Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

Pennsylvania Act 129

2023 Non-Residential Baseline Study

Prepared for the Pennsylvania Public Utility Commission

By Statewide Evaluation Team

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ACKNOWLEDGEMENTS

Partners

- Alana Lemarchand
- Jesse Smith

Consultant

- Tim Larsen

Senior Analysts

- Mike Jehl
- Zhuoning Li

Field Data Collection

- Abraxas Energy Consulting
- NMR Group Inc.

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. The study team especially appreciates the efforts of EDC key account managers who refined contact information and made introductions to the large accounts they manage.

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Pennsylvania Non-Residential Baseline Study

In 2023, Pennsylvania's Statewide Evaluation Team performed an energy-efficiency potential assessment for the state and its seven largest electric distribution companies: DLC, Met-Ed, Penelec, Penn Power, West Penn, PPL, and PECO. Auditors inspected 516 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 V energy efficiency market potential study.

44 Health | 52 Retail | 42 Warehouse | 69 Industrial/Manufacturing | 38 Education | 57 Office | 48 Institutional/Public Service | 27 Restaurant

Large C&I = 120
Small C&I - 396

*Additional segments: Grocery, Lodging, Religious, & Miscellaneous

Key Findings

LED Saturation

Indoor

General Service
2023: 57%*
2018: 19%*
*By fixture count.

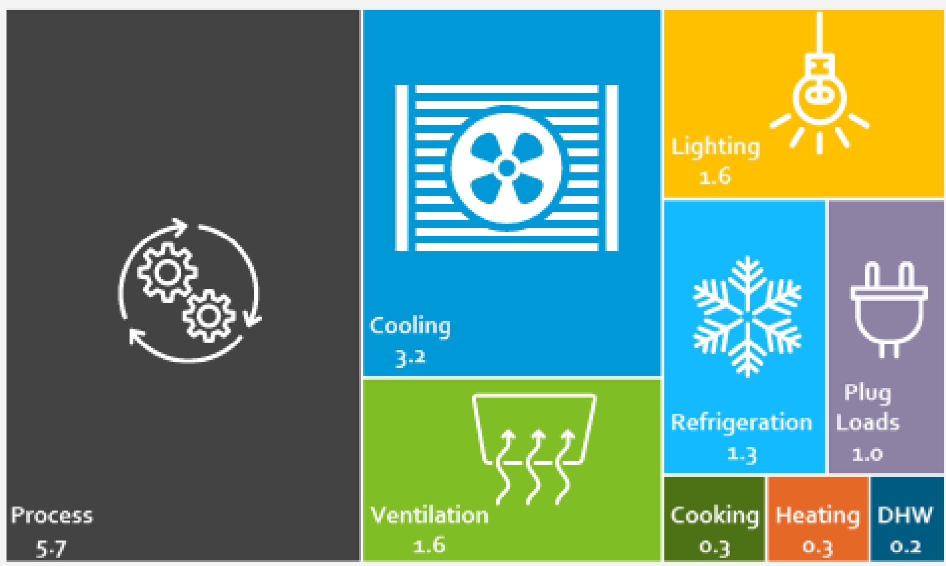
Screw-based
2023: 75%
2018: 44%

Outdoor

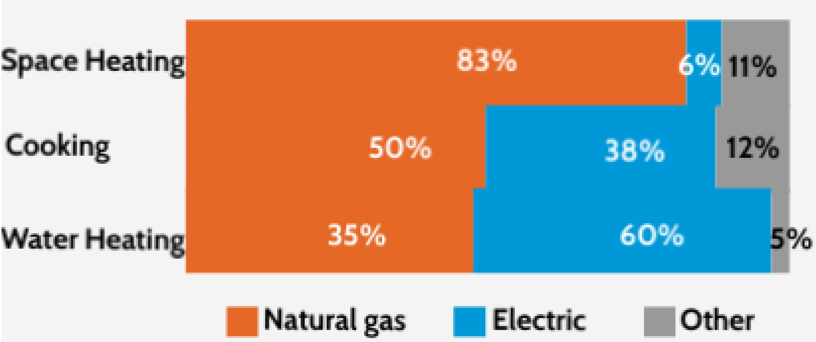
General Service
2023: 77%
2018: 43%

"LED saturation has increased significantly since 2018"

Statewide EUI by End Use

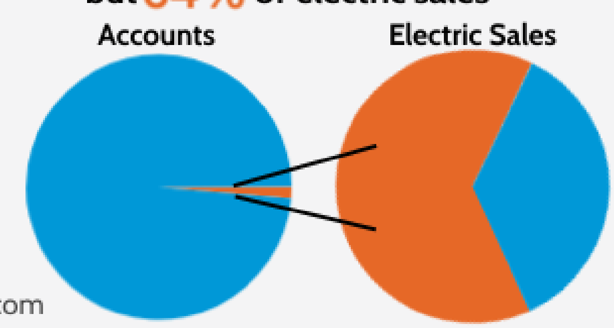


Fuel Share



Results by Sector

Large C&I is **1.4%** of non-residential accounts but **64%** of electric sales



1 EXECUTIVE SUMMARY

Demand Side Analytics (DSA), NMR Group (NMR), Brightline Group, Optimal Energy, 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:

- PECO Energy Company (PECO)
- PPL Electric Utilities Corporation (PPL)
- 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)

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 inform updates to the Technical Reference Manual (TRM) and will serve as key inputs to the Phase V Market Potential Study. The team collected primary data for this study from February to July 2023.

1.1 NON-RESIDENTIAL ELECTRIC SALES SUBJECT TO ACT 129

Data from the U.S. Energy Information Administration (EIA) for 2022, 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 most EDC accounts, non-residential customers consume over 60% of the electric energy. This report covers non-residential energy usage. The accompanying Residential Baseline Study describes usage for residential customers.

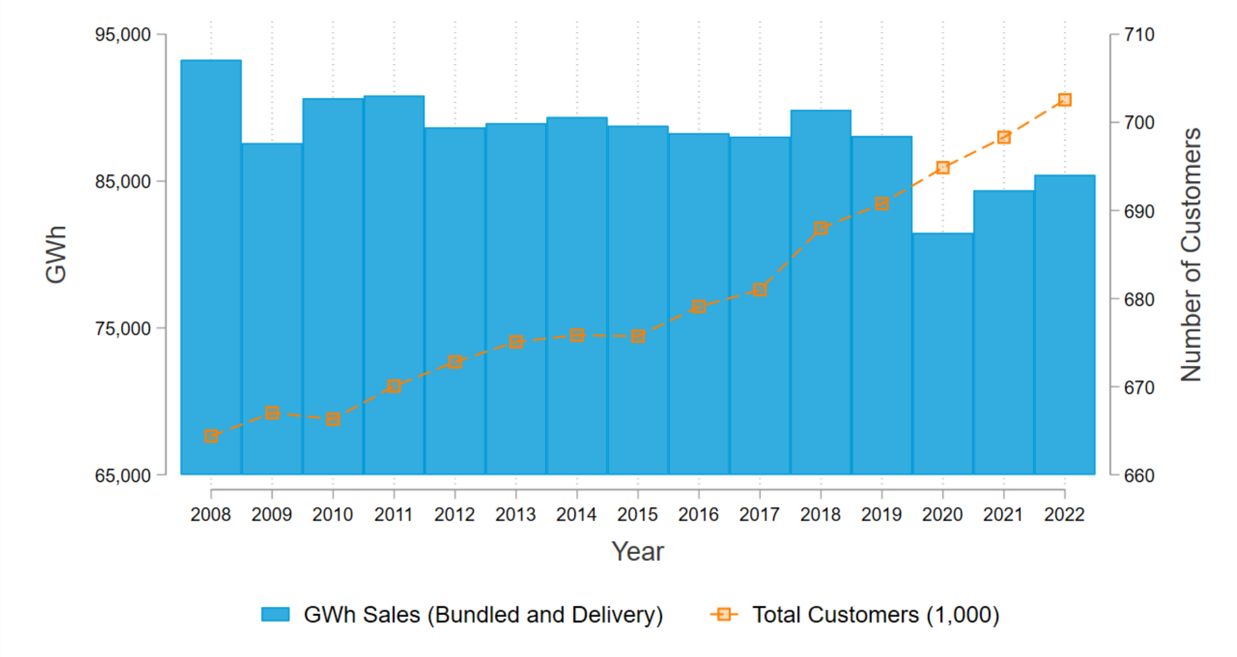
Table 1: 2022 Electricity Sales in Pennsylvania[1]

Category	Sales (MWh)	Customers
Pennsylvania	145,044,592	6,250,115
Act 129 EDCs	138,643,960	5,855,811
Non-Residential Sectors of Act 129 EDCs	85,427,112	702,569

[1] https://www.eia.gov/electricity/data/eia861/ Accessed December 8, 2023.

Figure 1 shows EIA sales and customer accounts from 2008 to 2022 for the seven EDCs subject to Act 129. Total non-residential electric consumption has declined slightly despite steady growth in the number of electric accounts, which implies declining consumption on a per-account basis. The data are not weather-normalized so some year-to-year variation is expected. The effect of the COVID-19 pandemic is evident in the reduced non-residential sales for 2020 and subsequent rebound in 2021 and 2022.

Figure 1: Historic Non-Residential Electric Sales and Customer Counts - Statewide



Note that while non-residential usage includes Master-Metered Multifamily customers, the Residential Baseline Study addresses usage for those customers 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 2021 through May 2022 sales rather than calendar year 2022. 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 78,366 GWh in Table 2 excludes 187,000 accounts and 9,214 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 and 3.

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

Segment	Accounts	Electric Sales (GWh) June 2021-May 2022
Education	14,122	6,524
Grocery	10,990	3,406
Health	22,090	5,696
Industrial Manufacturing	63,070	33,424
Institutional/Public Service	49,489	5,371
Lodging	10,528	1,389
Miscellaneous/Other	82,121	2,988
Office	133,499	9,579
Religious	21,686	763
Restaurant	21,871	1,882
Retail	48,822	3,470
Warehouse	35,212	3,875
Sector		
Small	506,317	28,266
Large	7,183	50,100
EDC		
PECO	129,629	20,226
PPL	141,209	20,504
Duquesne	39,158	8,316
FE: Met-Ed	49,358	7,628
FE: Penelec	65,592	8,142
FE: Penn Power	15,288	2,592
FE: West Penn	73,266	10,956
Statewide	**513,500**	**78,366**

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 types exceed ten years, suggesting an equipment useful life of at least 20 years. The central tendencies shown in Table 3 suggest that the 15-year maximum measure life for Act 129 measures artificially truncates 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 Central Boiler	105	21	18
HVAC Unitary Fossil Fuel Combustion	624	10	8
HVAC Unitary Electric Heating	1,443	18	18
HVAC Chiller	139	12	8
HVAC Direct Expansion Cooling	969	12	13
HVAC Ductless Mini Split	62	6	5
HVAC Air Source Heat Pump	268	9	11
Domestic Hot Water	732	9	7
Refrigeration - Walk In	81	14	12
Refrigeration - Reach In	481	8	8
Motors and Other Process Equipment	1,434	14	10

1.3 ENERGY USE INTENSITY

A key output of the Non-Residential Baseline Study is energy use intensity (EUI) by end use, shown in Figure 2. Electric EUI is defined as annual kWh per square foot (kWh/ft^2). N-values represent the number of sites included in the EUI calculations.[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. Penetration is defined as the percentage of sites where the end use is present and fuel share is the percentage of equipment powered by a given fuel. Fuel share explains why the Cooling end use is so much larger than the Heating end use. Most businesses have both space heating and cooling, but while all cooling is all-electric, only around 6% of space heating in Pennsylvania businesses is powered by electricity.

On a normalized square footage basis, the most energy intensive segments are Industrial, Grocery, and Restaurant. Manufacturing processes are the most energy intensive end use in the state at approximately 5.7 kWh/ft^2 statewide and nearly 32 kWh/ft^2 in the Industrial segment. Commercial refrigeration and cooking, which are uncommon in other segments, account for a significant share of electric consumption in the Grocery and Restaurant segments. Religious, Warehouse, Office, and Retail are the least energy intensive segments.

[2] Some sampled sites had only outdoor loads leading to an undefined EUI due to zero in the denominator. For others the SWE was unable to confidently align the surveyed buildings with the relevant EDC meter(s).

Figure 2: EUI in Each End Use Category by Segment

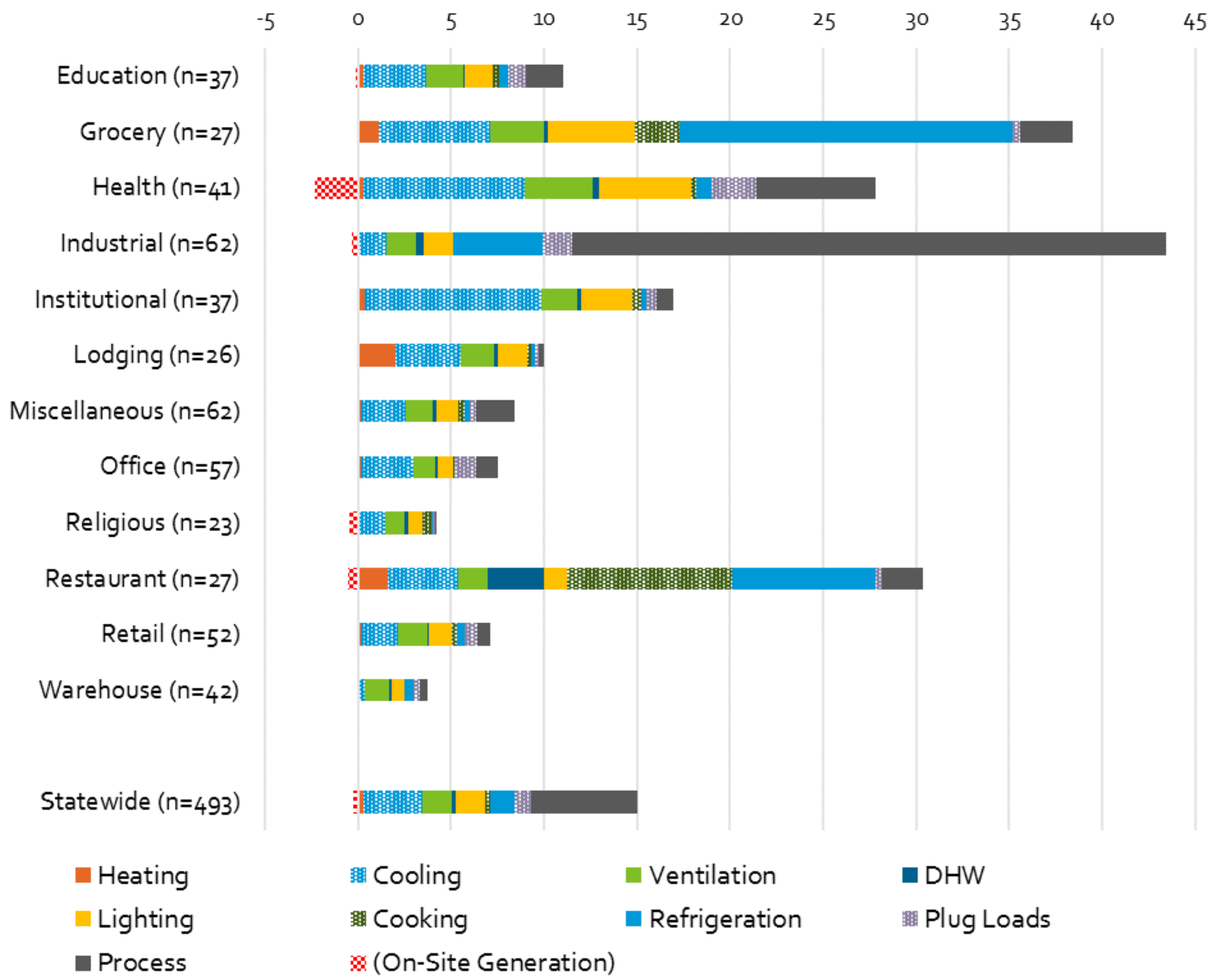


Figure 3 presents the statewide EUI values by end use. The Lighting end use EUI of 1.6 kWh/ft^2 from this 2023 Non-Residential Baseline Study is a significant reduction from the 2.5 kWh/ft^2 lighting EUI in the 2018 Non-Residential Baseline Study. Section 1.5 examines the changes in lighting equipment responsible for this dramatic decrease.

Figure 3: Statewide EUI by End Use

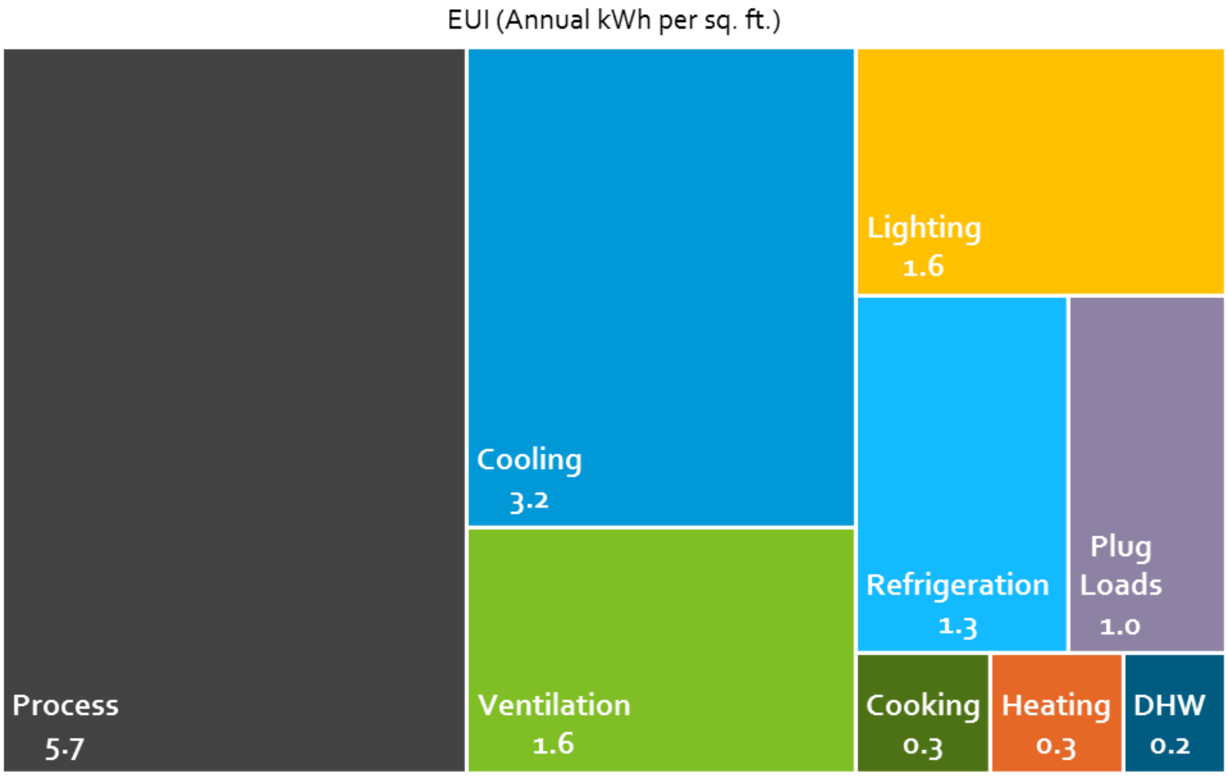
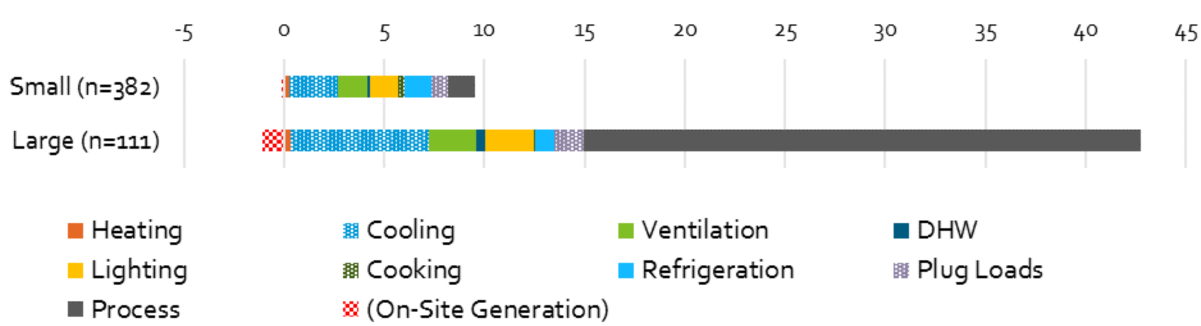


Figure 4 shows stacked end use EUI by sector. Large C&I customers have a much higher average EUI than Small C&I customers. In particular, the Cooling and Process EUIs are much larger for Large C&I accounts. The Lighting EUI is larger in the Large C&I sector despite more efficient equipment due to significantly higher hours of operation compared to the Small C&I sector.

Figure 4: EUI by End Use and Sector

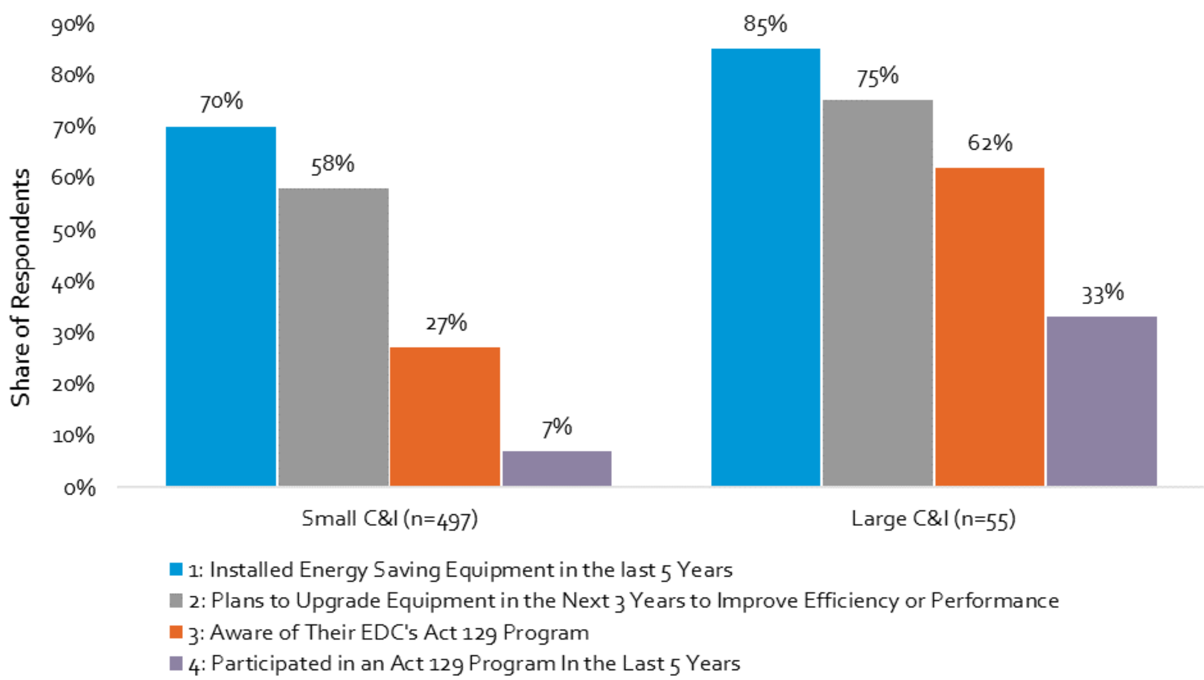


1.4 ADOPTION RESEARCH

In a parallel data collection effort, the SWE team conducted an online survey with direct questions on Energy Efficiency and Conservation (EE&C) program awareness and equipment purchase topics. Figure

5 compares responses to a series of questions about recent equipment upgrades, Act 129 program awareness, and past participation. Respondents from the Large C&I sector were twice as likely to be aware of their EDC's Act 129 program offerings and almost five times as likely to have participated compared to Small C&I respondents.

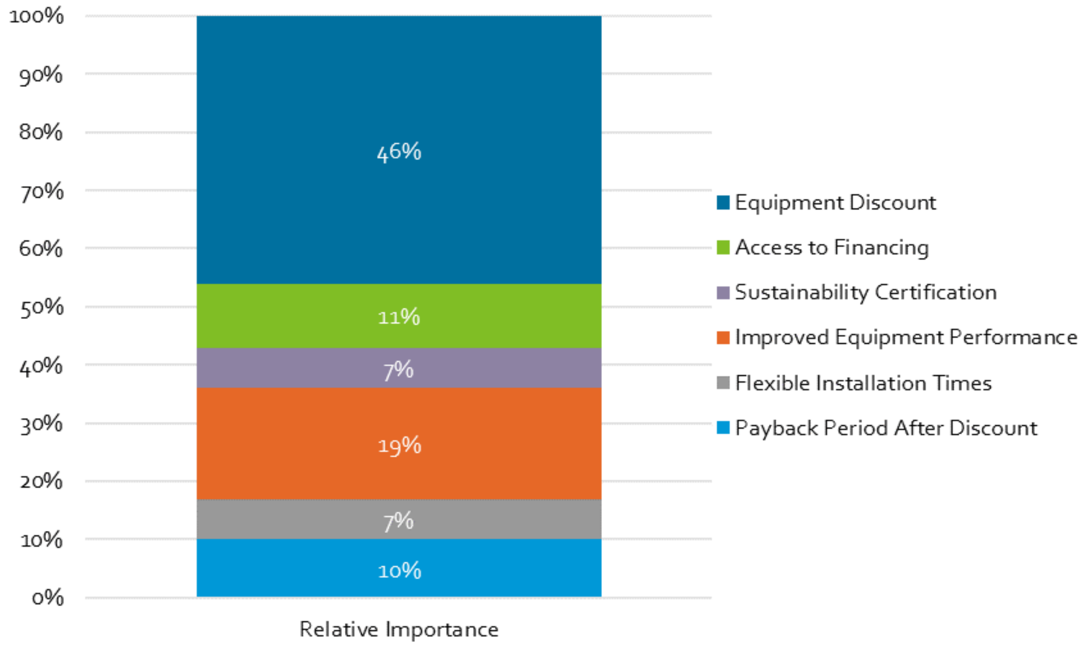
Figure 5: Upgrade Conversion Funnel by Sector



The survey also included a choice experiment, which presented the respondent possible EE&C program design configurations. A choice experiment, or conjoint survey, isolates and quantifies the influence of individual factors on a decision. It is a commonly used product design tool that enables researchers to model uptake likelihood for each combination of factors tested, without having to test each combination directly. To conduct a conjoint experiment, the product or program must be distilled into a set of attributes, each with mutually exclusive levels. Each survey respondent is shown a series of choice sets (one per screen) with multiple design configurations; one level is defined for each attribute simulating a real-world choice the respondent could encounter.

Figure 6 summarizes the results of the conjoint exercise by showing each program attribute's share of importance to respondents. Equipment discount (incentive amount) was by far the most influential attribute, influencing 46% of the participation decision. The three finance-related attributes comprise 67% of the participation decision while the three non-financial attributes influence the remaining third of the decision. The SWE plans to leverage this research to inform the adoption curves in the Phase V Energy Efficiency and Peak Demand Reduction Market Potential Study.

Figure 6: Choice Experiment Attributes and Relative Importance



1.5 COMPARISONS ACROSS BASELINE STUDIES

This study is the fourth statewide Act 129 non-residential baseline study since 2011. When referring to the results of previous non-residential baseline studies in this report, we use the year that the data was collected rather than the year the study was published.

- **2023 Non-Residential Baseline Study** – conducted as part of the Phase IV SWE contract to support planning efforts for a potential Phase V of Act 129. Docket No. M-2023-3044490.
- **2018 Non-Residential Baseline Study** – conducted by the Phase III SWE to support planning efforts for Phase IV of Act 129. Docket No. M-2019-3006866.
- **2013 Non-Residential End Use & Saturation Study** – conducted by the Phase II SWE to support planning efforts for Phase III of Act 129. Docket No. M-2014-2424864.
- **2011 Commercial and Industrial End Use and Saturation Study** – conducted by the Phase I SWE to support planning efforts for Phase II of Act 129. Docket No. M-2012-2289411.

The studies never return identical estimates of key metrics for a variety of reasons. There are two ways stakeholders can view differences in results across studies.

1. **There is a real trend that we expect to continue**. If the 2023 study shows increased or decreased prevalence of a key equipment type or characteristic relative to prior studies, we

may need to forecast the rate of change to estimate the state of the Commonwealth's non-residential stock from 2026 to 2031 in the Phase V Market Potential Study.

2. **There is measurement error, or random noise due to the sites visited in each study that drive the observed differences.** In this case, we might recommend the Market Potential Study team average the results of this study with prior baseline studies to arrive at a more robust estimate of the baseline characterization.

Figure 7 shows an example from the first category. The 2011 and 2013 baseline studies observed no LED lighting equipment whatsoever. In the 2018 baseline study, LED accounted for 12% of all lighting connected load. This study found 42% of all lighting Wattage statewide was LED. Since LEDs are more efficient, the share of lighting equipment is even higher. This 350% increase is clearly the result of a changing market dynamic and the success of the EDCs' non-residential lighting programs over the last five years. By June 2026, when a potential Phase V of Act 129 would begin, we expect an even higher share of LEDs statewide.

Figure 7: Statewide Share of Lighting Wattage by Technology

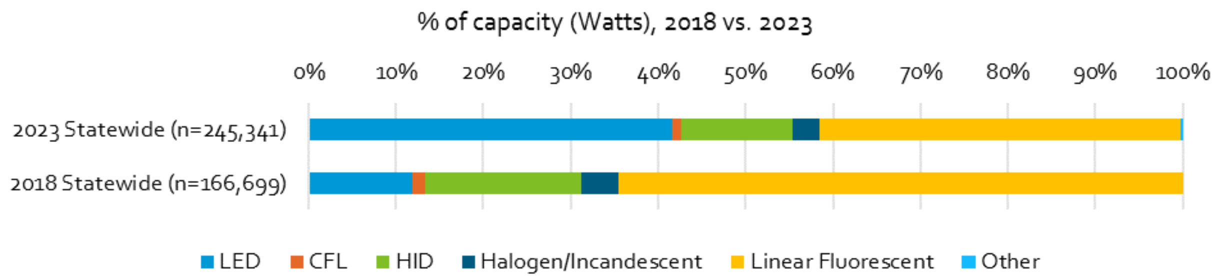
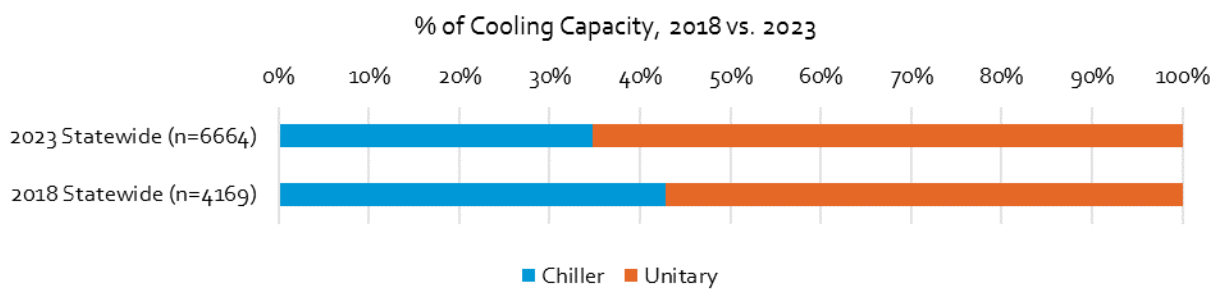


Figure 8 shows an example we believe falls in the second category. All cooling equipment observed on-site is classified as either a Chiller (central plant) or Unitary. The 2018 baseline study found 43% of all capacity (tons) statewide were Chillers and the other 57% were Unitary. This study found 35% Chiller and 65% Unitary. The 2011 and 2013 studies reported cooling shares by floorspace, so they are not directly comparable. The SWE cautions stakeholders from inferring that there is a trend away from Chillers and into Unitary systems based on the findings shown in Figure 8. Instead, we plan to pool the results and assume a 39% Chiller and 61% Unitary split in the Phase V Market Potential Study.

Figure 8: Statewide Cooling Capacity by System Type



Data collection protocols, analysis methodology, and reporting conventions have evolved over the four Act 129 non-residential baseline studies, but certain key metrics with similar methodologies can be compared. Figure 9 compares penetration for certain end uses across studies. Penetration of lighting, heating, and plug load equipment have been at or about 100% in each of the four studies. Space cooling and domestic hot water equipment is present at most, but all sites. This study found 17% penetration of both commercial refrigeration and commercial cooking, an increase from the 2018 study but lower than that 2011 or 2013 baseline studies.

Figure 9: End Use Penetration Comparison across Studies

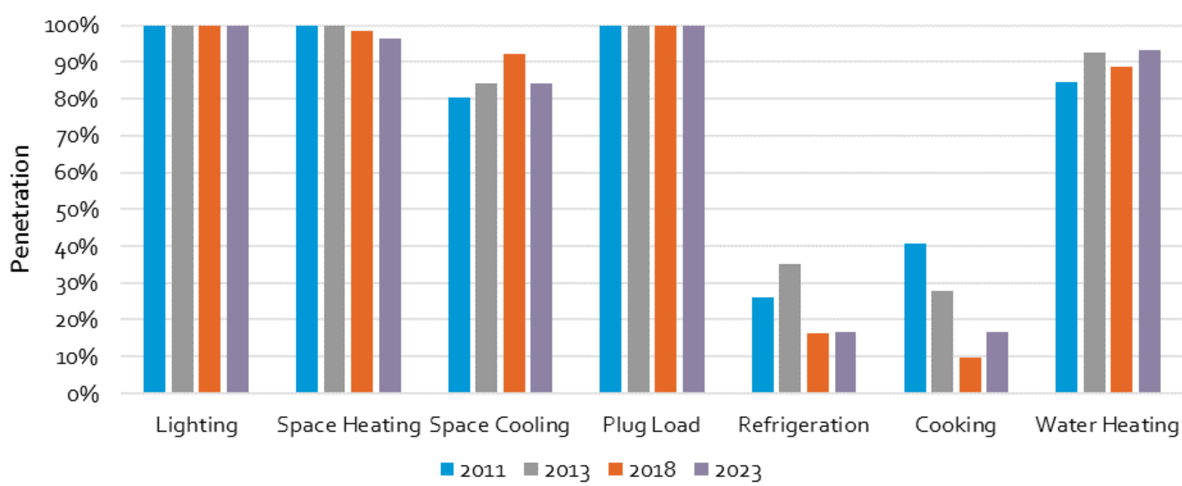
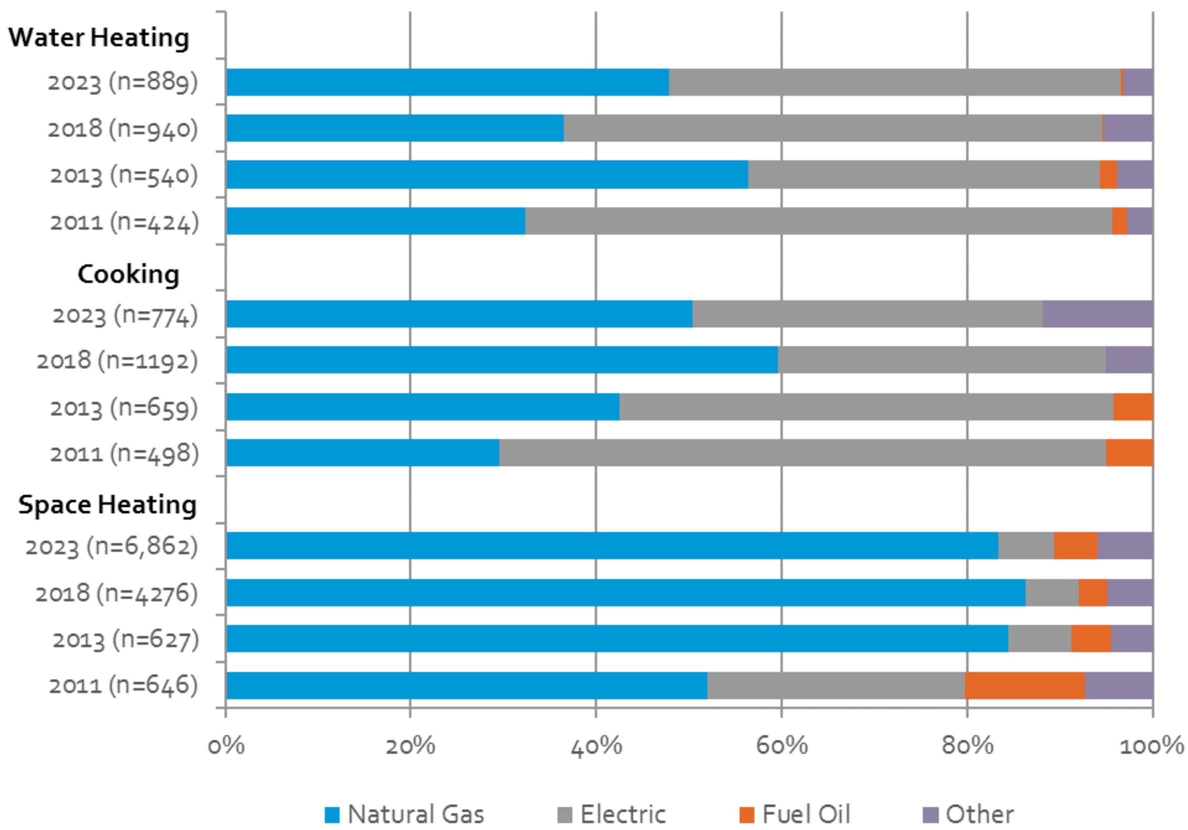


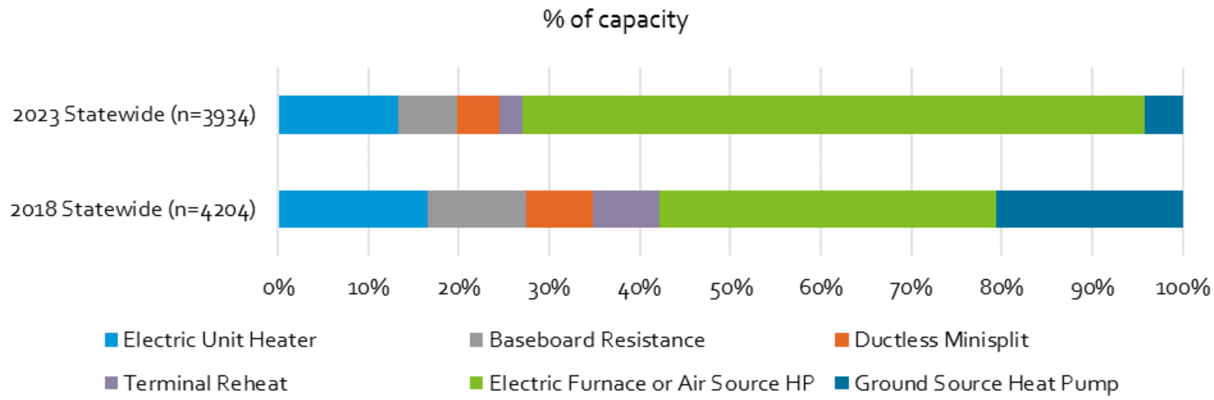
Figure 10 shows how fuel shares have changed for end uses that are often non-electric: water heating, cooking, and space heating. In each of the last three non-residential baseline studies, natural gas has been the dominant fuel for space heating. This study found an almost even split between electricity and natural gas for water heating with 49% and 48% fuel shares respectively. Propane showed an increased share of the cooking end use in this study relative to 2018, accounting for over 10% fuel share in the commercial cooking end use.

Figure 10: Fuel Share Comparison across Studies



As shown in Figure 10, space heating is predominantly powered by fossil fuels in Pennsylvania businesses. This has direct implications for EE&C programming because the Act 129 goals and funding target electricity savings and cannot claim savings from "beneficial electrification" fuel switching measures. Consequently, the equipment shares amongst electric heating equipment are an important planning parameter despite accounting for a limited share of overall heating energy consumption. Figure 11 shows the distribution of electric unitary heating capacity over time. Electric furnaces and air source heat pumps had the largest capacity shares in both studies, and the combined share increased substantially from 37% to 69% of capacity from 2018 to 2023. Electric furnaces and air source heat pumps are two distinct equipment types in the 2023 study, with capacity shares of 43% and 26%, respectively. Capacity shares of electric furnaces, which are among the least efficient electric heating options, are 6% greater in 2023 than the combined shares of electric furnaces and air source heat pumps in 2018. Notably, capacity shares of ground source heat pumps and ductless mini-split heat pumps are lower in the 2023 study than the 2018 baseline study. While EDCs cannot tap into the considerable energy saving potential from fossil fuel space heating in the Commonwealth due to policy constraints, there is clear opportunity to convert inefficient electric heating options (unit heaters, terminal reheat, baseboard resistance, and electric furnace) to more efficient heat pump technologies.

Figure 11: Distribution of Unitary Electric Subtype (by Capacity), 2023 vs. 2018



The most pronounced change in the non-residential sector over the last decade is the rapid growth of LED lighting. Figure 12 shows the change in technologies for each lighting style from 2018 to 2023. LEDs grew from 40% to over 80% of outdoor area/wall pack lighting from 2018 to 2023 (by count). While linear fluorescent bulbs are still common in linear fixtures, LEDs grew from only 20% to roughly 50% of units by 2023. Non-linear styles grew from 40% LED to over 75% LED.

Figure 12: Distribution of Lighting Technologies by Lighting Style

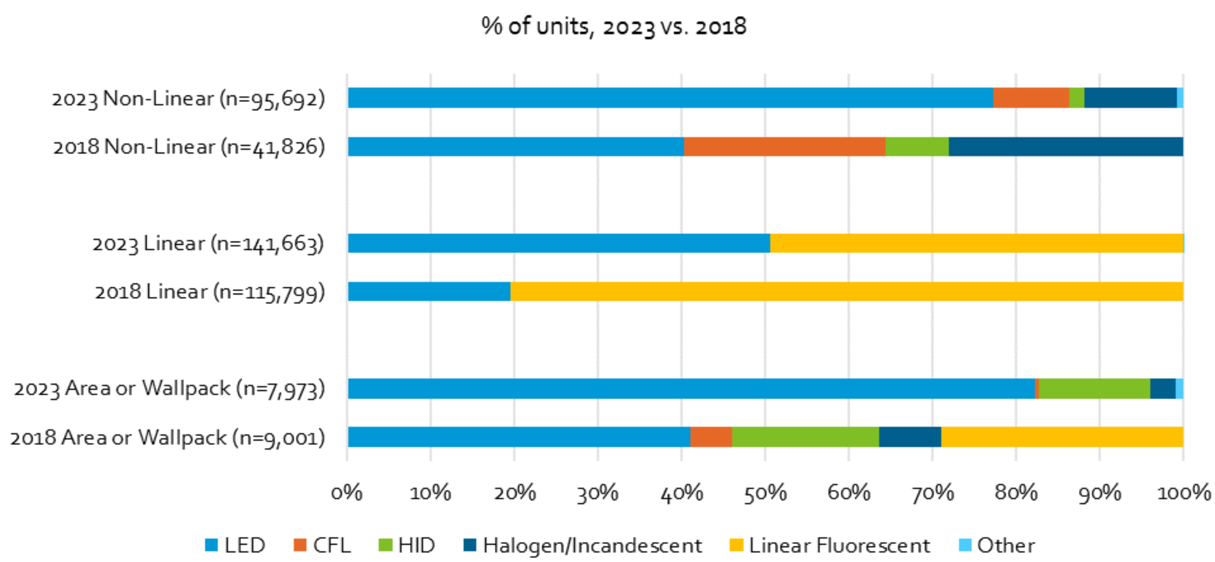
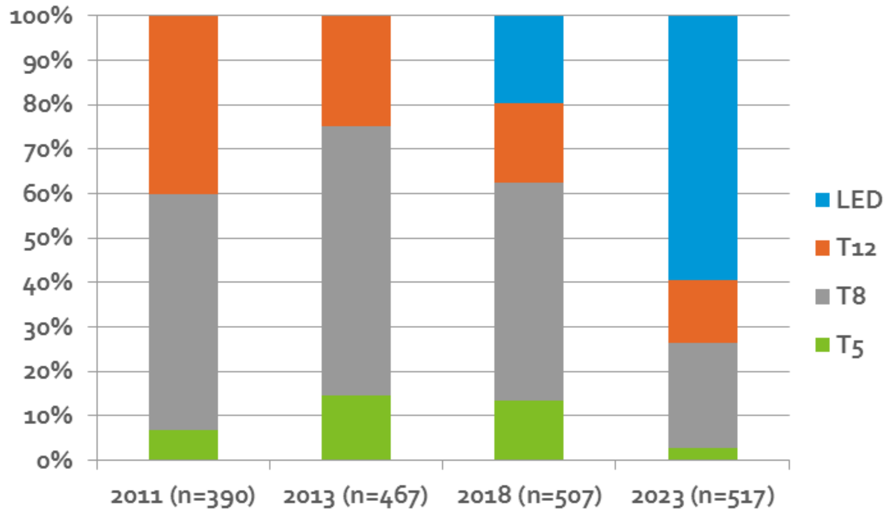


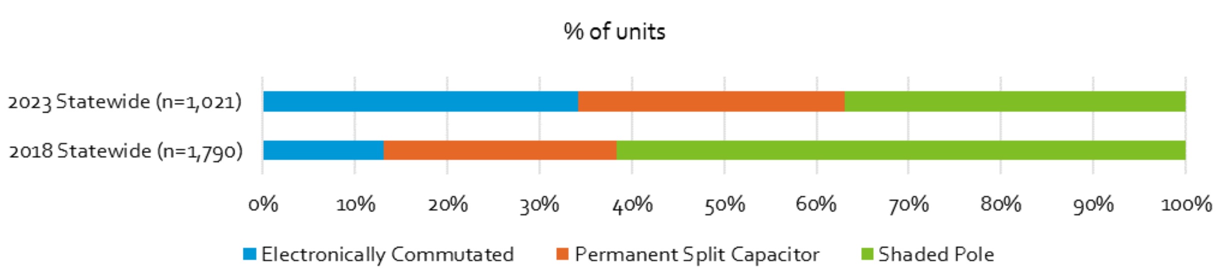
Figure 13 focuses on the linear lighting style that has traditionally been dominated by linear fluorescent lighting. Despite being the least efficient linear fluorescent technology, T12 lighting still accounts for over 14% of units statewide. T12 bulbs are roughly as common in 2023 as 2018, while the share of T8's and T5's has dropped sharply. Clearly, however, the major trend is the growing share of LEDs in linear lighting.

Figure 13: Linear Lighting Technologies, 2011-2023



Another area of notable efficiency improvement was evaporator fan motors in reach-in commercial refrigeration units. Electronically Commutated Motors (ECMs) are required in newer models, and they now make up about one-third of units statewide. Figure 14 shows a clear shift away from Shaded Pole motors, the least efficient option, to ECM fans since 2018.

Figure 14: Evaporator Fan Motor Types, Reach-In Units, 2023 vs. 2018



Like in previous studies, Process was the largest electric end use statewide. Processes are the predominant load in the Industrial segment, which accounts for over 40% of non-residential electric consumption in Pennsylvania. Figure 15 compares the share of capacity by process type between the 2023 and 2018 studies. Process Heating and Cooking accounted for a much higher share of capacity in the 2023 study, while Pumping showed a decreased share relative to the 2018 study. Metal formation also showed an increased share of process capacity in the 2023 study. Compressed Air, Battery Charger, and Process Ventilation were new process types in the 2023 data collection tool. We caution readers about inferring broader trends from this data as these results are sensitive to the types of large manufacturing facilities sampled. For example, the largest site visited in the 2018 study was a paper mill and the largest site visited in the 2023 study was a steel mill. The pulp/paper and primary metals industries are both incredibly energy intense, but the nature of the loads is different.

Figure 15: Distribution of Process Type (by Capacity), 2023 vs. 2018

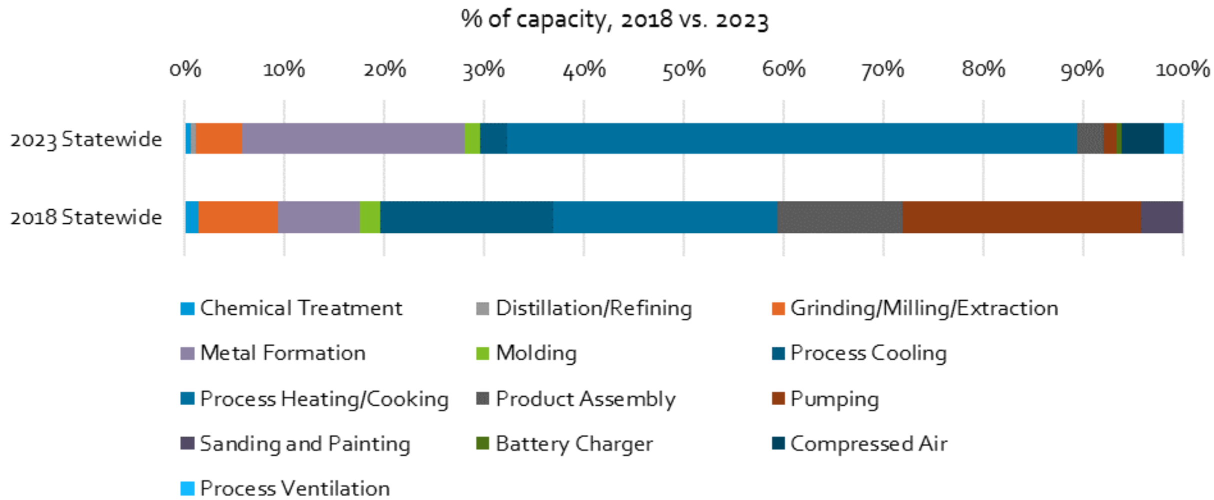
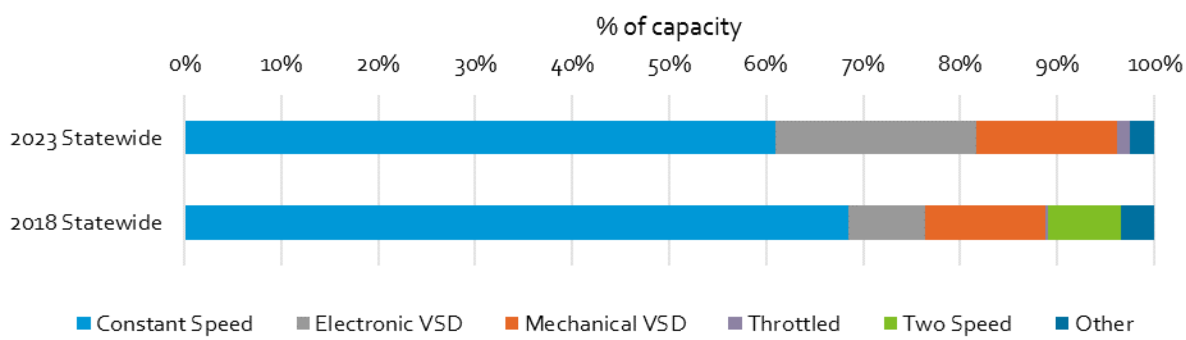


Figure 16 shows the distribution of motor control type over time as a percentage of capacity. The capacity shares of both Electronic Variable Speed Drives (VSD) and Mechanical VSD controls have grown since 2018. Capacity shares of Electronic and Mechanical VSD doubled from 2018 to 2023. Unlike the changes in Figure 15, likely due to variation in industries sampled, we interpret the differences in Figure 16 as a real trend towards variable speed/frequency drives in the Commonwealth's energy intensive motor-driven processes.

Figure 16: Distribution of Motor Control Type (by Capacity), 2023 vs. 2018



2 ELECTRIC CUSTOMERS AND SALES

2.1 SECTORS (LARGE/SMALL)

The Pennsylvania EDCs subject to Act 129 generally divide non-residential customers into two classes, or *sectors*, for rate-making purposes and cost recovery of Act 129 program expenditures. The distinction is essentially based on whether the site receives primary or secondary service from the utility: 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, volumetric electric rates for the Small C&I class are higher, while customers in the Large C&I class use substantially more energy. However, there is no direct division between the two sectors based on annual kWh or peak demand. Some sites use a large amount of kWh via secondary service, but they are included in rate classes with smaller sites that are treated differently for Act 129 programs. Some sites also have multiple meters in different rate classes—for sites with at least one meter receiving primary service, we classify the entire site as Large C&I. This definition of sectors is consistent with the 2018 Non-Residential Baseline Study.

Separation of non-residential customers by primary business activity is accomplished separately through the assignment of industry *segments*, discussed below.

2.2 SEGMENTS (INDUSTRY CLASSIFICATIONS)

A *segment*, or industry group classification, was assigned to all C&I accounts from the seven Pennsylvania Act 129 EDCs. The SWE used these assignments to disaggregate overall electric sales and to target a representative study sample. Separating sites by principal business activity allows us to present separate results for businesses with different energy-use patterns. Many of the results in later sections are reported separately for each segment.

The forthcoming Market Potential Study will incorporate data from each segment. The study will estimate potential energy savings in future program years. The forecast of potential savings and costs will leverage the historical EDC sales and equipment saturations reported here, disaggregated by sector and segment.

2.2.1 SEGMENT DEFINITIONS

All non-residential customers were classified into the segments shown in Table 4 and Table 5. These segments align closely with the Pennsylvania TRM and follow the classifications used in previous baseline studies.

Table 4: Segments Included in Pennsylvania Non-Residential Baseline Studies

Segment	Definition and Examples
Education	Institutions supporting academic studies, including K-12 schools, colleges and libraries, as well as childcare centers.
Grocery	Facilities where perishable food items are sold, generally with large refrigeration loads, including grocery stores, convenience stores, and gas stations. Also includes big-box stores that sell groceries
Health	Institutions that support physical and mental health, including hospitals, medical and dental offices, assisted living centers, and gyms.
Industrial	Facilities that create, process, and refine goods.
Institutional	Government and non-profit facilities, such as town halls, courthouses, federal/state offices, police stations, and emergency services. Also includes municipal water treatment systems, which are extremely energy intense.
Lodging	Facilities offering temporary accommodations, such as hotels, motels, and campgrounds.
Miscellaneous	Other facilities with higher energy usage than traditional offices or retail stores, including personal services (salons, laundromats, dry cleaners, etc.), auto repair, and entertainment (theaters, recreational facilities)
Office	Private offices, such as office buildings, law offices, and financial institutions.
Religious	Places of worship, not including church-run schools.
Restaurant	Food service facilities, including full-service and fast-service restaurants, bars, coffee shops, and catering facilities.
Retail	Retail establishments not included in the Grocery or Miscellaneous segments, such as clothing, hardware, electronics, furniture, and sporting goods stores
Warehouse	Facilities for storage, shipping, and wholesale trade, including refrigerated warehouses.

Accounts classified into three additional segments were excluded from the primary data collection elements of the study.

Table 5: Segments Excluded from Pennsylvania Non-Residential Baseline Studies

Segment	Explanation
Master-Metered Multifamily	Multifamily housing units with shared meters. These accounts are on non-residential rate codes, but since the buildings are residential in nature, they are included in the Residential Baseline Study.
Transportation, Communication, & Utilities (TCU)	Accounts that generally do not include buildings, such as electric, water, cable, and phone infrastructure; railroads; pipelines; cell towers; signs; and streetlights. TCU accounts are numerous, making up approximately one-sixth of all non-residential accounts, but are poor candidates for on-site data collection since they tend to be small and unoccupied.
Unclassified	A small percentage of remaining accounts that cannot be assigned to any of the above categories using available data.

These three groups were excluded from previous non-residential baseline studies as they are either poor candidates for on-site data collection (TCU), could not be included in a segment to disaggregate results (Unclassified), or fit better in the residential study (Master-Metered Multifamily).

2.2.2 Segment Classification Methods

The SWE received comprehensive data for each EDC's non-residential accounts. The content of the account data varied across EDCs, but generally included the following fields used for classification:

- Customer Name
- Account and premise numbers
- Service Address
- Service Address Coordinates (latitude/longitude)
- Standard Industrial Classification (SIC) Code, North American Industry Classification System (NAIC)S Code, or building type
- Rate Code
- Monthly Billed kWh and peak demand (June 2021 to May 2022)

The SWE also retained data on segment assignments from the 2018 study.

The Pennsylvania EDCs do not maintain comprehensive information on business types for non-residential accounts, so a direct segmentation of accounts was not possible. While the EDC data did contain industry codes for many accounts, these were incomplete and sometimes old or inconsistent.

To supplement, the SWE team used multiple methods to assign segments. Accounts were classified using the methods listed in Table 6.

Table 6: Classification Methods for Segments, Ordered by Hierarchy Used for Classification

Priority	Method	Details
1	**2018 Segments**	▪ For consistency across studies, kept 2018 segments when possible ▪ Needed a consistent account number since 2018 to link data from the previous study
2	**Industry Codes/ Building Types**	▪ SIC/NAICS codes or "building type" variables were included in EDC data for many accounts ▪ Codes/building types assigned to corresponding segments ▪ These codes are the only information on industry/building use from the EDCs. While more complete than in previous studies, some were missing or unreliable
3	**Property Tax Data**	▪ Matched service locations to PA property tax data, which has granular classifications for properties by use/business type ▪ Used meter coordinates (if available) or used a geocoding service to generate coordinates from the service addresses ▪ Distance-matched accounts to nearest record in property tax data ▪ Discarded some unreliable matches (long distance to matched property, accounts with close matches to multiple properties, etc.)
4	**String Classification**	▪ Used accounts already classified by SIC/NAICS codes to generate lists of key words in customer names that commonly match to segments (e.g., "Hospital", "Farm", "Burger", "Courthouse", etc.) ▪ Classified accounts based on one- and two-word combinations that matched to unique segments with high frequencies ▪ Some matches could be inaccurate (e.g., apartments named "Lancaster Farms"), so above strategies were used first ▪ Larger accounts checked for accuracy in #5 below
5	**Manual Classification**	▪ Manually assigned segments via web searches for the largest remaining unclassified accounts ▪ Checked classifications for the largest accounts in each segment ▪ Assigned a common segment to large chains with locations that had different industry codes in the EDC data (e.g., Walmart) ▪ Reclassified some smaller accounts in the survey after site visits (e.g., a warehouse for a manufacturing company, originally classified as Industrial)

Since different methods might yield different classifications for some accounts, segments were assigned by a hierarchy of methods, following the ordering in Table 6 above. Sufficient data for each method varied by account—wherever one classification method was not possible, the next method in the list was then applied. The SWE valued consistency with the 2018 study classification first, followed by direct information from the industry codes/building types.

In some cases, this hierarchy was overridden to improve classifications. This includes any manual re-classifications of large accounts in #5 above. Since more data was available to classify businesses in the 2023 study, 2018 segments were also updated for sites classified into another, common segment by at least two other methods.

Similarly, since some industry codes are inaccurate in the EDC data, segments were updated if another segment was assigned by both the property matching (#3) and string classifications (#4). For example, if a site had an SIC code corresponding to an office for a property manager, but both the property tax data and the company name corresponded to a retail store, then the segment was changed to Retail. Using all these methods, the SWE team minimized the number of unclassified accounts, consequently maximizing the number of accounts in the study and increasing the pool of candidates for primary data collection.

2.3 CUSTOMER COUNTS AND ELECTRIC SALES BY SEGMENT

Table 7 shows segment and EDC breakdowns of total electric sales (MWh) for the 12 months from June 2021 to May 2022. Note that this time span differs from the EIA data reported in Table 1, which covers calendar year 2022 instead. The n-values in column and rows headers indicate the total number of accounts within each segment and EDC.

