)

Total floorspace, age of the residence, and other demographic characteristics were not used in the weighting due to inadequate sample data.

2020 Residential Weighting Factor Update

For the 2020 update, sample data are not geographically diverse enough to allow for inclusion of region in the weighting factor. This differs from the 2015 LMC, which included region as a parameter for the weighting factor.

The above-mentioned differences in weighting methodology likely account for some of the differences between national residential inventory estimates presented in the 2020 LMC.

For the commercial sector, the 2018 CBECS was 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 2018 baseline to a 2020 baseline using growth estimates from the EIA's AEO 2021. [14] Using this methodology, the 2020 LMC estimates total U.S. commercial floorspace of 97.1 billion ft^2.

2020 Commercial Floorspace Update

The sources of data used to develop estimates of national commercial and industrial building stocks have been updated compared to the 2015 LMC. Based on the latest 2018 CBECS, the 2020 LMC estimates 97.1 billion ft^2 in total U.S. commercial floorspace for 2020. This represents an approximate 9% increase from the 2015 LMC.

The sample weight for each building is based on the use type of the building and the total U.S. floorspace dedicated to that use type. Due to a lack of sample lighting inventory data in the Midwest and South, the commercial sector analysis no longer calculates weighting of buildings by region. Buildings are instead weighted nationally. This represents a departure from the 2015 LMC methodology of calculating sample weights by census region.

The calculation for weighting commercial building interior lighting involves adjusting the building end-use proportions of the sample and scaling the sample to the national level:

$$Sample\ Weight_{Comm} = \frac{\sum Floor\ space\ in\ U.S.of\ type(y)}{\sum Floor\ space\ in\ sample\ dataset\ of\ type(y)}$$

Where:
y = type categories (hospital, lodging, office, etc.)

2020 Commercial Weighting Factor Update

The 2020 LMC weighting methodology excludes regional proportions as a part of the scale up to national population levels, due to a lack of lighting inventory data from the Midwest and South regions in this update. This differs from the 2015 LMC, which adjusted the regional proportions of the sample prior to adjusting building end-use proportions and scaling the sample to the national level. This difference in weighting methodology may account for some of the differences between commercial national inventory estimates presented in the 2015 LMC and those presented in the 2020 LMC.

2.2.1.1 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. This process of verification and adjustment is necessary since a portion of the lighting inventory sample data were collected in years prior to the 2020 baseline year.

The five-step process used to validate and (if necessary) adjust the nationally-weighted lighting inventory that leveraged lighting product shipments data is summarized in Figure 2.5 and described in detail below.

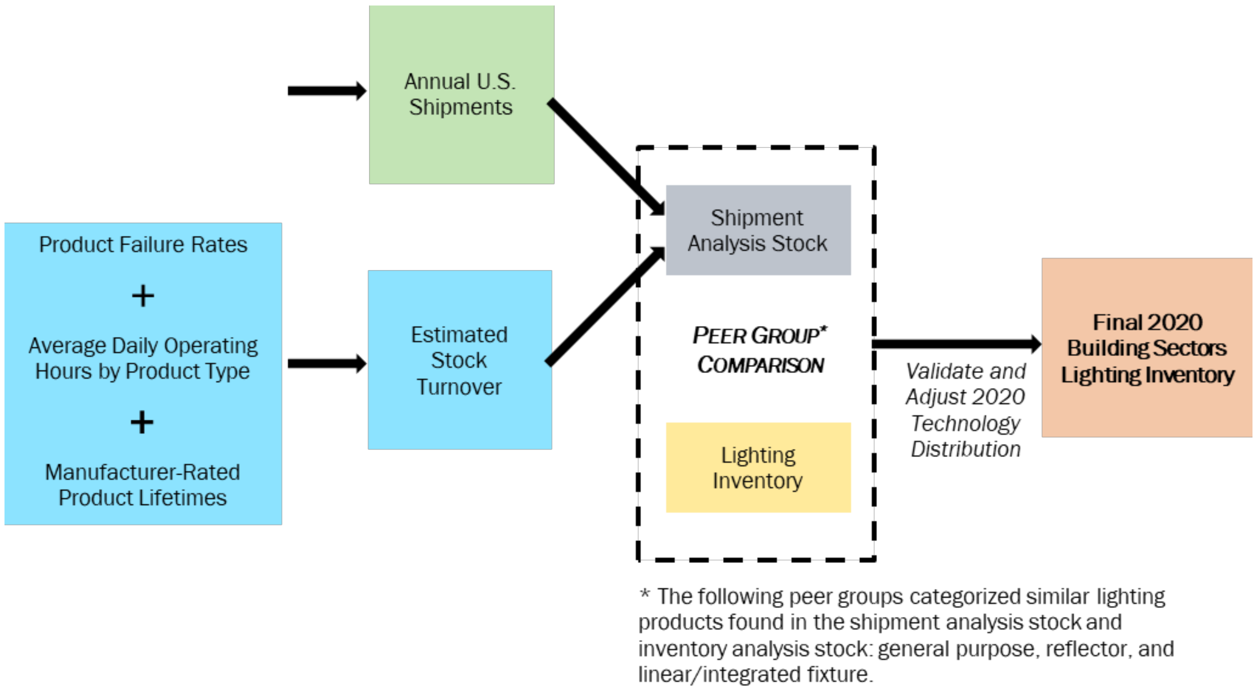

Figure 2.5 National Building Sectors Lighting Inventory Validation Methodology

Step 1 – Estimate Annual U.S. Shipments. NEMA provided historical U.S. lighting shipments data by product type for 2001 through 2020 (excluding LED lamps and luminaires). Additionally, supplemental LED lamp and luminaire sales data from manufacturers were used from analyses conducted for the LED Adoption and SSL Forecast reports. [15, 16] 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 2020. Stock turnover estimates were applied to annual shipments data to estimate installed stock in 2020 for each building sector by lighting technology and product type.

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

Step 5 – Validate and Adjust 2020 Technology Distribution. For each lighting peer group (e.g., general purpose, reflector, linear/integrated fixture), the 2020 technology distribution estimated from sample inventory data (using the weighting methodology described in Section 2.2.1) was compared against the 2020 technology distribution estimated using shipments data. Where the sample inventory technology mix was weighted too heavily for years prior to the 2020 baseline, or misrepresented due to low inventory counts for a specific lighting type, 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.

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.

2.2.2 Operating Hours

The daily hours of operation for lamps and luminaires in the residential sector are based on a DOE report written in 2012 and titled "Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates" [17]. Despite an extensive search for more up to date estimates, no data that provided the necessary level of detail could be found. The 2012 study used an ANCOVA model developed from the California Residential Lighting Metering Study dataset, collected from 2008 to 2009. It used other resources, including 2009 RECS, 2009 AHS, and a 2009 multi-state CFL study, to create linkages between sources. This made it possible to combine sources to arrive at complete estimates for the entire U.S.

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 sector, operating hours are based on surveys and on-site assessments with building owners and operators. Although operating hour data were not collected for every lighting installation, all the primary sources used in the commercial sector analysis provided some information on estimated operating hours. The operating hours were provided as average estimates of use over the entire year, and no adjustment factors were applied to them. These operating hours are sourced from the on-site assessments in 2018 and 2019.

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 installed unit 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.

2.2.3 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, [9] 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 [18]. 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

[9] 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.

average (system) wattage per lamp for the product categories presented in Figure 1.1 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 0.

2.2.4 Building Sector Controls

The data sources considered for the 2020 LMC building sector inventory often specify lighting control types at the installed unit level (lamp or luminaire). The availability of controls data within the on-site sample data facilitated the calculation of 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 2019 Energy Savings Forecast Report [16]. 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 standardizing the controls inventory, energy savings discounts based on baseline load profiles[10] (shown in Table 2.4) 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 2.2.1. For consistency with previous LMC report installments, control energy savings are presented as a separate results section in this report (see Section 3.2).

Table 2.4 Energy Savings Potential for Control Strategies Analyzed in 2020 LMC [16]

	Dimmer	Daylighting	Multi	EMS
Commercial – Office	5%	14%	37%	46%
Commercial – Warehouse	2%	15%	44%	55%
Commercial – Retail	6%	14%	49%	59%
Commercial – Lodging	3%	8%	63%	70%
Commercial – Health	7%	14%	46%	57%
Commercial – Education	5%	14%	52%	62%
Residential – All	2%	8%	27%	28%

[10] 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.

3 Lighting Inventory and Energy Consumption Estimates

Table 3.1 presents the estimate of the installed lighting inventory in the U.S. by technology, product type, and sector. The total installed base of residential and commercial lighting products in the U.S. for 2020 is estimated to be 8.1 billion. This represents an overall growth of 2.5% relative to 2010's estimate of nearly 7.9 billion lighting installations that year, and a decrease of 2.5% relative to 2015's estimate of 8.3 billion lighting installations that year. 0 details high-level trends in lighting in 2010, 2015, and 2020.

Since the 2015 LMC, the residential sector has experienced a roughly 5% growth of total lighting inventory, while the commercial sector inventory has decreased nearly 21% on an installed unit basis. While the residential sector accounts for 80% of total lighting installed units, the decline of installed units in the commercial sector has contributed to a slight overall decline in lighting product inventory counts in the U.S. Compared to 2010, the lighting inventories have increased by 12% in the residential sector and decreased by 21% in the commercial sector.

2020 Inventory Terminology Update

Historically, lighting installations were counted on the basis of lamps. In many cases, conventional multi-lamp systems were housed within one fixture. For the 2020 update, the total inventory utilizes "installed units" as a basis of counting. While this change does not change how the inventory is counted (i.e., the total number of units), it more accurately describes the fact that not all installed units are lamps, as in the case of integrated LED luminaires that contain no lamps, and often are considered direct LED replacements to multi-lamp fixtures.

The large decrease in installed units for the commercial sector is likely attributable to the increasing installation of integrated LED luminaires in lieu of multi-lamp systems. As an example, many commercial linear fluorescent lamp systems (e.g., for high/low bay and troffer applications) are 2-, 4-, 6-, or 8-lamp systems. If a 4-lamp high bay system is replaced with a single integrated LED luminaire, the total installed unit count decreases from 4 to 1. These types of replacement scenarios may account for some of the decreased total installed units in the commercial sector from 2015 to 2020. This same phenomenon is rarer in the residential sector, where most end-consumer replacements are focused on socket-based lamp-for-lamp replacements when transitioning from conventional lighting to LEDs.

