Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

Pennsylvania Act 129

2018 Non-Residential Baseline Study

Prepared for the Pennsylvania Public Utility Commission

By Statewide Evaluation Team

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ACKNOWLEDGEMENTS

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This study was made possible by the efforts and cooperation of staff at the seven electric distribution companies highlighted in this report. Their assistance in providing the necessary data on customer segmentation, consumption, and contact information was instrumental in the design and execution of the study.

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Pennsylvania Non-Residential End Use & Saturation Study

In 2018, Pennsylvania's Statewide Evaluation Team performed an energy-efficiency potential assessment for the state and its seven largest electric distribution companies: DLC, Met-Ed, Pennelec, Penn Power, West Penn, PPL, and PECO. Auditors inspected 507 randomly selected facilities to characterize the current baseline energy efficiency level of small and large C&I sectors. This study will be used to update the state's Technical Reference Manual and to support the Phase IV energy efficiency market potential study.

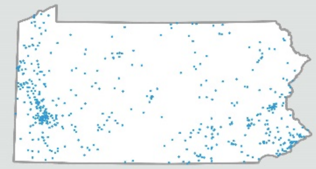
38 Health

60 Restaurant

40 Warehouse

75 Industrial/ Manufacturing

35 Education



507 All over PA

*Additional segments: institutional/public service, grocery, lodging, office, religious, retail, & miscellaneous

Key Findings

LED Saturation

Indoor

19%* General Service

*By fixture count.

44% Screw-based

Outdoor

43% General Service

2014 Study

<1% of commercial lighting stock

Average Energy Use Intensity

15 kWh/ft^2 annually

Highest EUI customer segments: Restaurant + Grocery

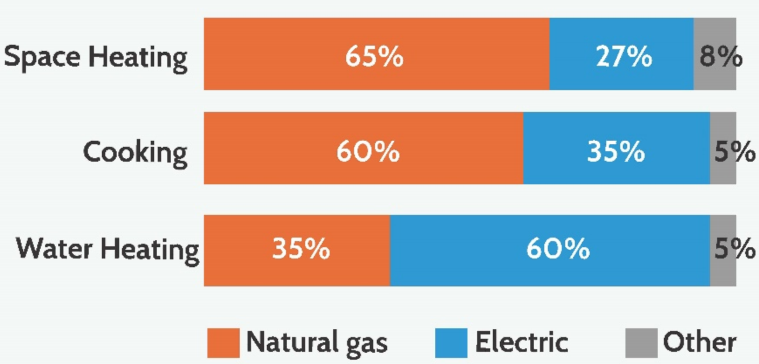
High refrigeration and cooking loads

Air Conditioning Capacity by System Type

43% Chilled Water

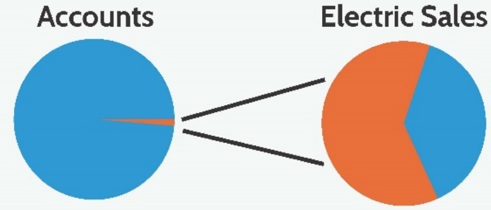
57% Conventional A/C

Fuel Share



Results by Sector

Large C&I is 1.4% of non-residential accounts and 62% of electric sales



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1 EXECUTIVE SUMMARY

Demand Side Analytics, LLC (DSA), NMR Group Inc. (NMR), and Abraxas Energy Consulting – collectively known as the Statewide Evaluation (SWE) Team – have been contracted by the Pennsylvania Public Utility Commission (PUC) to perform an energy-efficiency potential assessment for Pennsylvania and its seven largest electric distribution companies (EDCs). The EDCs included as part of this study are as follows:

- Duquesne Light Company (Duquesne or DLC)
- Metropolitan Edison Company (FE: Met-Ed or ME)
- Pennsylvania Electric Company (FE: Penelec or PN)
- Pennsylvania Power Company (FE: Penn Power or PP)
- West Penn Power Company (FE: West Penn or WPP)
- PPL Electric Utilities Corporation (PPL)
- PECO Energy Company (PECO)

The first step in this process is to establish baseline energy usage characteristics for the residential, small commercial and industrial (Small C&I), and large commercial and industrial (Large C&I) sectors. This report documents the findings of the end use and saturation study in the non-residential sectors and provides baseline energy use characteristics by sector, business type, and EDC. Findings from this Baseline Study will be used to update the Technical Reference Manual (TRM) and will serve as key inputs to the Phase IV Market Potential Study. Primary data was collected for this study from February to October of 2018.

1.1 NON-RESIDENTIAL ELECTRIC SALES SUBJECT TO ACT 129

Data from the U.S. Energy Information Administration (EIA) for 2017, summarized in Table 1, show that sales by the seven EDCs subject to Act 129 are close to 96% of the total electric sales statewide. While residential customers represent the majority of EDC accounts, non-residential customers consume almost 65% of the electric energy. This report covers non-residential energy usage. The accompanying Residential Baseline study describes usage for residential customers.

Table 1: 2017 Electricity Sales in Pennsylvania[1]

Category	Sales (MWh)	Customers
Pennsylvania	142,990,896	6,077,878
Act 129 EDCs	137,138,995	5,690,268
Non-Residential Sectors of Act 129 EDCs	88,785,457	681,013

[1] https://www.eia.gov/electricity/data.php. Accessed November 8, 2018.

Note that while non-residential usage includes Master-Metered Multifamily customers, usage for those customers is addressed in the Residential Baseline Study due to the residential nature of occupancy and end-uses of those customers. Table 2 summarizes the electric sales and accounts analyzed for this non-residential baseline study and differs from Table 1 in two respects. First, it covers June through May sales rather than a calendar year. The SWE team requested June-May billing records from the EDCs because it aligns with the Act 129 program year and PJM delivery year definition. Second, the 80.4 GWh in Table 2 excludes 211 thousand accounts and 7.6 GWh of electric sales from Master-Metered Multifamily accounts, Transportation, Communications and Utilities accounts (TCU), and a few accounts that could not be classified into the study segments. Segmentation details are covered in detail in Sections 2.2 and 2.3.

Table 2: Electric Sales and Accounts in Non-Residential Baseline Study

Segment	Electric Sales, June 2016-May 2017 (GWh)	Accounts
Education	5,739	14,488
Grocery	4,802	12,397
Health	5,346	19,705
Industrial Manufacturing	31,512	73,821
Institutional/Public Service	6,093	52,328
Lodging	1,192	7,669
Miscellaneous/Other	5,573	69,416
Office	8,244	106,727
Religious	1,021	22,703
Restaurant	1,821	16,961
Retail	7,256	62,808
Warehouse	1,849	14,062
Sector		
Large	50,195	6,845
Small	30,252	466,240
EDC		
PECO	21,186	108,278
PPL	20,674	127,215
Duquesne	7,789	43,779
FE: Met-Ed	7,818	47,111
FE: Penelec	8,574	62,102
FE: Penn Power	2,779	15,326
FE: West Penn	11,626	69,274
Statewide	**80,447**	**473,085**

** Segment, sector, and EDC totals may not sum to the statewide total due to rounding*

1.2 EQUIPMENT AGES

In addition to documenting the type, quantity, and efficiency of end use equipment, field technicians gathered equipment ages. Table 3 shows equipment ages for a variety of HVAC and other equipment. Average and median ages for most equipment ranges from 9 to 13 years, suggesting an equipment useful life of 20 to 25 years. The exception to this is boilers and process equipment, which tend to be large capital investments with longer useful lives. The central tendencies shown in Table 3 suggest that the fifteen-year maximum measure life for Act 129 measures may be artificially truncating the lifetime savings calculations and cost-effectiveness of capital intensive non-residential equipment measures.

Table 3: End Use Equipment Age

Equipment Type	n	Mean Age (Years)	Median Age (Years)
HVAC Fossil Fuel Boiler	177	19	19
HVAC Fossil Fuel Furnace	704	13	10
HVAC Miscellaneous Electric Heating	2,288	13	11
HVAC Central Plant Cooling	58	11	8
HVAC Direct Expansion Cooling	925	12	11
HVAC Miscellaneous Electric Cooling	2,137	13	13
Domestic Hot Water	732	10	8
Refrigeration - Walk In	149	12	10
Refrigeration - Reach In	1,046	9	8
Motors and Other Process Equipment	2,045	18	19

1.3 ENERGY USE INTENSITY

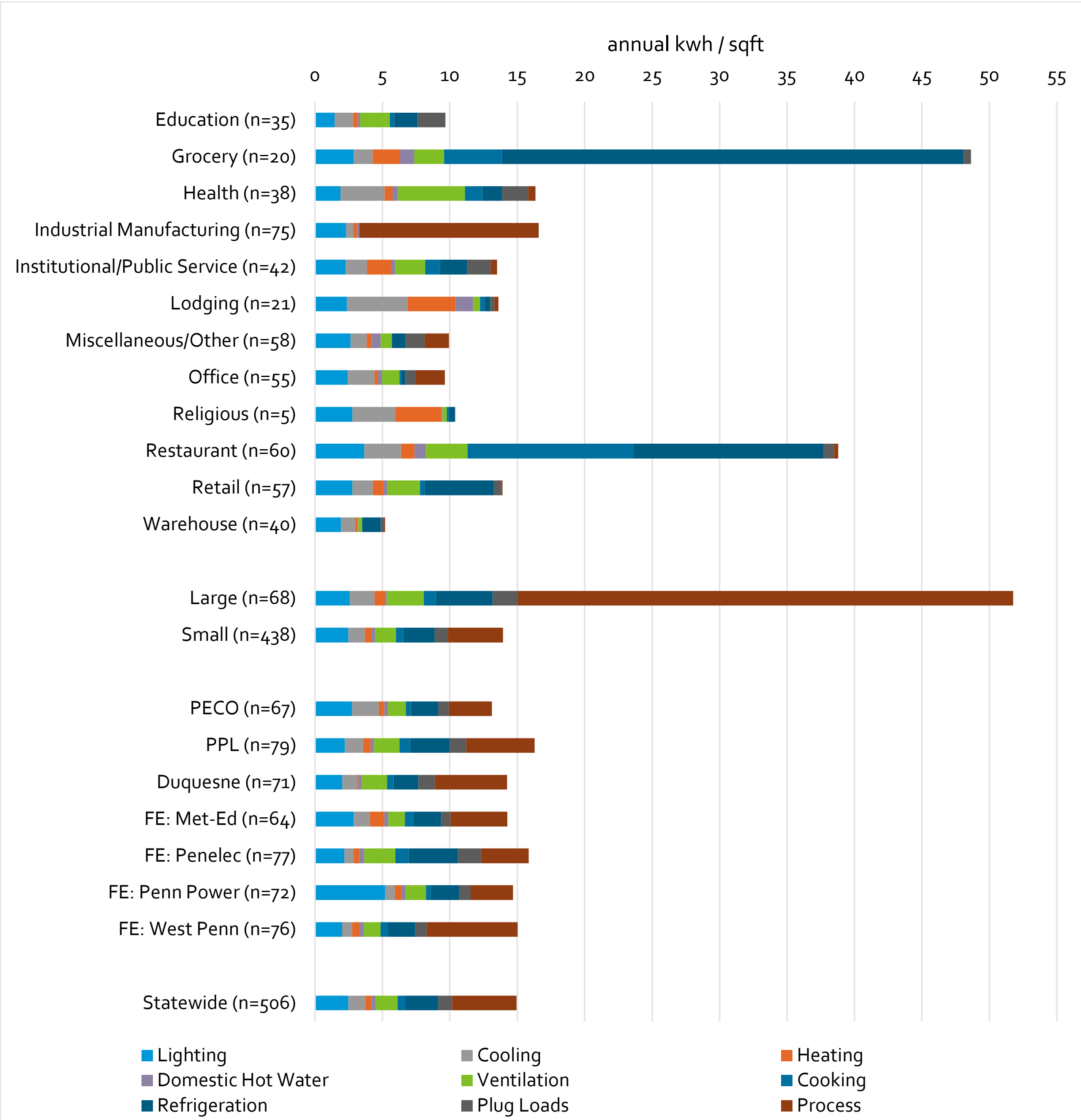
A key output of the C&I baseline study is energy use intensity (EUI) by end use, shown in Figure 1. EUI is defined as annual kWh per square foot (kWh/ft^2). N-values represent the number of sites surveyed.[2] Each bar shows individual end use EUIs stacked to form total EUI. Note that end use specific EUIs reflect the average across all sites, regardless of end use penetration or fuel share. Note that penetration is defined as percent of sites where the end use is present and fuel share is the percent of equipment powered by a given fuel. From a top down perspective, most segments have an EUI between 9 and 17 kWh/ft^2, with the exception of Grocery and Restaurant. This variation is primarily a function of the end uses common to each segment. Both Grocery and Restaurant segments have large amounts of energy usage for refrigeration and cooking.

Estimates of average EUI across the seven EDCs were all relatively close to the statewide average of 15 kWh/ft^2. Large C&I sector customers, who have a large representation of energy intense industrial manufacturing customers, have a much higher average EUI (52) than Small C&I customers (14). The segment with the lowest EUI is Warehouse (5), though it is notable that the sample for this segment

[2] Note that one site of the 507 surveyed had no interior floor space (square footage = 0) and was thus excluded from EUI calculation.

included several *self-storage* facilities, which are typically not heated or cooled and have very little lighting usage.

Figure 1: Energy Use Intensity (by Segment, Sector, EDC)



1.4 PROCUREMENT POLICIES AND AWARENESS OF EDC PROGRAMS

While on-site, engineers fielded a battery of questions about equipment purchase behavior and familiarity with Act 129 program offerings. A sample of these questions is provided in Table 4, where the value shows the percent of "Yes" respondents out of the number of sites that responded to a given question. The stark differences in response patterns among Large C&I and Small C&I study participants provides insight into the varying level of energy awareness EDCs and their conservation service providers face by sector. Further detail on these and related survey questions can be found in Section 13.

Table 4: Equipment Purchase Policies and Program Awareness (by Sector)

Survey Question	Large (n=63)	Small (n=418)	Statewide (n=481)
Does your company have any procurement policies or guidelines to purchase high efficiency options when they are available and would provide a lower life cycle cost?	51%	24%	24%
Do you do capital planning for major equipment replacements and proactively replace equipment when it is toward the end of its useful life (as opposed to waiting until something fails to replace it)?	85%	29%	30%
For significant energy-using equipment purchases, does your company routinely analyze the different efficiency and cost options to assess life cycle costs?	91%	47%	48%
Are you aware of your utility's energy efficiency rebate program?	87%	37%	39%
Have you participated in the program before?	71%	17%	18%

1.5 COMPARISONS ACROSS BASELINE STUDIES

Non-residential baseline studies for Pennsylvania were previously published in 2012 and 2014. The data collection for these studies occurred in 2011 and 2013, respectively. Comparisons can be made for certain key analyses with comparable methodologies. Specifically, the past studies provided comparisons in terms of percent of units of equipment. Figure 2 shows how fuel shares have changed for end uses that are often non-electric: water heating, cooking, and space heating. For water heating, electric fuel share of water heating units has stayed in the 50% to 60% range. For cooking, natural gas has been displacing electric cooking, which now presents a 35% share of cooking units. While electricity has retained about 25% of units for space heating, fuel oil and other fossil sources have been gradually replaced by natural gas, which now supplies about 65% of heating units.

Figure 2: Fuel Share Comparison across Studies

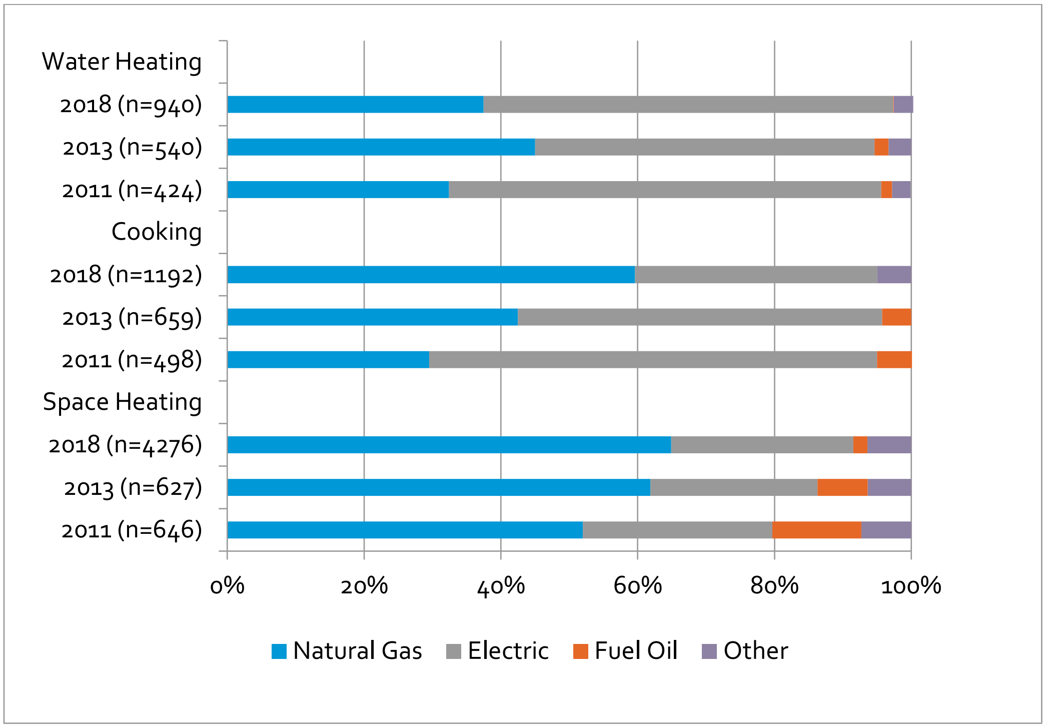
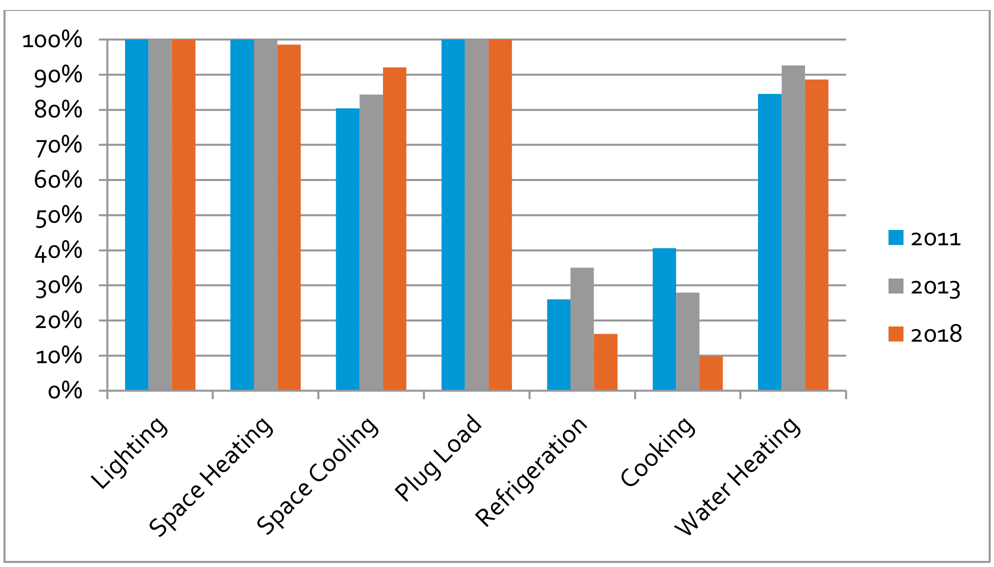


Figure 3 compares penetration for certain end uses across studies. This study sample showed lower penetration of commercial refrigeration and commercial cooking equipment than the prior C&I Baseline Studies.

Figure 3: End Use Penetration Comparison across Studies



The most pronounced change since the prior non-residential baseline studies was observed in the lighting end-use. Figure 4 compares shares of the lighting equipment stock over time. LED lighting was so uncommon in 2013 that it was grouped with neon lighting in the "Other" category. In this study, LEDs accounted for 11.9% of the total lighting connected load surveyed. This is particularly noteworthy because LEDs are the lighting technology with the highest efficacy (lumens per Watt).

Figure 4: Distribution of Lighting Technologies (by Connected Load)

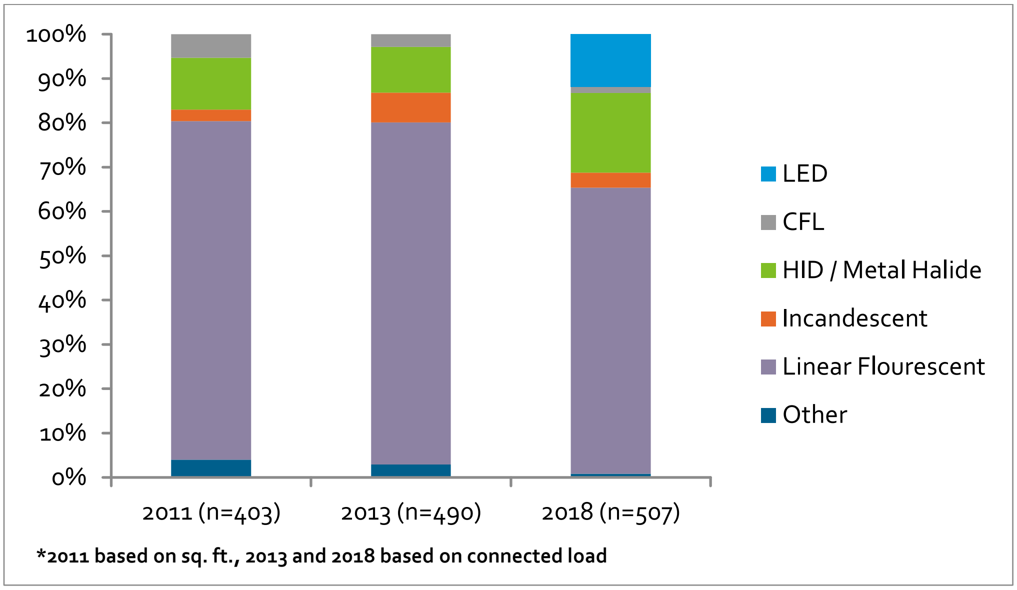
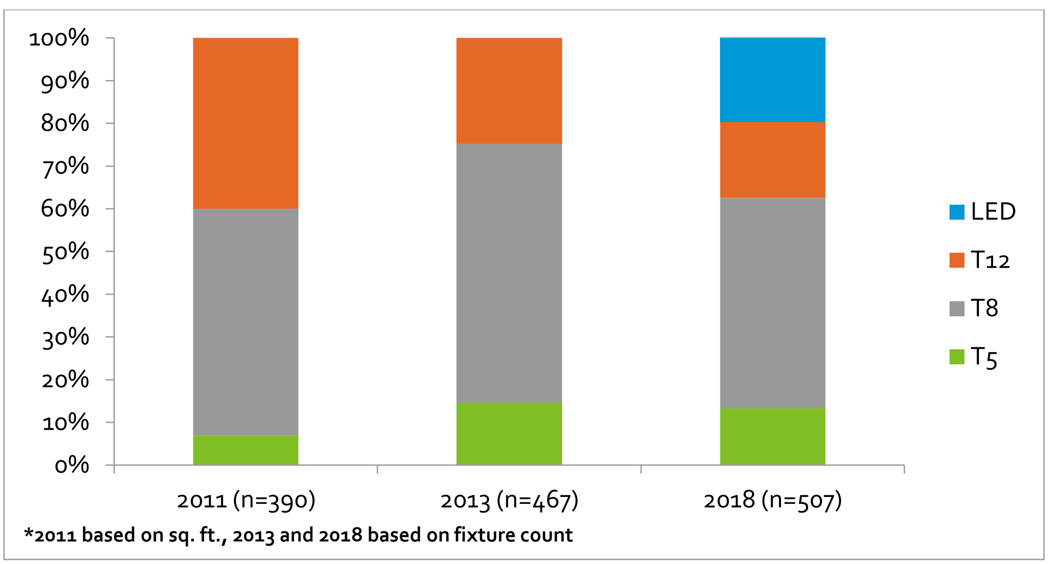


Figure 5 focuses on the general service style of lighting that has traditionally been dominated by linear fluorescent lighting. This study found that, by fixture count, 19.6% of general service troffers were LED, compared to 0% in 2013. T12 lighting is the least efficient linear fluorescent technology. Although T12 shares have decreased in each study, this study found that 17.8% of general service troffers were T12.

Figure 5: Comparison of Linear Fluorescent Lamp Type Distribution (by Fixture Count)



2 CHARACTERIZATION OF ELECTRIC CUSTOMERS AND SALES

2.1 SECTORS

The Pennsylvania EDCs subject to Act 129 generally divide non-residential customers into two classes, or sectors, for rate-making purposes and rate recovery of Act 129 program expenditures. The distinction is not a function of the business type, but with the way electricity is delivered to the facility. Small C&I customers take service at secondary voltage levels, while Large C&I customers take service at primary voltage (13.2 or 69 kV) and maintain their own switchgear and transformers to lower voltage to secondary levels. Generally, electric rates for the Small C&I class are higher than the Large C&I class and customers in the Large C&I class use substantially more energy.

This definition of sectors is a departure from the prior Act 129 Non-Residential Baseline Studies, which imposed a distinction between Commercial, Industrial, and Institutional customers. For this study, the SWE team elected to define sectors in a more consistent fashion with the EDC rate classes. Separation of non-residential customers by primary business activity is accomplished through the assignment of *segments*, as discussed in the following section.

2.2 SEGMENTATION

One of the main goals of the forthcoming Market Potential Study is to quantify the potential energy savings available in upcoming program years based on existing Pennsylvania-specific equipment saturations. This relies on EDC sales forecasts and the equipment trends observed in the Baseline Study and detailed in this report.

The SWE was provided with a comprehensive database of each EDC's non-residential accounts. The content of the databases varied across EDCs, but generally included the following fields:

- Customer Name
- Doing Business As
- Service Address
- Premise Type, Standard Industrial Classification (SIC) Code, North American Industry Classification System (NAIC)S Code
- Rate Code
- Monthly Billed kWh (June 2016 to May 2017)
- Monthly Peak kW (June 2016 to May 2017)

The SWE used these field as a starting point to assign each account to a segment, or primary business activity. Segmenting the customer datasets in this fashion allows the SWE to disaggregate the historic energy sales and peak demand into contributions by sector and segment. This historic distribution of sales will be the basis for the distribution of the electric sales forecast in the Market Potential Study.

2.2.1 Segment Definitions

The SWE assigned each customer within the utility datasets to one of the following segments:

- **Education:** Institutions supporting academic studies, including primary and secondary schools, colleges, universities, libraries, technical institutes, and vocational schools. Private facilities where skills are learned for profit, such as dance studios or martial arts studios, are not included within this segment.
- **Grocery:** Facilities where perishable food items are sold for profit.
- **Health:** Institutions that support the maintenance and improvement of physical and mental health, including health professional offices, hospitals, assisted living centers, and gyms.
- **Industrial Manufacturing:** Facilities that create, process, and refine goods.
- **Institutional/Public Service:** Federal, state, and municipal government facilities, such as borough and town halls, county courts, federal and state offices. Government subsidized services like police, fire, and emergency services were also assigned to this segment. This segment includes municipal water treatment systems, which are extremely energy intense.
- **Lodging:** Facilities that offer temporary housing accommodations, such as hotels, motels, and campgrounds.
- **Miscellaneous / Other:** All other facility types. Examples include auto repair shops; funeral homes; laundromats and drycleaners; kennels; theaters; salons; banquet halls; social organizations, such as VFWs and Elk Lodges; and local recreational facilities.
- **Master-Metered Multifamily**: Multifamily housing units with a single meter that includes both the common areas and tenant spaces. While these electric sales are on non-residential rate codes, the buildings are residential in nature. Analysis and findings for this segment is presented in the Residential Baseline Study report.
- **Office:** Facilities where services are performed, such as law offices, private offices, common office spaces, and banks.
- **Religious:** Places of worship; facilities falling into other segments such as education or health with a religious affiliation are not included within this segment.
- **Restaurant:** Food service facilities, including full-service and quick-serve restaurants. This segment also includes coffee shops, ice cream parlors, and catering companies.
- **Retail:** Facilities where other non-grocery goods are sold for profit, such as department stores and gas stations.
- **Transportation, Communication, and Utilities (TCU)**: These are generally non-building accounts, such as signs, radio towers, and street lights.
- **Warehouse:** Storage facilities.

2.2.2 Segment Assignment Methodology

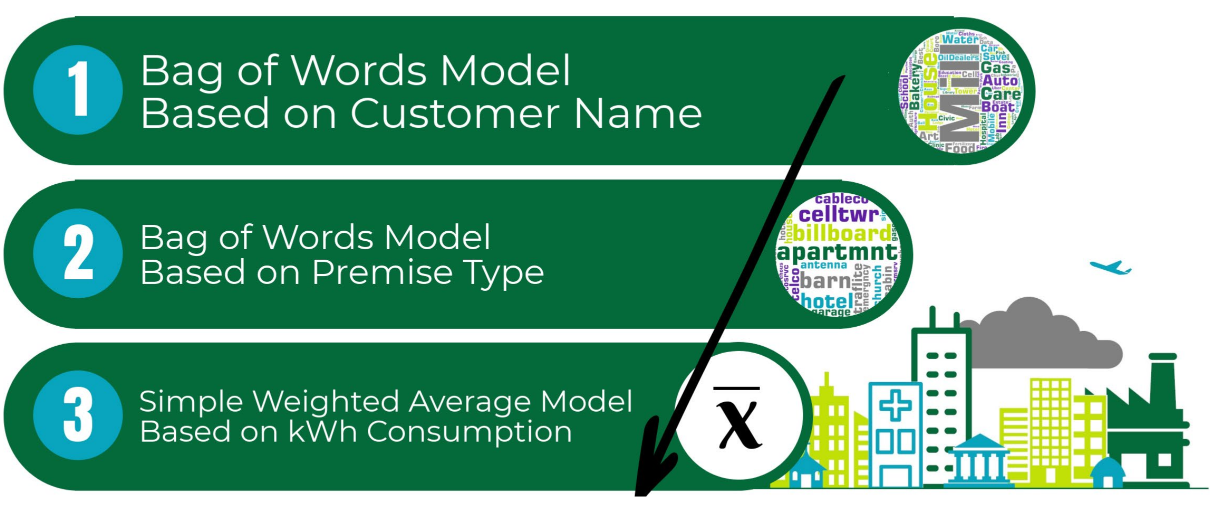
The Pennsylvania EDCs do not maintain comprehensive information regarding the type of business non-residential customers operate. The customer databases include SIC codes and NAICS codes for a subset of accounts, but these can be old or inaccurate. The SWE developed analysis code and heuristic logic to supplement EDC business type information and standardize the customer segmentation task across EDCs. The method relies on a text mining approach that looks for specific strings of text within the customer name and premise type fields. Additionally, the code uses the annual kWh consumption field to make determinations when the primary fields did not provide enough clarity.

The code first employed a "bag of words" strategy, which is a model where text is represented as the bag (multiset) of words, disregarding grammar and even word order but keeping multiplicity. The SWE created a list of 700 common strings of text, which the analysis code parsed to provide the matching segment. The code completed this task by relying on the customer name first. Where ambiguity existed within the customer name, the code then processed the unassigned customers based on their premise type, SIC code, or NAICS code where provided.

At this stage, the customer datasets still included approximately 20% unsegmented customers. Large C&I customers with significant energy consumption were investigated manually via web searches and classified. Upon visual inspection of the data, the SWE found a large portion of the remaining entries to be associated with the Office, Industrial Manufacturing, Retail, and Restaurant segments. The code processed these entries based on a known weighted average approach whereby the average kWh consumption of the unsegmented entity was compared to the average kWh consumptions of the four possible segments and classified accordingly.

The three-step process described above is represented visually in Figure 6. This process resulted in segmentation of 88% of Pennsylvania's C&I electric customers, with only 5% of those unsegmented customers falling within the top third of Pennsylvania C&I energy users. As a final step, string matching was applied to business names to ensure that common words (e.g., restaurant, store, university) and well-known brands (Wal-Mart, McDonald's) were correctly classified as well.

Figure 6: Segmentation Methodology



2.3 CUSTOMER COUNTS AND ELECTRIC SALES BY SEGMENT

As described above, all EDC accounts were classified into fourteen standard industry segments that align with those used in the Pennsylvania TRM. Table 5 shows the segment and EDC breakdown of total electric sales (MWh) for the 12-months from June 2016 to May 2017. Note that this time period differs from Table 1, which considered calendar year 2017. N-values in column and rows headers indicate the total number of accounts within each segment and EDC.

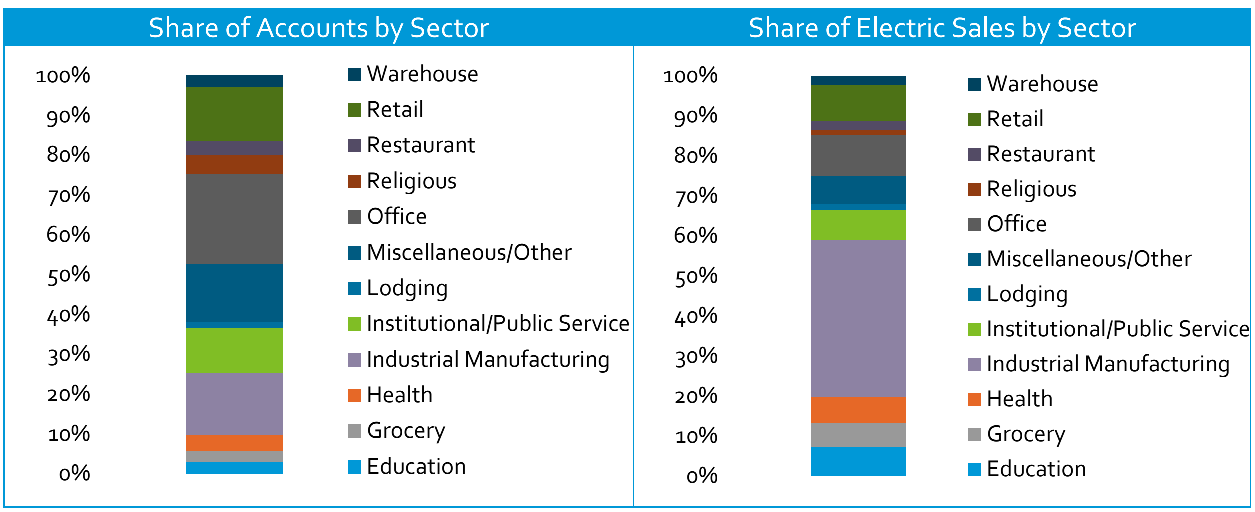
Table 5: Electric Sales (MWh) (by EDC and Segment)

Segment	PECO (n=166,650)	PPL (n=195,037)	Duquesne (n=67,996)	FE: Met-Ed (n=65,569)	FE: Penelec (n=82,939)	FE: Penn Power (n=20,558)	FE: West Penn (n=95,240)	Statewide (n=693,989)
Education (n=14,488)	1,742,508	1,217,007	924,630	456,232	491,027	134,973	772,399	5,738,776
Grocery (n=12,397)	1,564,391	1,386,636	343,507	390,399	546,680	107,347	463,299	4,802,260
Health (n=19,705)	1,599,052	1,551,080	757,562	362,534	506,541	94,954	473,907	5,345,631
Industrial Manufacturing (n=73,821)	5,546,200	8,397,401	2,328,555	3,658,012	3,948,965	1,340,467	6,292,123	31,511,724
Institutional/ Public Service (n=52,328)	2,469,531	1,142,340	587,178	428,822	771,427	103,121	590,501	6,092,921
Lodging (n=7,669)	260,001	461,935	74,802	85,464	100,045	33,776	175,612	1,191,636
Miscellaneous/ Other (n=69,416)	1,669,761	1,727,343	442,311	333,427	560,749	136,750	702,704	5,573,044
Office (n=106,727)	3,299,983	1,379,714	1,459,781	450,700	505,402	226,503	921,877	8,243,960
Religious (n=22,703)	257,211	246,395	103,840	157,409	72,922	51,108	132,481	1,021,367
Restaurant (n=16,961)	423,206	527,919	139,887	215,688	181,500	58,611	273,811	1,820,621
Retail (n=62,808)	2,035,777	1,956,227	549,813	813,955	800,802	360,569	738,636	7,255,778
Warehouse (n=14,062)	318,122	680,283	77,580	465,269	88,247	130,735	88,813	1,849,049
Master-Metered Multifamily (n=23,655)	646,204	391,096	150,071	143,931	178,636	92,187	124,800	1,726,924
Transportation, Communications, Utilities (n=92,190)	710,381	962,659	603,243	279,187	226,869	105,071	589,265	3,476,676
Unclassified (n=105,059)	1,196,614	332,360	365,518	110,764	259,994	24,321	156,732	2,446,303
Total MWh (n=693,989)	23,738,944	22,360,396	8,908,279	8,351,793	9,239,807	3,000,493	12,496,959	88,096,671
Total study MWh (n=473,085)	21,185,745	20,674,280	7,789,446	7,817,911	8,574,308	2,778,914	11,626,162	80,446,767

Of the 88.1 million MWh of electric sales, 2.5 million MWh could not be classified into a segment. These are predominantly small accounts, comprising less than 3% of sales but over 16% of accounts. Because they could not be classified, these accounts were excluded from the segment share of sales weights used for analysis and were excluded from the field data collection. Two additional segments were excluded from primary data collection. The first is Transportation, Communications, and Utilities. This segment comprises less than 5% of total C&I electric sales but over 11% of accounts, again indicative of generally small accounts. This segment includes billboards, cellular towers, traffic lights, and accounts that generally do not include any buildings. These small accounts were deemed of little value for survey purposes due to both their commercial activity and the focus of the data collection instrument on building characteristics and systems. Finally, the Master-Metered Multifamily segment was included in the residential baseline study in lieu of the non-residential baseline study given the residential nature of that segment. This was also the smallest segment by both share of accounts (fewer than 2%) and by share of electric sales (fewer than 1%). In all, unclassified accounts and the two segments excluded from the study comprise less than 8% of C&I electric sales but nearly 30% of accounts.

Figure 7 shows shares of accounts and electric sales by segment for the 12 segments included in the study. It is notable that Industrial Manufacturing comprises 16% of accounts but 41% of electric sales, indicative of the high energy consumption of that segment relative to others. Conversely, the Office segment comprises 24% of accounts but just 16% of sales.