Table 7: Electric Sales by EDC and Segment (Annual MWh, June 2021 – May 2022)

Segment	PECO (n=166,060)	PPL (n=204,983)	Duquesne (n=60,084)	FE: Met-Ed (n=67,329)	FE: Penelec (n=83,880)	FE: Penn Power (n=21,433)	FE: West Penn (n=96,465)	Statewide (n=700,234)
Education (n=14,122)	2,420,666	1,250,117	1,006,179	465,553	523,480	103,246	754,363	*6,523,605*
Grocery (n=10,990)	888,661	1,042,533	308,654	310,240	393,215	82,325	380,406	*3,406,035*
Health (n=22,090)	1,860,313	1,483,791	907,992	402,655	506,662	97,190	437,228	*5,695,831*
Industrial (n=63,070)	4,186,822	9,489,031	2,731,280	4,110,805	4,482,963	1,634,654	6,788,053	*33,423,608*
Institutional (n=49,489)	2,025,008	1,151,605	677,094	324,060	485,487	108,498	599,122	*5,370,873*
Lodging (n=10,528)	359,934	461,931	100,668	98,662	94,886	34,093	239,221	*1,389,395*
Miscellaneous (n=82,121)	991,529	874,656	240,873	221,370	229,697	58,475	371,197	*2,987,797*
Office (n=133,499)	4,641,419	1,676,883	1,362,461	576,931	632,709	230,009	458,741	*9,579,153*
Religious (n=21,686)	198,053	207,904	109,992	77,315	63,126	24,481	82,021	*762,891*
Restaurant (n=21,871)	447,521	532,124	233,497	177,932	201,676	60,347	228,904	*1,882,001*
Retail (n=48,822)	910,139	1,038,509	386,582	336,360	315,389	90,861	392,031	*3,469,870*
Warehouse (n=35,212)	1,295,671	1,295,061	251,089	526,494	212,980	68,176	225,171	*3,874,642*
Multifamily (n=40,334)	904,190	304,442	288,508	96,292	100,359	25,083	114,284	*1,833,159*
TCU (n=117,431)	2,090,429	1,383,618	862,701	532,009	487,770	242,288	811,657	*6,410,470*
Unclassified (n=28,969)	329,543	231,604	343,358	7,433	15,723	2,222	40,636	*970,519*
Total Study MWh (n=513,500)	*20,225,737*	*20,504,144*	*8,316,360*	*7,628,376*	*8,142,269*	*2,592,356*	*10,956,459*	*78,365,701*
Total C&I MWh (n=700,234)	*23,549,899*	*22,423,808*	*9,810,927*	*8,264,110*	*8,746,121*	*2,861,949*	*11,923,035*	*87,579,849*

The seven Act 129 EDCs had a combined 87.6 million MWh in C&I sales from June 2021 to May 2022. Of this, 78.4 million MWh falls into the 12 segments included in the non-residential baseline study. For 2023, only 971,000 MWh could not be classified into a segment, much less than in previous studies. These remaining Unclassified accounts are predominantly small accounts, comprising about 1% of sales but 4% of accounts.

Compared to previous years, this study classifies more accounts and MWh into the other two excluded segments, Master-Metered Multifamily and Transportation, Communications & Utilities (TCU). The amount of MWh consumed in these two segments is not trivial but seems to accurately represent their footprint in Pennsylvania's energy use profile. TCU has more accounts than any segment other than Office, with individual meters for each billboard and cell tower across the state. The largest excluded accounts are railroad and pipeline sites in the TCU segment.

Figure 17 graphs each segment's share of total MWh in the study. Industrial accounts for over 40% of sales alone, while Office is the only other segment over 10%. Education (8% of sales), Health (7%), and Institutional (7%) are the next largest. The three smallest segments by sales, Religious, Lodging, and Restaurant, have very specific energy-use profiles, so it is worthwhile to classify them separately rather than combined with larger segments.

Figure 17: Share of EDC Sales by Industry Segment

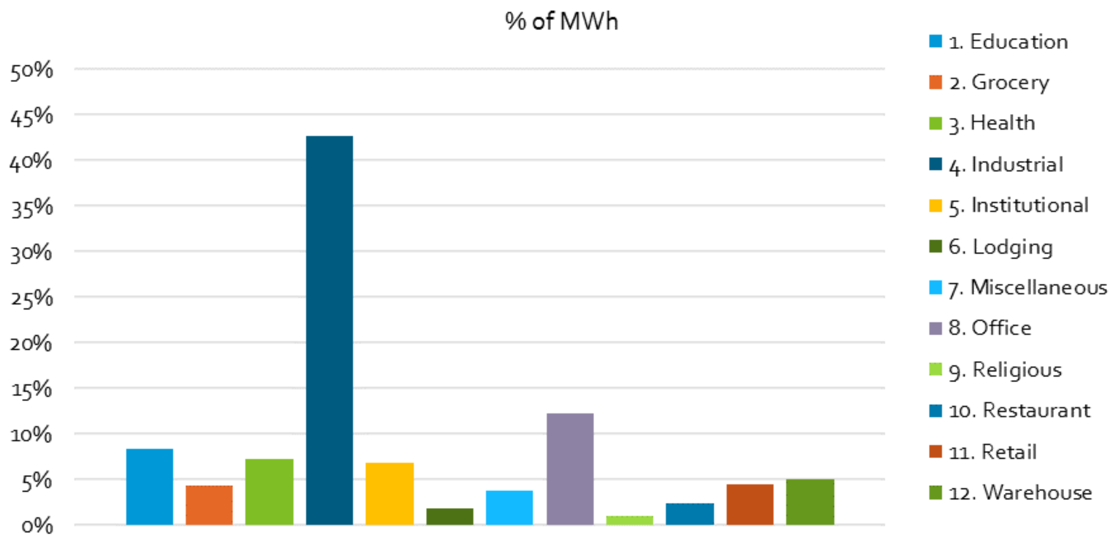
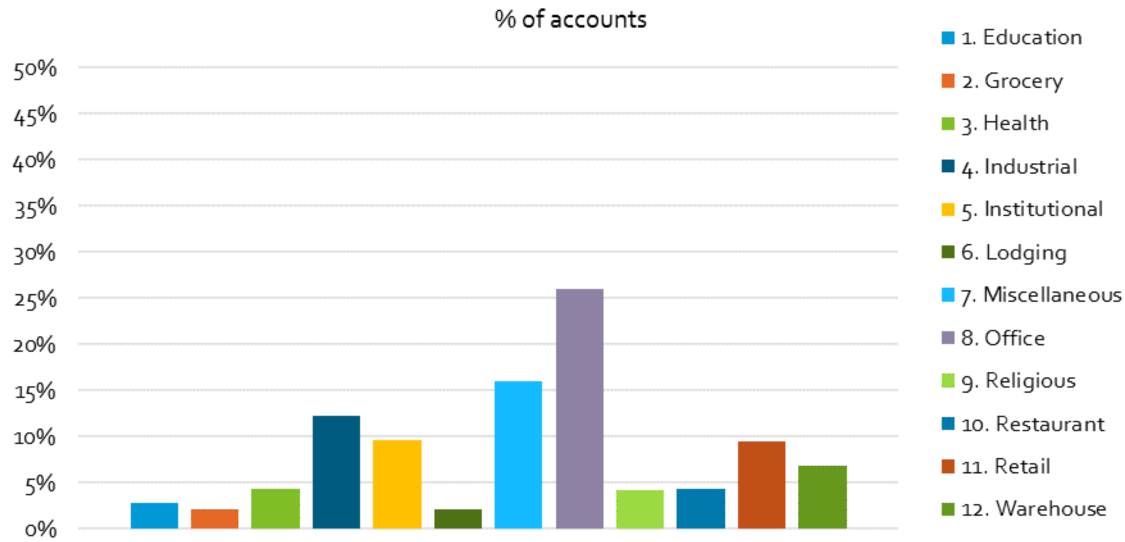


Figure 18: Share of EDC Accounts by Industry Segment

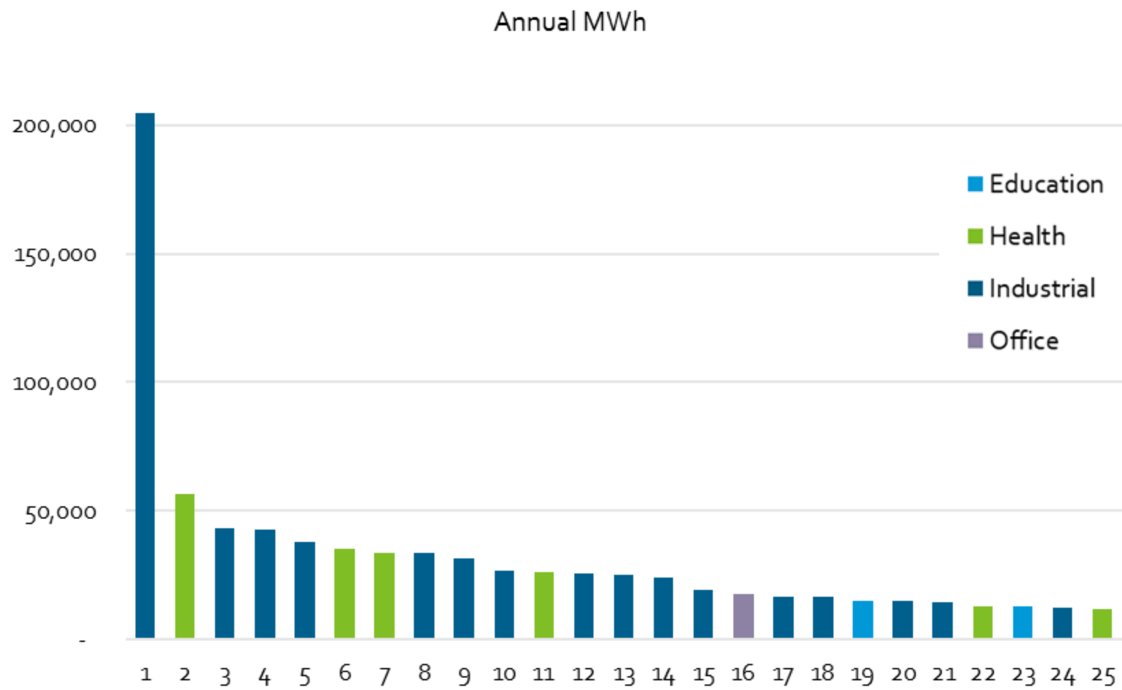


While the Industrial segment makes up a sizable percentage of electric sales, its usage comes from relatively fewer accounts with high MWh per site. As shown in Figure 18, the largest segment by number of accounts is Office, with over 25% of the C&I accounts in the study. However, as they only make up a combined 12% of total sales, these are much smaller accounts by MWh. Business types that fall into the Miscellaneous category make up another 16% of accounts, but only 4% of sales. Industrial (12%), Institutional (10%), and Retail (10%) are the next largest segments in Pennsylvania by number of accounts.

Figure 19 below gives some more context on the largest study sites by segment. The graph shows the 25 largest sites in the SWE's on-site data collection sample, ordered from largest to smallest. Each EDC (not shown) has multiple sites represented in the graph, so these sites can be seen as representative of energy use across the state.

The largest site—a steel mill—uses over 200 million kWh (200,000 MWh) of electricity annually. Overall, 16 of the 25 largest sites in the survey were factories in the Industrial segment, along with six hospitals (Health), two university sites (Education), and an office building (Office). Beyond the 25 sites in the graph, the next largest facilities in the survey by kWh were water treatment plants (Institutional).

Figure 19: Largest Accounts in On-Site Sample by Segment and Annual MWh



2.4 CUSTOMER COUNTS AND ELECTRIC SALES BY SECTOR

Customers in the Large C&I and Small C&I sectors often differ greatly in their energy consumption patterns, as reflected in the different electric rates they each pay. They also differ widely in total usage. As shown in Figure 20 and Table 8, customers in the Large C&I sector comprise just 1% of accounts but represent 64% of annual electric sales. Correspondingly, this means only 36% of sales go to the Small C&I sector, with 99% of the accounts.

Figure 20: Share of EDC Sales and Accounts by Sector

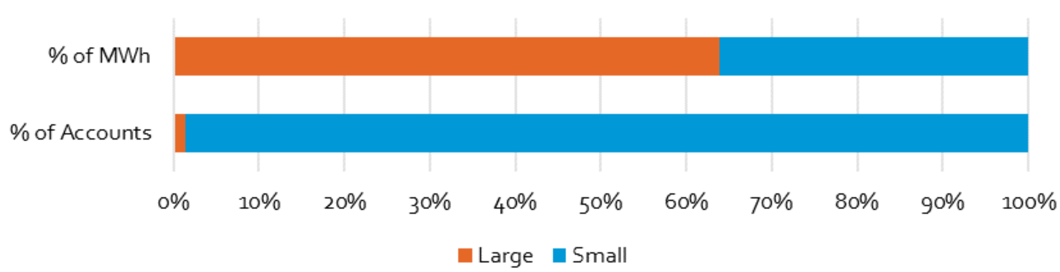
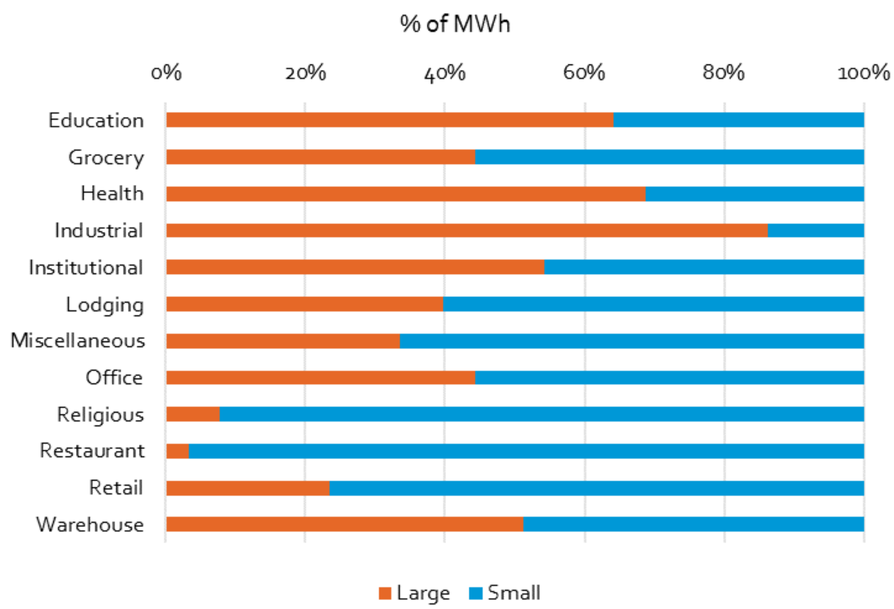


Table 8: Share of EDC Accounts and Electric Sales by Sector

Sector	Accounts	Electric Sales, June 2021 – May 2022 (MWh)
Small C&I	506,317	28,265,896
Large C&I	7,183	50,099,805

Figure 21 further details the share of sales to each sector across the different industry segments. 86% of Industrial MWh come from Large C&I accounts, driving the statewide total in Figure 20 above. Both Health and Education have a majority of MWh from Large C&I sites as well. On the other end of the spectrum, nearly all the MWh sales in the Religious and Restaurant segments go to Small C&I sites.

Figure 21: Large and Small Sector Shares of Total MWh by Segment



2.5 SAMPLING APPROACH

The Non-Residential Baseline Study sample was designed to provide ±10% precision at the 90% confidence level for each EDC. To meet this objective, roughly 70 sample visits are needed per EDC. Targets for the sample points (site visits) were then allocated across segments and sectors to match their relative shares of consumption and sites in 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).

Recruiting for actual site visits closely matched these targets by segment, sector, and EDC. Table 9 presents the number of sample points by segment and EDC. Each EDC had at least 70 site visits, and each had multiple site visits in nearly every segment. The Industrial segment, with the largest share of sales statewide, also had the most site visits statewide.

Table 9: Sample Points by Segment and EDC

Segment	PECO	PPL	Duquesne	FE: Met-Ed	FE: Penelec	FE: Penn Power	FE: West Penn	State-wide
Education	5	4	6	4	7	6	6	**38**
Grocery	3	9	3	4	2	3	3	**27**
Health	13	4	6	5	5	5	6	**44**
Industrial	2	6	13	11	12	12	13	**69**
Institutional	5	3	7	7	9	10	7	**48**
Lodging	8	3	1	1	4	6	4	**27**
Miscellaneous	6	11	8	6	8	11	12	**62**
Office	8	14	8	8	5	7	7	**57**
Religious	2	3	5	5	2	4	2	**23**
Restaurant	6	4	5	1	6	3	2	**27**
Retail	5	7	6	11	8	9	6	**52**
Warehouse	7	7	3	10	5	5	5	**42**
Total	**70**	**75**	**71**	**73**	**73**	**81**	**73**	**516**

Table 10 lists sample points by segment and sector. While most accounts in every segment are Small C&I, the sampling frequency for the Large C&I sector was much higher to account for its share of sales in each segment. Thus, the Industrial segment had more total site visits in the Large C&I sector than from Small C&I, since 86% of the sales in that segment come from Large C&I sites (see Figure 21 above). Health and Education similarly had many Large-sector site visits (mostly hospitals and universities). The Restaurant and Religious segments, on the other hand, had no Large C&I sites included since nearly all the consumption in those segments comes from the Small C&I sector. The SWE team had great success in recruiting Large C&I sites for the 2023 study, as detailed in the next chapter.

Table 10: Sample Points by Segment and Sector

	Small	Large	Total
Education	22	16	38
Grocery	18	9	27
Health	29	15	44
Industrial	23	46	69
Institutional	40	8	48
Lodging	22	5	27
Miscellaneous	61	1	62
Office	48	9	57
Religious	23	-	23
Restaurant	27	-	27
Retail	50	2	52
Warehouse	33	9	42
Total	**396**	**120**	**516**

3 METHODOLOGY

3.1 RECRUITING AND SCHEDULING

The SWE team reached out to sampled businesses via multiple methods to introduce the study and gather interest in participating in a site visit.

- **A postcard delivered via the United States Postal Service**. Each postcard included a short description of the study, a call to action, and a QR code interested parties could scan to take a short screening survey. Each postcard also contained a unique four-letter access code, which allowed the study team to associate survey responses with specific EDC accounts in the sample. All 45,000 sampled accounts received a postcard since every account has a service address on file with their EDC.

- **An outbound recruiting email**. Each email included a call to action in the subject line and a short description of the study as well as a unique link to the screening survey. One week after the initial email, a reminder email was issued to accounts that did not engage with the initial email. Approximately 60% of sampled accounts, or around 26,000, had email address on file with their EDC; therefore, the number of sample contacts that the team emailed was a subset of the postcard group.

- **Outbound telephone calls**. Following the postcard and email campaign, study recruiters made outbound phone calls to sampled accounts using the telephone number on file with the EDC. Outbound recruiting was concentrated on segments and sectors where inbound interest from the emails and postcards fell short of quotas.

Table 11 summarizes the results of the postcard and email outreach efforts. Statewide, 699 (1.6%) sampled accounts entered the screening survey and 365 (0.8%) volunteered to complete a site visit. Approximately 25% of the accounts who entered the survey did so by scanning a QR code on a postcard and the other 75% entered via an emailed link.

Table 11: Response Rate Summary

EDC	PECO	PPL	DLC	MET	PN	PP	WPP	Total
Total Sample	7,460	6,884	6,927	6,176	5,930	5,660	5,912	44,949
Incompletes	28	54	46	57	48	40	31	304
Disqualified	3	4	5	2	4	6	4	28
Total Entries	65	111	99	93	136	113	82	699
Email Entries	56	83	85	67	104	86	55	536
Postcard Entries	9	28	14	26	32	27	27	163
Interested Completes	34	53	46	34	84	67	47	365
Total Entry Rate	0.9%	1.6%	1.4%	1.5%	2.3%	2.0%	1.4%	1.6%
Total Interested Complete Rate	0.5%	0.8%	0.7%	0.6%	1.4%	1.2%	0.8%	0.8%

Sampled accounts with a managed relationship at the EDC were handled differently to maximize response rates and involve the EDC account managers. Prior to beginning outreach with each EDC, the SWE held a meeting with the key account manager to introduce the study and establish coordination protocols. The details varied slightly by EDC, but in general:

1. EDC account managers reviewed and improved the contact information for managed accounts in the sample. Often the contact information on file with the EDC would be an "accounts payable" email address and phone number. Key account managers provided names and contact information of energy managers, facilities supervisors, and maintenance directors whose role in the organization better aligned with the study objective.
2. Managed accounts received postcards but not bulk emails. Emails were customized and the EDC key account managers were cc'd on the communications to bolster legitimacy.
3. SWE team recruiters de-emphasized the $150 incentive and instead focused on how participating in the baseline study was a unique opportunity to shape the future of Act 129 energy efficiency programs and ensure program offerings met their unique needs.

Table 12 shows the recruiting and data collection timeline of the study.

Table 12: Recruiting and Data Collection Timeline

EDC	Feb Week 2	Feb Week 3	Feb Week 4	March Week 1	March Week 2	March Week 3	March Week 4	April Week 1	April Week 2	April Week 3	April Week 4	MayWeek 1	MayWeek 2	MayWeek 3	MayWeek 4	June Week 1	June Week 2	June Week 3	June Week 4	July Week 1	July Week 2	July Week 3
Duquesne Light	Outreach	Outreach	On-Sites	On-Sites	On-Sites																	
FE: Penn Power				Outreach	Outreach	On-Sites	On-Sites	On-Sites														
FE: Penelec						Outreach	Outreach	On-Sites	On-Sites	On-Sites												
FE: West Penn									Outreach	Outreach	On-Sites	On-Sites	On-Sites									
PPL												Outreach	Outreach	On-Sites	On-Sites	On-Sites						
FE: Met-Ed															Outreach	Outreach	On-Sites	On-Sites	On-Sites			
PECO																		Outreach	Outreach	On-Sites	On-Sites	On-Sites

(light shading)	Outreach
(dark shading)	On-Sites

3.2 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 can create one or more buildings for that site, then, within buildings, record equipment characteristics in a series of screens organized by end use. Engineers create as many different schedules as necessary to capture the hours of operation of the facility. Schedules are then associated with different equipment. The SWE team primarily uses hours-of-operation schedules in the EUI analysis.

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. Table 13 lists and describes the flags. When possible, the field technician resolved these issues based on a review of their notes and photos or a quick follow-up call or email to the site contact.

Table 13: Summary of QAQC Flags

Flag Name	Flag Description
flag_sqft	Lighting spaces square footage is not within 5% of surveyed square footage
flag_lighting	Total building lighting wattage per total square footage not in 0.2 - 2.0 Watts/ square footage range
flag_lighting_location	Disagreement between location of lighting equipment and lighting space. Fixture cannot be an Indoor Application in an Exterior Lighting Space, or an Outdoor Application in an Interior Lighting Space.
flag_ac	Building is set to air conditioned, but none of the underlying lighting spaces are air conditioned; OR building is not set to air conditioned, and > 20% of lighting spaces are air conditioned
flag_heat	Disagreement between stated presence of heating and count of heating units
flag_hefuel	Disagreement between stated type of heating system (e.g., boiler / furnace) and heating fuel
flag_heatpump	Disagreement between presence of heat pump heating and cooling (both or neither system should be heat pump)
flag_hotwater	Disagreement between stated presence of domestic hot water and hot water fixtures (e.g. in bathroom, shower, kitchen)
flag_processmotor	Disagreement between presence of processes and motors
flag_processocap	Process with zero capacity
flag_eui	Site EUI outside segment range. Acceptable range is 25% to 250% of the segment average from the 2018 non-residential baseline, flag not applied to industrial segment
flag_accapacity	Site ac capacity (total tonnage) outside 50% to 150% of expected range (using 1 ton/400 square footage of air-conditioned lighting spaces assumption)
flag_hecapacity	Site heating capacity (total kBTU) outside 30% to 170% of expected range (using 1 kBTU/20 square footage assumption)
flag_missingbldg	No building records for the site
flag_giftcard	For sites with complete status, gift card entry does not contain a 16-digit number
flag_nohotwater	No water heating equipment entered for the site
flag_nofridge	No refrigeration entered for sites in the Grocery or Restaurant segment

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 $150 gift card in exchange for allowing an audit of their facility.

3.3 WEIGHTING

As described above and shown in Table 14, the Small C&I and Large C&I sectors represent very different proportions of statewide electric sales and customer counts. Only approximately 1.4% of non-residential accounts in Pennsylvania are from the Large C&I sector, yet the Large C&I sector accounts for over 60% of the electric consumption. The sampling design for the study attempted to balance these two dimensions by allocating approximately 25% of the sample to the Large C&I sector and the other 75% of site visits to the Small C&I sector. Simply put, we oversampled Large C&I with respect to customer counts and oversampled Small C&I with respect energy consumption. The weighting scheme used for analysis subsequently addressed these unequal selection probabilities.

Table 14: Sample and Population Sales and Counts by Sector

Sector	MWh Sales	Population	Sample MWh	Sample Size
Small	28,966,320	506,317	57,050	396
Large	50,047,304	7,183	1,102,227	120
Total	**79,013,624**	**513,500**	**1,159,277**	**516**

Despite the variation in size across EDCs, sample points were assigned equally to each of the seven EDCs subject to Act 129, with a minimum of 70 completed site visits per EDC. The smallest EDC (Penn Power) ended up with the largest number of completed site visits (n=81). Unlike the 2018 non-residential baseline study, the weighting scheme for this study does not include a weighting component based on EDC size. This means a restaurant in Penn Power service territory is given the same level of influence on the segment, sector, and statewide results as a restaurant in PPL service territory.

Sample points were assigned to larger segments like Industrial and Office getting larger sample sizes than Religious or Lodging. The allocation was not directly proportional so that smaller segments would still have enough sample points to be reported independently.

The weighting approach was designed to correct for this intentional oversampling by sector and segment. This was done by applying a weight corresponding to the share of sales for each of the 24 sector-segment pairs included in the study, as summarized in Table 15. The segment-sector sales share weights were used for most analyses in combination with the case weights described below. The exception was analyses within segments that rely on just the case weights.

Table 15: Weights for Share of Sales (by Segment and Segment)

Segment	Small C&I	Large C&I	Total
Education	3.0%	5.1%	8.1%
Grocery	2.5%	1.9%	4.3%
Health	2.3%	4.8%	7.1%
Industrial	6.1%	37.0%	43.2%
Institutional	3.1%	3.6%	6.7%
Lodging	1.1%	0.7%	1.8%
Miscellaneous	2.6%	1.3%	3.8%
Office	6.9%	5.2%	12.1%
Religious	0.9%	0.1%	1.0%
Restaurant	2.4%	0.1%	2.4%
Retail	3.5%	1.0%	4.5%
Warehouse	2.5%	2.5%	5.0%
Total	**36.7%**	**63.3%**	**100.0%**

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 16, this was done within each sector and segment. 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.

Table 16: Case Weights (by Sector and Segment)

Segment	Large C&I Sector			Small C&I Sector		
	Accounts	Sample	Case Weight	Accounts	Sample	Case Weight
Education	923	16	58	13,199	22	600
Grocery	464	9	52	10,526	18	585
Health	487	15	32	21,603	29	745
Industrial	2,455	46	53	60,615	23	2,635
Institutional	612	8	77	48,877	40	1,222
Lodging	144	5	29	10,384	22	472
Miscellaneous	265	1	265	81,856	61	1,342
Office	1,007	9	112	132,492	48	2,760
Religious	34	0	0	21,652	23	941
Restaurant	36	0	0	21,835	27	809
Retail	323	2	162	48,499	50	970
Warehouse	433	9	48	34,779	33	1,054

The weighting used for all cross-sector analyses in the study was the product of the share of electricity sales weights in Table 15 and the case weights in Table 16. Table 17 shows the normalized weights. It is important to note that the Small C&I sector weights are much larger than the Large C&I weights. This feature is counterbalanced for analyses that focus on counts or capacity because sites from the Large

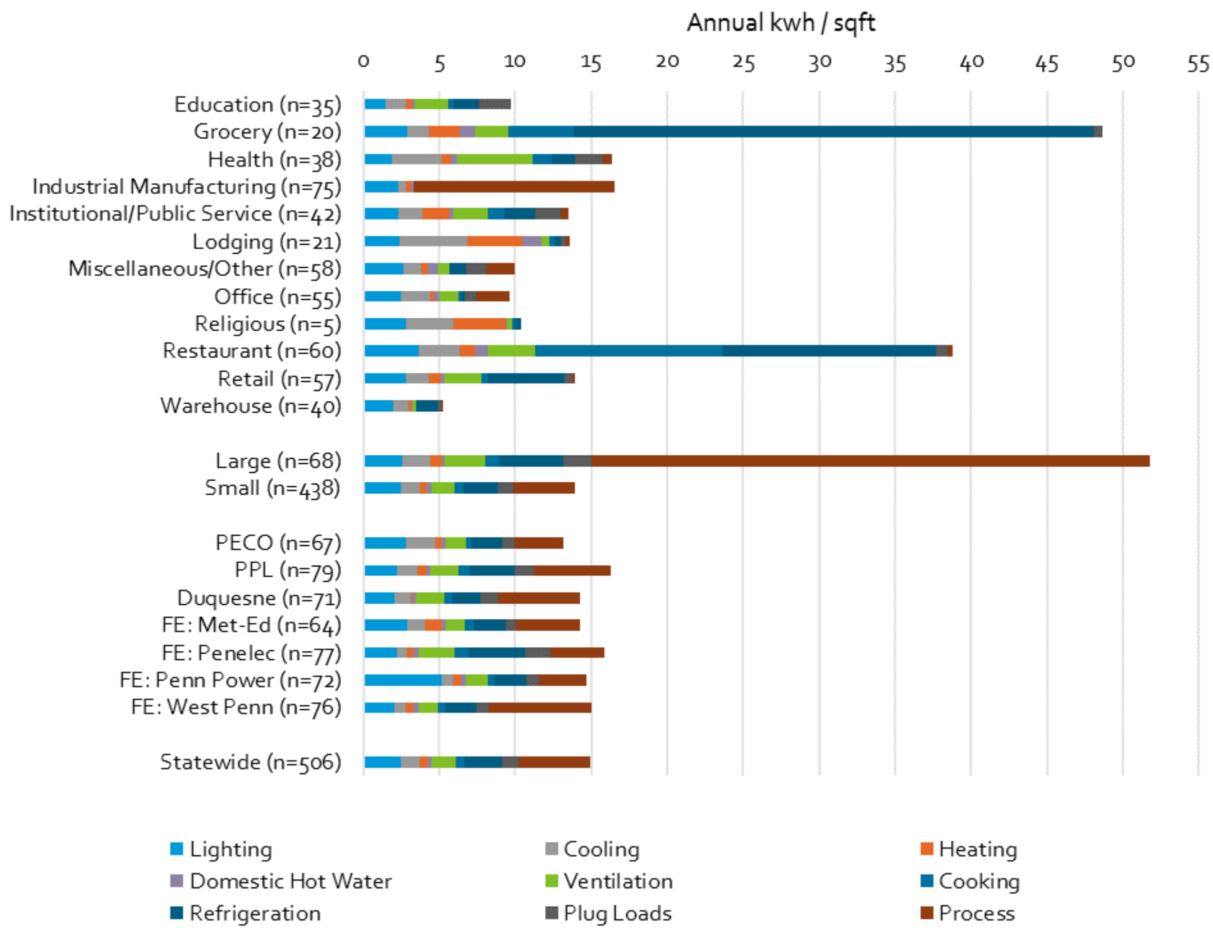
C&I tend to have far more equipment and equipment with larger capacity. Consider the Health segment where Small C&I sample points receive roughly ten times the weight of Large C&I sample points. The 15 Large C&I sample points in the study are all hospitals or medical complexes and average 2,000 tons of cooling capacity. The 29 Small C&I sample points are mostly smaller medical offices and average less than 50 tons of cooling capacity each.

Table 17: Normalized Study Weights

Segment	Small C&I	Large C&I
Education	2.92%	0.49%
Grocery	2.38%	0.16%
Health	2.82%	0.26%
Industrial	26.72%	3.26%
Institutional	6.32%	0.45%
Lodging	0.85%	0.03%
Miscellaneous	5.67%	0.55%
Office	31.32%	0.97%
Religious	1.38%	0.00%
Restaurant	3.15%	0.00%
Retail	5.53%	0.27%
Warehouse	4.30%	0.20%
Total	**93.35%**	**6.65%**

The sales weights shown previously in Table 15 consider total building electric consumption while much of the focus of this report is end-use specific. A sector or segment's contribution to the statewide consumption of a specific end-use can be very different from its contribution to overall electric sales. For example, Restaurants only account for 2.4% of total non-residential electric consumption in Pennsylvania but we would expect their share of the cooking end-use to be much higher. Similarly, the Industrial segment accounts for 43% of total non-residential electric consumption statewide but that is driven largely by manufacturing processes, and we don't expect the Industrial segment to account for nearly 43% of cooling, cooking, or refrigeration consumption in the Commonwealth. To address this phenomenon, the SWE team used the EUI estimates from the 2018 non-residential baseline study to develop end-use specific adjustment factors to the sales weights. Using the end-use EUI values shown in Figure 22, the SWE computed an adjustment factor to the base weights for each segment and end use.

Figure 22: EUI Results from the 2018 Baseline Study for Weighting Adjustments



Equation 1 give the formula for the adjustment factors.

Equation 1: End Use Adjustment Factor

$$Adjustment_{segement,end-use} = \frac{EUI_{segment,end-use} / EUI_{segment,total}}{EUI_{statewide,end-use} / EUI_{statewide,total}}$$

In the 2018 non-residential baseline study, the Education segment had an overall EUI of 9.67 annual kWh per square foot and the lighting EUI was 1.45. The overall non-residential EUI for Pennsylvania was 14.94 with a lighting EUI of 2.48. Plugging these values into Equation 1 returns the values below.

$$\frac{1.45/9.67}{2.48/14.94} = 0.905$$

Figure 23 shows the full array of adjustment factors by end use. The SWE team imposed a ceiling of 5 and a floor of 0.2 on the end use adjustments to prevent limiting the magnitude of this adjustment in either direction. The results follow the expected patterns based on primary business activity. For example, the Grocery segment has a large upward adjustment in the refrigeration weights and Office segment has a large downward adjustment in the refrigeration.

Figure 23: End Use Adjustments to Weights

Segment	Lighting	Cooling	Heating	DHW	Ventilation	Cooking	Refrigeration	Plug Load	Process
Education	0.91	1.71	1.20	0.84	2.08	0.93	1.09	3.05	0.20
Grocery	0.36	0.36	1.27	1.10	0.42	2.30	4.31	0.20	0.20
Health	0.70	2.42	1.10	1.32	2.77	2.05	0.56	1.68	0.20
Industrial	0.83	0.39	0.53	0.54	0.20	0.20	0.20	0.20	2.51
Institutional	1.02	1.42	4.15	0.98	1.51	2.13	0.92	1.83	0.20
Lodging	1.06	4.01	5.00	4.83	0.33	0.67	0.20	0.32	0.20
Miscellaneous	1.60	1.47	1.12	3.40	0.75	0.20	0.63	2.03	0.57
Office	1.52	2.52	0.78	1.64	1.21	0.35	0.21	1.13	0.70
Religious	1.60	3.71	5.00	0.32	0.29	0.40	0.28	0.20	0.20
Restaurant	0.57	0.85	0.80	1.09	0.73	5.00	2.23	0.29	0.20
Retail	1.20	1.33	1.70	1.02	1.60	0.72	2.25	0.54	0.20
Warehouse	2.24	2.42	1.07	0.65	0.49	0.20	1.63	0.72	0.20

3.4 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 18 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:

- 75% of non-residential accounts were observed to have some LED lighting (penetration)
- 50% of non-residential lighting equipment was LED (saturation)

Table 18: 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	$\frac{capacity\ (kW, kBTU, gal)\ with\ feature\ or\ within\ segment}{total\ capacity\ (kW, kBTU, gal)}$	Distribution of equipment technology Fuel share
Floor Space	Distinct Rooms or Spaces	$\frac{square\ feet\ of\ building\ with\ a\ feature\ or\ characteristic}{total\ square\ footage}$	Saturation of cooling or heating as a share of floor space

3.5 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 for sites with 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 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 cafeteria and a gymnasium – and only the cafeteria has commercial cooking equipment, then the site is counted as one site with cooking equipment.

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. Since the guiding recruitment quotas were based on segment and EDC totals, readers should be mindful of distribution of sites by segment within the EDC results. Recruitment for the study occurred west-to-east and only a few Industrial sites were needed to meet quota by the time PECO recruitment occurred. As a result, PECO has comparatively fewer Industrial sample points than Duquesne Light and the FirstEnergy companies.

4 ENERGY USE INTENSITY

4.1 EUI OVERVIEW & METHODOLOGY

Energy use intensity (EUI) quantifies the magnitude of customer energy use, normalized for building size. 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 is also much larger by square footage. This also allows comparison of energy consumption across different end uses. While this study collected equipment inventories regardless of fuel type, this section focuses on the electric EUI of Pennsylvania's businesses.

The study team computed EUI two ways for each site in the study sample.

- **Top-Down EUI** was calculated by dividing each sampled customer's most recent 12 months of billed electric usage by the total interior square footage recorded during the site visit.
- **Bottom-Up EUI** was calculated for each separate end use category based on 1) the capacity and efficiency of the equipment in the site visit inventory, and 2) the operating schedules participants provided to our technicians. These end-use specific EUI's were then summed to estimate the total EUI of the facility.

Top-down values are useful because they represent a ground truth from the EDC meter. Bottom-up calculations require more assumptions but allow for disaggregation of electric consumption across different end uses. This breakdown can then be combined with the segmentation results from Section 2 to disaggregate the Pennsylvania C&I load by end use and business type. This detailed depiction of electricity use over multiple dimensions is a key input to the Phase V Market Potential Studies.

The bottom-up method relies on a series of engineering calculations combining on-site equipment and schedule data. In some cases, these calculations are supplemented with parameters from the Pennsylvania TRM or other industry references. For example, bottom-up estimates for the commercial cooking end use leverage annual kWh estimates by appliance from the ENERGY STAR Commercial Food Savings (CFS) calculator.[3] Average plug load EUIs were applied by segment using data from the 2018 CBECS report.[4] Calculations for the ventilation end use combined TRM hours of use with the observed ratio of ventilation kW per square foot in the sample. Table 19 details the specific methods and calculations used for each end use.

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[3] ENERGY STAR Commercial Food Service (CFS) Calculator. https://www.energystar.gov/partner_resources/energy_star_training_center/commercial_food_service

[4] 2018 Commercial Buildings Energy Consumption Survey (CBECS), Table E6. https://www.eia.gov/consumption/commercial/data/2018/

Table 19: EUI Calculation Methodologies by End Use

End use	EUI Calculation	Input Source(s)
Electric Heating	$\frac{kBTU * \frac{0.293\ kW}{kBTU} * \%\ effic. * ann.hrs.}{building\ sq.ft.}$	▪ Field data collection for capacity and efficiency ▪ PA TRM Equivalent Full Load Hours (EFLH) for runtime by city
Cooling (A/C, Chiller, Heat Pump)	$\frac{tons * \frac{kW}{ton} * annual\ hours}{building\ sq.ft.}$	▪ Field data collection for type, capacity, and efficiency ▪ EFLH for runtime by city ▪ kW/ton values calculated separately for each A/C, heat pump type in TRM
Ventilation	$\frac{\frac{kW}{sq.ft.} * sq.ft. * annual\ hours}{building\ sq.ft.}$	▪ Average kW per sq. ft. calculated from sample ▪ Can be difficult to observe ventilation separate from other HVAC, so ratio applied to all sites ▪ Annual fan hours by sector, segment from PA TRM by city
Domestic Hot Water	$\frac{\frac{GPY}{effic.} * \frac{8.3lb.}{gal.} * \frac{H_2O\ Temp.Diff.}{3{,}412\ Btu/kWh}}{building\ sq.ft.}$	▪ Gallons per year (GPY): Annual gallons per sq. ft. by sector/segment from TRM, field data for % square footage served by electric DHW ▪ Efficiency from field data collection + TRM parameters ▪ TRM parameters for temp. diff.
Lighting	$\frac{qty. * wattage * annual\ hours}{building\ sq.ft.}$	▪ Field data collection (all)

End use	EUI Calculation	Input Source(s)
Commercial Cooking Commercial Refrigeration (Reach-in)	$\frac{Sum\ of\ annual\ kWh\ for\ appliances}{building\ sq.ft.}$	▪ ENERGY STAR CFS Calculator values by appliance
Commercial Refrigeration (Walk-in)	$\frac{kWh\ per\ day * 365}{building\ sq.ft.}$	▪ kWh per day by volume for refrigerators, freezers in PA TRM
Plug Loads	$Average\ EUI\ by\ segment, sector$	▪ CBECS 2018 Table E6 by segment, sector
Processes	$\frac{Process\ kW * annual\ hours}{building\ sq.ft.}$	▪ Field data collection (all)

4.2 EUI VALUES BY SECTOR, SEGMENT, & END USE

Figure 24 reports EUI values by segment and sector, with a statewide average of 14.8 kWh per square foot per year at C&I sites. Industrial accounts used electricity the most intensively on average. These were followed by Grocery stores (with large refrigeration loads) and the much-smaller but energy-intense Restaurant sites. Warehouses, with large square footage, and Religious sites, with fewer hours of use, had the lowest EUIs, consistent with other studies. The Large C&I sector had much higher EUIs than the Small C&I sector, which is not surprising since all Large C&I sites have chosen to take primary electric service from the EDCs.

The EUI values in Figure 24 are net of on-site electric generation. If a site has solar photovoltaics or other behind-the-meter generation, the electricity produced will lower the billed kWh from the EDC. Later in this chapter, Figure 31 shows EUI values with an estimate of on-site generation added back to the billed electric consumption.

Figure 24: 2023 Energy Use Intensity by Segment and Sector

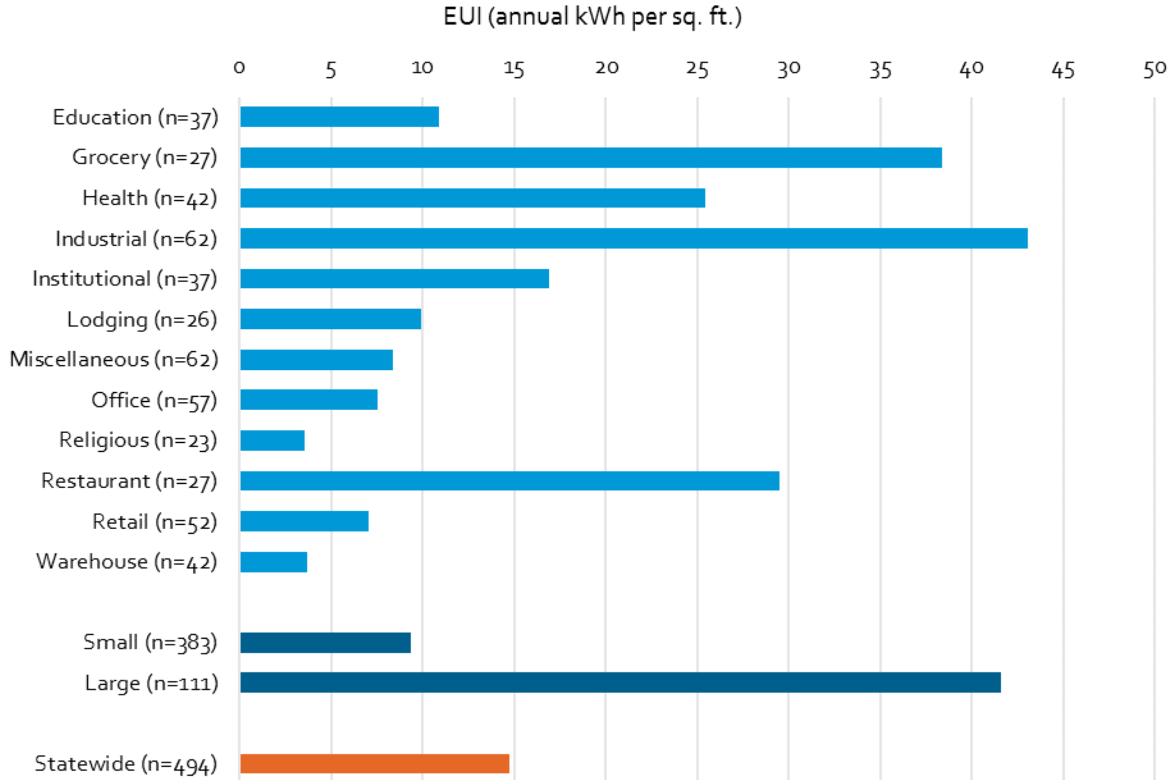


Figure 25 repeats these EUI figures for 2023 but compares them to those of the previous baseline study in 2018. Across most segments and in both sectors, EUI levels have fallen since 2018. The Health and Industrial segment are two notable exceptions, likely due to inclusion of more hospitals and large manufacturing operations in the 2023 sample.

Figure 25: EUI by Segment and Sector for 2018 and 2023

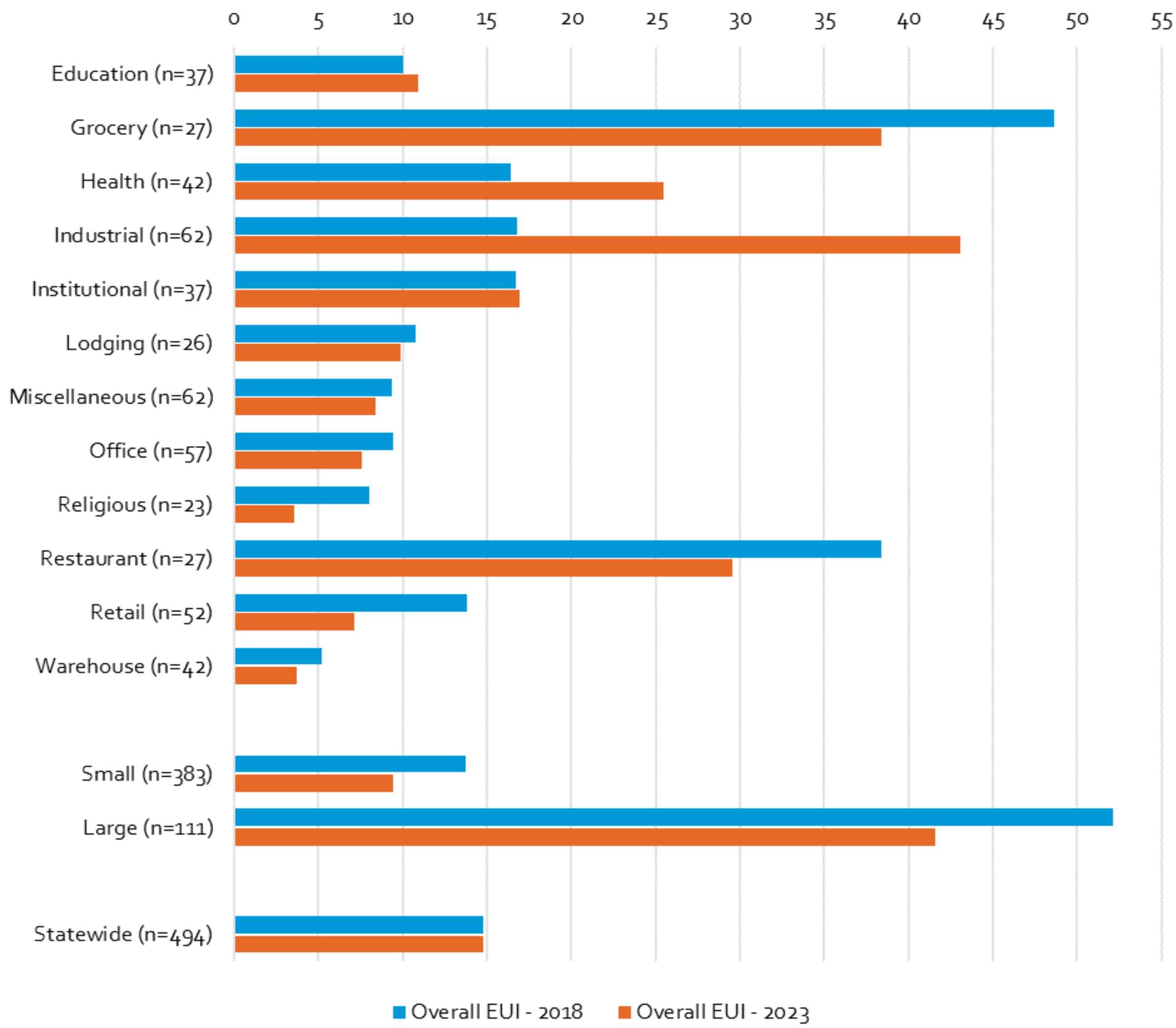


Figure 26 shows the relative magnitudes of EUI by end use. These come from the bottom-up EUI calculations explained above. Since the bottom-up and top-down approaches produced similar results, each site's estimated kWh by end use was scaled to exactly match the total 12-month billed kWh.

Processes, though largely confined to a single segment (Industrial), made up the greatest share of kWh/ft^2 statewide, with an EUI of 5.7. Cooling had the next greatest share followed by ventilation and lighting, as nearly all businesses have some load in those categories.

Figure 26: Statewide EUI by End Use Category

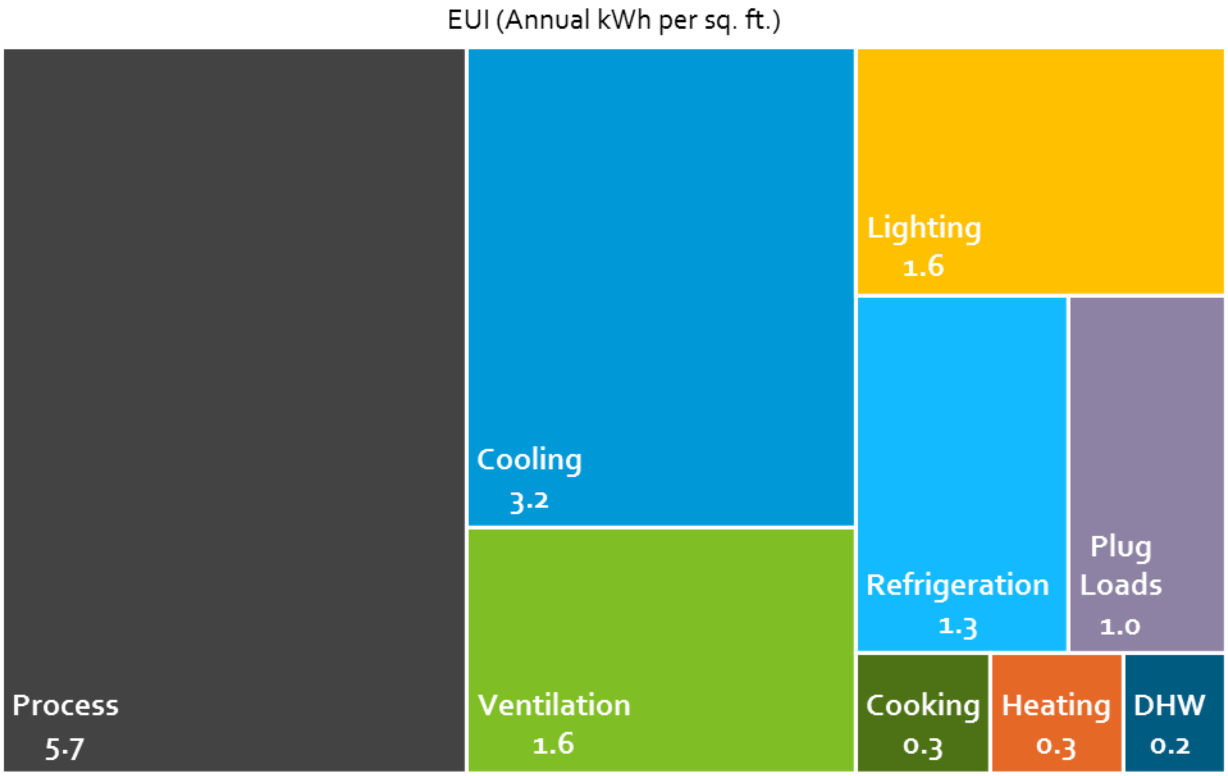


Figure 27 plots stacked end use EUIs for each segment. Notice that on-site generation is included as a negative end use since it lowers the amount of electricity supplied by the EDC. In cases with on-site generation, the sum of the non-generation end uses equals the gross electric consumption within the building. More detail on behind-the-meter generation and gross energy usage can be found in Section 4.5.

The Process EUI in the Industrial segment is the largest single category, making up over two-thirds of the Industrial EUI. Grocery sites, with the second highest EUI, are dominated by refrigeration, but also have large lighting, cooling, and ventilation loads. The refrigeration EUI in the Grocery segment alone is larger than most of the other segments' total EUI. Restaurants, as mentioned, are the smallest sites by average square footage but use energy very intensively in their spaces. While these businesses consume large amounts of natural gas for cooking, they still have the third-highest electric EUI in the study, with high individual EUIs for cooking, refrigeration, and cooling. These sites also have the highest EUI for Domestic Hot Water of any segment.

The Health segment, with many large hospitals, has the next highest EUI, with large Individual EUIs for cooling, ventilation, and lighting, as well as the highest plug load share of any segment. Lodging sites used electricity for heating most intensively, usually via individual units in guest rooms. This finding is a direct result of the Lodging segment showing the highest electric fuel share (34%) for space heating of any segment (shown later in Figure 74).

Figure 27: EUI in Each End Use Category by Segment

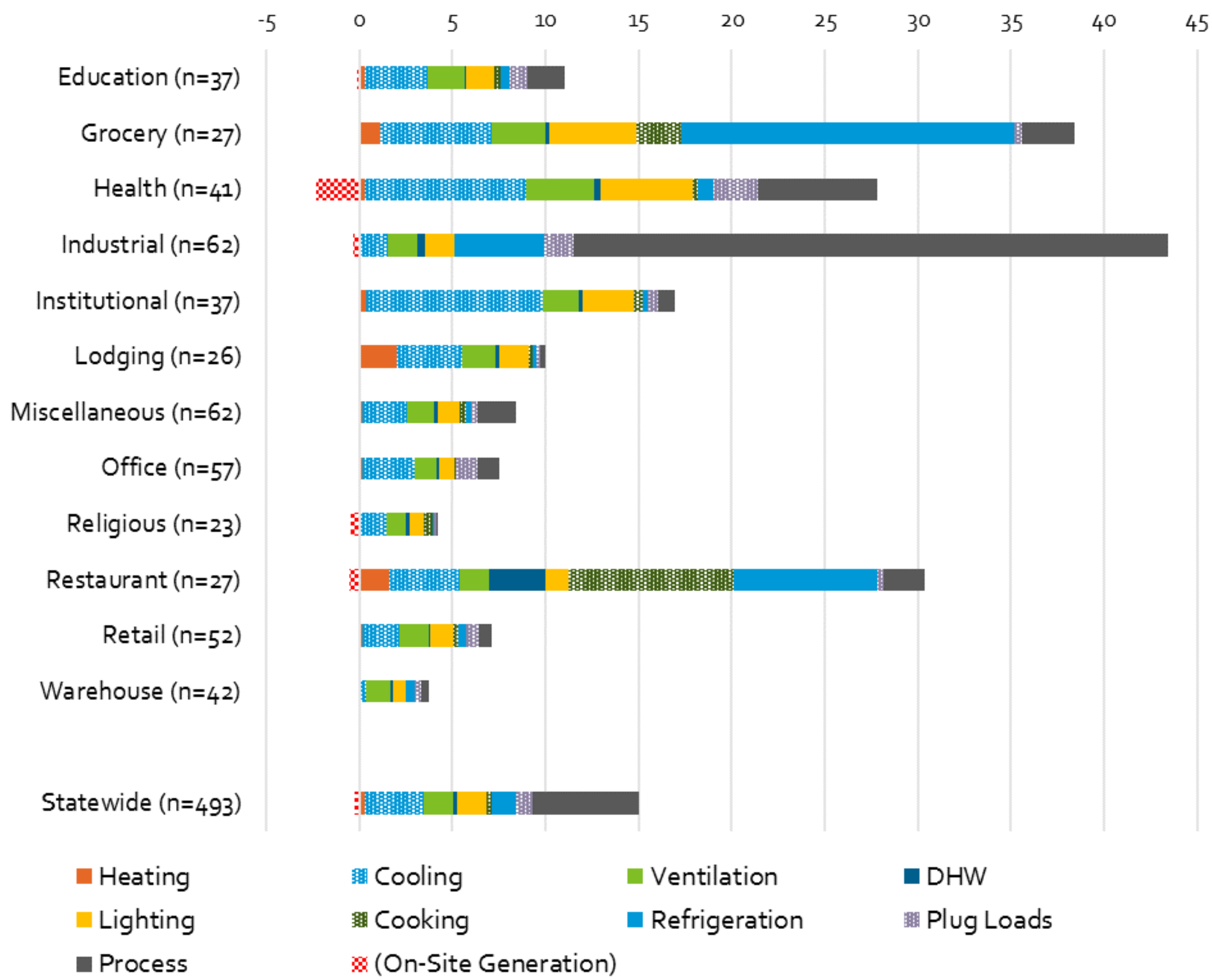
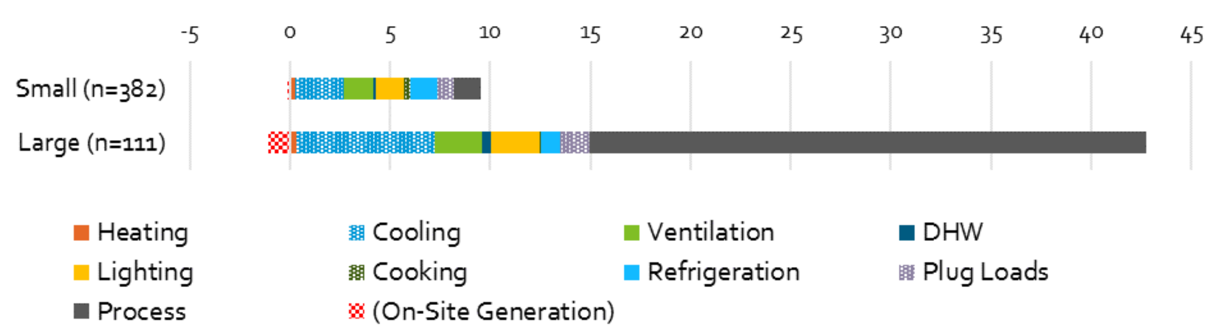


Figure 28 shows each end use EUI for the Large and Small C&I sectors. Large-sector energy use is dominated by Industrial process loads, but these sites also use more kWh per square foot for cooling, ventilation, and lighting. Plug loads, especially from hospitals, make up the next largest share.

Figure 28: EUI in Each End Use Category by Sector



4.3 END USE PENETRATION AND FUEL SHARES

EUI in this study is calculated for electricity only. Therefore, electric fuel shares are implicit in the EUI values by any category. This is important for end uses where gas and electricity are easily substituted, such as heating, cooking, and water heating. Table 20 shows penetration and fuel shares by end use. Ventilation is not included in the table since it was not always observable separate from other HVAC components.

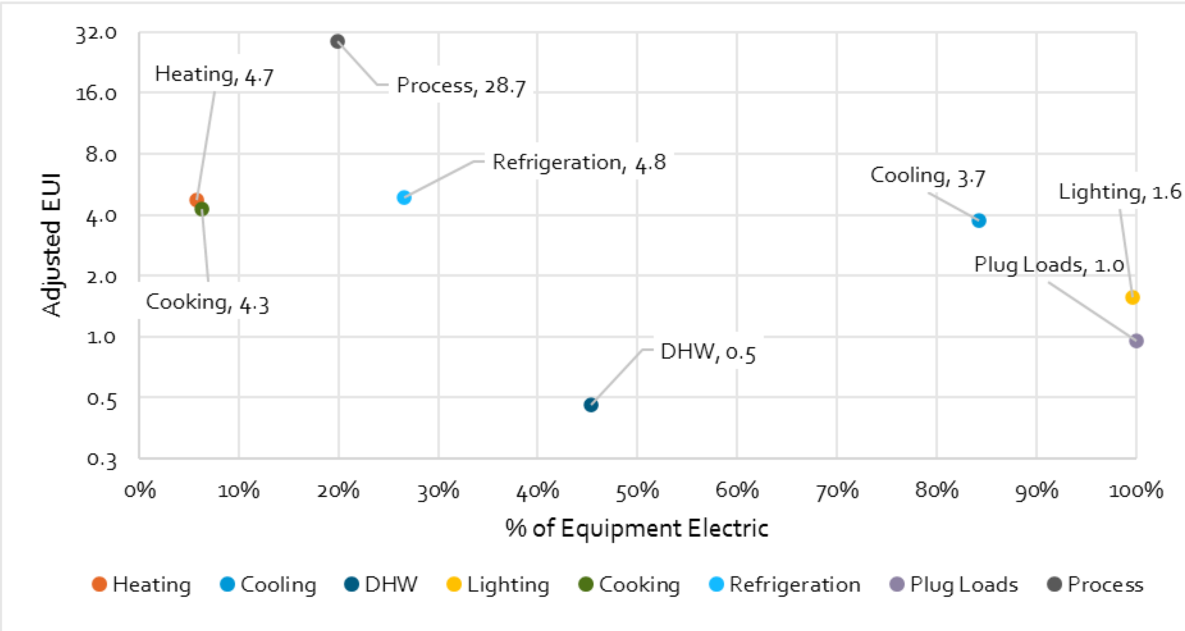
In the table, "Penetration" represents the percentage of sites where the end use is present in any quantity. Cooking and refrigeration are only found in certain business types, while end uses like lighting and plug loads are ubiquitous. "Fuel shares" in the table are the percentage of capacity from each fuel source. Some end uses are exclusively electric, and space heating is mainly gas-powered, with DHW, cooking, and processes falling in between.