Table 3.1 Estimated Inventory of Installed Units [11, 12] in the U.S. by End-Use Sector in 2020

	Residential	Commercial	Overall
Incandescent	**819,275,000**	**14,012,000**	**833,287,000**
General Service - A-Shape	161,395,000	2,451,000	163,846,000
General Service - Decorative	294,500,000	3,929,000	298,429,000
Reflector	334,367,000	5,415,000	339,782,000
Miscellaneous	29,013,000	2,217,000	31,230,000
Halogen	**430,576,000**	**3,042,000**	**433,618,000**
General Service - A-Shape	290,704,000	913,000	291,617,000
General Service - Decorative	12,577,000	52,000	12,629,000
Reflector	83,523,000	403,000	83,926,000
Miscellaneous	43,772,000	1,674,000	45,446,000
Compact Fluorescent	**1,599,236,000**	**53,763,000**	**1,652,999,000**
General Service - Pin	51,477,000	29,901,000	81,378,000
General Service - Screw	1,453,851,000	19,741,000	1,473,592,000
Reflector	66,453,000	2,429,000	68,882,000
Miscellaneous	27,455,000	1,692,000	29,147,000
Linear Fluorescent	**534,898,000**	**782,288,000**	**1,317,186,000**
T5	23,345,000	34,935,000	58,280,000
T8 Less than 4ft	5,370,000	32,416,000	37,786,000
T8 4ft	264,803,000	576,208,000	841,011,000
T8 Greater than 4ft	7,019,000	7,352,000	14,371,000
T8 U-shaped	-	18,026,000	18,026,000
T12 Less than 4ft	9,363,000	5,568,000	14,931,000
T12 4ft	201,779,000	86,632,000	288,411,000
T12 Greater than 4ft	20,766,000	9,379,000	30,145,000
T12 U-shaped	-	7,740,000	7,740,000
Miscellaneous	2,453,000	4,032,000	6,485,000
High Intensity Discharge	**7,346,000**	**3,539,000**	**10,885,000**
Mercury Vapor	111,000	42,000	153,000
Metal Halide	3,046,000	2,527,000	5,573,000
High Pressure Sodium	689,000	454,000	1,143,000
Miscellaneous	3,500,000	516,000	4,016,000
LED	**3,094,614,000**	**777,077,000**	**3,871,691,000**
General Service - A-Shape	1,778,092,000	149,420,000	1,927,512,000
General Service - Decorative	438,898,000	13,067,000	451,965,000
Integrated Fixture/Luminaire	146,951,000	235,247,000	382,198,000
Linear	24,504,000	301,502,000	326,006,000
Reflector	689,927,000	47,620,000	737,547,000
Miscellaneous	16,242,000	30,221,000	46,463,000
Other	**20,330,000**	**9,281,000**	**29,611,000**
Miscellaneous	20,330,000	9,281,000	29,611,000
Total	**6,506,275,000**	**1,643,002,000**	**8,149,277,000**

[11] 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.
[12] The "Other" category is comprised of installed units that do not fall into any of the previous categories, such as xenon and neon lamps, as well as lamps of unknown characteristics.

Table 3.2 shows the distribution of installed units by end-use sector, presenting the information in Table 3.1 as percentages. Relative to 2015 values, the results across both sectors for 2020 show a lower portion of incandescent, halogen, CFL, linear fluorescent, and HID lamps, with a corresponding shift to LED technologies. LED lamps and luminaires increased from only 8% of all lighting products in the 2015 LMC to account for nearly 48% of all installed lighting units in 2020.

In the residential sector, almost all lighting technologies experienced a decrease in saturation, with the notable exception of LED lamps and luminaires, which increased significantly from 7% in 2015 to 48% in 2020. The commercial sector followed similar lighting inventory saturation trends. These trends in both sectors are likely attributable to decreasing cost of LED replacements, utility-based incentive programs, features enabled by SSL technologies, and increased interest in energy conservation and financial savings.

Table 3.2 Distribution of Installed Units (%) by End Use Sector in 2020

	Residential	Commercial	Overall
Incandescent	**12.6%**	**0.9%**	**10.2%**
General Service - A-Shape	2.5%	0.1%	2.0%
General Service - Decorative	4.5%	0.2%	3.7%
Reflector	5.1%	0.3%	4.2%
Miscellaneous	0.4%	0.1%	0.4%
Halogen	**6.6%**	**0.2%**	**5.3%**
General Service - A-Shape	4.5%	0.1%	3.6%
General Service - Decorative	0.2%	-	0.2%
Reflector	1.3%	-	1.0%
Miscellaneous	0.7%	0.1%	0.6%
Compact Fluorescent	**24.6%**	**3.3%**	**20.3%**
General Service - Pin	0.8%	1.8%	1.0%
General Service - Screw	22.3%	1.2%	18.1%
Reflector	1.0%	0.1%	0.8%
Miscellaneous	0.4%	0.1%	0.4%
Linear Fluorescent	**8.2%**	**47.6%**	**16.2%**
T5	0.4%	2.1%	0.7%
T8 Less than 4ft	0.1%	2.0%	0.5%
T8 4ft	4.1%	35.1%	10.3%
T8 Greater than 4ft	0.1%	0.4%	0.2%
T8 U-shaped	-	1.1%	0.2%
T12 Less than 4ft	0.1%	0.3%	0.2%
T12 4ft	3.1%	5.3%	3.5%
T12 Greater than 4ft	0.3%	0.6%	0.4%
T12 U-shaped	-	0.5%	0.1%
Miscellaneous	-	0.2%	0.1%
High Intensity Discharge	**0.1%**	**0.2%**	**0.1%**
Mercury Vapor	-	-	-
Metal Halide	-	0.2%	0.1%
High Pressure Sodium	-	-	-
Miscellaneous	0.1%	-	-
LED	**47.6%**	**47.3%**	**47.5%**
General Service - A-Shape	27.3%	9.1%	23.7%
General Service - Decorative	6.7%	0.8%	5.5%
Integrated Fixture/Luminaire	2.3%	14.3%	4.7%
Linear	0.4%	18.4%	4.0%
Reflector	10.6%	2.9%	9.1%
Miscellaneous	0.2%	1.8%	0.6%
Other	**0.3%**	**0.6%**	**0.4%**
Miscellaneous	0.3%	0.6%	0.4%
Total	**100.0%**	**100.0%**	**100.0%**

Table 3.3 lists the average number of installed units 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 sector, a building is a single stand-alone building.

The average residence in 2020 is estimated to have about 51 installed units, which is roughly equivalent to the average number of lamps or luminaires installed per residence in 2015. In the commercial sector, the 2020 results estimate an average of 281 installed units per building, a 27% decrease from 2015. As explored above, this decrease is likely attributable to multi-lamp systems being replaced by integrated LED luminaires, rather than a decrease in the amount of lighting density in the commercial space.

Table 3.3 Average Number of Installed Units per Building by End-Use Sector in 2020

	Residential	Commercial
Incandescent	**6.5**	**2.4**
General Service - A-Shape	1.3	0.4
General Service - Decorative	2.3	0.7
Reflector	2.6	0.9
Miscellaneous	0.2	0.4
Halogen	**3.4**	**0.5**
General Service - A-Shape	2.3	0.2
General Service - Decorative	0.1	-
Reflector	0.7	0.1
Miscellaneous	0.3	0.3
Compact Fluorescent	**12.7**	**9.2**
General Service - Pin	0.4	5.1
General Service - Screw	11.5	3.4
Reflector	0.5	0.4
Miscellaneous	0.2	0.3
Linear Fluorescent	**4.2**	**133.8**
T5	0.2	6.0
T8 Less than 4ft	-	5.5
T8 4ft	2.1	98.6
T8 Greater than 4ft	0.1	1.3
T8 U-shaped	-	3.1
T12 Less than 4ft	0.1	1.0
T12 4ft	1.6	14.8
T12 Greater than 4ft	0.2	1.6
T12 U-shaped	-	1.3
Miscellaneous	-	0.7
High Intensity Discharge	**-**	**0.6**
Mercury Vapor	-	-
Metal Halide	-	0.4
High Pressure Sodium	-	0.1
Miscellaneous	-	0.1
LED	**24.5**	**132.9**
General Service - A-Shape	14.1	25.6
General Service - Decorative	3.5	2.2
Integrated Fixture/Luminaire	1.2	40.2
Linear	0.2	51.6
Reflector	5.5	8.1
Miscellaneous	0.1	5.2
Other	**0.2**	**1.6**
Miscellaneous	0.16	1.6
Total	**51.4**	**281.0**

Table 3.4 lists the average number of installed units per thousand square feet using the inventory counts from Table 3.1 and the floorspace estimates from Table 2.1. In 2015, there were approximately 24.4 lighting installed units per thousand square feet in the residential sector and 24.3 lighting installed units per thousand square feet in the commercial sector. The corresponding values in 2020 were 28.1 and 16.9, respectively.

In the residential sector, the 2020 analysis shows an increase in the average number of installations per thousand square feet. The slight increase (less than 4 installed units per 1,000 ft^2) may be a result of a move to lower lumen output lighting products, or it may be within the uncertainty of the 2015 and 2020 LMC estimates.

Conversely, in the commercial sector, there was a significant decline in the number of installations per thousand square feet over this time frame. As discussed, this decrease is likely attributable to multi-lamp systems being replaced by integrated LED luminaires, rather than a decrease in the amount of lighting density in the commercial space.

Table 3.4 Average Number of Installed Units per Thousand Square Feet by End-Use Sector in 2020

	Residential	Commercial
Incandescent	**3.53**	**0.14**
General Service - A-Shape	0.70	0.03
General Service - Decorative	1.27	0.04
Reflector	1.44	0.06
Miscellaneous	0.13	0.02
Halogen	**1.86**	**0.03**
General Service - A-Shape	1.25	0.01
General Service - Decorative	0.05	-
Reflector	0.36	-
Miscellaneous	0.19	0.02
Compact Fluorescent	**6.90**	**0.55**
General Service - Pin	0.22	0.31
General Service - Screw	6.27	0.20
Reflector	0.29	0.03
Miscellaneous	0.12	0.02
Linear Fluorescent	**2.31**	**8.06**
T5	0.10	0.36
T8 Less than 4ft	0.02	0.33
T8 4ft	1.14	5.94
T8 Greater than 4ft	0.03	0.08
T8 U-shaped	-	0.19
T12 Less than 4ft	0.04	0.06
T12 4ft	0.87	0.89
T12 Greater than 4ft	0.09	0.10
T12 U-shaped	-	0.08
Miscellaneous	0.01	0.04
High Intensity Discharge	**0.03**	**0.03**
Mercury Vapor	-	-
Metal Halide	0.01	0.03
High Pressure Sodium	-	-
Miscellaneous	0.02	0.01
LED	**13.35**	**8.01**
General Service - A-Shape	7.67	1.54
General Service - Decorative	1.89	0.13
Integrated Fixture/Luminaire	0.63	2.42
Linear	0.11	3.11
Reflector	2.98	0.49
Miscellaneous	0.07	0.31
Other	**0.09**	**0.10**
Miscellaneous	0.09	0.10
Total	**28.06**	**16.93**

Table 3.5 lists the average wattage per installed unit 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 2.2.3 for further detail on the calculation of average wattage per lamp or luminaire. In general, average wattage per installed unit has either decreased or stayed about the same on a per technology basis since 2015. However, overall average wattage per lamp decreased significantly in both the residential and commercial sectors. This was mainly driven by a strong shift to LED from technologies like incandescent and CFL in the residential sector, and from linear fluorescent in the commercial sector. The average LED integrated fixture/luminaire wattage is low because it contains many lower lumen products, such as downlights, alongside higher lumen products, such as high-bay luminaires. These trends are discussed in more detail in the sector-specific results presented in Section 3.1.