Figure 7: Share of EDC Accounts and Electric Sales (by Segment)



2.4 CUSTOMER COUNTS AND ELECTRIC SALES BY SECTOR

Customers in the Large and Small C&I sectors differ not only in their energy consumption patterns, as reflected in the different rates for each, but also in the concentration of usage across accounts. As shown in Figure 8 and Table 6, customers in the Large C&I sector comprise just 1% of accounts but represent 61% of electric sales. In other words, these Large C&I customers are few but use a very large amount of energy.

Figure 8: Share of EDC Accounts and Electric Sales (by Sector)

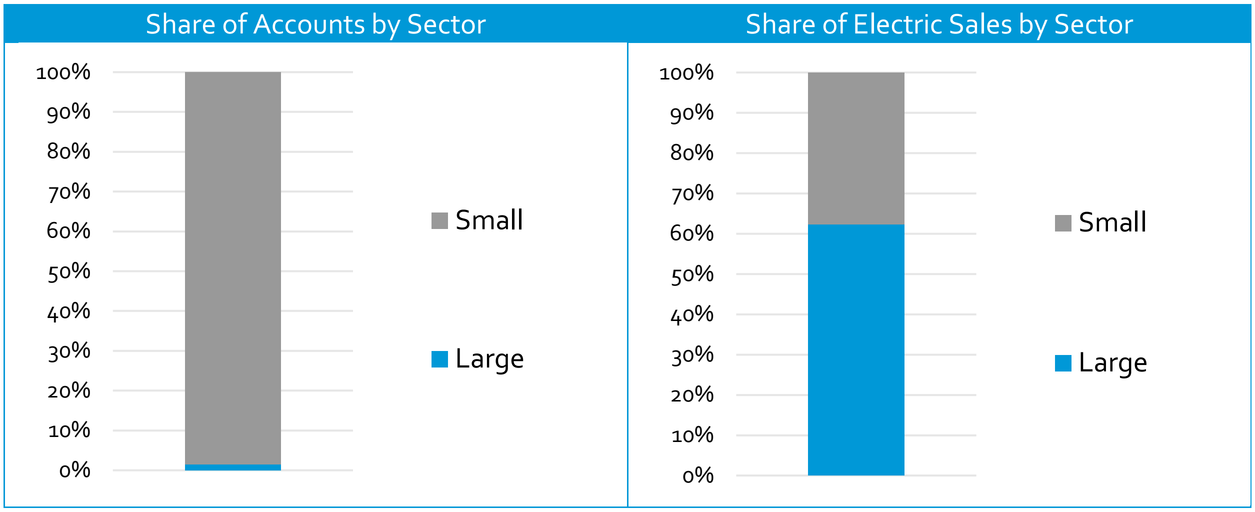


Table 6: Share of EDC Accounts and Electric Sales (by Sector)

Sector	Accounts	Electric Sales, June 2016-May 2017 (MWh)
Large C&I	6,845	50,194,627
Small C&I	466,240	30,252,140

2.5 SAMPLING APPROACH

The sample design for the Baseline Study was to provide ±10% precision at the 90% confidence level for each EDC. As the population is considered statistically infinite, the number of sample points needed to reach the desired precision and confidence is 70 per EDC. Sample points were allocated across segments to equitably select study participants in keeping with the consumption contributions of each utility's customer base. This approach allows for study results to be presented at the EDC-level (across all segments) and at the segment-level (across all EDCs).

The SWE team attempted to allocate samples between the Large C&I and Small C&I sectors proportionally to each EDC's consumption contributions. Customer sectors were assigned based on rate code as reported by the EDCs. Although recruiting was challenging in the Large C&I sector, the sampling frequency of the Large C&I sector was much higher than the Small C&I sector because the small number of Large C&I accounts represent a large share of each segment's total energy consumption. The sampling frequency, or *case weight*, was accounted for in the analysis of field survey data.

The number of completed sample points by segment and EDC are presented in Table 7.

Table 7: Segmented Sample Points (by EDC)

Segment	PECO	PPL	DLC	ME	PN	PP	WPP	State
Education	7	5	5	4	6	3	5	**35**
Institutional/Public Service	5	10	2	5	8	4	9	**43**
Grocery	3	4	4	2	2	1	4	**20**
Health	4	10	2	7	4	3	8	**38**
Industrial Manufacturing	6	13	11	12	11	11	11	**75**
Lodging	3	4	4	4	4	1	1	**21**
Miscellaneous / Other	8	6	7	7	11	10	9	**58**
Office	11	10	11	3	5	10	5	**55**
Religious	0	0	1	3	0	1	0	**5**
Restaurant	5	9	10	8	11	7	10	**60**
Retail	10	5	5	6	9	12	10	**57**
Warehouse	5	4	9	3	6	9	4	**40**
Total	**67**	**80**	**71**	**64**	**77**	**72**	**76**	**507**

3 METHODOLOGY

3.1 PRIMARY DATA COLLECTION

On-site data collection for the study utilized a web-based electronic data collection tool. When an engineer visits a site, they have the ability to create one or more buildings for that site. Within each building created, engineers record equipment characteristics in a series of forms organized by end-use. Engineers create as many different schedules as necessary to capture the hours-of-operation of the facility and schedules are then associated with different equipment. The SWE team primarily uses hours-of-operation schedules in the EUI analysis.

Primary data collection began in February 2018 and ended in October 2018. Each week, the completed surveys went through a quality check process where the SWE team applied a series of logical tests to flag potential inaccuracies or inconsistencies in the data. When possible, these issues were resolved by contacting the field technician or the site to follow up on any issues.

Data collected on-site was stored in a relationship database for analysis. For most end-uses, the data collection tool included a list of possible equipment types, as well as the option to choose "Other" and record free form notes on the observed equipment. During the data collection phase of the project, there was substantial communication between team members about how to capture different equipment configurations within the data collection instrument to ensure consistency.

Most surveys lasted between one and four hours depending on the size and complexity of the facility. In many cases, site contacts provided the SWE team with mechanical drawings or other documentation to facilitate the equipment inventory. To encourage participation, participants were offered a $100 gift card in exchange for allowing an audit of their facility.

3.2 WEIGHTING

As described above, the sampling scheme was designed to collect data from Large and Small C&I sector sites roughly in proportion to their share of electric sales. However, to ensure representation across segments and EDCs of varying sizes, sites were sampled roughly equally rather than proportionately by segment and EDC. The weighting approach was designed to correct for this intentional oversampling of smaller segments and EDCs. This was done by applying a weight corresponding to the share of sales for each of the 12 segments included in the study, as summarized in Table 8. This was done within each EDC to reflect differences across EDCs. These weights were then scaled to reflect the share of total C&I sales of each EDC, inclusive of the those from TCU, Master-Metered Multifamily, and Unclassified accounts. See Table 5 for the electric sales by segment and EDC used to calculate these weights.

The segment-EDC sales share weights were used for most analyses. The exception was analyses within segments, for which the overall EDC weights (the "All segments" row in Table 8) were used.

Table 8: Weights for Share of Sales (by Segment and EDC)

Segment	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn
Education	2.2%	1.5%	1.2%	0.6%	0.6%	0.2%	0.9%
Grocery	2.0%	1.7%	0.4%	0.5%	0.7%	0.1%	0.6%
Health	2.0%	1.9%	1.0%	0.4%	0.6%	0.1%	0.6%
Industrial Manufacturing	7.1%	10.3%	3.0%	4.4%	4.8%	1.6%	7.7%
Institutional/Public Service	3.1%	1.4%	0.8%	0.5%	0.9%	0.1%	0.7%
Lodging	0.3%	0.6%	0.1%	0.1%	0.1%	0.0%	0.2%
Miscellaneous/Other	2.1%	2.1%	0.6%	0.4%	0.7%	0.2%	0.9%
Office	4.2%	1.7%	1.9%	0.6%	0.6%	0.3%	1.1%
Religious	0.3%	0.3%	0.1%	0.2%	0.1%	0.1%	0.2%
Restaurant	0.5%	0.6%	0.2%	0.3%	0.2%	0.1%	0.3%
Retail	2.6%	2.4%	0.7%	1.0%	1.0%	0.4%	0.9%
Warehouse	0.4%	0.8%	0.1%	0.6%	0.1%	0.2%	0.1%
All segments	26.9%	25.4%	10.1%	9.5%	10.5%	3.4%	14.2%

In addition, a second weighting component was applied to adjust for the count of the sampled accounts relative to the accounts in the population. As shown in Table 9, this was done within each sector and segment. Essentially, case weights for each cell were calculated by taking the ratio of the number of accounts in the population to the number of accounts in the sample. Functionally, case weights indicate the number of sites in the population a single sampled site represents. The weighting used for the study was the product of the share of electricity sales weights and the case weights.

Table 9: Case Weights (by Sector and Segment)

	Large C&I Sector			Small C&I Sector		
Segment	Accounts	Sample	Case Weight	Accounts	Sample	Case Weight
Education	761	5	152	13,727	30	458
Grocery	493	5	99	11,904	15	794
Health	417	7	60	19,288	31	622
Industrial Manufacturing	2,037	24	85	71,784	51	1,408
Institutional/Public Service	758	9	84	51,570	34	1,517
Lodging	107	3	36	7,562	18	420
Miscellaneous/Other	443	3	148	68,973	55	1,254
Office	766	6	128	105,961	49	2,162
Religious	75	0	NA	22,628	5	4,526
Restaurant	51	1	51	16,910	59	287
Retail	726	2	363	62,082	55	1,129
Warehouse	211	3	70	13,851	37	374

3.3 ANALYSIS METHODS

A primary category of analyses reported in this non-residential baseline study are shares of end use technology or other characteristics. All analyses were weighted using the weighting scheme described above. However, for some analyses, site count was not the most meaningful unit of measure to use for penetration, fuel shares, or technology shares. Table 10 summarizes the three approaches used for evaluating technology or equipment shares. For example, while it may be meaningful to know which percentage of sites in each segment or sector have a given end use (heating, cooling, domestic hot water, etc.), it is less meaningful to evaluate penetration of specific heating or cooling end use types or fuel shares at the site level. Rather, it is more useful to assess the portion of heating capacity (kBTU) served by different fuel types or cooling capacity (in tons or kW) served by unitary equipment, such as rooftop AC units, versus large central plant equipment, such as chillers. Similarly, when assessing penetration of high-efficiency technology (such as LED lighting) or end uses where capacity is unknown or a less meaningful metric (such as cooking equipment or plug loads), it can also make sense to assess technology shares in terms of equipment count. In both cases, the analysis is describing equipment characteristics rather than site characteristics, so the level of observation is really the individual equipment units rather than customer sites.

All analyses in this report specify the unit used for N-values and for shares or penetration. Note that there is a distinction between penetration, which indicates the proportion of sites that have a certain technology, and saturation, which reflects the proportion of equipment of a certain technology type. For example, we might say the following:

- 50% of non-residential accounts were observed to have some LED lighting (penetration)
- 25% of non-residential lighting equipment was LED (saturation)

Table 10: Methodology for Technology Share Analyses

Share of…	N-value	Conceptual calculation	Analysis Application
Sites	Sites	$\frac{\#\ of\ sites\ where\ technology\ is\ present}{total\ \#\ of\ sites}$	Penetration of end uses or technology at the site level
Units	Items of equipment	$\frac{\#\ of\ units\ with\ feature\ or\ characteristic}{total\ \#\ of\ units}$	Saturation of end use technology features or efficiency Distribution of unit sizes Distribution of unit ages
Capacity	Items of equipment	$\frac{capacity\ (kW, kBTU, gal)\ with\ feature\ or\ within\ segment}{total\ capacity}$	Distribution of equipment technology Fuel share

3.4 UNCERTAINTY

This report analyzes a wide range of data from multiple perspectives. Because of this, the n-values are not consistent across figures and tables. There are two primary levels for n-values: unit and site. For a few charts, the analysis introduces a *buildings* n-value because sites can have multiple buildings. Units are used when a site is likely to have multiple of a specific device and the analysis is interested in the total count of these devices. For instance, the statewide lighting equipment count exceeds 100,000 because there are many fixtures and bulbs at each site. On the other end of the spectrum, statewide commercial cooking unit level n-values may be less than 100 because this type of equipment is less common than lighting. Many sites have no cooking equipment, and the sites that do have a relatively small number of pieces of cooking equipment.

Buildings are used as the n-value for several general tables and figures. Characteristics such as building age allow for analysis at the building level because individual buildings at a site may have been constructed at different times. This count will only differ from the site count for the sites with multiple buildings. Site counts roll up all buildings within the site to one n-value. For instance, the penetration tables for each end use are reported at the site level. If a site has two buildings – a storage garage and an office – and only the office has Air Conditioning, then the site is counted as one site with AC. There is generally a 1:1 relationship between sites and EDC accounts.

Readers should stay mindful of n-values when interpreting the findings presented in this report. Small n-values generally mean a wider range of uncertainty than large n-values. When differences are observed between segments, sectors, or EDCs with small n-values, there is a greater chance that the difference is a function of random chance rather than an underlying difference in the population of interest.

4 ENERGY USE INTENSITY (EUI)

Energy use intensity (EUI) quantifies the magnitude of customer energy use, normalized for the square footage of the customer site being served. It is expressed in units of annual kWh per square foot. This allows an apples-to-apples comparison of sites of different sizes. For example, we can compare a small restaurant with very little seating to a large office building, which may use more energy overall, but also has a much larger footprint. This also allows comparison of energy usage of different end uses. EUI across segments and within end uses were calculated using two complementary approaches: a top-down and a bottom-up method.

The top-down method consisted of simply dividing billed 12-month kWh electricity usage by the total interior square footage served at each customer site. The following adjustments were made to this calculation:

- **Usage was scaled to 12 months**. Some sites were billed for fewer than 12 months of usage over the June 2016 to May 2017 period. In these cases, billed usage was multiplied by the ratio of 12 months to the number of billed months.
- **Bottom-up usage was substituted for top down where usage was clearly out of range**. For whatever reason, a few sites had either very high[3] or very low[4] top down EUI results. After detailed review of data for these sites, it was deemed more appropriate to use overall EUI estimates from the bottom up calculation, described below.
- **Square footage for a handful of sites was updated based on observations in the field study**. In particular, one site was a central heating / cooling plant for an entire campus. Square footage was adjusted to reflect the campus square footage.

The bottom-up method was a combination of calculations based on field data and segment specific, publicly available data on energy usage and intensity. Table 11 summarizes the calculations and data sources used to derive EUI for each end use assessed. Note that in most cases, an annual kWh usage number was calculated then divided by the square footage surveyed during the field visit.[5] For the remainder of end uses, which represent a much smaller portion of energy usage but a much larger number of devices, study data was supplemented and validated with segment specific EUI values from EIA's 2012 CBECS[6] study and 2014 MECS[7].

[3] More than 150 annual kwh per square foot for the Industrial Manufacturing segment and more than 100 annual kwh per square foot for other segments.
[4] Less than 0.5 annual kwh per square foot.
[5] Due to access or other issues, it was not feasible or possible to survey the entire square footage at some sites.
[6] Commercial Buildings Energy Consumption Survey https://www.eia.gov/consumption/commercial/
[7] Manufacturing Energy Consumption Survey https://www.eia.gov/consumption/manufacturing/

Table 11: End Use Intensity Calculation Methodology

End use	EUI Calculation	Input Source(s)
Lighting	$\frac{qty * wattage * annual\ hours}{surveyed\ sqft}$	Field data collection
Cooling (AC, Chiller, Heat Pump)	$\frac{tonnage * kW/ton * annual\ hours}{surveyed\ sqft}$	Field data collection for capacity and efficiency PA TRM Equivalent Full Load Hours (EFLH) for runtime; used EDC specific weighted average of metro area values and applied segment specific values using space / building types
Heating (Heat Pump)	$\frac{tonnage * kW/ton * annual\ hours}{surveyed\ sqft}$	
Heating (Electric Resistance)	$\frac{kBTU * \frac{293.071kW}{kBTU} * \%efficiency\ rating}{surveyed\ sqft}$	Field data collection for capacity and efficiency
Domestic Hot Water	$\frac{gallon\ capacity * \frac{annual\ kWh}{gal\ capacity} * electric\ fuel\ share}{surveyed\ sqft}$	Field data collection for capacity and electric fuel share[8] Expert judgement for annual kWh per gallon was applied since no hot water volume or usage schedule data were collected - 175 kwh / gal for high water usage segments (Restaurant, Grocery, Health, and Lodging) - 75 kwh / gal for all other segments
Ventilation	Average EUI for segment	CBECS 2014 Table E6, by Principal building activity N/A for Industrial Manufacturing segment
Plug Loads	Average EUI for segment	
Commercial Cooking	Average EUI for segment	
Commercial Refrigeration	Average EUI for segment	
Processes	$\frac{process\ kW * annual\ hours}{surveyed\ sqft}$	Field data collection Overall industrial segment process usage as portion of overall were validated against MECS Table 5.1 (2017) Field data collection also included ventilation loads. CBECS ventilation N-values were subtracted from process loads to avoid double counting.

Figure 9 shows the resulting energy use intensity estimates. N-values represent the number of sites surveyed. Each bar shows individual end use EUIs stacked to form total EUI. Total EUI was determined using the top-down approach. To bridge the gap between the top-down and bottom-up EUI

[8] Electric fueled hot water is far less prevalent than natural gas fueled, therefore fewer field data points were collected for electric water heaters. However, water heating capacity (e.g., tank size in gallons) is not notably different for one fuel type versus another. Therefore, all surveyed water heaters were included in this calculation to ensure all relevant data was used for water heating EUI calculations. As a final step, water heating usage from non-electric fuels was backed out by applying the electric fuel share.

calculations, EUIs for end uses taken from CBECS were scaled so that the sum of end uses equaled total EUI minus the calculated EUIs for lighting, cooling, heating, process, and domestic hot water.

From a top down perspective, most segments have an EUI between 9 and 17 kWh/ft^2, with the exception of Grocery and Restaurant. Large C&I customers have a much higher EUI (52) than Small C&I customers (14). This variation is primarily a function of the end uses common to each segment. Both Grocery and Restaurant segments have large amounts of energy usage for refrigeration and cooking. Large C&I customers, who have a large representation of large industrial customers, have very large amounts of energy intensive processes. The segment with the lowest EUI is Warehouse (5.2), though it is notable that the sample for this includes several *self-storage* facilities, which are typically not heated or cooled and have very little lighting usage.

Figure 9: Energy Use Intensity (by Segment, Sector, EDC)

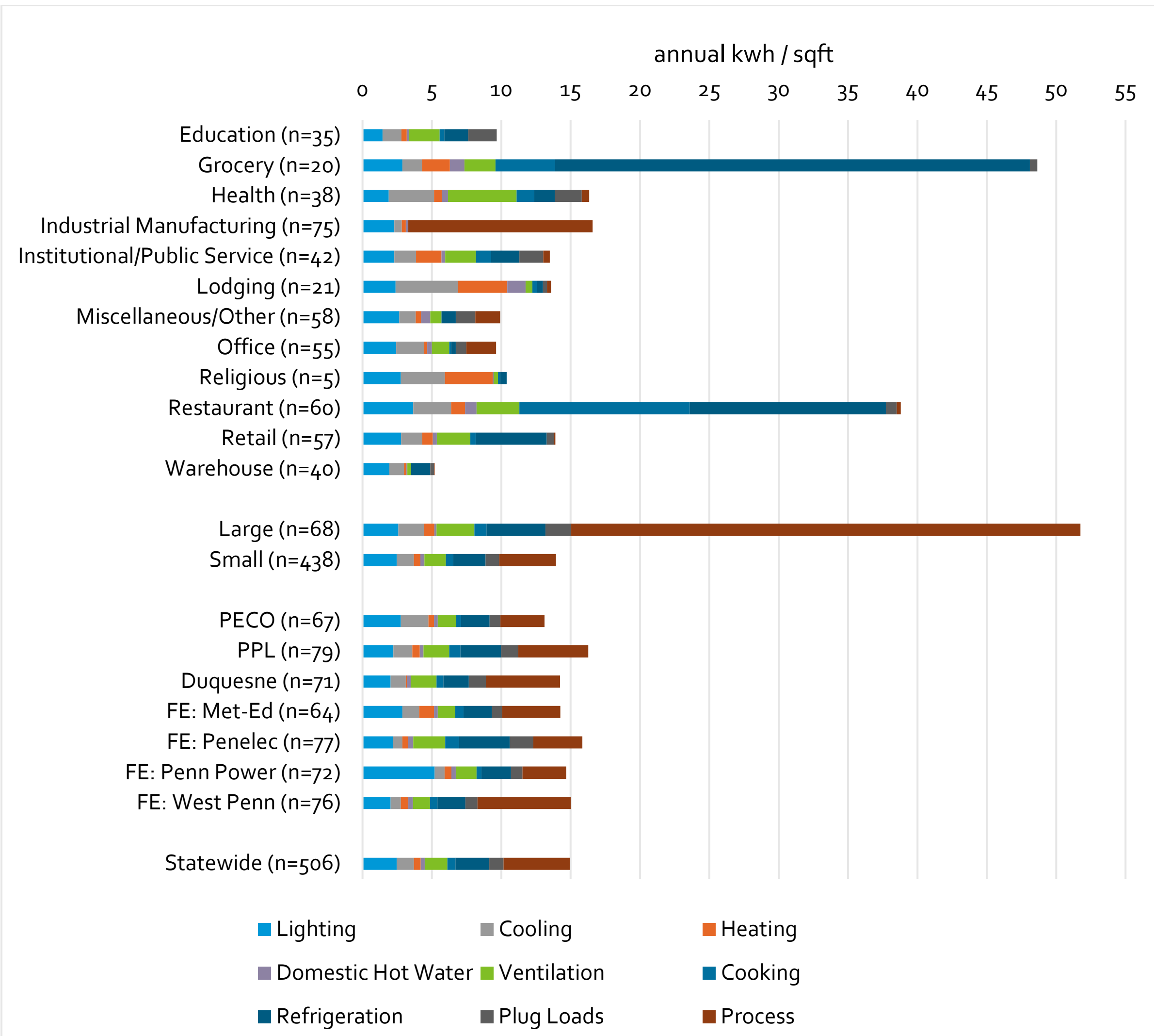


Table 12 shows penetration and fuel share for each end use.[9] Penetration represents the percent of sites where the end use is present.[10] Fuel share represents the percent of capacity fueled by each fuel source. N-values represent the number of equipment units used for the fuel calculations.

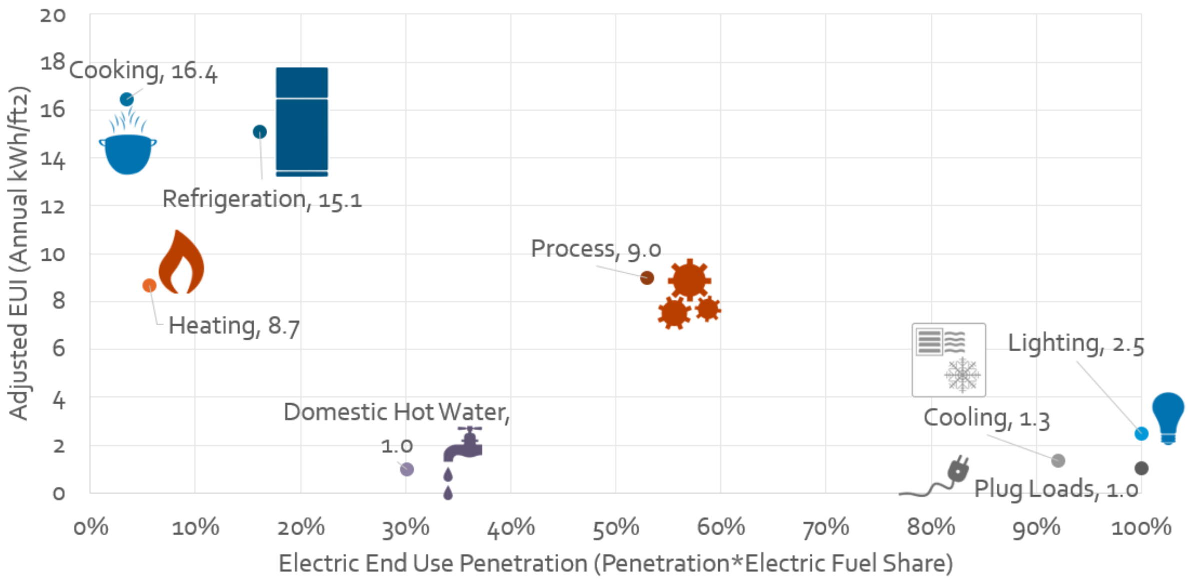
Table 12: Non-Residential End Use Penetration and Fuel Share

End Use	Penetration	Fuel Share				
		Natural Gas	Electric	Propane	Other	Unit n-values
Lighting	100%	0%	100%	0%	0%	
Space Heating	99%	86%	6%	5%	3%	4,276
Space Cooling	92%	0%	100%	0%	0%	
Plug Load	100%	0%	100%	0%	0%	
Refrigeration	16%	0%	100%	0%	0%	
Cooking	10%	60%	35%	5%	0%	1,192
Water Heating	89%	62%	34%	4%	3%	940
Process	58%	9%	91%	0%	0%	5,093

Figure 10 shows penetration and EUI for electric end uses. EUI was derived across all customers by dividing annual energy use by building square footage. Here, EUIs have been adjusted to reflect end use penetration and electric fuel share for heating, domestic hot water, cooking, and process end uses, with the values shown in Table 12. For example, heating EUI across all customers was 0.5 kWh/ft^2. However, since the penetration of electric heating is only 6%, heating EUI for sites where electric heating is used is much higher than average. Electric end uses with the highest EUIs are also those with the lowest electric end use penetration. For example, commercial cooking equipment is extremely energy intense in the businesses that have it, but it is relatively uncommon (10% penetration) and tends to be fueled by natural gas rather than electricity (35% fuel share for electricity).

[9] Ventilation excluded because penetration was not directly assessed specifically for this end use.
[10] Note that this is different than the approach used for the fuel study comparisons across studies in the executive summary. To ensure like to like comparisons with previous studies the shares shown in the executive summary represent percent of equipment units.

Figure 10: Non-Residential EUI and Electric End Use Penetration



As described above, EUI is a measure of energy usage per unit of building area and takes into account annual usage and building area for surveyed customer sites. As shown in Table 13, segment, sector, and EDC specific top down EUI was further combined with top down annual energy consumption within these classifications to estimate building area occupied by each category. Essentially, total top down sales divided by EUI (consumption per square foot) produces building stock square footage. By design, the 80.4 thousand GWh total sales correspond exactly to the sales summaries presented in Section 2.3. However, building stock estimates for each category may not add up exactly to the statewide estimate of 5.4 billion square feet to the extent that the customers sampled are not perfectly representative of customers across the state. That said, building stock totals for EDC and segment are quite close to the statewide estimate, indicating that the sample is still reasonably representative. Totals for building stock by sector are not as close, in part because large customers are few and have a wide variance in building square footage and energy intensity. For example, several Large C&I study participants were waste water treatment utilities, which have a very high EUI given that most energy usage comes from outdoor processes.

Table 13: Building Stock (by Segment, Sector, EDC)

Segment	Building Stock (1000 ft²)	Consumption (GWh)	Electricity Share
Education	570,995	5,739	7%
Grocery	98,772	4,802	6%
Health	325,661	5,346	7%
Industrial Manufacturing	1,878,288	31,512	39%
Institutional/Public Service	365,165	6,093	8%
Lodging	110,526	1,192	1%
Miscellaneous/Other	598,788	5,573	7%
Office	873,260	8,244	10%
Religious	127,890	1,021	1%
Restaurant	47,444	1,821	2%
Retail	524,391	7,256	9%
Warehouse	357,560	1,849	2%
Sector			
Large	963,071	50,195	62%
Small	2,200,602	30,252	38%
EDC			
PECO	1,645,659	21,186	26%
PPL	1,277,455	20,674	26%
Duquesne	548,204	7,789	10%
FE: Met-Ed	569,777	7,818	10%
FE: Penelec	536,134	8,574	11%
FE: Penn Power	192,386	2,779	3%
FE: West Penn	792,227	11,626	14%
Statewide	**5,445,029**	**80,447**	**100%**
** Segment, sector, and EDC totals may not sum to the statewide total due to rounding*			

The EUI results discussed above are based on EDC supplied sales, so total EUI by population reflects EUI net of any on-site generation. However, on-site generation was uncommon across the 507 sites surveyed.

Table 14 summarizes the types of on-site generation identified. Note that because so few sites had generation, this summary is not weighted and may not be representative of on-site generation across all EDC non-residential customers. Notably, combined heat and power (CHP) was found at one site, and ten of the natural gas generators were at a single site. The SWE team estimated annual productions by applying high level annual production assumptions.[11]

[11] The SWE team assumed 2,500 hours per year for Solar, 7,000 hours per year for CHP and natural gas (NG) generation, and 100 hours per year for back up generation.

Table 14: Summary of On-Site Generation Surveyed

Type	Units	Mean Capacity (kW)	Total Capacity (kW)	Estimated Annual Production (MWh)
Solar	9	329	2,958	7,395
CHP	1	7,900	7,900	55,300
Back Up	10	531	4,777	478
NG generator (no heat recovery)	15	1,238	16,100	112,703

Table 15 shows high-level customer characteristics for the nine solar and one CHP systems surveyed. Solar systems spanned multiple segments and EDCs, and both sectors. Solar system sizes ranged from 1 kW to 1.17 MW. A single 7.9 MW CHP system was surveyed at the site of a large PPL customer in the Health segment.

Table 15: On-Site Generation Systems Surveyed

Type	Segment	Sector	EDC	Generation Capacity (kW)
Solar	Health	Small	FE: Penelec	1,170
Solar	Industrial Manufacturing	Small	FE: Penn Power	900
Solar	Industrial Manufacturing	Small	PPL	245
Solar	Institutional/Public Service	Small	FE: West Penn	9
Solar	Office	Small	FE: West Penn	27
Solar	Office	Small	Duquesne	5
Solar	Office	Large	PECO	600
Solar	Restaurant	Small	PPL	1
Solar	Warehouse	Small	PECO	1
CHP	Health	Large	PPL	7,900

5 LIGHTING

5.1 LIGHTING EQUIPMENT OVERVIEW

At each site, field technicians collected a detailed lighting inventory. Equipment-specific information surveyed includes bulb type, length of bulb, wattage, quantity, bulbs per fixture, ballast type, and control type. The site visits also included data collection on the type of area serviced by the lighting equipment detailed above. This includes information on the area's square footage, hours of lighting use, and the type of business activity being lit by the specific lighting inventory.

Lighting equipment inventory data is categorized into three dimensions for analysis.

1) Lighting Technology
2) Lighting Style
3) Lighting Application

Lighting technology characterizes the mechanism by which the equipment produces light and is a useful indicator of efficiency. Similar lamp types in the collected data are grouped into two new umbrella categories to simplify the presentation of findings. The "linear fluorescent" lighting technology category includes High Bay T12, High Bay T8, High Bay T5, T12, T8, and T5 lamp types. The SWE team also grouped Induction, Mercury Vapor, Metal Halide, and High-Pressure Sodium equipment into a "high intensity discharge," or HID, category. The remaining lamp types each have their own category. The values of lighting technology are as follows:

- LED
- CFL
- HID (Induction, Mercury Vapor, Metal Halide, High Pressure Sodium)
- Halogen
- Incandescent
- Linear Fluorescent (High Bay T12, High Bay T8, High Bay T5, T12, T8, T5)
- Neon

Next, the SWE team categorized the lighting style based on type of luminaire or fixture used to house the technology. The values of Lighting Style include High Bay Linear, High Bay Non-Linear, Low Bay Linear, Low Bay Non-Linear, and Area or Wall Pack.

- High Bay Linear
  - High bay fixtures with linear fluorescent or LED tubes
- High Bay Non-Linear
  - HIDs or non-linear LEDs
- Low Bay Linear
  - LED, T12, T8, and T5 with inch lengths assigned, or U-Tubes

- Area or Wall Pack
    - Outdoor and parking garage lighting
- Low-Bay Non-Linear
    - CFL, LED, Incandescent, and Halogen lights with integral ballasts
    - This category also includes pin-based lamps, with separate ballasts commonly found in recessed can fixtures in commercial buildings

Lighting Application is the third mutually exclusive category. This category aligns most closely with hours of use and coincidence factor assumptions in the Pennsylvania TRM. All lighting equipment is assigned to either Indoor General Service, Indoor Screw-Based, or Outdoor. Outdoor lighting includes all exterior lighting space inventory. Screw-Based includes the screw-based equipment in the Low Bay Non-Linear style. It does not include pin-based lighting equipment. The remaining inventory is categorized as Indoor General Service.

Lighting analysis tables and figures can either look at connected load or lamp/fixture count distributions. For connected load, shares are calculated based on total wattage. For fixture count analysis, or saturation, each lamp/fixture counts the same. For some views of the data, both perspectives are presented. For example, LEDs, as the most efficient technology, will show larger shares in the lamp/fixture count figures than they show in the connected load figures. When relevant, the share-type will be noted in the title.

5.2 LIGHTING EQUIPMENT FINDINGS

Figure 11 shows the various technology types included in the survey weighted by wattage. The provided n-values represent units.

Figure 11: Distribution of Connected Load across Lighting Technologies

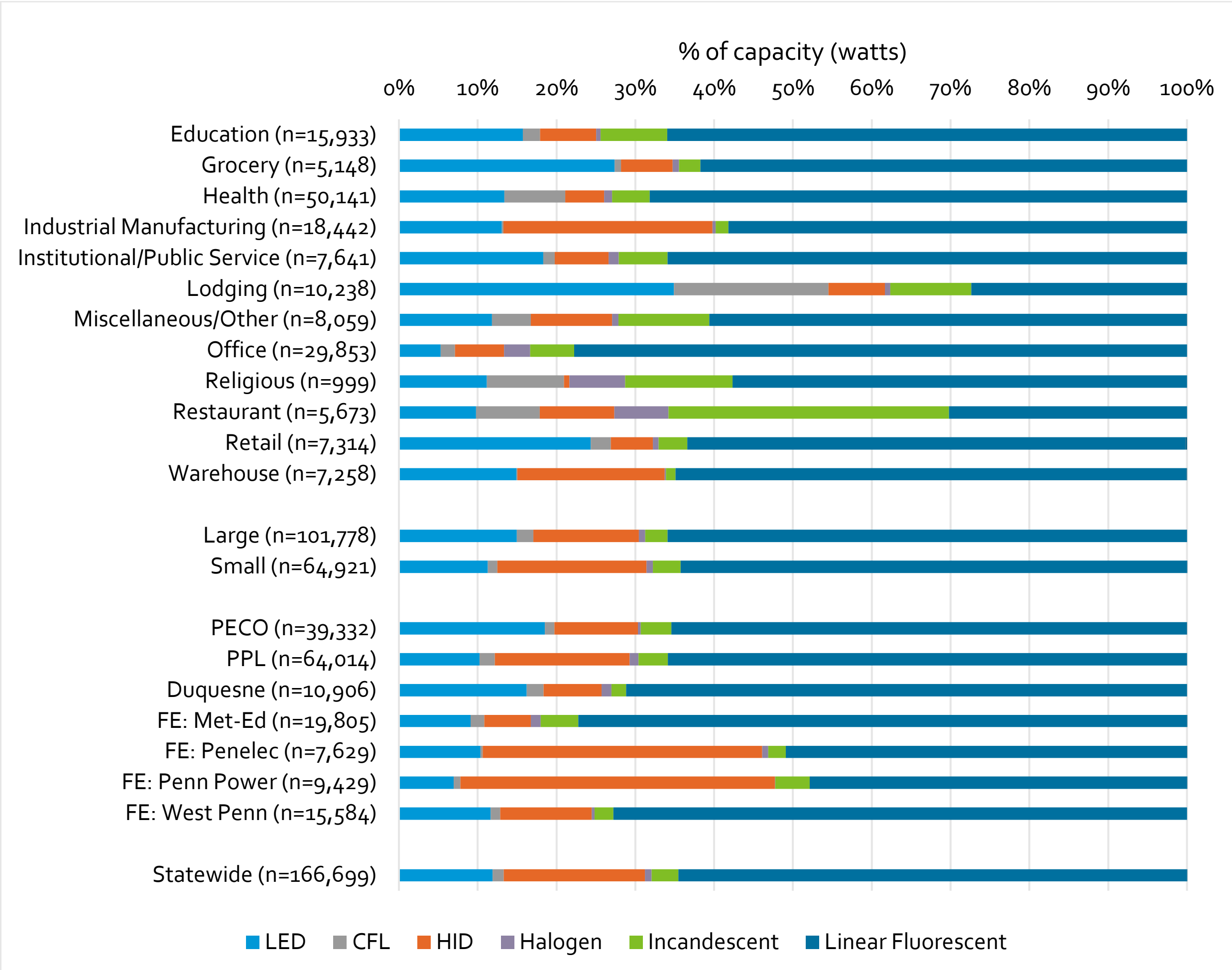


Figure 12 shows site-level penetration of LED lighting. It is important to note that a site with one LED bulb has the same impact as a site with 100% LED lighting for this figure. Sixty percent of non-residential facilities have at least some LED lighting statewide, with Large C&I customers showing higher LED penetration than Small C&I customers.