Table 20: Non-Residential End Use Penetration and Fuel Shares

End Use	Penetration	Fuel Share			
		Natural Gas	Electric	Propane	Other
Heating	96%	83%	6%	6%	5%
Cooling	83%	0%	100%	0%	0%
DHW	93%	48%	49%	3%	0%
Lighting	100%	0%	100%	0%	0%
Cooking	17%	50%	38%	12%	0%
Refrigeration	27%	0%	100%	0%	0%
Plug Load	100%	0%	100%	0%	0%
Process	42%	52%	47%	0.3%	0%

Figure 29 graphs EUI values that are adjusted by the penetration rates and fuel shares from Table 20. These EUIs can be interpreted as a customer's annual kWh/ ft^2 if they have electric equipment in the given end use category. For example, heating EUI across all C&I customers was only 0.5 kWh/ft^2. However, only 6% of these customers have electric heat. The adjusted figure (4.7), then, is the heating EUI among customers with electric heat.

Figure 29: Non-Residential EUI and Electric End Use Penetration



Some of the electric end use categories with the highest adjusted 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 at most C&I sites (17% penetration) and tends to be fueled by natural gas rather than electricity (38% fuel share for electricity). Processes are extremely energy intense by any measure, but these too are less common (42% penetration) and only about half electric by capacity.

Commercial refrigeration is always electric but rescaling its EUI to reflect the percentage of businesses with refrigerators or freezers (27%) increases its intensity considerably. Cooling, lighting, and plug loads are all very common and 100% electric, so they appear unadjusted in the figure.

The Lighting end use showed an EUI of 2.5 kWh per square foot in the 2018 baseline study. The 36% reduction in EUI in this study is due to the dramatic shift to LED lighting observed in the last five years in the Commonwealth. Section 5 presents detailed findings for the Lighting end use.

4.4 EUI AND BUILDING SIZES

Since EUI is calculated as energy usage per square foot of building area, the EUI values from the sample can be applied to statewide electric sales to estimate total C&I building square footage for Pennsylvania, as well as by segment and sector. This is shown in Table 21, where total sales in each category, as reported in Chapter 2, are divided by the EUI to estimate the total building stock in the second column.

While the sales across study segments and sectors sum to the statewide total of 78,366 GWh, the building stock estimates for each category set may not add up exactly to the statewide estimate of 5.4

billion square feet. This occurs to the extent that the customers sampled are not perfectly representative of customers across the state. Total building stock in the Large C&I sector, for example, can be difficult to estimate since there are few of these customers and they vary widely in building square footage and energy intensity. That said, building stock totals for EDC and segment are relatively close to the statewide estimate, indicating that the sample is still representative of the state.

Table 21: Building Stock (by Segment, Sector, EDC)

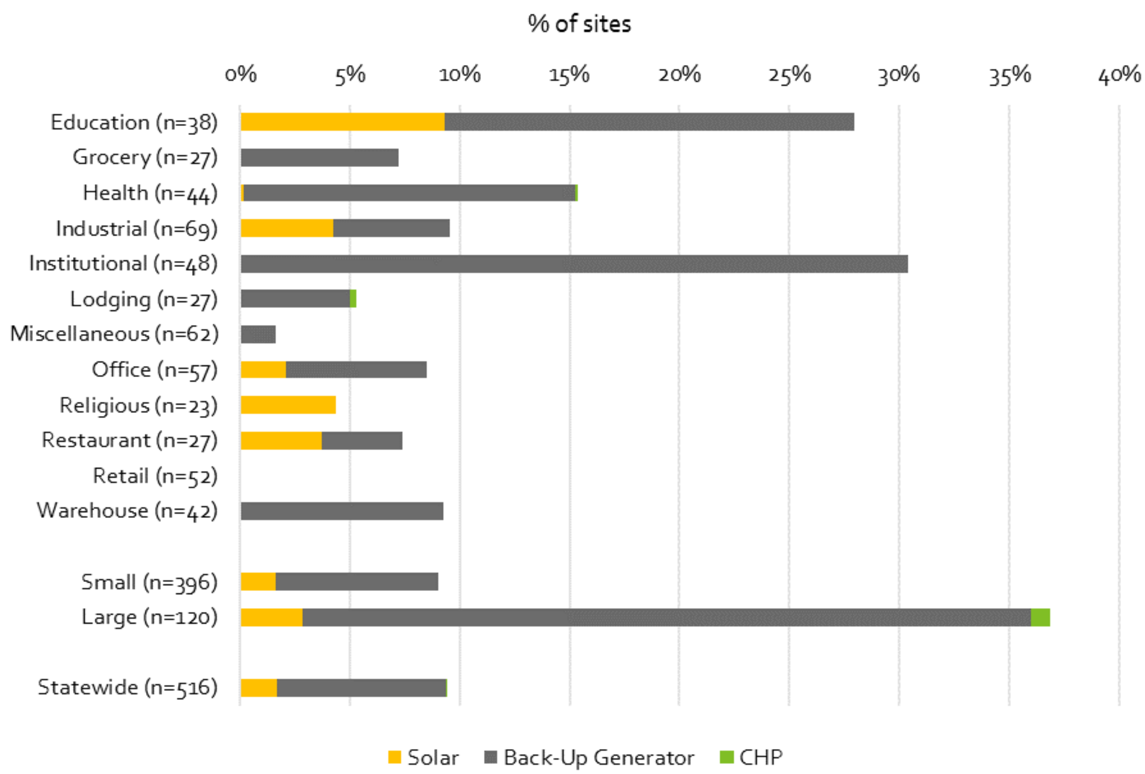
Category	Estimated Building Stock (1,000's ft²)	Consumption (GWh)	Share of Electric Sales
Education	599,891	6,524	8%
Grocery	88,699	3,406	4%
Health	223,504	5,696	7%
Industrial	776,457	33,424	43%
Institutional	317,975	5,371	7%
Lodging	140,453	1,389	2%
Miscellaneous	355,914	2,988	4%
Office	1,272,117	9,579	12%
Religious	216,055	763	1%
Restaurant	63,768	1,882	2%
Retail	489,697	3,470	4%
Warehouse	1,049,263	3,875	5%
Small	3,007,689	28,266	36%
Large	1,204,848	50,100	64%
PECO	2,003,702	20,226	26%
PPL	1,524,008	20,504	26%
Duquesne	536,054	8,316	11%
FE: Met-Ed	573,940	7,628	10%
FE: Penelec	1,035,881	8,142	10%
FE: Penn Power	94,233	2,592	3%
FE: West Penn	644,530	10,956	14%
Statewide	**5,314,250**	**78,366**	**100%**

4.5 ON-SITE ELECTRICITY GENERATION

The SWE also recorded data for C&I sites' electric generation equipment and capacities. EUI, as measured by *metered* kWh per square foot, may understate on-site electric consumption for sites with behind-the-meter electric generation. Distributed generation equipment was found at less than 10% of sites and the most common form was infrequently utilized emergency back-up generators. Data on distributed generation should be interpreted with caution here since results are extrapolated from relatively few sites.

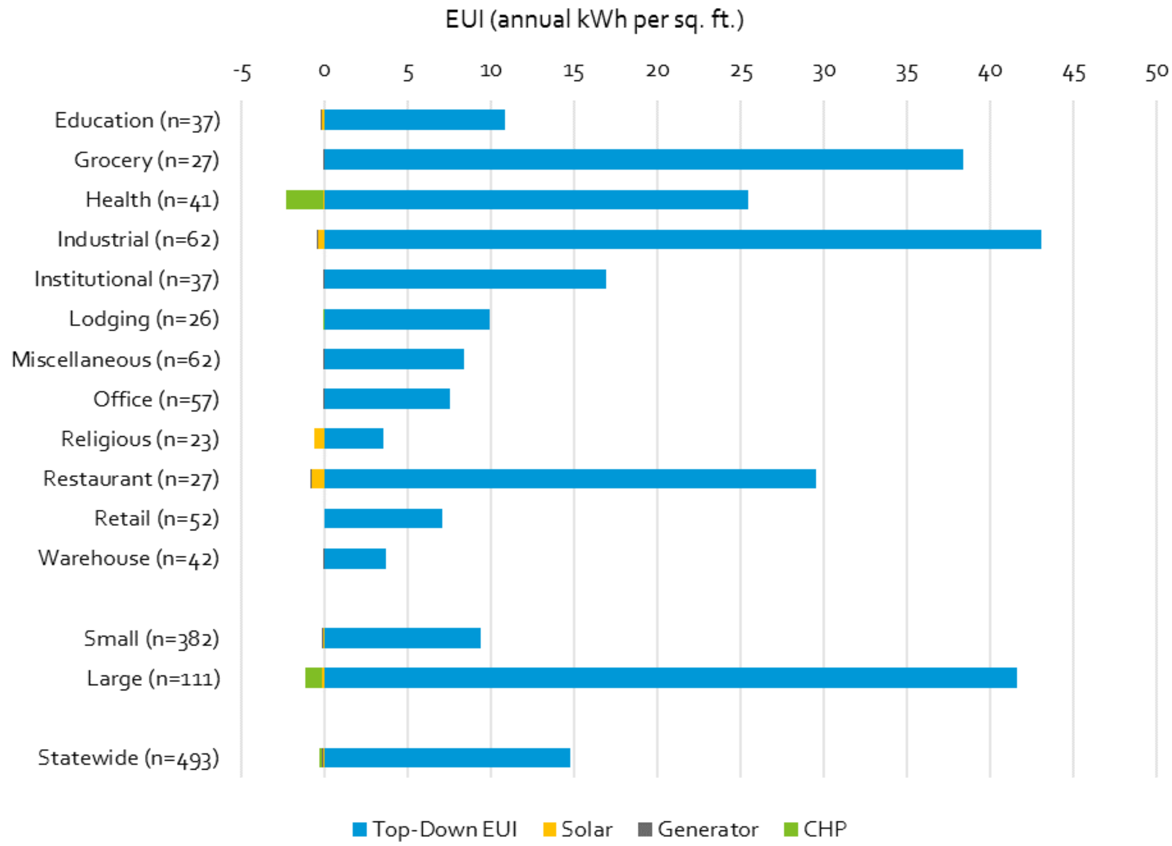
As Figure 30 shows, most C&I sites have little electric generation capacity outside of backup generators. These generators were powered by various fuels (diesel, natural gas, biofuels, etc.), but did not power a significant portion of the buildings' annual load. In addition to the generators, several sites had solar panels, and two had combined heat and power (CHP), including a large hospital.

Figure 30: Percent of Sites with On-Site Generation by Type



While backup generators were more common, the solar and CHP systems produced far more electricity. Figure 31 expresses our estimated on-site generation, by generation type, normalized by building square feet. The top-down EUI is also included to show behind-the-meter generation relative to total electric consumption. One large hospital CHP system accounts for most of the generation in the sample. Several other sites generated significant amounts of electricity via solar panels.

Figure 31: Top-Down EUI and On-Site Generation per Square Foot



As Figure 31 shows, the top-down EUIs reported in this chapter underestimate electrical consumption for C&I customers with significant on-site generation, since they were calculated as a share of total metered usage. For example, after accounting for behind-the-meter CHP output, gross energy usage in the Health segment (27.7 kWh/ft²) is somewhat higher than the top-down calculation (25.5 kWh/ft²). The other segments and the statewide average, however, are largely unaffected by the presence of distributed generation.

5 LIGHTING

5.1 LIGHTING EQUIPMENT OVERVIEW

At each site, field technicians collected a detailed lighting inventory, including details on the lamps, fixtures, and controls. This was supplemented with information on the lighted spaces, buildings, and daily lighting schedule for each. Across several lighting categories, the main finding is a dramatic increase in LED lighting in Pennsylvania businesses since the 2018 study.

Lighting equipment is categorized across three dimensions in this report:

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

Lighting Technology classifies lamps by their means of producing light, such as LED or fluorescent bulbs. Technology classifications can thus be useful indicators of efficiency. For simplicity, some related lamp types are grouped together in the graphs and tables: Mercury Vapor, Metal Halide, and High-Pressure Sodium bulbs are grouped together as "High Intensity Discharge" (HID), while halogen and incandescent bulbs are combined into a single category since they have become less common.

- **LED** (Integrated and TLED)
- **CFL**
- **HID** (Induction, Mercury Vapor, Metal Halide, High Pressure Sodium)
- **Halogen/Incandescent**
- **Linear Fluorescent** (T12, T8, T5)

Lighting Style refers to the type of luminaire housing the technology. Classifications include:

- **High-Bay Linear:** High-bay fixtures with linear fluorescent/TLED tubes or integrated LED panels
- **High-Bay Non-Linear:** HIDs or non-linear LEDs, such as corn cobs
- **Low-Bay Linear:** Same as high-bay linear, but at heights of less than 20 ft.
- **Low-Bay Non-Linear:** CFL, LED, Incandescent, and Halogen lights with integral ballasts as well as pin-based lamps or downlights with separate ballasts in recessed cans
- **Area or Wall Pack:** Outdoor and parking garage lighting

Lighting Application describes the use and location of the lighting fixtures:

- **Outdoor:** All exterior lighting
- **Indoor Screw-Based:** Screw-based equipment in the Low Bay Non-Linear style.
- **Indoor General Service:** All other indoor lighting (including low-bay linear and all high-bay fixtures)

Classifications by Lighting Application align most closely with hours of use and coincidence factor assumptions in the 2021 Pennsylvania TRM. Figure 32 shows examples of common lighting technologies and styles.

Figure 32: Examples of Lighting Classification Categories

Data in this section is generally reported in terms of 1) unit counts or 2) connected load (Watts). Sometimes both are shown to give a broader picture of the results. This is helpful in analyzing LEDs, for example. LEDs are relatively under-represented as a share of connected load since they use fewer input Watts per lumen of output than other technologies. LEDs instead show larger shares in graphs by unit counts. Unit counts thus better represent how common LEDs have become, while connected loads show the share of lighting consumption remaining that can potentially be replaced by LEDs via Act 129 programs.

All unit counts for indoor general service lighting are at the fixture level. This is important with the increased prevalence of integrated LED panels and retrofit kits that consist of a tray, or strips, of diodes rather than traditional lamps. These LED products often replace fixtures that previously held multiple linear fluorescent lamps. For example, an integrated LED panel installed in a 2' x 4' cavity in a ceiling grid is counted as a single unit. If the same location in the ceiling grid housed a three-lamp T8 fixture, that fixture would also be treated as a single lighting unit.

5.2 LIGHTING EQUIPMENT FINDINGS

LED GROWTH

Figure 33 shows LED penetration, measured as the percentage of businesses with any LED lighting, in both 2018 (orange) and 2023 (blue). This is perhaps the most significant trend in energy usage since the 2018 study, with the percentage of sites with LEDs increasing across every category. Statewide, over 80% of businesses now use some amount of LED lighting. Large C&I sites had a higher LED penetration in both studies, with nearly 95% of sites using LEDs in 2023, but even the Small C&I sites have reached over 80% penetration.

Figure 33: Percent of Sites with Any LED Lighting, 2018 and 2023

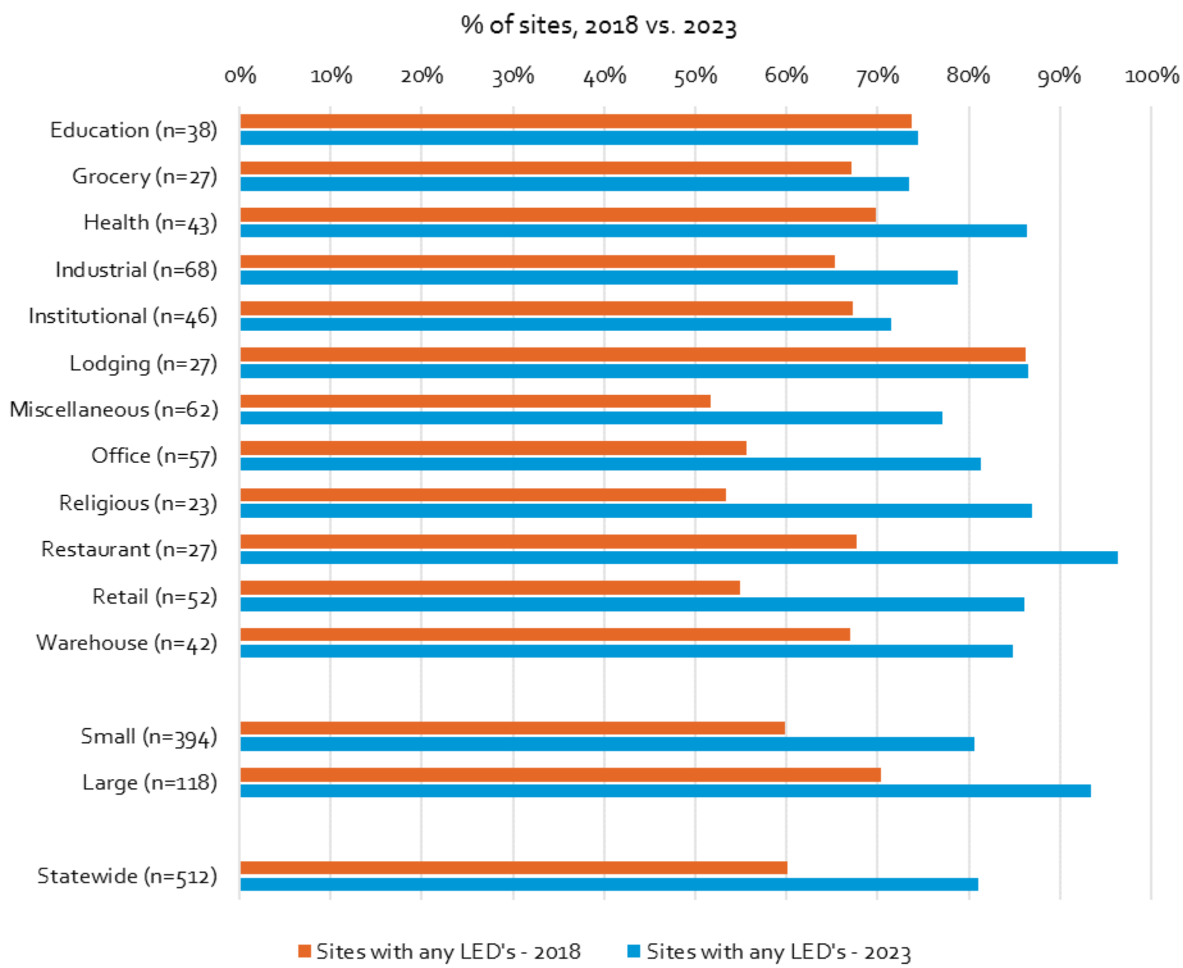
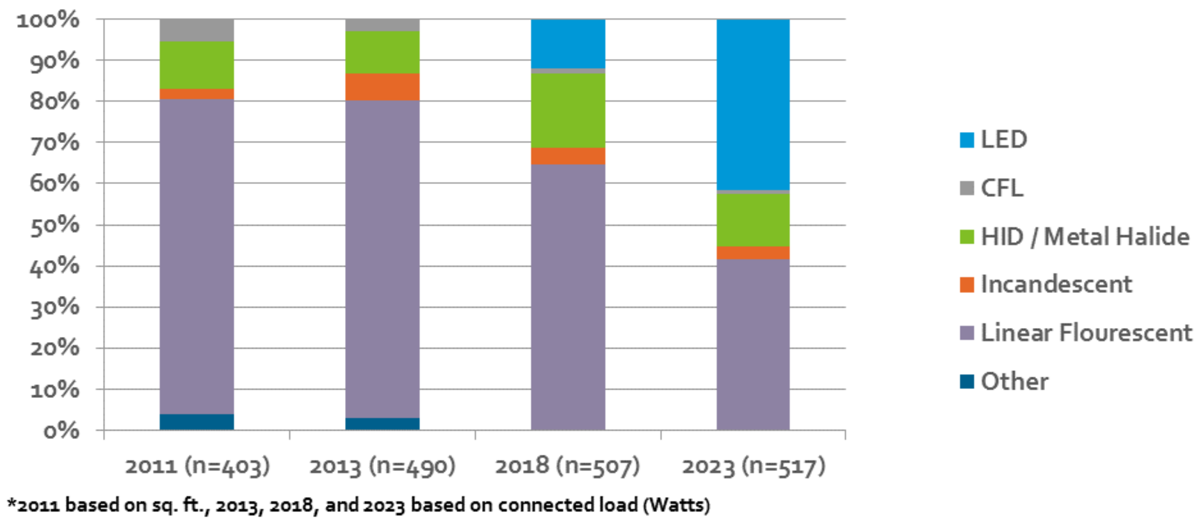


Figure 34 shows a longer time series, with each lighting technology graphed as a percentage of total connected load (Watts). LEDs were essentially non-existent in the earlier studies, but now account for over 40% of the total non-residential lighting wattage. Note that since LED bulbs are the most efficient technology, their 40% share of Watts represents a much larger share of actual lighting units and light created. Linear fluorescent technologies comprised most of the lighting in each of the previous studies.

They are still common in certain applications, but they have increasingly been displaced by TLED bulbs and integrated LED fixtures.

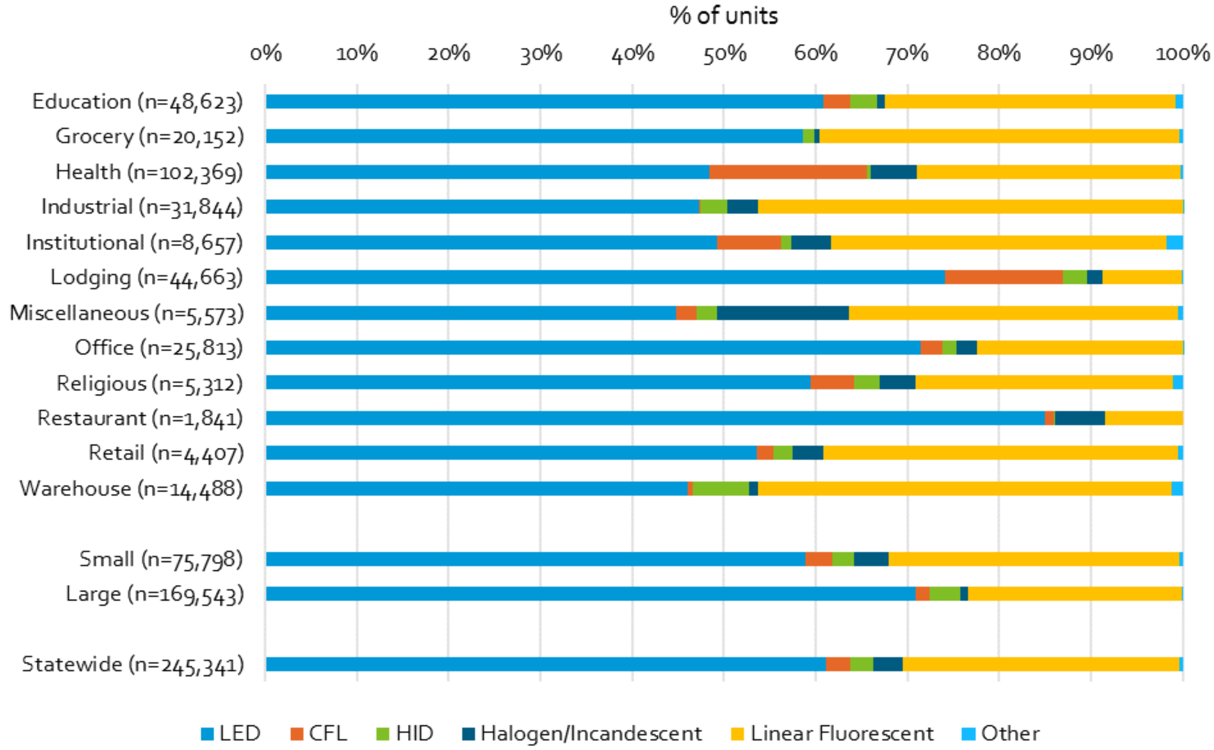
Figure 34: Commercial Lighting Technology, 2011-2023



LIGHTING TECHNOLOGIES

Figure 35 shows the full distribution of lighting technologies in the current study. By unit count, LEDs now make up over 60% of commercial lighting statewide. They are even more common at Large C&I sites, where over 70% of lighting is LED. Linear fluorescent bulbs make up roughly 30% of lighting statewide, with another 10% split between CFL, HID, and halogen/incandescent bulbs.

Figure 35: Lighting Technology (by Count)



As shown in Figure 36, LEDs make up a smaller share of the total wattage statewide. Despite the growth of LEDs, linear fluorescent bulbs still make up the largest share of the lighting load. HID bulbs, though not a large share by count, make up a significant share as measured by Watts (11%) since they use so many Watts per lamp.

Figure 36: Lighting Technology (by Connected Load)

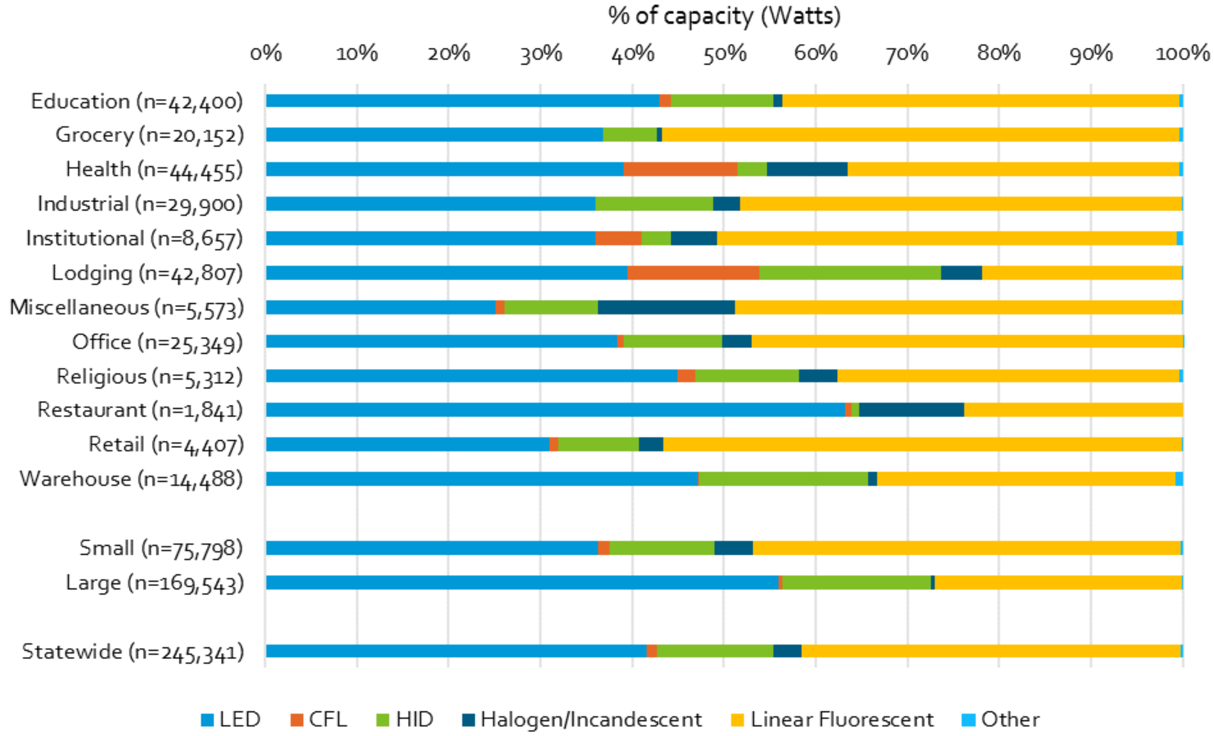


Figure 37 compares the distribution of statewide lighting technologies in 2018 and 2023. While linear fluorescent lighting still accounts for slightly more Watts than LEDs, the LED share has increased dramatically, from 12% in 2018 to 42% in 2023.

Figure 37: Lighting Technology by Connected Load, 2018 and 2023

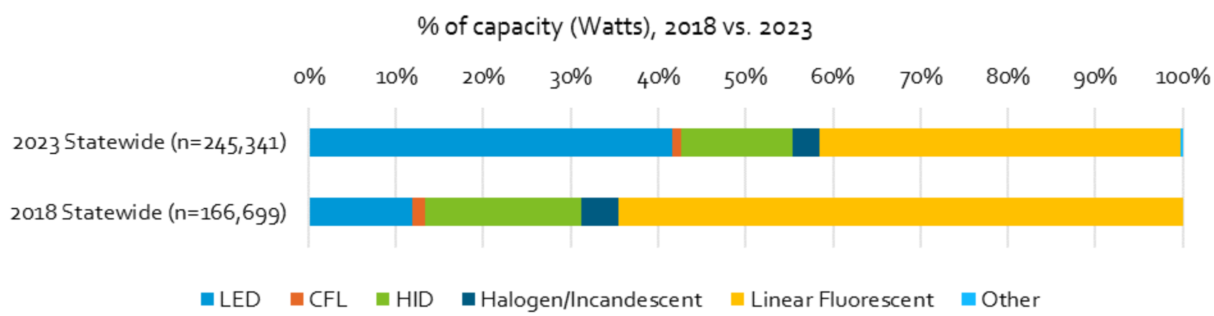


Figure 38 repeats the lighting technology breakdown by unit counts from Figure 35, but for the Low-Bay Non-Linear style only. This style includes residential-style screw-in bulbs and pin-based lighting in recessed cans. In this category, LEDs represent over 75% of lamps statewide. Some CFLs and Halogen or Incandescent bulbs remain, but both have increasingly been displaced by LEDs. Some segments, such as Health, Institutional, and Lodging, appear to have adopted more CFLs previously, which may be replaced more slowly by LED bulbs. Other segments, such as Grocery, Industrial, and Restaurant show essentially no remaining CFLs. As in the previous graphs, LEDs make up an even greater share of lighting in the Large C&I sector.

Figure 38: Lighting Technology in Low-Bay Non-Linear Fixtures (by Count)

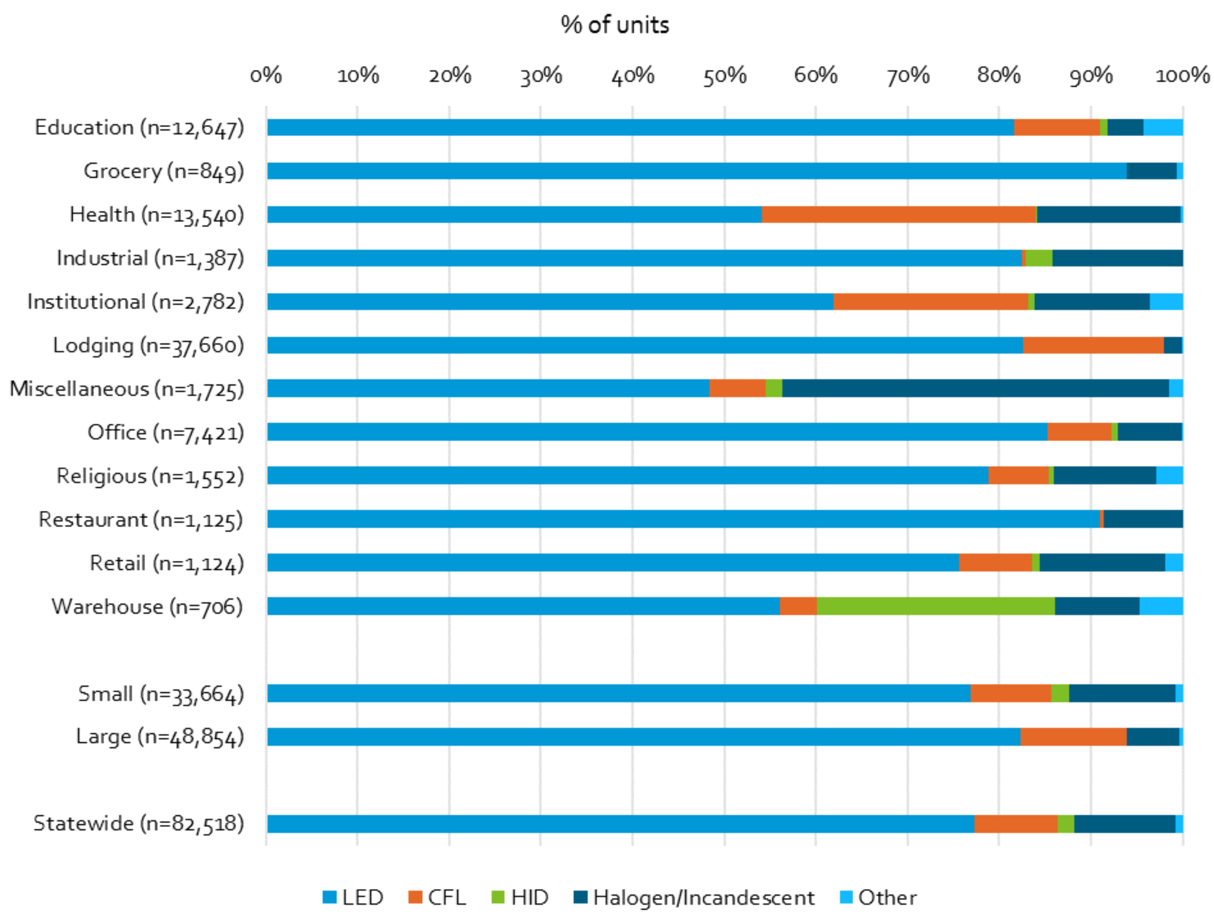
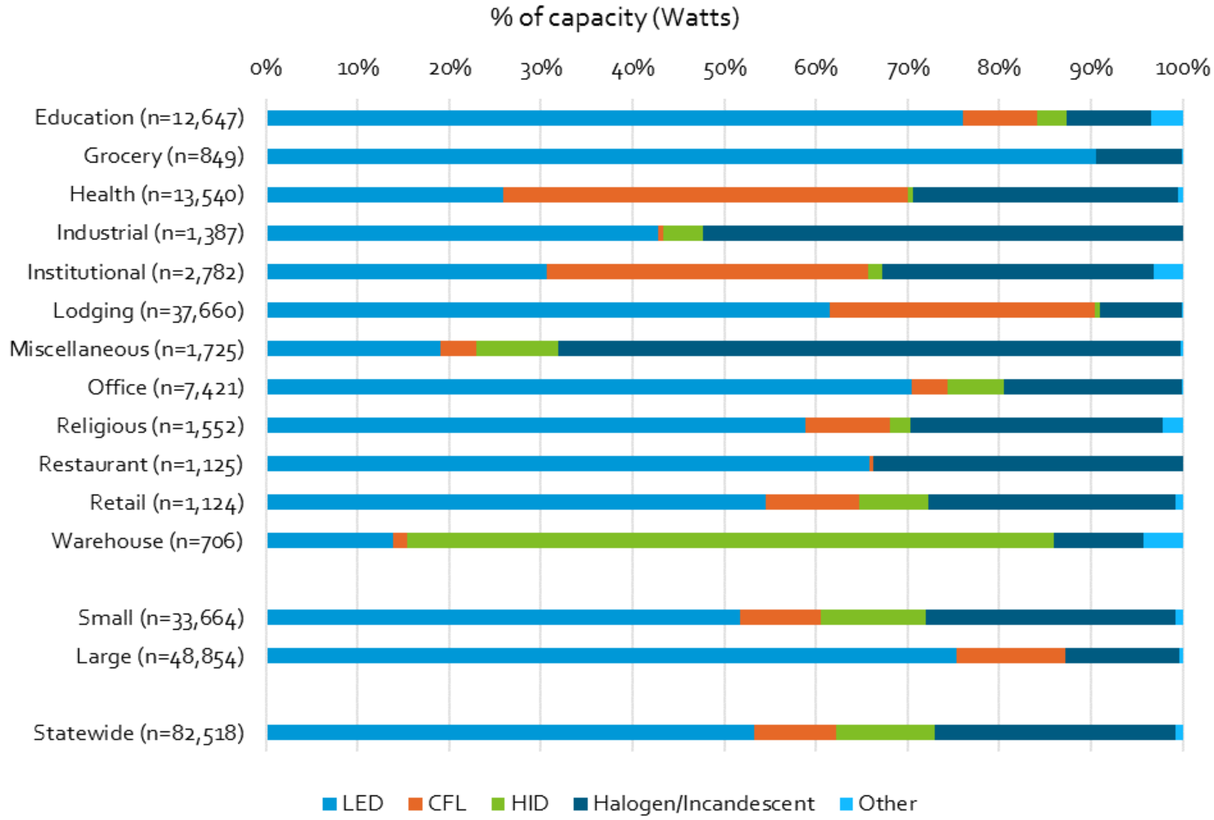


Figure 39 shows lighting technologies in the same application (Low-Bay Non-Linear) by Watts. Here the LED share is somewhat smaller while CFL and HID bulbs make up 10% each. The share of CFLs is larger by Wattage for the Health, Institutional, and Lodging segments, while large HIDs make up the bulk of Wattage for low-bay non-linear fixtures in the Warehouse segment. Halogen/incandescent bulbs still account for over 25% of the wattage in this category, despite only representing 12% of the lighting units.

Figure 39: Lighting Technology in Low-Bay Non-Linear Fixtures (by Connected Load)

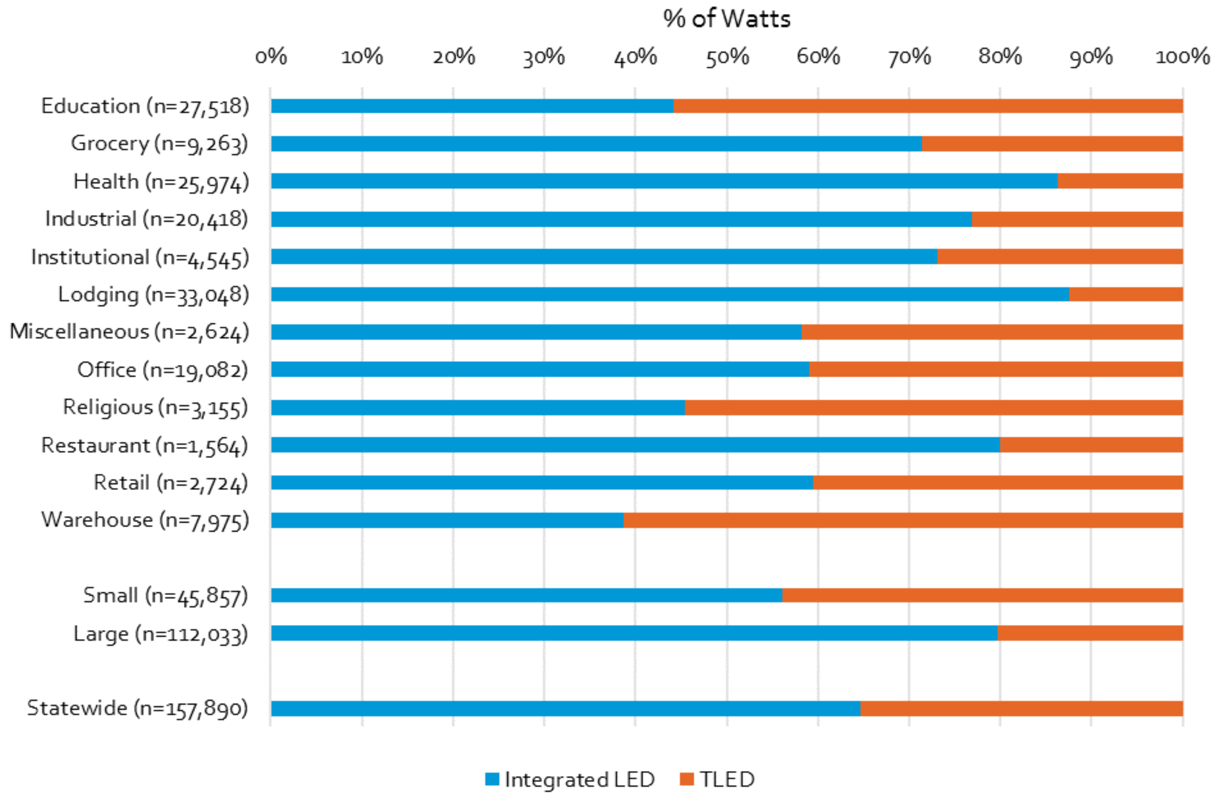


INTEGRATED LEDS AND TLEDS

Since most Pennsylvania businesses' lamps are now LED, data was also collected on the relative shares of integrated LED fixtures and TLED lamps. TLEDs were a popular "first generation" LED product designed for compatibility with existing, ballasted fixtures. Integrated LEDs, on the other hand, are self-ballasted or have a driver that makes them both more durable and more efficient. Since both LED types are very efficient, graphs are shown as shares of connected load to better represent the amount of light produced by each lamp or fixture.

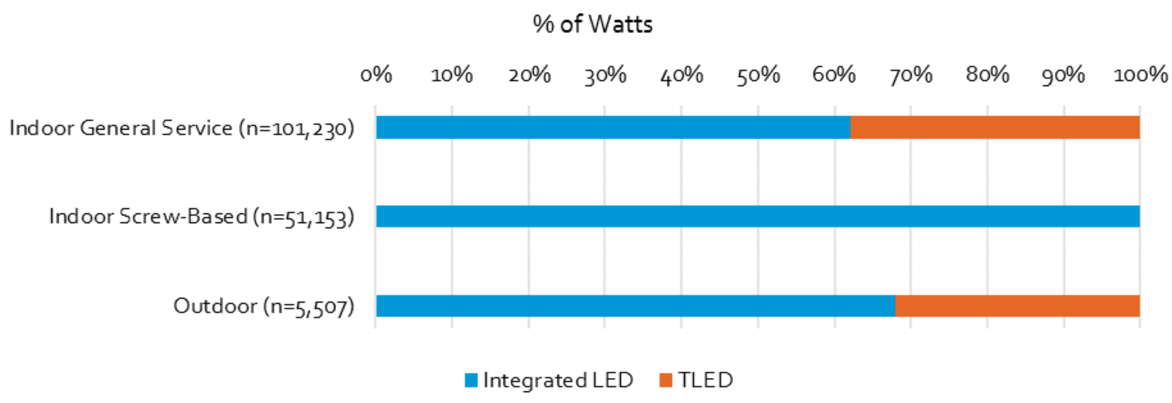
Statewide, about two-thirds of LED units are integrated (Figure 40 below). The Large C&I sector has nearly 80% integrated LEDs. Future Act 129 lighting programs may be able to capture modest savings from conversion of TLED technologies to integrated LED fixtures during Phase V of Act 129 as the first-generation of LED equipment reaches the end of its useful life.

Figure 40: LED Technology Types (by Connected Load)



The Education, Religious, and Warehouse segments have over 50% of their LED load from TLEDs. This is likely driven by the different shares of lighting applications in different building types. Figure 41 shows this breakdown for each lighting application. Indoor screw-based fixtures are self-ballasted and thus only use integrated LEDs. Larger light fixtures can use either technology, however: In general service applications, TLED bulbs can simply plug into existing fixtures, or entire fixtures can be replaced with integrated LED fixtures. Over 60% of the connected load for Indoor General Service is now integrated LEDs. Outdoor LED fixtures are about 67% integrated and 33% TLED.

Figure 41: LED Technoology Types by Application (by Connected Load)



LIGHTING APPLICATIONS

Figure 42 shows the distribution of wattage across the three lighting applications. Almost 80% of lighting is Indoor General Service, so that category weighs heavily in the other graphs and figures in this chapter. The Lodging, Health, and Restaurant segments also have significant amounts of Indoor Screw-Based lighting. Outdoor lighting accounts for approximately 7% of lighting load statewide excluding streetlighting, which falls in the excluded TCU segment.

Figure 42: Lighting Application by Watts

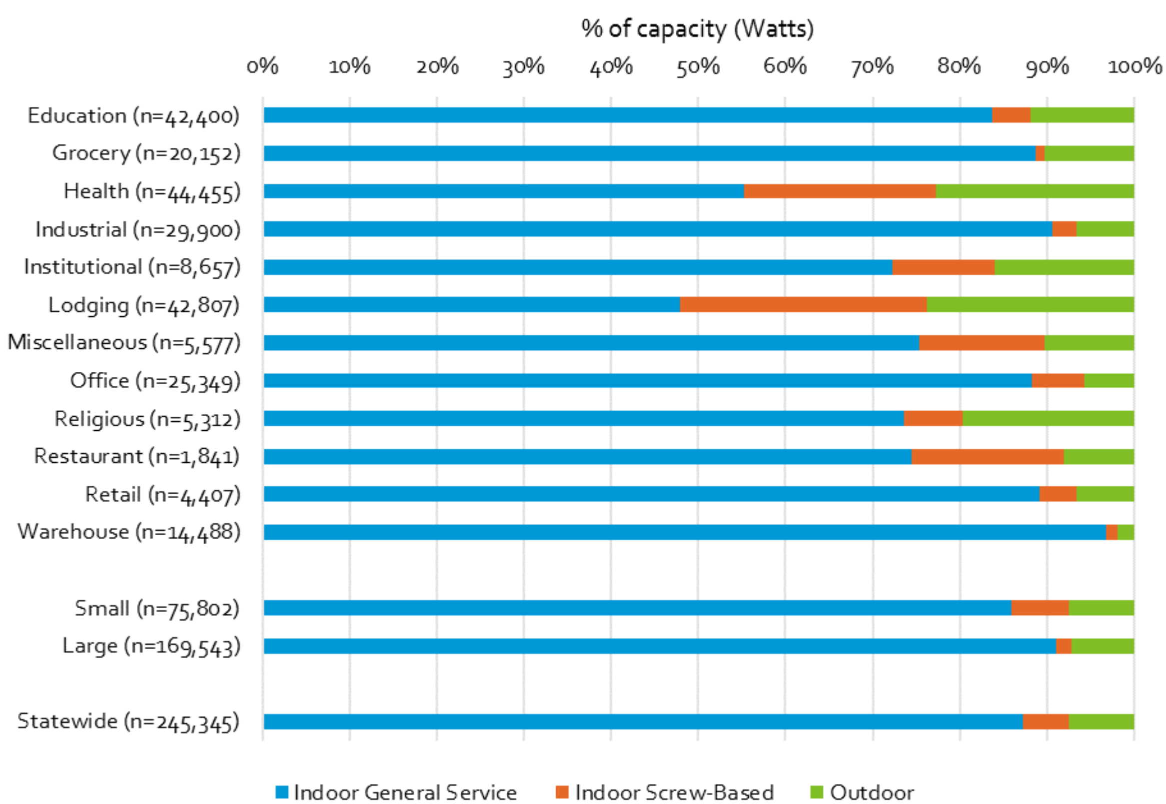


Figure 43 and Figure 44 show the distribution of lighting technologies used in each application, as a share of unit count and total Watts respectively. LEDs are the most prevalent technology in each application. Linear fluorescent fixtures still make up about 40% of the Indoor General Service units, as well as almost 50% of the wattage. Halogen and incandescent bulbs are only 13% of the Indoor Screw-Based application by count, but they represent 42% of the wattage in that category. The large, high-wattage HID bulbs make up almost half of the wattage in outdoor applications, though most units are now LED.

Figure 43: Lighting Technology by Application (Counts)

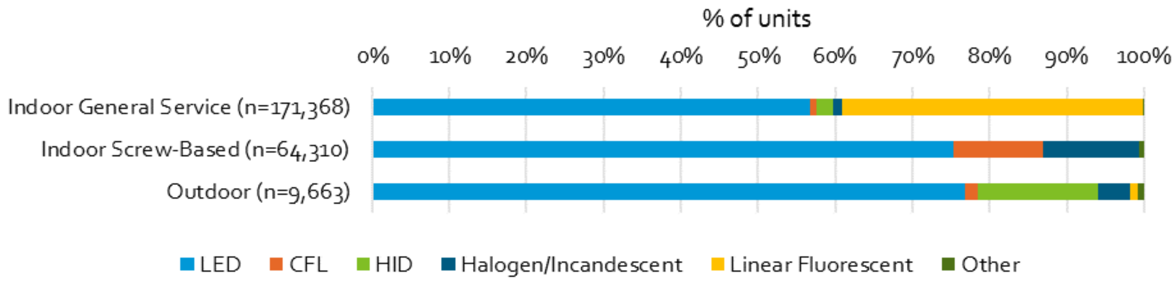
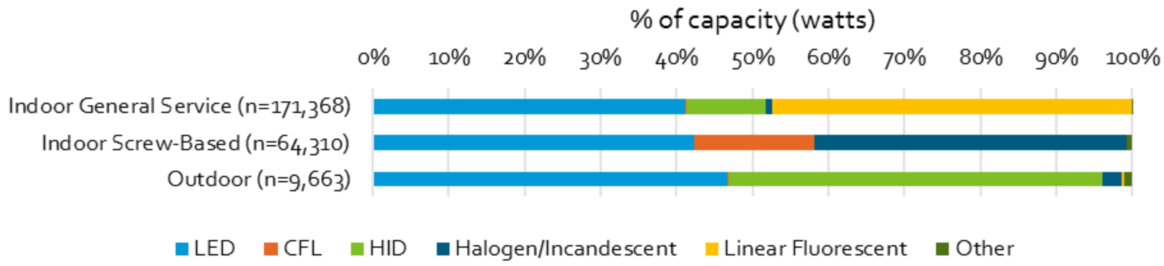
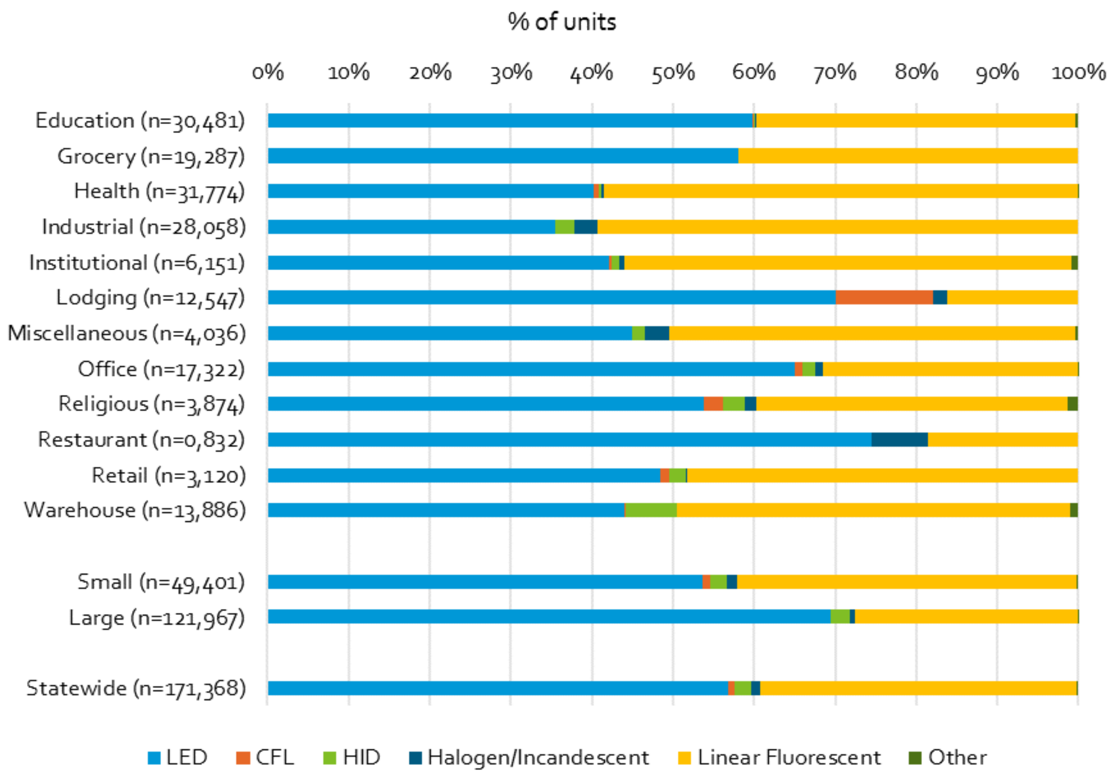


Figure 44: Lighting Technology by Application (Watts)



Since so much of non-residential lighting falls in the Indoor General Service application, Figure 45 shows the technologies used in that application for each sector and segment. Most segments follow similar trends, with slightly greater shares of linear fluorescent bulbs in the Health, Industrial, and Institutional segments. The Lodging segment has a significant share of CFLs, while the Restaurant segment has the only significant share of halogen/incandescent bulbs remaining. The Large C&I sector also has a greater share of LED (70%) relative to linear fluorescent (less than 30%) than is seen in the Small C&I sector.

Figure 45: Indoor General Service Lighting by Technology



LIGHTING STYLES

Figure 46 shows the distribution of lighting styles for each segment and sector. Overall, low-bay linear lighting makes up the greatest share of connected load in commercial buildings, accounting for 43% statewide. High-bay lighting, both linear and non-linear, is more common for the Grocery, Industrial, and Warehouse segments as well as in the Large C&I sector. The Lodging segment has a large share of low-bay, non-linear applications.

Figure 46: Lighting Styles (by Connected Load)

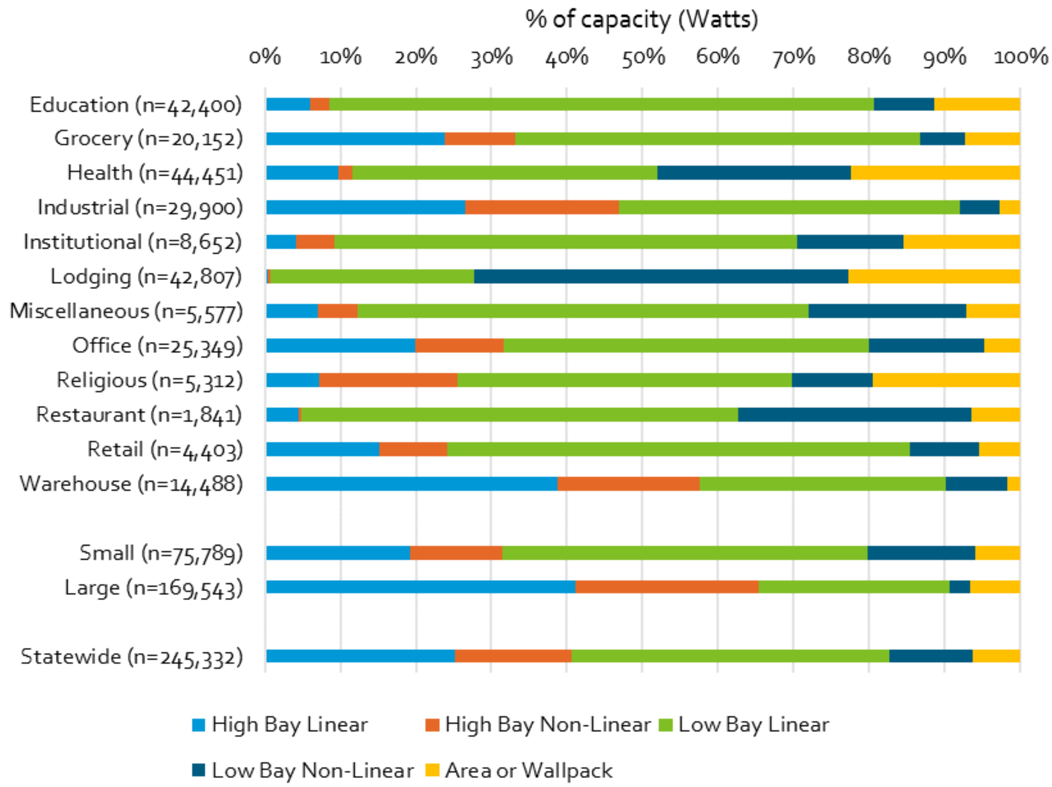


Figure 47 shows the share of each lighting style by application, again as percentages of the connected load in each category. Outdoor lighting is dominated by area lights and wall packs, while Indoor Screw-Based lighting is almost all low-bay non-linear. Indoor General Service applications are about 50% low-bay linear, with significant shares of both linear and non-linear high bays as well.

Figure 47: Lighting Style by Application

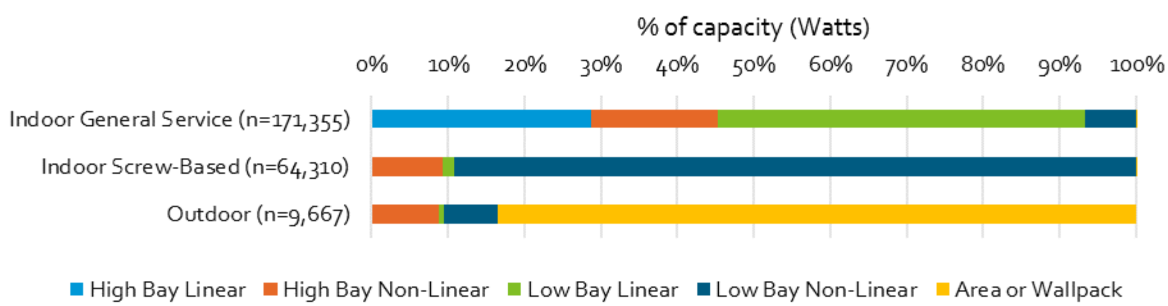
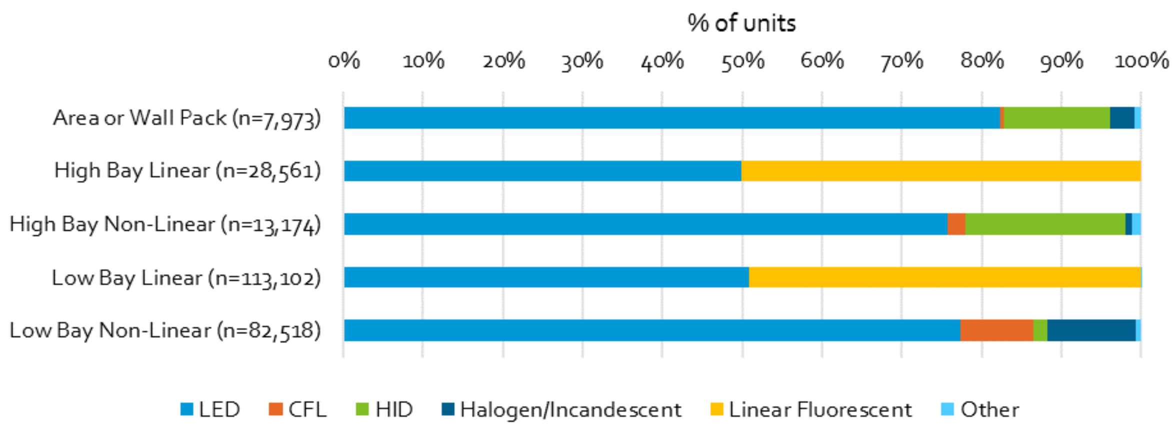


Figure 48 shows the technologies used for each lighting style. Both linear styles are only about 50% LED. Replacement of linear fluorescent bulbs is slower since these bulbs are still efficient relative to some other technologies, such as incandescent bulbs, that LEDs have replaced more quickly. Fluorescent lamps also have somewhat longer useful lives and, as such, tend to be replaced more slowly. Outdoor area/wall pack lighting is over 80% LED by count, with a significant share of HIDs as well. Note that, as before, the HIDs would make up an even larger share of connected loads.

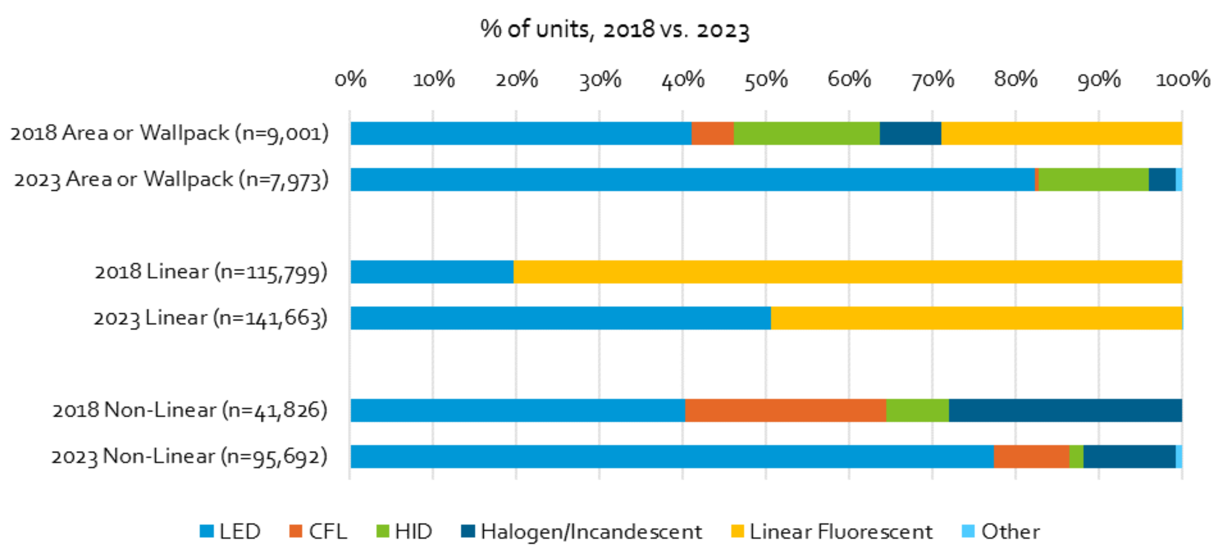
Figure 48: Distribution of Lighting Technology by Lighting Style (by Count)



Technologies used in low-bay non-linear lighting were shown previously for each sector and segment in Figure 38 and Figure 39. LEDs make up 75% of this category by count. Halogen/incandescent bulbs now only make up about 10% of low-bay non-linear lighting by count, but they still represent 25% of the connected load, evidence of the wide gap in efficiency compared to LEDs.