Table 3.5 Average[13] Wattage per Installed Unit by End-Use Sector in 2020

	Residential	Commercial	Overall
Incandescent	**56.1**	**57.4**	**56.2**
General Service - A-Shape	63.8	58.1	63.7
General Service - Decorative	35.8	35.5	35.8
Reflector	65.7	72.1	65.8
Miscellaneous	109.8	59.6	106.2
Halogen	**51.9**	**61.2**	**52.0**
General Service - A-Shape	49.9	85.5	50.0
General Service - Decorative	27.3	68.7	27.5
Reflector	45.6	49.1	45.6
Miscellaneous	84.6	50.7	83.3
Compact Fluorescent	**15.2**	**21.7**	**15.4**
General Service - Pin	13.5	20.9	16.2
General Service - Screw	15.3	21.8	15.4
Reflector	14.9	20.6	15.1
Miscellaneous	13.4	35.1	14.7
Linear Fluorescent	**38.9**	**32.6**	**35.1**
T5	17.4	33.3	26.9
T8 Less than 4ft	17.5	23.9	23.0
T8 4ft	34.1	31.3	32.2
T8 Greater than 4ft	46.1	37.8	41.9
T8 U-shaped	-	32.1	32.1
T12 Less than 4ft	24.4	35.1	28.4
T12 4ft	44.8	38.6	43.0
T12 Greater than 4ft	76.5	74.2	75.8
T12 U-shaped	-	36.2	36.2
Miscellaneous	25.6	33.3	30.4
High Intensity Discharge	**36.5**	**215.8**	**94.8**
Mercury Vapor	-	100.0	27.5
Metal Halide	37.7	219.4	120.1
High Pressure Sodium	99.9	249.2	159.2
Miscellaneous	24.2	178.3	44.0
LED	**8.5**	**19.3**	**10.7**
General Service - A-Shape	9.1	13.7	9.5
General Service - Decorative	5.4	5.4	5.4
Integrated Fixture/Luminaire	4.8	28.7	19.5
Linear	10.9	16.0	15.6
Reflector	9.7	13.1	9.9
Miscellaneous	9.4	21.7	17.4
Other	**26.9**	**26.8**	**26.9**
Miscellaneous	26.9	26.8	26.9
Total	**21.6**	**26.6**	**22.6**

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

Table 3.6 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 3.1 by the wattages per installed unit in Table 3.5.While on an inventory basis incandescent lamps have relatively low saturation at only about 10%, they account for over 25% of the total installed wattage across all sectors. This is due to their very low efficacy relative to newer technologies. Notably, LED units make up only about 23% of the total installed wattage. This is quite low relative to their nearly 50% share of installed units in both categories.

Table 3.6 Distribution (%) of Installed Wattage by End-Use Sector in 2020

	Residential	Commercial	Overall
Incandescent	**32.7%**	**1.8%**	**25.4%**
General Service - A-Shape	7.3%	0.3%	5.7%
General Service - Decorative	7.5%	0.3%	5.8%
Reflector	15.6%	0.9%	12.2%
Miscellaneous	2.3%	0.3%	1.8%
Halogen	**15.9%**	**0.4%**	**12.3%**
General Service - A-Shape	10.3%	0.2%	7.9%
General Service - Decorative	0.2%	-	0.2%
Reflector	2.7%	-	2.1%
Miscellaneous	2.6%	0.2%	2.1%
Compact Fluorescent	**17.3%**	**2.7%**	**13.8%**
General Service - Pin	0.5%	1.4%	0.7%
General Service - Screw	15.8%	1.0%	12.3%
Reflector	0.7%	0.1%	0.6%
Miscellaneous	0.3%	0.1%	0.2%
Linear Fluorescent	**14.7%**	**58.4%**	**25.2%**
T5	0.3%	2.7%	0.9%
T8 Less than 4ft	0.1%	1.8%	0.5%
T8 4ft	6.4%	41.4%	14.7%
T8 Greater than 4ft	0.2%	0.6%	0.3%
T8 U-shaped	-	1.3%	0.3%
T12 Less than 4ft	0.2%	0.4%	0.2%
T12 4ft	6.4%	7.7%	6.7%
T12 Greater than 4ft	1.1%	1.6%	1.2%
T12 U-shaped	-	0.6%	0.2%
Miscellaneous	-	0.3%	0.1%
High Intensity Discharge	**0.1%**	**1.7%**	**0.6%**
Mercury Vapor	-	-	-
Metal Halide	0.1%	1.3%	0.4%
High Pressure Sodium	-	0.3%	0.1%
Miscellaneous	0.1%	0.2%	0.1%
LED	**18.8%**	**34.3%**	**22.5%**
General Service - A-Shape	11.5%	4.7%	9.9%
General Service - Decorative	1.7%	0.2%	1.3%
Integrated Fixture/Luminaire	0.5%	15.5%	4.1%
Linear	0.2%	11.0%	2.8%
Reflector	4.7%	1.4%	4.0%
Miscellaneous	0.1%	1.5%	0.4%
Other	**0.4%**	**0.6%**	**0.4%**
Miscellaneous	0.4%	0.6%	0.4%
Total	**100.0%**	**100.0%**	**100.0%**

Table 3.7 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 2.2.2 for details on the methodology for calculating operating hours.

Hours of Use and the COVID-19 Pandemic

Although the operating hour estimates presented below are the best available 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.

In addition, the results from this 2020 LMC do not account for changes in occupant behavior due to the COVID-19 pandemic. The pandemic precipitated a major shift in how and where people spent their time, as many employees shifted to remote work. The pandemic also made it largely difficult to conduct on-site lighting inventory assessments, and thus much of the data used in this report was collected prior to 2020. While the changes associated with the pandemic have evolved since 2020, the long-term impacts of increased remote work and its consequences for lighting hours of use remain to be seen.

The 2020 average operating hour estimates for the residential sector are similar to those in 2015. Some technologies have slightly different operating hour estimates, but the overall sector-weighted averages are similar. Compared to the 2015 LMC, average operating hours estimated for the commercial sector are 14% greater. This variability may be due to the smaller subset of sample data available for the 2020 update.

Table 3.7 Average Daily Operating Hours by End-Use Sector in 2020

	Residential	Commercial	Overall
Incandescent	**1.3**	**10.5**	**1.4**
General Service - A-Shape	1.2	9.9	1.3
General Service - Decorative	1.3	10.0	1.4
Reflector	1.3	11.2	1.5
Miscellaneous	1.2	10.4	1.9
Halogen	**1.5**	**10.1**	**1.6**
General Service - A-Shape	1.4	7.9	1.5
General Service - Decorative	1.7	10.5	1.7
Reflector	1.7	8.7	1.7
Miscellaneous	1.6	11.6	2.0
Compact Fluorescent	**1.9**	**11.5**	**2.2**
General Service - Pin	2.0	11.2	5.4
General Service - Screw	1.9	12.6	2.0
Reflector	2.1	8.9	2.3
Miscellaneous	2.0	8.8	2.3
Linear Fluorescent	**1.5**	**9.2**	**6.1**
T5	1.6	9.9	6.6
T8 Less than 4ft	1.6	10.2	9.0
T8 4ft	1.4	9.1	6.7
T8 Greater than 4ft	1.6	9.2	5.4
T8 U-shaped	-	9.2	9.2
T12 Less than 4ft	1.6	8.8	4.3
T12 4ft	1.5	9.4	3.9
T12 Greater than 4ft	1.4	9.3	3.9
T12 U-shaped	-	8.8	8.8
Miscellaneous	1.5	9.1	6.2
High Intensity Discharge	**2.8**	**7.0**	**4.1**
Mercury Vapor	1.5	6.0	2.7
Metal Halide	3.0	7.5	5.0
High Pressure Sodium	2.0	1.6	1.9
Miscellaneous	2.8	9.1	3.6
LED	**1.5**	**11.0**	**3.4**
General Service - A-Shape	1.5	12.1	2.3
General Service - Decorative	1.5	14.0	1.9
Integrated Fixture/Luminaire	1.7	11.1	7.4
Linear	1.6	10.1	9.5
Reflector	1.7	11.4	2.3
Miscellaneous	1.6	11.1	7.8
Other	**1.8**	**9.1**	**4.1**
Miscellaneous	1.8	9.1	4.1
Total	**1.6**	**10.1**	**3.3**

Table 3.8 presents the electricity consumed in 2020 by lighting technology, calculated by summing the inventory-weighted electricity consumption values by lighting product type and technology. In the residential and commercial sectors, total electricity consumed in the U.S. in 2020 is estimated to be 244 terawatt-hours (TWh), or roughly 2.3 quadrillion British thermal units (quads) of primary energy. Linear fluorescent and LED installed units consumed the greatest amount, constituting 43% and 31%, respectively, of total lighting electricity consumption. LED energy consumption is driven primarily by the technology's high saturation, and despite its large share of electricity consumption, LEDs have contributed significantly to the decline in total lighting energy. Linear fluorescent energy consumption is driven primarily by the lower efficacy (relative to LEDs) of the technology, although these lamps still make up a sizeable portion of the commercial lighting market.

Similar to 2015, lighting in the commercial sector in 2020 consumed more electricity than the residential sector, at approximately 69% of the total. This is due to higher output products in the commercial sector as well as drastically higher operating hours.