Figure 12: LED Penetration

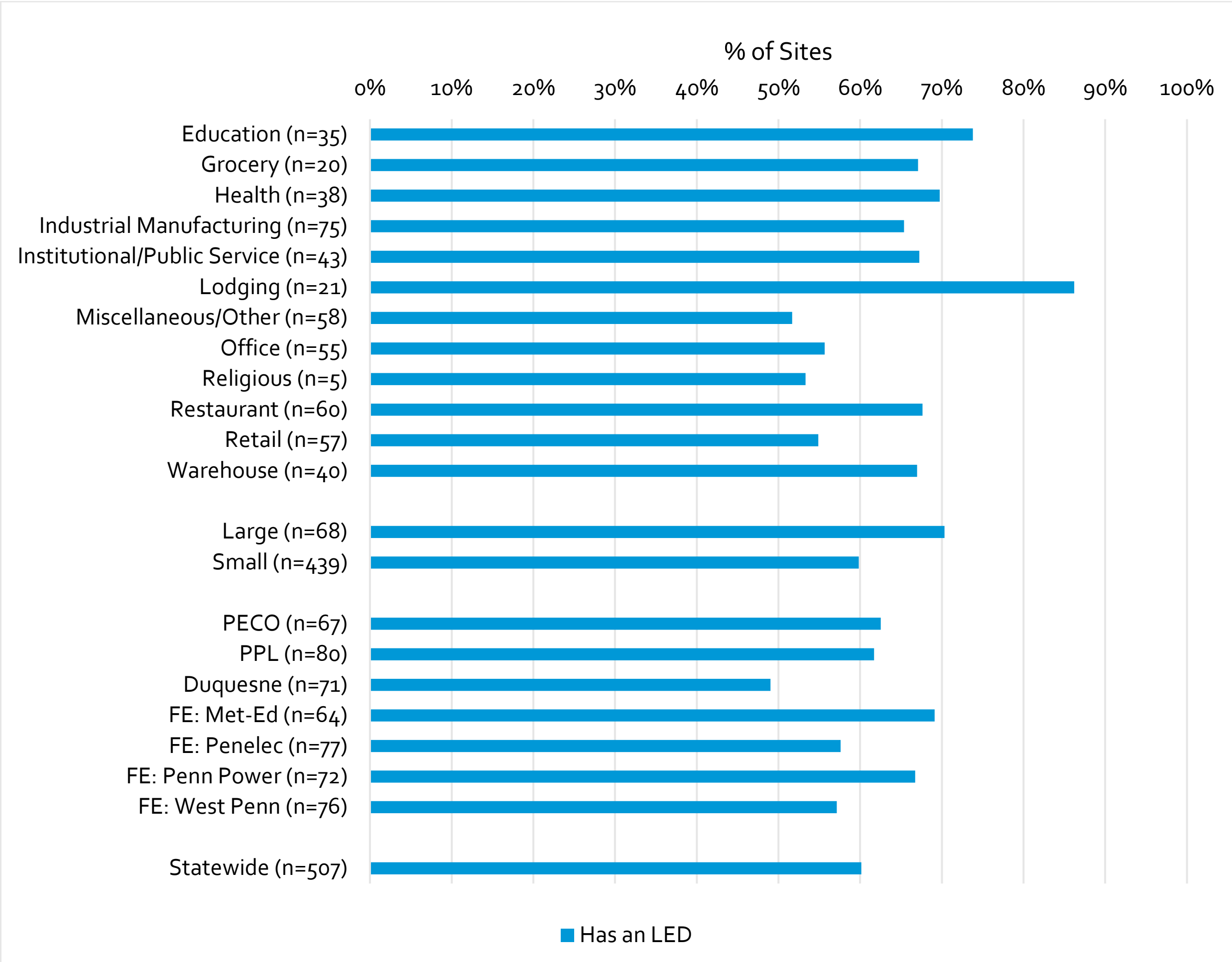


Figure 13 shows application share weighted by wattage. Recall that pin-based lighting is included in the General Service category. Provided n-values are units of lighting. General service lighting is approximately 85% of the lighting connected load statewide in the non-residential sector, and outdoor lighting is approximately 10%. Indoor screw-based lighting is only around 5% of the total non-residential lighting connected load statewide, but makes up close to 50% of the connected in specific segments like Lodging and Restaurant.

Figure 13: Distribution of Connected Load across Lighting Applications

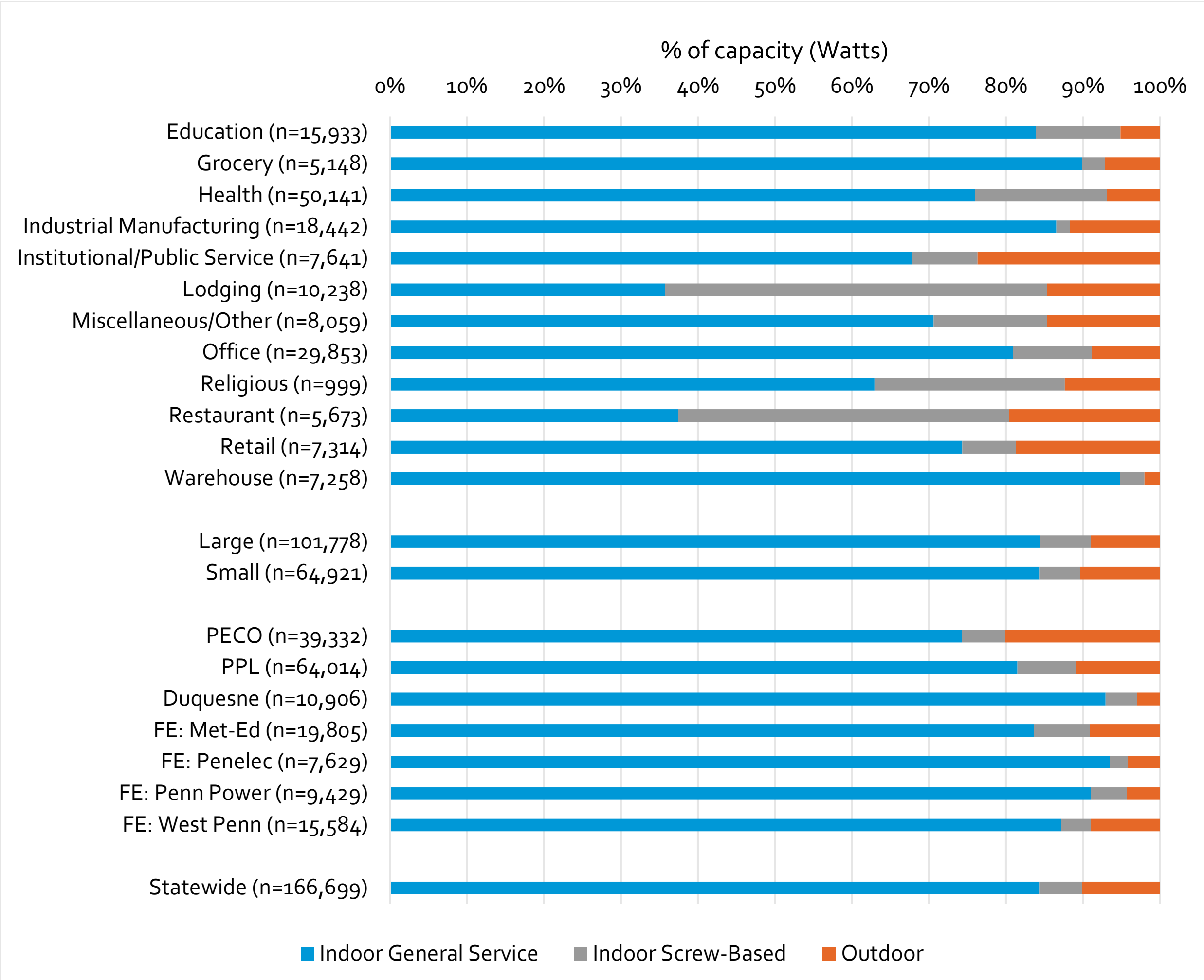


Figure 14 shows the style categories weighted by wattage. The provided n-values are units of lighting.

Figure 14: Distribution of Connected Load across Lighting Styles

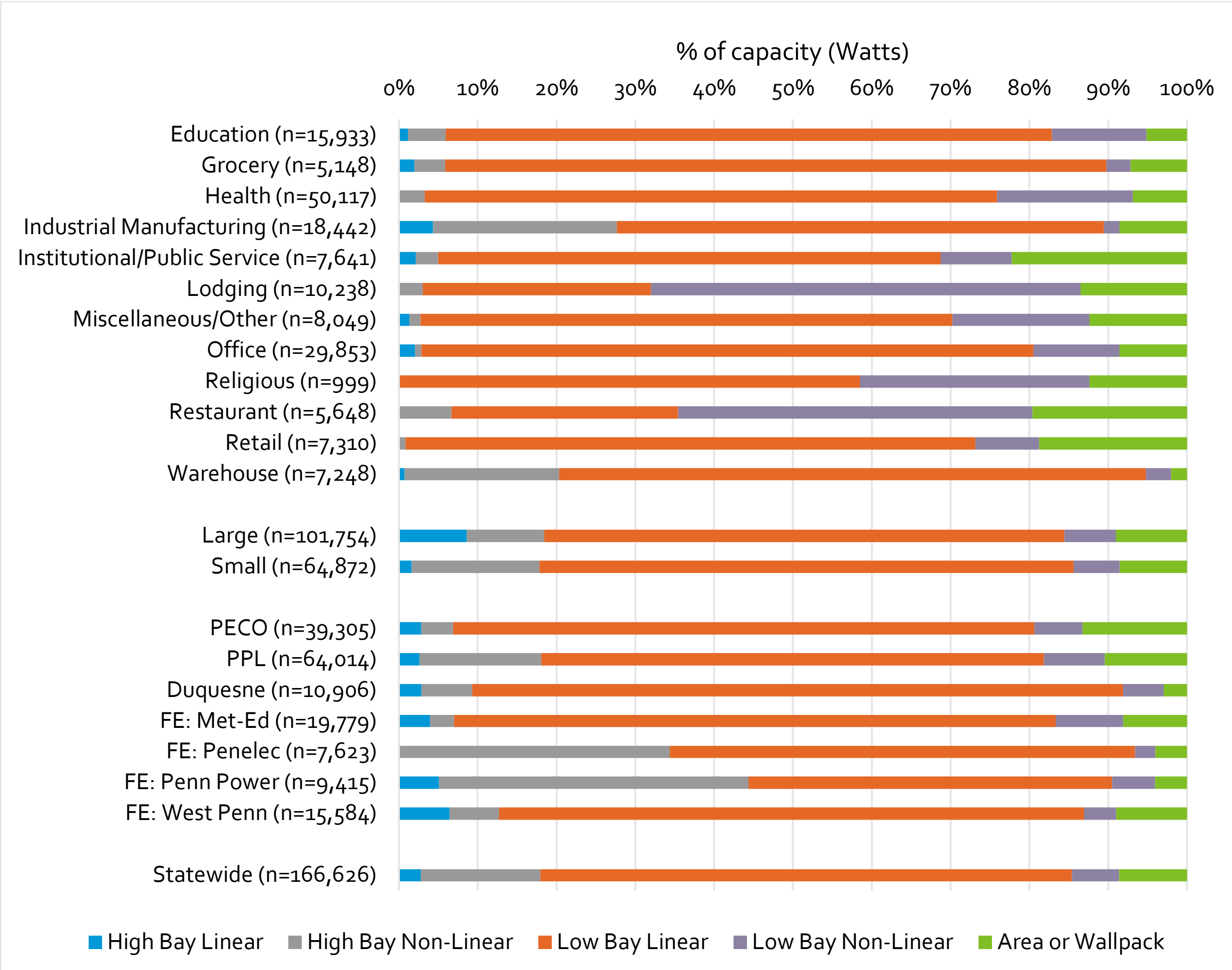


Figure 15 and Figure 16 show the technology type distribution for each application. Provided n-values are the units of lighting. Figure 15 provides equal weight to each unit of lighting, and Figure 16 weights these units by watts. Comparing these two figures shows a unique perspective of LED lighting share. By fixture count, LEDs make up 19% of Indoor General Service, 44% of Indoor Screw-Based, and 43% of the Outdoor lighting application. Because of the high efficiency of LEDs, the respective watts-weighted shares drop to 10%, 17%, and 27%, respectively. The inefficiency of incandescent bulbs is highlighted in the steep increase in share from units to watts in the Indoor Screw-Based category.

Figure 15: Technology Type by Application (by Fixture Count)

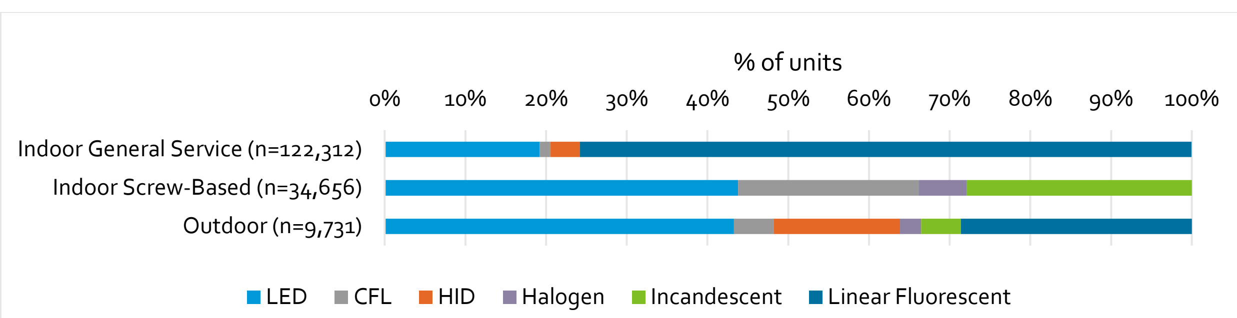


Figure 16: Technology Type by Application (by Connected Load)

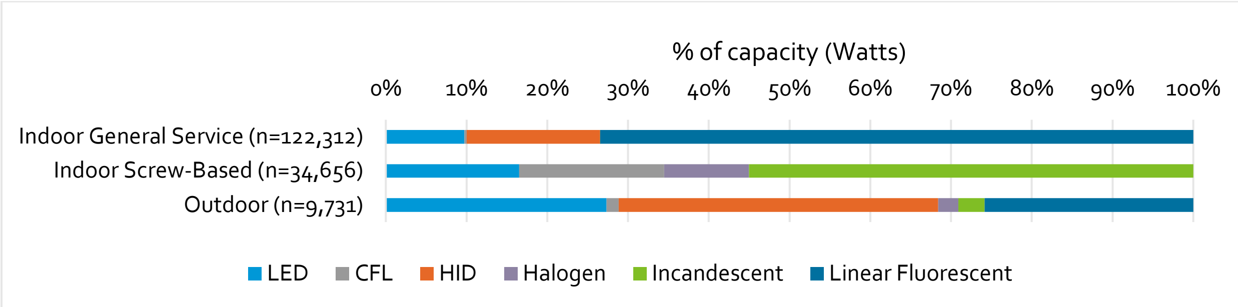


Figure 17 and Figure 18 show the technology type distribution for each style of lighting. Provided n-values are the units of lighting. Figure 17 provides equal weight to each unit of lighting, and Figure 18 weights these units by watts. Comparing these two figures shows the dramatic impact lighting efficiency can have on share. There is a strong presence of LEDs in the market, but their efficiency allows them to make a smaller impact on the energy used for lighting. From another perspective, Incandescent lighting makes up 25% of the units in the Low Bay Non-Linear category, but 52% of the wattage for that category.

Figure 17: Technology Type by Style (by Fixture Count)

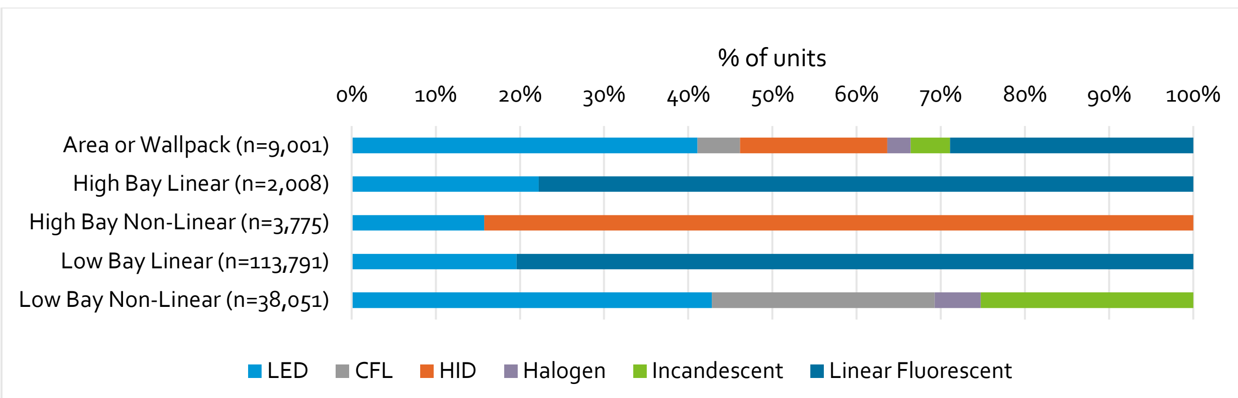


Figure 18: Technology Type by Style (by Connected Load)

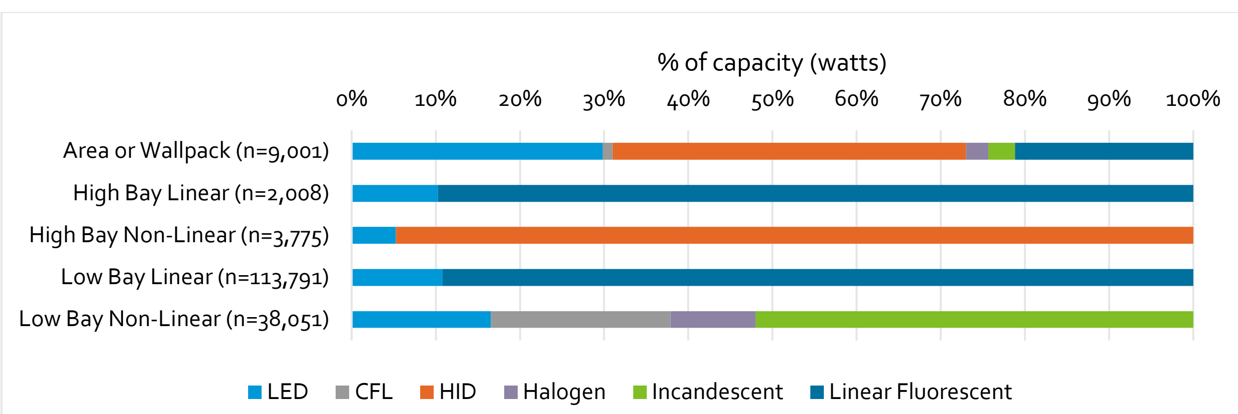


Figure 19 and Figure 20 show the lamp type distribution for linear troffers. Provided n-values are the units of lighting. Figure 19 provides equal weight to each unit of lighting, and Figure 20 weights these units by watts. T12 lighting was very uncommon in Large C&I facilities, but linear LEDs were observed at similar frequencies in the Large and Small sector.

Figure 19: Linear Troffers Lamp Type Distribution (by Fixture Count)

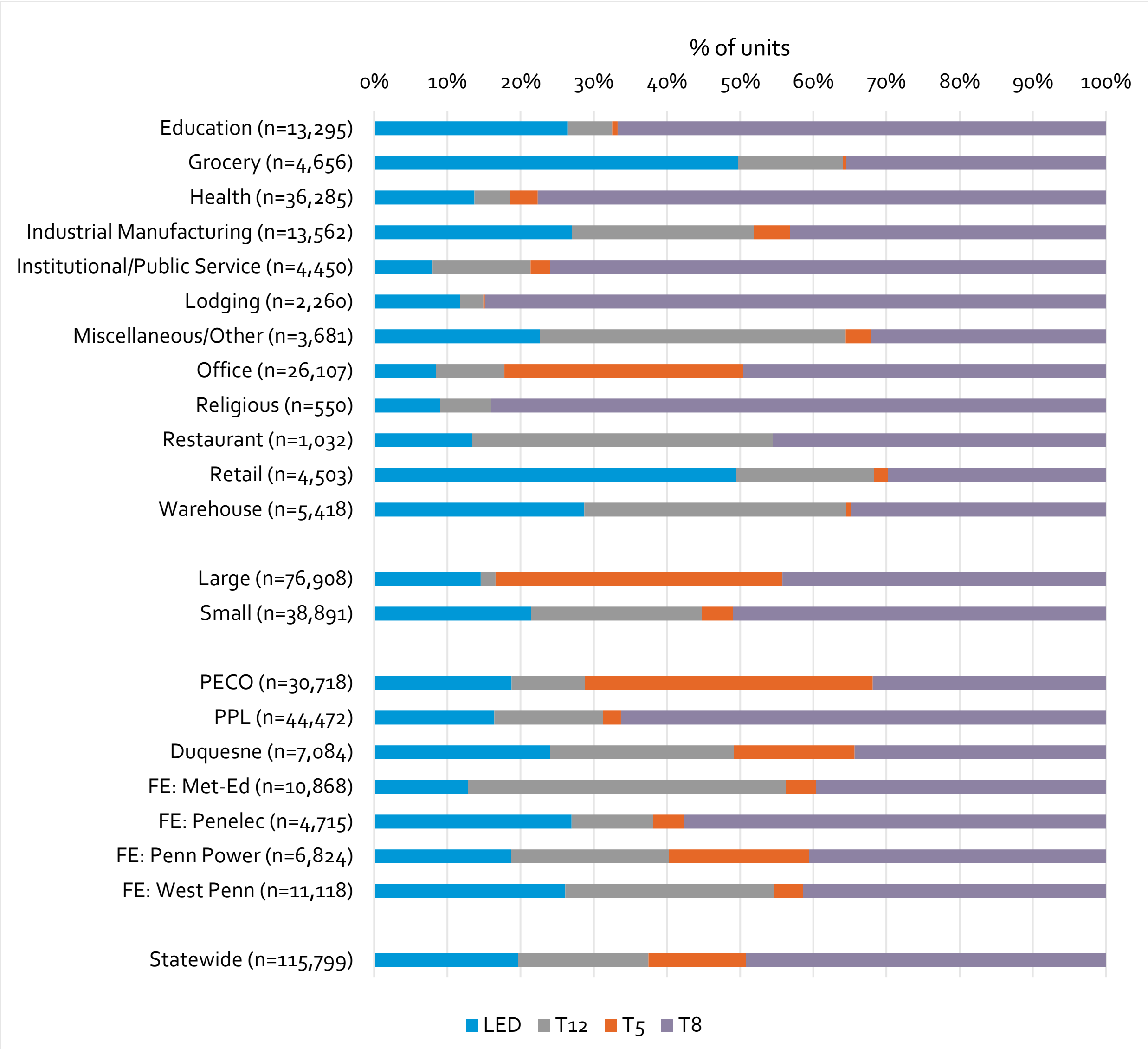


Figure 20: Linear Troffers Lamp Type Distribution (by Connected Load)

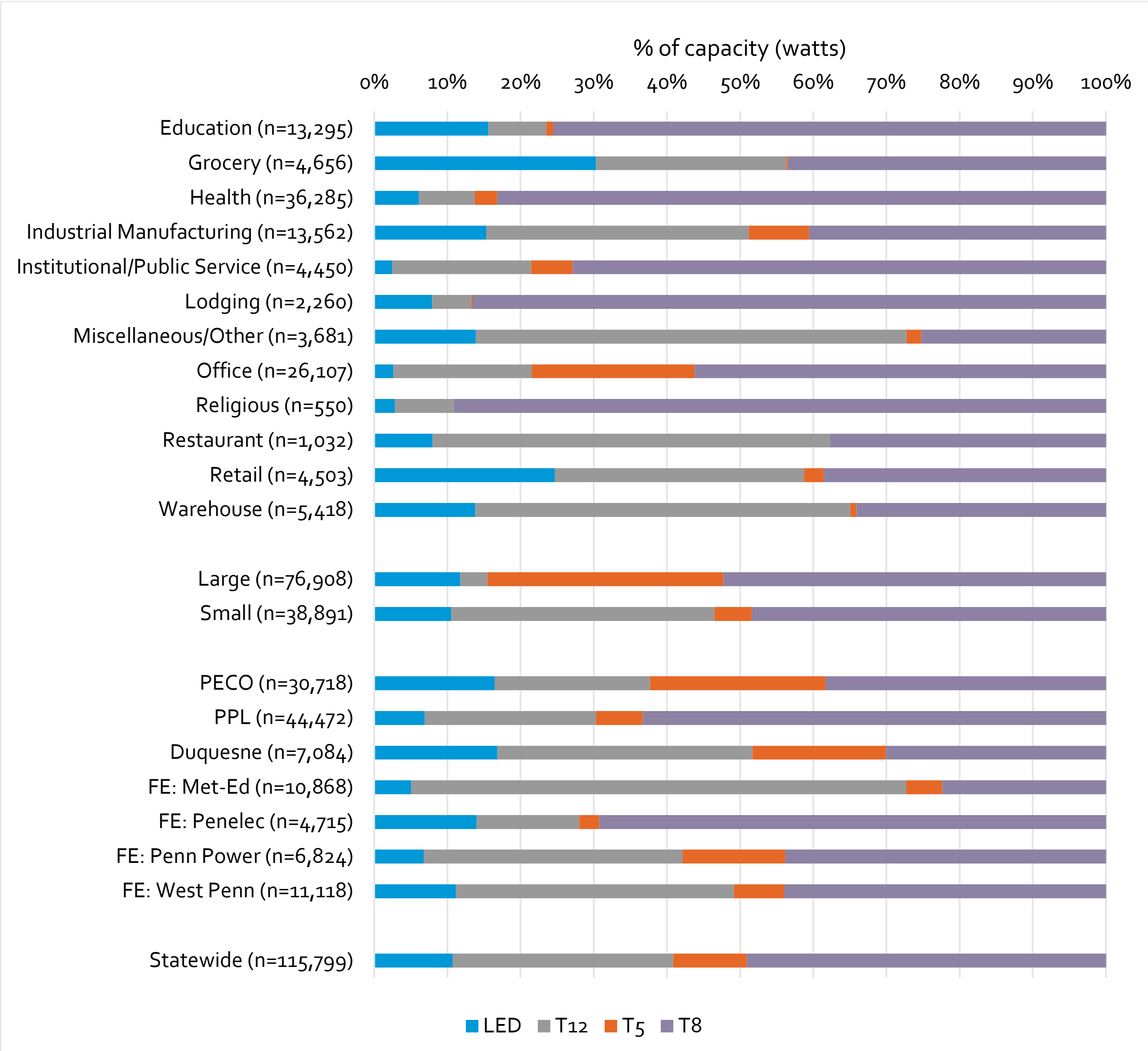
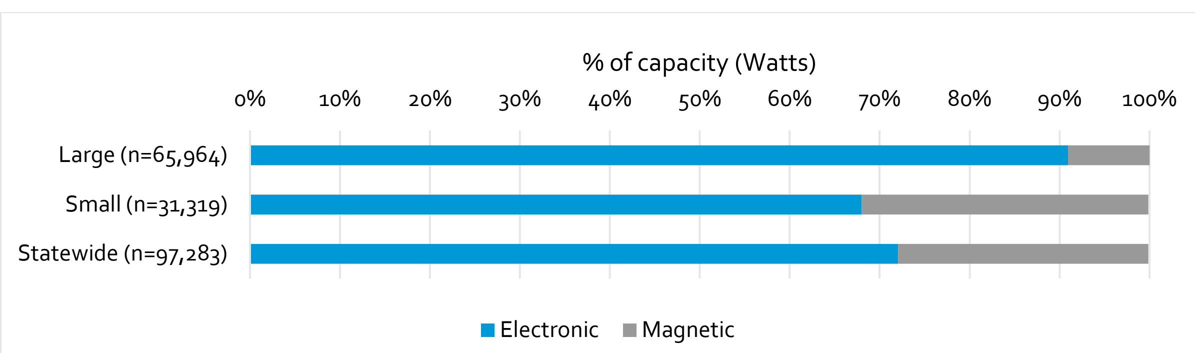


Figure 21 shows the distribution between Electronic and Magnetic ballasts for linear fluorescent fixtures. These values are weighted by connected load. The n-values are units.

Figure 21: Linear Fluorescent Ballast Type (by Connected Load)



For linear style fixtures, Figure 22 shows the distribution of lengths. The overwhelming majority is 48-inch lamps. Each unit is represented equally, and the n-values are fixture counts.

Figure 22: Lighting Length (by Fixture Count)

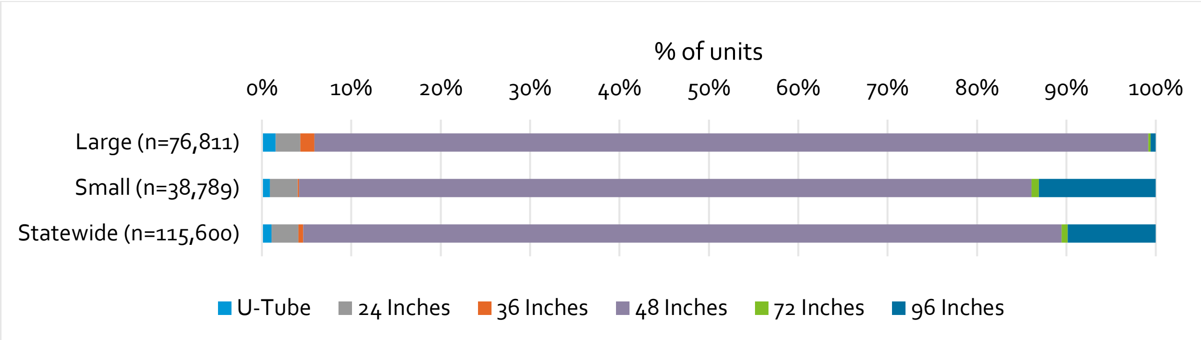


Figure 23 and Figure 24 show how the technology types within the low bay non-linear style are distributed. The n-values are units. The share is determined by units for Figure 23 and Wattage for Figure 24. Comparing these two figures shows the dramatic impact that lighting efficiency can have on share. There is a strong presence of LEDs in the market, but their efficiency allows them to make a smaller impact on the energy used for lighting.

Figure 23: Distribution of Low Bay Non-Linear Technology Type (by Fixture Count)

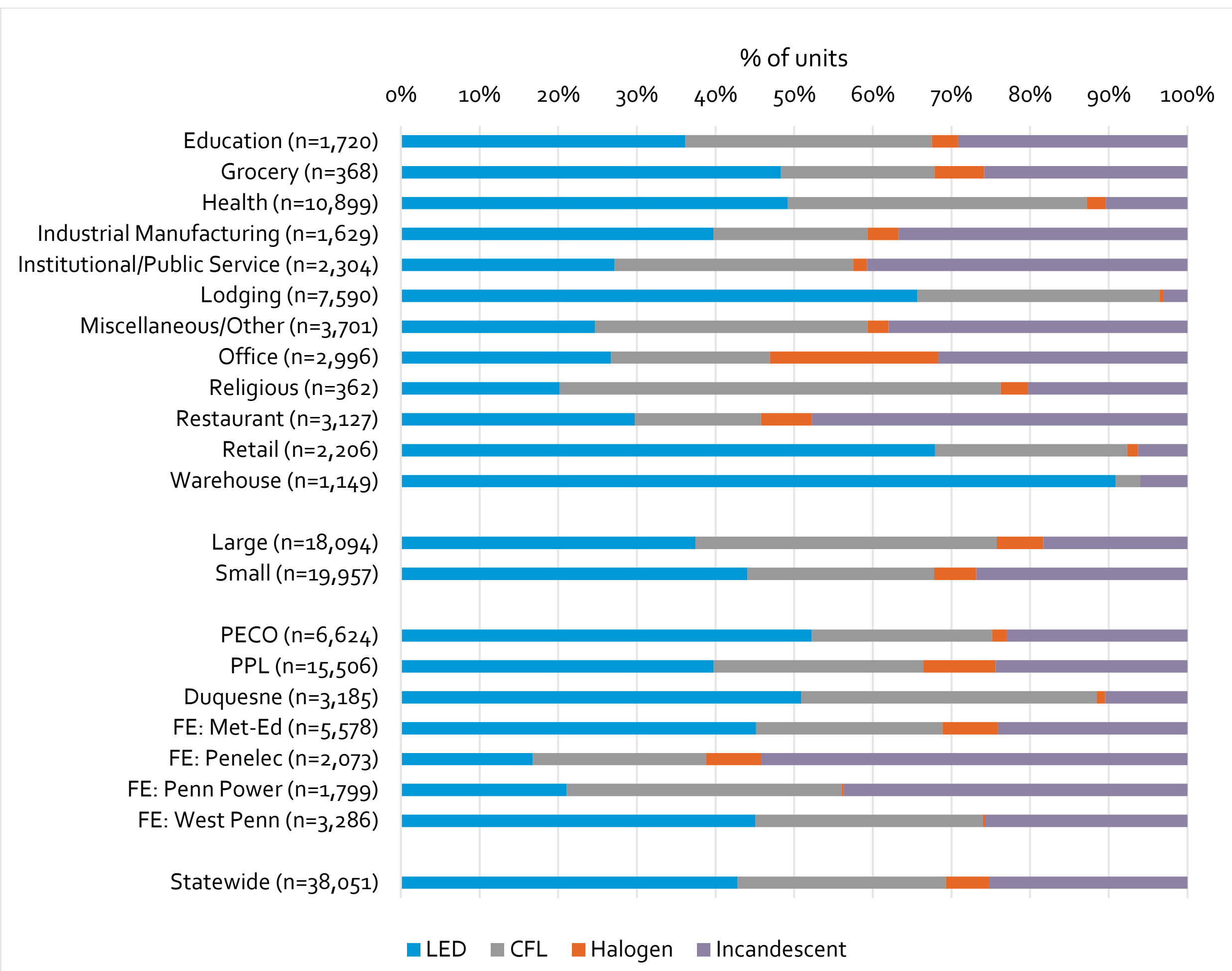


Figure 24: Distribution of Low Bay Non-Linear Technology Type (by Connected Load)

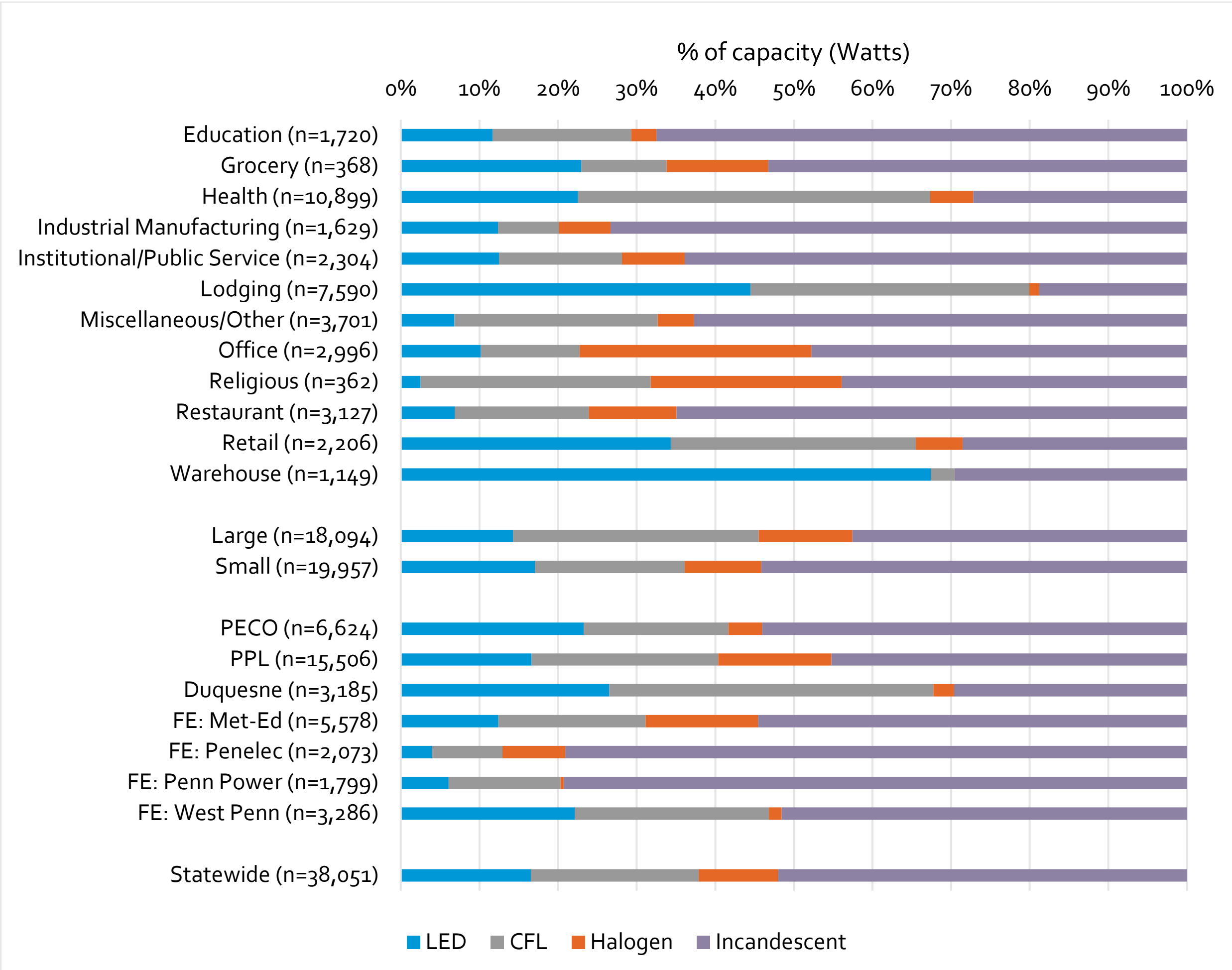


Table 16 and Table 17 show the wattage-weighted distribution of control types. Table 16 shows this distribution for all lights and Table 17 includes only outdoor lighting. Both sectors have mostly switch-controlled lighting, but the Large C&I sector has more of a mixture. Outdoor lighting uses a high percentage of photocell controls, particularly in the Large C&I sector.

Table 16: All Lighting Control Type Saturation (% of Connected Load)

Control Type	Large C&I	Small C&I	Statewide
n	101,741	64,479	166,220
Switch	49%	89%	82%
Circuit Breaker	8%	2%	3%
Continuous	6%	0%	1%
Daylighting	5%	0%	1%
Dimmer	0%	0%	0%
Energy Management System (EMS)	2%	0%	0%
Motion/Occupancy Sensor	20%	3%	6%
Photocell	6%	3%	3%
Stepped Switch	1%	0%	0%
Timer	4%	2%	3%

Table 17: Outdoor Lighting Control Type Saturation (% of Connected Load)

Control Type	Large	Small	Statewide
n	4,405	5,118	9,523
Switch	6%	37%	32%
Continuous	7%	15%	14%
Daylighting	2%	0%	1%
Motion/Occupancy Sensor	14%	5%	7%
Photocell	63%	29%	35%
Timer	9%	13%	12%

5.3 LIGHTING POWER DENSITY

Pennsylvania has now adopted the International Energy Conservation Code (IECC 2015) building code, which lowers the allowable Lighting Power Density (Watts/ft^2) standards for new construction in the Commonwealth. These values are listed in Table 18. Findings from indoor lighting surveyed in the 2018 Non-Residential Baseline Study are provided in Table 19. While the nomenclature of the categories does not perfectly align, general categories of Lighting Power Density (LPD) are already within range of or catching up to the new building code.