Figure 49 shows the change in technologies for each lighting style from 2018 to 2023. For simplicity, the high and low-bay distinctions are dropped here, with those styles grouped as either linear or non-linear.

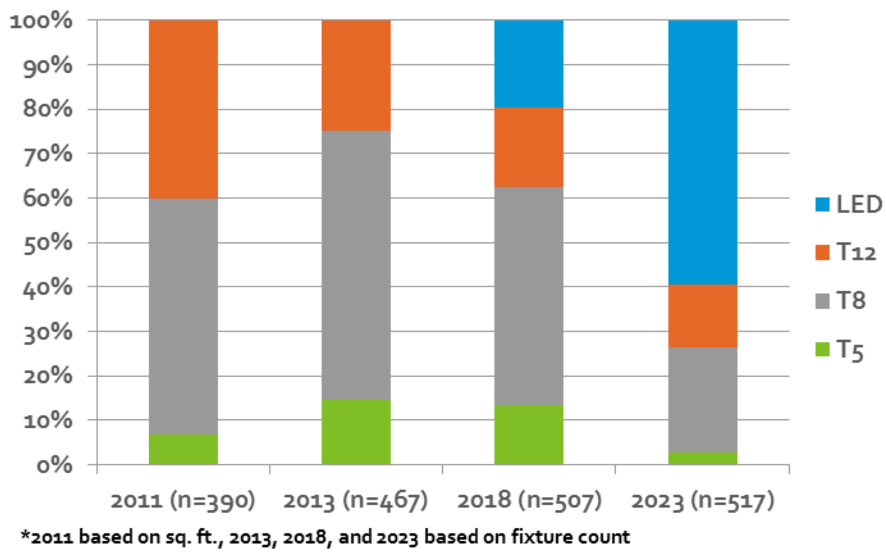
Figure 49: Lighting Styles by Technology, 2018 and 2023



LEDs grew from 40% to over 80% of outdoor area/wall pack lighting from 2018 to 2023 (by count). While linear fluorescent bulbs are still common in both linear styles, LEDs grew from only 20% to roughly 50% of units by 2023. Non-linear styles grew from 40% LED to over 75% LED. Non-linear lighting also saw corresponding decreases for CFLs, HIDs, and halogen/incandescent bulbs, with each decreasing by more than half of their 2018 levels.

Linear lighting styles are of particular interest since they make up such a large share of the C&I lighting stock (70% combined across high-bay and low-bay). Figure 50 shows the share of different linear lighting technologies from 2011 to 2023.

Figure 50: Linear Lighting Technologies, 2011-2023



This graph combines TLED and integrated LED lighting into a single category since that distinction was not recorded in previous studies, but it shows the three types of linear fluorescent bulbs separately. Despite being the least efficient linear fluorescent technology, T12 lighting still accounts for over 14% of units statewide. T12 bulbs are roughly as common in 2023 as 2018, while the share of T8s and T5s has dropped sharply. Clearly, however, the major trend is the growing share of LEDs in linear lighting.

Lighting Controls

Data was also collected for up to two types of controls for each fixture. These are reported separately for indoor (Table 22) and outdoor (Table 23). Technicians could assign multiple types of controls for each fixture, so the rows in the tables sum to greater than 100%. This was especially helpful for indoor lighting, where most fixtures are operated by switches but may have a secondary control as well.

Most indoor lighting is operated by manual on/off switches, but about 15% of businesses also use occupancy sensors, either in place of or in addition to a switch. In the Large C&I sector, about 30% of lighting is controlled by occupancy sensors. Some industry segments operate up to 10% of their lighting continuously (controlled only by circuit breakers), while Grocery and Industrial buildings had just over 10% controlled by timers. Most other control types were uncommon indoors. As LED lighting becomes more ubiquitous and the program opportunity from technology improvement wanes, lighting controls may prove to be an important opportunity for non-residential lighting programs.

Table 22: Indoor Lighting Controls

	Switch	Circuit Breaker/ Contin.	Day-lighting	Dimmer/ Trim	EMS/ NLC	Motion/ Occupancy Sensor	Timer
Education (n=39,243)	91.6%	-	0.5%	-	5.0%	9.4%	7.0%
Grocery (n=19,580)	47.0%	1.6%	-	-	44.8%	9.5%	10.6%
Health (n=43,083)	77.7%	8.8%	0.1%	-	9.1%	9.3%	-
Industrial (n=28,928)	80.5%	4.3%	-	0.5%	-	5.0%	13.2%
Institutional (n=8,068)	98.2%	0.1%	-	-	-	3.4%	4.1%
Lodging (n=41,564)	90.4%	9.1%	-	-	-	52.6%	-
Miscellaneous (n=5,165)	95.7%	-	-	-	-	9.3%	0.3%
Office (n=24,830)	92.1%	2.7%	0.1%	-	-	14.3%	-
Religious (n=4,763)	98.6%	0.2%	-	0.1%	-	2.1%	-
Restaurant (n=1,690)	84.7%	7.9%	-	-	5.7%	8.9%	-
Retail (n=4,210)	97.7%	2.0%	-	-	5.2%	0.3%	-
Warehouse (n=14,237)	83.8%	0.4%	-	-	0.3%	37.5%	-
Small (n=71,346)	93.5%	1.7%	-	-	0.4%	12.2%	2.1%
Large (n=164,015)	67.3%	12.8%	0.5%	0.8%	2.7%	28.4%	2.7%
Statewide (n=235,361)	**88.7%**	**3.8%**	**0.1%**	**0.2%**	**0.8%**	**15.2%**	**2.2%**

Controls are more common for exterior lighting applications with 58% of outdoor lighting controlled by photocells, and another 31% is controlled by timers. Healthcare and Office buildings predominantly use photocells, while over half of Education, Institutional, and Religious buildings use timers.

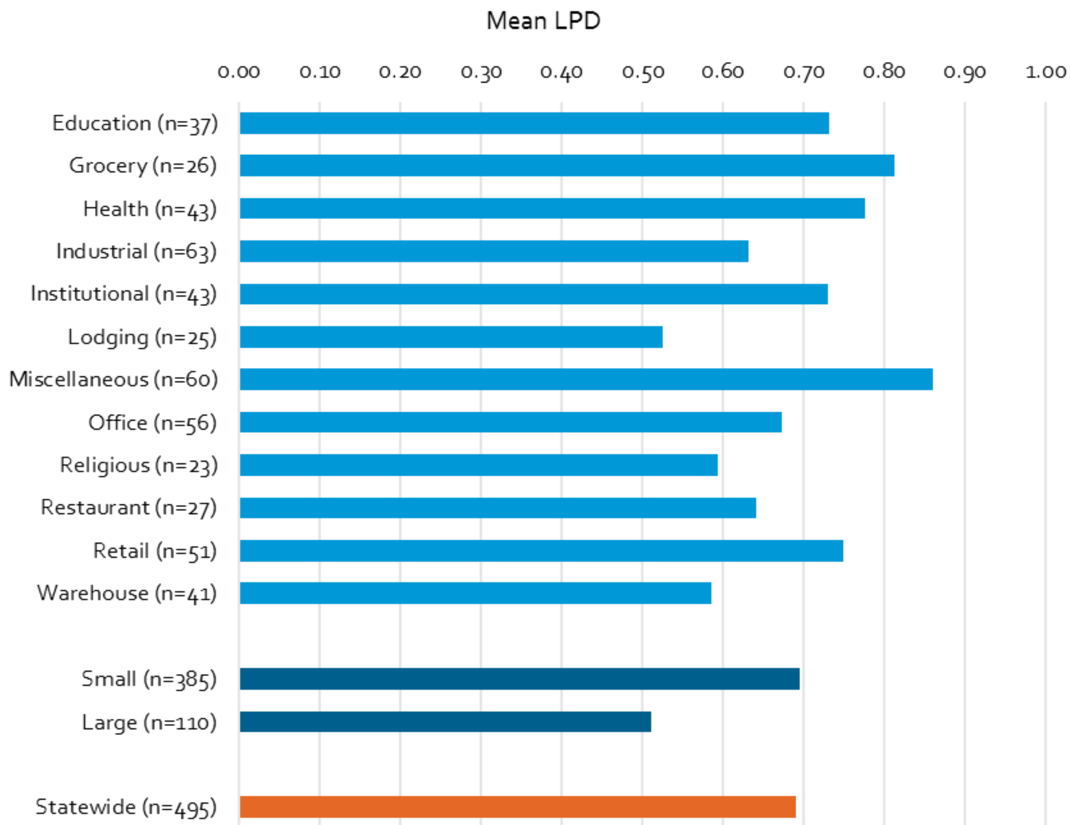
Table 23: Outdoor Lighting Controls

	Switch	Circuit Breaker/ Contin.	Day-lighting	EMS/ NLC	Motion/ Occ. Sensor	Photo-cell	Timer
Education (n=39,243)	11.4%	-	-	-	1.1%	26.7%	63.0%
Grocery (n=19,580)	15.1%	-	-	-	2.7%	36.3%	48.6%
Health (n=43,083)	9.8%	-	-	2.8%	-	83.3%	4.1%
Industrial (n=28,928)	34.4%	-	-	-	0.3%	46.2%	19.4%
Institutional (n=8,068)	4.7%	-	-	-	-	17.5%	77.8%
Lodging (n=41,564)	25.7%	1.5%	1.4%	-	-	61.5%	14.5%
Miscellaneous (n=5,165)	35.8%	0.5%	-	-	-	34.5%	37.9%
Office (n=24,830)	4.5%	1.2%	-	-	0.3%	74.5%	19.8%
Religious (n=4,763)	3.6%	-	-	-	-	16.4%	80.0%
Restaurant (n=1,690)	47.9%	-	-	9.0%	-	16.7%	27.8%
Retail (n=4,210)	15.5%	4.5%	1.3%	-	0.6%	43.0%	35.6%
Warehouse (n=14,237)	16.9%	-	-	-	0.7%	66.3%	16.1%
Small (n=71,346)	12.5%	0.8%	0.1%	0.2%	0.3%	58.5%	29.0%
Large (n=164,015)	2.2%	0.2%	0.0%	-	0.7%	51.0%	47.2%
Statewide (n=235,361)	**11.2%**	**0.8%**	**0.1%**	**0.2%**	**0.3%**	**57.6%**	**31.1%**

5.3 LIGHTING POWER DENSITY

Lighting Power Density (LPD) expresses a building's lighting Wattage per square foot. It does not account for hours of use, but simply normalizes the installed Wattage by building size. This measure varies by industry segment based on businesses' different lighting needs. Increasingly, it also varies by technology employed, since LEDs can produce equivalent lighting amounts to older technologies while using a fraction of the wattage. Figure 51 reports the LPD values for each segment along with the small/large sectors and the statewide average. Total indoor lighting wattage and total building square feet were summed to calculate site-level LPD, and the figure shows the average of these values across all sites in each category.

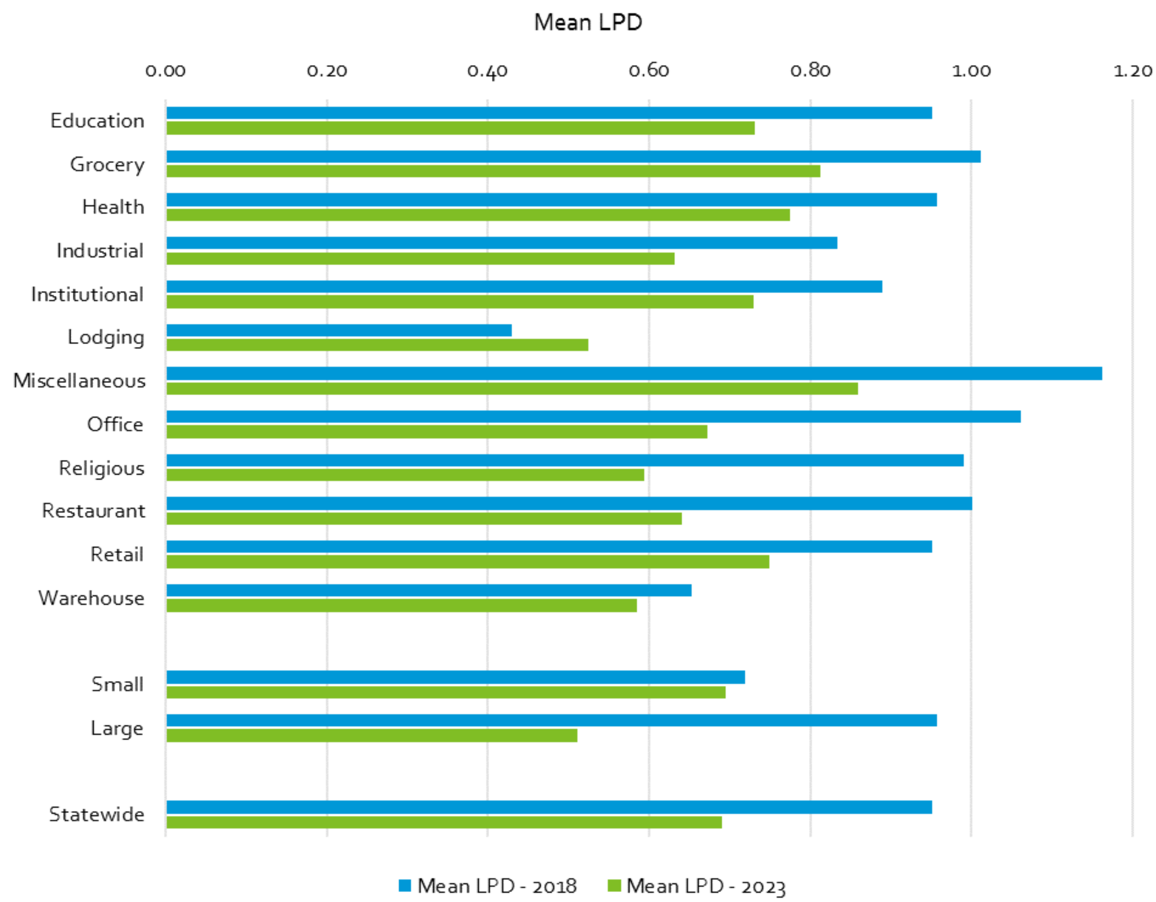
Figure 51: Average LPD by Segment and Sector



Every segment and sector have an average LPD below one, with a statewide average of 0.78 Watts per square foot. The Large C&I sector had much lower LPD's, with an average of 0.52. Miscellaneous had the highest LPD's—this segment includes facilities with higher energy usage than traditional offices or retail stores, including personal services (salons, laundromats, dry cleaners, etc.), auto repair, and entertainment (theaters, recreational facilities). The Grocery, Health, and Retail segments had the next highest LPD values.

Figure 52 compares the 2023 LPD values to those reported in the 2018 study. Presumably, building types and businesses' lighting requirements have not changed very much since 2018, so the differences shown are attributable to more efficient lighting technology. LPDs are down significantly in nearly every category, with a statewide decrease of nearly 20%.

Figure 52: Average LPD by Segment and Sector, 2018 and 2023

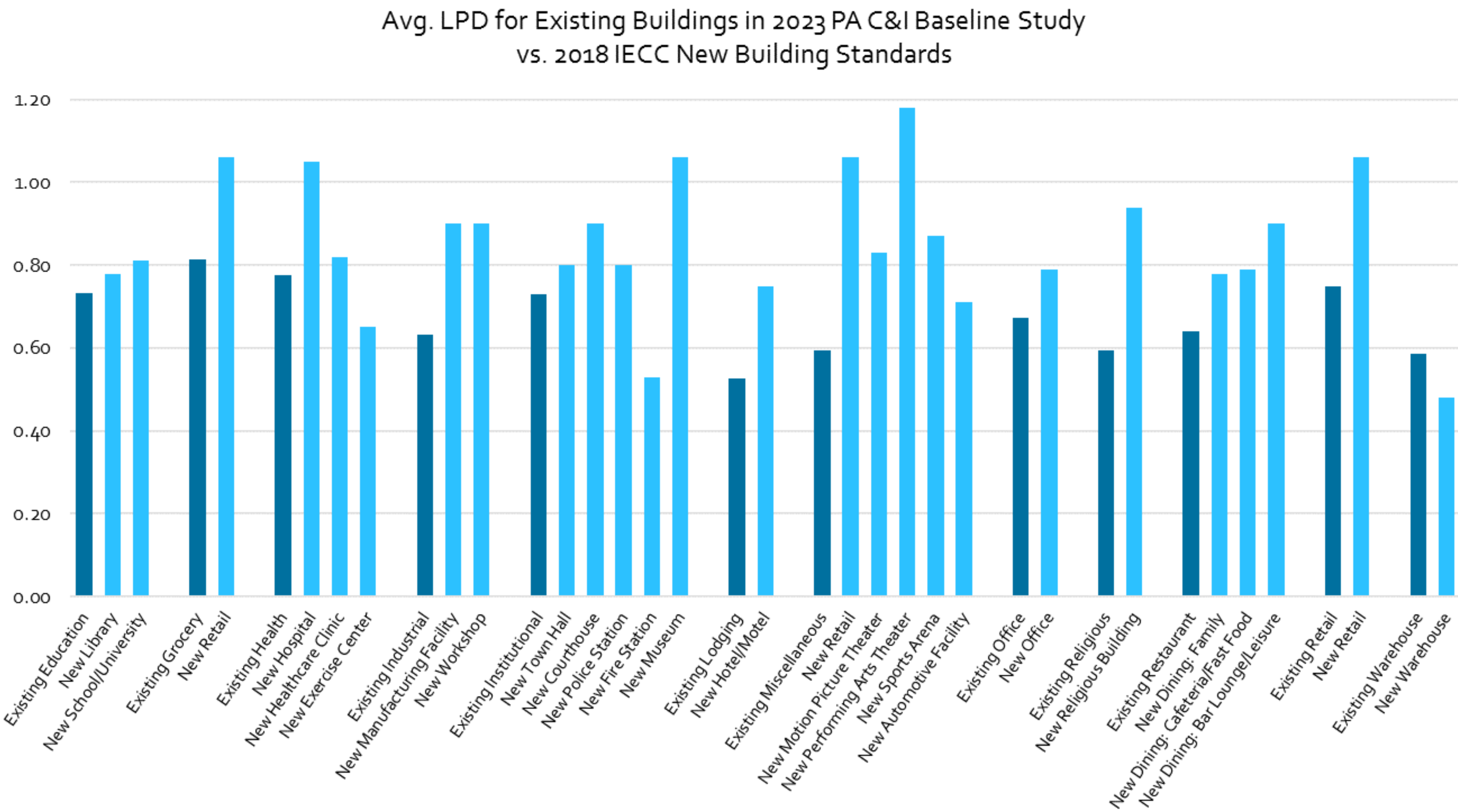


The Commonwealth of Pennsylvania updated its Uniform Construction Code to include the International Energy Conservation Code (IECC) 2018, effective February 14, 2022[5]. IECC 2018 dictates allowable LPD standards for new construction in the Commonwealth. While the existing building stock can have higher LPD values than new construction, comparing the gap between the two is instructive.

Figure 53 plots average LPDs for each of the study segments against relevant building types from the IECC standards. These do not match up perfectly, but most of the IECC building types are nested within the study segments. The IECC standard for new retail buildings is shown for each of the Grocery, Miscellaneous, and Retail segments since buildings in each would use that standard. Pennsylvania's existing non-residential building stock does not lag the New Building Standards, but instead significantly exceeds them across nearly every relevant building type. While LED adoption has been rapid since 2018, this is still a surprising result for older buildings. This further indicates the IECC standards place little to no restriction on the lighting that businesses would install in new buildings without any regulation.

[5] https://www.dli.pa.gov/ucc/pages/default.aspx

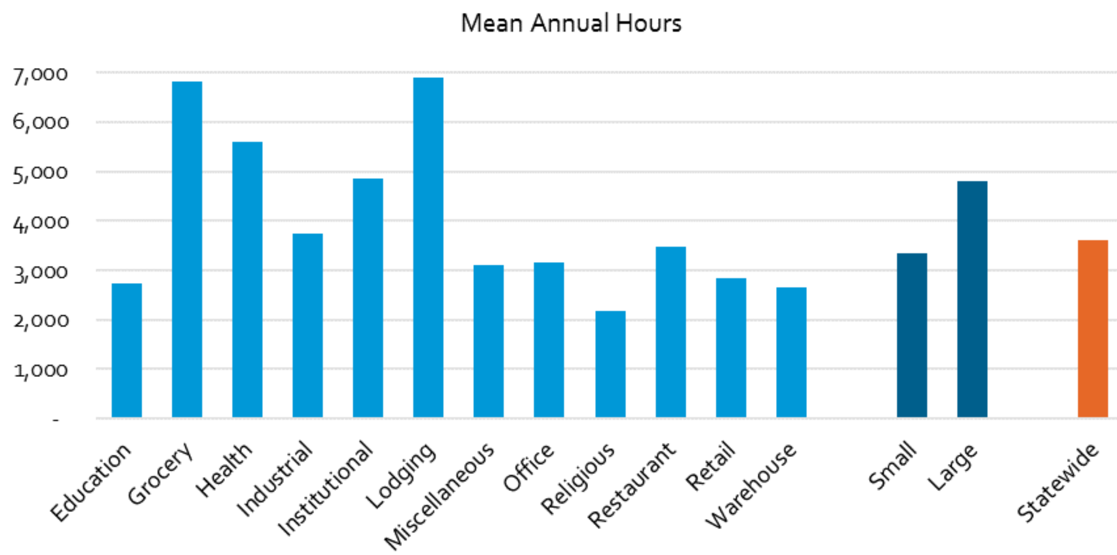
Figure 53: LPD for Existing Pennsylvania Buildings vs. IECC New Building Standards



As stated above, LPD does not consider operating hours, though this can vary widely across business types. Understanding LPD in conjunction with hours of use is thus important for assessing energy efficiency potential. Self-reported annual lighting hours are presented in Figure 54. These annual hours of use come from self-reported schedules and are not an exact measure of operation, so they should be interpreted with caution.

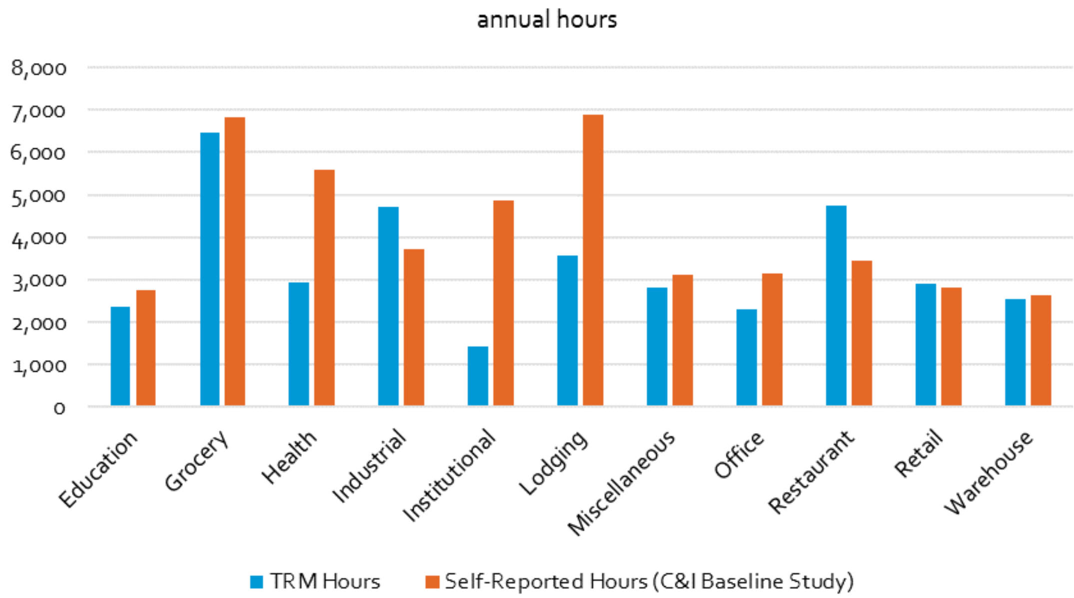
Grocery and Lodging, which stay open for long hours, have the highest values on average, while Religious has the lowest. While the Large C&I sector has much lower LPD values than the Small C&I sector, hours of operation are much higher. Total annual kWh used for lighting in the Large C&I sector, then, is greater than what would be inferred from the LPD alone.

Figure 54: Mean Annual Hours of Lighting by Sector and Segment



As shown in Figure 55, the self-reported hours align well with the Pennsylvania TRM assumptions in most cases. The TRM has three values for Industrial Manufacturing (1-shift, 2-shift, 3-shift), but for simplicity we show the 2-shift value in the figure. The inclusion of multiple hospitals in the baseline study may account for the higher values in the Health segment. Managers in the Lodging segment likely reported building lighting hours for guest rooms, leading to high self-reported values in that category. There is not a lighting hours of use value for Religious buildings in the 2021 TRM, so that segment is omitted from the comparison in Figure 55.

Figure 55: TRM Values for Annual Hours (General Service Lighting) vs. Self-Reported Hours in 2023



6 HEATING, VENTILATION, AND AIR CONDITIONING

6.1 HVAC EQUIPMENT OVERVIEW

Heating ventilation and air conditioning (HVAC) equipment is present at virtually all non-residential buildings and accounts for a large share of energy use. 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 24 provides a description for each cooling and heating equipment type and groups equipment by end use. Note that some types of equipment only supply one end use, while others supply 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. Heating and cooling equipment is generally paired with ventilation equipment to move conditioned air around the building.

Table 24: Heating and Cooling Equipment Descriptions

Equipment Category	Equipment Name	Description
Central Plant Cooling	Air-Cooled Chiller	Refrigeration machines that provide chilled water to multiple buildings for space or process cooling purposes. Installed outdoors without a cooling tower.
	Water-Cooled Chiller	Refrigeration machines that provide chilled water to multiple buildings for space or process cooling purposes. Installed indoors with a cooling tower.
Central Plant Heating	Fossil Fuel Boiler	Fossil fueled devices that generate steam or hot water for space heating purposes. Central boilers can serve various "emitters" such as wall or floor radiant tubing or an air handler with a heat exchanger.
Unitary Cooling Only	DX Cooling	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.
	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.

Equipment Category	Equipment Name	Description
Unitary Cooling and/or Heating	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 / Water 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 compressor coils use water as a heat sink rather than ambient air. With a ground source unit, buried lines allow the earth to extract and reject heat. Water source units are generally paired with a cooling tower and low temperature boiler.
	Ductless Mini-split Heat Pump	Like PTAC units, Ductless Mini-split units are typically used to condition a single room. They can also 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. Larger variable refrigerant flow (VRF) systems were classified as ductless mini-split for this study.
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.
	Fossil Fuel Boiler	Boilers heat water within a vessel, which is then turned into steam or kept in liquid form and sent through the building to one or more emitters via hydronics – typically to a radiator.
	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.
	Wall Unit Heater	A unit heater can be free-standing or integrated into a wall and provides heat to a single room.
	RTU Gas Pack	An RTU (Roof Top Unit) Gas Pack is an HVAC system that is assembled into a single, self-contained unit and installed on the roof of a building. The gas pack's heating function involves the use of a gas-fired burner or heating element to generate heat, which is then circulated through the building's ductwork and distributed to various spaces.

Equipment Category	Equipment Name	Description
Central Plant or Unitary Heating	Air Handler Unit / Air Rotation Unit	In the context of unitary heating systems, an air rotation unit is a freestanding unit responsible for both conditioning and circulating air to a dedicated area. An air handler can also be an emitter type for a built-up system with a central boiler and chiller. The air handler is integrated to exchange hot or chilled water and distribute conditioned air through a network of ducts.

Figure 56 displays images of common cooling equipment types as well as heat pumps, which supply both heating and cooling. Figure 57 shows common heating equipment types as well emitters, which distribute heating or cooling to spaces within a building.

Figure 56: Common Cooling Equipment Types

Figure 57: Common Heating Equipment Types

Central Boiler		RTU Gas Pack	
Hydronic (Wall / Floor Radiant)		Wall Unit	
Air Handler		Fossil Fuel Furnace	
Electric Baseboard		Terminal Reheat	

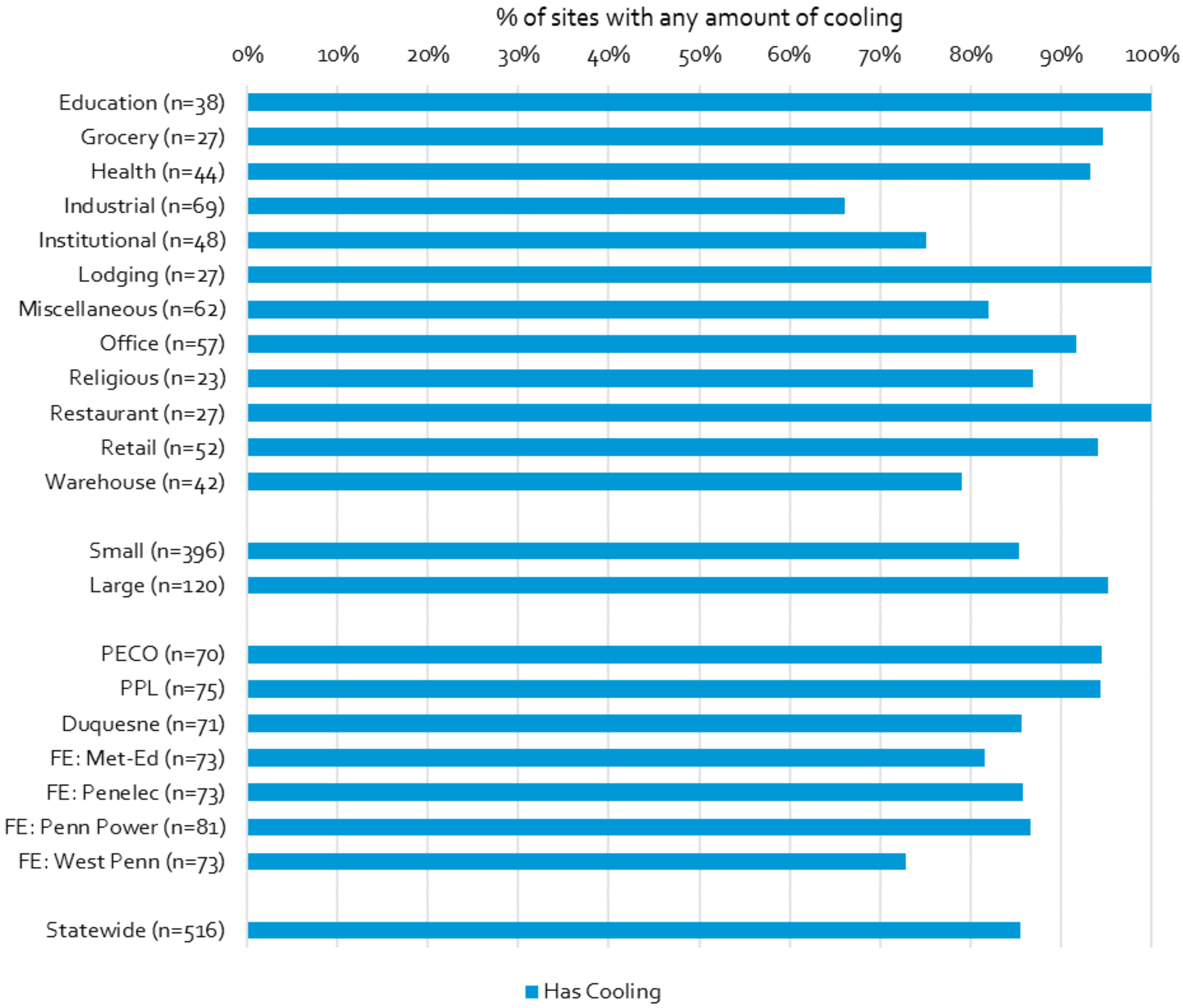
Throughout this chapter, most cooling and heating units are characterized as percentage share of total capacity (e.g., tons of cooling or kBTU/hour of heating capacity). Where the analysis groups units by size bin, percentage share of units is shown.

6.2 COOLING FINDINGS

PENETRATION

Most businesses in Pennsylvania have some amount of cooling equipment, and space cooling is crucial to the summer operations of most segments. All sites in the Education, Grocery, and Lodging segments had some amount of cooling equipment, for example. Figure 58 shows the site-level penetration of cooling equipment for each segment and sector along with the statewide average. As expected, segments like Industrial and Warehouse are less likely to have cooling equipment.

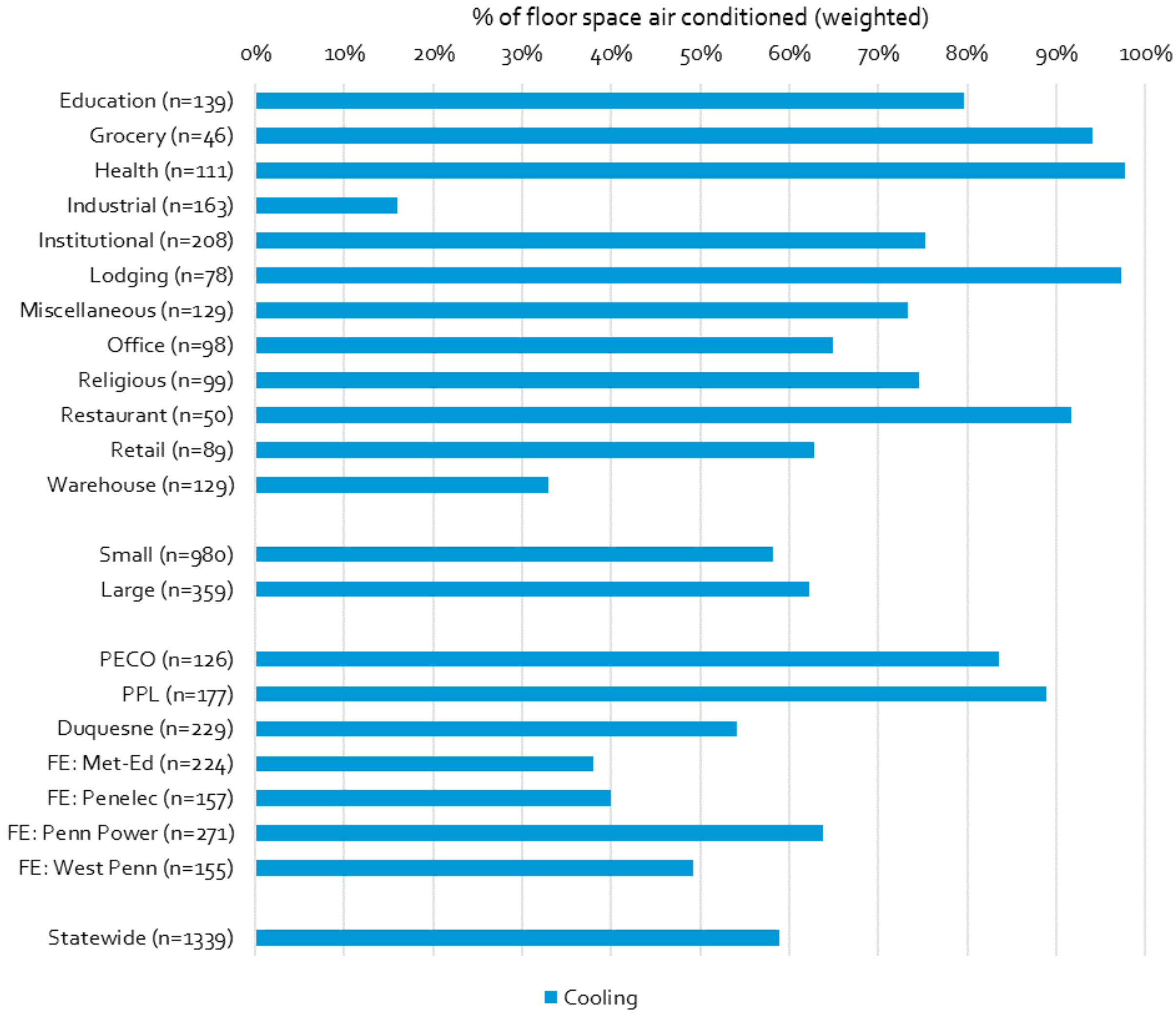
Figure 58: Penetration of Cooling Equipment



SATURATION

Nearly 85% of sites in Pennsylvania have some amount of cooling equipment, but a more important view into energy use is how much of the floor space is air conditioned. It is common for businesses to only cool a subset of their buildings so while a site has some air conditioning, much of the floor space may not be cooled. Figure 59 shows the site-level saturation of cooling equipment for each segment and sector along with the statewide average. As expected, segments like Industrial and Warehouse cool a smaller share of their footprint compared to other segments.

Figure 59: Saturation of Cooling Equipment



COOLING SYSTEM TYPES

Figure 60 shows the share of cooling capacity (tons) for central plant ("chillers") versus unitary cooling systems. N-values indicate the number of cooling systems surveyed. Statewide, unitary systems provide 65% of cooling capacity. This split is different for the Large C&I and Small C&I sectors: chillers make up most capacity for Large C&I customers, while Small C&I 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 60: Distribution of Cooling System Type (by Capacity)

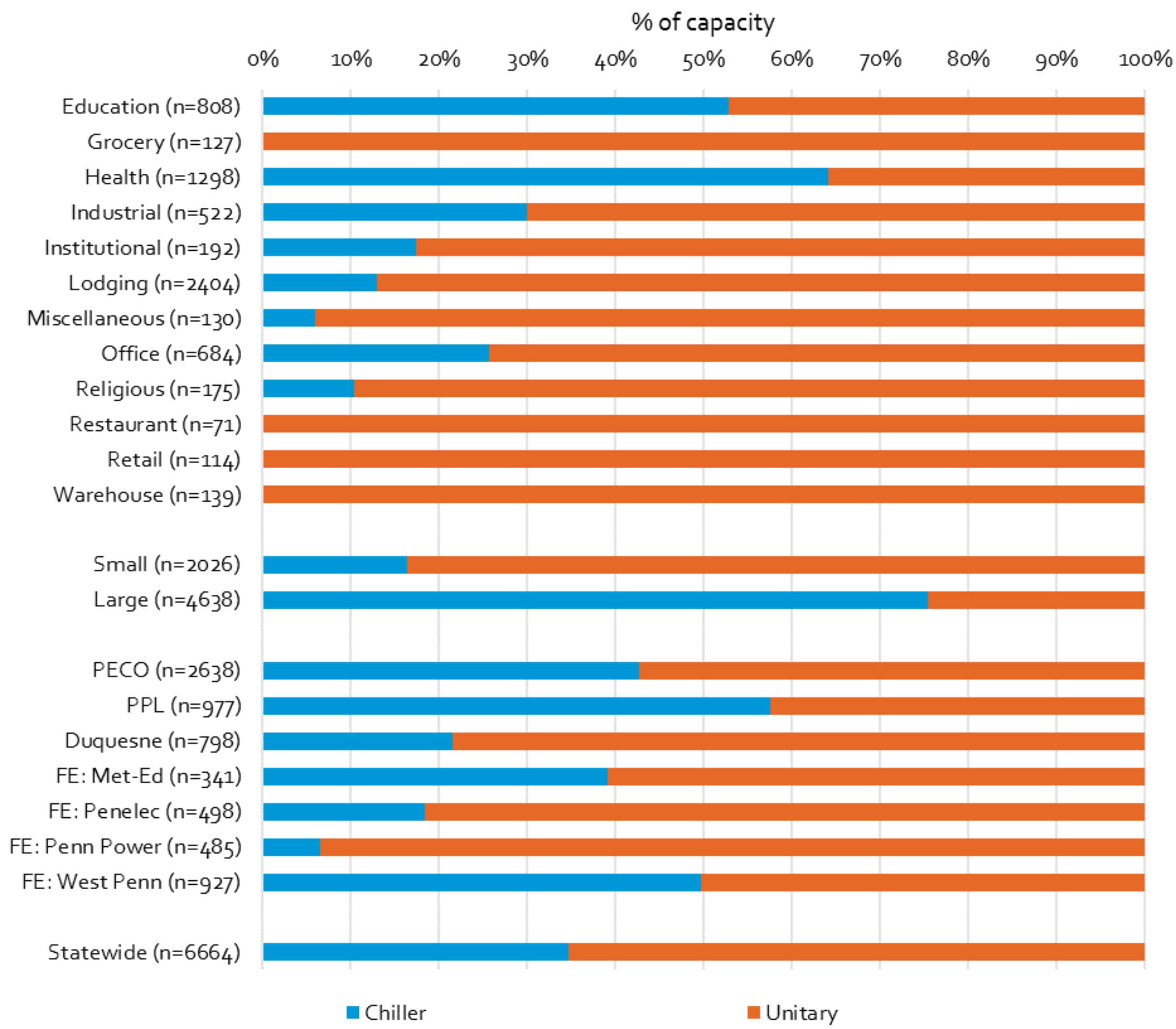


Figure 61 and Figure 62 show the distribution of unitary cooling units across different size categories by count and capacity, respectively. As logic would imply, smaller units represent a much larger share of cooling units. The smallest units (those below five tons) make up 81% of units, six- to ten-ton units make up another 12% of units, and the larger units make up the remainder. Units ten tons or smaller account for only 74% of cooling capacity despite making up 95% of the total count.

Figure 61: Distribution of Unitary Equipment Size (by Units)

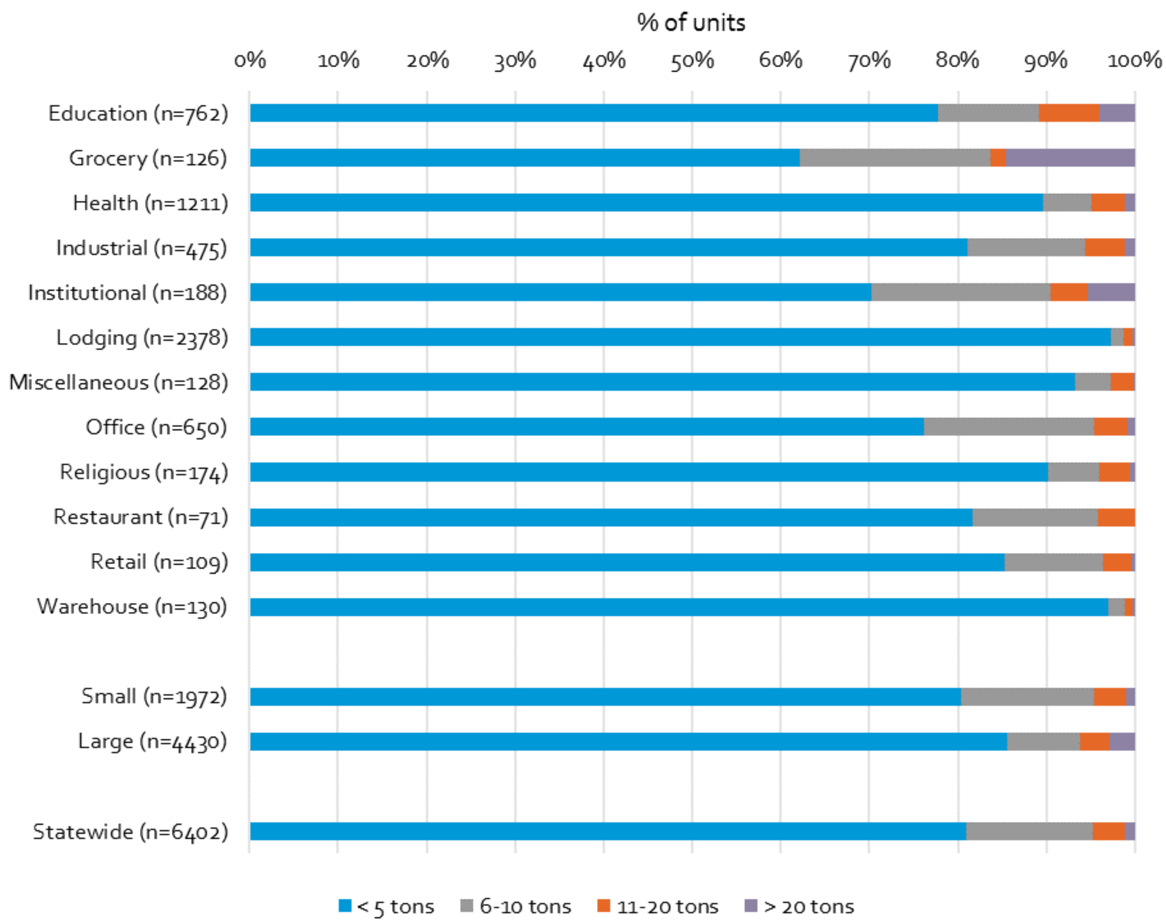


Figure 62: Distribution of Unitary Equipment Size (by Capacity)

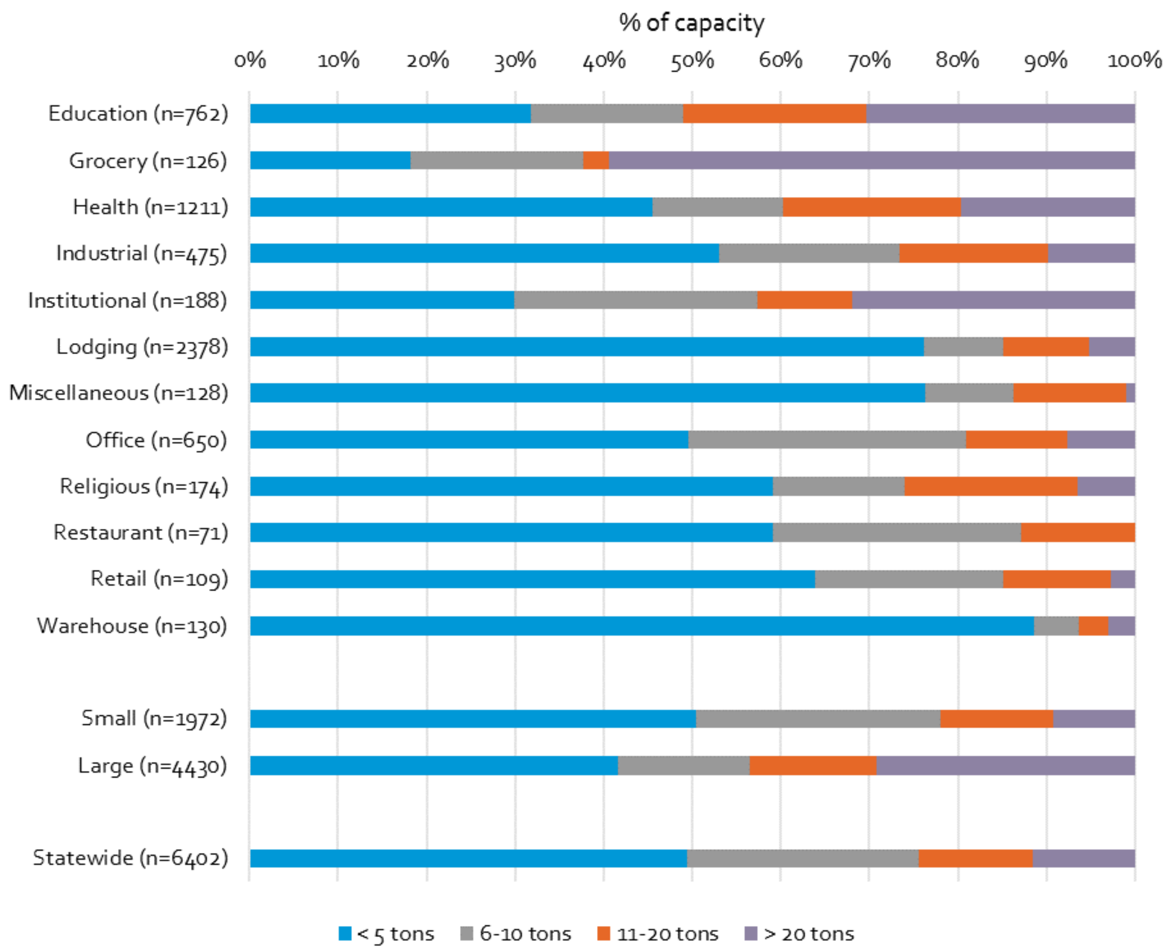


Figure 63 and Figure 64 show the distribution of chillers across different size categories by count and capacity, respectively. Whereas the largest central plant systems (above 300 tons) provide over half the cooling capacity, these largest units represent a small fraction of cooling system units (fewer than 10%). Smaller units represent a much larger share of cooling units. The smallest units (those below 50 tons) make up 75% of units but less than 25% of capacity.

Chiller size bins are also broken out by sector, segment, and EDC. Large C&I sector customers have considerably more very large units – nearly 50% of units for large customers are above 100 tons. This reflects what is shown in Figure 64: Large C&I sites are more likely to use large central plant cooling systems. Note the sites visited in the Grocery, Restaurant, Retail, and Warehouse segments had no chillers at all.

Figure 63: Distribution of Chiller Equipment Size (by Units)

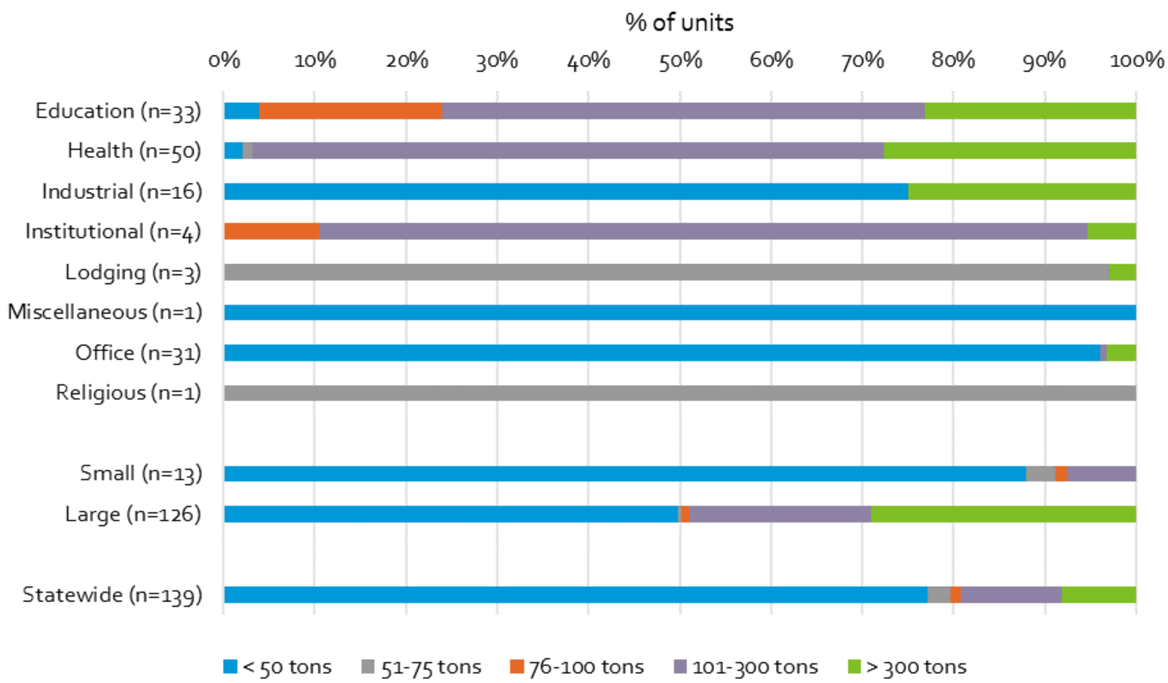
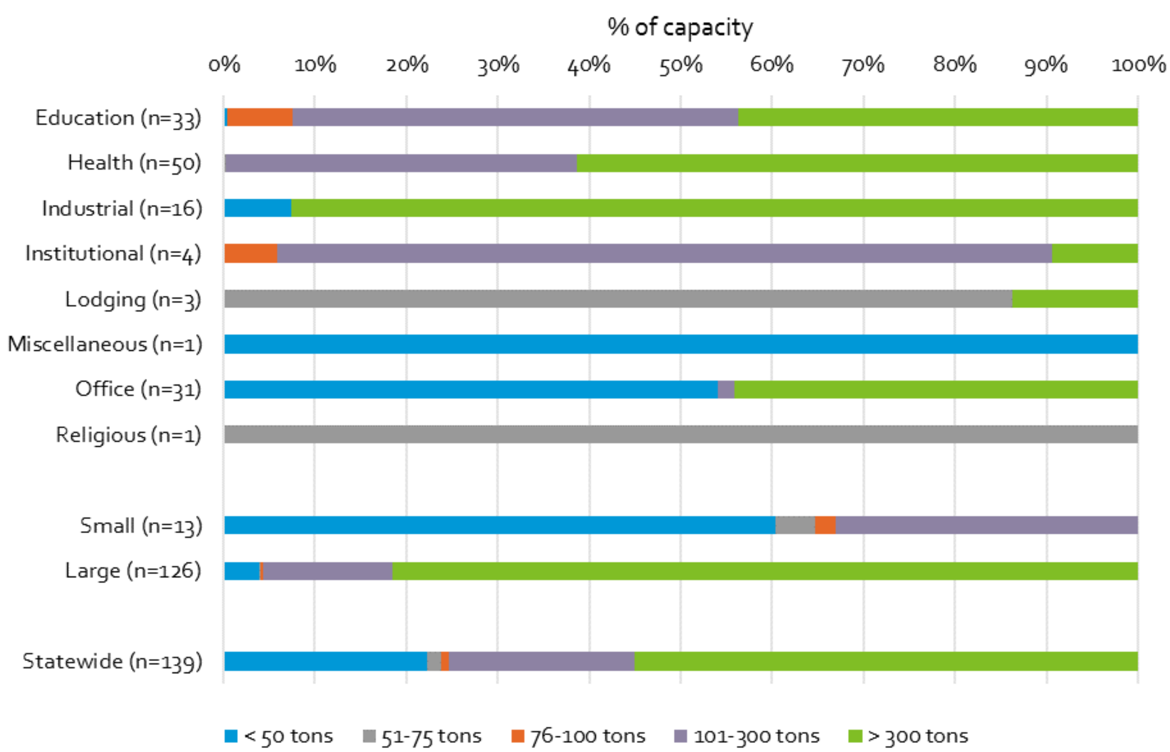


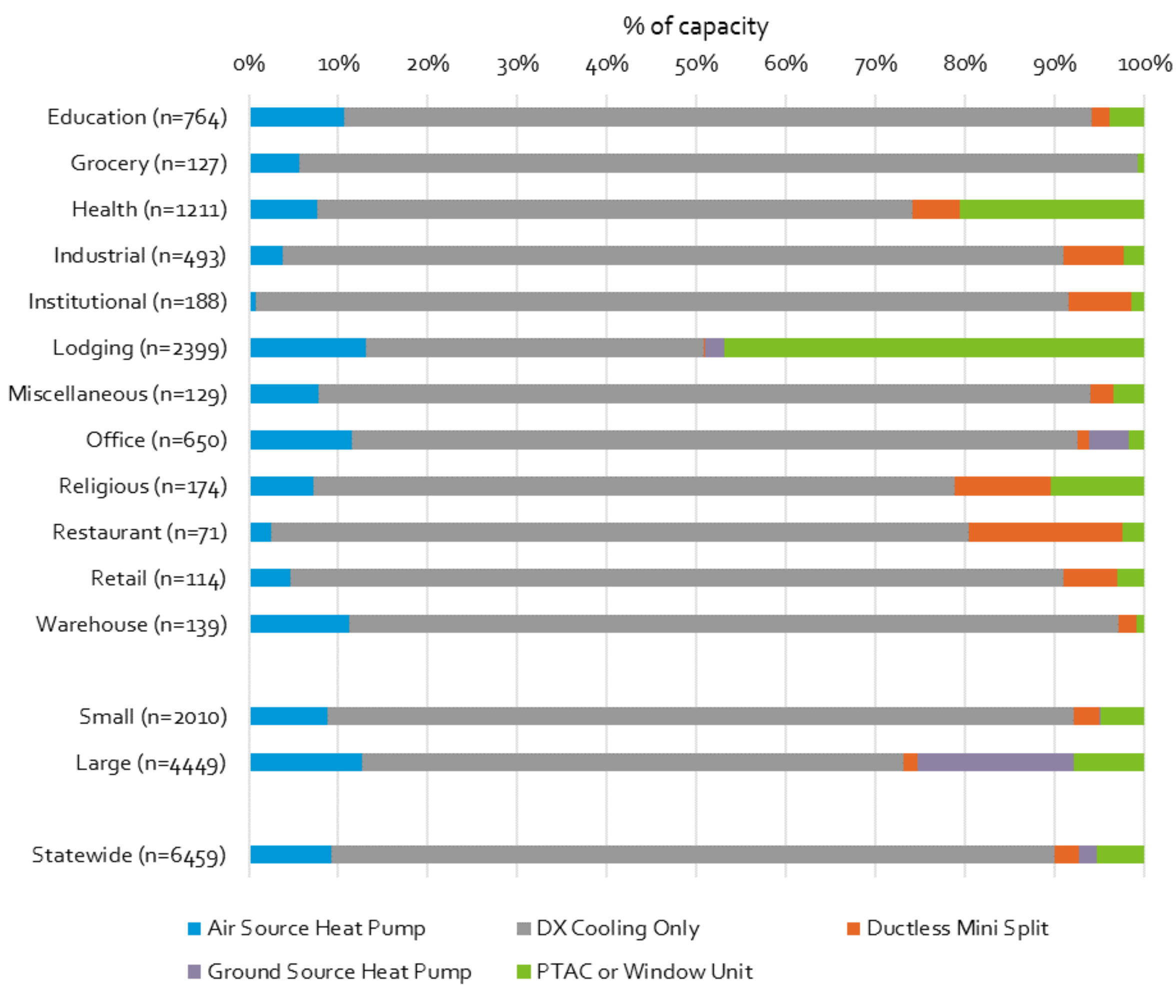
Figure 64: Distribution of Chiller Equipment Size (by Capacity)



Unitary cooling systems include a variety of different cooling equipment types, described in more depth in Table 24. Figure 65 shows the share of unitary cooling system capacity by equipment subtype. 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%). Air source heat pumps are the next most common system type (9% of capacity). Other system types are rare and comprise about 8% of unitary cooling capacity. Air source heat pumps, ground source heat pumps, and ductless mini split heat pumps also provide heating, as seen in Figure 79.