Table 3.8 Annual Lighting Electricity Consumed (TWh) by End-Use Sector in 2020

	Residential	Commercial	Overall
Incandescent	**21.2**	**3.1**	**24.3**
General Service - A-Shape	4.5	0.5	5.1
General Service - Decorative	4.8	0.5	5.3
Reflector	10.6	1.6	12.2
Miscellaneous	1.3	0.5	1.8
Halogen	**12.3**	**0.7**	**12.9**
General Service - A-Shape	7.6	0.2	7.9
General Service - Decorative	0.2	0.0	0.2
Reflector	2.4	0.1	2.4
Miscellaneous	2.1	0.4	2.4
Compact Fluorescent	**16.7**	**5.1**	**21.8**
General Service - Pin	0.5	2.8	3.3
General Service - Screw	15.2	1.9	17.1
Reflector	0.7	0.2	0.9
Miscellaneous	0.3	0.2	0.4
Linear Fluorescent	**11.1**	**95.1**	**106.1**
T5	0.2	4.6	4.9
T8 Less than 4ft	0.1	3.0	3.0
T8 4ft	4.6	65.6	70.2
T8 Greater than 4ft	0.2	1.0	1.2
T8 U-shaped	-	2.1	2.1
T12 Less than 4ft	0.1	0.7	0.8
T12 4ft	5.0	13.9	18.9
T12 Greater than 4ft	0.8	2.7	3.5
T12 U-shaped	-	1.0	1.0
Miscellaneous	-	0.5	0.5
High Intensity Discharge	**0.2**	**2.4**	**2.6**
Mercury Vapor	-	0.0	0.0
Metal Halide	0.1	1.9	2.0
High Pressure Sodium	0.1	0.1	0.1
Miscellaneous	-	0.5	0.5
LED	**14.7**	**60.4**	**75.1**
General Service - A-Shape	8.7	8.8	17.5
General Service - Decorative	1.3	0.4	1.6
Integrated Fixture/Luminaire	0.4	26.4	26.8
Linear	0.1	19.8	19.9
Reflector	4.1	2.6	6.7
Miscellaneous	0.1	2.6	2.7
Other	**0.3**	**0.8**	**1.2**
Miscellaneous	0.3	0.8	1.2
Total	**76.5**	**167.6**	**244.0**

3.1 Sector Specific Results

The following two subsections examine the cumulative results for all lighting technologies by building sector focusing on the subsector-level results. Specifically, the sections detail the installed base, average system wattage, and operating hours for defined subsectors (room, building or business types) within the residential and commercial building sectors.

As discussed in Section 2, the data populating tables for the residential and commercial sectors are based on sample building inventory data. The sample data were scaled to a national level based on residence type for the residential sector and based on building size and end-use type for the commercial sector. The data were then adjusted using shipments data to characterize the lighting market in 2020, accounting for the fact that sample data was collected in years prior to 2020. For a detailed discussion of the sector methodologies, see Section 2.

3.1.1 Residential Subsector Results

Table 3.9 provides the number of residential households considered in this analysis by residence type and census region. As discussed in Section 2.1.1, the values are drawn from the 2019 and 2021 AHS. Each residency represents a single housing unit, even if it is part of a multifamily structure.

Table 3.9 Estimated Number of Residences by Census Region and Type in 2020

	Single Family	Multifamily	Mobile/Manufactured	Total
Northeast	14,209	7,669	479	22,357
Midwest	20,642	5,977	949	27,568
South	34,335	9,962	3,693	47,990
West	19,206	7,670	1,498	28,374
Total	**88,391**	**31,279**	**6,619**	**126,289**

Table 3.10 presents the lighting technology distribution by room type. As seen below, there is significant variation between room types. Notably, LEDs have increased from only 7% of the installed base in 2015 to almost 50% in 2020. The increase is significant across all room types. Garages lag the rest of the room types in technology adoption, as they still have a large share of inefficient lighting. Overall, it seems that room types where units may not be turned on as much have less efficient lighting than room types where the lights are on often. This may be because residents are prone to upgrade their lighting when existing units burn out and lights that are on often burn out more quickly. Another explanation could be that residents choose to only change their most used lights when they make lighting upgrades to save money.

Table 3.10 Lighting Technology Distribution of Residences by Room Type in 2020

	Incandescent	Halogen	CFL	Linear Fluorescent	HID & Other	LED	Total
Basement/Crawlspace	9.0%	4.4%	28.0%	25.0%	0.1%	33.5%	100%
Bathroom	19.3%	8.1%	25.2%	1.2%	0.5%	45.7%	100%
Bedroom	11.8%	7.1%	35.2%	2.4%	0.2%	43.3%	100%
Closet	11.5%	7.6%	27.4%	13.7%	0.3%	39.5%	100%
Dining Room	18.6%	7.0%	20.7%	0.4%	0.5%	52.7%	100%
Exterior	15.2%	6.9%	31.4%	1.7%	3.0%	41.8%	100%
Garage	4.7%	3.7%	15.4%	56.2%	0.1%	19.8%	100%
Hall/Stair/Entry	13.0%	5.0%	26.7%	13.1%	0.3%	42.0%	100%
Kitchen	12.6%	5.0%	18.6%	11.9%	0.4%	51.5%	100%
Living Room/Den	15.4%	7.7%	24.7%	2.7%	0.3%	49.3%	100%
Office	9.0%	5.9%	27.9%	8.6%	0.3%	48.3%	100%
Utility	6.2%	3.8%	27.8%	30.5%	0.1%	31.6%	100%
Other	9.7%	4.6%	20.1%	30.3%	-	35.2%	100%
Unknown*	11.1%	6.9%	22.6%	6.7%	0.3%	52.4%	100%
Average	**12.6%**	**6.6%**	**24.6%**	**8.2%**	**0.4%**	**47.6%**	**100%**

*Unknown indicates data which did not include room type.

Table 3.11 presents the average operating hours per day by residence type and room type. As seen below, for every residence type, exterior lighting has the highest number of operating hours. The daily operating hours overall and by residence type remain largely unchanged since 2010, due to the lack of updated data at the LMC's level of detail. See Section 2.2.2 for more information on the residential hours of use data used for the 2020 LMC.

Table 3.11 Average Daily Operating Hours by Residence Type and Room Type in 2020[14]

	Single Family	Multifamily	Mobile/Manufactured	Average
Basement/Crawlspace	1.4	1.5	1.4	1.4
Bathroom	1.2	1.2	1.3	1.2
Bedroom	1.1	1.1	1.2	1.1
Closet	1.4	1.4	1.5	1.4
Dining Room	1.5	1.5	1.6	1.5
Exterior	3.0	3.2	3.0	3.1
Garage	1.2	1.3	1.2	1.2
Hall/Stair/Entry	0.7	0.7	0.9	0.7
Kitchen	2.5	2.6	2.6	2.5
Living Room/Den	1.6	1.6	1.7	1.6
Office	1.7	1.8	1.7	1.7
Utility	1.4	1.4	1.5	1.4
Other	1.4	1.4	1.4	1.4
Unknown	1.6	1.6	-	1.6
Average	**1.6**	**1.6**	**1.7**	**1.6**

Table 3.12 shows the installed units per thousand square feet by residence type in 2020. Total installed units per thousand square feet remain fairly similar across home types. Table 3.13 below gives a breakdown of the technology distribution by residence type.

Table 3.12 Installed Units per Thousand Square Feet by Residence Type in 2020

	Single Family	Multifamily	Mobile/Manufactured	Total
Incandescent	3.64	2.89	3.26	3.53
Halogen	1.82	1.91	2.55	1.86
CFL	6.52	8.93	8.81	6.90
Linear Fluorescent	2.09	3.70	2.43	2.31
HID & Other	0.09	0.29	0.10	0.12
LED	13.38	13.90	10.52	13.35
Total	**27.55**	**31.62**	**27.67**	**28.06**

Mobile and manufactured homes lag slightly behind other home types in terms of new technology adoption. A larger portion of these homes' installed units is made up of inefficient lighting technologies. A relatively lower median household income for people living in mobile and manufactured homes may explain the lower likelihood of lighting upgrades [6]. Multifamily homes also lag single family homes in this category, although the difference is not as pronounced. This difference could also reflect income disparities between single family and multifamily residents. The difference may also be attributable to the differing interests of multifamily occupants and their landlords. Multifamily occupants often rent their units and are not responsible for making lighting or other upgrades to the property, and landlords are not incentivized to make upgrades as they often pass utility bills onto tenants. This creates a split-incentive, where tenants are unwilling to pay to upgrade someone else's property and landlords are unwilling to pay for an upgrade that will not save them money.[15]

[14] These operating hours were calculated using a 2012 DOE study which only had HOU data for certain room types, and thus the HOU figure for "Other" had to be used in many cases. This may add error to the HOU figures listed for various room types included in the LMC, but not in the original study.
[15] The split incentive phenomenon has been extensively researched and discussed in the green building and energy efficiency communities. More information can be found here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4819331/

Table 3.13 Lighting Technology Distribution by Residence Type in 2020

	Single Family	Multifamily	Mobile/Manufactured	Total
Incandescent	13%	9%	12%	12.6%
Halogen	7%	6%	9%	6.6%
CFL	24%	28%	32%	24.6%
Linear Fluorescent	8%	12%	9%	8.2%
HID & Other	0.3%	0.9%	0.4%	0.4%
LED	49%	44%	38%	47.6%
Total	**100%**	**100%**	**100%**	**100.0%**

Table 3.14 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, mobile and manufactured homes rank the highest and multifamily homes rank second.

Table 3.14 Lighting Electricity Use by Residence Type in 2020

	Average Floorspace	Installed Wattage (W/ft^2)	Lighting Electricity Use per Household (kWh/yr)	Household Intensity ($kWh/yr/ft^2$)	Intensity Rank
Single Family	2,205	0.60	719	0.33	3
Multifamily	925	0.64	321	0.35	2
Mobile/Manufactured	1,214	0.61	441	0.36	1

3.1.2 Commercial Subsector Results

Fourteen commercial building space types were examined for the 2020 LMC. Table 3.15 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 2.2.1, these sector characteristics were collected from the 2018 CBECS and scaled to a 2020 baseline by using the total square footage estimates from the EIA's AEO 2021.

Table 3.15 Estimated Number and Floorspace of Commercial Buildings in 2020

	Average Square Feet	Number of Buildings	Total Square Feet
Education	31,174	447,000	13,947,809,000
Food Sales	6,172	167,000	1,029,986,000
Food Service	4,843	293,000	1,418,022,000
Health Care - Inpatient	251,000	9,000	2,312,861,000
Health Care - Outpatient	13,643	132,000	1,801,963,000
Lodging	33,700	212,000	7,142,326,000
Mercantile	20,853	529,000	11,038,048,000
Offices (Non-Medical)	17,177	993,000	17,059,266,000
Other	21,549	116,000	2,493,057,000
Public Assembly	14,738	500,000	7,363,476,000
Public Order and Safety	18,988	83,000	1,574,670,000
Religious Worship	12,462	449,000	5,601,443,000
Services	7,197	888,000	6,388,778,000
Warehouse and Storage	17,413	1,028,000	17,899,841,000
Average/Total	**16,604**	**5,846,000**	**97,071,546,000**

Table 3.16 illustrates the distribution of technologies across the commercial sector by commercial building type. Linear fluorescent and LED lighting technologies dominate the commercial sector, accounting for 95% of all lighting inventory. These two technologies represent over 85% of installations for all subsectors. No other lighting technology accounts for at least 10% of any building type, except for CFLs in the lodging category.