Table 18: IECC 2015 Lighting Power Density (LPD) Building Standards

Building Type	LPD	Building Type	LPD
Automotive Facility	0.80	Multifamily	0.51
Convention Center	1.01	Museum	1.02
Courthouse	1.01	Office	0.82
Dining: Bar Lounge/Leisure	1.01	Parking Garage	0.21
Dining: Cafeteria/Fast Food	0.90	Penitentiary	0.81
Dining: Family	0.95	Performing Arts Theater	1.39
Dormitory	0.57	Police Station	0.87
Exercise Center	0.84	Post Office	0.87
Fire Station	0.67	Religious Building	1.00
Gymnasium	0.94	Retail	1.26
Health-Care Clinic	0.90	School/University	0.87
Hospital	1.05	Sports Arena	0.91
Hotel / Motel	0.87	Town Hall	0.89
Library	1.19	Transportation	0.70
Manufacturing	1.17	Warehouse	0.66
Motion Picture Theater	0.76	Workshop	1.19

Table 19: Lighting Power Density – 2018 Field Data Collection

Segment (n = sites)	Mean LPD
Education (n=35)	0.95
Grocery (n=20)	1.01
Health (n=38)	0.96
Industrial Manufacturing (n=74)	0.83
Institutional/Public Service (n=43)	0.89
Lodging (n=21)	0.43
Miscellaneous/Other (n=58)	1.16
Office (n=55)	1.06
Religious (n=5)	0.99
Restaurant (n=60)	1.00
Retail (n=56)	0.95
Warehouse (n=40)	0.65
Sector	
Large (n=68)	0.72
Small (n=437)	0.96
Statewide (n=505)	**0.95**

An important consideration for LPD is that it does not reflect hours of use, only connected Wattage. With more operating time, improved efficiency leads to more savings potential. Understanding LPD in conjunction with hours of use is important for assessing energy efficiency potential. Self-reported annual lighting hours are presented in Table 20 and align fairly well with the Pennsylvania TRM assumptions. A final consideration for hours of use is that these values are self-reported schedules of lighting use and not an exact measure of operation. While the Large C&I sector is generally more efficient with respect to LPD, hours of operation are higher, on average, than Small C&I facilities.

Table 20: Mean Self-Reported Annual Hours of Lighting Use

Segment (n = units)	Mean Annual Hours
Education (n=15,933)	2,694
Grocery (n=5,148)	4,110
Health (n=50,141)	6,662
Industrial Manufacturing (n=18,442)	3,659
Institutional/Public Service (n=7,641)	4,882
Lodging (n=10,238)	7,153
Miscellaneous/Other (n=8,059)	3,540
Office (n=29,853)	2,728
Religious (n=999)	3,071
Restaurant (n=5,673)	3,921
Retail (n=7,314)	3,633
Warehouse (n=7,258)	3,332
Sector	
Large (n=101,778)	4,741
Small (n=64,921)	3,460
EDC	
PECO (n=39,332)	3,209
PPL (n=64,014)	4,225
Duquesne (n=10,906)	3,583
FE: Met-Ed (n=19,805)	3,804
FE: Penelec (n=7,629)	3,502
FE: Penn Power (n=9,429)	3,428
FE: West Penn (n=15,584)	3,748
Statewide (n=166,699)	**3,766**

5.4 COMPARISON WITH PRIOR STUDY FINDINGS

Figure 25 compares the current baseline study with the two previous Pennsylvania non-residential baseline studies. The most notable difference in the current study is the penetration of LED lighting. An important distinction to note is that the first phase weighted the lighting technology by square footage, while the next two studies used watts for weighting these distributions.

Figure 25: Comparison of Lighting Technologies (by Connected Load)

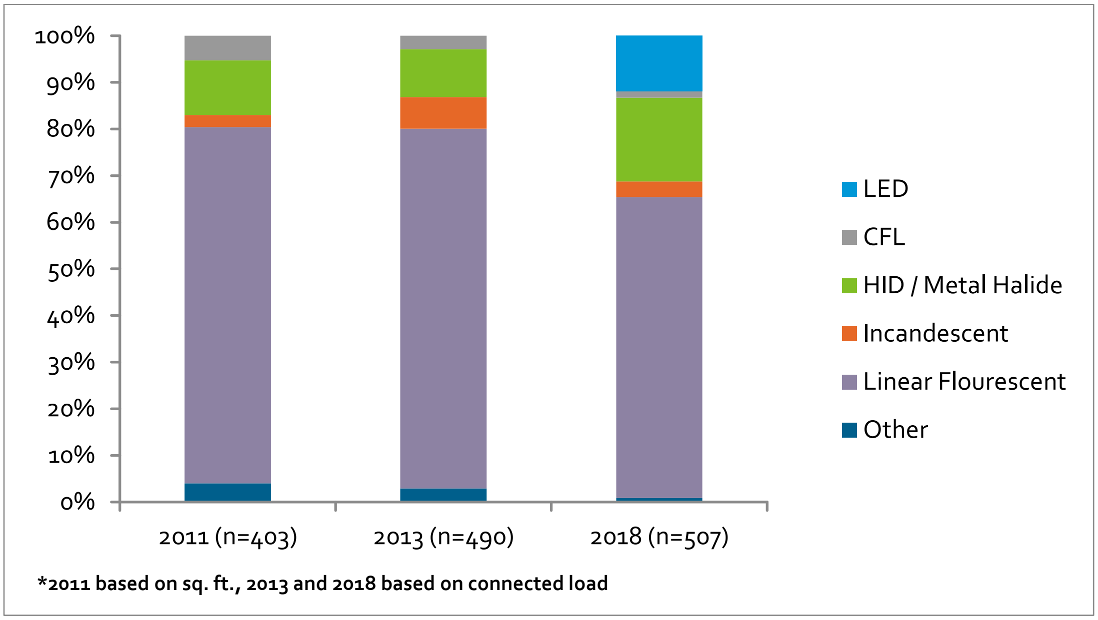
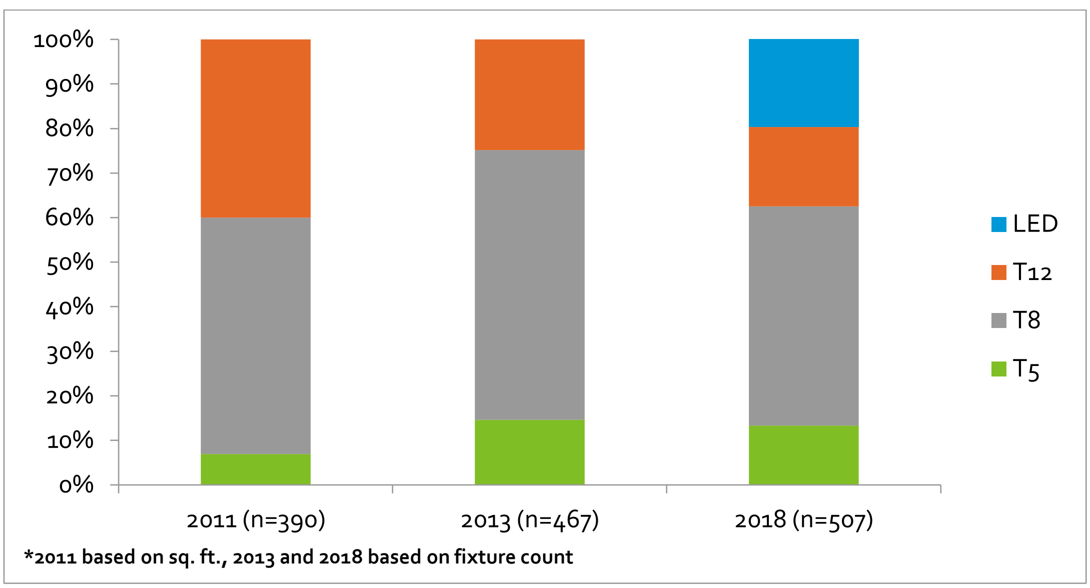


Figure 26 compares the linear fluorescent lamp types from all three phases of the baseline study. The notable change is the market penetration of LEDs. Also note that Phase 1 analyzed this distribution with respect to square footage covered, but the two more recent studies use fixture count.

Figure 26: Comparison of Linear Fluorescent Lamp Type Distribution (by Fixture Count)



6 SPACE HEATING AND COOLING

6.1 HVAC EQUIPMENT OVERVIEW

Space heating and cooling are provided to buildings via a wide array of equipment types. The following section uses various terms to describe the equipment observed at customer sites. Table 21 provides a description for each equipment type and groups equipment by end use. Note that some types of equipment only supply one end use, while others can be packaged to provide both heating and cooling. The typical scale of space conditioning provided by each equipment type is also noted: some equipment are individual components of large multi-building central plant systems, some are designed to provide space conditioning just to a single room, and others fall in between.

Table 21: Heating and Cooling Equipment Descriptions

Equipment Category	Equipment Name	Description
Central Plant Cooling	Chiller	Refrigeration machines that provide chilled water to multiple buildings for space or process cooling purposes.
Central Plant Heating	Fossil Fuel Boiler	Fossil fueled devices that generate steam or hot water for space heating purposes.
Unitary Cooling and / or Heating	DX Cooling or Heating	Direct expansion (DX) systems use refrigerant liquid and vapor compression via a heat exchanger to remove heat directly from the air to provide space cooling. Essentially, DX cooling systems are central air conditioners. Space heating can be provided either with a packaged fossil fuel or electric resistance furnace. DX systems generally provide space conditioning for multiple rooms or entire buildings via a duct system.
	Air Source Heat Pump	An air source heat pump functions similarly to a DX unit, except the electric compressor system can be run in reverse to create vapor expansion via a heat exchanger and inject heat directly into the space.
	Ground Source Heat Pump	A ground source heat pump functions similarly to an air source heat pump and can provide both heating and cooling via the heat pump compressor. The key difference is the compressor coils are buried and are therefore using the ground as a heat sink.
	PTAC / Window Unit	Packaged Terminal Air Conditioners (PTAC) are individual units that are typically installed in or below a window and provide space conditioning to a single room. The air conditioner compressor units are positioned on the exterior facing portion of the unit. Heating, if included, is typically electric resistance heat.
	Ductless Minisplit / AC / Heat Pump	Like PTAC units, Ductless Minisplit units are typically used to cool a single room. They can also sometimes provide space heating by running the heat pump compressor in reverse. A key difference with PTAC units is that it is divided into two parts connected by refrigerant lines: an indoor evaporator and an outdoor condenser.
Unitary Heating Only	Fossil Fuel Furnace	A fossil fuel furnace uses combustion, usually of natural gas, to generate heat which is then distributed through a building or series of rooms via a duct system.

Equipment Category	Equipment Name	Description
	Baseboard Radiator	Baseboard radiators are typically used to distribute central plant steam to individual rooms.
	Terminal Reheat (Electric Resistance)	Terminal electric resistance units are used to provide heat to a single room, typically via heat terminals located along the wall or ceiling.
	Unit Heater	A unit heater can be free standing or integrated into a wall and provides heat to a single room.

Throughout this chapter, most cooling and heating units are characterized as percent share of total capacity (e.g., tons of cooling or kBTU of heating capacity). Where the analysis groups units by size bin, percent share of cooling or heating units is shown.

6.2 COOLING EQUIPMENT FINDINGS

Figure 27 shows the share of cooling capacity (tons) for central plant versus unitary cooling systems. N-values indicate the number of cooling systems surveyed. Statewide, unitary systems provide nearly 60% of cooling capacity. This split is different for the Large C&I and Small C&I sectors: central plant cooling systems make up the majority of capacity for large sector customers, while small sector customers' cooling capacity is mostly unitary. Shares are also broken down by segment and EDC and show some degree of variation. Note however, that some of this variation reflects the sample that was surveyed.

Figure 27: Cooling Equipment Type (Share of Cooling Capacity)

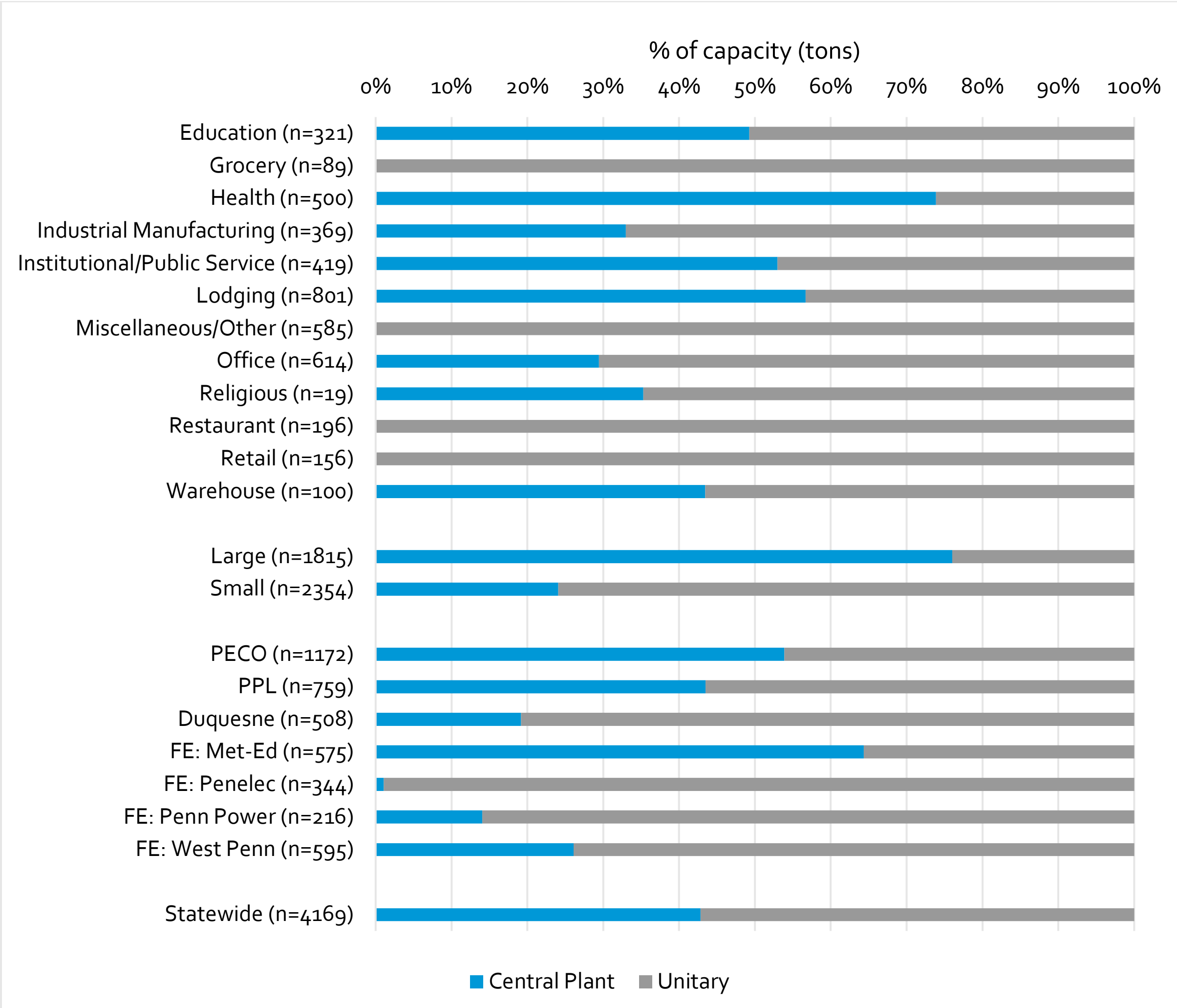
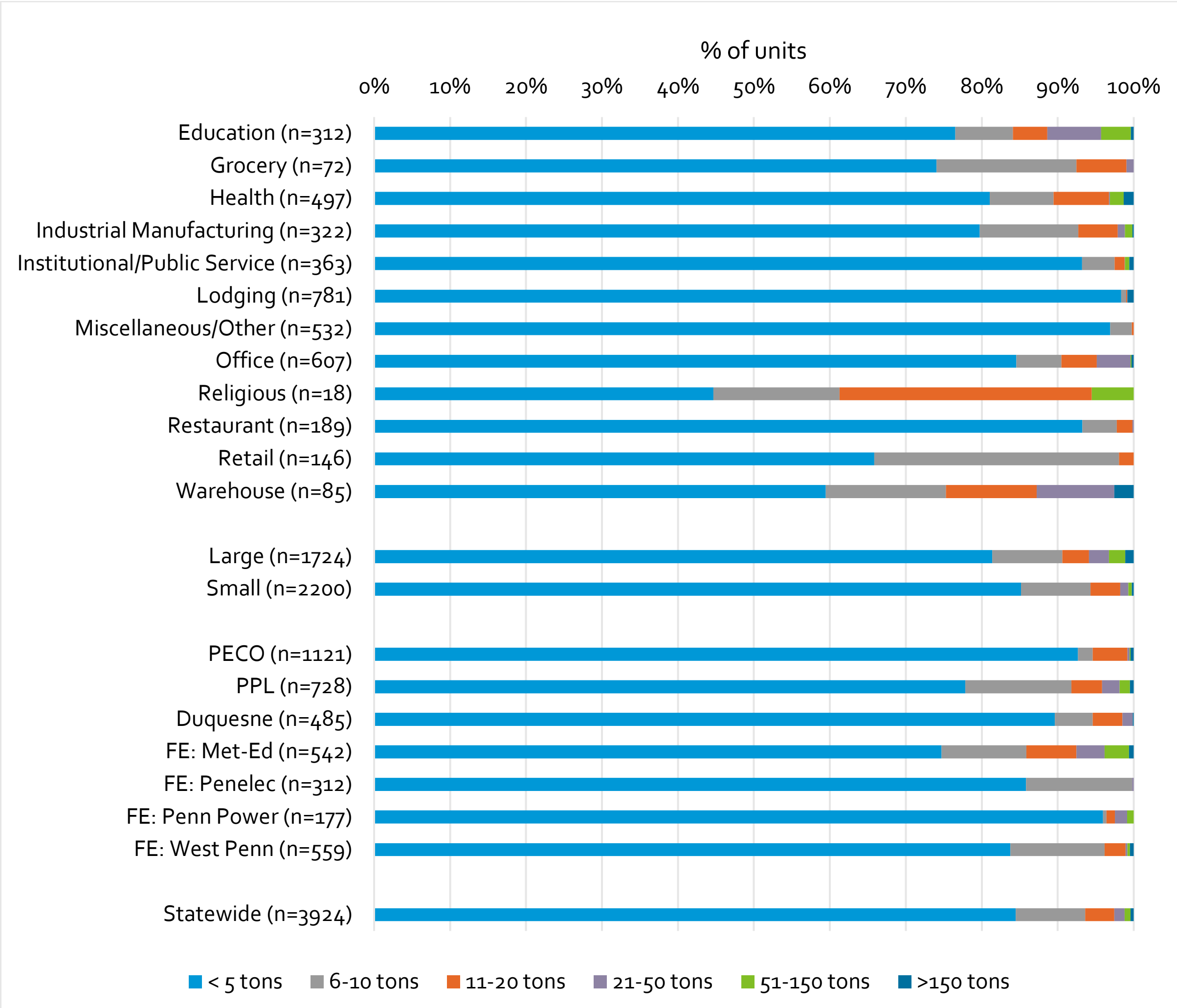


Figure 28 shows the distribution of cooling units by size bin. Whereas large central plant systems provide the majority of cooling capacity, large units (above 150 tons) represent a small fraction of cooling system units (fewer than 1%). As logic would imply, smaller units represent a much larger share of cooling units. The smallest units (those below 5 tons) make up 84% of units, 6- to 10-ton units make up another 9% of units, and the larger units make up the remainder.

Cooling unit size bins are also broken out by sector, segment, and EDC. While large and small sector customers have similar shares of the smallest cooling units, large sector customers have considerably more very large units – 6% of units for large customers are above 20 tons. This reflects what is shown in Figure 27: Large C&I sites are more likely to be cooled by large central plant cooling systems.

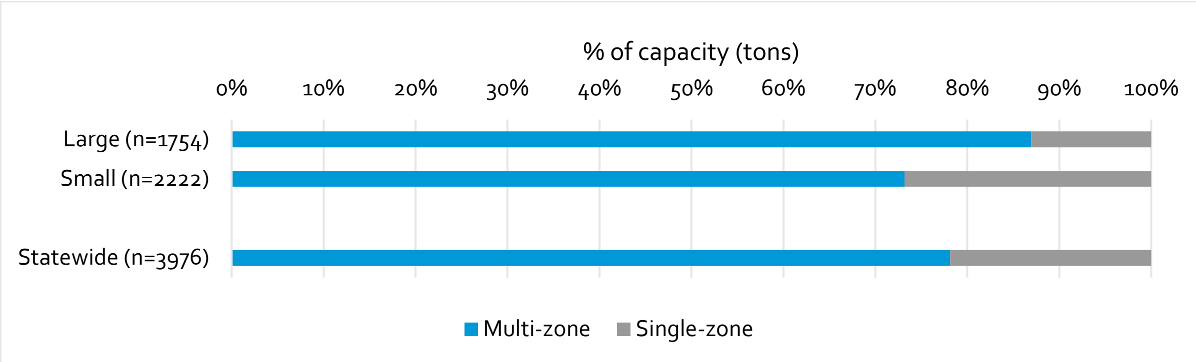
There is also some degree of variation across segments. However, it is notable that the two segments with the widest variation (Religious and Warehouse) are also those with the smallest number of systems surveyed.

Figure 28: Cooling Unit Size Distribution (Share of Units)



Another characteristic of cooling units is whether they cool a single zone or multiple zones. Figure 29 shows the share of capacity for multi-zoned versus single-zoned cooling systems. The majority (78%) of non-residential systems statewide supply cooling to multiple zones, but the share of capacity supplied by multi-zoned systems is somewhat lower for small customers.

Figure 29: Cooling Equipment Zoning (Share of Cooling Capacity)



6.2.1 Cooling System Parameters

In addition to capacity and zoning information, various parameter information was collected for cooling systems. Table 22 shows the penetration of various parameters for central plant systems as a percentage of cooling capacity. The high penetration of technologies such as variable frequency fan controls and EMS systems reflect the larger size and sophistication typical of central plant systems.

Table 22: Central Plant Parameters

Parameter	Share of Tonnage
Condenser Type (n=47)	
Air Cooled Condenser	21%
Cooling Tower	79%
Capacity Control (n=19)	
Fixed Temp	41%
Floating Temp	59%
Fan Control (n=21)	
2 Speed	10%
Constant	5%
Variable Frequency	85%

Table 23 shows the penetration of various parameters by sector, and statewide for unitary systems, as a percentage of cooling capacity. N-values represent number of systems surveyed. The penetration of high-efficiency measures, such as variable frequency drives (VFDs) and insulated ducts, is higher for Large C&I sector customer than for the Small C&I sector.

Table 23: Penetration of Unitary Cooling Energy Efficiency Options

Parameter	Large (n=623)	Small (n=1,037)	Statewide (n=1,676)
Share of capacity			
VFD	23%	6%	8%
Insulated Ducts	51%	26%	30%
Air-to-Air Recovery	0%	3%	3%
Economizer	16%	18%	18%
Demand Control Ventilation	0%	1%	1%

Unitary cooling systems include a variety of different cooling equipment types, described in more depth in section 6.1. Figure 30 shows the share of unitary cooling system capacity by equipment type. N-values represent unitary cooling systems surveyed. Direct expansion (DX) systems, essentially central air conditioners, are the most common by share of cooling capacity (80%). Window cooling units are the next most common system type (12% of capacity). Other system types are rare and comprise about 8% of unitary cooling capacity.

Window units are more prevalent among unitary systems for large customers than among small customers. However, as previously mentioned, unitary systems only represent about 25% of cooling capacity for large customers (versus 75% for small customers). This means that window units are still a much smaller share of cooling system capacity for large customers overall (including central plant systems). This should also be kept in mind when considering the variation in unitary equipment type across segments, given the variation in sector share by segment.

Figure 30: Detailed Unitary Cooling Equipment Type

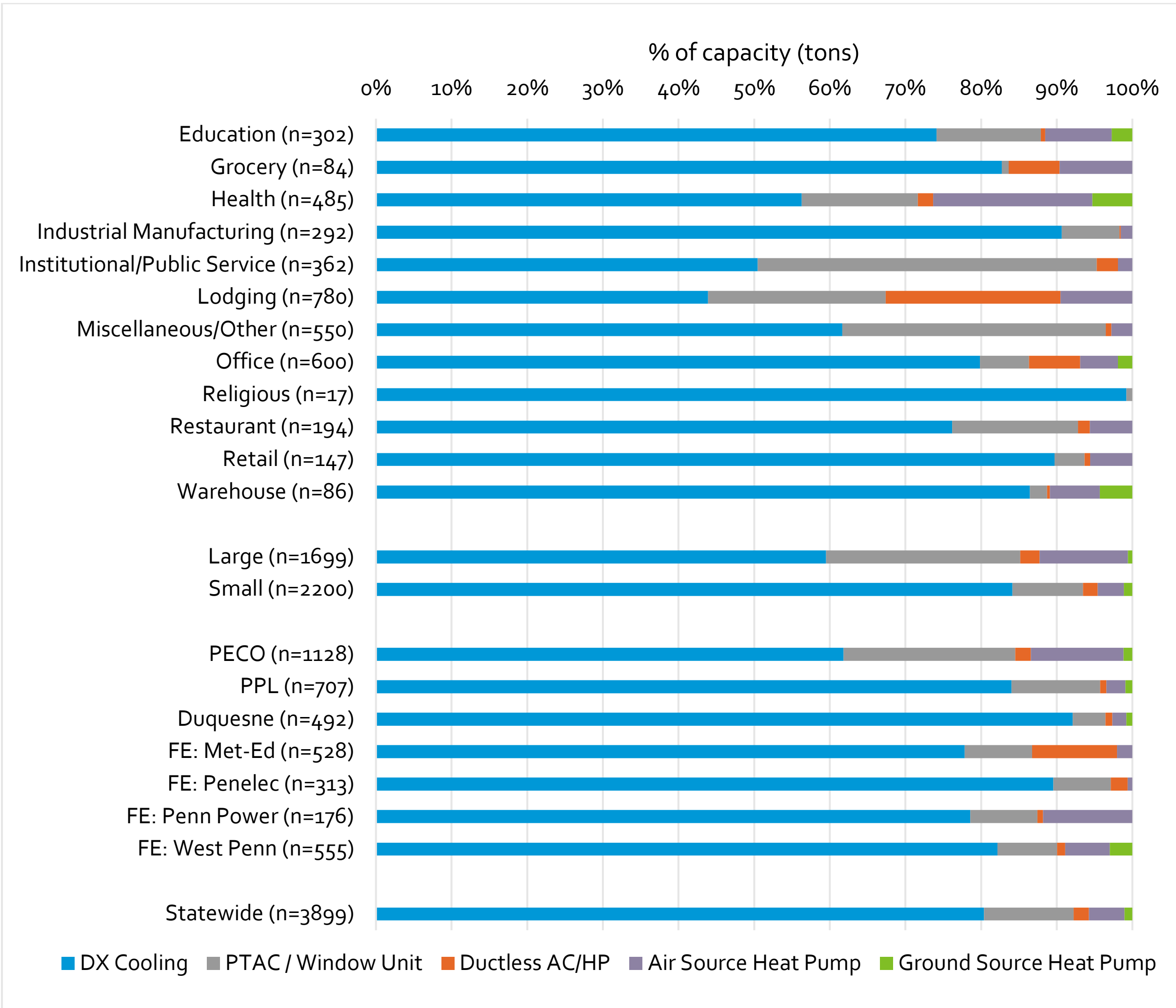
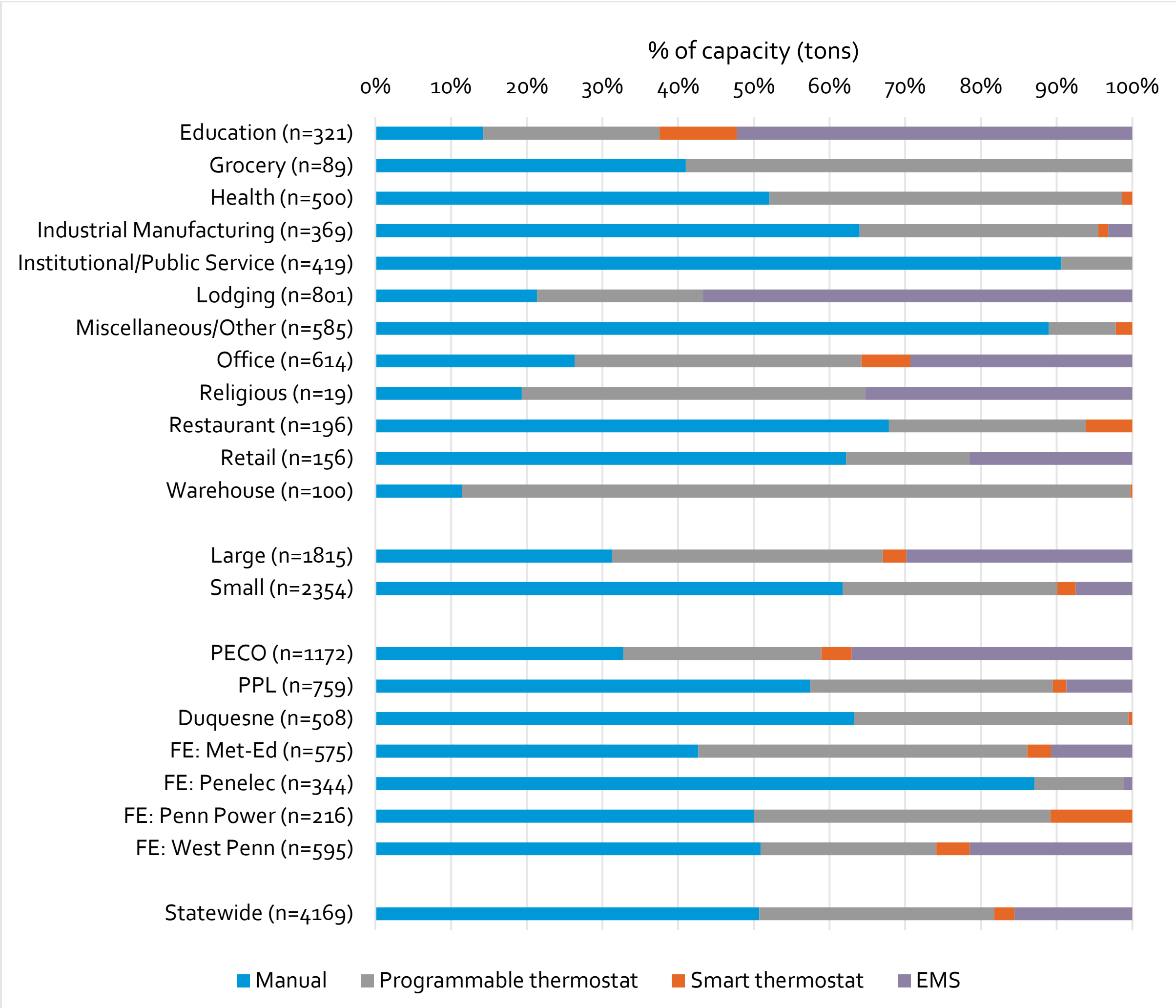


Figure 31 shows the share of cooling capacity controlled by different control types. Note that this analysis shows controls for all system types (central plant and unitary). Notably, about 50% of cooling capacity is controlled manually. Penetration of smart thermostats is low (3%) and is not meaningfully different by sector. In contrast, Energy Management System (EMS) control penetration is much higher for the Large C&I sector (30%) than for the Small C&I sector (7%).

Figure 31: Cooling Temperature Controls



6.2.2 Cooling System Setpoints

The primary function of cooling controls is to regulate cooling setpoints. Deploying a higher cooling setpoint when buildings are not occupied can help conserve energy. Figure 32 shows average cooling setpoints for buildings when they are normally occupied versus when they are not occupied.[12] N-values represent the number of systems surveyed where setpoints were verified at the thermostat by the SWE engineer. As expected, cooling setpoints are a few degrees higher (3.6 F) when buildings are unoccupied. Note that the small amount of variation in setpoints by sector, segment, and EDC, is likely mostly a function of the sites surveyed.

[12] About one third of set point levels were verified by assessing thermostat settings as opposed to self-report.

Figure 32: Mean Cooling Setpoints (by Occupancy)

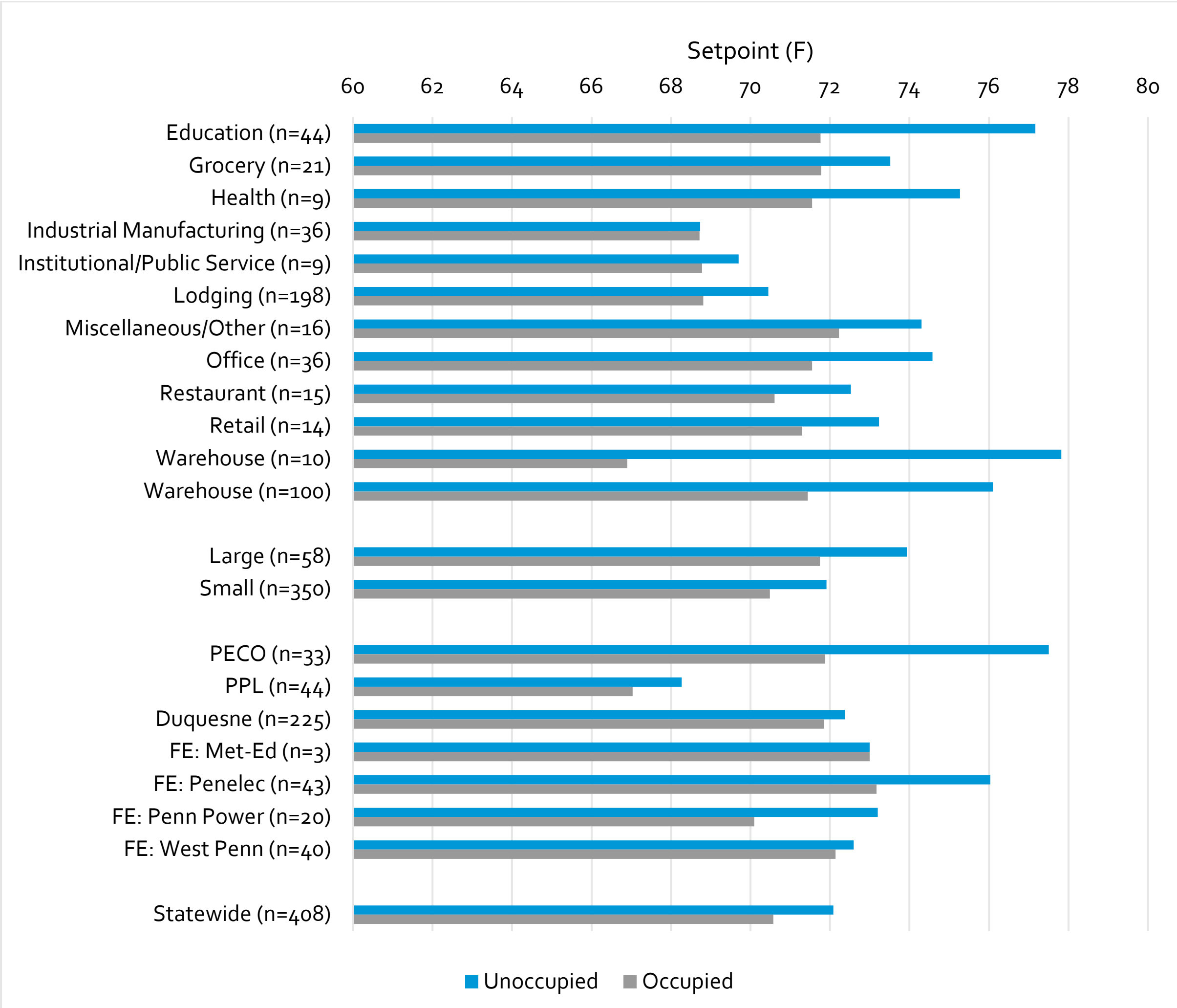


Table 24 shows how cooling setpoints vary by control type, along with the difference between occupied and unoccupied setpoints. N-values represent the number of systems surveyed for which control and set point data was collected and could be verified at the thermostat. Notably, unoccupied setbacks are larger for programmable thermostats (+2.4 F) and EMS systems (+4.9 F) than for manual (+0.3 F). Setbacks are even higher for smart thermostats (+6.6 F), but there are also few smart thermostats with verified setpoints (n=23).