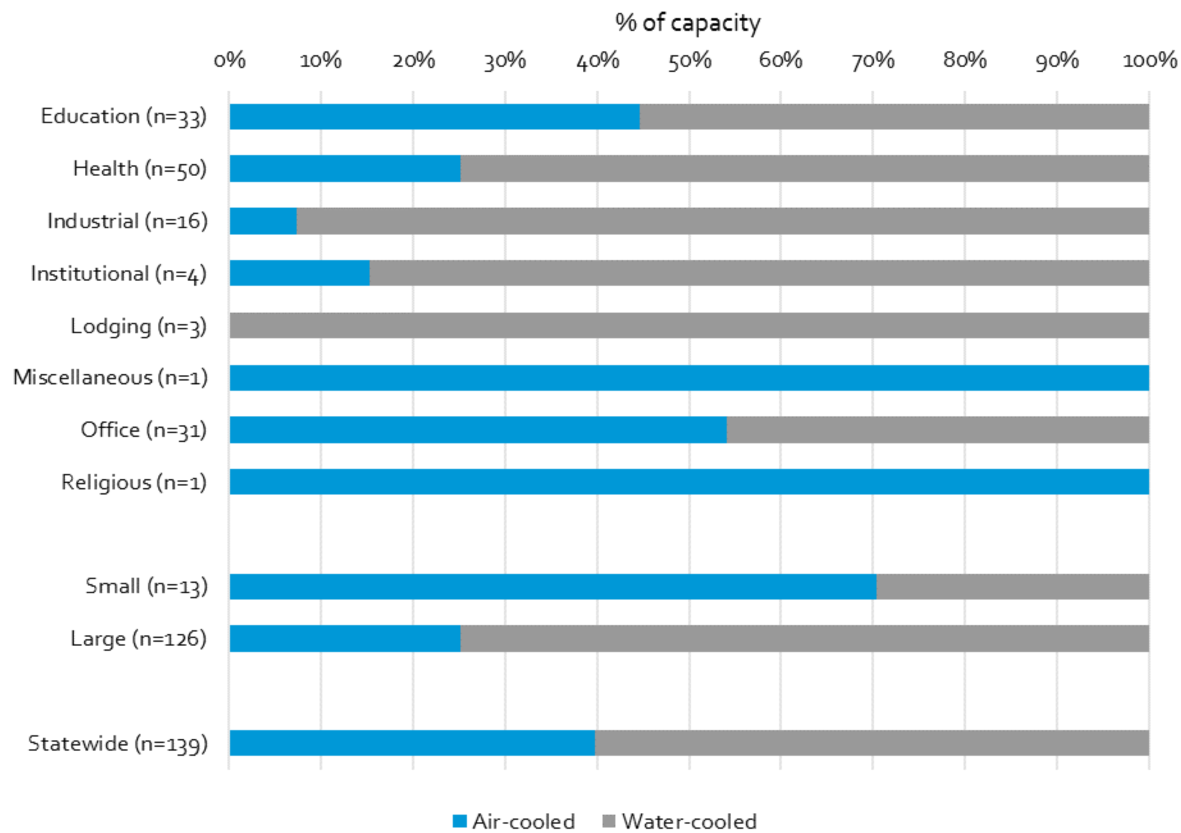
Window units are more prevalent among unitary systems for Large C&I customers than among Small C&I businesses. However, as previously mentioned, unitary systems only represent about 25% of cooling capacity for the Large C&I sector (versus 84% for small customers). This means that window units are still a much smaller share of cooling system capacity for Large C&I overall (including central plant systems). This is important when considering the variation in unitary equipment type across segments, given the variation in sector share by segment.

Figure 65: Distribution of Unitary Subtype (by Capacity)



Central plant cooling systems include two major equipment types: air-cooled and water-cooled systems. These are described in more depth in Table 24. Figure 66 shows the share of chiller capacity by equipment subtype. The n-values represent cooling systems surveyed. Water-cooled systems are the most common by share of cooling capacity (61%). Water-cooled systems are prevalent in large Health and Industrial settings, while air-cooled systems account for most of the capacity share in smaller businesses.

Figure 66: Distribution of Chiller Subtype (by Capacity)



COOLING CAPACITY AND EFFICIENCY

Table 25 shows the average capacity and efficiency by cooling equipment across the study sample. Cooling capacity is expressed in tons, which is equal to 12,000 BTU/hour. Cooling efficiency is expressed using different rating types for different types of cooling equipment. Smaller equipment might be rated in SEER or CEER while larger equipment is rated in EER or IPLV. Technicians were allowed to enter cooling efficiency ratings in the metric listed on the equipment nameplate and then ratings were standardized across metrics to create a simplified kW-per-ton efficiency metric. A low kW-per-ton value indicates high efficiency because less input of electrical power is required per unit of cooling produced.

Table 25: Average Size and Efficiency by Cooling System Type

System Type	Average Tonnage	kW per Ton	n-value
Air-Cooled Chiller	53.6	0.99	71
Water-Cooled Chiller	410.5	0.57	68
All Chillers	**112.4**	**0.80**	**139**
Air Source Heat Pump	3.7	0.84	730
DX Cooling only	6.0	0.96	1,838
Ductless Mini Split	1.5	1.13	266
Ground Source Heat Pump	2.4	0.80	377
Packaged Terminal/Window Unit	0.9	0.97	3,191
All Unitary	**4.1**	**0.93**	**6,402**

Water-cooled chillers were the most efficient cooling equipment observed in the field and showed a considerably lower average kW-per-ton rating. Inclusion of ancillary equipment such as cooling tower fans and condenser water pumps would make the differential between water-cooled and air-cooled chillers less pronounced. Ductless mini split heat pumps showed the lowest cooling efficiency among the unitary equipment inventoried. Inverter-driven mini split heat pumps, especially cold climate models, sacrifice cooling efficiency for heating efficiency and capability to perform under extreme winter conditions so this is not an unexpected finding.

Temperature Control Types

Figure 67 through Figure 70 show the share of cooling capacity controlled by different control types. Figure 67 compares control strategies for both cooling system types (chillers and unitary). Notably, over 50% of chiller capacity is controlled by Energy Management Systems (EMS), and over 50% of unitary capacity is controlled by programmable thermostats. Statewide penetration of smart thermostats is low for both chillers and unitary systems.

Figure 67: Distribution of Control Type Statewide (by Capacity)

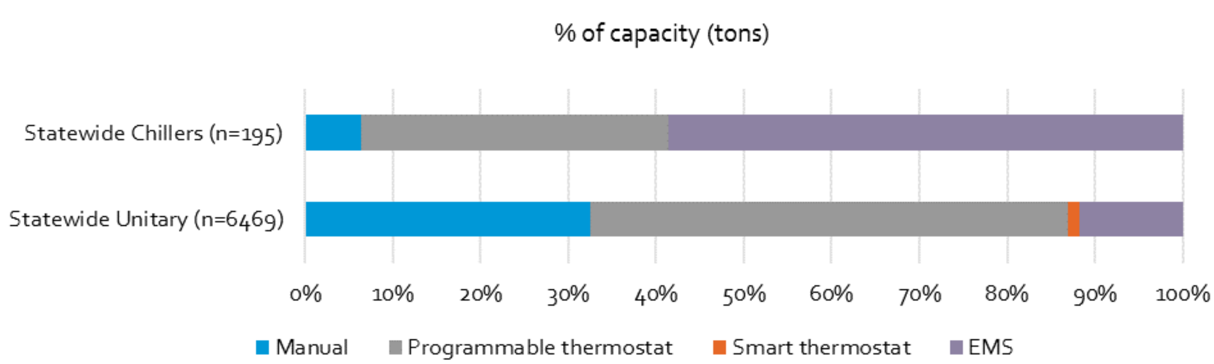


Figure 68 shows the distribution of cooling control types for unitary cooling systems. Energy Management System (EMS) controls account for a much greater share of unitary cooling capacity within the Large C&I sector (52%) than for the Small C&I sector (6%). Manual and programmable thermostats dominate capacity shares in the Small C&I sector, and smart thermostat shares are small for both sectors.

Figure 68: Distribution of Unitary Cooling Capacity by Control Type, Segment, and Sector

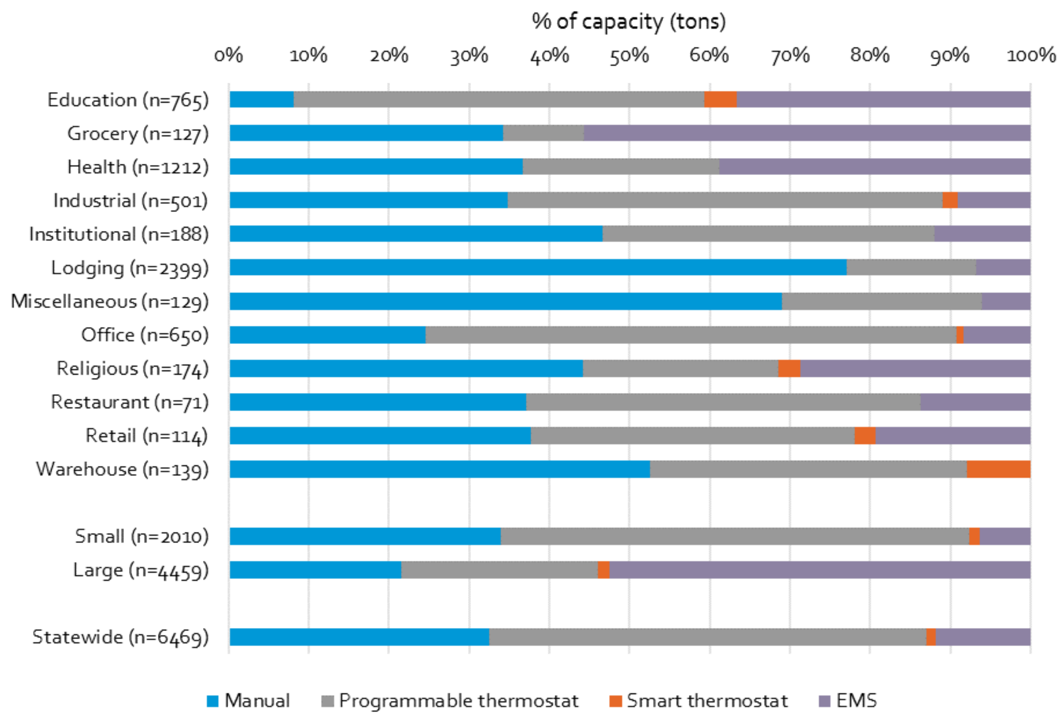


Figure 69 breaks down the capacity shares by unitary equipment subtype. Capacity shares vary widely by control type depending on the equipment.

Figure 69: Distribution of Unitary Control Type by Subtype (by Capacity)

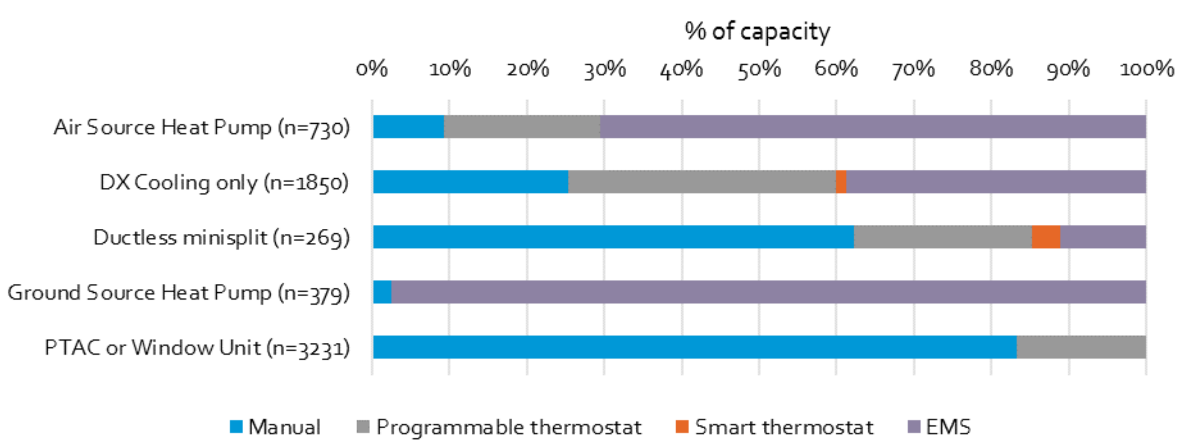
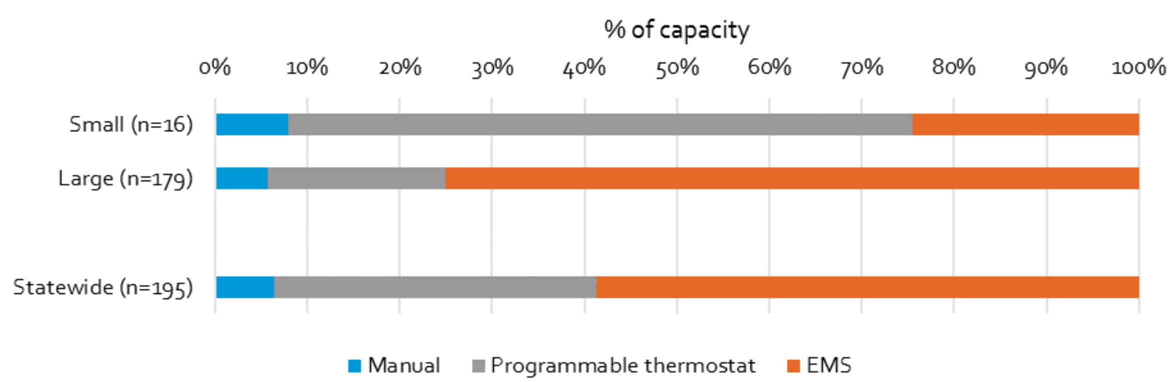


Figure 70 shows the capacity shares by control type for chillers. Energy Management System (EMS) controls and programmable thermostats dominate capacity shares across both the Large C&I and Small C&I sectors. Smart thermostat controls are negligible for chiller systems. The high penetration of technologies such as EMS systems reflect the larger size and sophistication typical of central plant systems.

Figure 70: Distribution of Chiller Control Type (by Capacity)



Cooling System Parameters

In addition to capacity and temperature control information, various parameter information was collected for cooling systems. Table 26 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 drives and EMS systems reflect the larger size and sophistication typical of central plant systems.

Table 26: Central Plant Parameters

Parameter	Share of Tonnage
Condenser Type (n=84)	
Air Cooled Condenser	39%
Cooling Tower	61%
Capacity Control (n=75)	
Fixed Temp	52%
Floating Temp	39%
Head Pressure	10%
Fan Control (n=75)	
Cycle	3%
Constant	31%
Variable Frequency	65%
Pony Motor	1%

Table 27 shows the penetration of various parameters by sector, and statewide for unitary systems, as a percentage of cooling capacity. N-values represent the number of systems surveyed. The penetration of high-efficiency measures, such as variable frequency drives (VFDs), is higher for Large C&I sector customers than for the Small C&I sector.

Table 27: Penetration of Unitary Cooling Energy Efficiency Options

Parameter	Large (n=1,633)	Small (n=835)	Statewide (n=2,468)
Share of capacity			
VFD	51%	37%	38%
Insulated Ducts	17%	26%	25%
Air-to-Air Recovery	8%	3%	3%
Economizer	49%	54%	53%
Demand Control Ventilation	2%	3%	3%

Cooling System Setpoints

The primary function of cooling controls is to regulate indoor temperature via setpoints. Deploying a higher cooling setpoint when buildings are not occupied can help conserve energy. Figure 71 shows average cooling setpoints for buildings when they are normally occupied versus when they are not occupied. About one-third of set point levels were verified by assessing thermostat settings as opposed to self-report. The n-values represent the number of systems surveyed where setpoints were verified at the thermostat by the SWE engineer. As expected, cooling setpoints are several degrees higher (2.1° 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.

Figure 71: Mean Cooling Setpoints (by Occupancy)

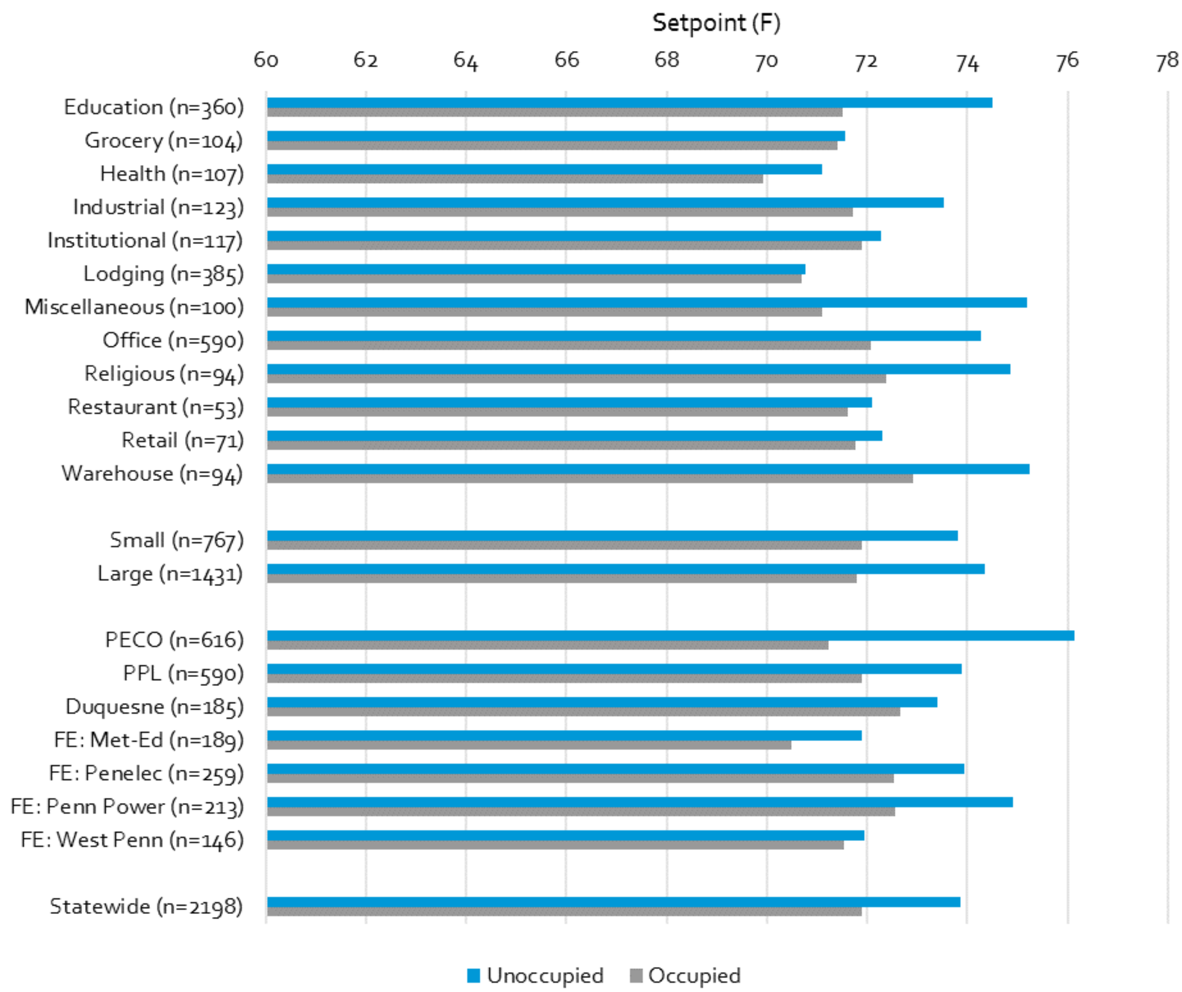


Table 28 shows how cooling setpoints vary by control type, along with the difference between occupied and unoccupied setpoints. The n-values represent the number of systems surveyed for which control and set point data was collected. Notably, unoccupied setpoints are higher for all system types. Setbacks are highest for smart thermostats (+6.1◦ F), but there are also few smart thermostats with verified setpoints (n=24).

Table 28: Cooling Setpoints (by AC Control Type)

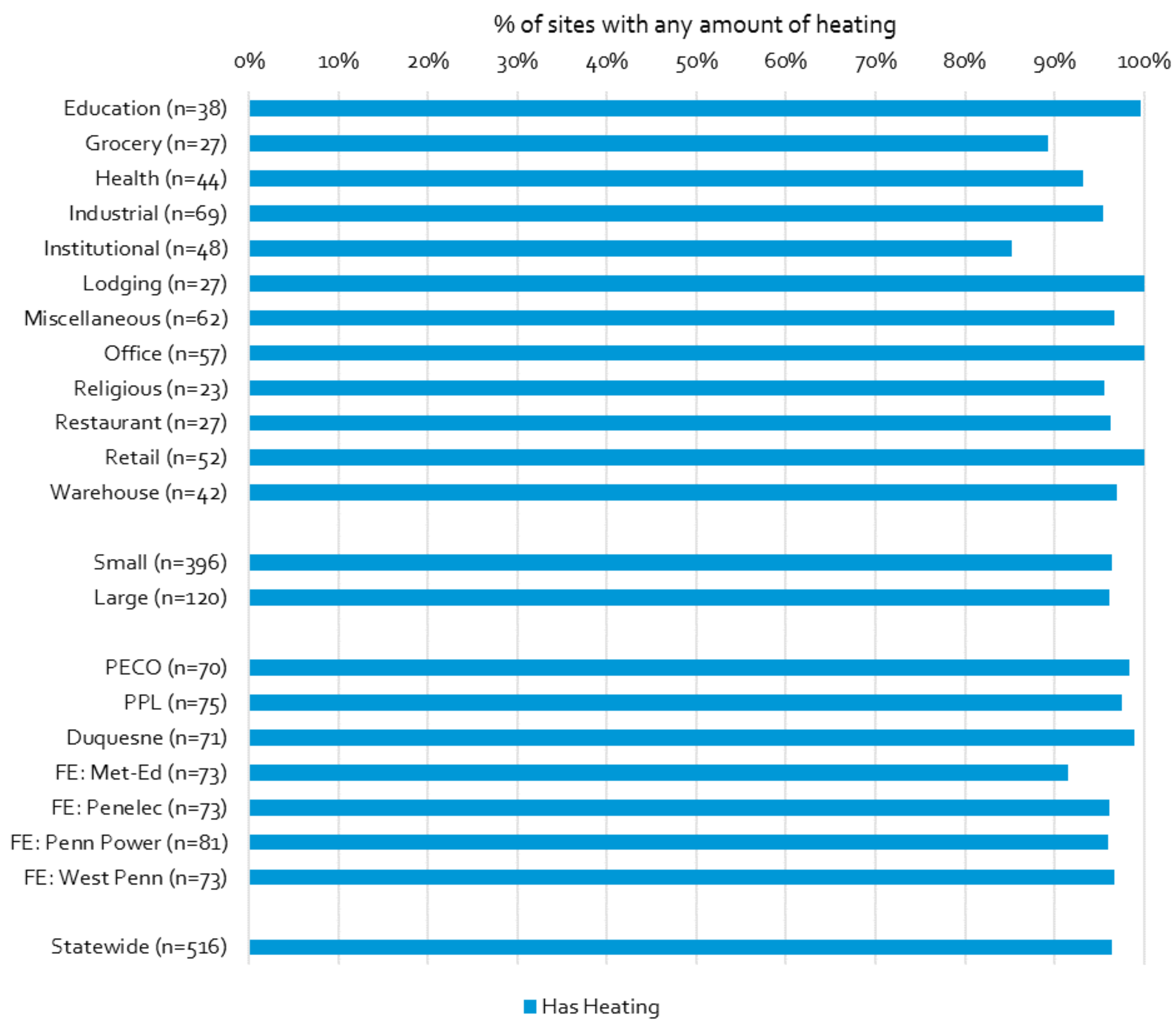
AC Control Type	Unoccupied	Occupied	Difference
Manual (n=1,294)	72.8	71.4	+1.4
Programmable (n=1,001)	71.8	71.0	+0.8
Smart (n=24)	79.7	73.6	+6.1
EMS (n=1,156)	74.4	71.9	+2.5

6.3 HEATING FINDINGS

PENETRATION

Most businesses in Pennsylvania have some amount of heating equipment, and space heating is crucial to the operations of a select few segments. All sites in the Education, Lodging, Office, and Retail segments had some amount of heating equipment, for example. Figure 72 shows the site-level penetration of heating equipment for each segment and sector along with the statewide average. The absence of heating in some segments seems surprising for the prototypical member of the segment. However, readers should keep in mind that the Grocery segment included a seasonal farm stand, and the Institutional segment included the pumping station of a wastewater treatment facility.

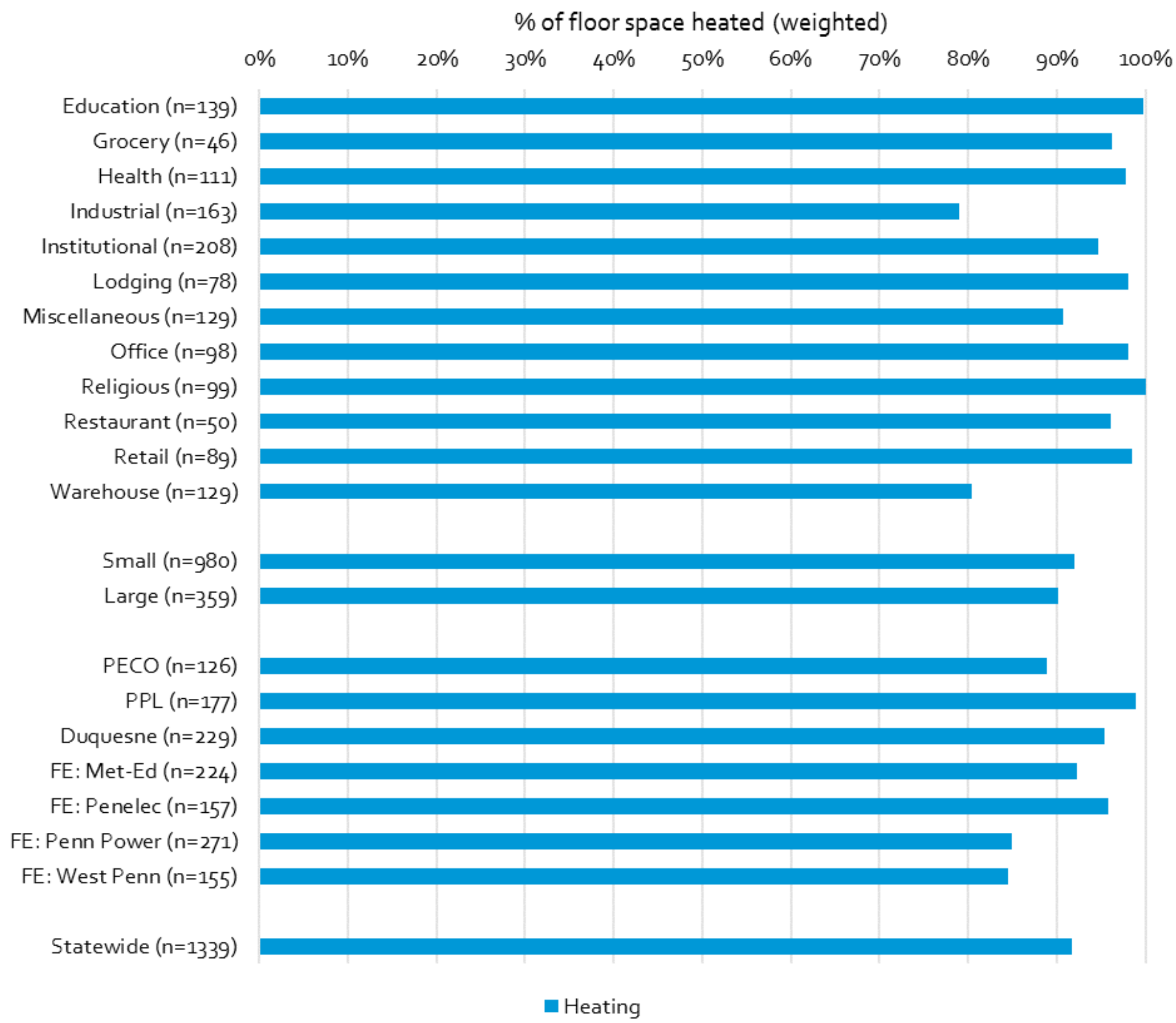
Figure 72: Penetration of Heating Equipment



Saturation

Nearly 96% of sites in Pennsylvania have some amount of heating equipment, but a more important view into energy use is how much of the floor space is heated. Figure 73 shows the saturation of heating equipment for each segment and sector along with the statewide average on a square footage basis. Heating saturation is over 90% for all segments except Industrial and Warehouse. Heating saturation is much more aligned with heating penetration when compared to cooling. As shown previously in Figure 59, the percentage of floor space that is air conditioned is less than 60%. This makes intuitive sense given the Commonwealth's generally colder climate and the need to keep spaces heated for suitable working conditions.

Figure 73: Saturation of Heating Equipment



HEATING FUEL TYPES

Figure 74 shows the fuel share for heating systems by percentage of heating capacity (kBTU heat output). To ensure equivalence between electric and fossil fuel heat sources, efficiency factors were applied to convert nameplate heat input ratings to heat output. N-values indicate the number of heating systems surveyed. Statewide, electric systems provide about 6% of space heating capacity, with the remainder supplied by various fossil fuel sources, primarily natural gas (83%). The electric to fossil fuel split is largely similar for the Large C&I and Small C&I 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 (shown as "Other"), while Small C&I customers have a small but notable amount of fuel oil (5%) and propane heat (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 74: Distribution of Fuel Type (by Capacity)

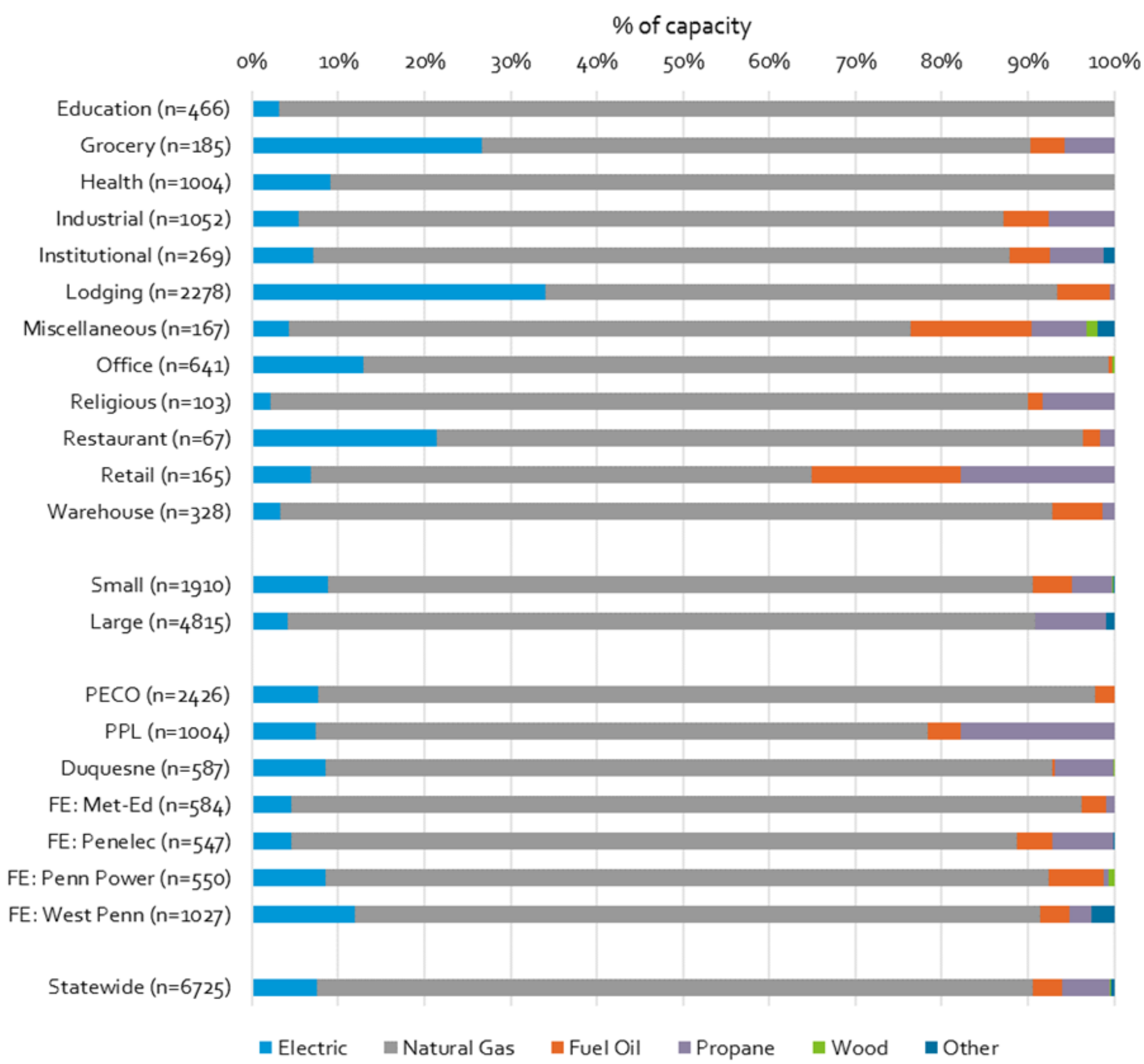


Figure 75 and Figure 76 show the fuel share for heating systems by percentage of heating capacity (kBTU heat output) for unitary and central boiler systems. N-values indicate the number of heating systems surveyed. Statewide, unitary electric systems provide about 13% of space heating capacity, with the remainder supplied by various fossil fuel sources, primarily natural gas (76%). The electric-to-fossil fuel split is largely similar for Large and Small C&I sectors, but they differ in their mix of fossil fuels. While both are primarily fueled by natural gas, large C&I customers had a notable amount of propane heat (17%). Statewide, central boiler natural gas systems provide over 93% of space heating capacity. Small C&I customers with central boilers had a notable amount of propane heat (5%) and fuel oil (5%). Shares for both unitary and central boiler systems 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 75: Distribution of Unitary Fuel Type (by Capacity)

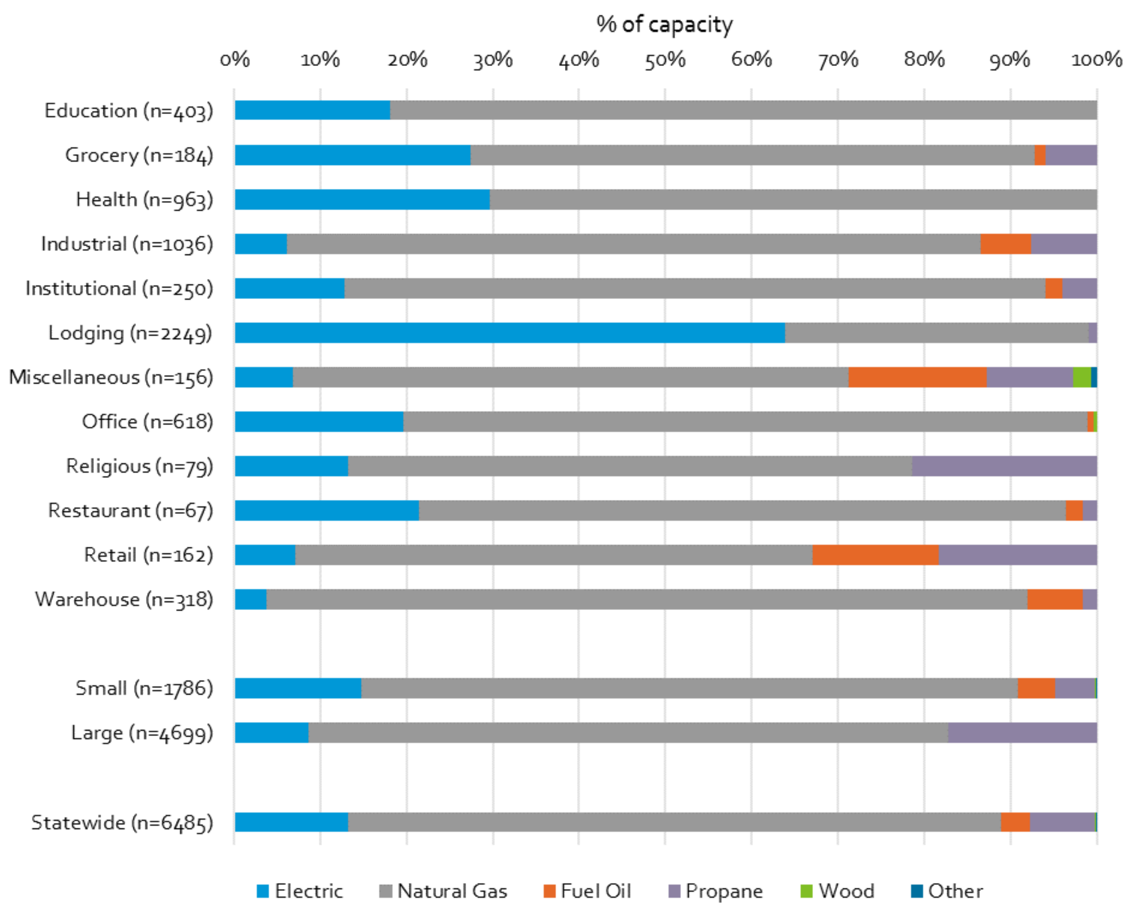
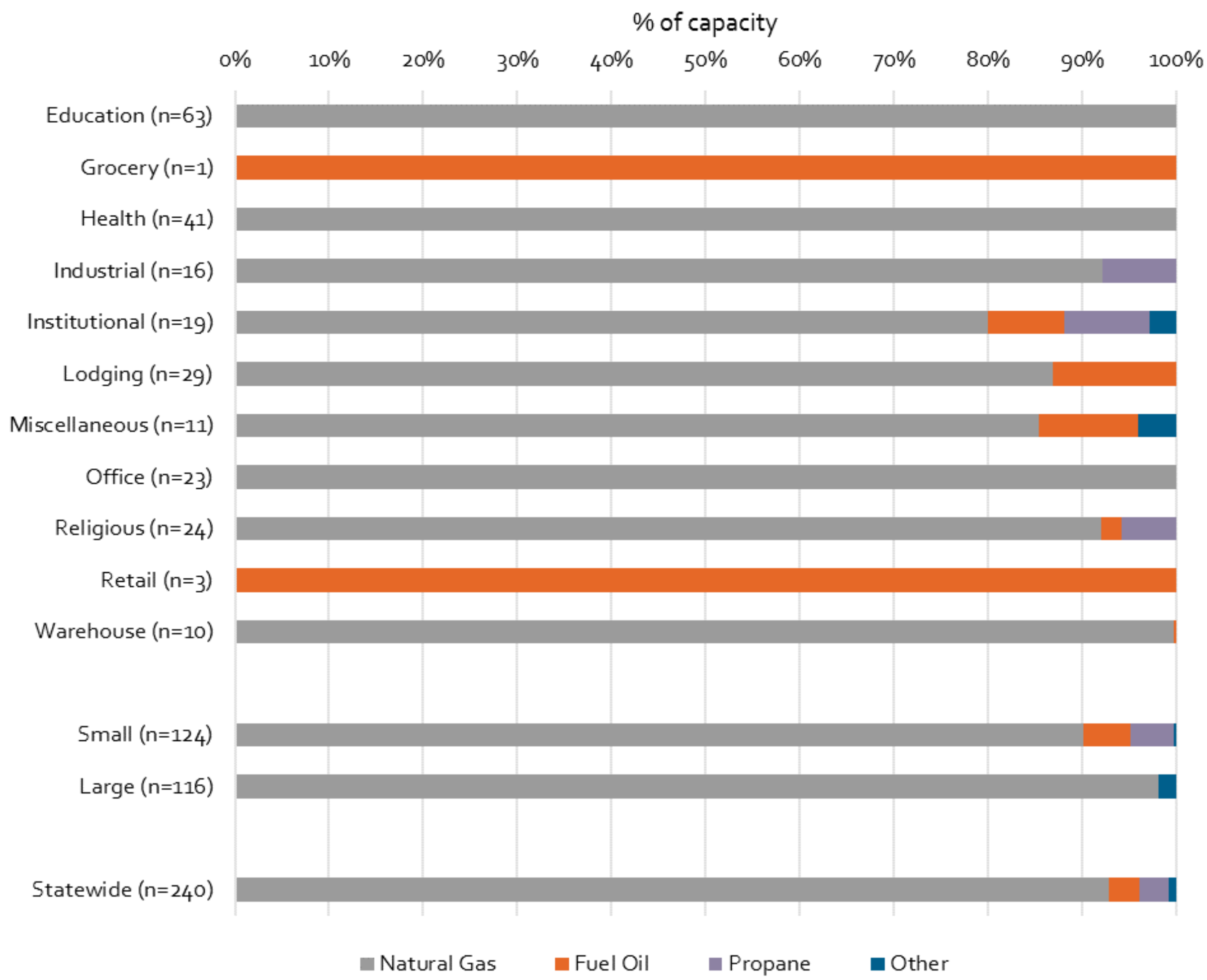


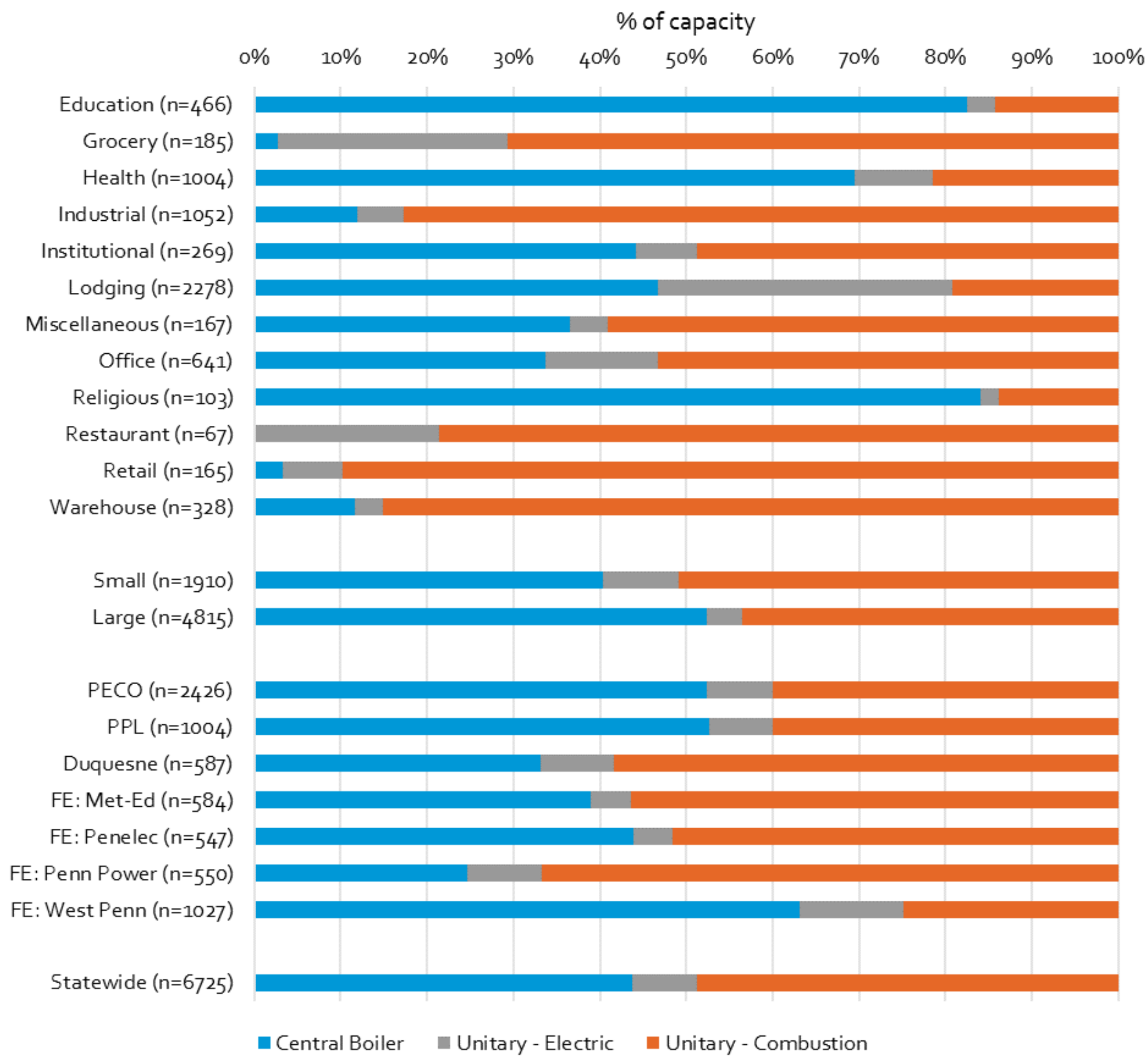
Figure 76: Distribution of Central Boiler Fuel Type (by Capacity)



HEATING SYSTEM TYPES

Figure 77 shows the share of heating capacity (kBTU/hour) for central boilers versus unitary electric and combustion heating systems. N-values indicate the number of heating systems surveyed. Statewide, unitary systems provide 46% of heating capacity, with the majority coming from combustion-based equipment. Central boilers account for a small share of capacity in the Grocery, Restaurant, and Retail segments. 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.

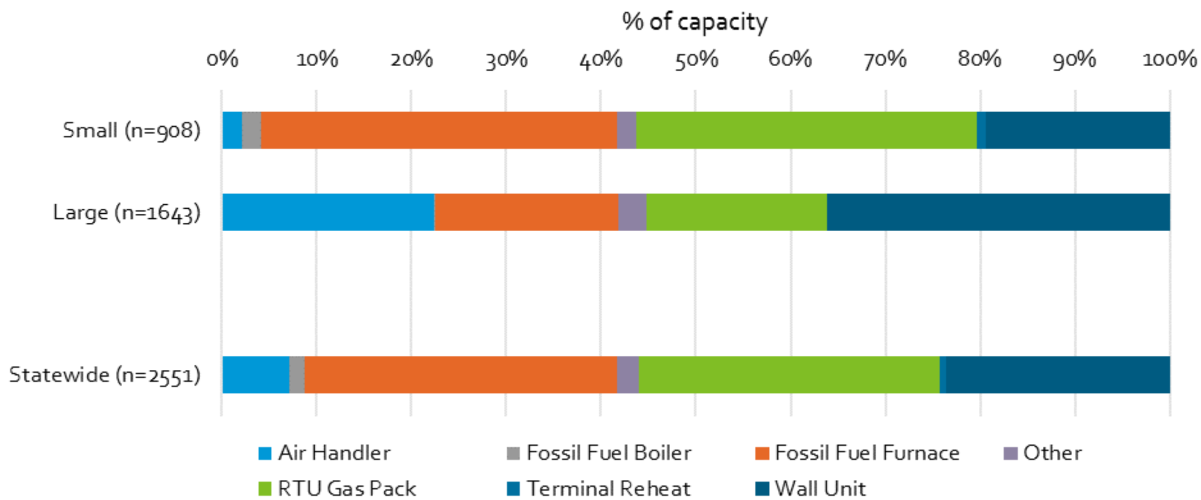
Figure 77: Distribution of Heating System Type (by Capacity)



Heating systems include a variety of different equipment types, described in more depth previously in Table 24. Figure 78, Figure 79, and Figure 80 show the share of heating system capacity by equipment subtypes. The 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.

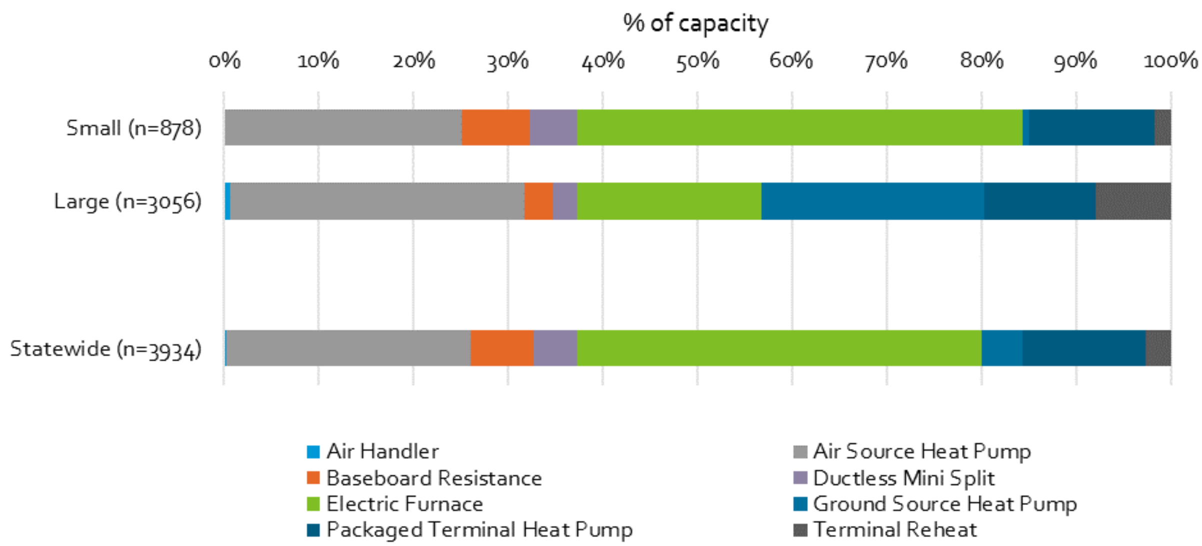
Six unitary combustion heating equipment subtypes were identified at surveyed sites. Figure 78 shows the distribution of heating capacity (kBTU/hour) by unitary combustion subtype. Fossil fuel furnaces and RTU gas packs account for most of the heating capacity statewide. Statewide numbers closely follow capacity shares seen in the small sector. Air rotation units (labeled "air handler") and wall units make up almost 60% of the unitary combustion heating capacity in the Large C&I sector.

Figure 78: Distribution of Unitary Combustion Subtypes (by Capacity)



Eight unitary electric heating equipment subtypes were identified at surveyed sites. Figure 79 shows the distribution of heating capacity (kBTU) by unitary electric subtype. As with the combustion capacity shares above, statewide numbers closely follow capacity shares seen in the Small C&I sector. Electric furnaces and air source heat pumps make up nearly 75% of unitary electric heating capacity statewide. Notably, ground source heat pumps account for 24% of capacity in the Large C&I sector compared to only 1% in the Small C&I sector.

Figure 79: Distribution of Unitary Electric Subtypes (by Capacity)



Five central boiler heating equipment emitter types were identified at surveyed sites. Figure 80 shows the distribution of heating capacity (kBTU) by central boiler emitter type. Wall radiant makes up nearly 46% of capacity statewide. Intuitively, air handlers make up much more capacity in the Large C&I sector (53%) compared to the small sector (10%) due to the higher penetration of centralized cooling systems in Large C&I facilities. If a site has a chiller for cooling, boiler with air handler is the logical heat configuration so that the two end uses share common ventilation equipment.

Figure 80: Distribution of Central Boiler Emitter Type (by Capacity)

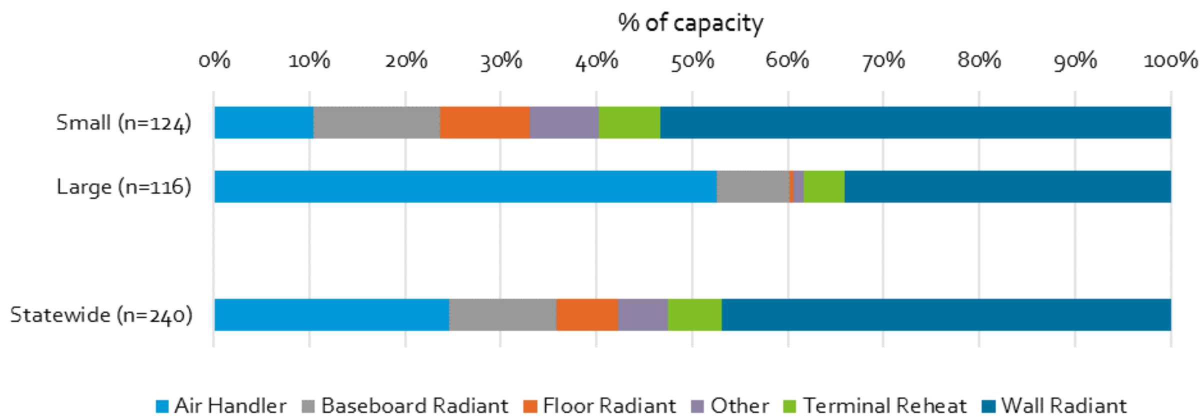


Figure 81 and Figure 82 show the distribution of electric unitary heating units across different size categories by count and output heating capacity, respectively. As expected, smaller units represent a much larger share of heating units than capacity. The smallest units (those below 25 kBTU) make up 74% of units, 25 – 65 kBTU units make up another 20% of units, and the larger units make up the remainder. Smaller units account for only 66% of capacity despite making up nearly 95% of the total count.

Heating unit size bins are also broken out by sector, segment, and EDC. The Grocery segment had the most variation in electric unitary system size. Notably, Large C&I and Small C&I sector customers have similar shares of the heating units, with small sector customers seeing more of their electric unitary heating capacity coming from larger units.

Figure 81: Distribution of Unitary Electric Equipment Size (by Units)

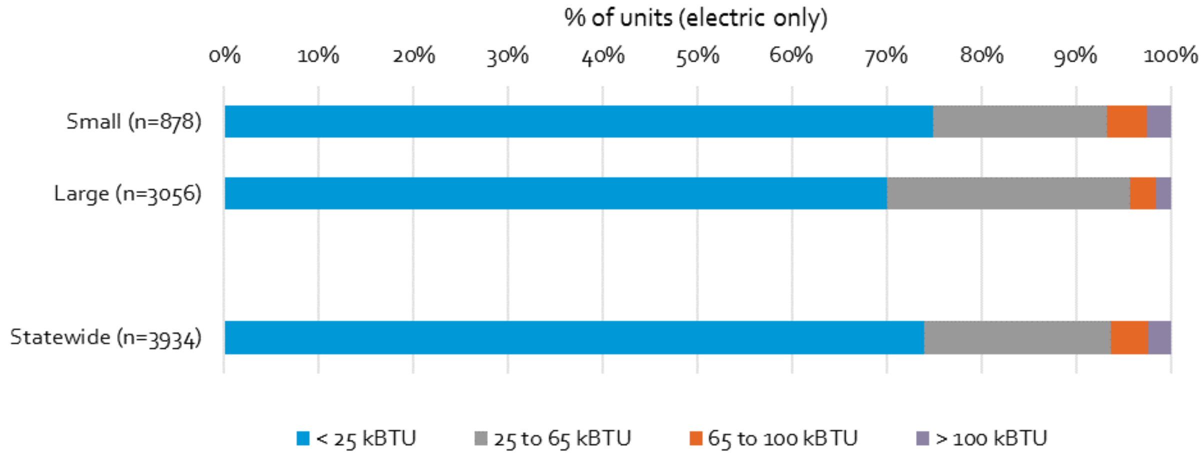


Figure 82: Distribution of Unitary Electric Equipment Size (by Capacity)

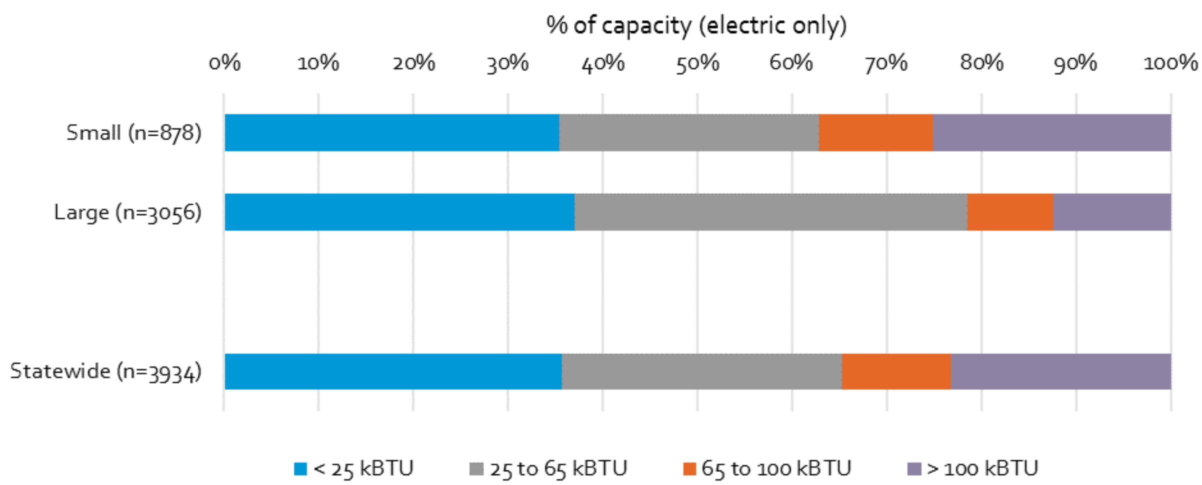


Figure 83 and Figure 84 show the distribution of central boilers across different capacity bins by count and heating capacity, respectively. N-values reflect the number of boiler systems surveyed. Note that few boiler systems were surveyed, indicative of the fact that boiler systems, which typically 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 35% of boiler systems are over 2,500 kBTU. In contrast, boilers at small customer sites tend to be smaller: just 2% 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 (Warehouse, Grocery, and Retail) are also those with the smallest number of systems surveyed. Smaller units account for only 9% of capacity despite making up over 45% of the total count. Notably, nearly 85% of capacity shares in Large C&I come from large units above 2,500 kBTU.

Figure 83: Distribution of Central Boiler Equipment Size (by Units)

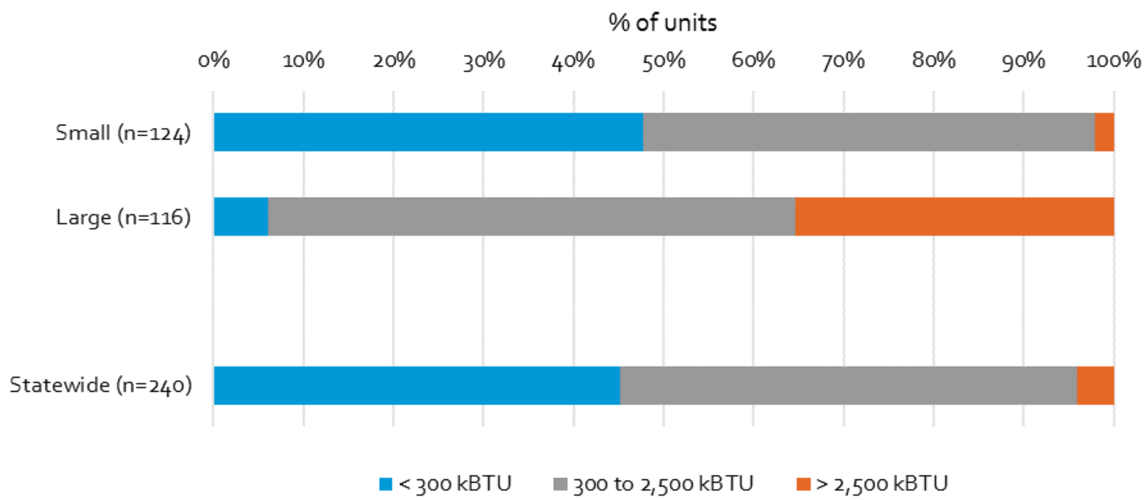
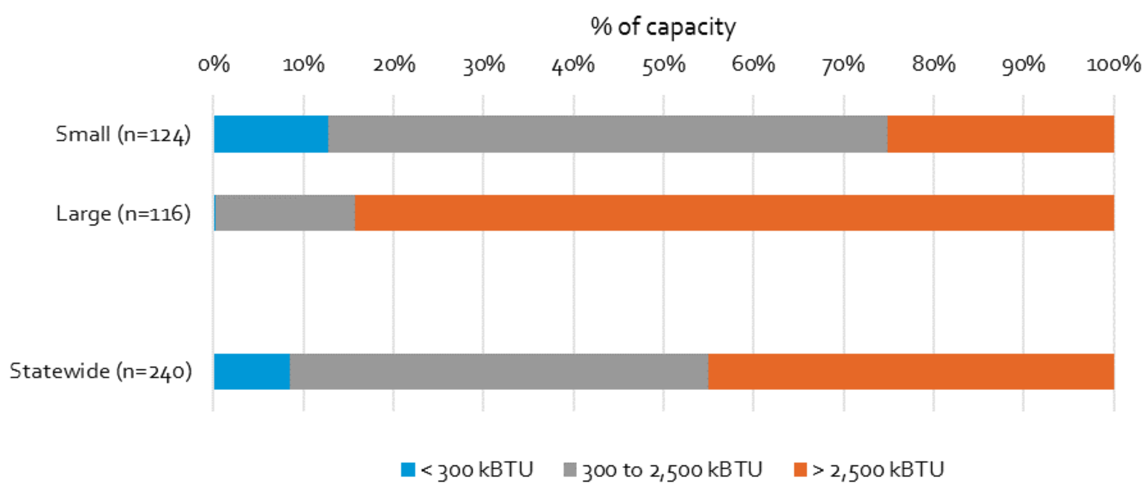


Figure 84: Distribution of Central Boiler Equipment Size (by Capacity)



Heating Capacity and Efficiency

Table 29 shows the average output capacity and efficiency by heating equipment across the study sample. Output capacity is expressed in kBTU/hour, a common metric for electric heating equipment. Fossil fuel equipment is typically rated by *input* capacity. We use the thermal efficiency of fossil fuel equipment to convert input heating capacity to output heating capacity for fossil fuel combustion equipment. Technicians were allowed to enter heating efficiency ratings in the metric listed on the equipment nameplate and then ratings were standardized across metrics to create a simplified unitless ratio of thermal output over energy input. Heat pumps have efficiency over 100% because they use a refrigeration cycle to move heat from a source (air or water) to the space. This is sometimes referred to as a coefficient of performance (COP) and means more heat is output than the energy embedded in the electricity that powers the heat pump.