Education buildings have the lowest adoption rate of LEDs. The following factors have all contributed to a slower adoption rate of LEDs in education buildings: relative ease of maintaining and replacing linear fluorescent lamps, competing budget priorities within school districts, lack of qualified electricians and complexity to install and maintain integrated LED troffer offerings across a large quantity and size of buildings within a school district, and the low operating hours compared to other building types.[16] Table 3.18 provides more information on daily operating hours by commercial building type.

Table 3.16 Lighting Technology Distribution by Commercial Building Type in 2020

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Total
Education	0%	0%	3%	75%	0%	21%	0%	100%
Food Sales	0%	0%	1%	45%	0%	52%	2%	100%
Food Service	7%	0%	4%	22%	0%	64%	2%	100%
Health Care (Inpatient)	0%	0%	6%	43%	0%	49%	1%	100%
Health Care (Outpatient)	0%	0%	7%	37%	0%	54%	1%	100%
Lodging	2%	0%	11%	21%	0%	65%	1%	100%
Mercantile	1%	0%	1%	44%	0%	54%	0%	100%
Office	0%	0%	3%	49%	0%	46%	1%	100%
Other	1%	1%	6%	31%	1%	59%	0%	100%
Public Assembly	1%	0%	3%	40%	0%	55%	0%	100%
Public Order and Safety	0%	0%	1%	49%	1%	49%	0%	100%
Religious Worship	2%	1%	3%	62%	0%	32%	1%	100%
Service	1%	0%	2%	36%	0%	61%	1%	100%
Warehouse and Storage	0%	0%	1%	53%	0%	45%	0%	100%
Average	**1%**	**0%**	**3%**	**48%**	**0%**	**47%**	**1%**	**100%**

[16]See Illuminating Engineering Society's LD+A Magazine, pp. 16-17, available at: https://media.ies.org/2024/04-lda/index.html#p=16

Table 3.17 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. Two building types of note – lodging and food service – have the lowest average wattages, due to these categories having the highest rates of LED penetration (shown in Table 3.16). For most building types, overall average wattages decreased compared to 2015 estimates, due to the shift to more-efficient LED lighting.

Table 3.17 Average Lighting Wattage by Commercial Building Type in 2020

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Average
Education	64	158	25	35	167	28	28	34
Food Sales	54	105	27	33	340	18	18	26
Food Service	56	46	18	38	-	12	24	21
Health Care (Inpatient)	57	91	28	34	-	20	25	27
Health Care (Outpatient)	45	98	26	34	-	21	20	27
Lodging	67	51	20	35	168	15	43	21
Mercantile	47	52	29	38	386	18	17	27
Office	65	58	24	35	280	21	24	28
Other	60	37	22	36	74	27	26	30
Public Assembly	47	51	24	35	276	21	27	28
Public Order and Safety	-	-	18	37	296	16	-	30
Religious Worship	57	72	20	36	-	16	28	30
Service	61	46	20	40	210	18	34	27
Warehouse and Storage	70	66	25	37	466	32	38	36
Average	**57**	**61**	**23**	**36**	**253**	**20**	**27**	**29**

The average operating hours by lighting technology for each commercial building space is provided in Table 3.18. The average operating hours for each space type align closely with the two dominant technologies: linear fluorescent and LED. Inpatient health care and food sales had the largest average daily operating hours of any building type, while education, religious worship, and service accounted for the least usage. In general, daily operating hours trends are more correlated to building type than to lighting technology. The commercial sector-wide average daily operating hours increased by about 1.3 hours relative to the 2015 LMC.

Table 3.18 Daily Operating Hours by Commercial Building Type in 2020

	Incandescent	Halogen	CFL	Linear Fluorescent	HID	LED	Other	Average
Education	7.3	9.8	7.2	7.5	6.0	7.0	3.6	7.4
Food Sales	16.5	12.8	19.4	19.1	17.4	18.5	24.0	18.9
Food Service	12.3	11.5	15.6	13.6	-	15.0	12.3	14.4
Health Care (Inpatient)	23.2	16.1	21.0	20.6	-	18.9	20.0	19.8
Health Care (Outpatient)	7.5	7.7	9.9	10.0	-	6.6	8.4	8.1
Lodging	16.8	20.3	17.6	17.9	13.0	18.4	21.0	18.2
Mercantile	8.5	7.6	9.8	10.4	12.1	10.8	17.8	10.6
Office	8.5	9.9	8.6	8.6	7.8	8.6	8.4	8.6
Other	10.8	8.6	9.8	9.2	5.7	12.9	9.5	11.4
Public Assembly	10.7	16.8	11.5	7.9	9.1	12.2	11.4	10.4
Public Order and Safety	-	-	16.6	22.0	17.7	14.4	-	18.2
Religious Worship	5.4	4.9	7.5	7.7	-	8.3	6.8	7.8
Service	6.6	7.6	8.4	7.5	7.6	7.9	5.0	7.8
Warehouse and Storage	7.3	6.1	10.0	8.3	6.8	10.4	3.4	9.3
Average	**10.5**	**10.1**	**11.5**	**9.2**	**8.7**	**11.0**	**11.1**	**10.2**

Table 3.19 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 and 2015, inpatient health care buildings consume the largest amount of lighting electricity per building due to their substantial area footprint and high operating hours. The final column in Table 3.19 provides an intensity ranking of electricity use per floorspace to compare all subsectors by a common metric. Building types with high energy intensity rankings, such as food sales, food service, and public order and safety buildings, are often operational through the night, while lower intensity building types are operational mostly during daylight hours.

Table 3.19 Lighting Electricity Use by Commercial Buildings in 2020

	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	16	0.6	46,500	1.5	12
Food Sales	21	0.5	22,800	3.7	1
Food Service	31	0.7	16,200	3.3	2
Health Care (Inpatient)	13	0.3	631,900	2.5	5
Health Care (Outpatient)	16	0.4	18,300	1.3	13
Lodging	16	0.3	72,700	2.2	7
Mercantile	22	0.6	47,100	2.3	6
Office	19	0.5	28,300	1.6	11
Other	22	0.7	57,800	2.7	4
Public Assembly	18	0.5	27,900	1.9	8
Public Order and Safety	15	0.5	61,000	3.2	3
Religious Worship	21	0.6	21,600	1.7	10
Service	24	0.6	12,900	1.8	9
Warehouse and Storage	8	0.3	16,200	0.9	14

3.2 Lighting Controls

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 environment to provide adequate lighting only when and where needed.

This report considers only lighting controls that can save energy by either reducing input wattage (and thereby reducing light output) 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, other controls such as dimmers, reduce light levels and therefore also reduce wattages.

The 2020 LMC estimates the prevalence and energy savings of lighting controls in the residential and commercial sectors based on the available controls data in the various sampled datasets. Data were scaled to a national level using the same methodology described in Section 2.2.1. 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) during compilation. The actual saturation of controls is likely higher than the estimates this report presents.

As discussed in Section 2.2.4, 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 2019 Energy Savings Forecast Report [16]. 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[17] 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 lighting hours of operation.
- **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.
- **Energy management systems** are information and control systems that monitor occupancy and lighting in the built environment to provide centralized lighting control. They often combine several of these control technologies to reduce energy consumption.[18]

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[17] 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.

[18] This definition applies only to the scope of lighting energy. Energy management systems can be used to monitor, control, and optimize energy performance in many other applications, including lighting, HVAC, building automation, and other systems.

- **Multi-strategy systems** are any combination of more than one of the above-mentioned control strategies (e.g., occupancy sensors and dimming) implemented together on the same lamp or luminaire. However, this study assumes that there is no communication between different lamps and luminaires within spaces using multi-strategy systems.

As depicted in Table 3.20, lighting controls are more frequently installed in the commercial sector than in the residential sector, with an estimated 30% of installed units in the commercial sector being used in conjunction with lighting controls. This is in contrast to only 11% of residential lighting installations being used with lighting controls.

Table 3.20 Prevalence of Lighting Controls by Sector

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Residential	89%	9%	0%	0%	0%	0%	1%	100%
Commercial	70%	0%	0%	16%	7%	5%	1%	100%

Table 3.21 presents the prevalence of lighting controls in the residential sector by lighting type. The analysis indicates that incandescent lamps and LED lamps and luminaires share a similar likelihood of having controls. Both of these technologies are most likely to be used with dimmers over other control types. A large share of HID lamps also have controls. However, these lamps make up only a small portion of the total installed units, so estimates for HID lamps may be more prone to error than the other technologies.

Table 3.21 Prevalence of Lighting Controls in the Residential Sector by Lighting Technology

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Incandescent	84%	13%	0%	1%	0%	0%	2%	100%
Halogen	85%	10%	0%	1%	0%	0%	3%	100%
CFL	96%	3%	0%	0%	0%	0%	0%	100%
Linear Fluorescent	99%	0%	0%	1%	0%	0%	0%	100%
HID	82%	1%	12%	3%	0%	0%	2%	100%
LED	85%	13%	0%	0%	0%	0%	2%	100%
Other	83%	10%	4%	0%	0%	0%	2%	100%

Table 3.22 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 most prevalent lighting control strategy. The other category with notable levels of controls is exterior applications, which often have motion sensors, photosensors or both.

Table 3.22 Prevalence of Lighting Controls in the Residential Sector by Room Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Basement/Crawlspace	93%	6%	0%	1%	0%	0%	0%	100%
Bathroom	98%	2%	0%	0%	0%	0%	0%	100%
Bedroom	95%	5%	0%	0%	0%	0%	0%	100%
Closet	96%	1%	0%	3%	0%	0%	0%	100%
Dining Room	83%	17%	0%	0%	0%	0%	0%	100%
Exterior	87%	0%	4%	4%	0%	0%	6%	100%
Garage	97%	0%	0%	3%	0%	0%	0%	100%
Hall/Stair/Entry	98%	2%	0%	0%	0%	0%	0%	100%
Kitchen	91%	9%	0%	0%	0%	0%	0%	100%
Living Room/Den	88%	11%	0%	0%	0%	0%	0%	100%
Office	97%	3%	0%	0%	0%	0%	0%	100%
Utility	98%	0%	0%	2%	0%	0%	0%	100%
Other	91%	7%	0%	1%	0%	0%	0%	100%

Table 3.23 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 most prevalent control strategy.

Table 3.23 Prevalence of Lighting Controls in the Residential Sector by Residence Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Single Family	88%	10%	0%	0%	0%	0%	1%	100%
Multifamily	91%	7%	1%	0%	0%	0%	1%	100%
Mobile Home	94%	3%	0%	1%	0%	0%	1%	100%

Table 3.24 shows the prevalence of lighting controls in the commercial sector. Approximately 30% of all installed units, regardless of technology type, are used in conjunction with lighting controls. Occupancy sensors are the most common form of lighting controls deployed in the commercial sector. Timers and EMS are also widely used.