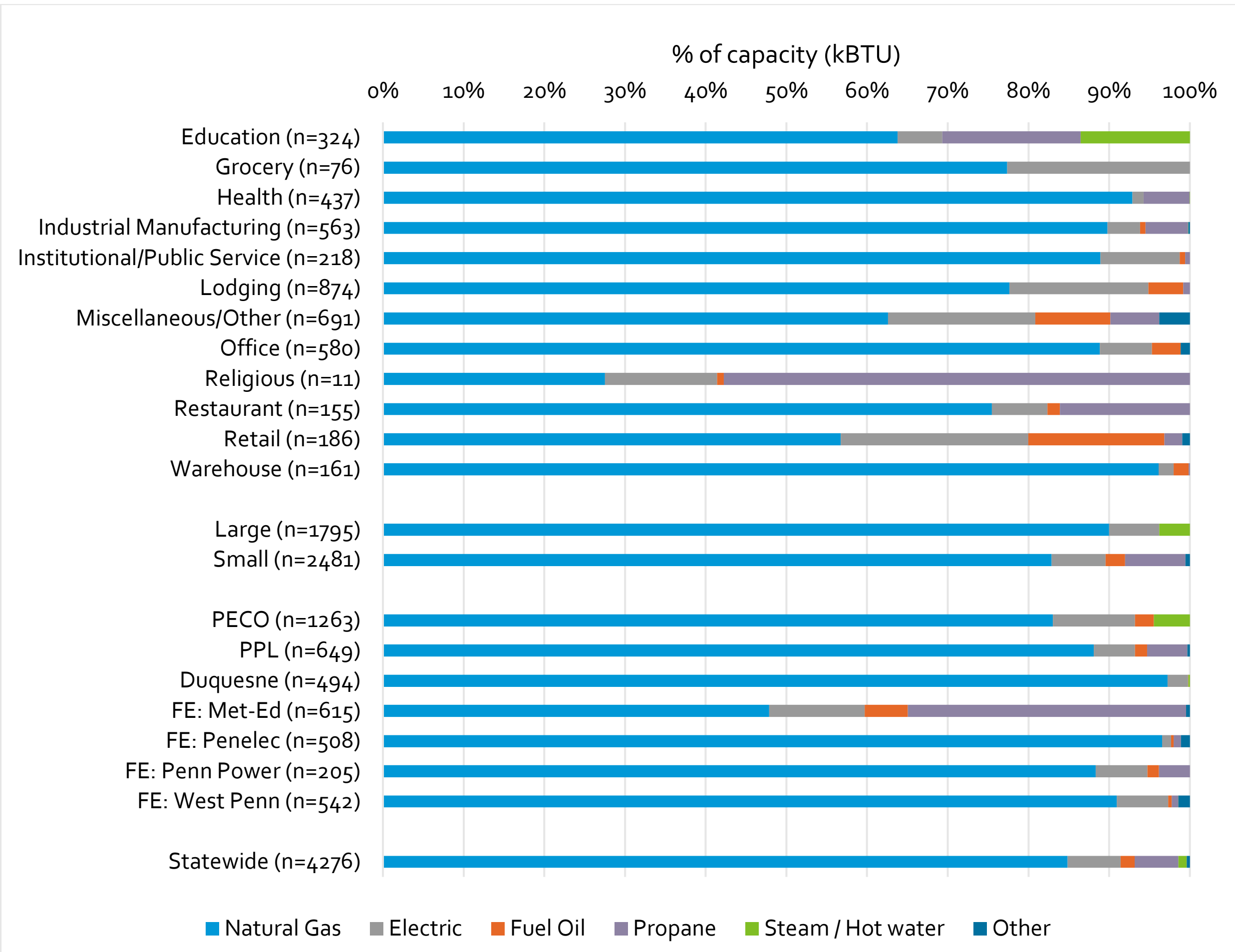
Table 24: Cooling Setpoints (by AC Control Type)

AC Control Type	Unoccupied	Occupied	Difference
Manual (n=199)	68.5	68.2	+0.3
Programmable (n=166)	74.9	72.5	+2.4
Smart (n=23)	77.6	70.9	+6.6
EMS (n=72)	75.7	70.8	+4.9

6.3 HEATING

Figure 33 shows the fuel share for heating systems by percent of heating capacity (kBTU heat output).[13] N-values indicate the number of heating systems surveyed. Statewide, electric systems provide about 7% of space heating capacity, with the remainder being supplied by various fossil fuel sources, primarily natural gas (85%). The electric to fossil fuel split is largely similar for large and small sectors, but they differ in their mix of fossil fuels. While both are primarily fueled by natural gas, large C&I customers had some municipal steam heat, while small customers have a small but notable amount of fuel oil (2.4%) and propane heat (7.5%). Shares are also broken down by segment and EDC and show some degree of variation. However, note that some of this variation reflects the sample that was surveyed.

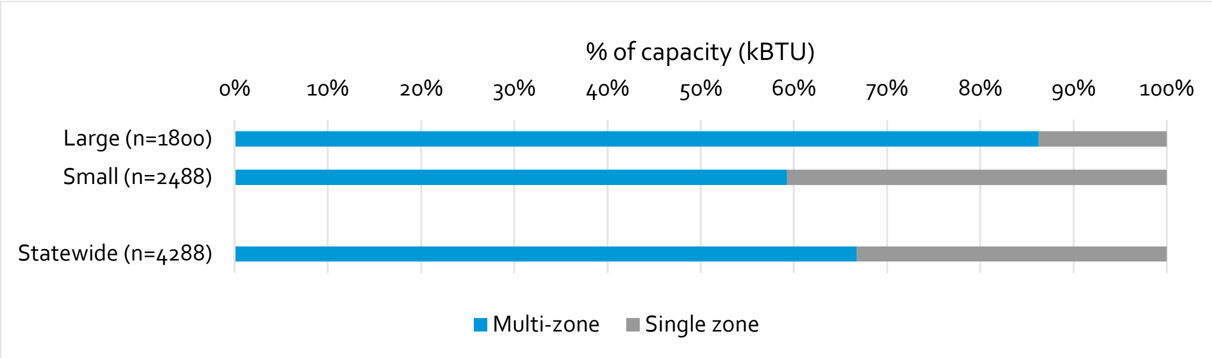
Figure 33: Heating Fuel Shares (Share of Heating Capacity)



Another characteristic of heating units is whether they heat a single zone or multiple zones. Figure 34 shows the share of capacity for multi-zoned versus single-zoned cooling systems. The majority (67%) of non-residential systems statewide supply heating to multiple zones, but the share of capacity supplied by multi-zoned systems is somewhat lower for Small C&I customers.

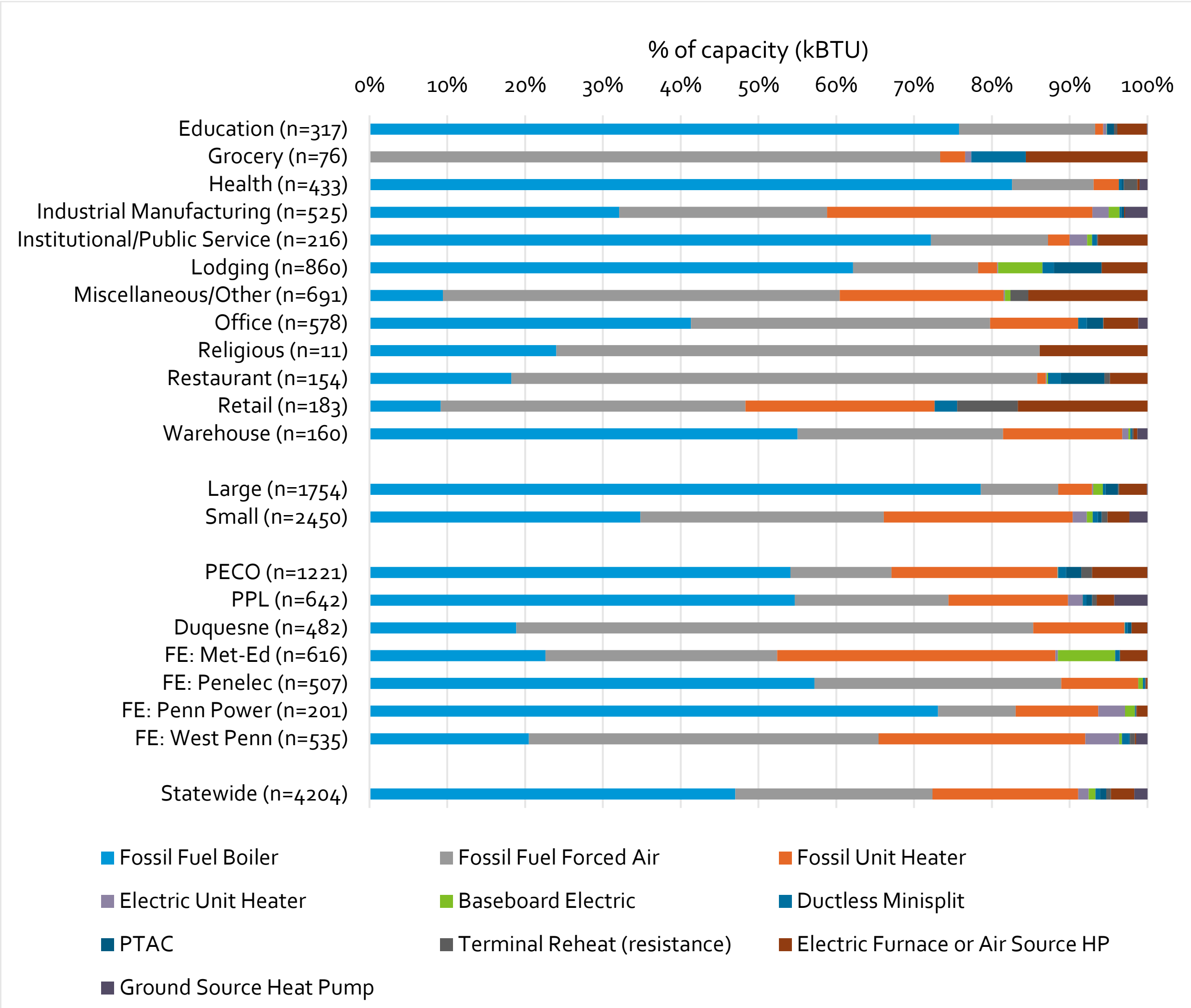
[13] To ensure equivalence between electric and fossil fuel heat sources, efficiency factors were applied to convert nameplate heat input ratings to heat output.

Figure 34: Heating Equipment Zoning (Share of Heating Capacity)



Heating systems include a variety of different equipment types, described in more depth in Section 6.1. Figure 35 shows the share of heating system capacity by equipment type. N-values represent heating systems surveyed. As implied by the fuel share analysis, over 90% of systems are fossil fuel (boilers, forced air, and unit heaters). Electric heating systems vary somewhat across segments and EDCs, but these systems are rare in general, so granular differences are likely also a reflection of the sample that was surveyed.

Figure 35: Detailed Heating Equipment Type (Share of Heating Capacity)



6.3.1 Fossil Fuel Boiler Parameters

Fossil fuel boilers provide the largest heating capacity share of any equipment type. Figure 36 shows the distribution of boiler units by size bin. N-values reflect the number of boiler systems surveyed. Note that few boiler systems were surveyed, indicative of the fact that boiler systems, which typically supply large central plant systems, tend to be very large in size and very small in number. For Large C&I customers, who have a large penetration of central plant systems, nearly half of boiler systems are over 2,500 kBTU. In contrast, boilers at small customer sites tend to be smaller: just 7% are above 2,500 kBTU.

Boiler unit size bins are also broken out by segment and EDC. There is also some degree of variation across segments. However, given the small number of units, it is likely that any variation is due in part to the population sampled. Note for example that the segments with the widest variation (Miscellaneous, Religious, Restaurant, and Retail) are also those with the smallest number of systems surveyed.

Figure 36: Boiler Unit Size Distribution (Share of Units)

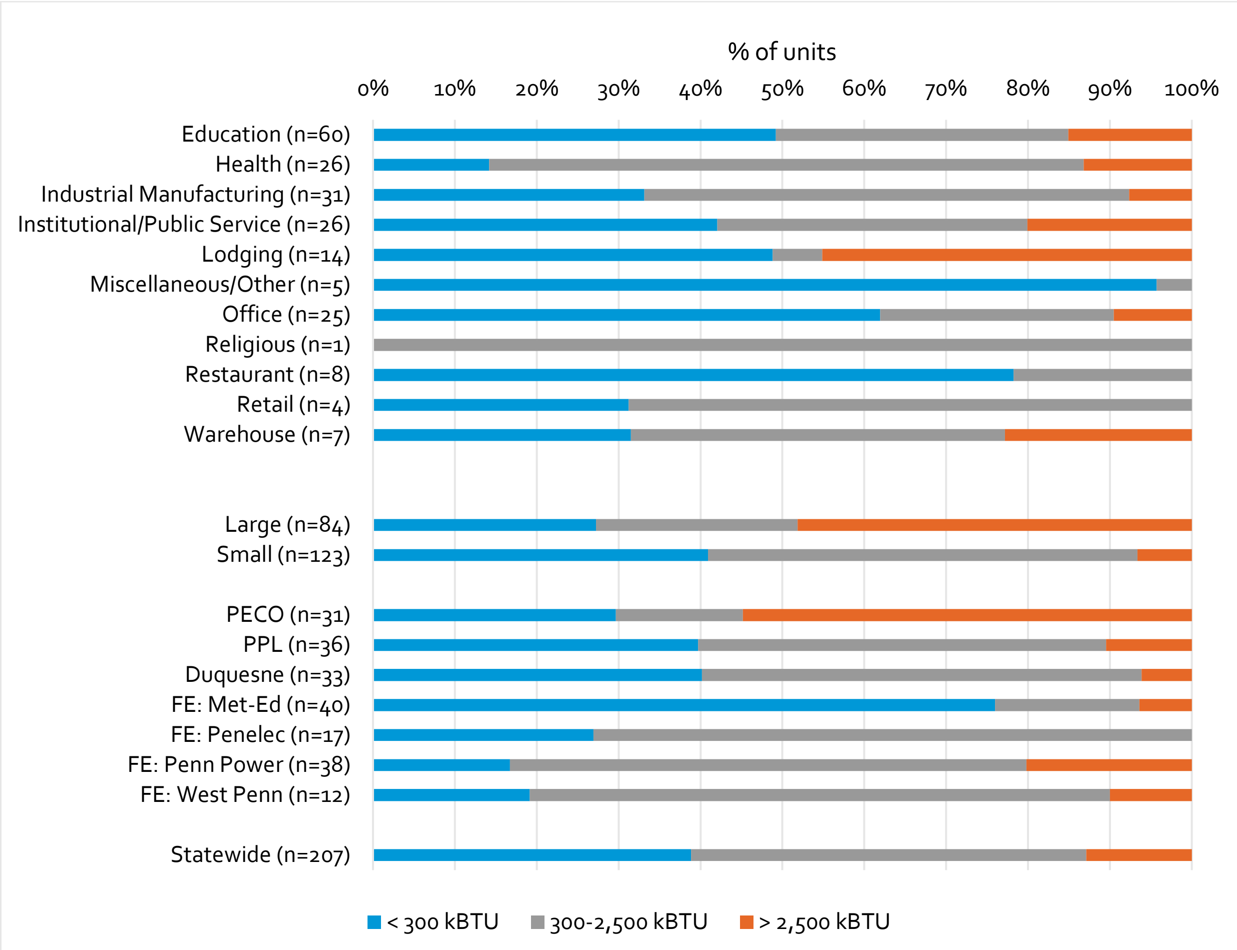


Figure 37 shows the average statewide boiler thermal efficiency for each size bin. N-values represent the number of boiler units surveyed for which thermal efficiency ratings were collected. Regardless of size range, thermal efficiency is about 80%, meaning that 80% of heat energy from fuel is converted to heat output.

Figure 37: Boiler Unit Efficiency (by Size Bin)

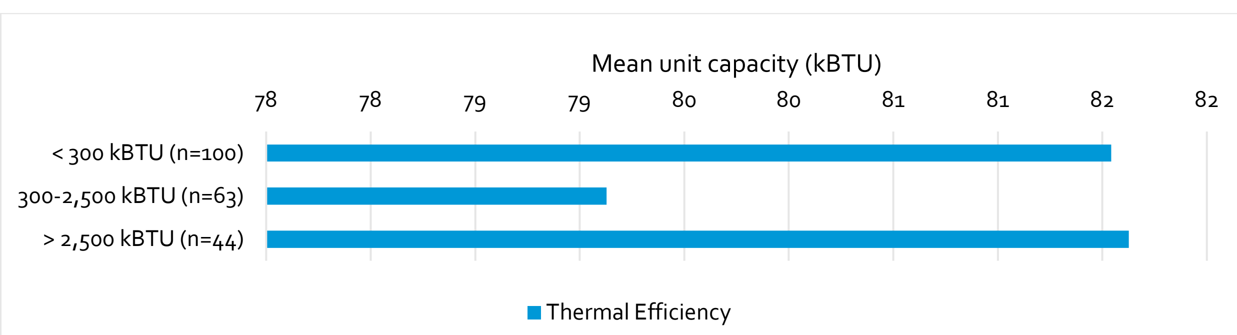
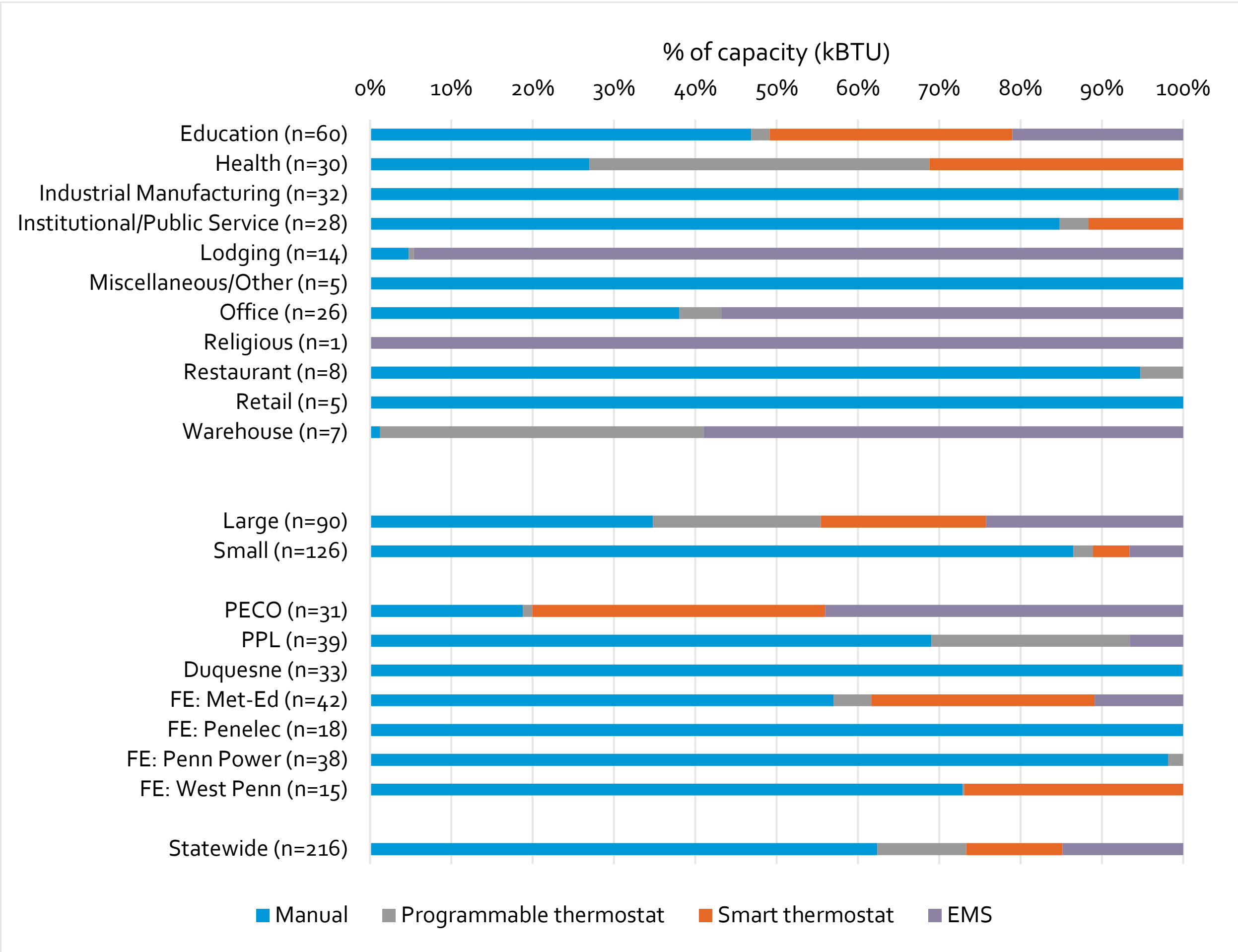


Figure 38 shows the share of boiler capacity controlled by different control types. N-values correspond to the number of boiler units surveyed. Notably, over 60% of boiler heating capacity is controlled manually, though this is not evenly split between sectors. Over 85% of small sector boiler capacity is controlled manually, while only about a third of large sector capacity is controlled manually. In contrast, a much larger share of large sector boiler capacity (24%) is controlled by EMS systems, compared with 7% of boiler capacity for Small C&I sector customers.

Figure 38: Boiler Temperature Controls (Share of Boiler Capacity)



6.3.2 Fossil Fuel Forced Air Parameters

Fossil fuel forced air units provide the second largest heating capacity share of any equipment type, after boilers. Figure 39 shows the distribution of forced air units by size bin. N-values reflect the number of forced air systems surveyed. The four size bins correspond to the four statewide size quartiles. As would be expected, forced air units tend to be larger for Large C&I customers than for Small C&I customers.

Fossil fuel forced air unit size bins are also broken out by segment and EDC. There is also some degree of variation across segments. However, given the small number of units, it is likely that any variation is due in part to the population sampled.

Figure 39: Fossil Fuel Forced Air Unit Size Distribution (by Size Bin)

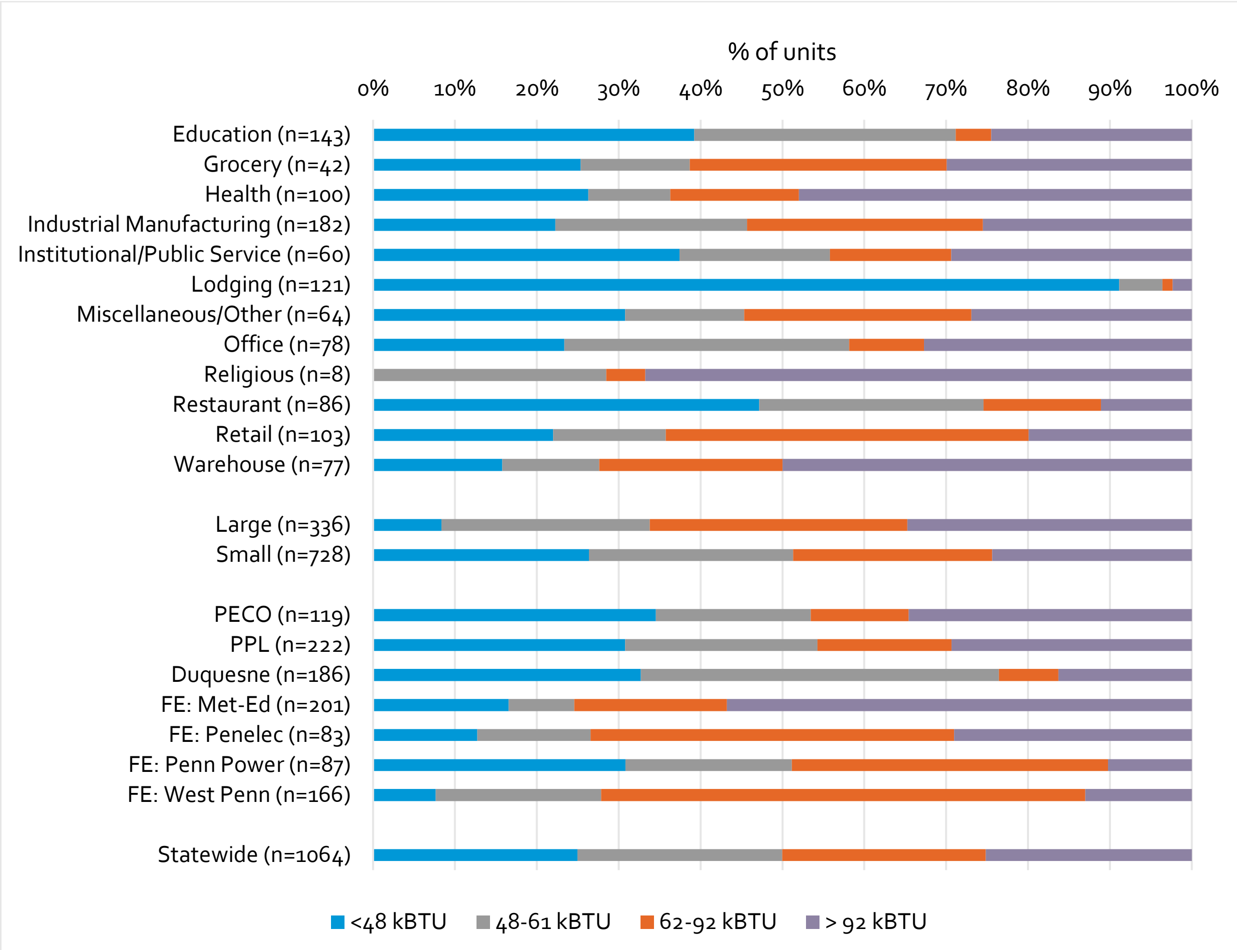


Figure 40 shows the average statewide fossil fuel forced air thermal efficiency for each size bin. N-values represent the number of fossil fuel forced air units surveyed for which thermal efficiency ratings were collected. Thermal efficiency tends to be slightly higher for larger units than for small units but, regardless of size range, thermal is between 81% and 83%, meaning that 81% to 83% of heat energy from fuel is converted to heat output.

Figure 40: Fossil Fuel Forced Air Unit Size Efficiency (by Size Bin)

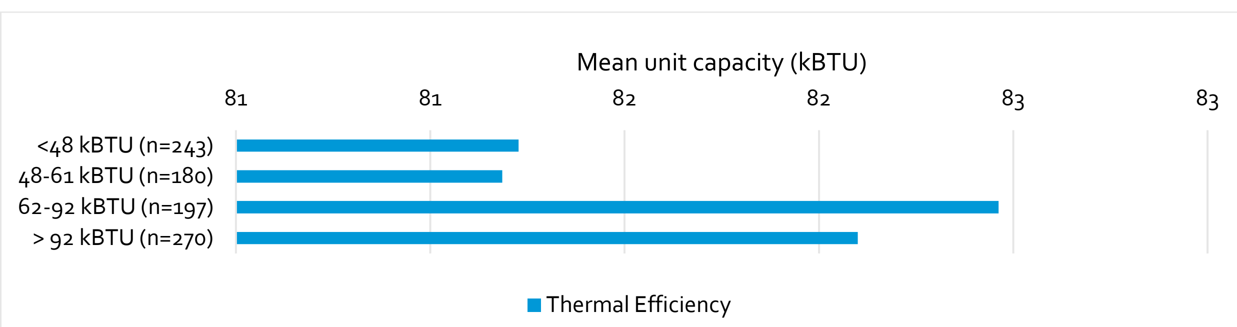
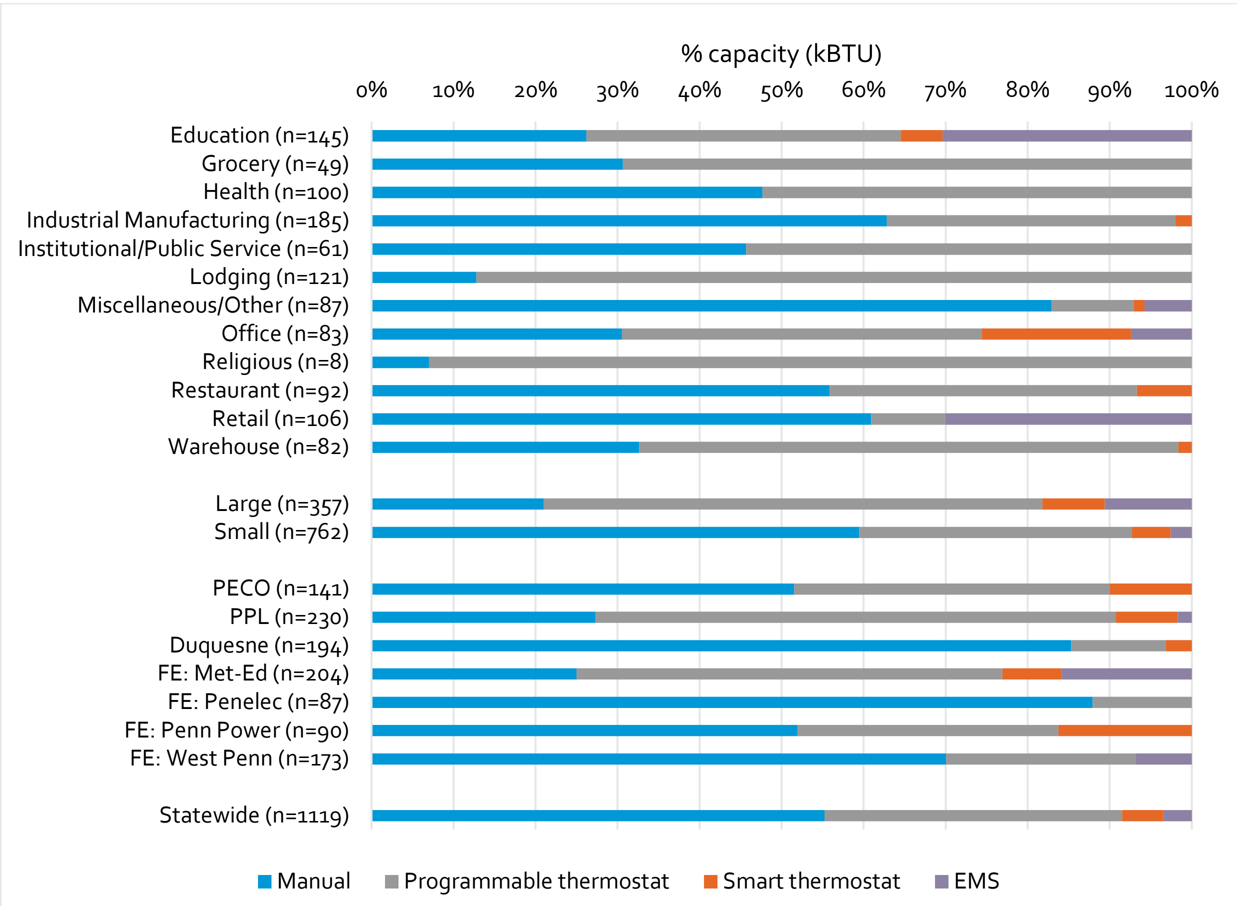


Figure 41 shows the share of forced air capacity controlled by different control types. N-values correspond to the number of forced air units surveyed. Notably, over 50% of forced air heating capacity is controlled manually, though this is not evenly split between sectors. Nearly 60% of small sector forced air capacity is controlled manually, while only about 20% of large sector capacity is controlled manually. In addition, a meaningful share of large sector forced air capacity (11%) is controlled by EMS systems, compared with 3% of forced air capacity for small sector customers.

A key difference between forced air and boiler units is that programmable thermostats are much more prevalent for forced air systems, controlling 36% of forced air capacity compared to 11% of boiler capacity.

Figure 41: Fossil Fuel Forced Air Temperature Controls (Share of Heating Capacity)



6.3.3 Electric Heat Parameters

Seven electric heat equipment types were identified at surveyed sites. These systems are defined in detail in section 6.1. Figure 42 shows the average size (kBTU) of electric heat systems. N-values indicate the number of systems surveyed. PTAC systems tend to be the smallest in size, while heat pumps and terminal reheat equipment units tend to have the highest capacity.

Figure 42: Electric Heating System Average Capacity (by Equipment Type)

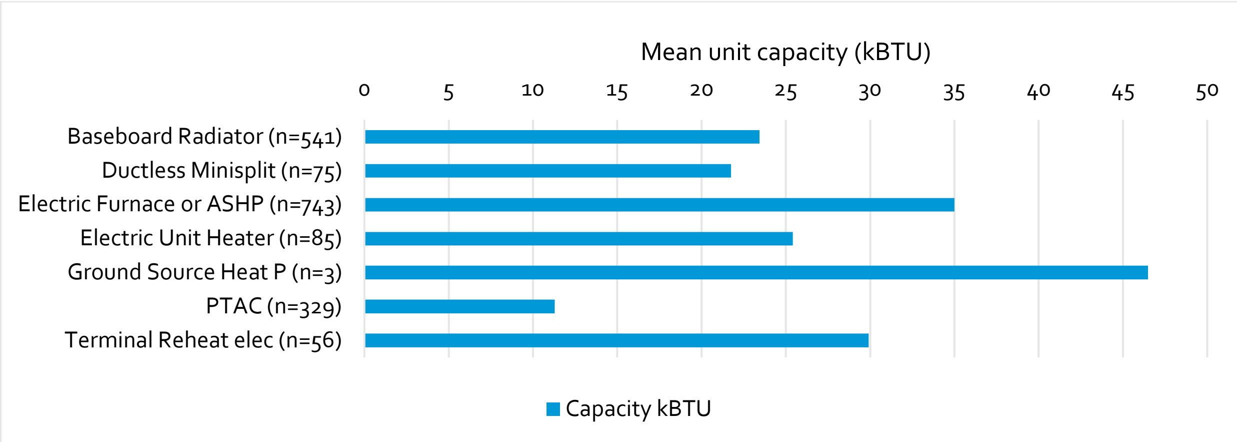
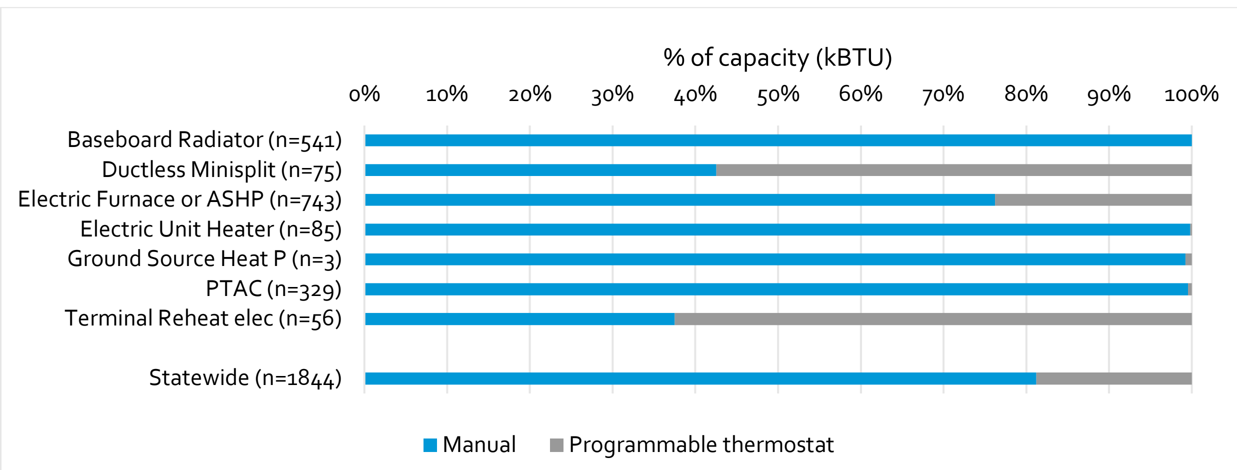


Figure 43 shows the share of electric heat capacity controlled by different control types. N-values correspond to the number of electric heat units surveyed. Notably, over 80% of electric heating capacity is controlled manually. The only surveyed systems with programmable controls were ductless mini-split heat pumps, air source heat pumps, and terminal reheat units.

Figure 43: Electric Heating System Temperature Controls (Share of Heating Capacity)



6.3.4 HEATING SYSTEM SETPOINTS

The primary function of heating controls is to regulate heating setpoints. Deploying a lower heating setpoint when buildings are not occupied can help conserve energy. Figure 44 shows average heating setpoints across all heating systems for when buildings are normally occupied versus when they are not occupied.[14] N-values represent the number of systems surveyed where setpoints were verified at the thermostat by the SWE engineer. As expected, heating setpoints are a few degrees lower (3.2 F) when heating systems are unoccupied. Note that the small amount of variation in setpoints by sector, segment, and EDC is likely a function of the sites surveyed. The result for the Institutional/Public

[14] About one third of set point levels were verified by assessing thermostat settings.

Service segment is influenced heavily by several water treatment/pumping facilities (Large C&I sector), which maintained setpoints necessary to prevent freezing, not for human comfort.

Figure 44: Mean Heating Setpoints (by Occupancy)

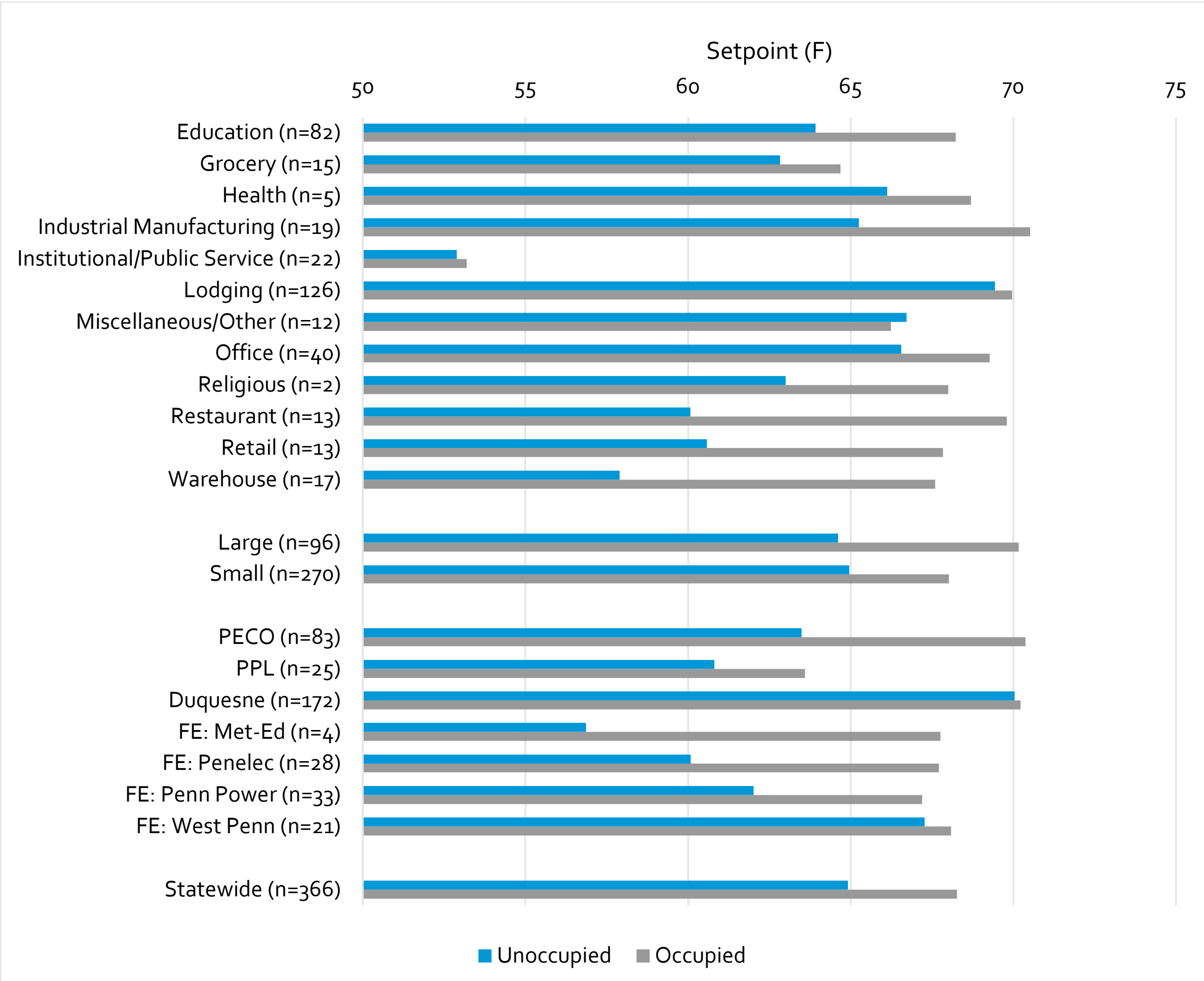


Table 25 shows how heating setpoints vary by control type, along with the difference between occupied and unoccupied setpoints. N-values represent the number of systems surveyed for which control and set point data was collected and could be verified at the thermostat. Notably, unoccupied setbacks are larger for programmable thermostats (-6.0 F) than for manual (-1.1 F). Setbacks are even higher for smart thermostats, but there are too few thermostats with verified setpoints (n=5) to make inferences. Heating setbacks for EMS systems (-1.0 F) are small relative to cooling setbacks for these same systems (+4.9 F).