Table 29: Average Size and Efficiency by Heating System Type

System Type	Efficiency (%)	Output Heating Capacity (kBTU/hour)	n-value
Central Boiler	**84.7**	**868.8**	**208**
Unitary Combustion	**84.0**	**115.8**	**2,445**
Air Rotation Unit	91.7	374.0	95
Fossil Fuel Boiler	89.3	101.6	23
Fossil Fuel Furnace	85.5	81.6	1,358
RTU Gas Pack	81.0	144.7	503
Wall Unit	79.8	131.5	466
Unitary Electric	**191.0**	**34.8**	**2,102**
Air Source Heat Pump	277.6	36.6	732
Baseboard resistance	99.5	14.2	128
Ductless Mini-split Heat Pump	270.6	19.2	70
Electric Furnace	99.0	54.1	480
Ground Source Heat Pump	383.5	23.5	378
Terminal Reheat	99.0	23.7	314

Fossil fuel combustion equipment generally falls between 80% and 90% thermal efficiency. Wall unit heaters had the lowest average efficiency across the study. Electric heating equipment falls into two broad categories – heat pumps and electric resistance. The resistance equipment all falls very close to 100% efficiency while heat pumps are three to four times more efficient at turning electricity into heat. The ground source heat pump category (which includes water source heat pumps) was the most efficient heating equipment, on average, in the study.

Temperature Control Types

Figure 85 through Figure 88 show the share of heating capacity controlled by different control types. Note that this analysis shows controls for both system types (central boilers and unitary). Notably, over 50% of central boiler capacity is controlled by Energy Management Systems (EMS), and over 50% of unitary capacity is manually controlled. A key difference between unitary and central boiler units is that programmable thermostats are much more prevalent for unitary systems, controlling 32% of forced air capacity compared to 11% of boiler capacity. Statewide penetration of smart thermostats is low for both central boilers and unitary systems, and nearly 10% of central boilers operate continuously (Always On).

Figure 85: Distribution of Control Types Statewide (by Capacity)

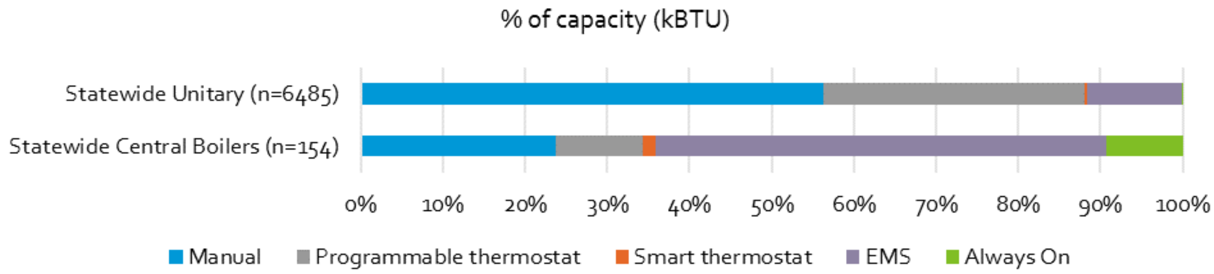


Figure 86 shows the share of unitary capacity controlled by different control types. N-values correspond to the number of units surveyed. Notably, over 50% of heating capacity is controlled manually and does not vary much between sectors. 54% of small sector unitary capacity is controlled manually, while about 62% of large sector capacity is controlled manually. In addition, a meaningful share of small sector capacity (34%) is controlled by programmable systems, compared with 26% of capacity for large sector customers. Programmable control types account for a much smaller capacity share in heating systems (32%) than in cooling systems (54%), as seen in Figure 68 previously. Figure 87 breaks down the capacity shares by unitary equipment subtype. Capacity shares vary widely by control type depending on the equipment. Notably, EMS controls accounted for most capacity for ground source heat pumps and terminal reheats.

Figure 86: Distribution of Unitary Control Type (by Capacity)

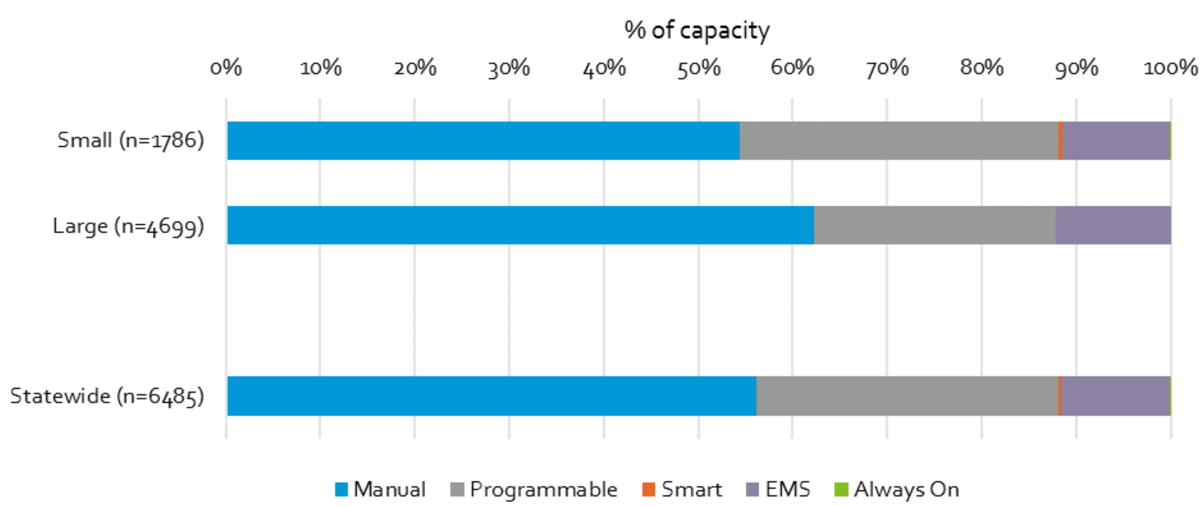


Figure 87: Distribution of Unitary Control Type by Subtype (by Capacity)

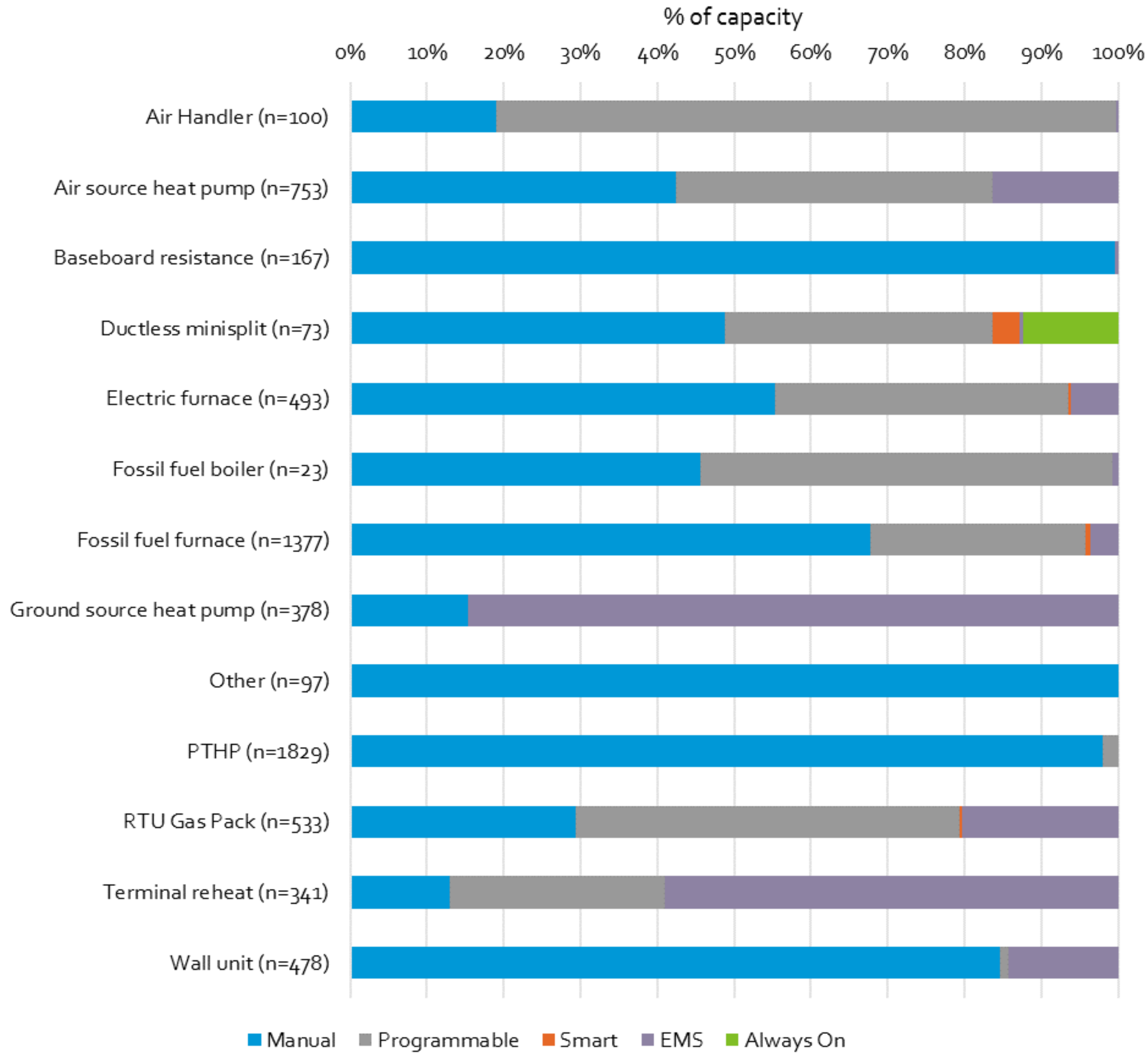
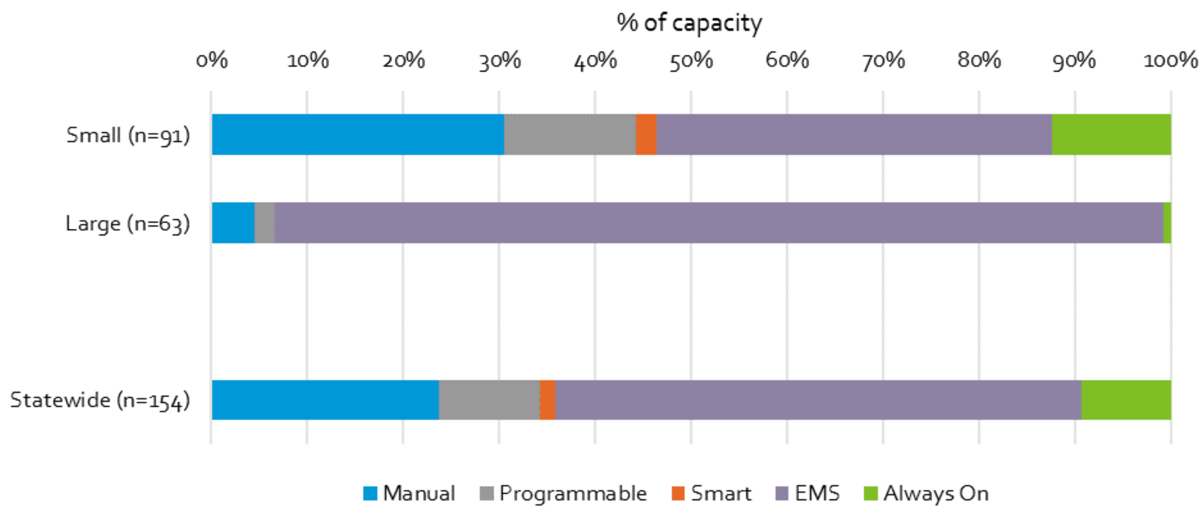


Figure 88 shows the share of boiler capacity controlled by different control types. N-values correspond to the number of boiler units surveyed. Notably, 55% of boiler heating capacity is controlled by EMS, though this is not evenly split between sectors. In contrast, a much larger share of large sector boiler capacity (93%) is controlled by EMS systems, compared with 41% of boiler capacity for Small C&I sector customers.

Figure 88: Distribution of Central Boiler Control Type (by Capacity)



HEATING SYSTEM SETPOINTS

The primary function of heating controls is to regulate indoor temperature via heating setpoints. Deploying a lower heating setpoint when buildings are not occupied can help conserve energy. Figure 89 shows average heating setpoints across all heating systems for when buildings are normally occupied versus when they are not occupied.[6] 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 couple degrees lower (1.5 F) when heating systems are unoccupied. Note that the amount of variation in setpoints by sector, segment, and EDC is likely a function of the sites surveyed. The results for the Warehouse and Lodging segments make intuitive sense, with Warehouse seeing the largest difference between occupied and unoccupied setpoints and the Lodging setpoints being more equal to maintain comfort levels for inhabitants.

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

Figure 89: Mean Heating Setpoints (by Occupancy)

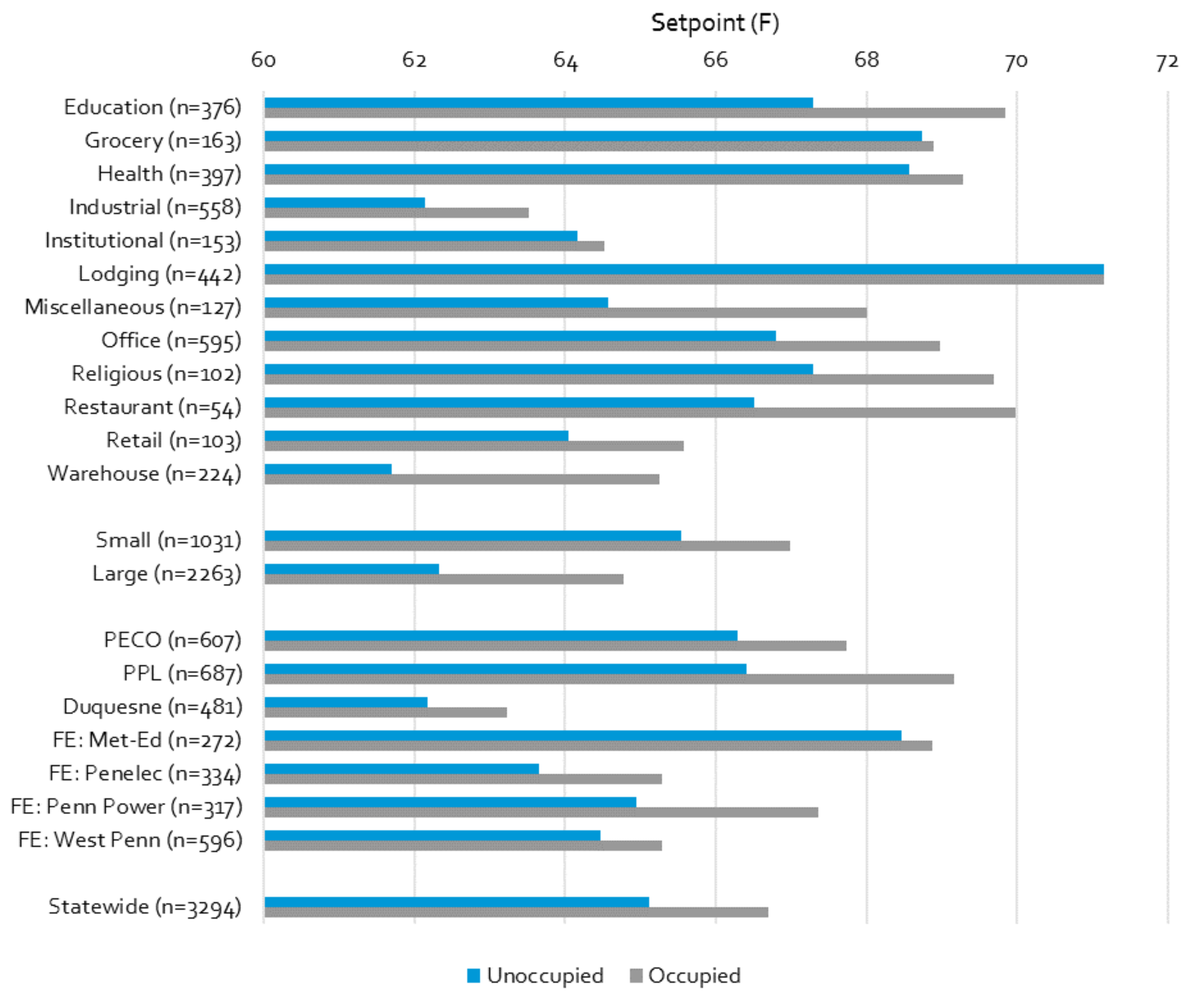


Table 30 shows how heating setpoints vary by control type, along with the difference between occupied and unoccupied setpoints. N-values represent the number of systems surveyed for which control and set point data was collected. Notably, unoccupied setbacks are larger for programmable thermostats (- 2.6◦ F) than for manual (-1.4◦ F). Heating setbacks for EMS systems (-0.2◦ F) are small relative to cooling setbacks for these same systems (+2.5◦ F).

Table 30: Heating Setpoints (by Heating Control Type)

Heating Control Type	Unoccupied	Occupied	Difference
Manual (n=1,344)	63.9	65.3	-1.4
Programmable (n=688)	66.4	69.0	-2.6
Smart (n=8)	62.9	64.2	-1.2
EMS (n=1,254)	67.8	68.0	-0.2

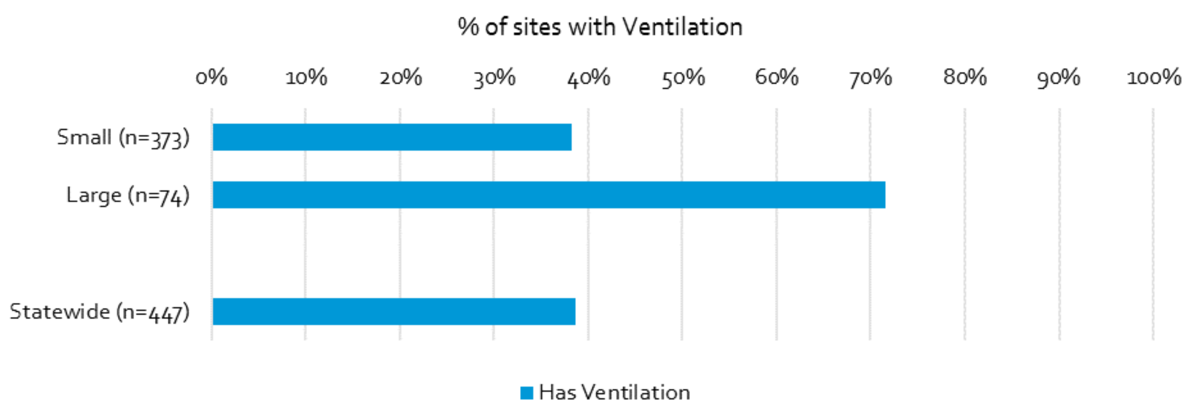
6.5 VENTILATION FINDINGS

PENETRATION

Figure 90 shows the site-level penetration of ventilation equipment for each sector along with the statewide average. Industrial ventilation equipment is excluded from this section and can be found in the Process section of the report. This data only includes dedicated ventilation equipment recorded in inventory. For example, if the equipment recorded on site was a rooftop air conditioning unit with a single cabinet housing both the compressor and blower motor, the engineers generally did not inventory the fan component separately as ventilation. In other words, many unitary HVAC systems have embedded ventilation equipment. Engineers were instructed to collect ventilation data for built-up systems only. Additionally, bathroom fans were not a priority data collection item.

Large C&I sites are much more likely to have built-up ventilation systems, whereas only 38% of small sites had any amount of dedicated ventilation equipment recorded in the on-site inventory. The statewide results closely follow the Small C&I sector results because the case weights are so much larger for Small C&I and the penetration calculation does not consider capacity.

Figure 90: Ventilation Equipment in Inventory



VENTILATION MOTORS

Figure 91 summarizes the control method for the motors that power these ventilation systems. Most motors statewide utilize electronic variable speed drives. N-values are provided at the motor level, and the figure is weighted by capacity of the ventilation system.

Figure 91: Distribution of Ventilation Motor Control Type (by Capacity)

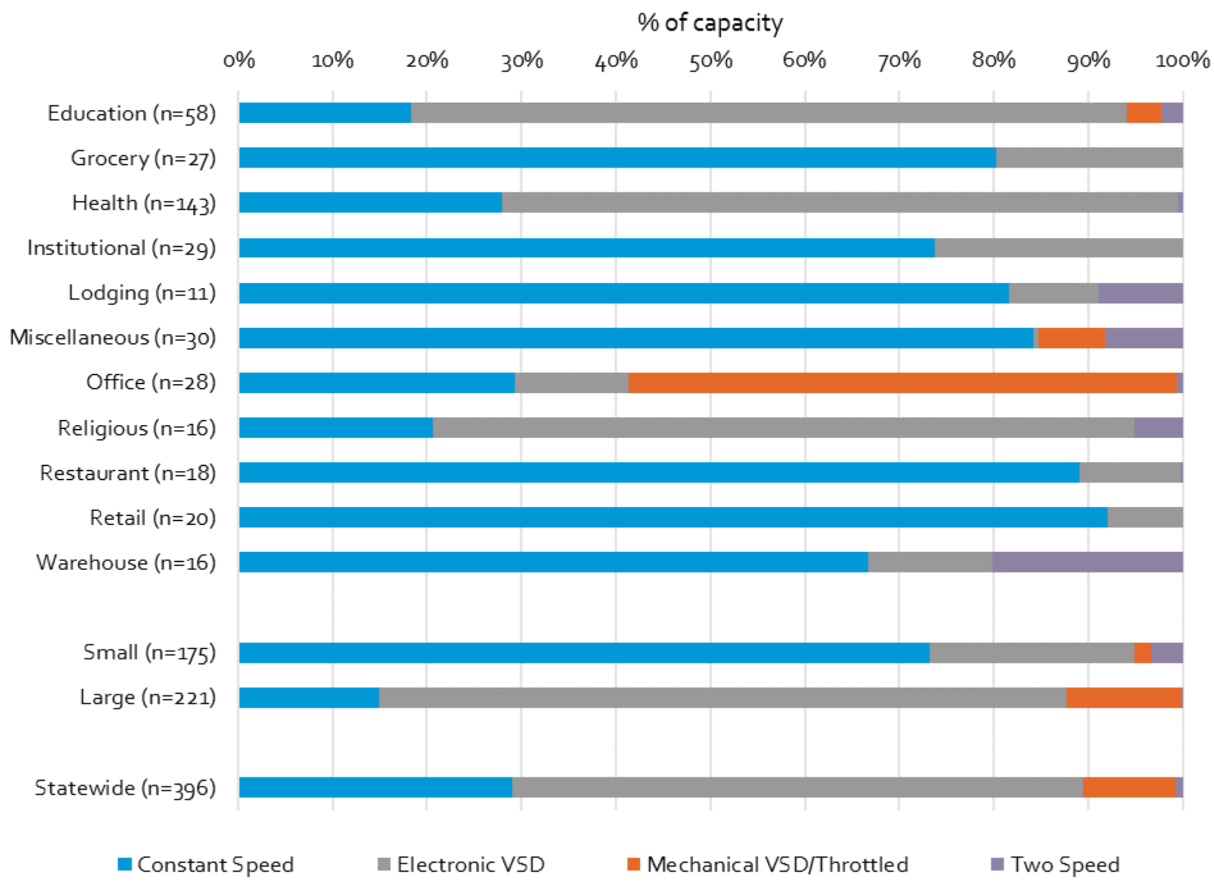
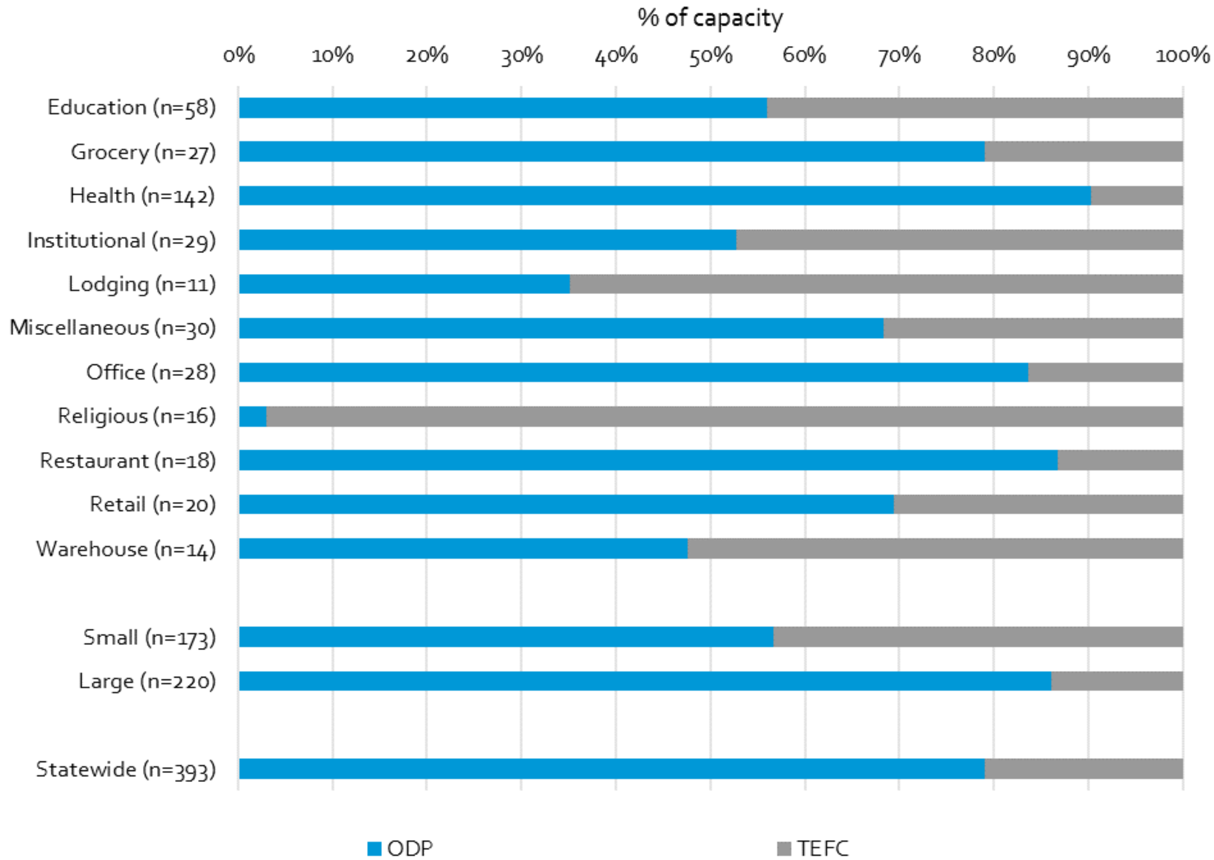


Figure 92 shows the distribution between open drip proof (ODP) and totally enclosed fan cooled (TEFC) casings for NEMA motors. Baseline efficiency ratings in the Pennsylvania TRM depend on casing type. Provided n-values are at the motor level, and shares are capacity weighted (horsepower) in both figures. Nearly 80% of NEMA casing types statewide are ODP.

Figure 92: Distribution of NEMA Casing Type (by Capacity)



BUILDING-LEVEL FINDINGS

Figure 93 shows the percentage of buildings with ventilation surveyed that are controlled by carbon dioxide (CO_2) sensors. Controlling ventilation in commercial buildings using CO_2 sensors is a strategy to ensure optimal indoor air quality while also improving energy efficiency. Only 2% of ventilation statewide is controlled by CO_2 sensors. Nearly 11% of ventilation seen in large C&I buildings is controlled by CO_2 sensors. The statewide number follows the Small C&I sector closely because most buildings in the state come from the Small C&I sector and this calculation does not consider size/capacity.

Figure 93: Percentage of Buildings with Ventilation Controlled by CO2 Sensors

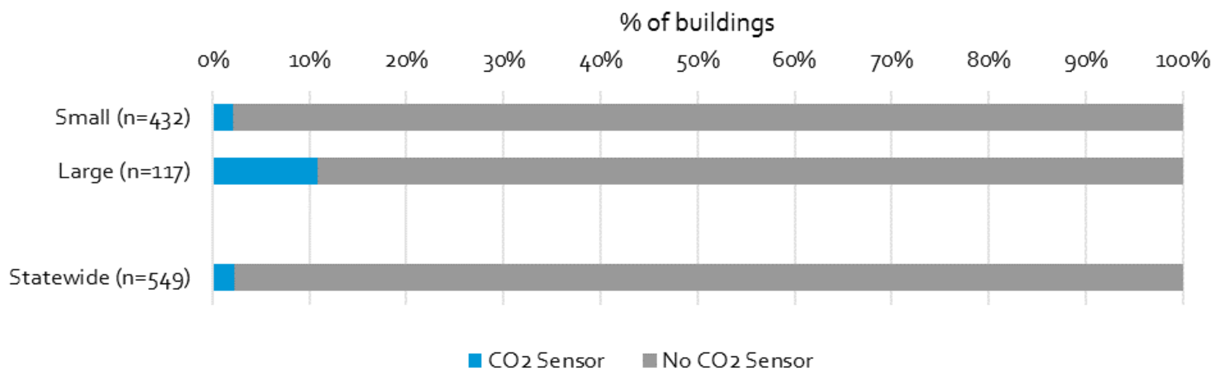
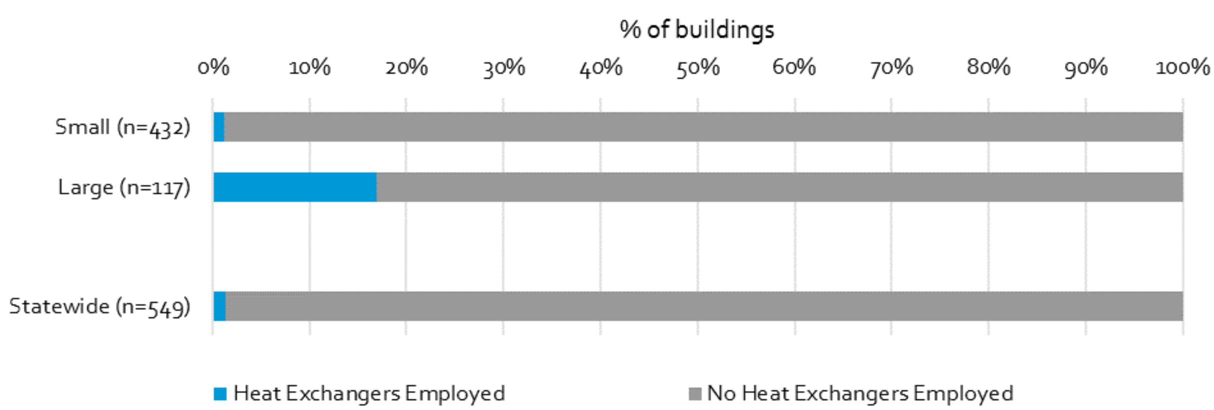


Figure 94 shows the percentage of buildings with ventilation surveyed that have heat exchangers employed. Ventilation in commercial and industrial buildings use heat exchangers for energy efficiency and indoor air quality reasons. Heat exchangers, specifically energy recovery ventilators (ERVs) or heat recovery ventilators (HRVs), are designed to transfer heat between incoming and outgoing airstreams. Only 1% of ventilation in the Small C&I sector use heat exchangers, while nearly 17% of Large C&I buildings uses heat exchangers. The statewide number follows the Small C&I sector closely because most buildings in the state come from the Small C&I sector and this calculation does not consider size/capacity.

Figure 94: Percentage of Buildings with Ventilation with Heat Exchangers Employed



Horsepower

Knowing the amount of ventilation horsepower per square foot or ton of cooling in a building is valuable for several reasons related to energy efficiency, indoor air quality, and compliance with building codes and standards. Among the 159 buildings surveyed with ventilation horsepower data, the SWE engineers recorded an average of 0.0007 HP/ft^2 or 1 horsepower for every 1,400 square feet. Regarding cooling, the SWE engineers recorded an average of 0.388 HP/ton, or one horsepower of ventilation for every 2.58 tons of cooling.

6.6 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 31 summarizes mean and median system ages for the high-level equipment types described above. The mean age for most systems is 14 to 16 years, implying a useful life of about 25 to 30 years.[7]

Ductless mini splits have the lowest mean age because it's a relatively new technology that has only become common in the last ten years. Therefore, the expected useful life rule of thumb does not apply to ductless mini splits yet.

Table 31: HVAC System Age (by Equipment Type)

Equipment Type	n	Mean Age	Median Age
Heating			
Central Boiler	105	21	18
Unitary (Combustion)	624	10	8
Unitary (Electric)	1,443	18	18
Cooling or Cooling + Heating			
Chiller	139	11.5	8
Air Source Heat Pump	268	9	11
DX Cooling	969	12	13
Ductless Mini Split	62	6	5
Ground Source Heat Pump	24	18	18
Packaged Terminal	1,076	13	13

COOLING SYSTEM AGE

Table 32 shows mean and median cooling system age 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 ten years old, about four years younger than for Large C&I customers. 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 ten or 20 years.

Table 32: Cooling Unit Age (by Sector)

Sector	Mean Age	Median Age
Large (n=1,711)	14.2	13.0
Small (n=746)	9.9	9.0
Statewide (n=2,457)	**10.3**	**10.0**

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

Heating System Age

Table 33 shows mean and median heating system age 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 ten years younger than for Large C&I customers. Act 129 imposes a 15-year measure life limit on all EE&C measures. This policy requirement appears to understate the mechanical life of heating equipment, particularly in the Large C&I sector.

Table 33: Heating Unit Age (by Sector)

Sector	Mean Age	Median Age
Large (n=1,455)	23.2	22.0
Small (n=716)	13.8	10.0
Statewide (n=2,171)	**20.1**	**13.0**

6.7 COMPARISON WITH PRIOR STUDY FINDINGS

The following graphs and tables compare 2023 results with the 2018 non-residential baseline study to better illustrate trends in Pennsylvania businesses' heating and cooling equipment. Figure 95 shows the distribution of cooling system type over time, graphed here as the percentage of capacity. Unitary systems accounted for an 8% higher share of cooling capacity in 2023. Figure 96 shows the distribution of heating system type over time as the percentage of capacity. Central Boiler systems seem to account for a much smaller share of heating capacity in 2023, down by 23% from 2018 levels. However, data collection and weighting methods evolved in 2023. Notably, central boiler capacity was split between heating and domestic hot water for systems that served both end uses. Therefore, the share of heating capacity from central boilers is expected to be lower in 2023.

Figure 95: Distribution of Cooling Equipment Type (by Capacity), 2018 vs. 2023

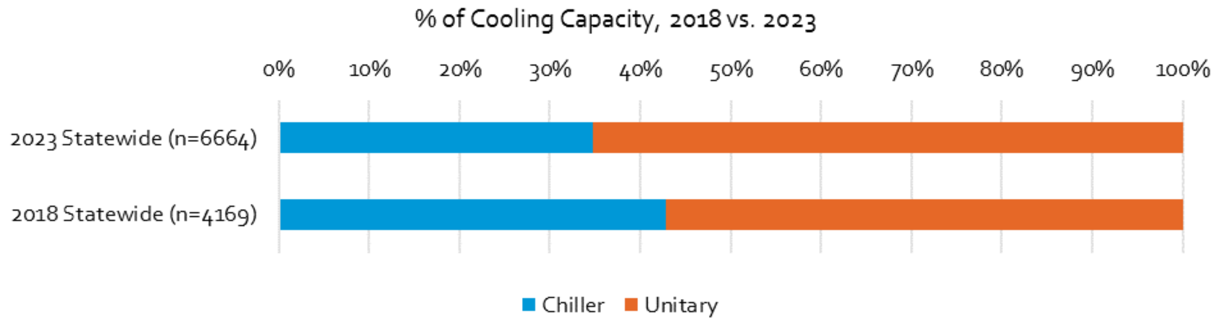


Figure 96: Distribution of Heating Equipment Type (by Capacity), 2018 vs. 2023

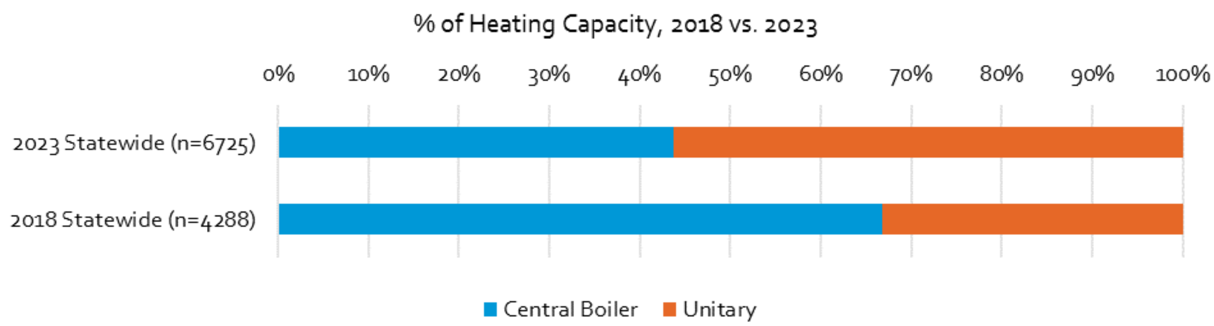
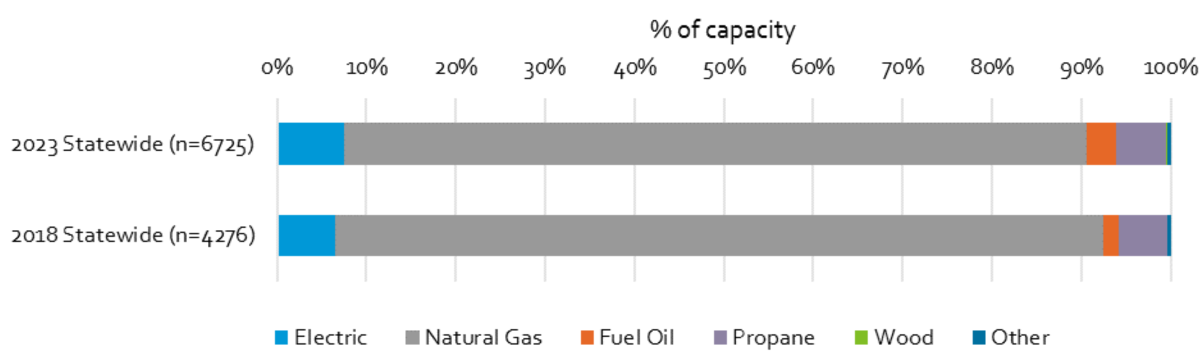


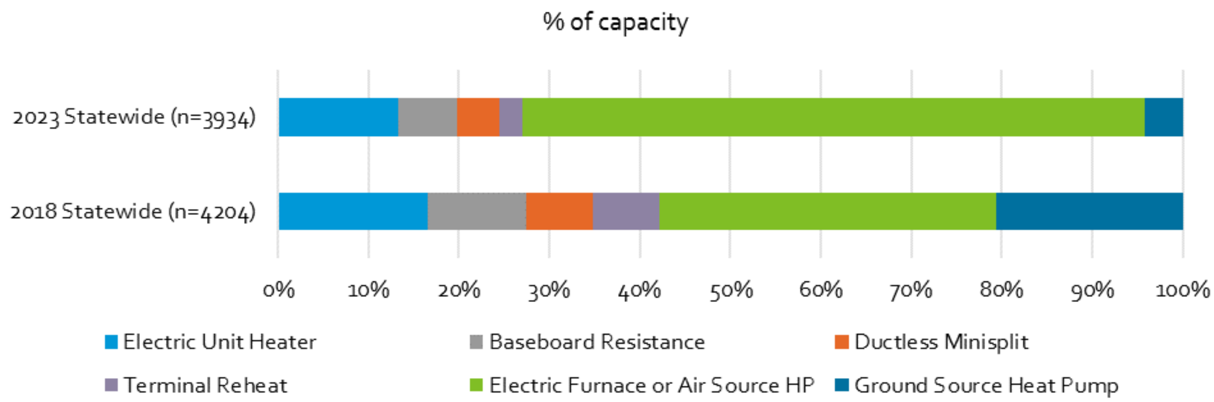
Figure 97 shows the distribution of heating fuel type over time as the percentage of capacity. Electric fuel shares increased slightly from 6.5% to 7.5%. Wood was not a fuel type category in 2018, and the hot water/steam category from 2018 was folded into natural gas to be consistent with the 2023 classification scheme.

Figure 97: Distribution of Heating Fuel Type (by Capacity), 2018 vs. 2023



Finally, Figure 98 shows the distribution of electric unitary heating capacity over time. Electric furnaces and air source heat pumps had the largest capacity shares in both years, and the share increased substantially from 37% to 69% of capacity from 2018 to 2023. Electric furnaces and air source heat pumps are two distinct subtypes in the 2023 study, and Figure 79 previously showed the capacity shares of electric furnaces and air source heat pumps are 43% and 26%, respectively. Capacity shares of electric furnaces in 2023 are 6% greater than the combined shares of electric furnaces and air source heat pumps in 2018. Notably, capacity shares of ground source heat pumps and ductless mini splits decreased in 2023 relative to the 2018 study results.

Figure 98: Distribution of Unitary Electric Subtype (by Capacity), 2018 vs. 2023



7 DOMESTIC HOT WATER

7.1 DOMESTIC HOT WATER EQUIPMENT OVERVIEW

This chapter details findings on hot water for non-industrial applications as well as related data on water fixtures and recreational water features. Data collection was focused on both heater and tank types, capacities, fuels, and several optional efficient characteristics. In this analysis, we categorize water heaters by:

1. **Type**
   - Large/Central (including boilers)
   - Unitary (Residential style)
   - Small/Point-of-Use
2. **Tank Type**
   - Tank
   - Tankless
3. **Fuel**
   - Electric
   - Natural Gas
   - Propane
   - Fuel Oil

For simplicity, we also combine natural gas, propane, and fuel oil together as “Fossil Fuel” units in some graphs. As a reference, Figure 99 shows some examples of water heaters by their “Type” and “Tank Type” classifications:

Figure 99: Hot Water Heater Examples Classified by Type and Tank Type

Data in the tables and figures is generally weighted by either:

- Number of water heaters
- Tank capacity (gallons)
- Input capacity (kBTU)

While comparisons based on counts of water heaters are straightforward, the capacity weights give greater importance to larger units and can better describe energy usage.

Tankless water heaters pose two challenges in presenting results: First, to include these units in all the analyses, a "tank capacity" in gallons is assumed for each Small/Point-of-Use (five gallons), Unitary (40 gallons), or Large/Central (100 gallons) unit. Second, input capacities can over-represent tankless units' total energy usage since, by design, they use large amounts of energy discontinuously. For these reasons, the domestic hot water data is shown separately by unit counts, gallons, and kBTU where possible. Comparing results across each of these dimensions paints a clearer picture of the current equipment stock and energy use.

Each segment's relative weight in statewide results reflects its share of total, statewide energy used for domestic hot water. Since this chapter evaluates hot water for non-industrial applications, the Industrial segment receives relatively less weight while segments such as Lodging, Grocery, and Restaurant receive greater weight.

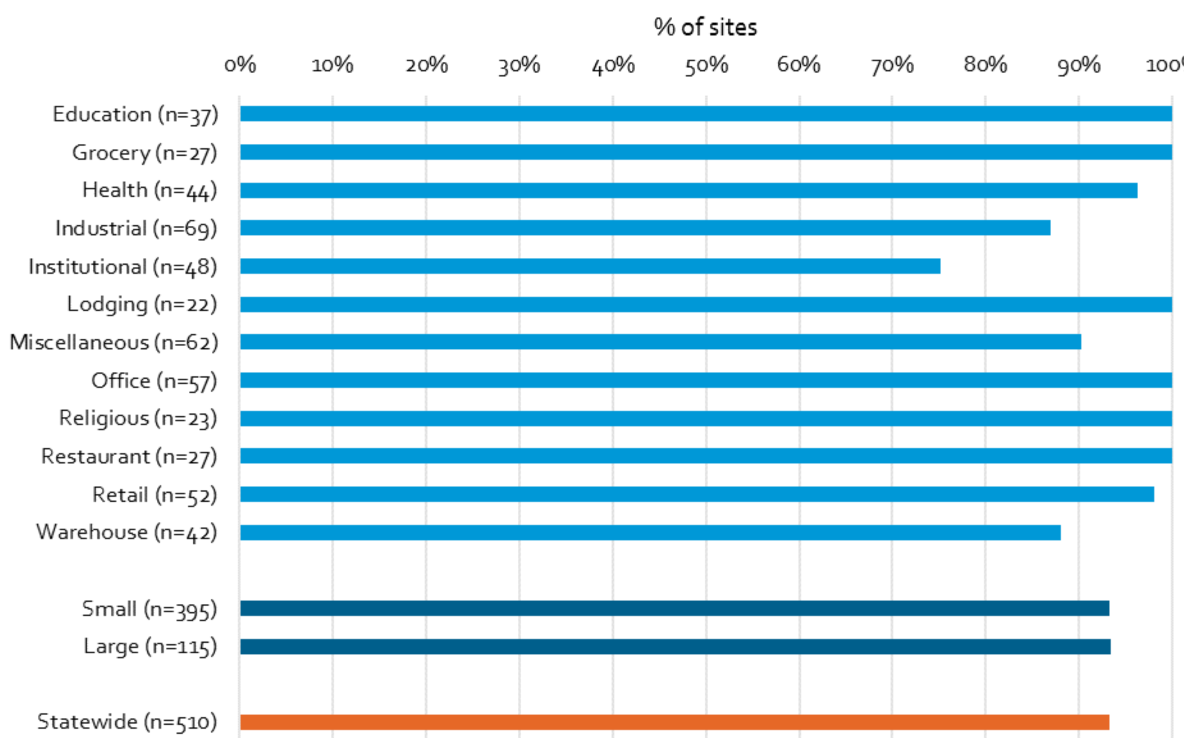
This chapter also includes an analysis of recreational water features, such as pools and hot tubs, including the heaters and motors associated with them. A final section discusses data on faucets and showerheads.

7.2 DOMESTIC HOT WATER FINDINGS

PENETRATION

Most Pennsylvania businesses have at least one water heater. Figure 100 shows the site-level penetration of water heaters for each segment and sector along with the statewide average. For several industry segments, every site surveyed uses some amount of energy for water heating. Some of the sites with no water heaters are largely outdoor operations or take their hot water from a separate account that was not included in the site visit. Figure 100, then, represents a lower bound of what would be present at a common single-building, indoor, commercial site.

Figure 100: Penetration of Domestic Hot Water Heaters



TANK TYPE & SIZE

Figure 101 shows the distribution of tank types by the count. Statewide, about 10% of businesses' water heaters are tankless. Figure 102 repeats the analysis while weighting by input capacity, with 20% of energy going to tankless units. The Lodging segment had the highest share of tankless units by both measures.

The Large C&I sector had a greater share of tankless units by both measures. These large tankless units include some indirect water heaters that draw heat from another end use but have no storage tank.

Figure 101: Share of Tank/Tankless Water Heaters by Device Count

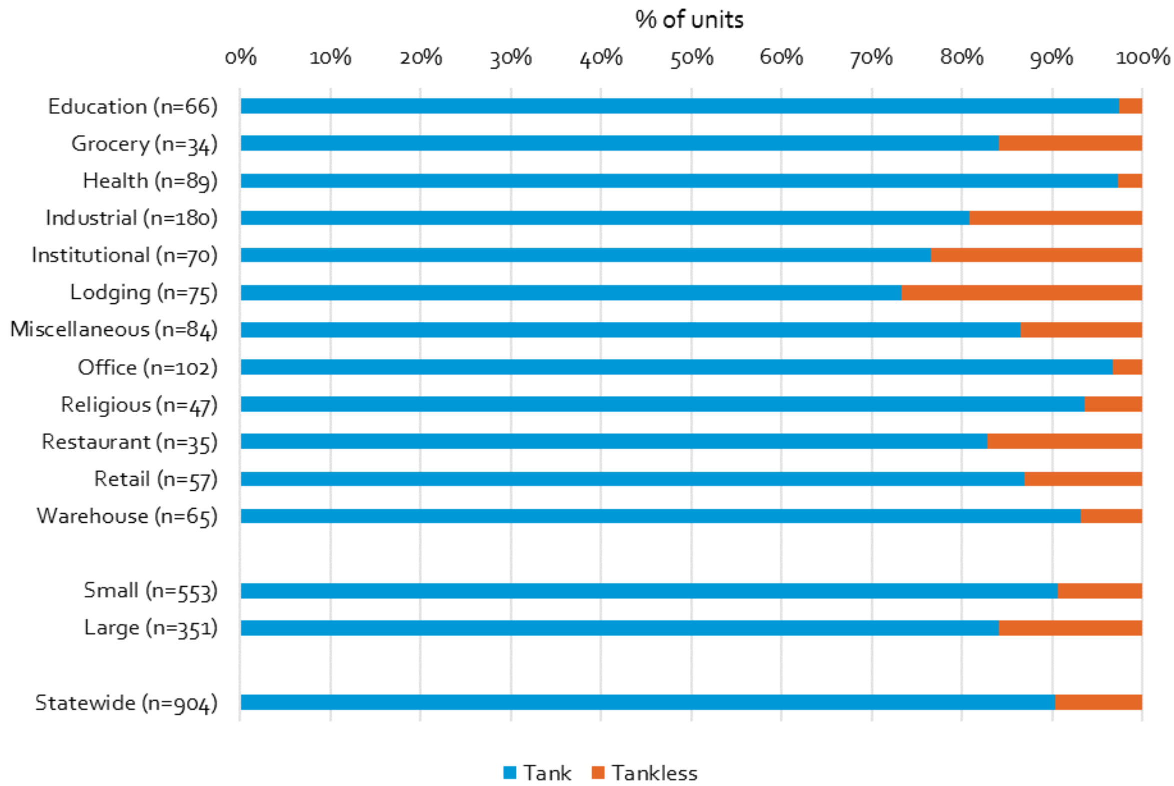


Figure 102: Share of Tank/Tankless Water Heaters by Input Capacity

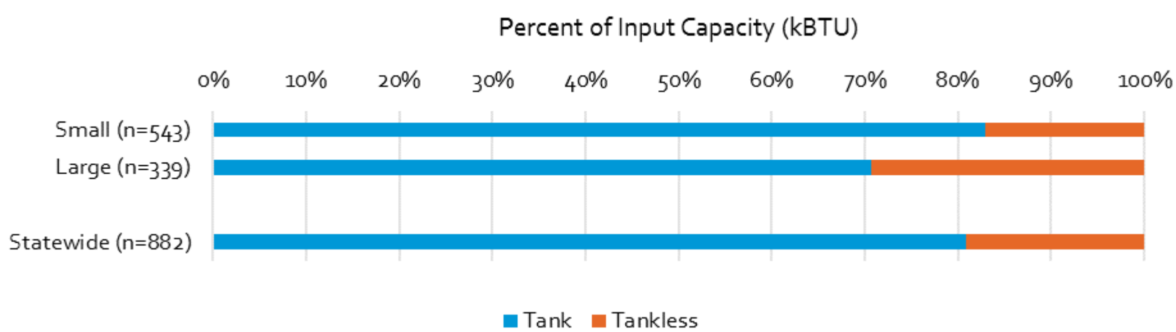


Figure 103: Distribution of Tank Capacity (by Device Count)

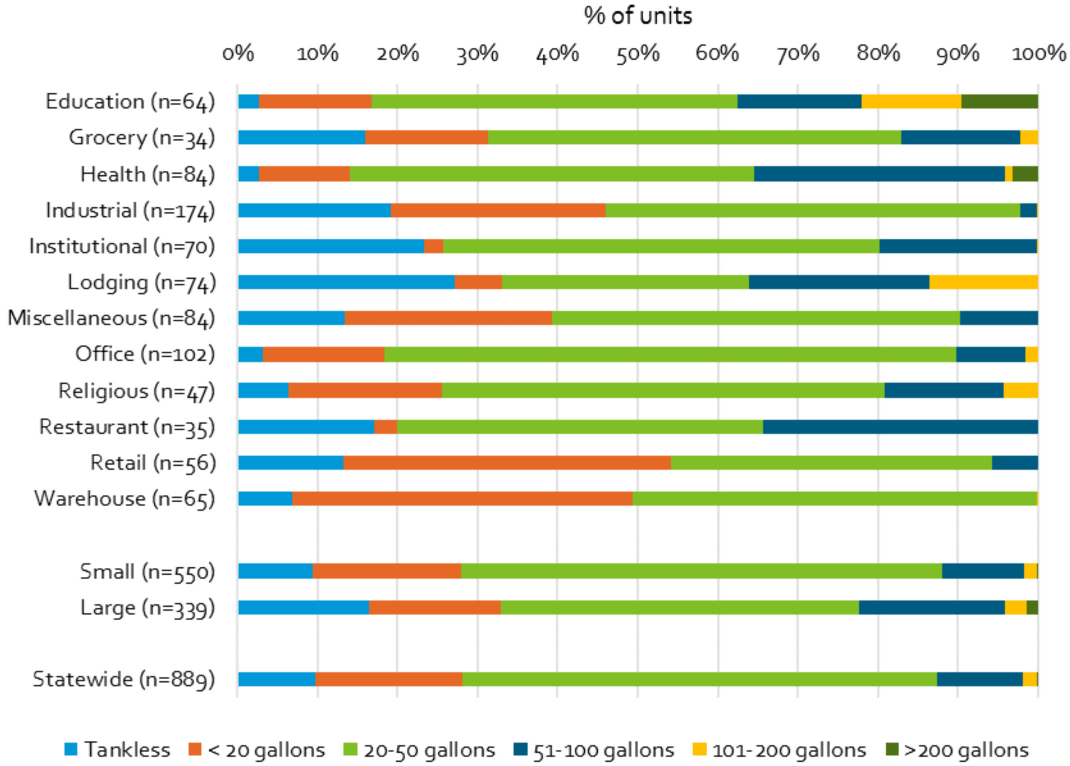


Figure 103 above shows the distribution of water heater tank sizes. Since tankless units only carry an assigned value for capacity in gallons, they are displayed separately on the graph. Aside from the tankless units, the size bins in the graph can be grouped into the three water heater types:

Unitary: More than half of Pennsylvania businesses' water heaters are domestic-style units with tank capacities in the range of 40 – 50 gallons. For this study, tanks in both the 20 – 50- and 51 – 100-gallon bins are classified as "Unitary" models, accounting for a combined 70% of water heaters in the sample, plus additional tankless units with similar capacities.

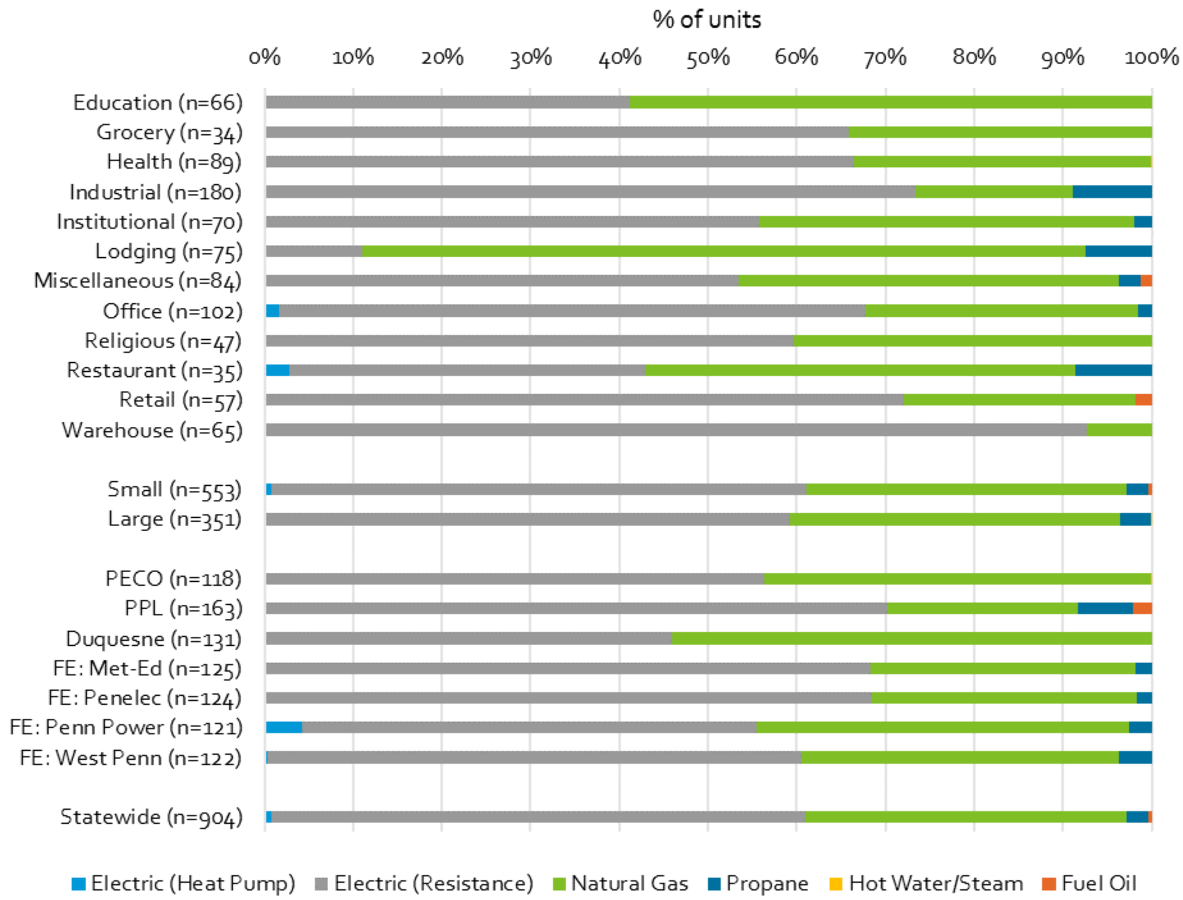
Small/Point-of-Use: Water heaters with tanks of less than 20 gallons are classified as "Small/Point-of-Use," with most holding five gallons or less. These tend to serve a single room or faucet, often for handwashing. Small/Point-of-Use units make up almost 20% of the water heaters in the sample, plus some additional tankless units.

Large/Central: Units that hold over 100 gallons are classified as "Large/Central", along with tankless units with similar capacities. These make up a much smaller fraction of the sample by count, but still account for a large share of energy use. Many of these units are truly central systems such as boilers or central units serving more than one building. However, aside from boilers and similar devices where the hot water is co-generated alongside another end use, central systems and large stand-alone units are hard to differentiate. There is no attempt to distinguish between them here.

FUEL SHARES

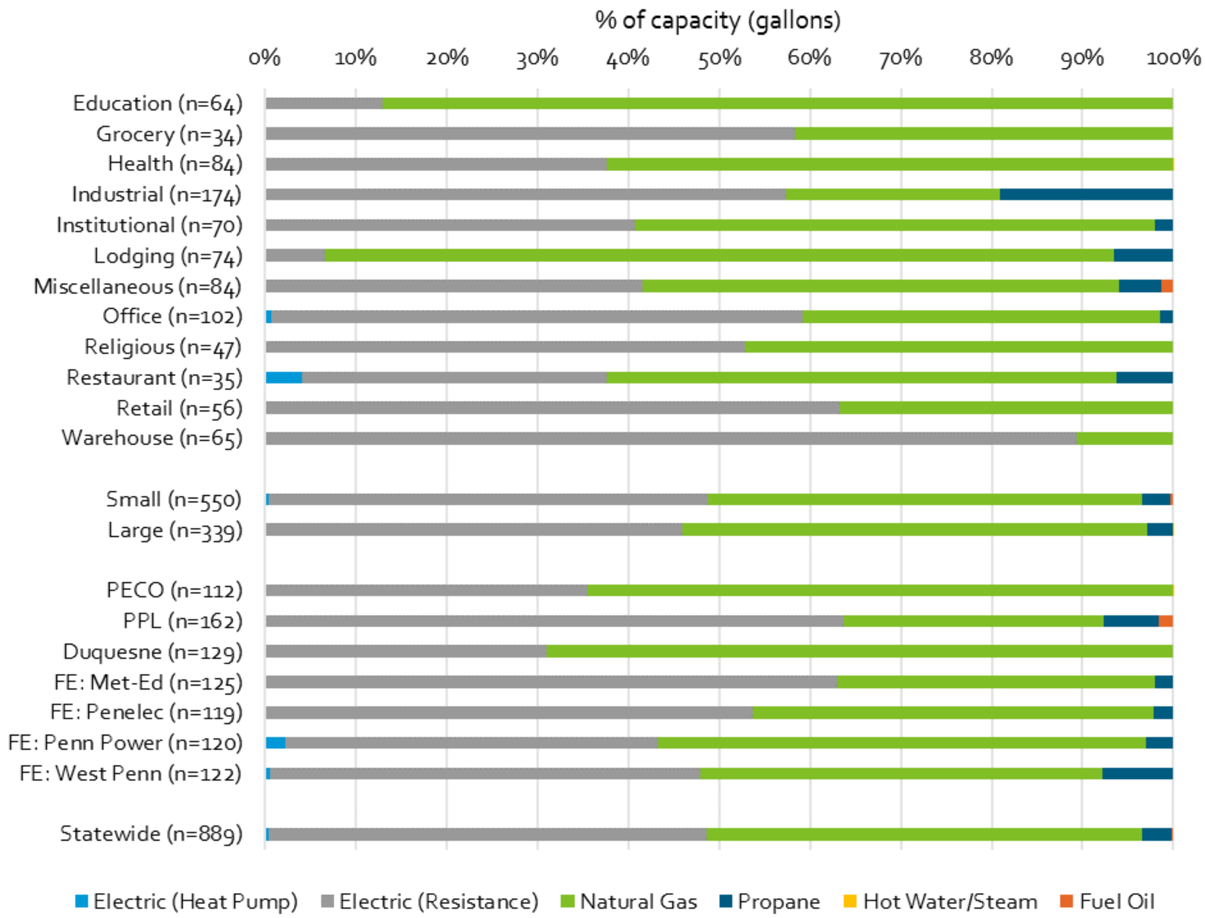
Figure 104, Figure 105, and Figure 106 show water heater fuel shares weighted by unit count, tank capacity, and input capacity respectively. Most water heating is fueled by natural gas or electricity, with propane somewhat common in rural areas without natural gas service. As in past studies, the survey also checked for solar and hot water/steam-powered water heaters but did not encounter any.