Table 3.24 Prevalence of Lighting Controls in the Commercial Sector by Lighting Technology Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Incandescent	96%	0%	1%	0%	2%	0%	0%	100%
Halogen	83%	0%	0%	3%	11%	2%	0%	100%
CFL	85%	0%	0%	5%	3%	7%	0%	100%
Linear Fluorescent	75%	1%	0%	14%	4%	6%	0%	100%
HID	74%	0%	1%	11%	5%	9%	0%	100%
LED	64%	0%	0%	18%	10%	4%	2%	100%
Other	87%	0%	0%	3%	0%	10%	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 3.25, 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 mercantile (retail) and education buildings.

Table 3.25 Prevalence of Lighting Controls in the Commercial Sector by Building Type

	None	Dimmer	Daylighting	Occupancy Sensor	Timer	EMS	Multi	Total
Education	56%	0%	0%	26%	3%	14%	1%	100%
Food Sales	90%	0%	0%	7%	3%	1%	0%	100%
Food Service	98%	1%	0%	2%	0%	0%	0%	100%
Health Care (Inpatient)	87%	0%	0%	10%	0%	3%	0%	100%
Health Care (Outpatient)	61%	0%	0%	31%	1%	8%	0%	100%
Lodging	91%	0%	1%	5%	2%	1%	0%	100%
Mercantile	55%	1%	0%	3%	28%	13%	0%	100%
Office	73%	0%	0%	23%	1%	2%	0%	100%
Other	90%	1%	0%	6%	2%	0%	0%	100%
Public Assembly	78%	0%	0%	14%	3%	5%	0%	100%
Public Order and Safety	86%	0%	0%	14%	0%	0%	0%	100%
Religious Worship	93%	0%	0%	7%	1%	0%	0%	100%
Service	71%	0%	0%	13%	15%	1%	0%	100%
Warehouse and Storage	51%	2%	0%	31%	3%	0%	13%	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 2019 DOE Energy Savings Forecast Report. Table 3.26 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 that impact wattage.[19] Overall, an estimated 6.2 TWh is saved in the national inventory considered in this analysis due to the impact of controls.

Table 3.26 Expected Energy Savings of Lighting Controls by Sector (Expected GWh Saved Per Year)

	Dimmer	Daylighting	EMS	Multi	Total
Residential	131	25	67	363	586
Commercial	21	7	4,940	634	5,601
Total	**152**	**32**	**5,007**	**997**	**6,188**

[19] For consistency with past LMC installments, Table 3.8 in Section 3 does not incorporate the energy savings discussed in this section.

4 Results Summary

In 2020, the total primary source energy consumption in the United States was 93 quads across all sectors, according to the EIA's AEO 2021.[20] [19] Roughly 37.5 quads (or 39%) of this primary source energy was consumed in the residential and commercial sectors. The breakout of the total source energy consumption by sector is displayed in Figure 4.1. Note that this is a breakdown of total source energy consumption, and not just electricity.

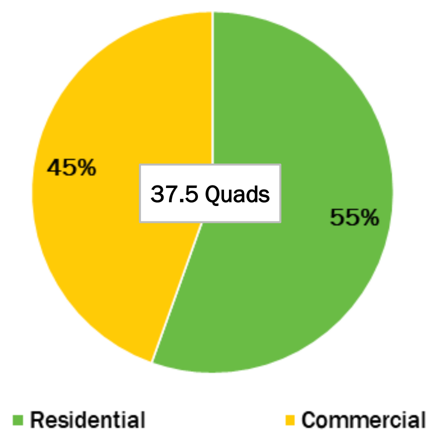

Figure 4.1 U.S. Residential and Commercial Source Energy Consumption in 2020[21]

In 2020, the total amount of delivered electricity consumed by residential and commercial lighting technologies was estimated to be 244 TWh, or 2.3 quads of primary source energy.[22] Thus, residential and commercial lighting accounted for 2.5% of the total source energy across all U.S. sectors and 6% of the total source energy consumed specifically in the residential and commercials sectors in the U.S. in 2020.[23] Additionally, the 244 TWh of electricity consumed for residential and commercial lighting is 9% of the total delivered electricity consumed in these building sectors. This is equivalent to the total electricity consumed by over 22 million homes annually.

The following section summarizes the results presented in Section 3 of this report.

4.1 Lighting Market Characteristics

Figure 4.2 displays the breakdown of the inventory estimates and total lighting electricity consumption by sector. The residential sector accounts for the overwhelming majority of installed lighting at 80% of the nationwide installed base. However, in terms of electricity, the sector only consumes approximately 77 TWh, or 31% of the national total. While the commercial sector accounts for only 20% of installed units, it is responsible for approximately 69% of the total lighting electricity consumption due to typically greater output lighting installations and significantly longer operating hours.

[20] Source energy consumption includes distribution losses.
[21] Residential sector includes public street and highway lighting, interdepartmental sales, and other.
[22] Conversion to quads from TWh estimates includes site to source electricity conversion factor of 2.8: https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf
[23] Based on a total source energy consumption of 37.5 quads for residential and commercial sectors from AEO 2021.

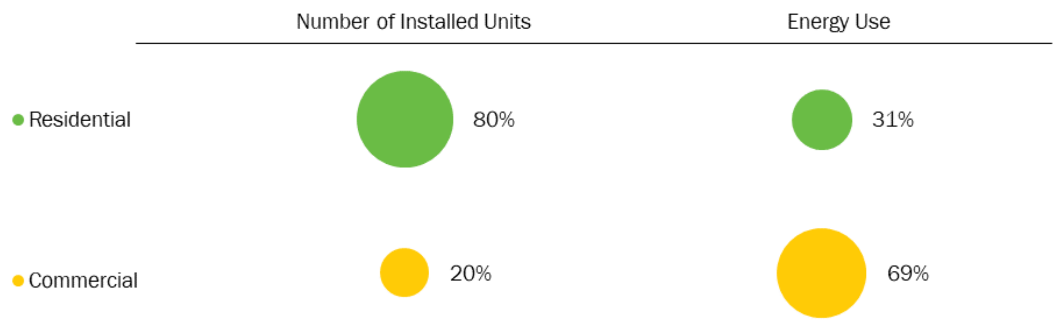

Figure 4.2 U.S. Lighting[24] Inventory and Electricity Consumption in 2020

Figure 4.3 displays the same electricity consumption data from Figure 4.2 disaggregated by lighting technology. At 43% of the total, linear fluorescent lamps consumed the greatest amount of electricity, followed by LED lamps and luminaires at 31% of the total.

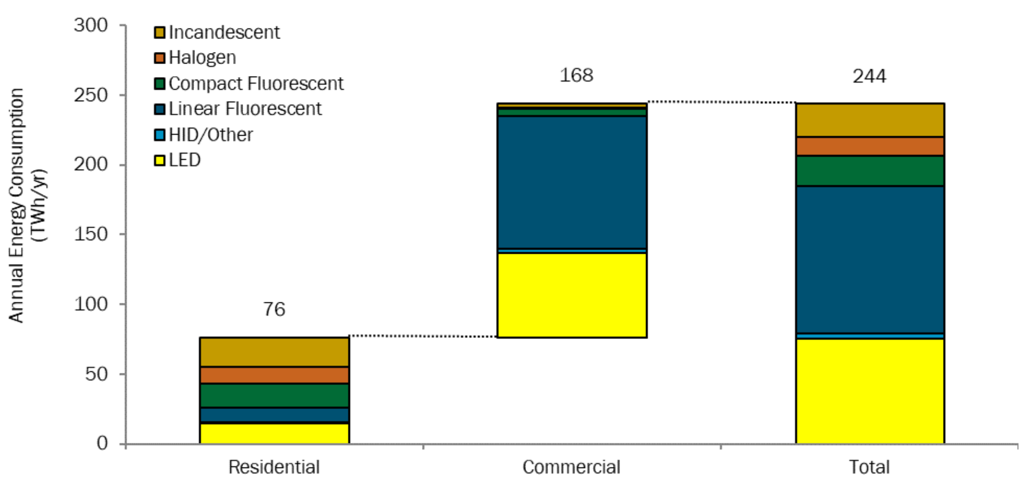

Figure 4.3 U.S. Lighting Electricity Consumption by Sector and Technology Type in 2020

In the residential sector, incandescent lamps remained the largest consumers of electricity, yet the overall percentage of total sector energy attributed to incandescent lamps has continued to decline. In 2020, these lamps made up 28% of the total sector consumption, down from 42% in 2015 and 78% in 2010. LED lamp energy consumption in the residential sector increased substantively since 2015, from 2% to 20% in 2020, as the installed units increased from 7% to 48%.

In the commercial sector, linear fluorescent lamps consumed the most energy, accounting for 57% of the sector's lighting electricity consumption. Following a similar trend as the residential sector, LED lighting was

[24] For the 2020 LMC, LED integrated fixtures and luminaires are also included.

the second largest electricity consuming technology. Commercial sector LED energy consumption increased from 6% in 2015 to 36% in 2020, while the installed units increased from 11% to 47%.

In summary, Table 4.1 and Table 4.2 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 4.1 U.S. Annual Lighting Energy Use Estimates by Sector in 2020

	Lighting Electricity Use Per Building (kWh/yr)	Number of Buildings	Total Lighting Site Energy Consumption (TWh/yr)	Total Lighting Primary Energy Consumption (quads/yr)	Percent of Total Lighting Energy
Residential	606	126,289,000	76	0.7	31%
Commercial	28,665	5,846,000	168	1.6	69%
Total	**N/A**	**N/A**	**244**	**2.3**	**100%**

Table 4.2 U.S. Annual Lighting Energy Use Estimates by Sector and Lighting Technology in 2020

	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	21	0.20	12	0.12	17	0.16	11	0.11	0	0.00	15	0.14	0	0.00	76	0.73
Commercial	3	0.03	1	0.01	5	0.05	95	0.91	2	0.02	60	0.58	1	0.01	168	1.60
Total	**24**	**0.23**	**13**	**0.12**	**22**	**0.21**	**106**	**1.01**	**3**	**0.03**	**75**	**0.72**	**1**	**0.01**	**244**	**2.33**

4.2 Comparison to 2010 and 2015 LMC Results

Section 2 describes departures in the analysis methodology relative to the 2015 LMC. Section 3 presents the detailed results of the 2020 LMC, with references to how characteristics of the installed base of lighting have changed since 2015. The beginning of Section 4 provides an overall summary of the 2020 LMC results. The following subsection provides a holistic, but higher-level comparison of installed lighting characteristics between the 2010, 2015, and 2020 LMC installments.

Between 2010 and 2020, the general trend in lighting nationwide has been an increase in lighting inventory, while wattages, typical operating hours, and total electricity use have decreased.[25] Table 4.3 provides a sectoral breakdown of these changes.