Table 25: Heating Setpoints (by Heating Control Type)

Heating Control Type	Unoccupied	Occupied	Difference
Manual (n=224)	65.8	66.9	-1.1
Programmable (n=137)	63.9	69.9	-6.0
Smart (n=5)	61.8	69.8	-8.0
EMS (n=64)	72.7	73.7	-1.0

6.4 HVAC SYSTEM AGE

A variety of efficiency characteristics are correlated with HVAC system age. For example, newer systems may be more efficient and more likely to include programmable controls. Table 26 summarizes mean and median system ages for the high-level equipment types described above. The mean age for most systems is 11 to 13 years, implying a useful life of about 20 to 25 years.[15] Fossil fuel boilers are notably older, with a mean age of 19 years, implying a useful life of about 40 years.

Table 26: HVAC System Age (by Equipment Type)

Equipment Type	n	Mean Age	Median Age
Heating			
HVAC Fossil Fuel Boiler	177	19	19
HVAC Fossil Fuel Furnace	704	13	10
HVAC Miscellaneous Electric Heating	2,288	13	11
Cooling			
HVAC Central Plant Cooling	58	11	8
HVAC DX Cooling	925	12	11
HVAC Miscellaneous Electric Cooling	2,137	13	13

6.4.1 Cooling System Age

Table 27 shows mean and median cooling system age by sector. Figure 45 shows the cumulative distribution of cooling system ages by sector. N-values reflect the number of systems surveyed, and ages are weighted by the number of systems surveyed. The mean cooling system for Small C&I customers is about 13 years old, about four years older than for Large C&I customers.

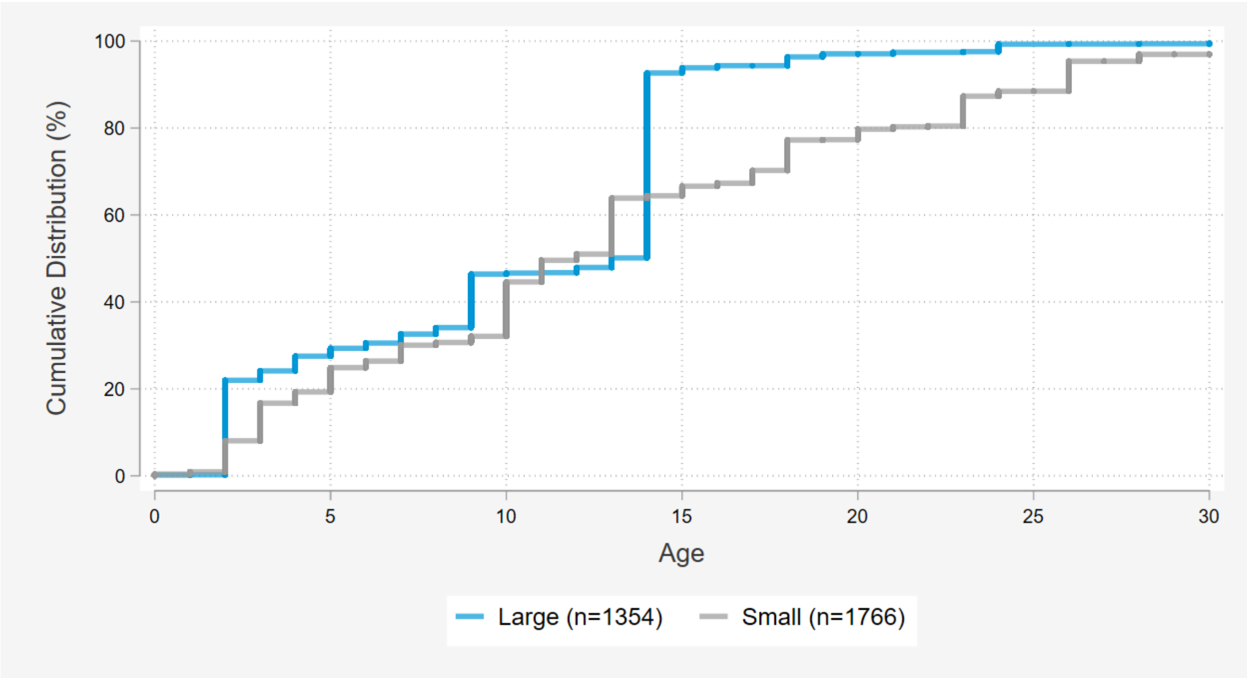
As shown in Figure 45, over 30% of cooling systems for the Small C&I sector are more than 25 years old. It is important to keep in mind that the age during the survey is just a snapshot and includes a mix of units at all points in their lifecycles (e.g., a unit that was two years old during the survey may stay in-service for another 10 or 20 years). In contrast, about 90% of cooling systems for Large C&I customers are less than 15 years old. The Large C&I sample happened to include several large sites with numerous cooling systems installed in 2004. This creates the large step in the Large C&I distribution at age = 14 years.

Table 27: Cooling Unit Age (by Sector)

	Mean Age	Median Age
Large (n=1354)	9.3	9.0
Small (n=1766)	13.7	13.0
Statewide (n=3120)	12.7	12.0

[15] Useful life is typically about twice the median age of equipment stock, assuming a relatively linear age curve (e.g., half of units are older than the median).

Figure 45: Cooling Unit Age (by Sector)



6.4.2 HEATING SYSTEM AGE

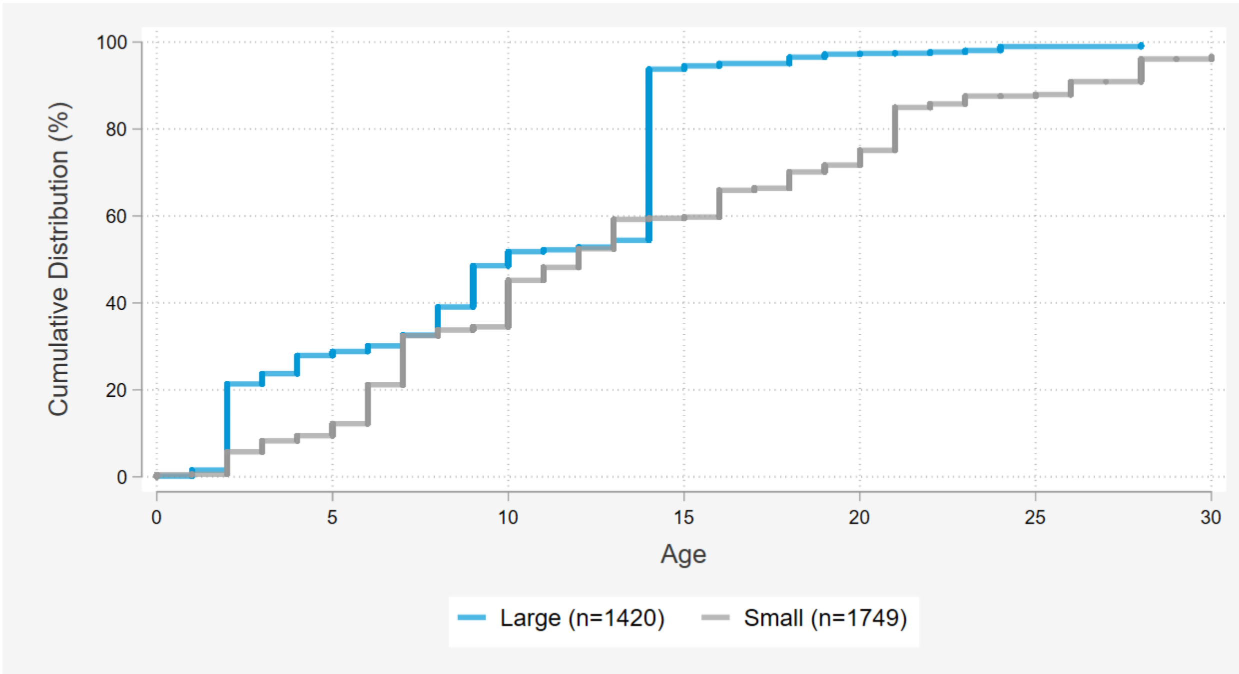
Table 28 shows mean and median heating system age by sector. Figure 46 shows the cumulative distribution of heating system ages by sector. N-values reflect the number of systems surveyed, and ages are weighted by the number of systems surveyed. The mean heating system for Small C&I customers is about 14 years old, about five years older than for Large C&I customers. Heating system ages closely mirror cooling system ages.

As shown in Figure 46, about 90% of heating systems for the Small C&I sector are less than 25 years old, substantially higher than the 15-year measure useful life for heating efficiency measures. In contrast, about 90% of heating systems for Large C&I customers are less than 15 years old. The Large C&I sample happened to include several large sites with numerous heating systems installed in 2004. This creates the large step in the Large C&I distribution at age = 14 years.

Table 28: Heating Unit Age (by Sector)

Sector	Mean Age	Median Age
Large (n=1,420)	9.3	9.0
Small (n=1,749)	14.3	11.0
Statewide (n=3,169)	13.2	11.0

Figure 46: Heating Unit Age (by Sector)



7 DOMESTIC HOT WATER

7.1 DOMESTIC HOT WATER EQUIPMENT OVERVIEW

Domestic Hot Water survey questions focus on water heater type, tank capacity, quantity, fuel type, age, location, percent of building serviced, make and model, input capacity, efficiency, and other unit-specific characteristics. Water heater types included in the analysis are as follows:

- Heat Recovery
- Instantaneous (Tankless)
- Self-Contained (Tank)
- Solar
- Storage Tank (Central Boiler)
- Other

Much of the analysis in this section uses tank capacity for weighting. In the case of tankless water heaters, we impose a capacity of 40 gallons because this is the most commonly observed tank capacity. Some figures are reported both with and without tank capacity weighting to provide a clear understanding of the impact of tank size. This section also includes analysis for recreational water features, such as pools and hot tubs. Information collected includes heating fuel type, age, pump horsepower, RPM, and efficiency. A third component captured in this section is the number of faucets and showers in each building surveyed. Bath, kitchen, and showerheads are counted and reported separately.

7.2 DOMESTIC HOT WATER FINDINGS

Figure 47 shows the site-level penetration of water heaters by segment, sector, EDC, and at the statewide level. Most sites have water heating.

Figure 47: Penetration of Water Heating Devices

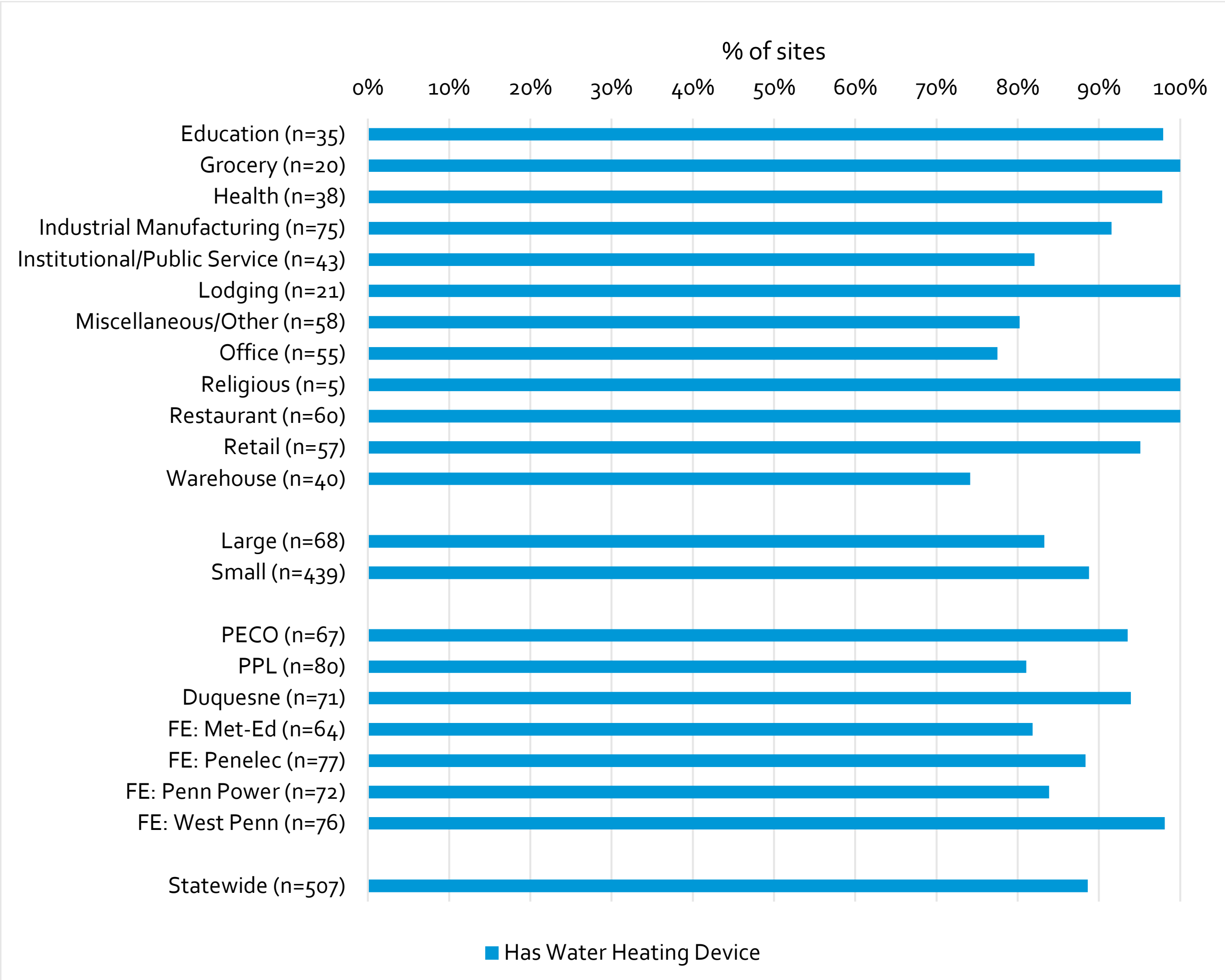


Figure 48 and Figure 49 show the fuel share distribution based on unit count and capacity, respectively. Capacity is measured in gallons. For tankless water heaters, 40 gallons is applied for weighting purposes. The n-values presented are units. Natural gas and electric represent the overwhelming majority of the fuel shares.

Figure 48: Distribution of Fuel Share (by Device Count)

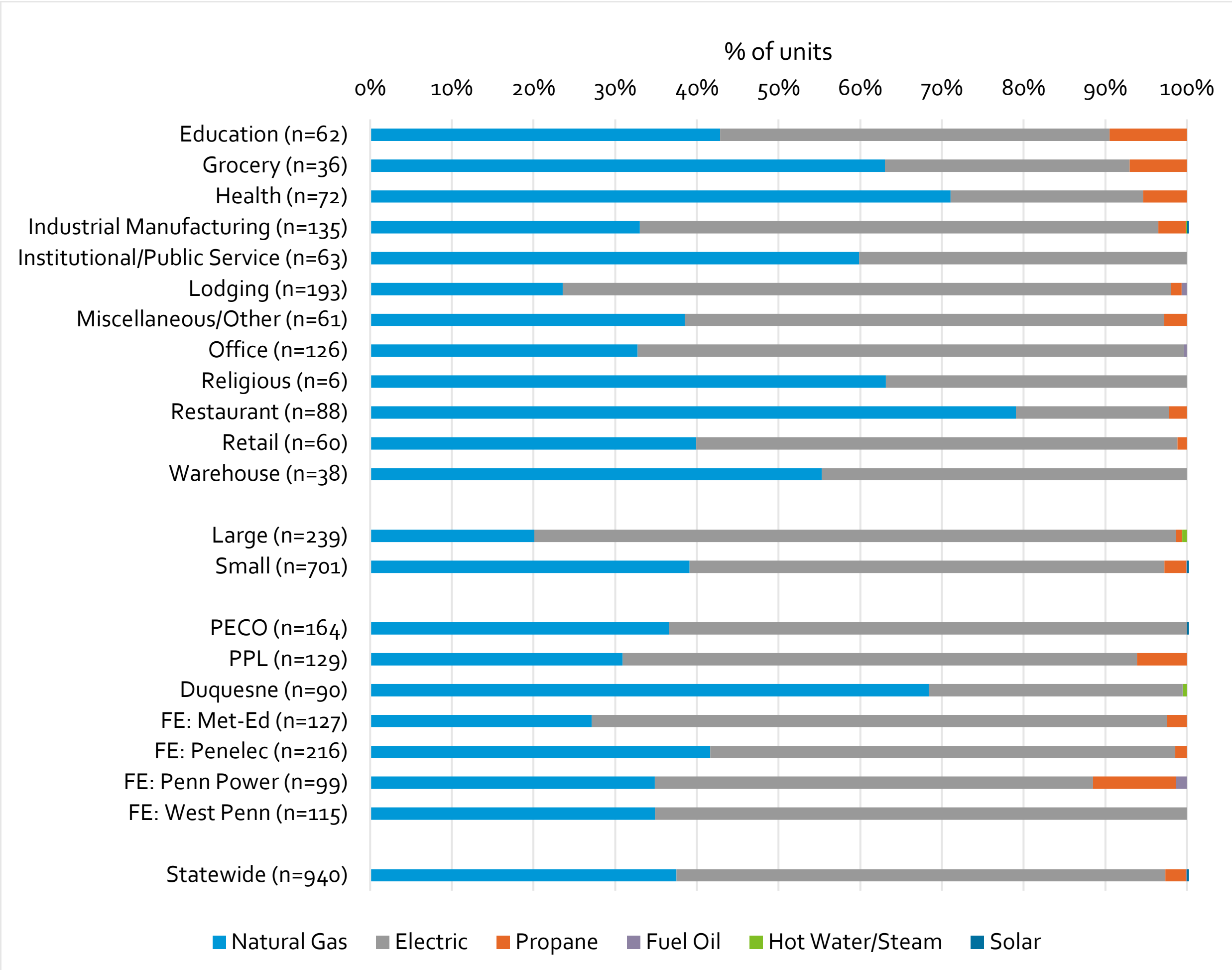


Figure 49: Distribution of Fuel Share (by Capacity Share)

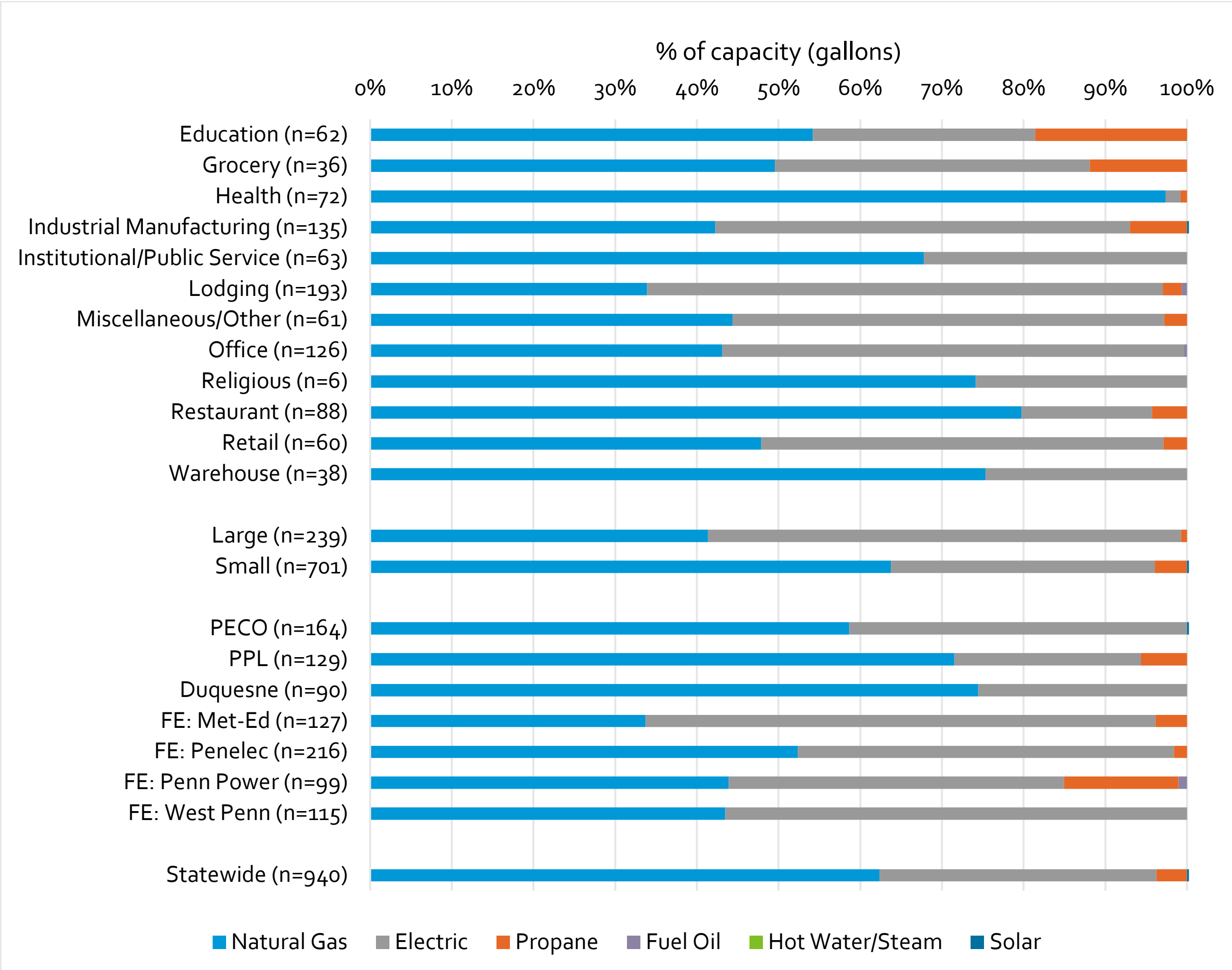


Figure 50 shows the distribution of tank types by the number of units. Ninety-four percent of the heaters are standard self-contained tank water heaters. The n-values provided are at the unit level.

Figure 50: Distribution of Tank Type (by Device Count)

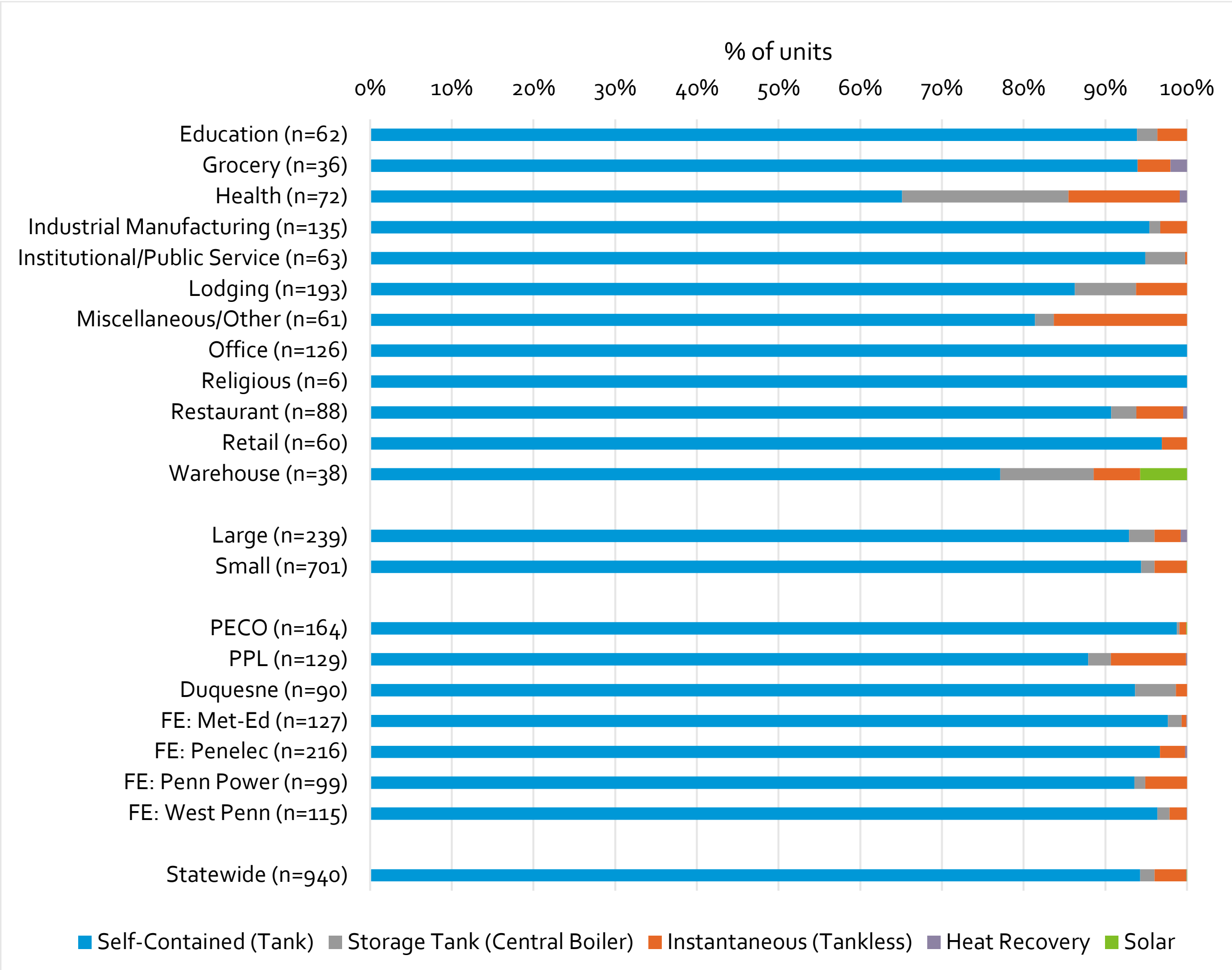


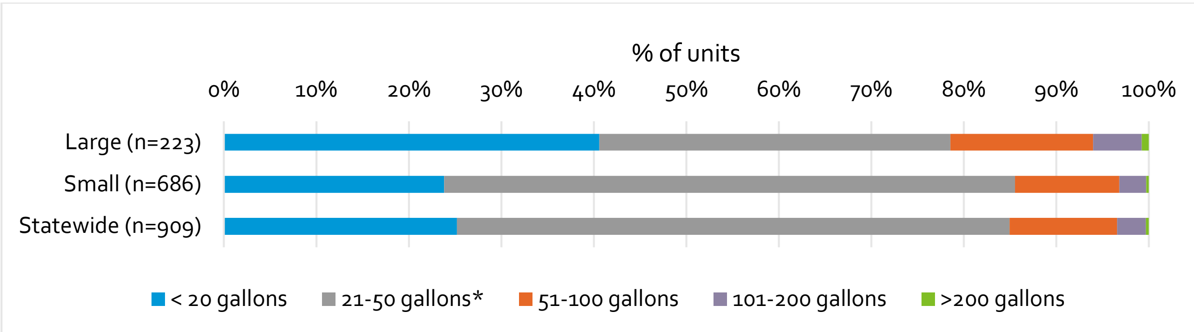
Table 29 provides average values for the surveyed water heating units. Average age, percent with tank wrap, percent with pipe wrap, tank capacity, efficiency, and input capacity are provided. The n-values are at the unit level. The statewide n-value reported in this table is slightly higher than the previous figures. The three units included here are missing information on tank capacity. These tanks are included because they do provide some relevant information for this table.

Table 29: Domestic Hot Water Unit Characteristics

Segment	Avg. Age	% w/ Tank Wrap	% w/ Pipe Wrap	Avg. Tank Capacity	Avg. Input Capacity (BTU/h)	Avg. Efficiency of Electric Units	Avg. Efficiency of Fossil Fuel Units
Education (n=62)	7.8	1%	31%	61.8	148,658	94	86
Grocery (n=34)	5.6	0%	5%	46.7	61,448	90	82
Health (n=72)	11.4	17%	47%	618.6	209,870	77	84
Industrial Manufacturing (n=135)	10.5	1%	11%	44.7	58,202	92	81
Institutional/Public Service (n=64)	9.7	6%	19%	54.9	48,057	97	80
Lodging (n=192)	18.9	15%	12%	51.1	157,080	88	87
Miscellaneous/Other (n=61)	8.8	4%	1%	42.3	59,015	95	80
Office (n=126)	8.6	3%	17%	34.7	27,752	92	82
Religious (n=6)	11.0	0%	0%	42.8	33,100	92	80
Restaurant (n=89)	7.7	4%	4%	53.3	71,302	90	78
Retail (n=61)	9.2	0%	3%	42.7	60,211	97	79
Warehouse (n=38)	5.2	4%	28%	45.1	30,410	98	78
Sector							
Large (n=239)	5.8	0%	9%	45.7	52,150	85	81
Small (n=701)	9.9	3%	10%	62.8	58,600	92	81
EDC							
PECO (n=162)	7.6	6%	14%	38.3	42,637	94	82
PPL (n=129)	10.3	2%	14%	109.2	75,456	91	84
Duquesne (n=91)	10.3	5%	9%	54.6	113,844	94	78
FE: Met-Ed (n=127)	9.1	2%	5%	48.9	35,030	95	81
FE: Penelec (n=217)	10.1	2%	6%	35.5	47,943	92	80
FE: Penn Power (n=99)	10.6	1%	1%	42.4	36,564	91	79
FE: West Penn (n=115)	10.0	0%	4%	42.0	40,384	83	78
Statewide (n=940)	**9.5**	**3%**	**10%**	**61.4**	**58,014**	**92**	**81**

Figure 51 shows the distribution of water heater tank size. Keep in mind that tankless water heaters use a 40-gallon assumption for reporting. Figure 50 shows that tankless heaters do not make up a large proportion of the heaters, so the 21-50 gallon category is only slightly inflated by this assumption.

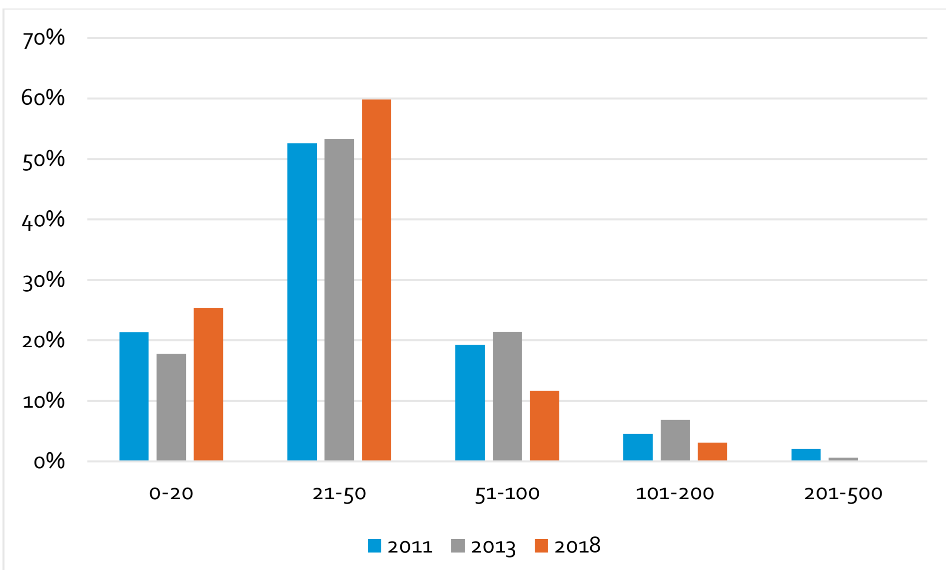
Figure 51: Distribution of Tank Capacity (by Device Count)



7.3 COMPARISON WITH PRIOR STUDY FINDINGS

Distribution of water heater tank size remains fairly consistent across the three studies, as seen in Figure 52. Some of the differences in the 21- to 50-gallon category is due to the increased prevalence of tankless water heaters.

Figure 52: Comparison of Water Heating Tank Capacity Distribution



7.4 RECREATIONAL WATER

Of the 507 completed site surveys, ten sites had information for a total of 19 recreational water features. With the appropriate weighting applied, 88% of those water features were pools and the remaining 12% were hot tubs. Ninety-four percent of the heating for these facilities was from natural gas, 3% had electric heating, and the remaining 3% were not heated. The heating controls were 77% timer, 12% always on, and 11% listed as other or not heated.

7.5 FAUCETS AND SHOWERHEADS

Table 30 provides details on the average number of showerheads and bathroom and kitchen faucets across the relevant sites. The n-value is the site count. Motion sensors were only present in the bathroom faucets. Large facilities had a much larger share of motion sensors than the small sector sites. Overall, non-residential sites have many more bathroom faucets than kitchen faucets or showerheads, and a low number of motion sensor bathroom sinks.

Table 30: Faucet and Motion Sensor Saturation (by Sector)

Sector	n	Bath Faucets	% Motion Sensor	Kitchen Faucets	Showerheads
Large	68	32.2	7.1%	8.4	11.1
Small	439	4.5	0.3%	2.0	1.2
Statewide	**507**	**5.2**	**0.5%**	**2.1**	**1.5**

8 REFRIGERATION

8.1 REFRIGERATION EQUIPMENT OVERVIEW

Refrigeration includes both walk-in and reach-in refrigeration equipment. While the survey questions vary slightly between these two categories, general questions include quantity, device type, fan type, size, age, and ENERGY STAR certification. Site surveys also recorded the following characteristics: compressor type; compressor horsepower; and whether the compressor or condenser was equipped with VFD, LED lighting, motion sensors, no sweat/anti-sweat/special doors, demand defrost, and floating head pressure controls.

Walk-in Refrigeration includes the following types:

- Freezer Warehouse
- Walk-In Freezer
- Walk-In Refrigerator

Reach-in Refrigeration includes the following types:

- Freezer Glass Door
- Freezer Solid Door
- Refrigerator Glass Door
- Refrigerator Solid Door
- Open Case, Low Temperature
- Open Case, Medium Temperature

Walk-in systems are closed door units that you can physically walk into and allow for storage of larger items or larger quantities of food products. Reach-in systems can either have a door or no door, such as the open case device types. Open case refrigerators are the units that often store items such as cheese or beer at grocery stores.

8.2 REFRIGERATION EQUIPMENT FINDINGS

Table 31 provides penetration rates for all refrigeration, walk-in, and reach-in devices. Note that refrigeration here is the commercial style refrigeration, not residential-style. Restaurant and Grocery segments have the highest penetration of refrigeration equipment. N-values are presented at the site level.

Table 31: Refrigeration Penetration

Segment	n	Any Refrigeration	Walk-In Refrigeration	Reach-In Refrigeration
Education	35	39%	17%	39%
Grocery	20	100%	59%	96%
Health	38	50%	20%	44%
Industrial Manufacturing	75	11%	6%	9%
Institutional/Public Service	43	15%	3%	15%
Lodging	21	48%	30%	48%
Miscellaneous/Other	58	16%	10%	15%
Office	55	5%	4%	1%
Religious	5	69%	0%	69%
Restaurant	60	100%	69%	93%
Retail	57	38%	12%	38%
Warehouse	40	30%	19%	26%
Sector				
Large	68	28%	19%	23%
Small	439	16%	7%	14%
EDC				
PECO	67	19%	9%	18%
PPL	80	17%	4%	15%
Duquesne	71	19%	16%	14%
FE: Met-Ed	64	12%	5%	12%
FE: Penelec	77	14%	3%	14%
FE: Penn Power	72	18%	13%	6%
FE: West Penn	76	12%	6%	12%
Statewide	**507**	**16%**	**7%**	**14%**

Figure 53 presents the distribution of electric commutated, permanent split capacitor, and shaded pole motor types. Shaded pole is the least efficient, but most commonly used, with 62% of the surveyed market. Provided n-values are at the unit level. The detail by segment type is limited to those where refrigeration is prevalent, with at least 100 units represented. Despite this visual simplification, the Large C&I, Small C&I, and Statewide shares still include all data from the full range of segments.

Figure 53: Refrigeration Motor Type

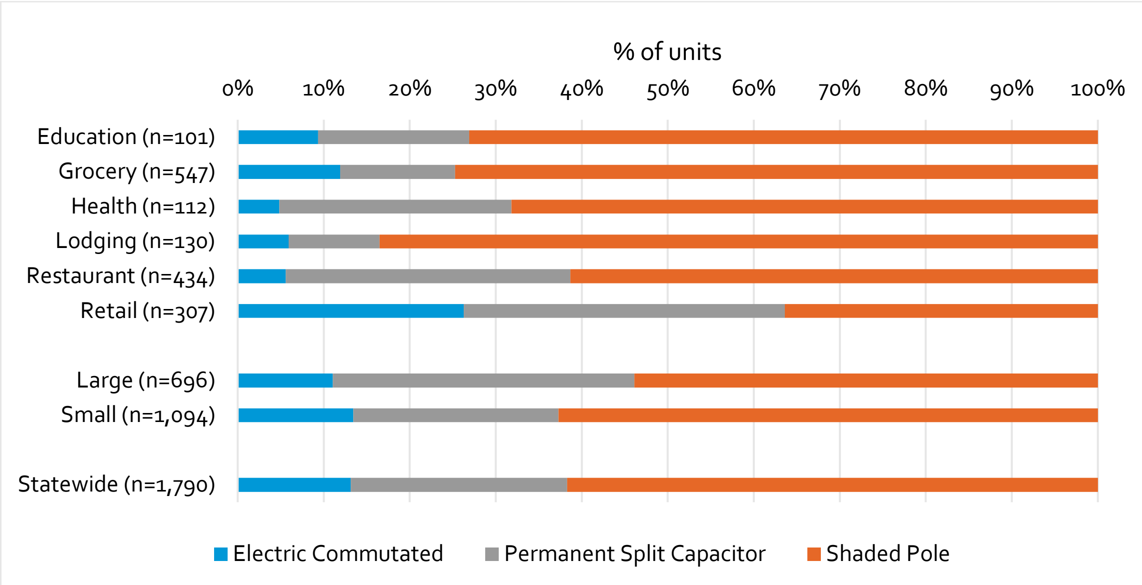


Table 32 shows various characteristics of refrigeration. Some of these characteristics are unique to one type of refrigeration – walk-in or reach-in units. Presented n-values are at the site level.