Figure 104: Water Heater Fuel Share by Device Count



Electric heat pumps were only present at one site in the sample and had almost no representation in the statewide results. Most heat pump water heaters are Unitary devices with similar tank capacities to the gas and electric units that dominate the sample. Heat pump water heaters are far more efficient than comparable electric resistance or fossil fuel units, so they are a promising energy efficiency measure. However, we observed essentially no penetration in Pennsylvania commercial buildings to date.

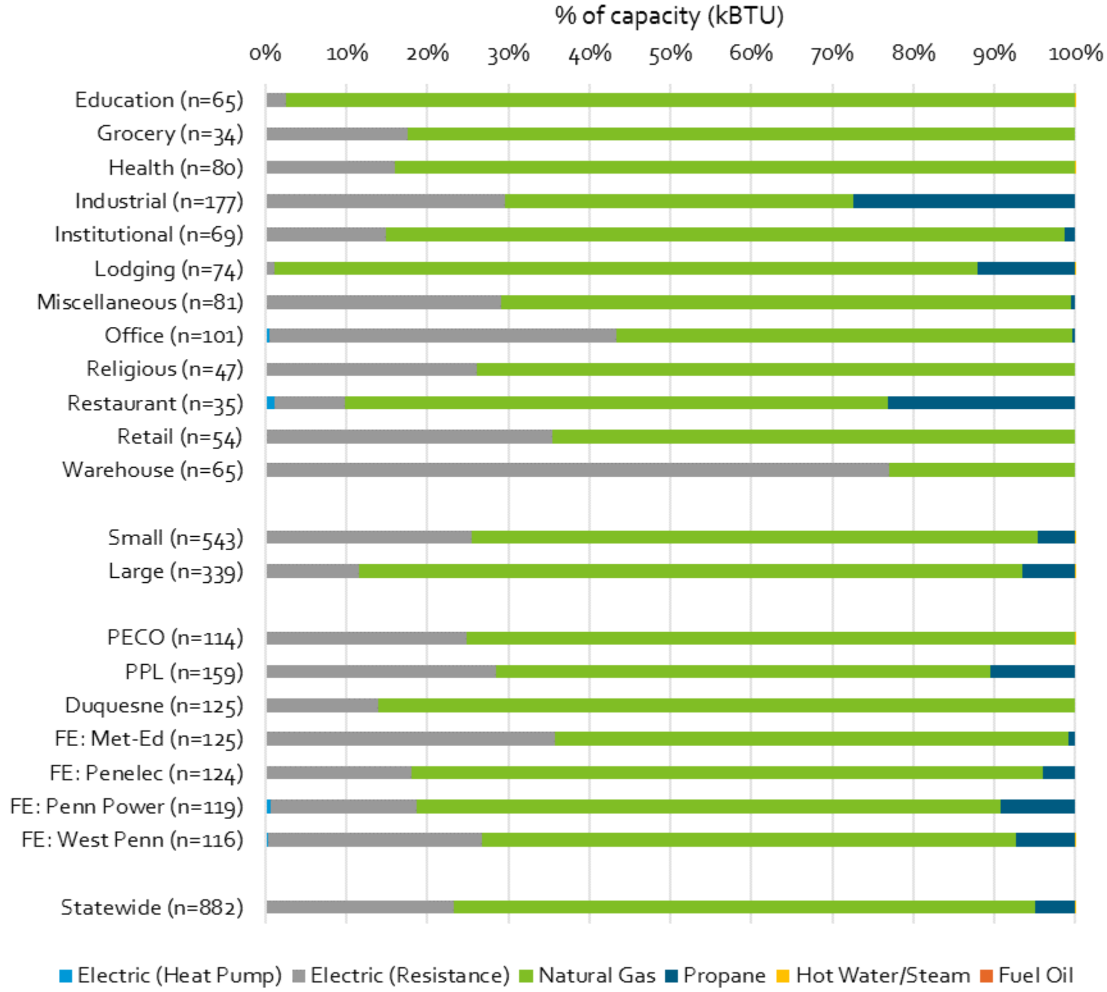
Figure 105: Water Heater Fuel Share by Tank Capacity



Comparing fuels as a percentage of total tank capacity (Figure 105 above) shows natural gas with a larger share, since very large water heaters are almost exclusively gas fired. Comparing fuels by input capacities (Figure 106 below) shows an even larger share for gas, driven in part by high input capacities for tankless gas units.

Natural gas and propane shares vary by EDC in ways consistent with the gas availability in their service territories. We observed no PECO or Duquesne customers with propane water heating, for example.

Figure 106: Water Heater Fuel Share by Energy Capacity



FUEL SHARES FOR UNITARY TANK/TANKLESS UNITS

Figure 107 below shows fuel shares for unitary tank and tankless water heaters, with all fossil fuels combined into a single category for simplicity. 55% of water heaters are electric tank water heaters while another 6% are electric tankless units.

Figure 107: Fuel Shares for Tank/Tankless Water Heaters

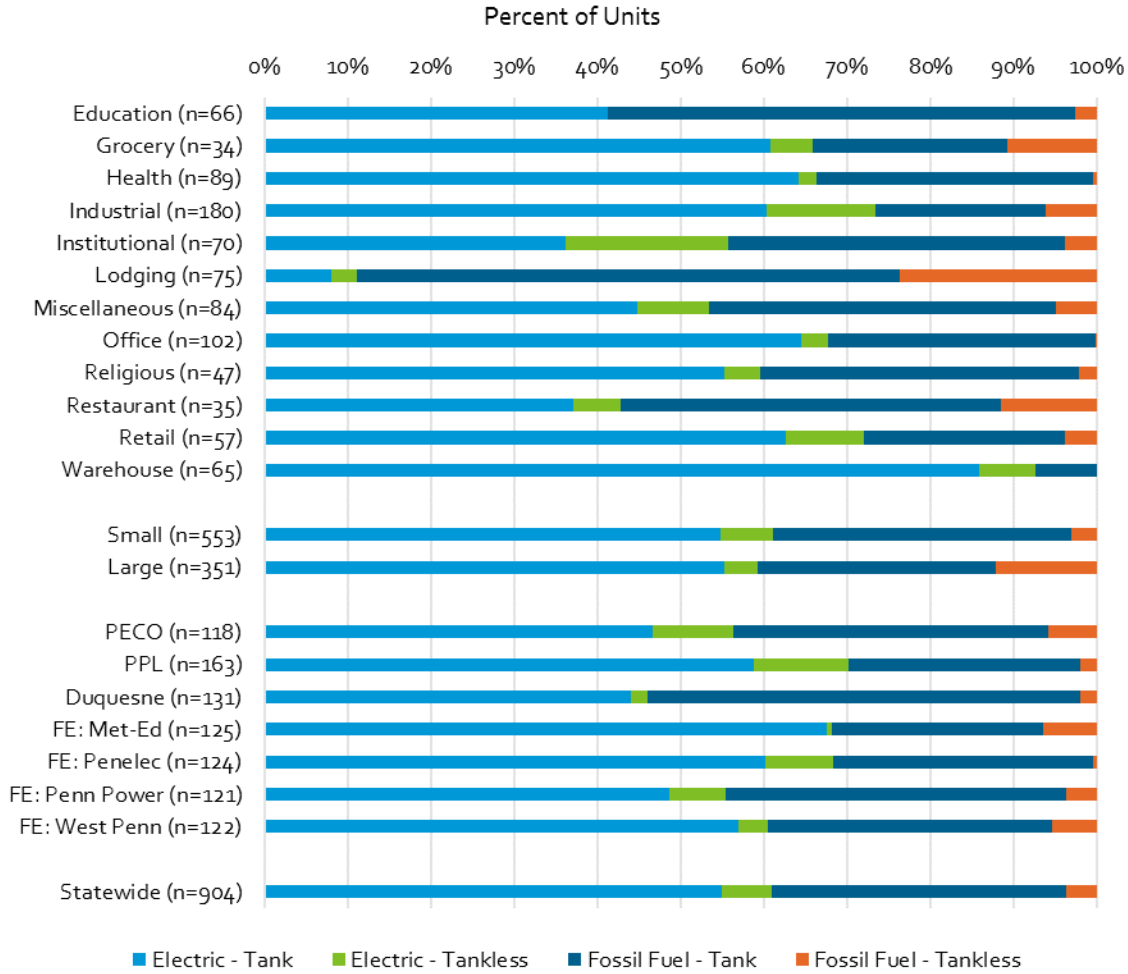


Figure 108 shows the same splits for Large/Central water heaters only (units with tanks greater than 100 gallons or tankless units with equivalent capacity). These large central water heating systems are more prevalent in the Large C&I sector. Almost all are gas-fired tank units.

Figure 108: Large/Central Water Heaters: Fuel and Tank Types

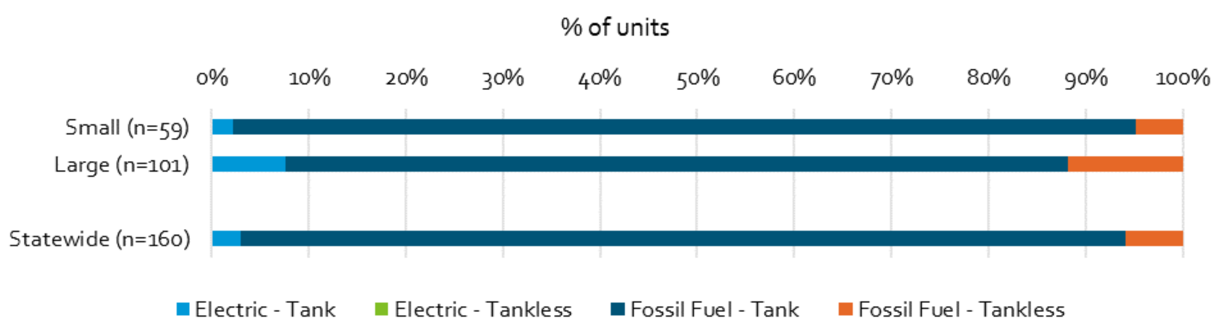


Figure 109 repeats this comparison for Unitary (residential style) water heaters. Electric units make up almost 60% of the stock statewide for this equipment category.

Figure 109: Unitary Water Heaters: Fuel and Tank Types

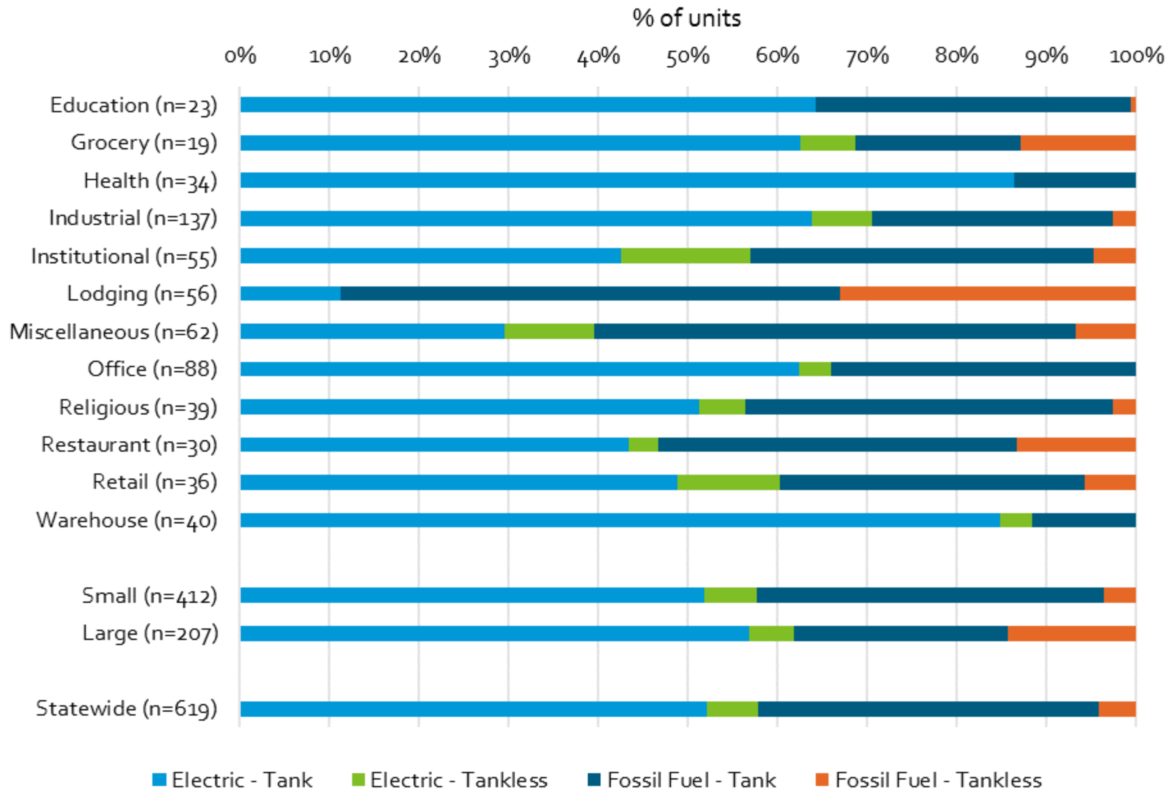
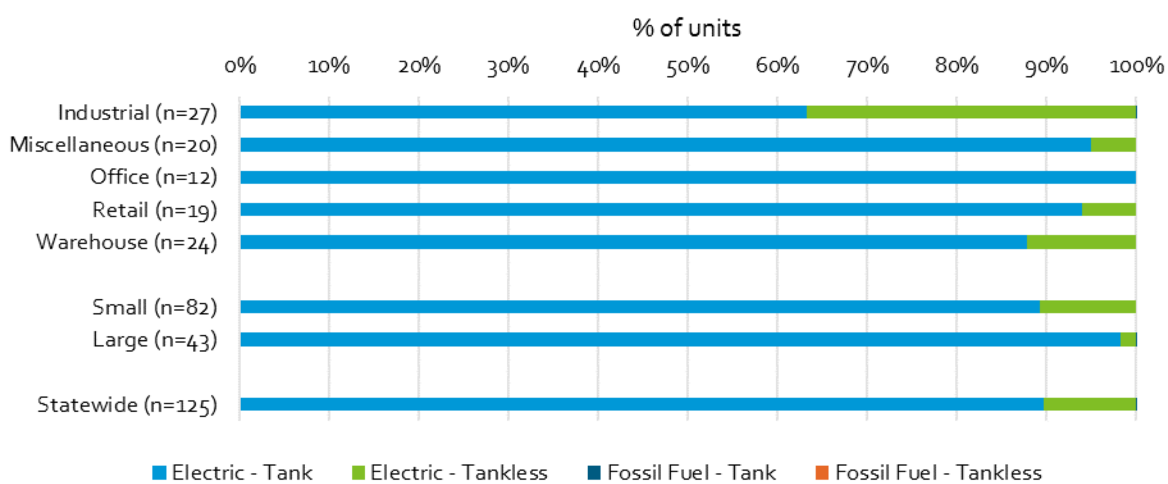


Figure 110 shows that essentially all the smaller water heaters are electric, including some very small tankless units that supply a single sink or small bathroom.

Figure 110: Small/Point-of-Use Water Heaters: Fuel and Tank Types



DOMESTIC HOT WATER EQUIPMENT AGE

Figure 111 plots the median age and the age range of water heaters by segment. Most units are between five and ten years old, so they are replaced relatively often. The Religious and Education segments often had older units while Grocery and Lodging tended to have newer units. Warehouses also had somewhat newer units, generally small point-of-use water heaters.

Figure 111: Water Heater Age Distribution by Segment

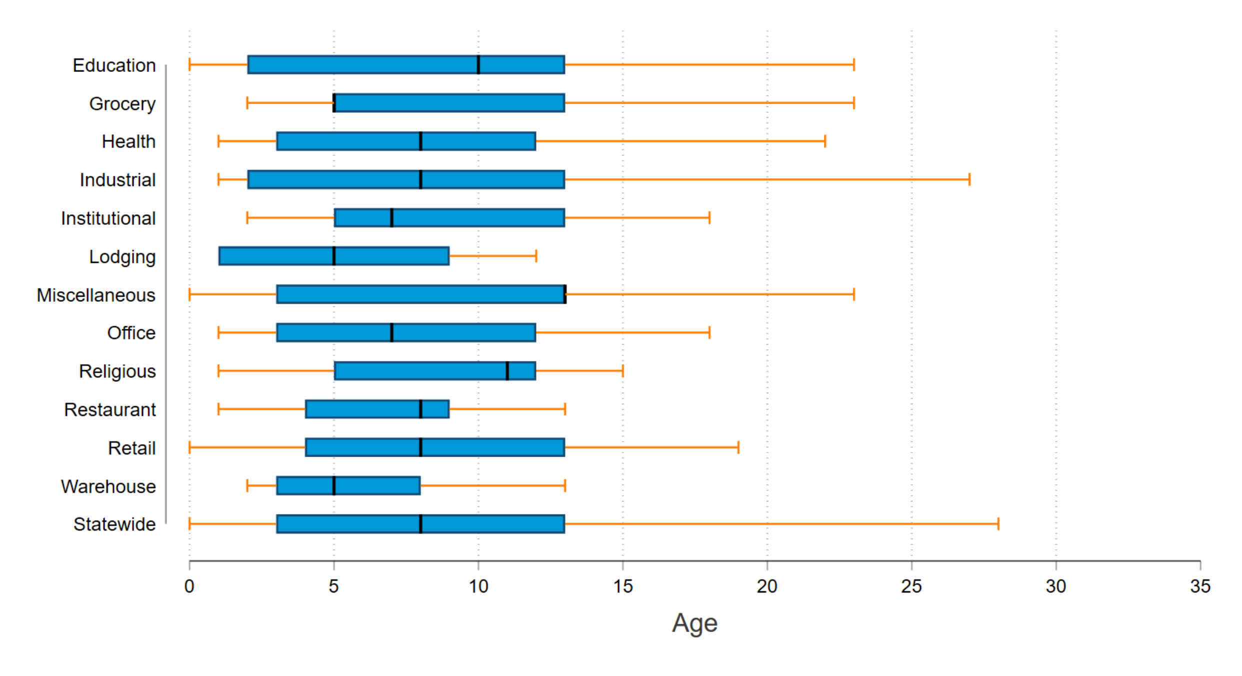
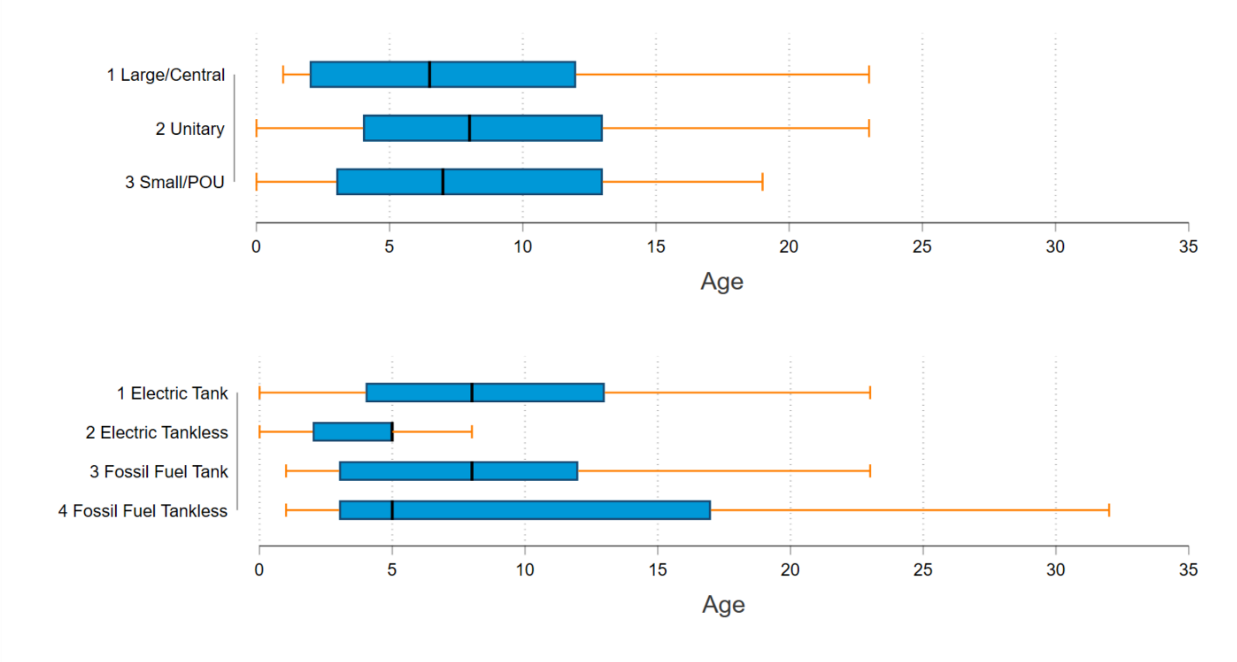


Figure 112 repeats this comparison for the three water heater types as well as the four fuel/tank combinations. Electric tankless units, while still a small share of the overall stock, tended to be very new. Many tankless fossil-fuel units were relatively new, but some of the indirect water heaters in that category, which draw heat from another end use and have no storage tank, were quite old.

Figure 112: Age Distribution by Heater Type, Fuel/Tank Type



Other Characteristics

The 2023 study recorded additional details on water heaters at commercial sites, including the presence of several energy-saving features. Table 34 reports average values in each of the listed categories.

Table 34: Average Domestic Hot Water Heater Characteristics by Segment and Sector

Segment	Age (years)	% with Tank Wrap	% with Pipe Wrap	Tank Capacity (gal.)	Input Capacity (kBTU/h)	Recovery Efficiency (Electric)	Recovery Efficiency (Fossil Fuel)
Education (n=68)	10.9	14%	55%	94.1	185.0	98.3	88.7
Grocery (n=36)	9.3	0%	37%	46.4	51.6	95.3	91.0
Health (n=89)	9.0	4%	44%	80.4	69.6	96.2	82.1
Industrial (n=180)	9.2	0%	15%	34.0	33.7	98.8	85.7
Institutional (n=70)	9.8	8%	45%	46.7	52.6	98.6	82.7
Lodging (n=75)	5.7	0%	27%	60.2	144.5	99.0	87.2
Miscellaneous (n=84)	9.1	1%	5%	36.9	28.6	97.8	82.2
Office (n=102)	8.2	3%	35%	42.9	23.4	97.6	85.1
Religious (n=47)	8.9	0%	32%	47.0	33.4	98.2	84.6
Restaurant (n=35)	8.4	3%	20%	54.9	74.2	98.8	83.9
Retail (n=57)	10.1	2%	23%	29.4	24.1	96.5	82.6
Warehouse (n=65)	7.0	0%	8%	26.9	12.7	97.6	82.0
Small (n=555)	8.5	3%	26%	42.6	34.8	97.6	84.3
Large (n=353)	9.3	1%	28%	51.2	109.6	97.8	88.8
Statewide (n=908)	**8.6**	**3%**	**26%**	**43.1**	**39.1**	**97.6**	**84.4**

Figure 113 summarizes the prevalence of additional energy-saving characteristics for Large/Central water heaters only. Grocery stores frequently capture heat from refrigeration and/or drain water to use for water heating. Large hospitals use steam that is co-generated from heat or electricity production in several cases. Overall, pipe and tank wrapping are much more common on these larger units, as is circulating the hot water continuously around the building.

Figure 113: Efficient Characteristics of Large/Central Water Heaters

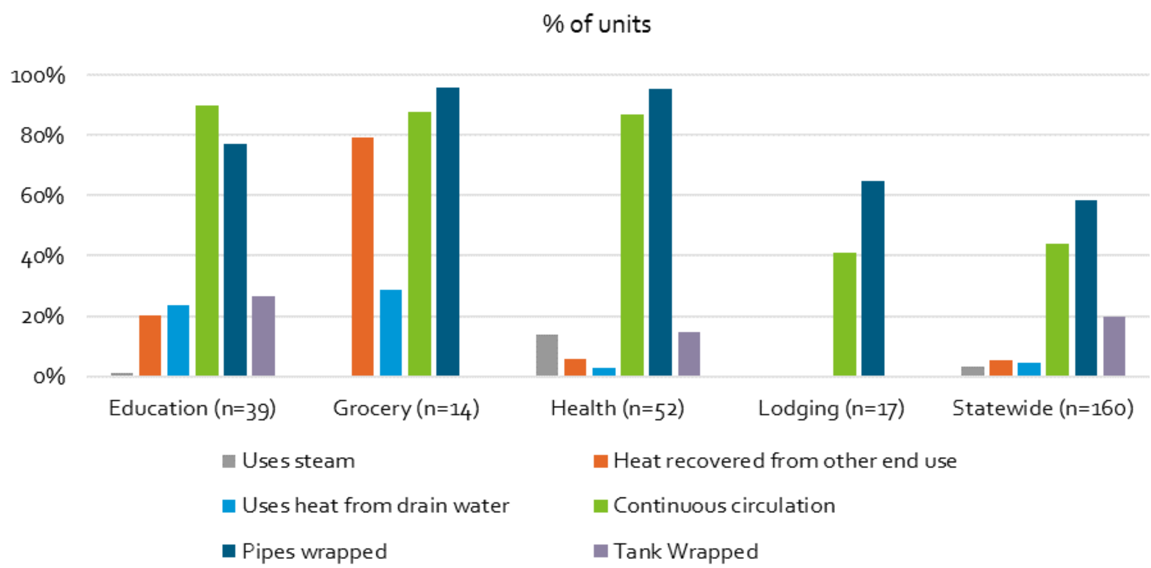
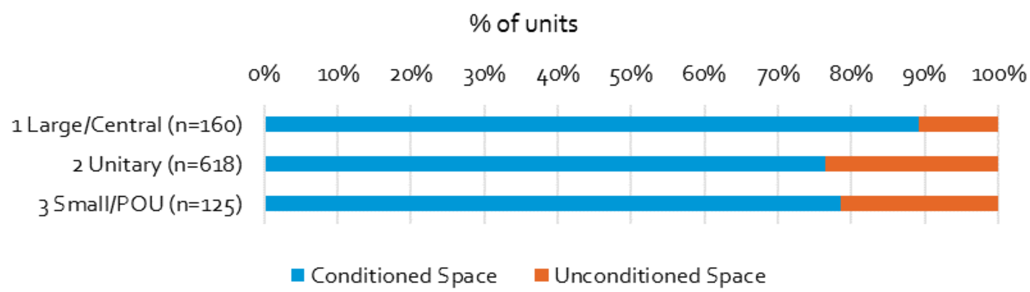


Figure 114 shows the location of water heaters, in either conditioned or unconditioned spaces. Most are in conditioned spaces, reducing their energy burden to maintain tank temperatures in the winter. This is also important for the potential adoption of heat pump water heaters since they perform more efficiently in conditioned spaces. In some cases, their space requirements would necessitate changing the water heater's location, however.

Figure 114: Water Heater Location (Conditioned vs. Unconditioned Spaces)

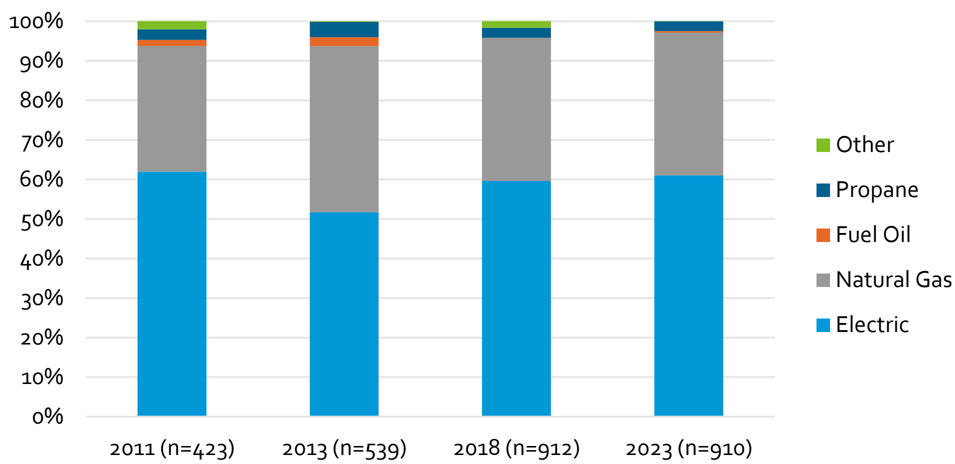


7.3 COMPARISON WITH PRIOR STUDY FINDINGS

The SWE team collected 2023 domestic hot water data using a similar structure to the data in previous studies. The following graphs and tables compare 2023 results with previous studies to better illustrate Pennsylvania businesses' energy use.

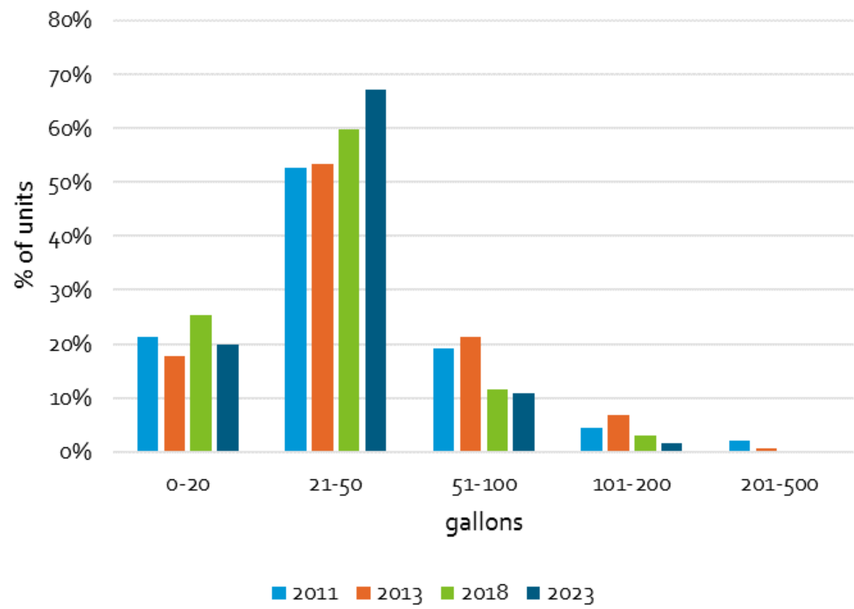
Figure 115 shows the measured fuel shares over time, graphed here as the percentage of total units (not capacity). Electric units were slightly more common in 2023, but the overall shares have not changed greatly over time. More important insights into the number of electric water heaters can likely be found in the 2023 graphs of fuel shares by water heater types and tank types (Figure 115 through Figure 117), without a comparison to 2018.

Figure 115: Comparison of Domestic Hot Water Fuel Shares by Equipment Count, 2011-2023



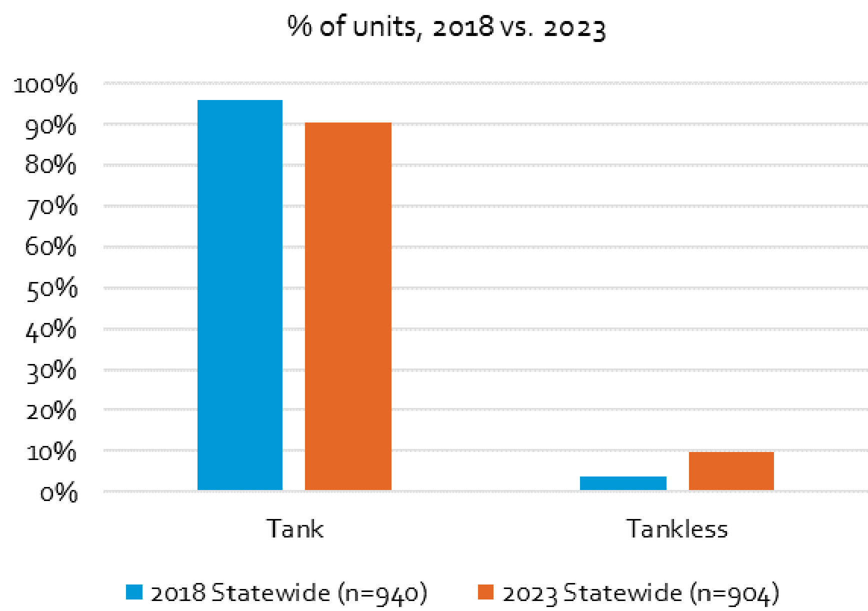
The overall distribution of tank size has remained consistent across the four studies, as seen in Figure 116. Some of the differences in the 21- to 50-gallon category is due to the increased prevalence of tankless water heaters: most have capacities in the range of a standard 40-gallon domestic unit, so they are included with the 40-gallon units in this graph.

Figure 116: Comparison of Water Heating Tank Capacity Distributions, 2011-2023



There does appear to be growth in tankless water heaters as a share of total units, shown below in Figure 117 below. As noted earlier, these include both electric units and large-capacity units along with more traditional gas and small-capacity tankless water heaters.

Figure 117: Growth of Tankless Water Heaters, 2018 to 2023



7.4 RECREATIONAL WATER

Only 19 of the sites surveyed had recreational water features, most of which are pools and hot tubs (Figure 118 below). The features were most common in the Lodging segment.

Figure 118: Types of Recreational Water

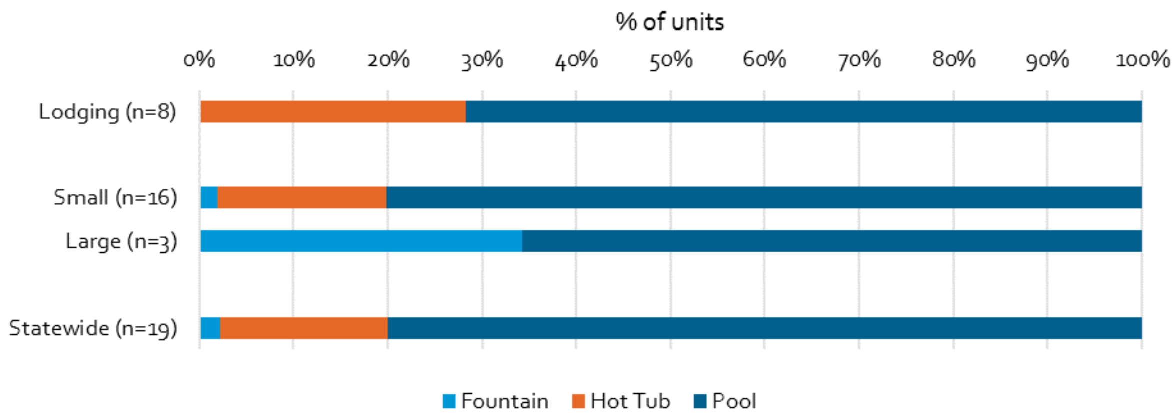
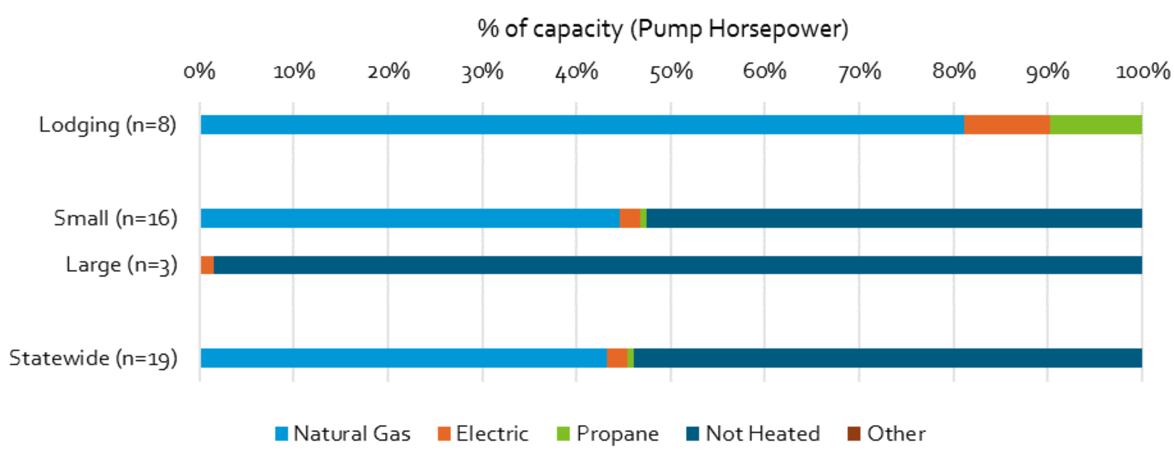


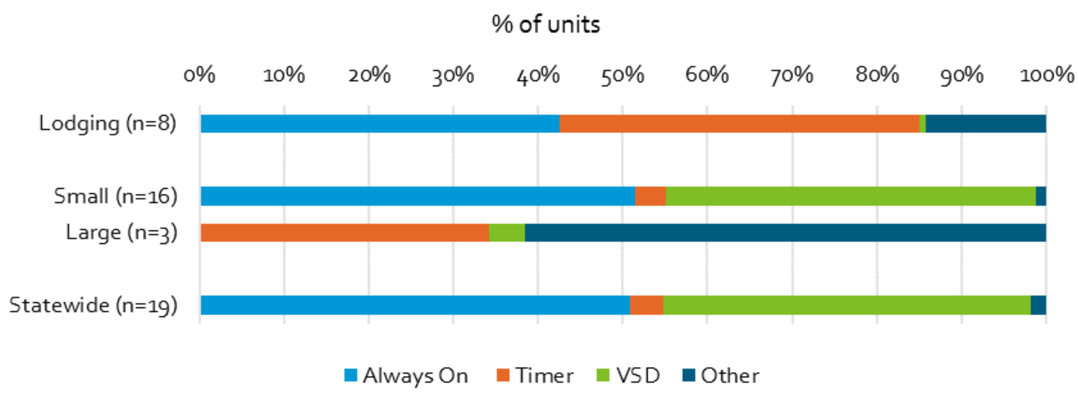
Figure 119 reports heating fuels for recreational water features, weighted by pump horsepower (as a proxy for size and energy use). Just over 50% of recreational water is heated, with nearly all of it heated by gas. Lodging, which accounts for the largest share of recreational water, had heating for all units, with 8% using electric heaters.

Figure 119: Water Heater Fuel Type for Recreational Water, Weighted by Pump Horsepower



Timers are often used with water pumps and heaters. Figure 120 shows that most of the recreational water features run continuously. A small number used traditional timers, though these were common in the lodging sector, and over 30% have variable-speed drives (VSD's).

Figure 120: Recreational Water Controls



7.5 FAUCETS AND SHOWERHEADS

Table 35 provides detail on faucets and showerheads at non-residential sites. Sites had five bathroom faucets on average, with very few motion sensors outside of businesses involved in food preparation. Kitchen faucet numbers follow expected trends by industry segment, with two per site on average across the state. Showers were most prevalent at lodging sites, with a significant amount in the health sector (from hospitals and gyms).

Table 35: Faucet and Motion Sensor Saturation

Segment	n	Bath Faucets	% Motion Sensor	Kitchen Faucets	Shower Faucets
Education	38	14.5	11.4%	3.2	2.3
Grocery	27	2.5	17.5%	3.0	0.0
Health	44	21.1	7.4%	5.6	8.9
Industrial	69	2.0	0.8%	0.9	0.1
Institutional	48	4.3	2.2%	1.3	1.4
Lodging	14	66.2	0.7%	10.8	65.1
Miscellaneous	62	2.6	0.0%	1.2	0.5
Office	57	4.7	2.3%	2.1	0.8
Religious	23	7.0	0.0%	3.0	0.1
Restaurant	27	3.2	15.1%	3.3	0.1
Retail	52	2.5	2.1%	0.8	0.1
Warehouse	42	3.1	4.2%	0.7	0.2
Small	387	4.0	2.5%	1.7	0.9
Large	116	20.7	18.7%	3.5	5.1
Statewide	503	4.8	3.2%	1.8	1.1

8 REFRIGERATION

8.1 REFRIGERATION EQUIPMENT OVERVIEW

Commercial refrigeration equipment is concentrated in a few specific segments, especially Grocery, but it represents a large share of the electric energy used in those segments. There is an increasing array of energy-saving options for refrigeration devices—these are catalogued here for Pennsylvania businesses along with traditional specifications such as a refrigerator/freezer types, age, size, compressor types, and compressor horsepower.

Surveyed refrigeration equipment includes both walk-in and reach-in refrigerators and freezers. Walk-in systems are closed-door units with enough space to walk into. Reach-in systems, on the other hand, only have sufficient space for the food itself and are accessed from outside the device. Walk-in systems are generally much larger than reach-in units, though some reach-in systems can still be quite large, such as long banks of reach-in cases in grocery stores.

Here we present results for the following types of reach-in and walk-in refrigeration units:

Reach-In Refrigerators

- Solid Door
- Glass Door
- Open Case

Reach-In Freezers

- Solid Door
- Glass Door
- Open Case

Walk-In Refrigerators

- Walk-In Refrigerator
- Refrigerated Warehouse

Walk-In Freezers

- Walk-In Freezer
- Freezer Warehouse

The distinctions here are straightforward: reach-in units—both refrigerators and freezers—are classified by having a solid door, glass door, or no door ("open-case"). Each has different implications for energy use (such as less-efficient open-case units) as well as energy-efficient options available, such as anti-sweat heater controls for glass-door units.

Walk-in units are classified as either a small room within a building (walk-in refrigerator, walk-in freezer) or a large portion of the building/entire building (refrigerated warehouse, freezer warehouse).

There is less differentiation between “walk-in” and “warehouse” units aside from the scale, with much of the larger equipment employed in the warehouses. As a reference, Figure 121 shows examples of the three reach-in refrigerator/freezer types in the left panel and the four walk-in types in the right panel:

Figure 121: Commercial Refrigeration Types

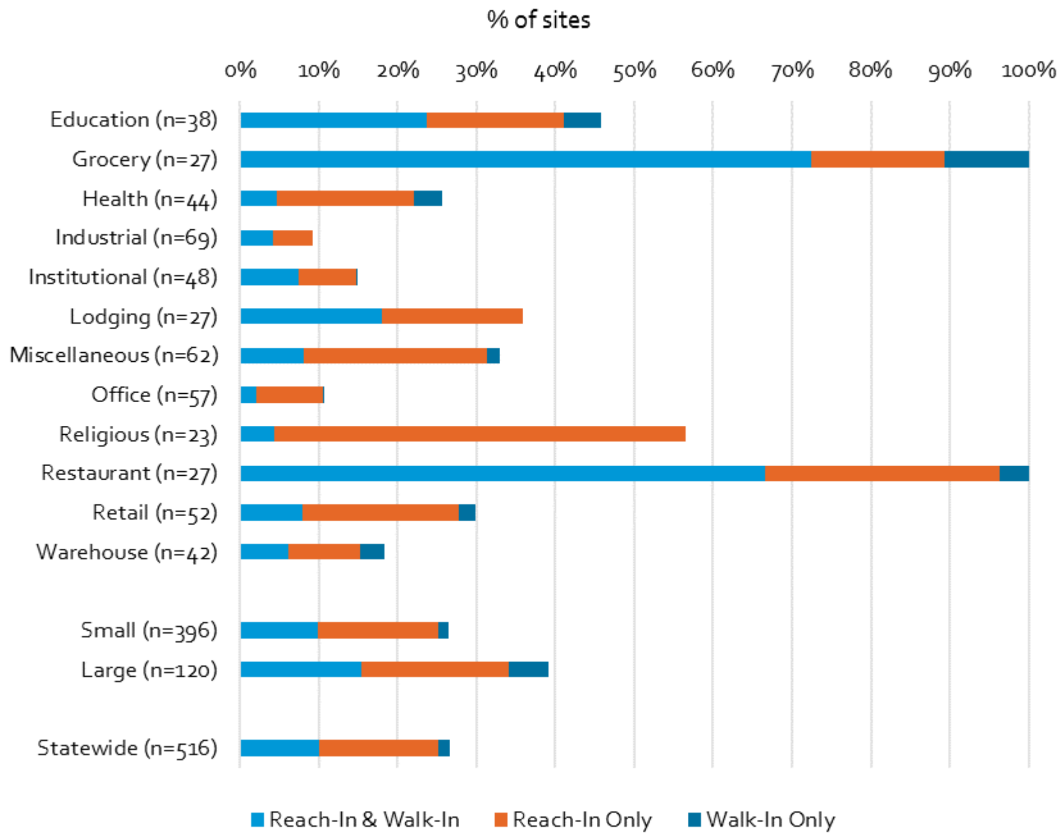
Each segment’s relative weight in statewide results reflects its share of total, statewide energy used for refrigeration. The Grocery segment represents the largest share of the statewide refrigeration load and thus factors heavily in the statewide results, as do segments like Restaurant, Health, and Education.

8.2 REFRIGERATION EQUIPMENT FINDINGS

PENETRATION

Figure 122 shows the penetration of commercial refrigeration devices in Pennsylvania businesses. The percentages of sites with 1) reach-in devices only, 2) walk-in devices only, and 3) both reach-in/walk-in units are shown together as stacked bars in the graph. For example, businesses in the Grocery segment—grocery stores, convenience stores, and gas stations—all had at least one refrigerator or freezer. Over 70% had both reach-in and walk-in devices, 15% had only reach-in devices, and the remaining 12% had walk-in devices only.

Figure 122: Percent of Sites with Commercial Refrigeration by Type

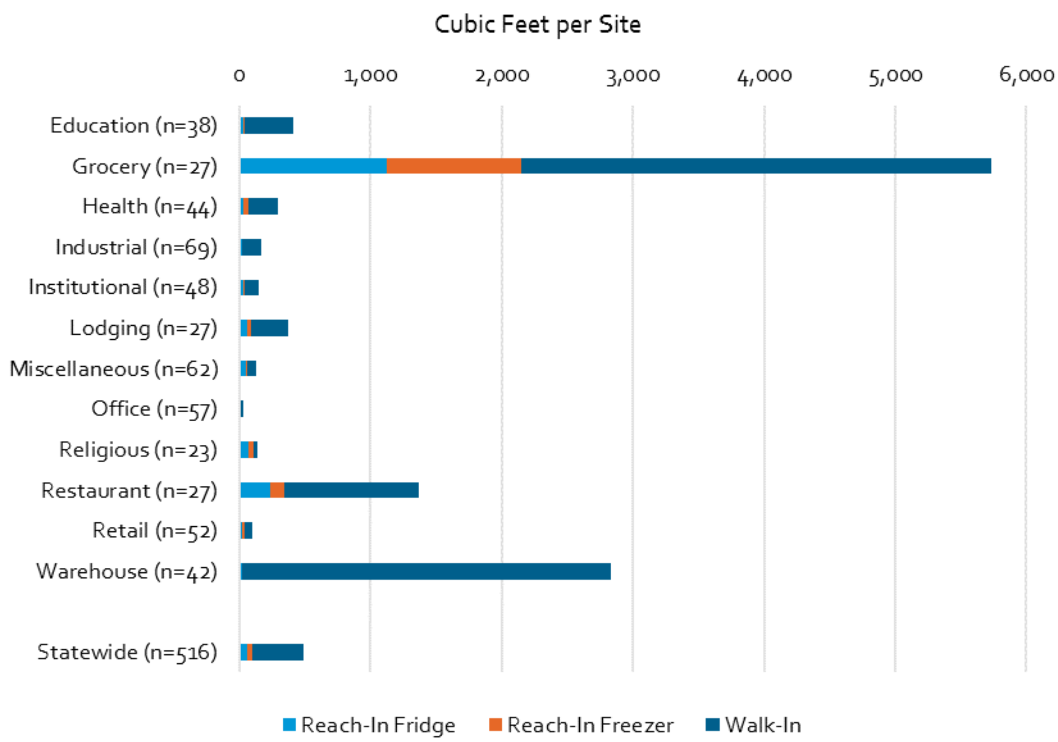


Every site in the Restaurant segment used energy for refrigeration as well. In the Education segment, all K-12 schools had refrigeration, but other building types (some college buildings, day care centers, libraries) did not. Religious sites often had refrigeration devices, but they were generally the smaller reach-in units. Statewide, less than 30% of businesses had commercial refrigeration devices. Thus, while refrigeration is a large energy load when present, there are many businesses this end use does not affect. All refrigeration equipment encountered in this study and previous baseline studies are electric, so the fuel share considerations that complicate other end uses are not relevant to refrigeration.

Figure 123 shows the average cubic feet devoted to refrigeration at each site in the survey. For sites with no devices, this is simply zero—several categories have little to no cubic feet of refrigeration on average. Grocery sites, however, have nearly 6,000 cubic feet of refrigeration on average, with a majority going to walk-in devices.

While most warehouses have no refrigeration, those that do carry an enormous refrigeration footprint. So, while the graph shows an average of 2,800 cubic feet of refrigeration per warehouse, in practice nearly all the sites have zero while those that do have over 100,000 cubic feet.

Figure 123: Average Cubic Feet of Refrigeration per Site, by Type



REACH-IN & WALK-IN DEVICE TYPES

The types of reach-in refrigerators found in Pennsylvania business facilities are shown below as a share of total equipment count (Figure 124) and as a share of cubic feet (Figure 125). Solid-door refrigerators are the most common type outside of the Grocery segment. However, Grocery sites have a significant number of both glass-door and open-case units, including very large open-case units by cubic feet. Statewide, open-case refrigerators also account for the largest share of cubic feet, since the Grocery segment represents such a large percentage of the overall refrigeration load.

Figure 124: Reach-In Refrigerator Types as a Percent of Devices

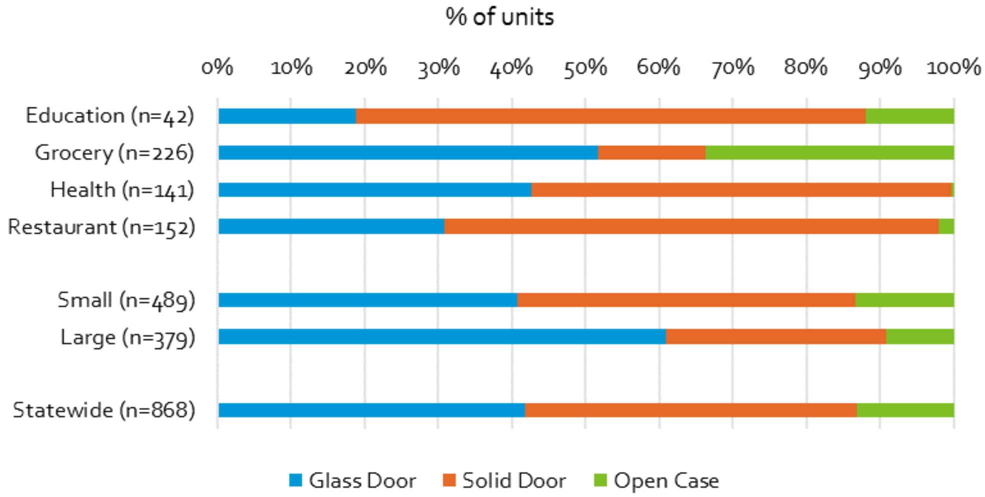
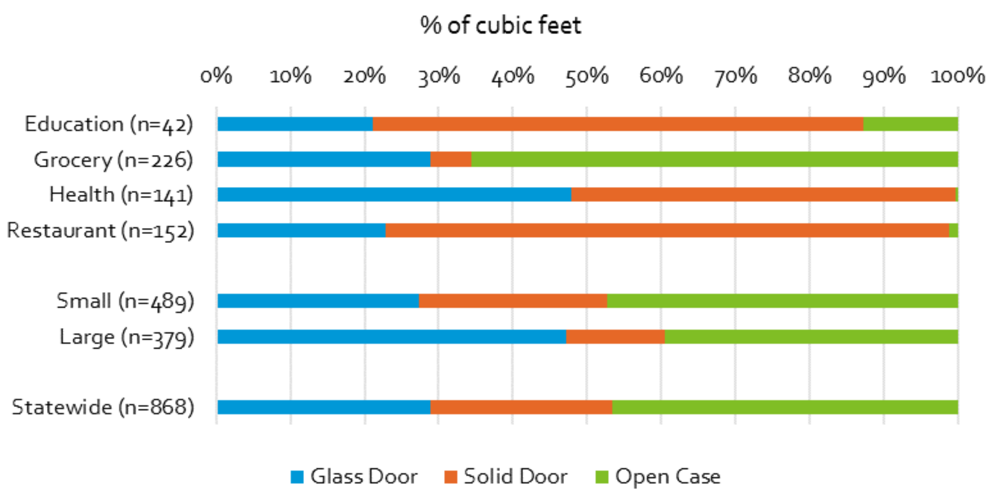


Figure 125: Reach-In Refrigerator Types as a Percent of Cubic Feet



As shown in Figure 126 and Figure 127 below, glass-door freezers dominate the Grocery segment and the Statewide results, both as a percentage of units and cubic feet. Outside of the Grocery segment, glass-door freezers were much less common, however, and open-case freezers were rare across all segments.

Figure 126: Reach-in Freezer Types as a Percent of Devices

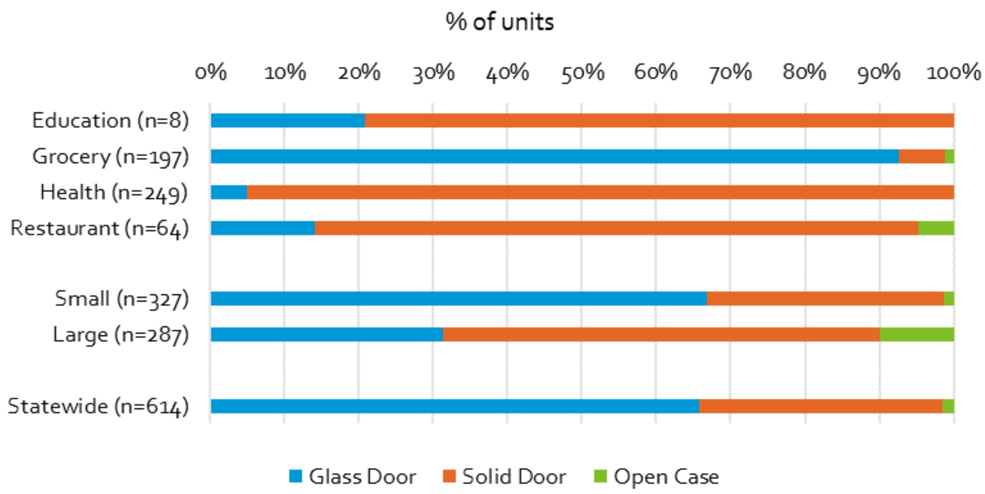


Figure 127: Reach-In Freezer Types as a Percent of Cubic Feet

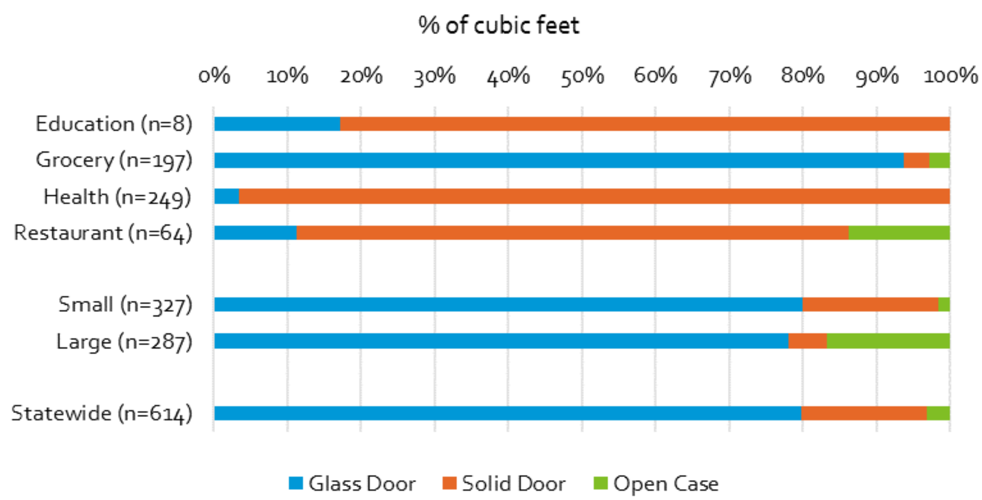


Figure 128 charts the relative shares of reach-in device types over time in Pennsylvania. Glass-door refrigerators and freezers were somewhat more common in 2018 and 2023, while solid-door units have become less common. While open cases still make up a relatively small share of the stock of reach-in devices, as shown above, they account for a much larger share of cubic feet.

Figure 128: Reach-In Device Types over Time

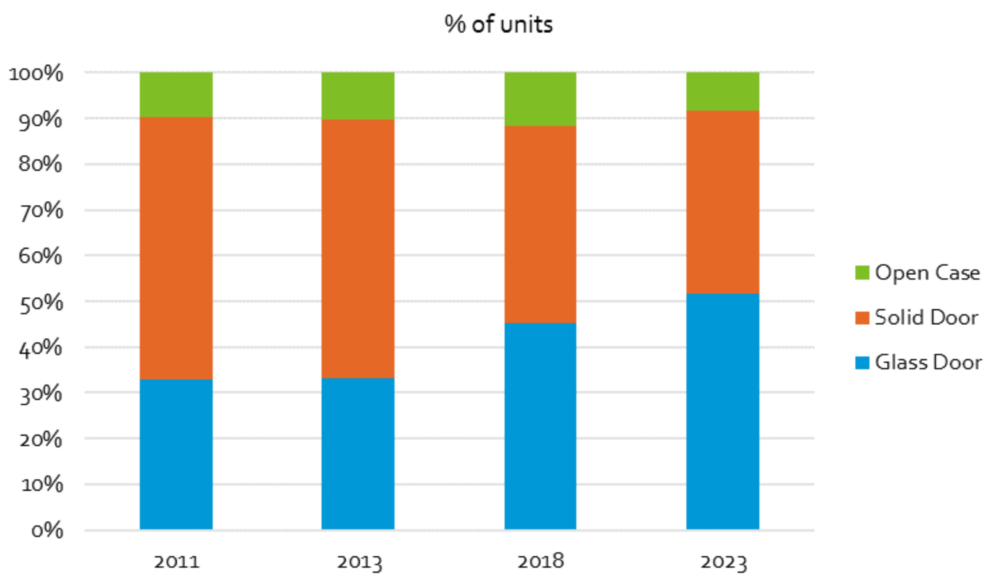


Figure 129 and Figure 130 show walk-in device types, again as the share of total units and total cubic feet. Walk-in refrigerators are by far the most common type, followed by walk-in freezers. Both are large units with heavy energy loads, and they make up most walk-in refrigeration cubic feet statewide as well. The warehouses, however, still account for a significant share of cubic feet since the few sites surveyed are so large.