Table 4.3 Comparison of Lighting Characteristics in 2010, 2015, and 2020

	Installed Units (million)			Average Daily Operating Hours			Wattage per Lamp			Electricity Use (TWh)		
	2010	2015	2020	2010	2015	2020	2010	2015	2020	2010	2015	2020
Residential	5,812	6,219	6,506	1.8	1.9	1.6	46	38	22	175	149	76
Commercial	2,069	2,076	1,643	11.2	8.9	10.1	42	36	27	349	237	168
Total	**7,881**	**8,295**	**8,149**	**4.3**	**3.6**	**3.3**	**45**	**37**	**23**	**524**	**386**	**244**

Figure 4.4 depicts a summary of the changes in lighting inventory between the 2010, 2015, and 2020 LMC editions.

[25] Note that 2010 and 2015 LMC analyzed the industrial and outdoor sectors, in addition to the residential and commercial sectors. The results in the 2010 and 2015 LMC have been edited to reflect only the residential and commercial sectors for consistency with the 2020 LMC.

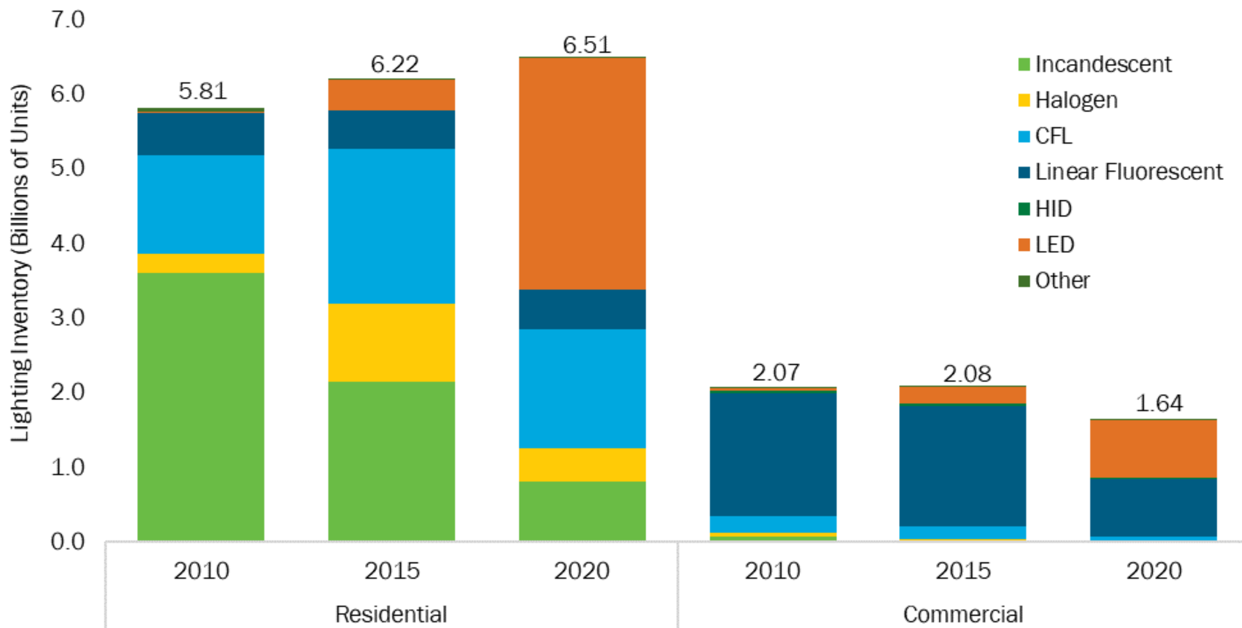

Figure 4.4 Comparison of Lighting Inventories by Sector and Technology Type in 2010, 2015, and 2020

Figure 4.5 shows the change in estimated national floorspace and buildings from 2010 to 2020.

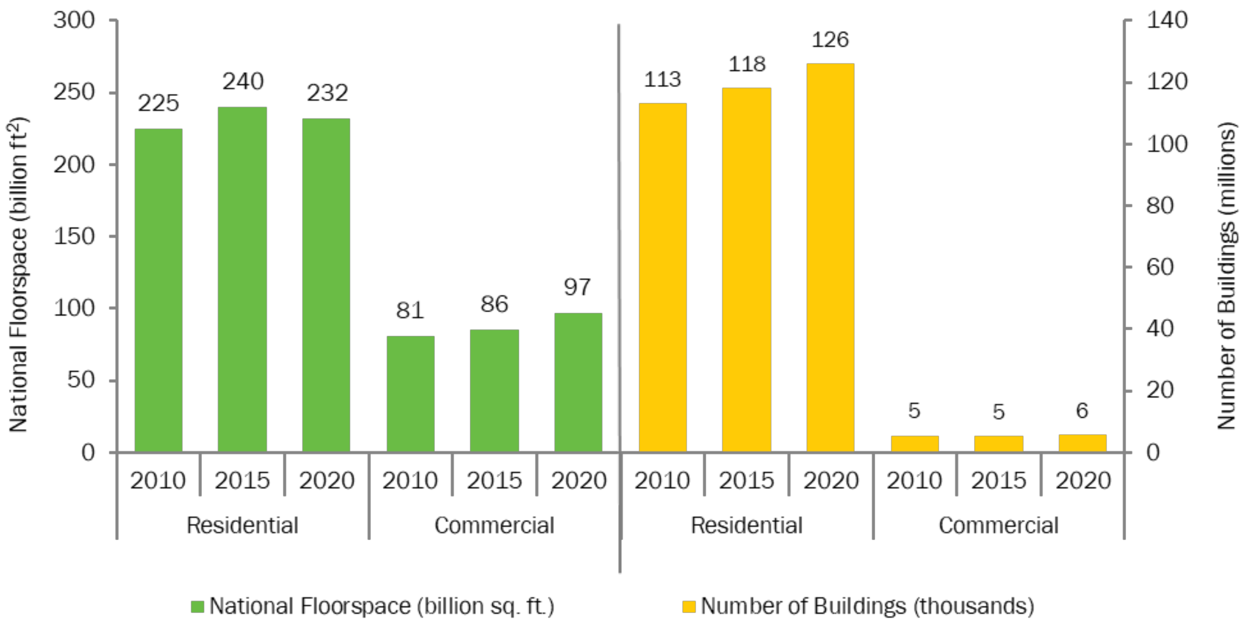

Figure 4.5 Trends in National Floorspace and the Number of Buildings Nationwide[26]

Figure 4.6 provides the corresponding summary of the ways in which electricity consumption has varied by lighting technology and sector.

[26] The residential quantities shown in Figure 4.5 for 2010 and 2015 differ slightly from those found in previous LMC reports. For the sake of consistency and trend comparison to the 2020 LMC, total occupied floorspace and housing units for 2010 and 2015 in this figure have been updated with data from 2015 RECS (previously unavailable at the time of publication of the 2015 LMC), alongside corresponding AHS data.

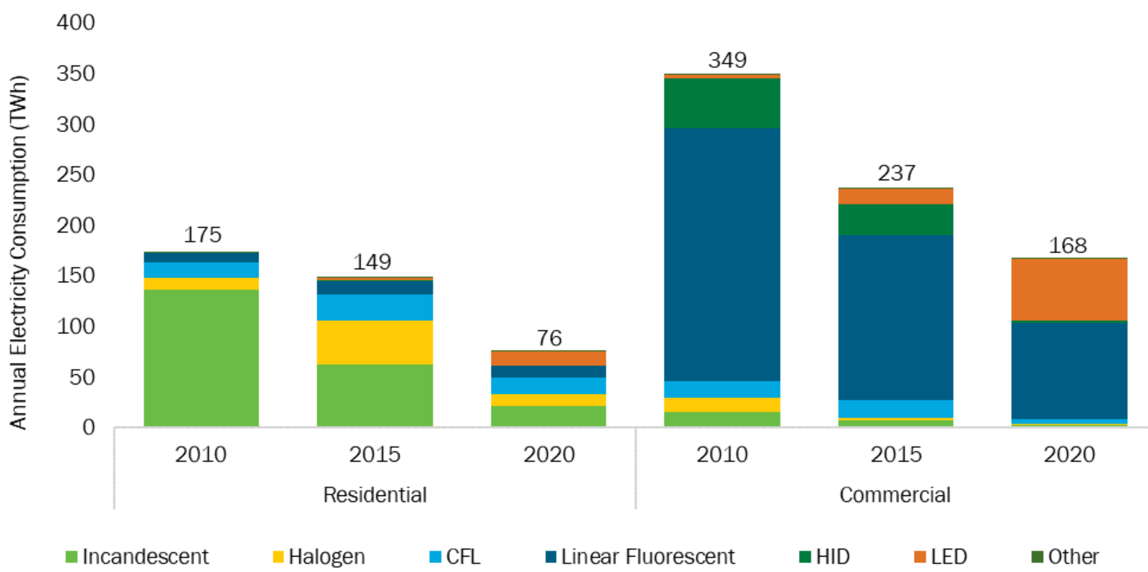

Figure 4.6 Comparison of Electricity Consumption by Sector and Lighting Technology in 2010, 2015, and 2020

Within the residential sector, total floorspace and the overall number of buildings both increased by roughly 6% between 2010 and 2015. However, between 2015 and 2020, the number of buildings continued to increase by a similar rate but total floorspace conversely declined by approximately 3%. It is important to note that both of these figures, residential total floorspace and buildings/units, only include occupied units. Vacant units are excluded from these totals.

While floorspace declined, the increasing prominence of LED, compact fluorescent, and halogen lighting (and decreased prominence of incandescent lamps) further caused a decrease in average wattage, which largely explains the decline in electricity use.

Between 2010 and 2020, the commercial sector installed base increased, but this increase lagged the growth of commercial floorspace. From 2010 to 2020, the number of installed units grew approximately 0.6% annually, whereas commercial floorspace grew approximately 1.9% annually. Overall, the commercial sector saw a decrease in lighting electricity consumption, in part the result of decreasing installed unit wattages and increasing installations of LED lighting.

Appendix A: Comparison of Lighting Electricity Consumption Estimates

The previous sections of this report provide discussion and analysis comparing the 2020 LMC results to those of the 2010 and 2015 LMC installments. Though the 2010 and 2015 LMC values are shown in Section 4.2 for comparison, this discussion focuses on comparing the 2020 LMC results to the results of the other studies referenced.

Table 4.4 Annual Lighting Electricity Consumption Estimates

Source	Model Year	Annual Lighting Electricity Consumption (TWh/yr)
Residential		
LMC, 2011	2010	175
EIA, AEO 2011	2010	208
EIA, AEO 2016	2015	143
LMC, 2017	2015	149
EIA, AEO, 2021	2020	62
LMC, 2020	**2020**	**76**
Commercial		
EIA, AEO 2011	2010	299
LMC, 2011	2010	349
CBECS, 2016	2012	212
EIA, AEO 2016	2015	254
LMC, 2017	2015	237
CBECS, 2018	2018	199
EIA, AEO, 2021	2020	157
LMC, 2020	**2020**	**168**

Overall, the estimates between the 2020 LMC and the EIA AEO 2021 are similar, but in both the residential and commercial sectors, the LMC estimates a higher lighting electricity consumption.