Table 32: Unit Characteristics of Walk-In and Reach-In Refrigeration

	Walk-In		Reach-In	
	Large C&I	Small C&I	Large C&I	Small C&I
n (sites)	21	88	22	147
Anti-Sweat Heating Control	N/A	N/A	14%	5%
Special Doors	N/A	N/A	42%	15%
LED Lights	66%	18%	39%	45%
Motion Sensors	13%	0%	11%	1%
VFDs on Compressors	30%	11%	N/A	N/A
VFDs on Condensers	30%	10%	N/A	N/A
Demand Defrost Controls	35%	19%	22%	9%
Floating Head Pressure	32%	8%	N/A	N/A
System Commissioned	44%	12%	N/A	N/A
Heat Recovery	7%	0%	N/A	N/A

Figure 54 and Figure 55 show the distribution of equipment type among those sites that have equipment that falls within the relevant category. Provided n-values are at the unit level. Figure 54 shows walk-in equipment, of which there are only two options – freezers and refrigerators. Figure 55 shows reach-in equipment, which has freezers with glass or solid doors, refrigerators with glass or solid doors, and open-case units at low or medium temperature.

Figure 54: Walk-In Refrigeration Equipment Type

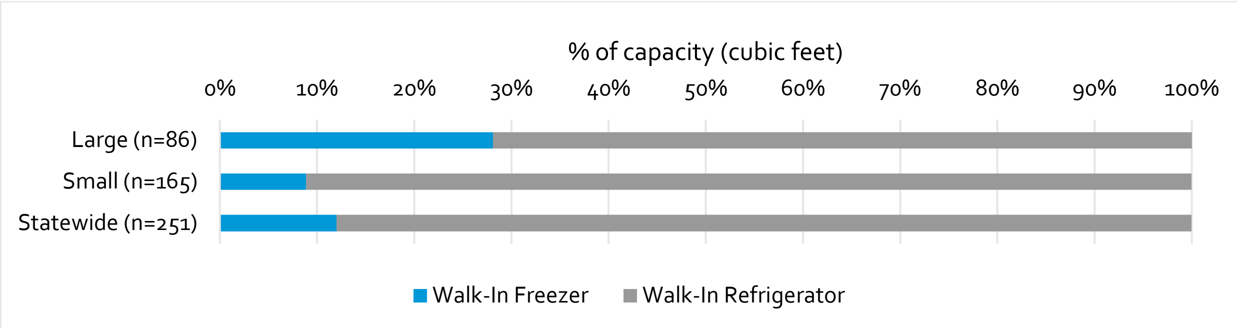


Figure 55: Reach-In Refrigeration Equipment Type

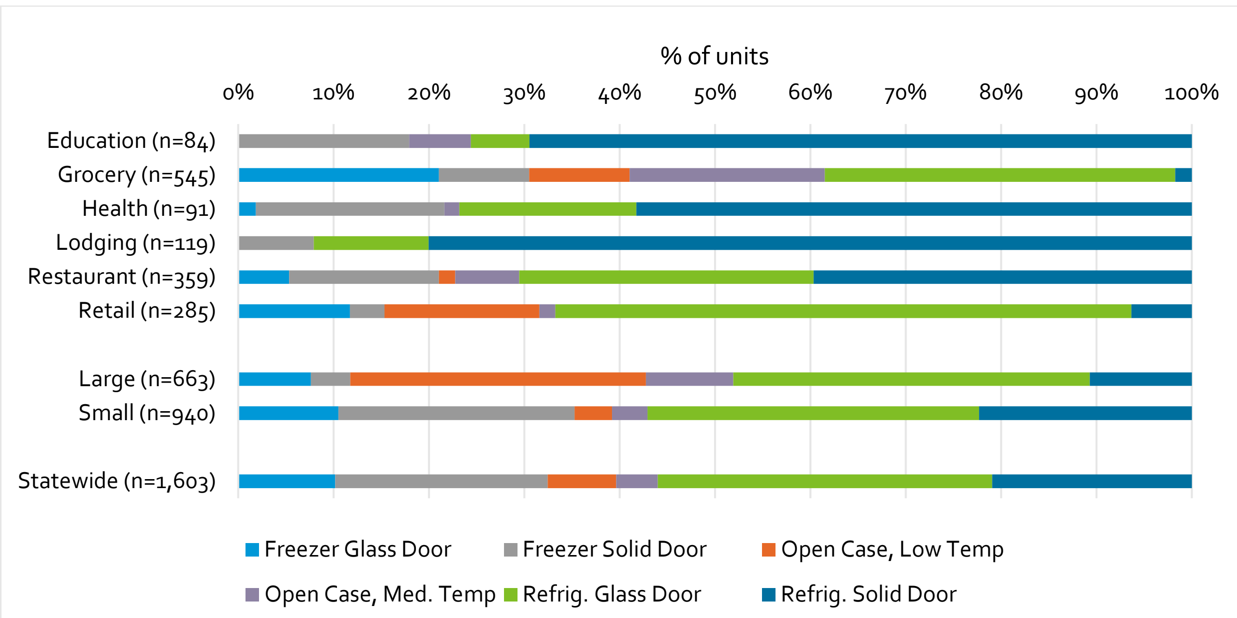


Table 33 shows the percent of devices that are ENERGY STAR rated, by equipment type. N-values are listed at the unit level.

Table 33: Percent of Reach-In Equipment with Energy Star Rating

Kitchen Equipment Type	% ENERGY STAR
Freezer Glass Door (n=152)	4.6
Freezer Solid Door (n=164)	13.4
Open Case Low Temp (n=174)	1.1
Open Case Med Temp (n=185)	0.5
Refrigerator Glass Door (n=508)	17.9
Refrigerator Solid Door (n=420)	22.4

9 PROCESS

9.1 PROCESS EQUIPMENT OVERVIEW

This section examines survey data on processes and corresponding motors. For processes, information collected includes type and quantity, manufacturer, model number, fuel type, capacity, and age. A process can have multiple motors associated with it. Each motor type has details regarding quantity, service type, control type, horsepower, and North American Manufacturers Association (NEMA) type.

Most of the processes fall into the following categories:

- Chemical Treatment
- Distillation/Refining
- Grinding/Milling/Extraction
- Metal Formation
- Molding
- Process Cooling
- Process Heating/Cooking
- Product Assembly
- Pumping
- Sanding and Painting

Motor service type categories include the following:

- Compressor
- Fan/Blower
- Machine Tools
- Material Separation
- Material Transport (Belts)
- Pump

Because of the two-part taxonomy, quantity for this section requires some additional attention. For each unique process motor, quantity is calculated by multiplying process quantity by motor quantity. This is the n-value reported for charts representing unit values. A representative example is a printing process that requires two distinct types of motors. This process requires one air handler motor and five press motors. This process will result in six units for representation in the analysis. If a site has two identical instances of this processes, it will have 12 units of representation, as shown in the formula below.

$$\#\ Units = \#\ Identical\ Processes * \#\ Motors\ per\ Process$$

Shares analyzed in this section can be weighted by process capacity, motor horsepower, or unweighted. Figure descriptions include information on weighting strategy when relevant.

9.2 PROCESS EQUIPMENT FINDINGS

Figure 56 and Figure 57 show the distribution of various types of processes, by the capacity of those processes. A few selected segments are shown in which processes are most crucial to operations. Provided n-values are at the unit level. Figure 56 includes processes that are powered by all forms of fuel, and Figure 57 restricts the data to only those processes that are electrically powered. Note the small difference in n-values showing how many processes are not powered by electricity. The figure is weighted by capacity of the process.

Figure 56: Distribution of Process Type (by Capacity)

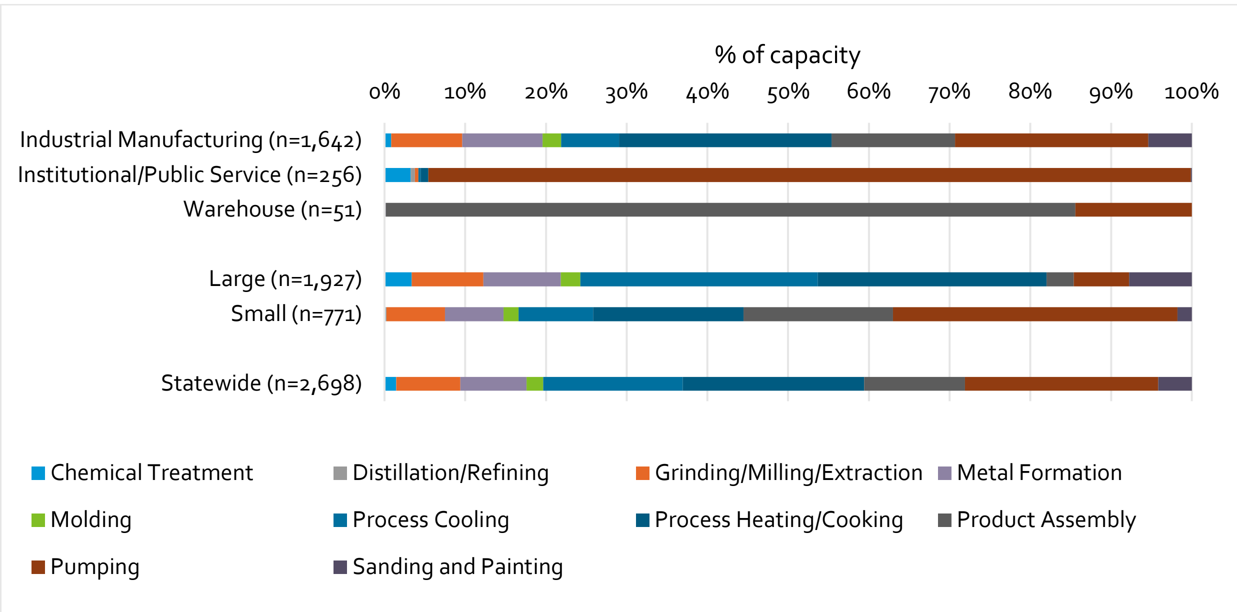


Figure 57: Distribution of Process Type for Electric Processes (by Capacity)

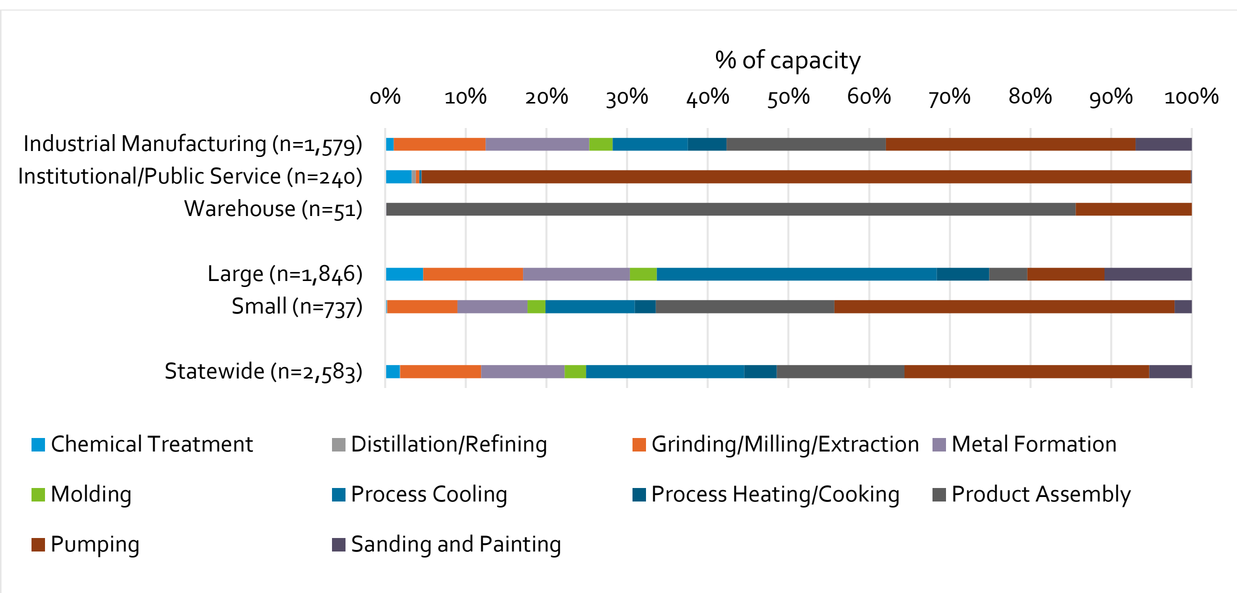


Figure 58 provides detailed analysis of the various control types available for the motors of these processes. The majority of motors utilize constant speed controls. N-values are provided at the motor level. The figure is weighted by capacity of the process.

Figure 58: Distribution of Motor Control Type (by Capacity)

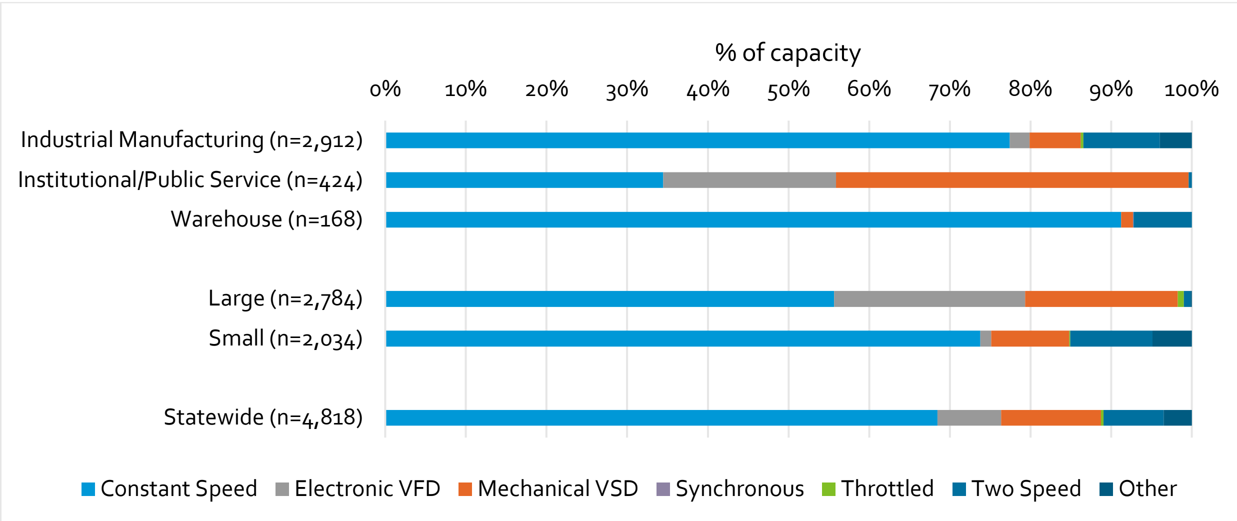
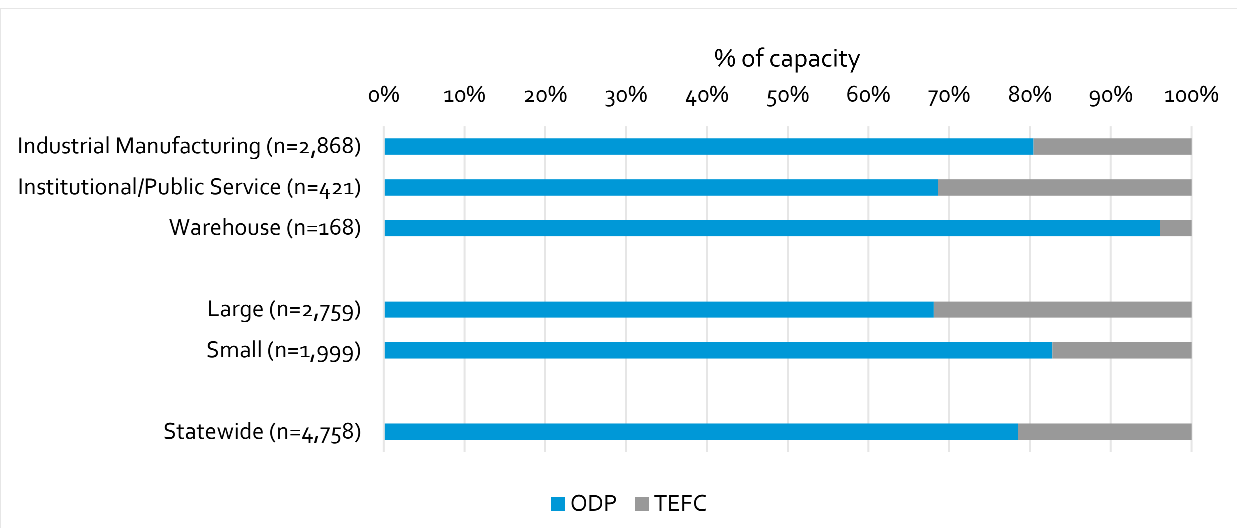


Figure 59 shows the distribution between open drip proof (ODP) and totally enclosed fan cooled (TEFC) casings for NEMA motors. The selected segments shown are the most representative of process-dependent industries and had the most inventoried motors. Provided n-values are at the motor level. Shares are capacity weighted.

Figure 59: Distribution of NEMA Casing Type (by Capacity)



Motor service type is shown in Figure 60. The selected segments shown are the most representative of process-dependent industries. Provided n-values are at the motor level. Shares are capacity weighted.

Figure 60: Distribution of Service Type (by Capacity)

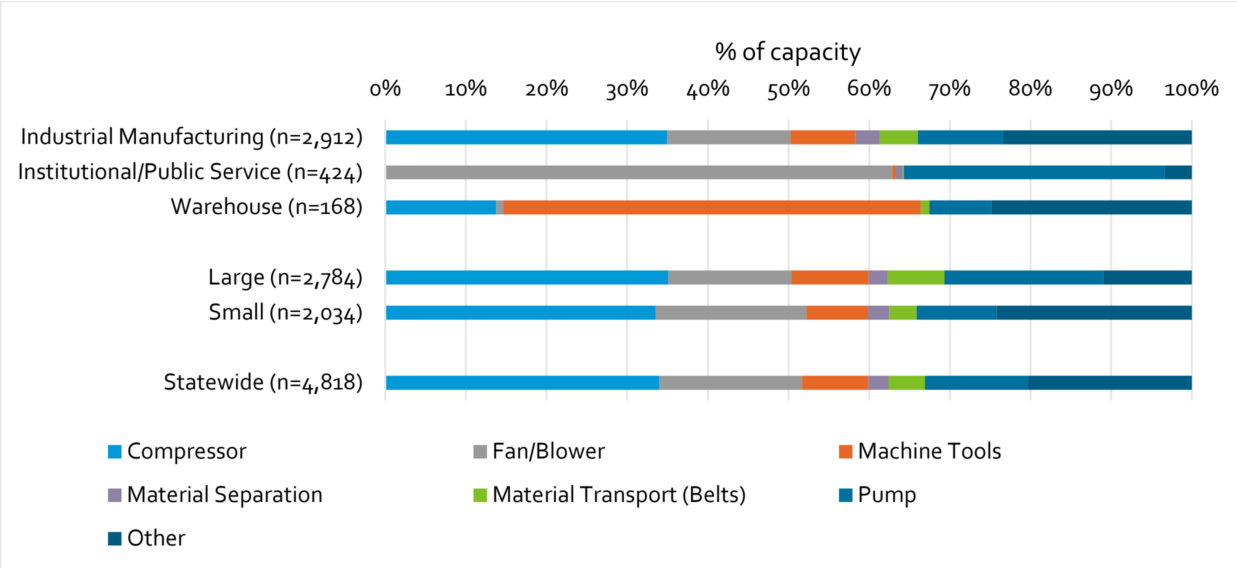


Table 34 shows average surveyed motor horsepower based on the categories provided in Figure 58, Figure 59, and Figure 60.

Table 34: Average Motor Horsepower (by Control Type, Motor Type, and Service Type)

Control Type	n	Avg. Motor HP
Constant Speed	3,284	29.0
Electronic VSF	475	61.7
Mechanical VFD	605	171.2
Synchronous	3	0.6
Throttled	95	9.6
Two Speed	246	16.4
Other	110	15.6
Motor Type	**n**	**Avg. Motor HP**
ODP	2,742	31.1
TEFC	2,016	31.8
Service Type	**n**	**Avg. Motor HP**
Compressor	827	123.6
Fan Blower	796	21.2
Machine Tools	624	24.2
Material Separation	187	19.0
Material Transport Belts	561	15.0
Pump	847	28.9
Other	976	21.3

10 COOKING

10.1 COOKING EQUIPMENT OVERVIEW

The commercial cooking end-use focuses on equipment used for high-volume preparation. These devices are typically found in restaurants or cafeterias. It does not include smaller equipment like microwaves and toaster ovens, which are typically found in offices and break rooms across most commercial businesses. The devices included in the survey were as follows:

- Commercial Dishwasher
- Convection Oven
- Electric Steam Cooker
- Fryer
- Griddle
- Hot Food Holding Cabinet
- Range
- Standard Oven

Due to the type of devices analyzed in this section, not all surveyed sites will include each of these devices. This is evident in the lower penetration and n-values exhibited in these tables. In the case that zero surveyed sites within a segment have a device of interest, this segment will not be represented in the figure. In this section, the SWE team examines the saturation of each equipment type among sites with any cooking equipment, fuel share of all devices together, and fuel share for each individual device type. Fuel types of interest for commercial cooking are limited to three categories:

1. Natural Gas
2. Electric
3. Propane

10.2 COOKING EQUIPMENT FINDINGS

Table 35 shows the proportion of sites that have various types of cooking equipment. Presented n-values denote the number of surveyed sites. Commercial kitchens are common in Restaurants; somewhat common in Education, Grocery, and Health; and not very common in the remaining segments. Due to the nature of segmenting commercial buildings into one of the 12 categories, there can be a diverse array of companies within each segment. For instance, coffee shops and ice cream parlors are included in the Restaurant segment, but they are not likely to have ovens or fryers.

Table 35: Commercial Cooking Equipment Penetration

Category	n	Commercial Dishwasher	Convection Oven	Steam Cooker	Fryer	Griddle	Hot Food Holding Cabinet	Range	Standard Oven
Education	35	23%	20%	15%	4%	6%	24%	20%	23%
Grocery	20	21%	18%	0%	32%	10%	11%	40%	33%
Health	38	31%	31%	8%	21%	11%	31%	31%	22%
Industrial Manufacturing	75	5%	3%	0%	4%	4%	4%	4%	4%
Institutional/Public Service	43	0%	0%	0%	0%	0%	0%	2%	10%
Lodging	21	29%	27%	1%	18%	11%	15%	35%	32%
Miscellaneous/Other	58	2%	7%	1%	11%	6%	6%	14%	13%
Office	55	1%	0%	0%	0%	1%	0%	1%	1%
Religious	5	23%	23%	0%	23%	23%	0%	47%	23%
Restaurant	60	56%	49%	27%	75%	44%	37%	72%	53%
Retail	57	0%	2%	1%	2%	1%	3%	1%	3%
Warehouse	40	0%	0%	0%	0%	0%	0%	0%	0%
Sector									
Large	68	10%	9%	5%	10%	9%	7%	7%	11%
Small	439	5%	4%	1%	5%	3%	4%	6%	6%
EDC									
PECO	67	2%	1%	0%	4%	1%	3%	6%	6%
PPL	80	11%	4%	1%	9%	8%	9%	11%	10%
Duquesne	71	6%	11%	0%	0%	0%	0%	1%	2%
FE: Met-Ed	64	3%	5%	1%	5%	4%	5%	6%	5%
FE: Penelec	77	1%	2%	1%	2%	1%	0%	4%	4%
FE: Penn Power	72	2%	1%	0%	0%	2%	1%	2%	7%
FE: West Penn	76	3%	4%	2%	4%	3%	4%	3%	4%
Statewide	**507**	**5%**	**4%**	**1%**	**5%**	**4%**	**4%**	**6%**	**6%**

Figure 61 shows how the devices are distributed between natural gas, electric, and propane fuel sources. Provided n-values are at the device, or unit, level. Segments selected for this figure are those that are more likely to have commercial cooking equipment.

Figure 61: Distribution of Fuel Share (by Equipment Count)

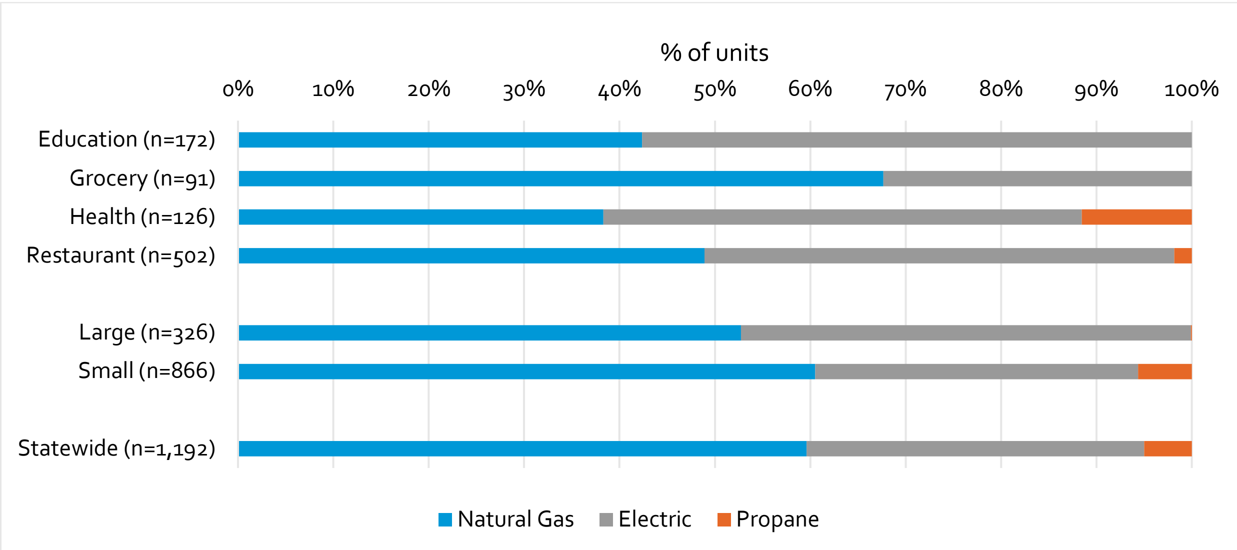


Figure 62 takes a closer look at each of the equipment types included in the commercial cooking survey. The fuel share distribution is provided at the statewide level, where n-values represent the number of units of equipment. Fuel share for commercial dishwashers indicates the type of fuel used for the water heating component of the dishwasher.

Figure 62: Distribution of Fuel Share (by Equipment Type)

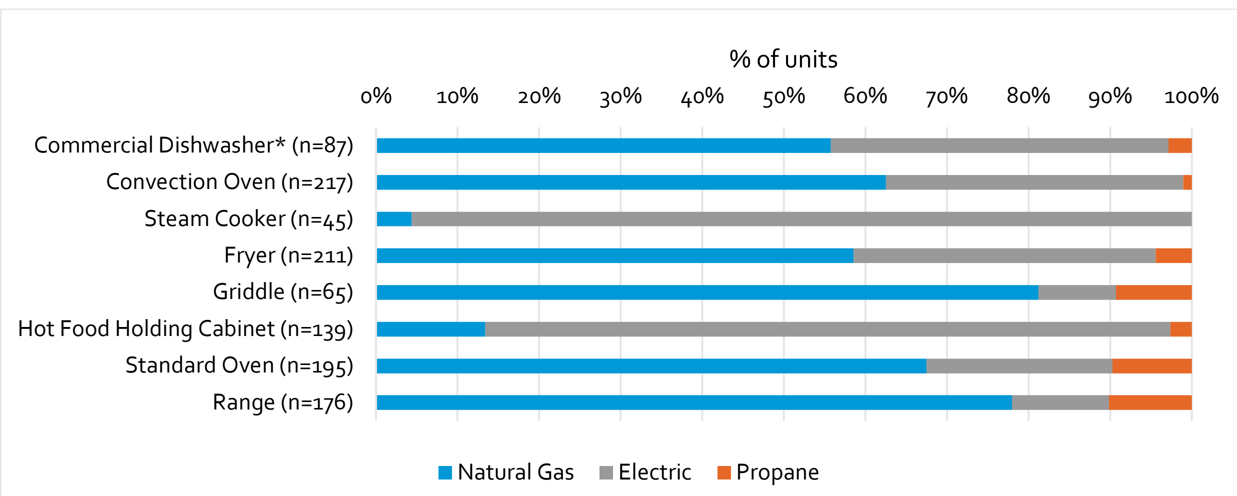


Table 36 shows the percent of devices that are ENERGY STAR rated, by equipment type. N-values are listed at the unit level. In the case that the field technician was unclear of the ENERGY STAR status, the unit is omitted from the following table.

Table 36: Percent of Equipment with Energy Star Rating

Kitchen Equipment Type (n=unit)	% ENERGY STAR
Commercial Dishwasher (n=59)	6.8
Convection Oven (n=142)	9.3
Fryer (n=89)	8.2
Griddle (n=44)	16.5
Hot Food Holding Cabinet (n=70)	4.3
Range (n=130)	4.3
Standard Oven (n=139)	7.1
Steam Cooker (n=28)	10.7

11 PLUG LOAD

11.1 PLUG LOAD EQUIPMENT OVERVIEW

This section analyzes the remaining devices that use standard 120V electrical plugs. Survey questions for this include age, quantity, and energy star rating. The equipment in this section includes the following:

- Office Imaging Units
- Ice Makers
- Laptops
- Monitors
- Vending Machines
- Shredders
- Computers
- Residential Style Refrigerators
- Servers
- Fax Machines
- Photocopiers
- Printers
- Scanners
- Televisions
- Uninterruptable Power Supply
- Water Coolers

11.2 PLUG LOAD EQUIPMENT FINDINGS

Of the locations that have plug loads recorded (94%), Table 37 shows the percentage of sites that have each type of device and the percent of the recorded devices that were ENERGY STAR certified. Provided n-values are the sites that have plug loads recorded.

Table 37: Plug Load Equipment Penetration (by Type and Percent ENERGY STAR)

Equipment Type	Large	Small	Statewide	% ENERGY STAR
n-value	64	413	477	-
All-in-One Imaging	85%	55%	56%	44.5
Servers	58%	34%	35%	19.4
Laptops	47%	31%	32%	44.8
Personal Computers	90%	89%	89%	25.3
Monitors	94%	83%	84%	38.9
Paper Shredders	42%	27%	27%	14.3
Standalone Fax Machine	15%	8%	8%	21.5
Standalone Photocopiers	8%	7%	7%	36.1
Standalone Printers	70%	62%	62%	28.8
Standalone Scanners	0%	3%	3%	39.4
Televisions	53%	38%	38%	29.6
Uninterruptable Power Supply	2%	1%	1%	2.8
Water Coolers	51%	36%	36%	15.2
Refrigerated Vending Machines	50%	18%	19%	12.2
Non-Refrigerated Vending Machines	35%	17%	17%	7.7
Residential Style Refrigerators	68%	81%	81%	25.4
Ice Makers	8%	3%	3%	11.5

Table 38 and Table 39 show the average number of devices per site. For these two tables, sites without any plug load are included in the calculations. Table 38 includes the device types that are related to office work or computing, such as computers. Table 39 shows the remaining devices that relate more closely to consumption, such as refrigeration

Table 38: Computing-Related Average Counts of Equipment

Category	n	All-in-one Imaging	Servers	Laptops	Personal Computers	Monitors	Paper Shredders	Fax Machine	Photocopiers	Printers	Scanners	Televisions	Uninterruptable Power Supply
Education	35	4.3	2.3	28.1	38.6	23.7	0.7	0.3	0.4	4.5	0.1	6.9	0.1
Grocery	20	0.3	0.1	0.4	1.6	2.0	0.1	0.0	0.0	0.5	0.0	0.7	0.0
Health	38	5.1	1.2	19.1	67.2	132.0	1.4	0.2	0.0	5.9	0.0	51.0	0.0
Industrial Manufacturing	75	1.2	0.6	0.5	11.2	7.4	0.3	0.0	0.0	2.0	0.0	0.6	0.1
Institutional/ Public Service	43	2.6	0.4	4.2	14.8	12.8	0.6	0.1	0.0	1.8	0.0	8.2	0.0
Lodging	21	1.4	1.7	1.1	5.6	5.7	0.4	0.2	0.0	1.2	0.0	51.0	0.0
Miscellaneous/ Other	58	0.6	0.3	0.4	3.9	4.1	0.0	0.0	0.0	1.2	0.0	2.8	0.0
Office	55	1.9	0.9	7.3	17.0	34.4	0.8	0.2	0.6	4.5	0.1	0.9	0.0
Religious	5	2.1	0.5	3.9	4.8	1.8	0.9	0.0	0.2	2.0	0.2	3.0	0.0
Restaurant	60	0.4	0.1	0.7	2.1	2.7	0.1	0.1	0.0	0.8	0.0	2.9	0.0
Retail	57	0.5	0.2	0.6	3.8	4.1	0.1	0.0	0.1	1.2	0.1	1.2	0.0
Warehouse	40	1.2	0.5	1.9	15.3	16.4	0.3	0.1	0.2	1.8	0.1	0.6	0.3
Sector													
Large	68	5.7	3.2	65.7	55.3	162.0	0.8	0.4	0.1	7.0	0.0	12.0	0.0
Small	439	1.4	0.5	2.0	11.7	12.9	0.4	0.1	0.2	2.2	0.0	2.2	0.1
EDC													
PECO	67	1.5	0.9	9.4	9.4	25.5	0.4	0.1	0.7	2.3	0.0	1.3	0.0
PPL	80	2.0	0.6	3.1	23.3	24.0	0.4	0.1	0.0	3.0	0.0	3.9	0.0
Duquesne	71	1.8	0.6	3.8	11.2	13.8	0.8	0.2	0.3	1.7	0.2	0.7	0.0
FE: Met-Ed	64	0.8	0.4	1.2	8.1	9.0	0.3	0.0	0.0	2.6	0.0	2.3	0.0
FE: Penelec	77	1.0	0.6	0.4	8.7	8.7	0.3	0.2	0.1	2.2	0.1	0.7	0.0
FE: Penn Power	72	1.3	0.4	2.5	4.8	5.4	0.5	0.1	0.1	0.8	0.0	0.8	1.1
FE: West Penn	76	0.9	0.4	2.2	8.1	9.5	0.2	0.1	0.0	2.0	0.0	4.8	0.0
Statewide	507	1.5	0.6	3.7	12.9	16.9	0.4	0.1	0.2	2.3	0.0	2.4	0.1

Table 39: Non-Computing Average Count of Equipment (by Device Type)

Category	n	Water Coolers	Refrigerated Vending Machines	Non-Refrigerated Vending Machines	Residential Style Refrigerators	Ice Makers
Education	35	1.4	0.4	0.4	4.2	0.1
Grocery	20	0.0	0.0	0.0	0.3	0.0
Health	38	1.6	0.7	0.6	5.1	0.6
Industrial Manufacturing	75	0.5	0.3	0.4	1.2	0.0
Institutional/Public Service	43	0.4	0.2	0.2	9.2	0.1
Lodging	21	0.3	0.6	0.5	34.0	1.3
Miscellaneous/Other	58	0.2	0.2	0.1	2.5	0.1
Office	55	0.6	0.2	0.1	1.7	0.0
Religious	5	0.5	0.0	0.0	3.0	0.0
Restaurant	60	0.0	0.1	0.2	0.3	0.5
Retail	57	0.1	0.1	0.1	1.1	0.1
Warehouse	40	0.9	0.3	0.3	1.2	0.0
Sector						
Large	68	2.4	1.2	0.8	7.8	0.1
Small	439	0.5	0.2	0.2	1.9	0.0
EDC						
PECO	67	0.7	0.2	0.1	1.7	0.0
PPL	80	0.4	0.3	0.3	3.5	0.0
Duquesne	71	0.6	0.2	0.3	1.5	0.1
FE: Met-Ed	64	0.9	0.1	0.4	2.0	0.1
FE: Penelec	77	0.3	0.3	0.3	0.9	0.0
FE: Penn Power	72	0.5	0.2	0.2	1.3	0.0
FE: West Penn	76	0.4	0.2	0.2	1.3	0.1
Statewide	**507**	**0.5**	**0.2**	**0.2**	**2.0**	**0.0**

12 GENERAL BUILDING CHARACTERISTICS

In addition to the end-use equipment survey component, information was collected about the characteristics of the buildings visited. This information can be utilized for more complicated calculations, such as EUI, or to gain a broader understanding of the trends and energy use of these buildings over time.

Sites included in this survey may have more than one building. Each of the characteristics provided in Table 40 have been merged to the site level. Average age is the mean age of all buildings within a site. The two occupancy values take the sum of occupancy for all buildings within a site. Average number of floors is the mean number of floors for a sites' buildings. Average square footage shows the cumulative square feet of all buildings within a site. Once these values are calculated for a site, the average across all sites is taken. N-values are presented at the site level.

Table 40: Building Characteristics

Segment	n	Ft²	Avg. Age	Avg. # of Occupants: Core Business	Avg. # of Occupants: Non-Core Business	Avg. # of Floors
Education	35	35,412	53.9	214.6	16.5	1.9
Grocery	20	7,317	39.7	15.4	1.2	1.0
Health	38	49,225	38.6	141.7	49.7	1.9
Industrial Manufacturing	75	26,334	43.6	20.4	4.5	1.1
Institutional/Public Service	43	20,826	65.1	28.8	10.6	1.7
Lodging	21	22,907	42.6	82.2	58.4	3.4
Miscellaneous/Other	58	9,149	53.6	13.9	2.5	1.4
Office	55	12,239	47.6	27.6	1.1	1.6
Religious	5	15,593	154.2	20.5	0.0	1.7
Restaurant	60	4,001	61.4	28.3	2.4	1.5
Retail	57	6,806	53.4	9.8	0.2	1.3
Warehouse	40	38,173	45.3	25.8	0.3	1.3
Sector						
Large	68	174,092	50.4	307.4	118.6	2.1
Small	439	15,433	49.7	20.5	2.0	1.3
EDC						
PECO	67	18,088	55.1	29.3	2.7	1.5
PPL	80	23,777	47.7	36.1	6.6	1.3
Duquesne	71	12,478	50.9	27.8	1.7	1.7
FE: Met-Ed	64	32,742	57.2	43.2	26.2	1.3
FE: Penelec	77	20,603	54.3	14.6	1.1	1.2
FE: Penn Power	72	14,357	41.2	13.2	0.4	1.0
FE: West Penn	76	13,230	36.5	21.9	2.3	1.1
Statewide	**507**	**19,669**	**49.7**	**28.2**	**5.1**	**1.3**

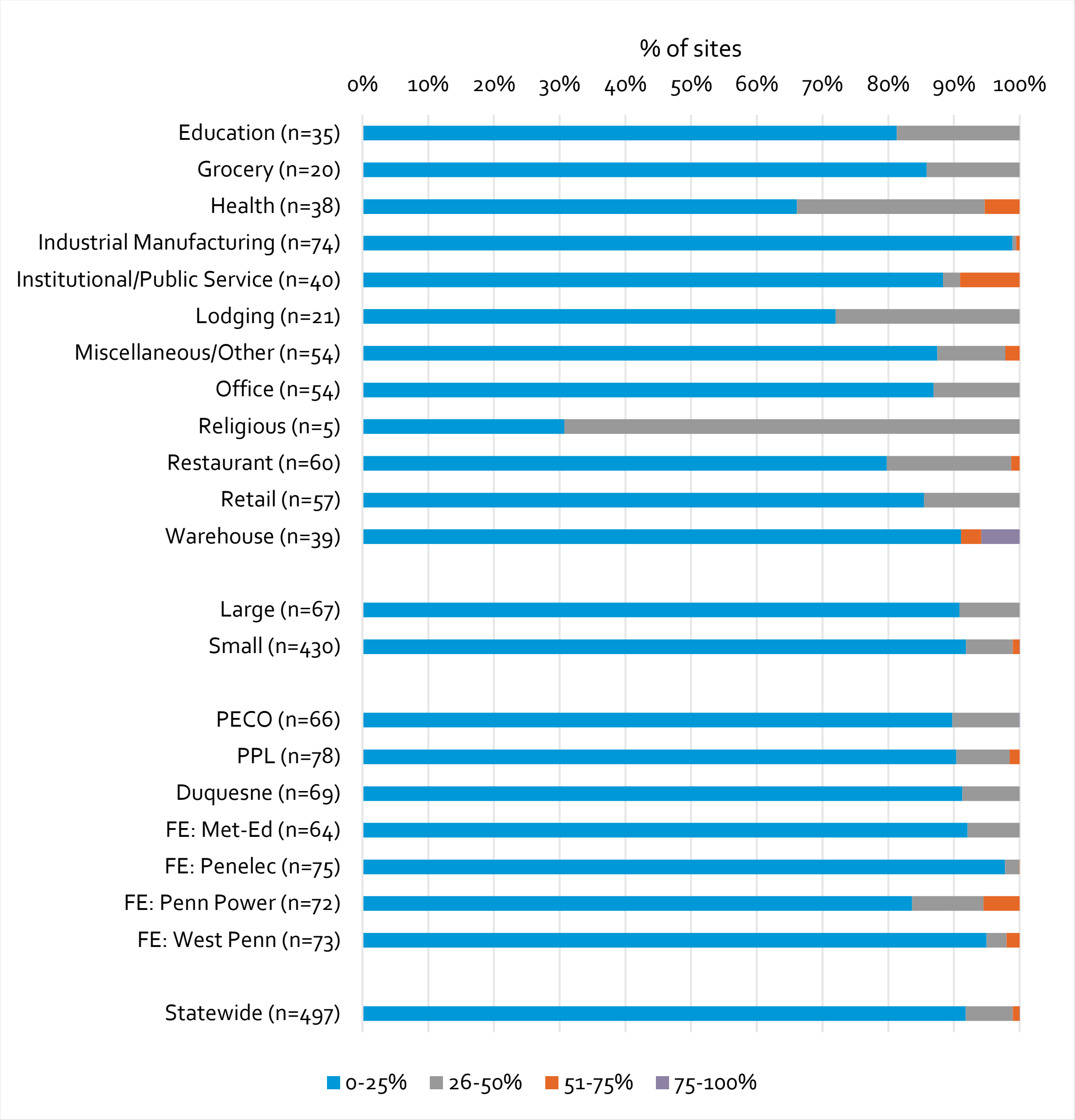
The average site-level wall R-value for buildings is provided in Table 41. R-value is an estimate based on the type and thickness of the wall. Wall types included in this survey are Cellulose, Fiberglass, and Rockwool. Provided n-values are at the site level. The difference between the n-values in this table and the full survey are due to missing information on wall type or thickness.

Table 41: Building Wall Insulation R-Value

Segment	n	Avg. Insulation (R-Value)
Education	18	19.0
Grocery	11	19.1
Health	23	19.3
Industrial Manufacturing	33	16.5
Institutional/Public Service	20	18.7
Lodging	17	20.4
Miscellaneous/Other	26	15.8
Office	34	17.1
Religious	3	15.6
Restaurant	24	19.4
Retail	27	16.8
Warehouse	19	19.7
Sector		
Large	33	17.5
Small	222	17.1
EDC		
PECO	36	17.0
PPL	44	16.3
Duquesne	40	18.1
FE: Met-Ed	32	14.7
FE: Penelec	29	17.3
FE: Penn Power	45	19.2
FE: West Penn	29	18.4
Statewide	**255**	**17.2**

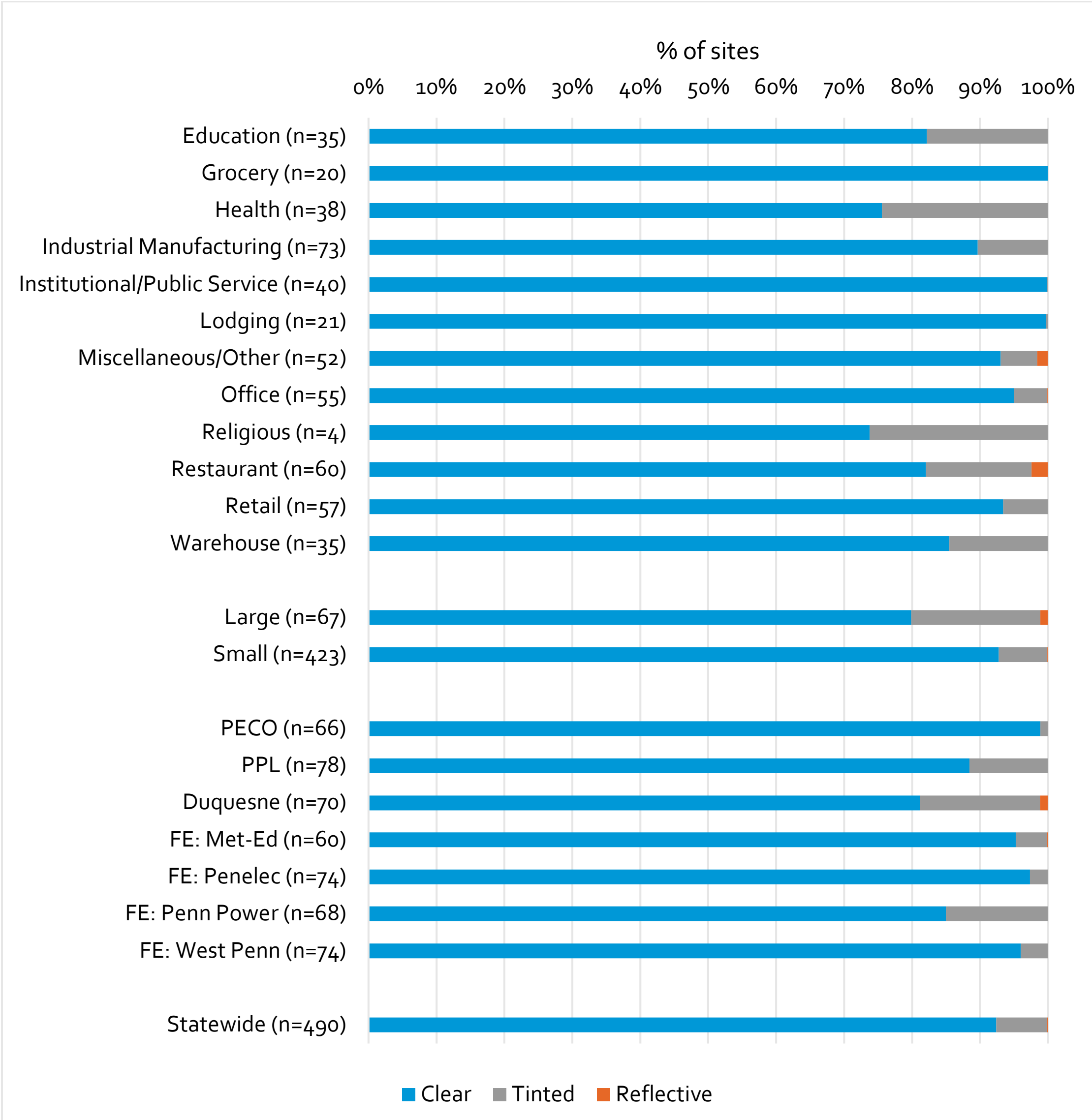
The survey provides four options to capture the percentage of walls covered by windows. Most of the buildings fall under the 0-25% category, but the Religious segment opposes this trend with a majority of 26-50% window coverage. The sample size for Religious is very small, so it is unclear if this is enough information to support a trend. Not all sites have window information reported. This explains the difference between surveyed sites and the site-level n-values provided.

Figure 63: Windows as a Percentage of Walls



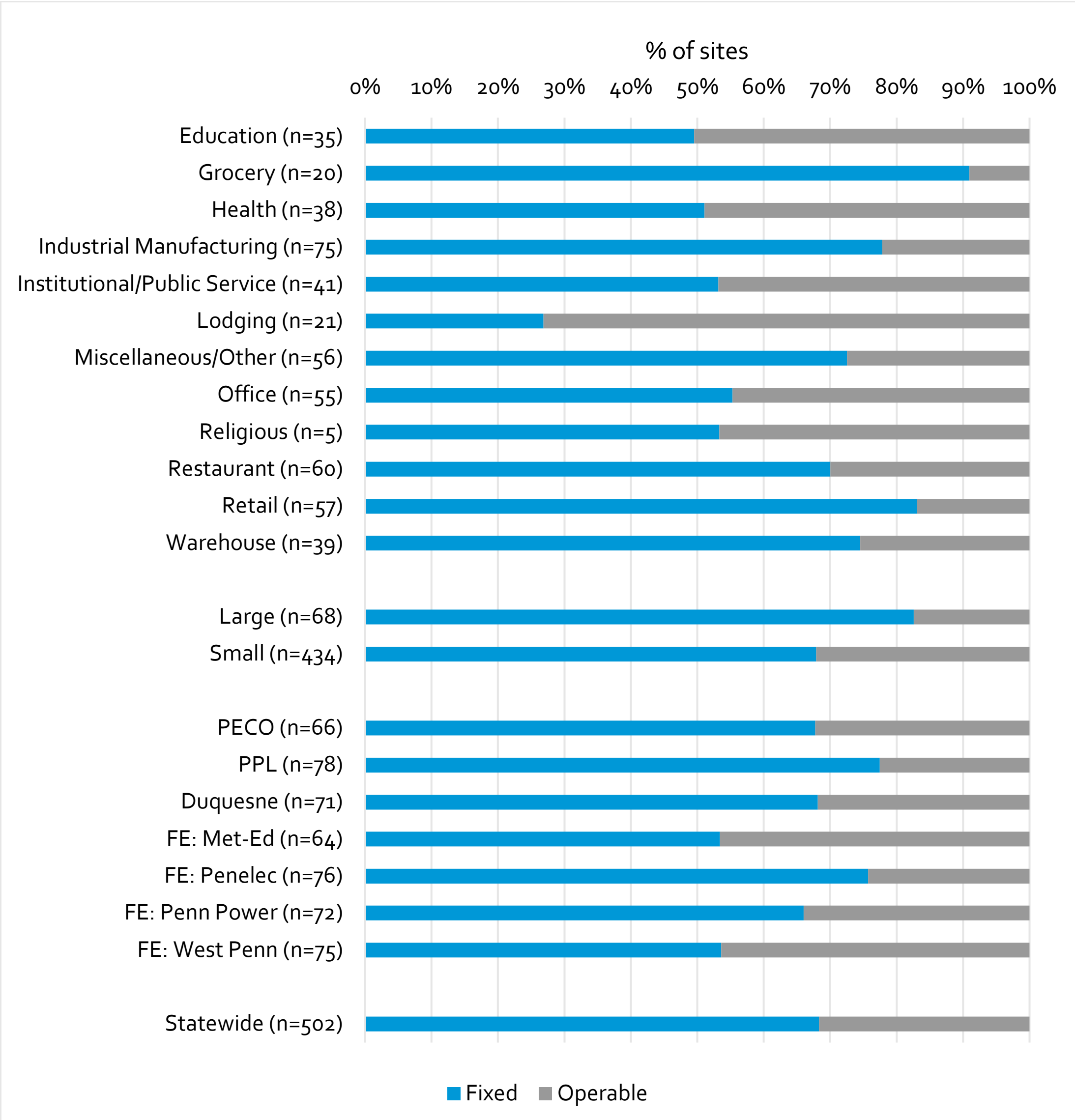
Window glazing can be clear, tinted, or reflective. Most of the windows in this survey are clear, as can be seen in Figure 64. Not all sites have window glazing reported. This explains the difference between surveyed sites and the site-level n-values provided.

Figure 64: Distribution of Window Glaze



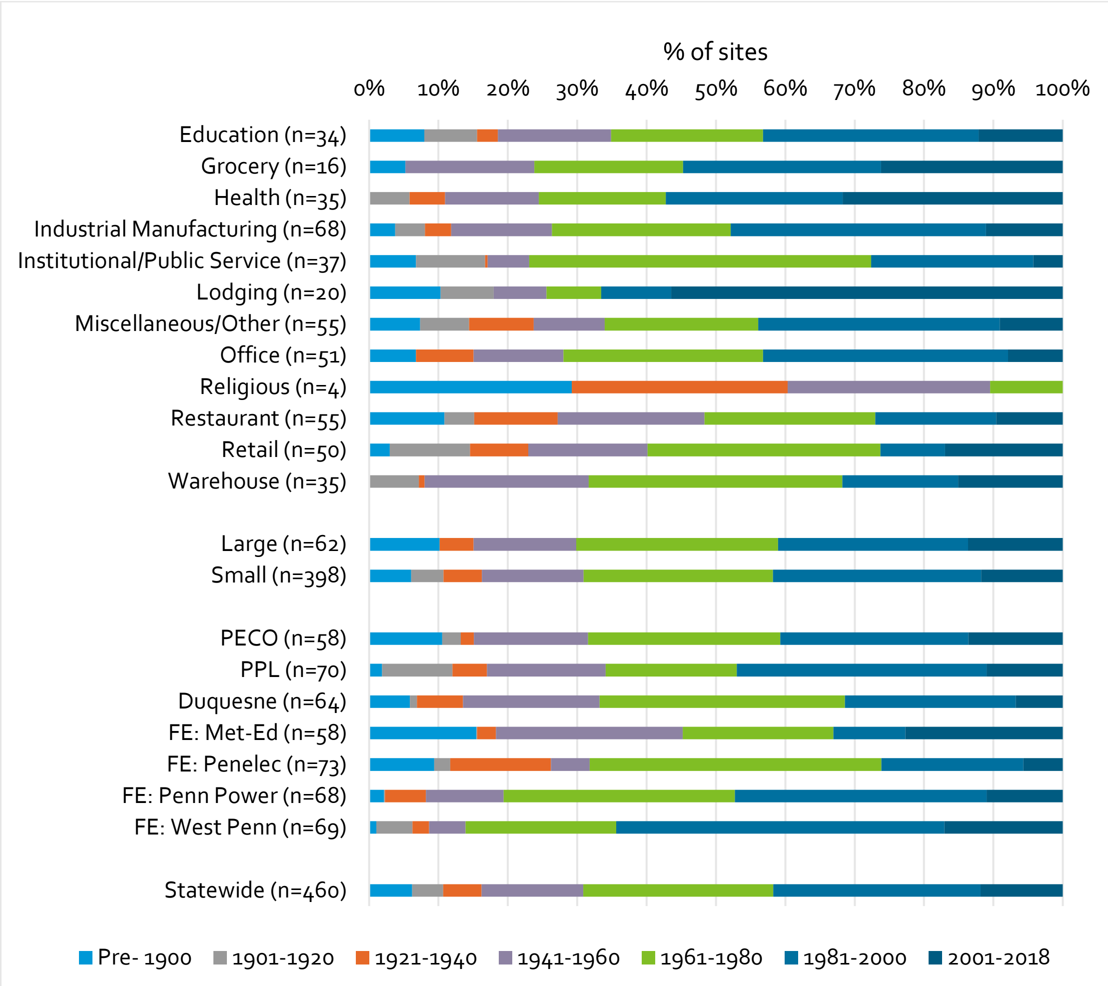
Windows can either be fixed or operable. In Figure 65, this distribution is presented. Not all sites have window type reported. This explains the difference between surveyed sites and the site-level n-values provided.

Figure 65: Distribution of Window Type



Year of construction for buildings, as described in Table 40, is shown in further detail in Figure 66. For sites with multiple buildings, the value is averaged and the mean *build date* is calculated prior to aggregation. Because of this methodology, a site with buildings constructed in 1900 and 2000 would appear in the average as a site that was built in 1950.

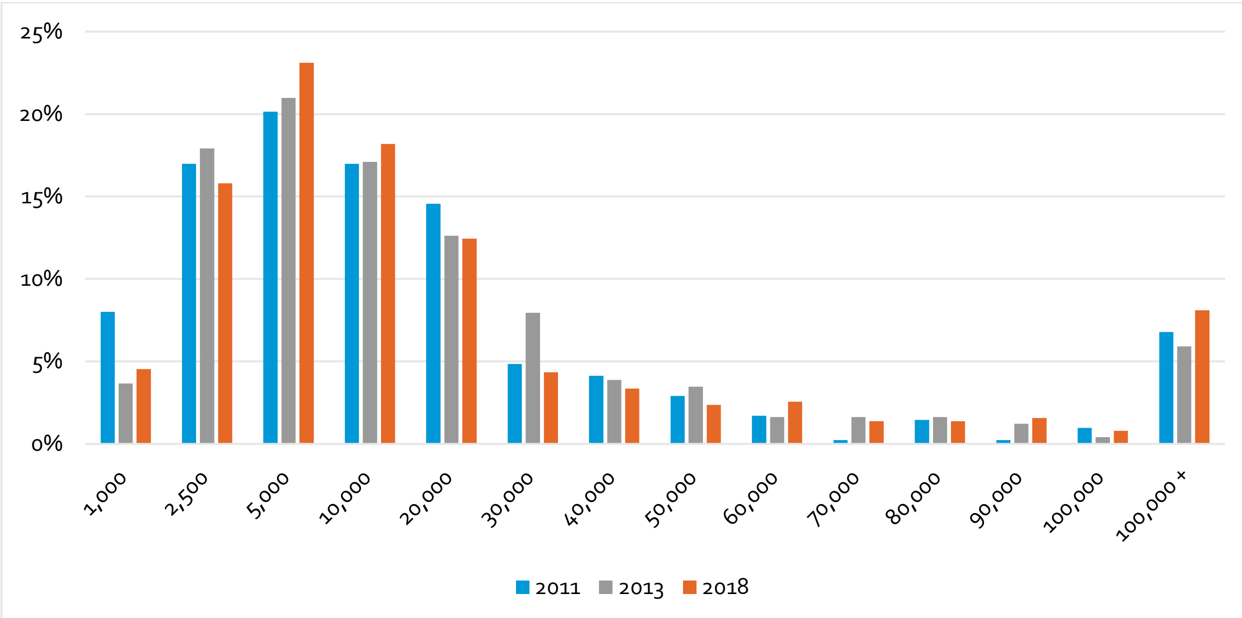
Figure 66: Distribution of Building Age



12.1 COMPARISON WITH PRIOR STUDY FINDINGS

Figure 67 shows the distribution of building size in each of the three baseline studies. Overall, the figure suggests a similar distribution of building sizes across the three studies.

Figure 67: Comparison of Building Sizes Surveyed



13 WILLINGNESS TO PAY

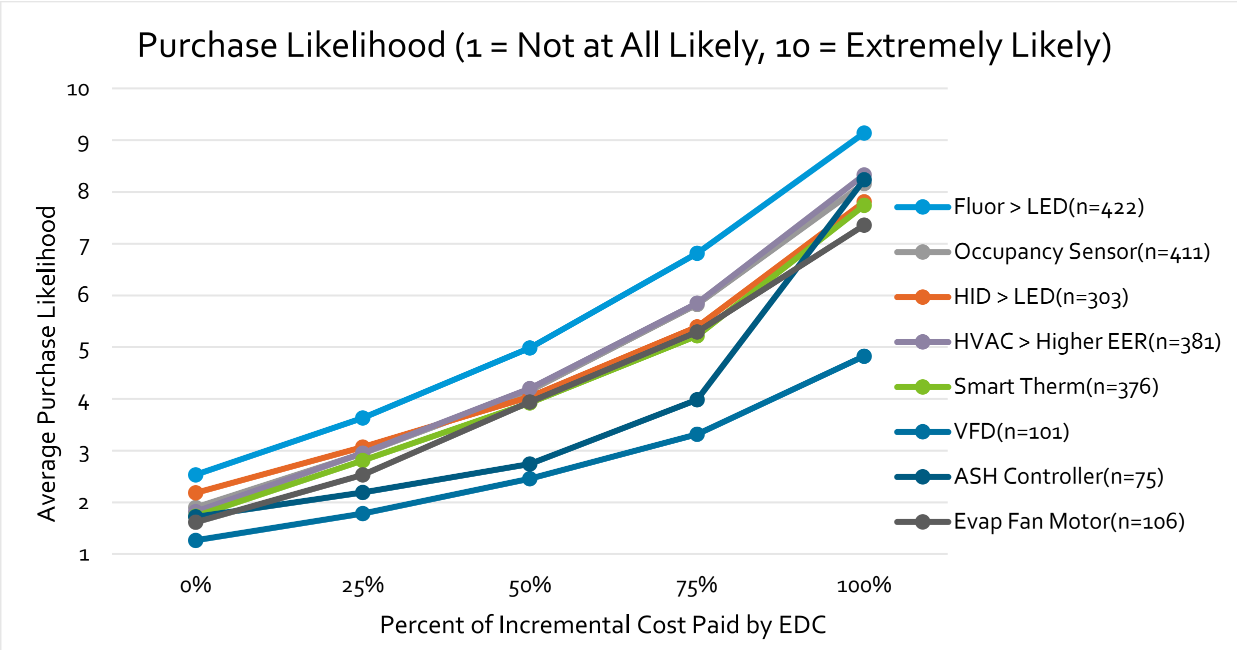
13.1 UPGRADE LIKELIHOOD

Site representatives were asked to answer a series of questions that deal with upgrades. For each question, there is a series of sub-questions that ask about the representative's likelihood of upgrading electric equipment, given five levels of incentive – 0%, 25%, 50%, 75%, and 100%. The incentive level indicates that for a given upgrade, some percentage (the incentive level) will be covered by the EDC. The representative then chooses, for each question and incentive level, the likelihood of purchasing that upgrade on a scale from 1 to 10 (1 = not at all likely, 10 = extremely likely). Questions were only asked of site contacts where the relevant end-use was present. These questions are presented below.

1. If converting one of your fluorescent fixtures to a more energy-efficient LED costs $180 per fixture, how likely are you to make that upgrade in the next two years?
2. I noticed that rooms in your building have manual control light switches. If installing a more energy-efficient occupancy sensor in one room costs $150, how likely are you to purchase one in the next two years?
3. If converting one of your exterior HID fixtures to a more energy-efficient LED costs $210 per fixture, how likely are you to make that upgrade in the next two years?
4. If converting one of your HVAC units to a more energy-efficient unit with a higher EER rating costs $250 per ton, how likely are you to make that upgrade in the next two years?
5. I noticed your HVAC is controlled by a manual thermostat. If installing a Smart Thermostat costs $250, how likely are you to purchase one in the next two years?
6. You mentioned your pumps/fans do not utilize variable frequency drives. If installing a VFD on one pump/fan costs $1728, how likely are you to purchase one in the next two years?
7. You mentioned your refrigerated cases do not utilize anti-sweat heater (ASH) controls. If installing an ASH controller costs $70 per door, how likely are you to purchase one in the next two years?
8. You mentioned utilizing shaded pole evaporator fan motors. If converting one evaporator fan motor to an electrically commutated motor costs $250, how likely are you to purchase one in the next two years?

Figure 68 shows the mean response for the questions at each incentive level. The legend is ordered from top to bottom for questions one through eight. The Y-Axis starts at 1 because the representative's choices range from 1 to 10. To further clarify, a choice of 1 indicates there is no chance of investing in the upgrade for the given incentive level. A selection of 10 suggests a certain investment; however, this survey answer does not necessarily relate to an action, only a hypothetical investment.

Figure 68: Average Purchase Likelihood (by Incentive Level)



It is interesting to note that not all participants rated upgrades a 10, even in the scenario where the EDC program pays 100% of the equipment and labor cost of the upgrade. This finding has important implications for modeling achievable potential. The response pattern at 0% is sometimes considered a proxy for free-ridership because respondents indicate an intent to make an energy-efficient investment absent any EDC program support. Upgrades from linear fluorescent to LED lighting has the highest purchase likelihood at all five prompt levels, and VFDs have the lowest purchase likelihood at all five prompt levels.

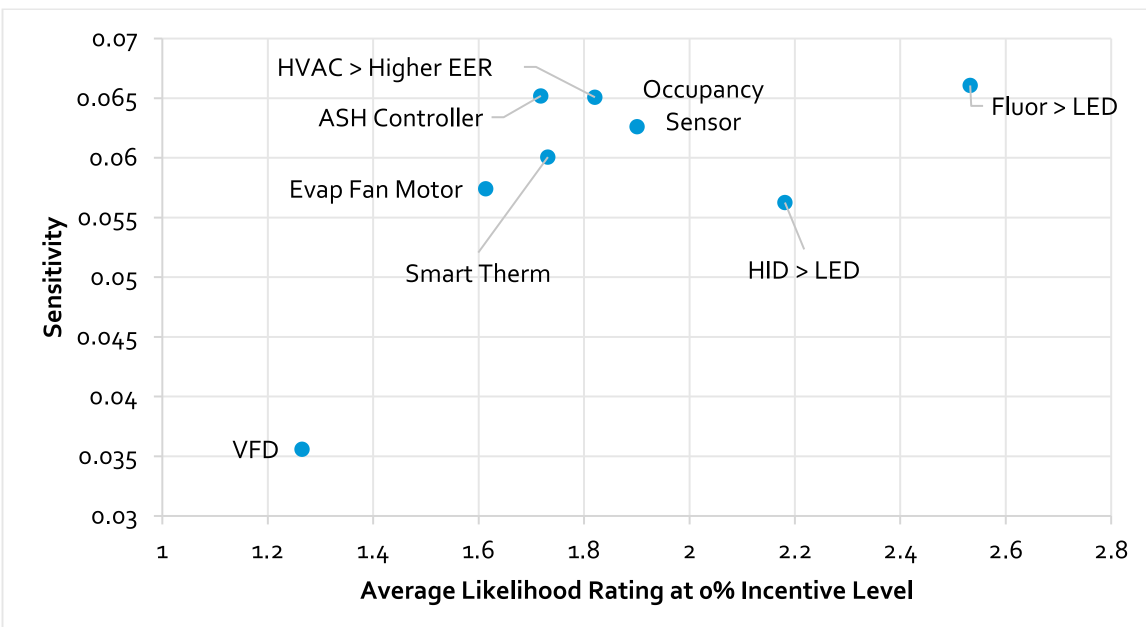
Likelihood was further analyzed for likelihood sensitivity, which is a variation on the economic concept of elasticity. Sensitivity measures the percentage change in purchase likelihood relative to the percentage change in price – 0% purchase discount vs. 100% purchase discount. Higher sensitivity values imply larger changes in purchase likelihood given a change in the purchase discount. This value is the average slope of the likelihood curve shown above. Table 42 shows this value for each of the measures of interest. The order of the measures in the table correspond to the ordered list of provided questions.

Table 42: Likelihood Sensitivity for Each Measure

Measure	Average Sensitivity
Fluor > LED (n=422)	0.066
Occupancy Sensor (n=411)	0.063
HID > LED (n=303)	0.056
HVAC > Higher EER (n=381)	0.065
Smart Thermostat (n=376)	0.060
VFD (n=101)	0.036
ASH Controller (n=75)	0.065
Evaporator Fan Motor (n=106)	0.057

Figure 69 maps these two measures together. The X-axis indicates the average likelihood of adopting an incentive without any discount. The upgrade from Fluorescent to LED lighting is the most likely of the eight investments. The Y-axis increases with difference in likelihood of investing in an upgrade when the purchase price is fully covered vs not covered. VFD implementation is a slight outlier.

Figure 69: Sensitivity as a Function of Un-incented Purchase Likelihood (0% Purchase Discount)



13.2 PURCHASE DECISIONS: MOTIVATORS & BARRIERS, RETURN ON INVESTMENT, AND PROGRAM AWARENESS METRICS

Decision criteria/motivations and barriers to energy-efficient purchases participation vary across non-residential organizations. To obtain estimates of the importance of a handful of these inputs, the survey asks two questions. These questions focus on motivations that encourage energy-efficient purchases and barriers that discourage energy-efficient purchases. The motivation question was phrased as follows, "Using a scale of 1 (not important) to 5 (very important), please rate the importance of the following motivational factors in your purchasing decisions." The motivations are listed, and the average responses are reported in Table 43. Survey responses indicate that the highest motivator for purchasing decisions is improved cash flow, closely followed by lower energy bills.

Table 43: Importance of Motivators for Energy Efficiency

Motivation of Interest	Mean Response (1-5)
Availability to Utility Rebate (n=481)	3.5
Environmental Concerns (n=483)	3.2
Health Benefits (n=483)	3.4
Higher Rent for Tenants (n=483)	1.3
Improved Cash Flow (n=483)	4.4
Interest in Advanced Technologies (n=483)	3.1
Lower Energy Bills (n=483)	4.2

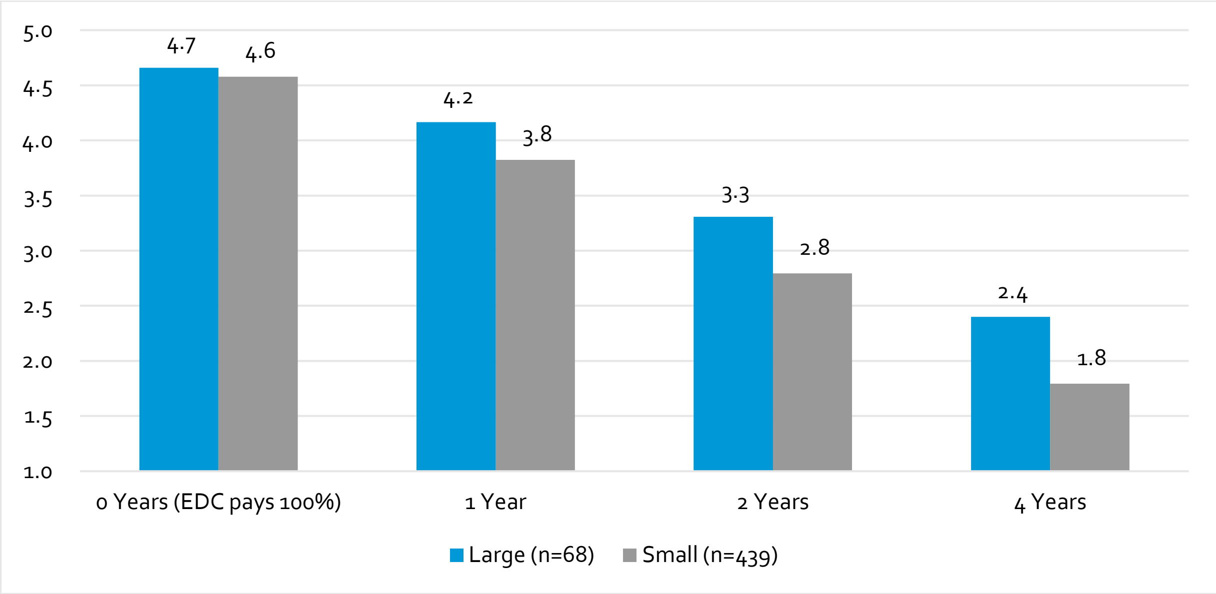
The barrier question was phrased as follows, "Using a scale of 1 (never) to 5 (often), please rate the prevalence of the following barriers to your purchasing decisions." The barriers and the average responses are reported in Table 44. The most prevalent barrier to a purchasing decision is return on investment, closely followed by service disruption.

Table 44: Importance of Barriers to Efficient Purchasing Decisions

Barrier of Interest	Mean Response (1-5)
Access to Financing (n=483)	2.6
Awareness of Efficient Technology (n=483)	2.3
Company Branding Restrictions (n=483)	1.2
Concerns for Tenant Comfort (n=483)	1.8
Disruptions to Service (n=483)	2.9
Return on Investment (n=483)	3.0

To further gain information on how important return on investment is to an organization's representative, the following question was asked, "If a utility offered a program that effectively addressed your main barriers to installing more efficient equipment, and provided assistance through the process, please indicate how likely you would be to utilize the program (1 not at all likely, 5 very likely)." The survey prompts the representative to provide a ranking, from 1 to 5, indicating their likelihood of program participation for four scenarios – immediate return on investment (where the EDC pays the full cost), return of investment in one year, two years, and four years. Average likelihood for large and small sectors is provided in Figure 70. Note that the average stated response pattern for Large C&I participants was higher than Small C&I participants for each hypothetical payback period.

Figure 70: Likelihood of Investment based on Various Timing of Return



The following series of questions deals with equipment purchasing policies and Act 129 program awareness among the surveyed organizations:

1. Does your company have any procurement policies or guidelines to purchase high-efficiency options when they are available and would provide a lower life cycle cost?
2. Do you do capital planning for major equipment replacements and proactively replace equipment when it is toward the end of its useful life (as opposed to waiting until something fails to replace it)?
3. For significant energy-using equipment purchases, does your company routinely analyze the different efficiency and cost options to assess life cycle costs?
4. Are you aware of your utility's energy-efficiency rebate program?
5. Have you participated in the program before?

Table 45 shows the percent of "Yes" respondents out of the number of sites that responded to a given question. Note that about 26 sites did not respond to these questions. This table is shown by segment, sector, EDC, and statewide to give more detailed insight on how different areas compare for these program awareness questions. Most notably, Large C&I sites are more likely to plan for and participate in their utility's energy-efficiency rebate programs. These results, coupled with many other findings about current efficiency levels in this report, suggest that significant energy-efficiency opportunities exist in the Small C&I sector, but that EDC programs may have to work harder to engage these customers. This likely means increased administrative spending and incentive levels and a higher overall program acquisition cost relative to the Large C&I sector.

Table 45: Mean Procurement and Program Awareness Response Rates

Segment	Q1: Procurement	Q2: Capital	Q3: Equipment Purchase	Q4: Rebate Aware	Q5: Program Before
Education (n=33)	18%	58%	83%	66%	40%
Grocery (n=19)	14%	25%	61%	58%	29%
Health (n=36)	16%	42%	54%	52%	41%
Industrial Manufacturing (n=75)	29%	28%	56%	46%	19%
Institutional/ Public Service (n=41)	38%	50%	58%	48%	20%
Lodging (n=20)	69%	35%	83%	60%	31%
Miscellaneous/Other (n=54)	28%	24%	38%	19%	9%
Office (n=50)	18%	31%	36%	39%	26%
Religious (n=5)	45%	23%	92%	47%	0%
Restaurant (n=58)	30%	27%	48%	47%	15%
Retail (n=52)	28%	27%	40%	21%	9%
Warehouse (n=38)	29%	25%	41%	75%	13%
Sector					
Large (n=63)	51%	85%	91%	87%	71%
Small (n=418)	24%	29%	47%	37%	17%
EDC					
PECO (n=61)	17%	26%	50%	34%	12%
PPL (n=78)	38%	33%	58%	52%	31%
Duquesne (n=64)	34%	37%	47%	37%	14%
FE: Met-Ed (n=62)	17%	19%	40%	30%	14%
FE: Penelec (n=74)	11%	27%	34%	36%	23%
FE: Penn Power (n=68)	24%	31%	41%	38%	4%
FE: West Penn (n=74)	19%	36%	47%	28%	10%
Statewide (n=481)	**24%**	**30%**	**48%**	**39%**	**18%**

APPENDIX A – TABLE OF ACRONYMS

Table 46 lists each of the acronyms used in this report and the phrase it is used to represent.

Table 46: Table of Acronyms

Acronym	Phrase
ASH	Anti-Sweat Heater
BTU	British Thermal Units
C&I	Commercial And Industrial
CBECS	Commercial Buildings Energy Consumption Survey
CFL	Compact Fluorescent Lamp
CHP	Combined Heat And Power
DLC	Duquesne Light Company
DSA	Demand Side Analytics, LLC
DX	Direct Expansion
EDC	Electric Distribution Company
EER	Energy Efficient Ratio
EFLH	Equivalent Full Load Hours
EIA	U.S. Energy Information Administration
EMS	Energy Management System
EUI	Energy Use Intensity
FE: ME, Met-Ed	First Energy Metropolitan Edison Company
FE: PN, Penelec	Pennsylvania Electric Company
FE: PP, Penn Power	Pennsylvania Power Company
FE: WPP, West Penn	West Penn Power Company
HID	High-Intensity Discharge Lamp
HP	Horsepower
HVAC	Heating, Ventilation, And Air Conditioning
IECC	International Energy Conservation Code
kBTU	Kilo British Thermal Units
kV	Kilovolt
kWh	Kilowatt Hour
LED	Light-Emitting Diode
LPD	Lighting Power Density
MECS	Manufacturing Energy Consumption Survey

MWh	Megawatt Hour
NAICS	North American Industry Classification System
NEMA	National Electrical Manufacturers Association
NG	Natural Gas
NMR	NMR Group Inc.
ODP	Open Drip Proof
PECO	PECO Energy Company
PTAC	Packaged Terminal Air Conditioner
SIC	Standard Industrial Classification
SWE	Statewide Evaluation Team
TCU	Transportation, Communications, And Utilities
TEFC	Totally Enclosed Fan-Cooled
TRM	Technical Reference Manual
VFD	Variable Frequency Drive