Appendix B: Lighting Product Category Descriptions

Table 4.5 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, and 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.
	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.

HID	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.
	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 C: 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 discussed in Section 2.2.1, lighting inventory sample data were weighted to account for deviations from the building type distributions of the total U.S. building stock.

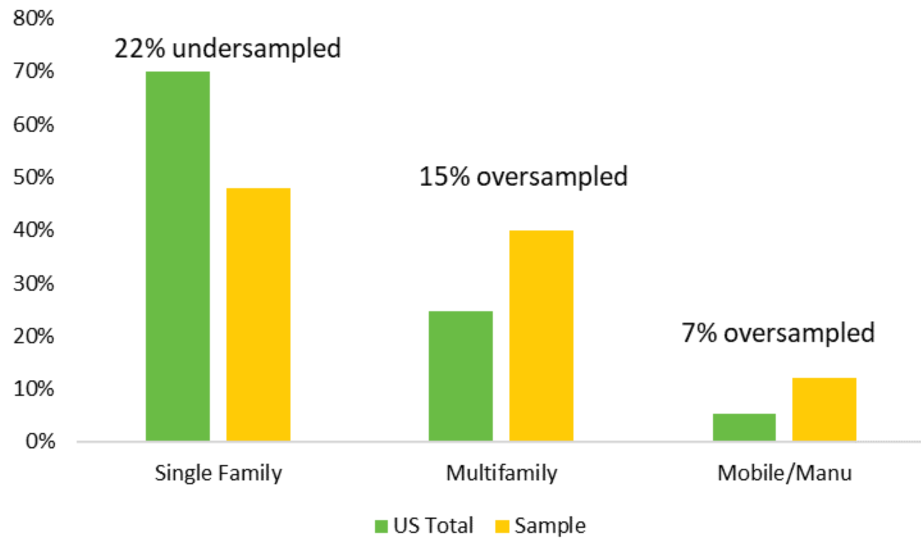

Figure 4.7 2020 Residential Sector Building Distribution by Residence Type

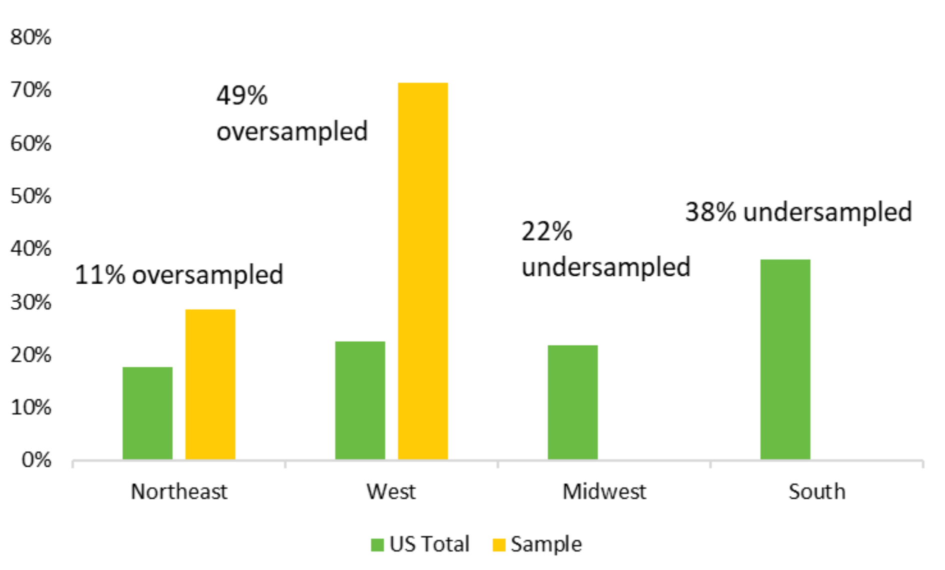

Figure 4.8 Residential Sector Building Distribution by Geographic Region

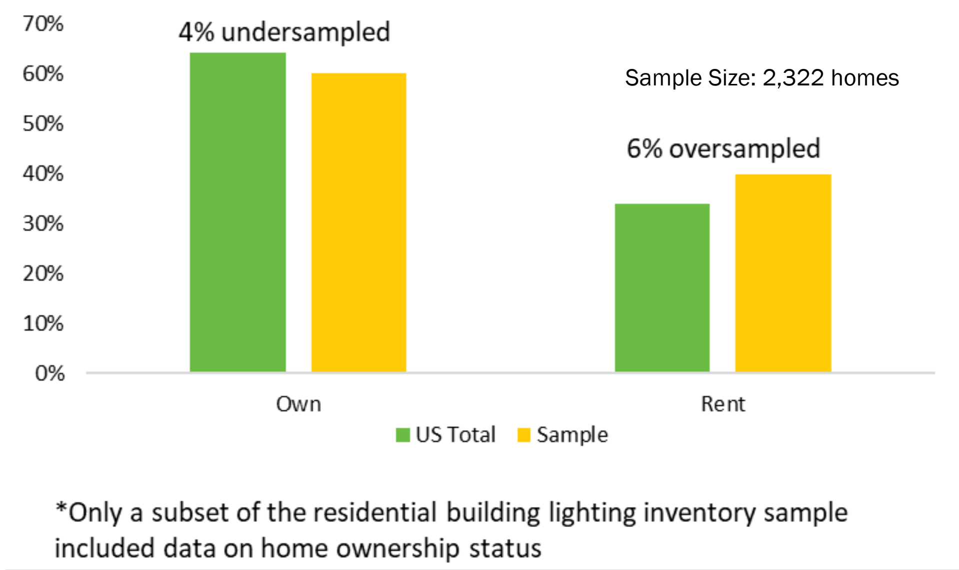

Figure 4.9 Residential Sector Building Distribution by Ownership Status

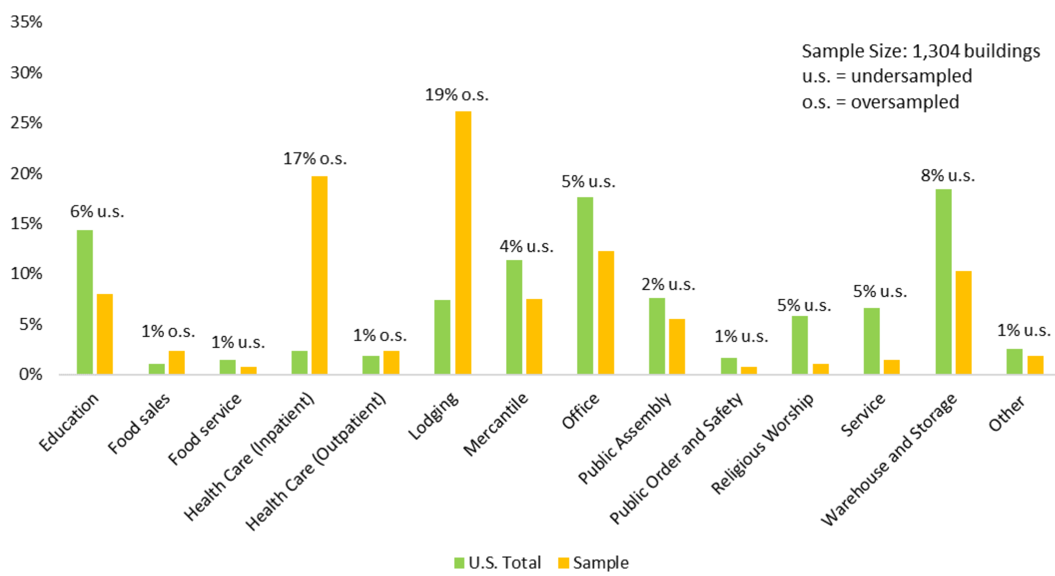

Figure 4.10 Commercial Sector Square Footage Distribution by Building Type

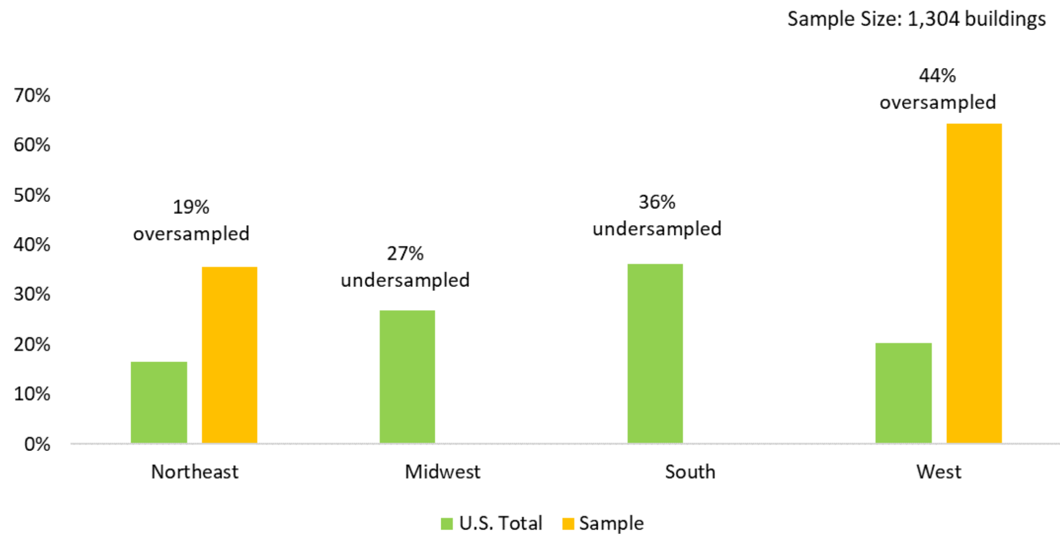

Figure 4.11 Commercial Sector Square Footage Distribution by Geographic Region

Appendix D: Wattage Calculation Assumptions (Ballast and Driver)

The total electricity consumption estimate provided in this report accounts for ballast and driver effects for non-integrated lamps. Limited ballast data were provided in the data sources discussed in Section 2.1, so the average ballast values, shown in Table 4.6, are based on manufacturer catalog data.

Table 4.6 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, three types of linear LED lamps are 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 (for 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, the average system efficiency for each type was calculated using the same process described in Section 2.2.3. 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 4.7, were determined using data collected for Bonneville Power Administration's lighting market research [20].

Table 4.7 Estimated Linear LED Lamp Distribution by Type[27]

LED Linear Lamp Types	Estimated LED Linear Lamp Distribution
Type A	61%
Type B	39%
Type C	1%

[27] Note: this distribution does not sum to 100% due to rounding.

Appendix E: References

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