Figure 129: Walk-In Device Types by Count

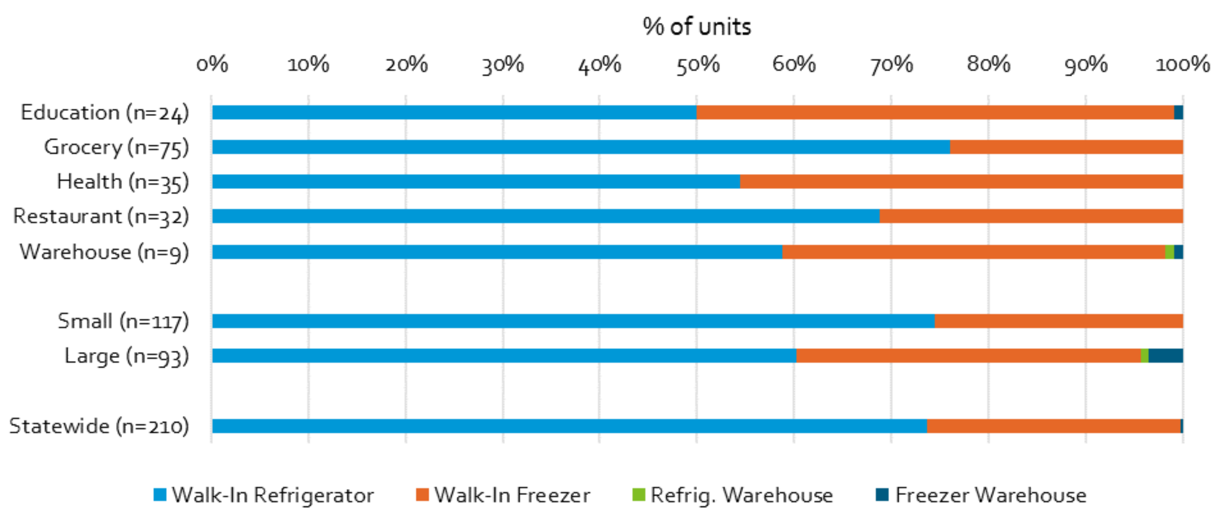
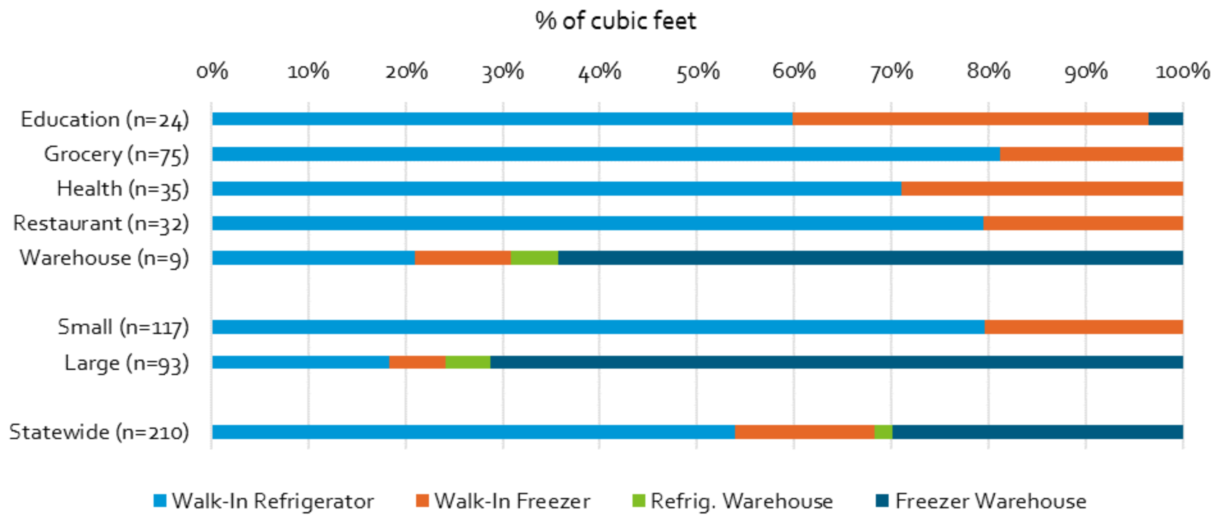


Figure 130: Walk-In Device Types by Cubic Feet



COMPRESSORS

Figure 131 and Figure 132 show the prevalence of more-efficient remote compressors that power multiple reach-in units. By count, these only supply about 30% of units statewide, but they represent almost 70% of the cubic feet of reach-in refrigeration. This is especially true for the large systems in the Grocery segment.

Figure 131: Reach-in Compressor Type by Count of Devices

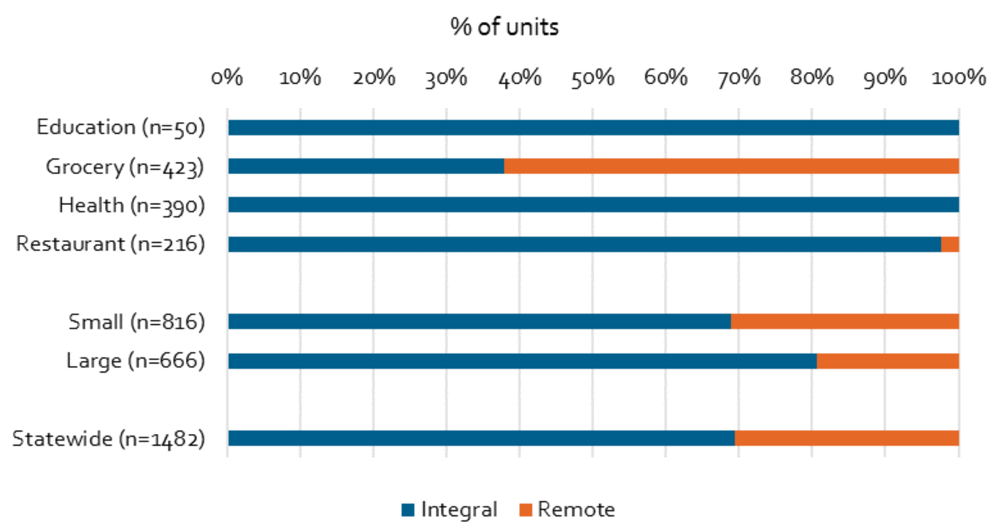


Figure 132: Reach-In Compressor Type by Cubic Feet of Devices

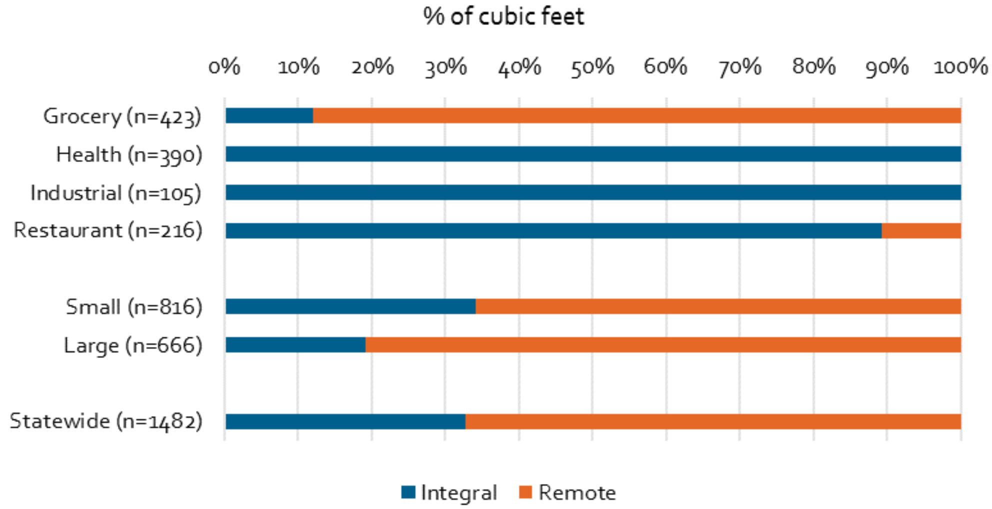


Figure 133 shows horsepower levels for compressor motors, with most units powered by relatively small 1- 1.5 HP units. However, the horsepower for the larger walk-in units can be very high.

Figure 133: Compressor Motor Horsepower, Walk-in Units

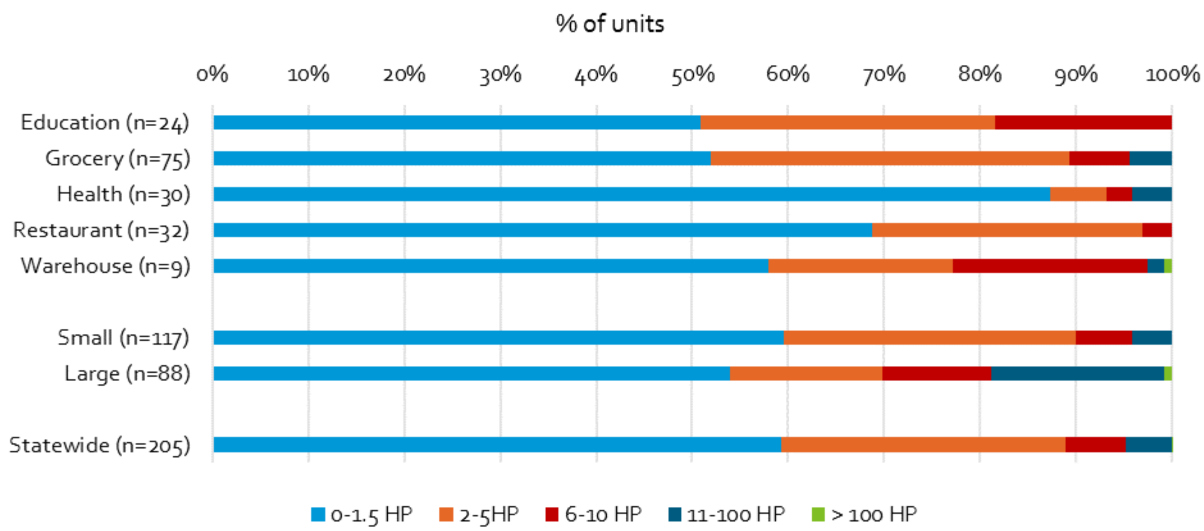
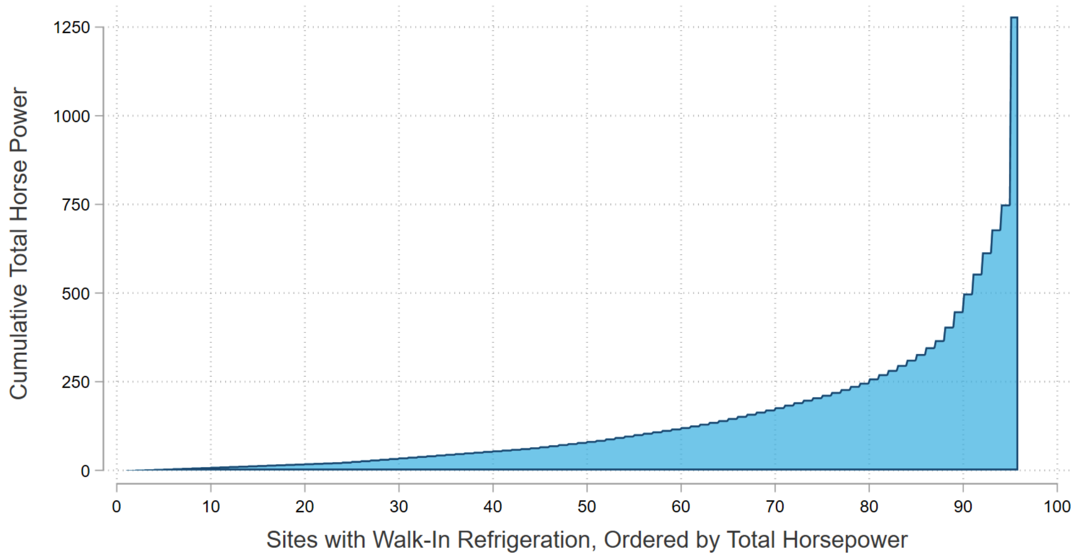


Figure 134 combines compressor horsepower for all walk-in units at a given site. The sites are then ordered from least to greatest, with statewide total horsepower on the vertical axis. This shows the relative share of the statewide horsepower from smaller (on the left) and larger sites (on the right).

Most sites with walk-in units still only had one or two 1-1.5 HP motors. While sites with more compressor horsepower were less common, they make up a wide majority of total horsepower statewide: Over 80% of statewide horsepower belongs to less than 20% of the sites with walk-in units (15 total sites in the survey). Over half of the total horsepower comes from the three largest sites.

Figure 134: Total Compressor Horsepower by Site as a Percent of Total Statewide Horsepower



Thus, while many businesses have refrigeration devices, most of Pennsylvania's commercial refrigeration load is made up by relatively few, large sites, especially grocery stores and warehouses.

AGE, FAN MOTORS, & EE CHARACTERISTICS

Figure 135 and Figure 136 report the age distribution of commercial refrigeration devices. The bars show the median age (dark line in center), the 25th to 75th percentiles (blue box) and the range of ages (orange bars). These graphs do not show outliers, which include a few walk-in units that were 30 – 50 years old. Most of the refrigerators and freezers were less than ten years old. The statewide median age was eight years, and across all the segments shown the median age was at most ten years. In the Grocery segment, which accounts for the largest share of the statewide load, the median age for units was only five years.

Figure 135: Age Distribution of Refrigeration Devices by Segment

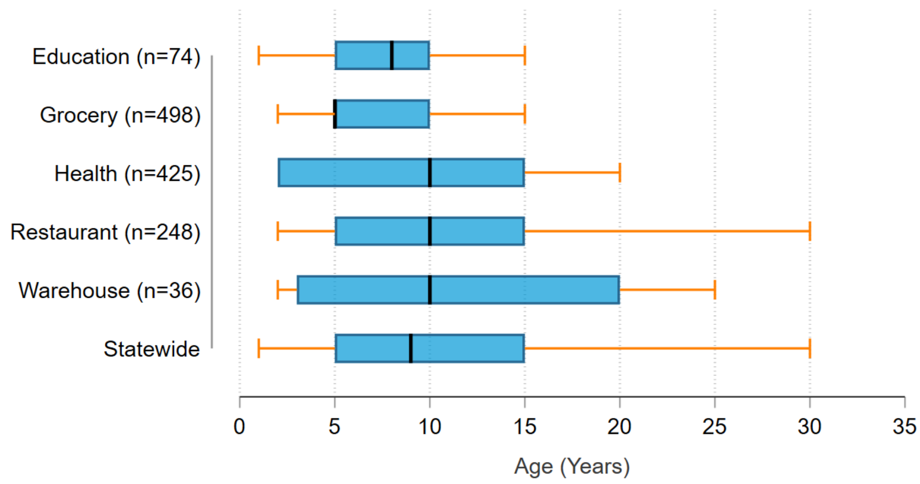


Figure 136 shows the average age of refrigeration equipment by type. Open case refrigerators were the newest by median age, but all the common reach-in types (bars one through five in the graph) had similar age ranges, with almost all the reach-in devices between two and 15 years old. Walk-in units, on the other hand, tend to be older. The upper range of ages shown in Figure 135 is largely explained by these older walk-in units, especially in the Restaurant and Warehouse segments.

Figure 136: Age Distribution of Refrigeration Devices by Type

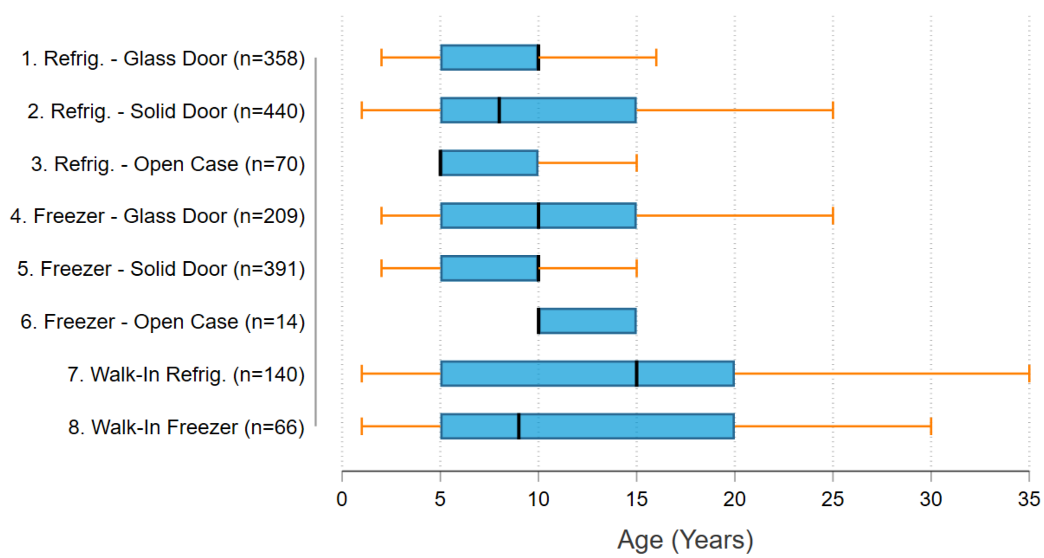
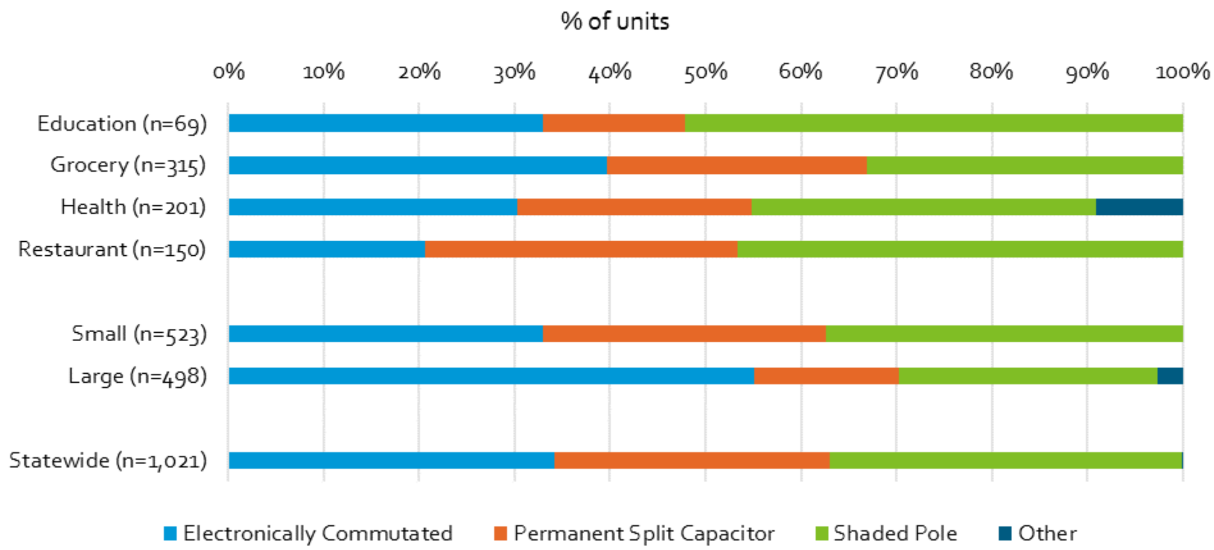


Figure 137 reports the types of evaporator fan motors for reach-in units. Electronically Commutated Motors (ECMs) are required in newer models, and they now make up about one-third of units statewide. More than half of the fan motors at Large C&I sites were ECMs. Since Grocery units were slightly newer on average, they also had a larger share of ECMs. Permanent Split Capacitors, which are less efficient than ECMs, made up just under 30% of the fan motors statewide, while Shaded Pole motors, the least efficient type, made up the largest share at 37%.

Figure 137: Evaporator Fan Motor Types, Reach-In Units



The relative share of ECMs and Shaded Pole motors changed significantly from 2018, however. These are likely driven by the changes in codes and standards, but Figure 138 shows a substantial replacement of older Shaded Pole motors with ECMs since 2018.

Figure 138: Evaporator Fan Motor Types, Reach-In Units, 2023 vs. 2018

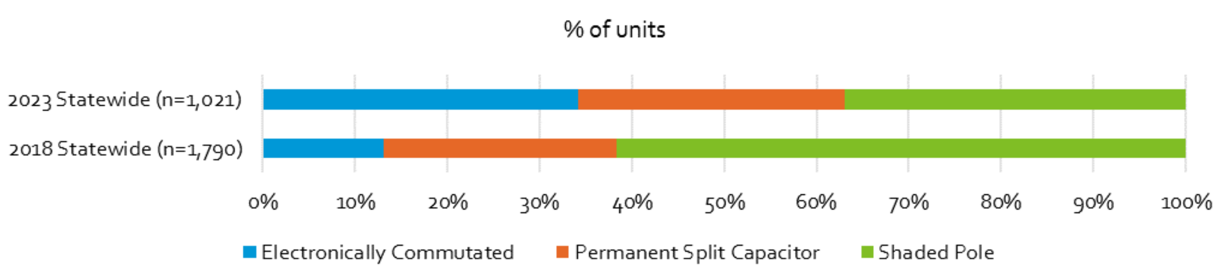


Table 36 reports several additional characteristics that affect energy use for reach-in units. These are listed as the percentage of relevant units with the given characteristic. For example, anti-sweat heaters are shown as a percentage of glass-door units and demand defrost controls are shown as a percentage of reach-in freezers only.

Most units now have LED lighting, especially in the Grocery segment (87%). Motion sensors (7%) are uncommon. Demand defrost controls for freezers are somewhat less common statewide, but they are common at Large C&I sites. Most glass-door units (80%) have anti-sweat heaters, but only 28% of these have anti-sweat heater controls to moderate them.

Table 36: Optional Characteristics, Reach-In Units

Category	LED Lights n = 1,482	Motion Sensors n = 1,482	Dem. Defrost Controls (Freezers) n = 600	Anti-Sweat Heaters (Glass doors) n = 567	Anti-Sweat Heating Control n = 406
Education (n= 50)	64%	1%	38%	95%	9%
Grocery (n= 423)	87%	9%	8%	88%	25%
Health (n= 390)	47%	7%	35%	0%	52%
Restaurant (n= 216)	55%	3%	21%	75%	50%
Small (n= 816)	71%	6%	13%	81%	26%
Large (n= 666)	72%	15%	49%	70%	86%
Statewide (n= 1,482)	**71%**	**7%**	**14%**	**80%**	**28%**

Table 37 reports similar optional characteristics for walk-in freezers and refrigerators. An even larger share of walk-in units had LED lighting (81%), while motion sensors remain rare outside of Large C&I sites. Roughly 30% of units had VFDs on their compressors and condensers respectively, with higher levels in the Grocery segment and the Large C&I sector. Floating head pressure controls and commissioned systems were common at Large C&I sites but uncommon elsewhere. Heat recovery for other end uses follows a similar pattern, with 45% of Large C&I sites recovering heat but almost no Small C&I sites. Demand defrost controls were much more common in the walk-in units (45% statewide) than they were for reach-ins.

Table 37: Optional Characteristics, Walk-In Units

Segment	LED Lights	Motion Sensors	VFDs on Comp-ressors	VFDs on Cond-ensers	Floating Head Pressure	System Commis-sioned	Heat Recovery	Dem. Defrost Controls (Freezers)
Education (n=24)	89%	3%	39%	39%	0%	9%	0%	56%
Grocery (n=75)	84%	8%	48%	48%	18%	6%	9%	67%
Health (n=35)	90%	39%	2%	2%	0%	0%	0%	4%
Restaurant (n=32)	81%	3%	13%	16%	6%	6%	6%	25%
Warehouse (n=9)	61%	1%	21%	21%	2%	0%	0%	61%
Small (n=117)	81%	6%	27%	28%	7%	2%	3%	43%
Large (n=93)	92%	49%	56%	56%	58%	45%	45%	64%
Statewide (n=210)	**81%**	**8%**	**28%**	**29%**	**10%**	**4%**	**5%**	**45%**

Finally, Table 38 reports the percentage of reach-in devices with ENERGY STAR certification. This information can be hard to observe on installed equipment, especially larger systems.

Table 38: Percent of Reach-In Equipment with ENERGY STAR Rating

Refrigeration Type	% ENERGY STAR
Freezer: Glass Door (n=209)	2%
Freezer: Solid Door (n=389)	42%
Freezer: Open-Case (n=14)	0%
Refrigerator: Glass Door (n=354)	55%
Refrigerator: Solid Door (n=440)	21%
Refrigerator: Open Case (n=68)	0%

9 PROCESS

9.1 PROCESS EQUIPMENT OVERVIEW

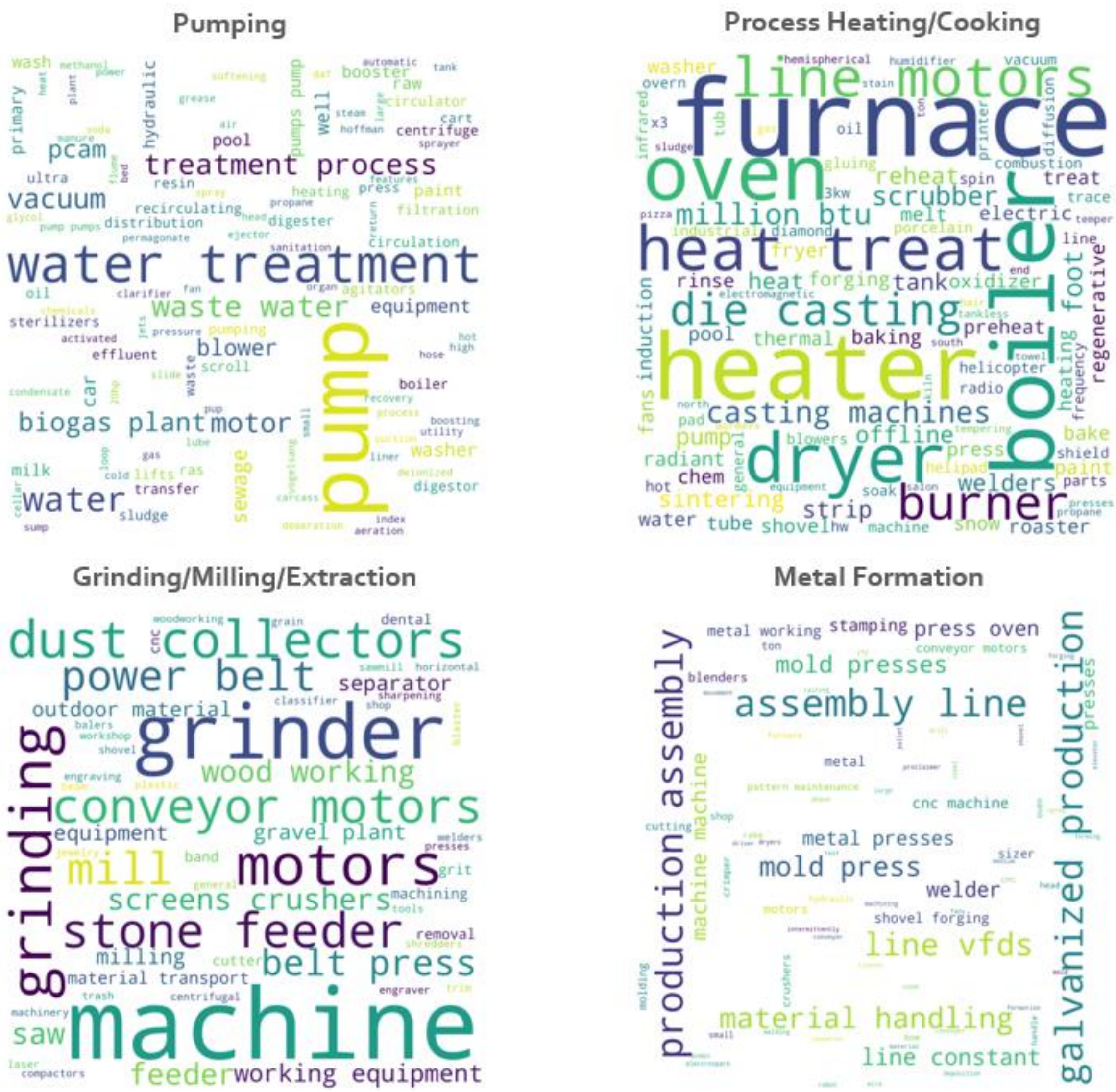
This section examines survey data on processes and the motors that power them, as well as the energy characteristics of non-motor processes. Most processes support some sort of manufacturing operation so are specific to the nature of the industry the site is engaged in. For the processes end use, information 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 National Electrical Manufacturers Association (NEMA) type.

Most of the processes fall into the following categories:

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

The on-site data collection tool requires technicians to name each process entered in the site inventory. Figure 139 shows the names commonly used to describe four process types.

Figure 139: Common Names for Four Process Types



Motor service type categories include the following:

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

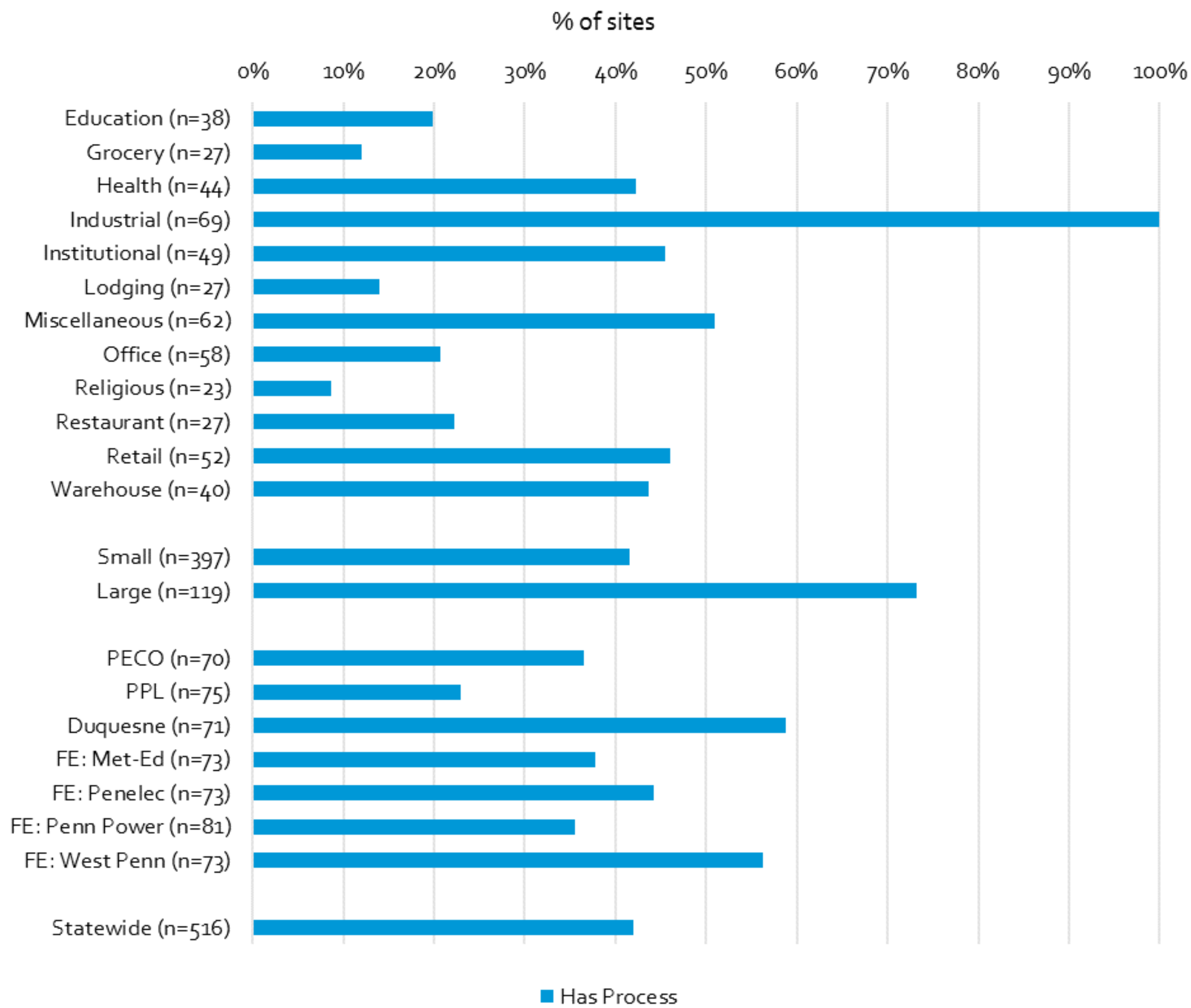
While most processes are motor-driven, processes like Battery Charging and Process Heating or Cooking generally do not rely on an electric motor as the primary source of mechanical energy. These non-motor driven processes tend to have less sophisticated control systems and, in the case of Process Heating/Cooking, rely heavily on natural gas as the primary fuel source.

9.2 PROCESS FINDINGS

PENETRATION

Most businesses in Pennsylvania do not have process equipment, but process equipment is crucial to the operations of a select few segments. All sites in the Industrial segment had some amount of process equipment, for example. Figure 140 shows the site-level penetration of process equipment for each segment and sector along with the statewide average. As expected, segments like Religious and Grocery had very little process equipment on site, and Large C&I customers tend to have more process equipment.

Figure 140: Penetration of Process Equipment



PROCESS TYPE

Nearly 90% of process capacity statewide is concentrated in the Industrial segment. The following graphs focus on Industrial because it includes the most process-dependent facilities and had the most inventoried motors. Breakdowns by other segments are shown where relevant. Figure 141 and Figure

142 show the distribution of various types of processes, by the capacity of those processes. Figure 141 includes processes that are powered by all forms of fuel, and Figure 142 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. Most of the difference comes from Process Heating/Cooking, which are mostly powered by combustion-based fuel sources.

Figure 141: Distribution of Process Type (by Capacity)

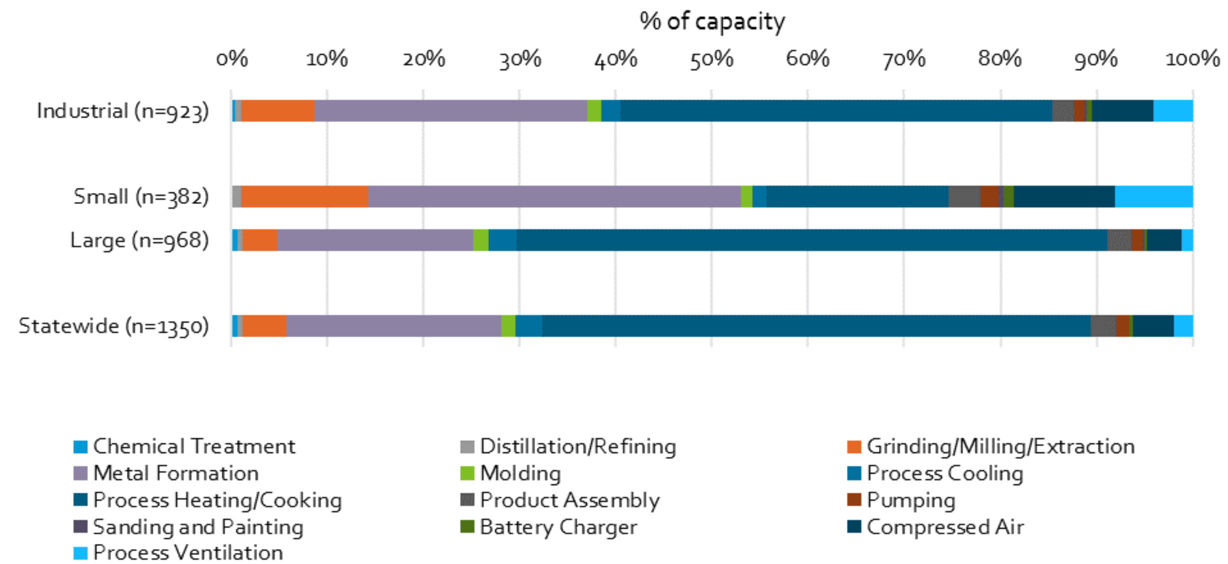


Figure 142: Distribution of Process Type for Electric Processes (by Capacity)

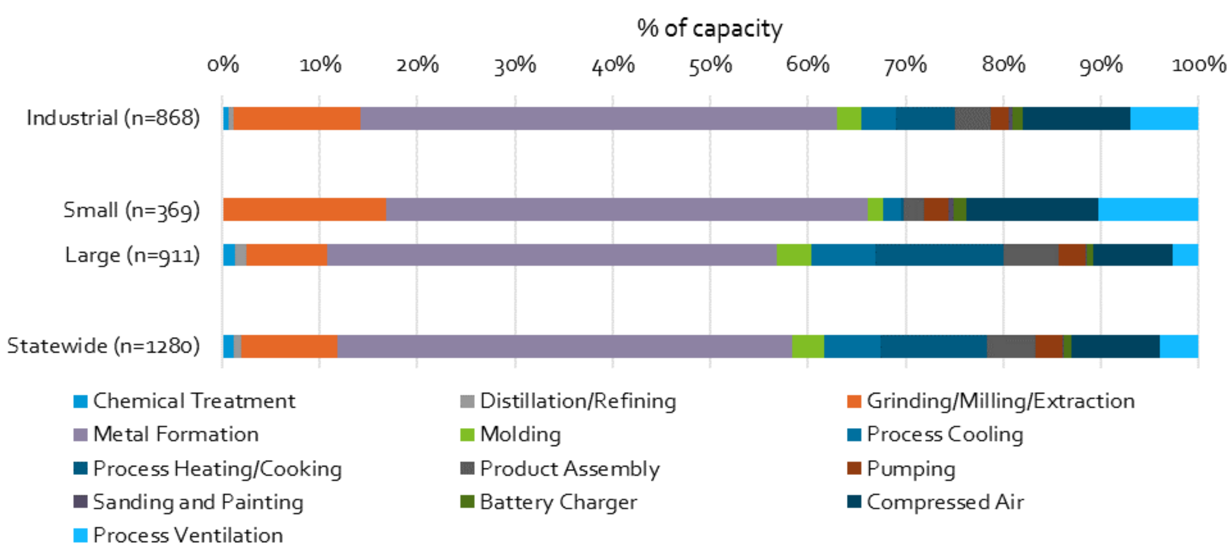
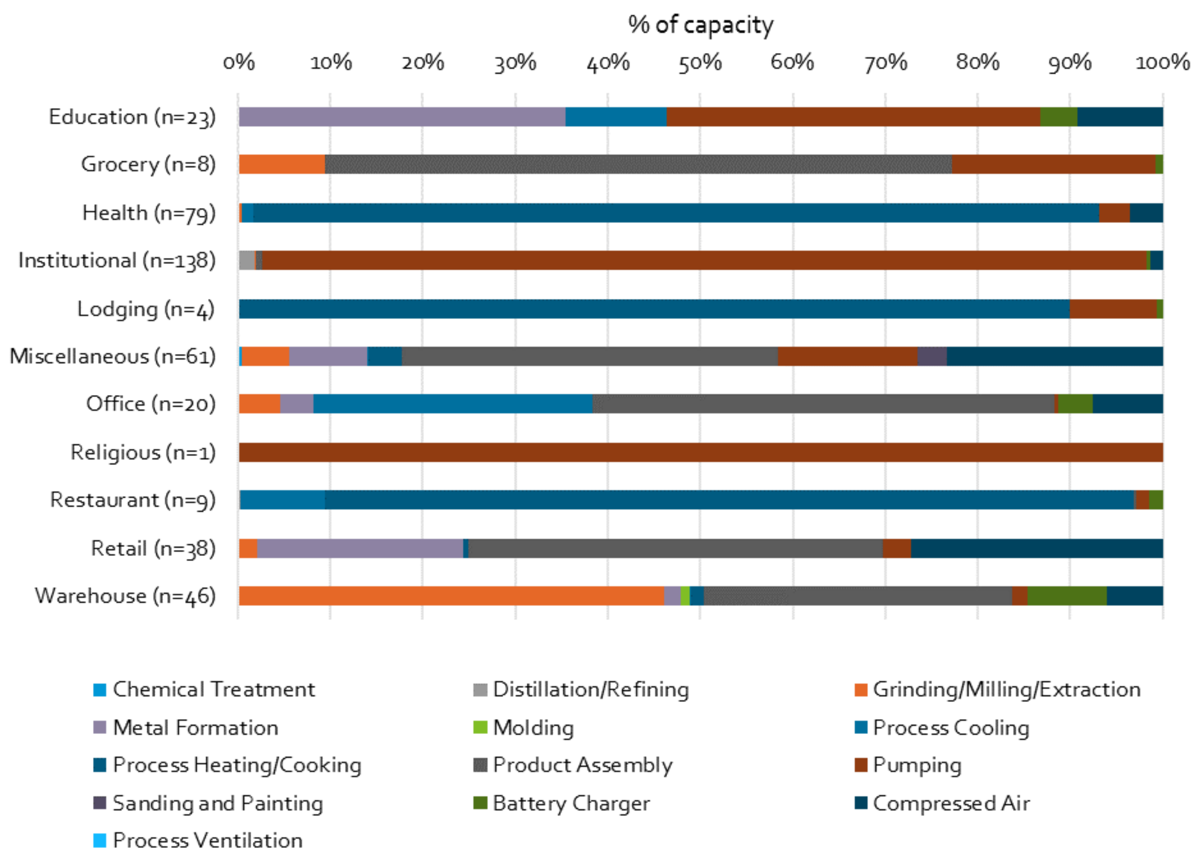


Figure 143 shows the distribution of process type for all other segments. Process Heating/Cooking is prominent in Health because healthcare facilities require a lot of heat for sterilization. The Institutional segment includes water treatment plants where pumping loads are common.

Figure 143: Distribution of Process Type (by Capacity), All Other Segments



PROCESS FUEL TYPE

Figure 144 shows the distribution of fuel type by capacity with a focus on Industrial, while Figure 145 focuses on all other segments. Statewide fuel type distribution closely follows Large Industrial, with Natural Gas-fueled processes accounting for a slightly greater share of capacity than Electric. Propane is more common in other segments, like Office, Retail, and Warehouse, due to the presence of forklifts, but propane-fueled processes make up less than 1% of overall capacity statewide. Note the 14 pieces of process equipment recorded in the Restaurant segment. Some process cooking equipment, like mixers and pumps used to facilitate the beer brewing process at a microbrewery/gastropub, are separate and distinct from the standard commercial cooking equipment inventory. Details on regular commercial cooking equipment can be found in Section 10.

Figure 144: Distribution of Process Fuel Type (by Capacity)

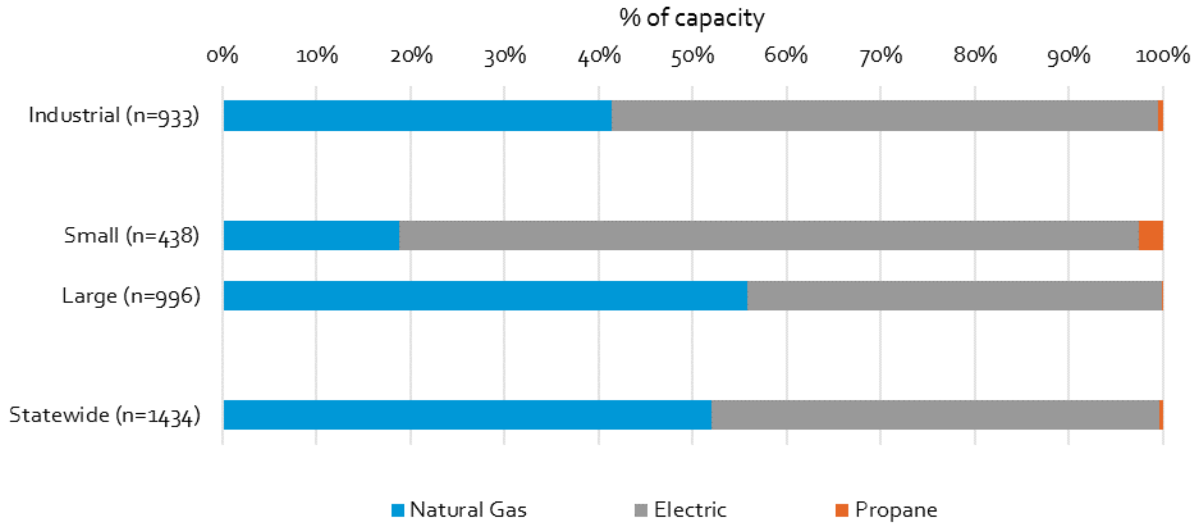
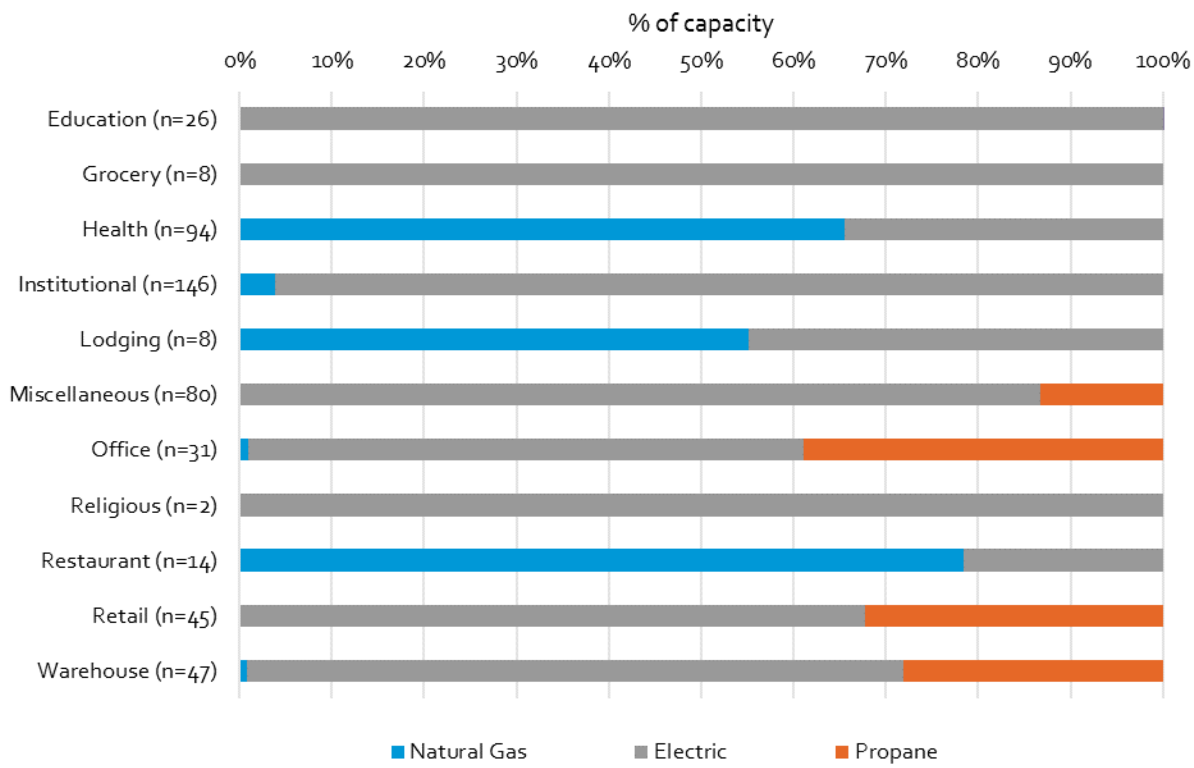


Figure 145: Distribution of Process Fuel Type for Non-Industrial Segments (by Capacity)



Process Motors

Figure 146 summarizes the control method for the motors that power these processes. Most motors utilize constant speed controls. N-values are provided at the motor level, and the figure is weighted by capacity (horsepower).

Figure 146: Distribution of Motor Control Type (by Capacity)

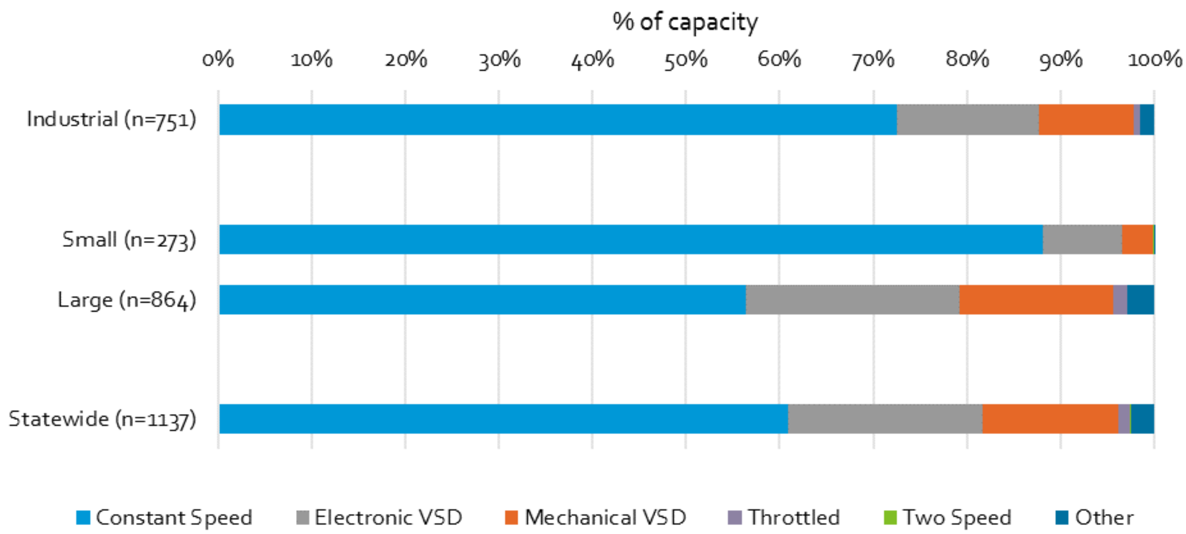


Figure 147 shows the distribution of motor control type by process type in the Industrial segment. The top eight process types by equipment count are shown. Variable speed drives (VSD) are most common in pumping, process cooling, and compressed air applications. Data collection and reporting for this study groups variable frequency drives (VFD) under the Electronic VSD category.

Figure 147: Distribution of Motor Control Type in Industrial Segment (by Capacity)

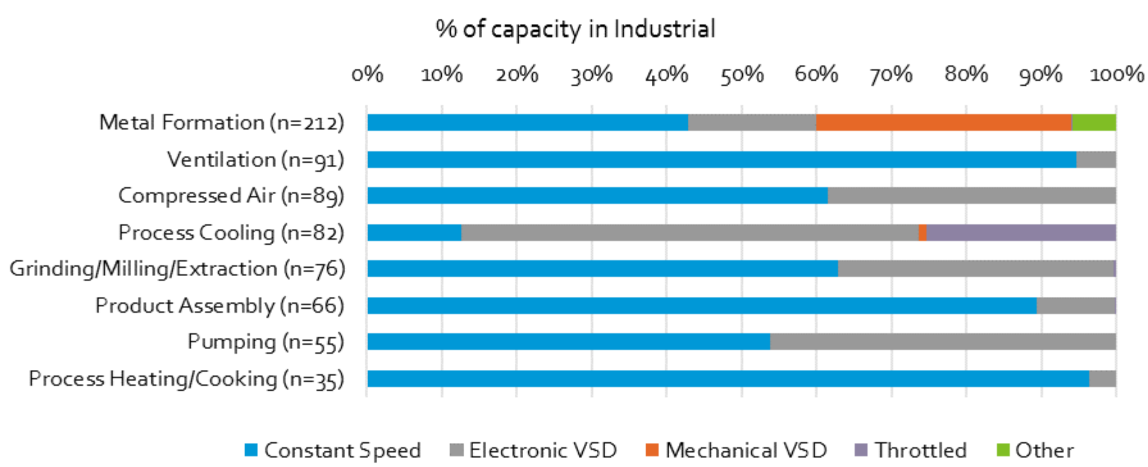


Figure 148 shows the distribution between open drip proof (ODP) and totally enclosed fan cooled (TEFC) casings for NEMA motors, and Figure 149 breaks down the distribution by process type.

Baseline efficiency ratings in the Pennsylvania TRM depend on casing type. The provided n-values are at the motor level, and shares are capacity weighted (horsepower) in both figures. Over 80% of NEMA casing types statewide are ODP. Intuitively, motors for processes that create a lot of debris like Sanding and Painting or Grinding/Milling/Extraction are more likely to use a TEFC casing type.

Figure 148: Distribution of NEMA Casing Type (by Capacity)

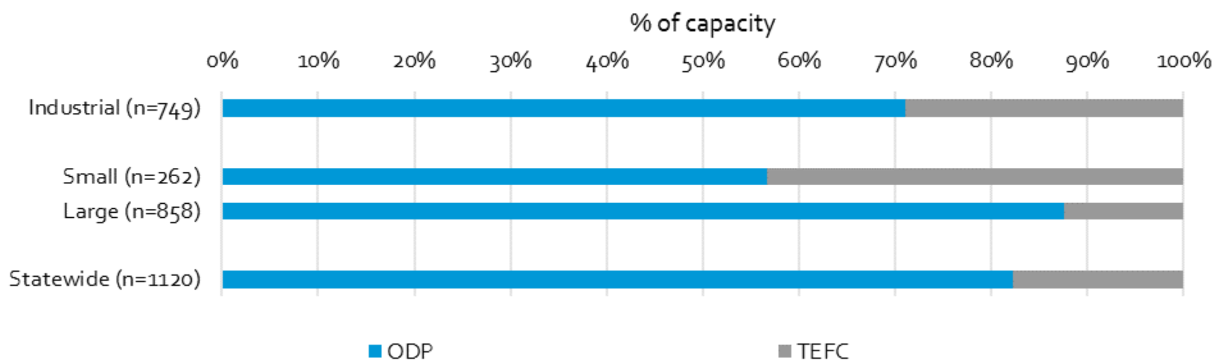


Figure 149: Distribution of NEMA Casing Type by Process Type (by Capacity)

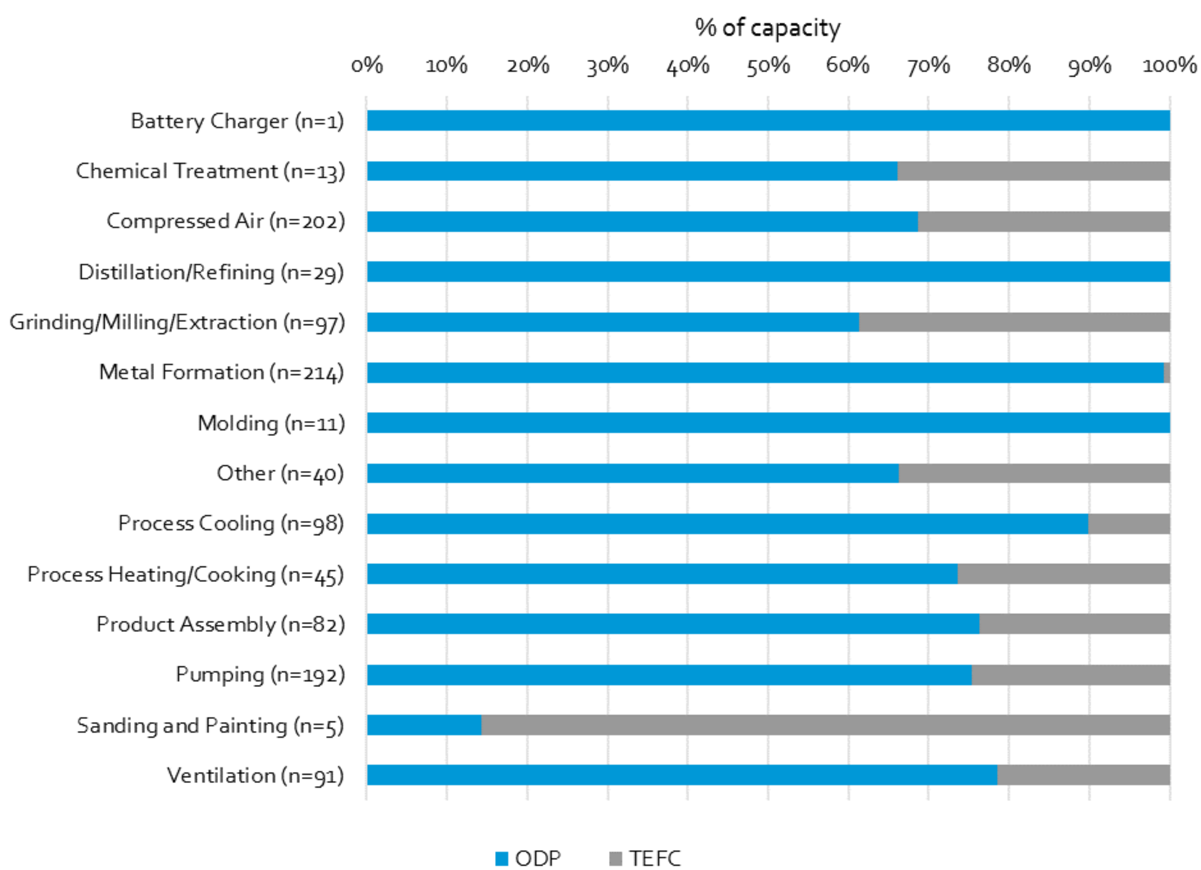


Figure 150 shows the distribution of motor service type. The provided n-values are at the motor level, and shares are capacity weighted.

Figure 150: Distribution of Motor Service Type (by Capacity)

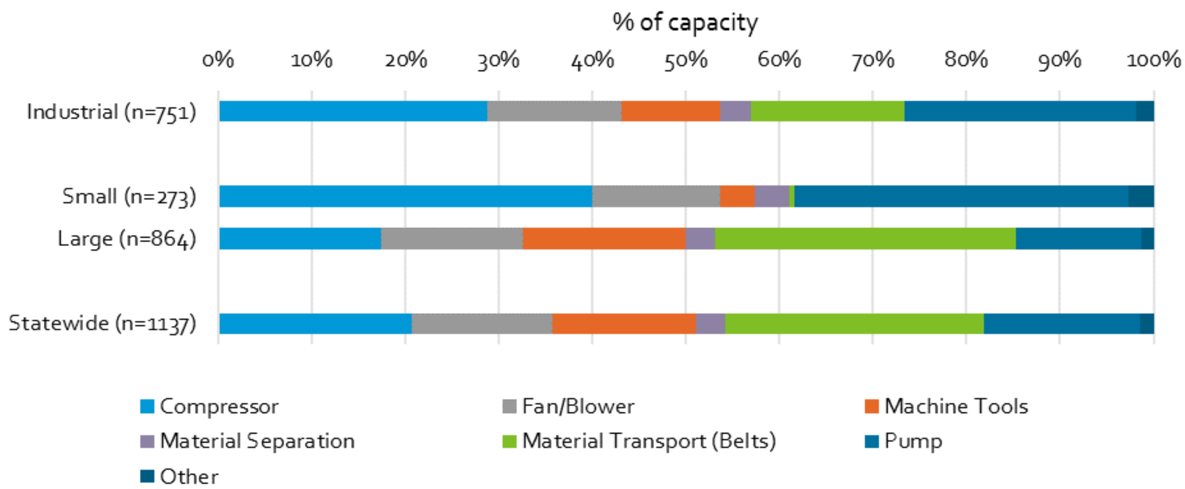


Figure 151 and Figure 152 show the distribution of service type by control type across all segments, weighted by process capacity and unit count, respectively.

Figure 151: Motor Control Mechanism by Service Type (by Capacity)

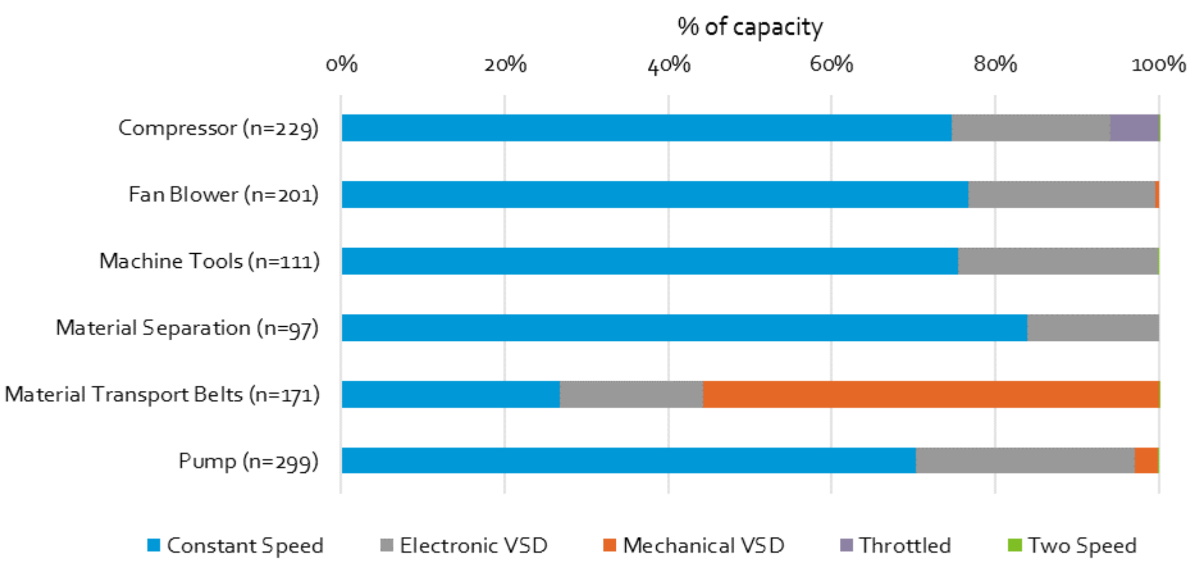


Figure 152: Motor Control Mechanism by Service Type (by Units)

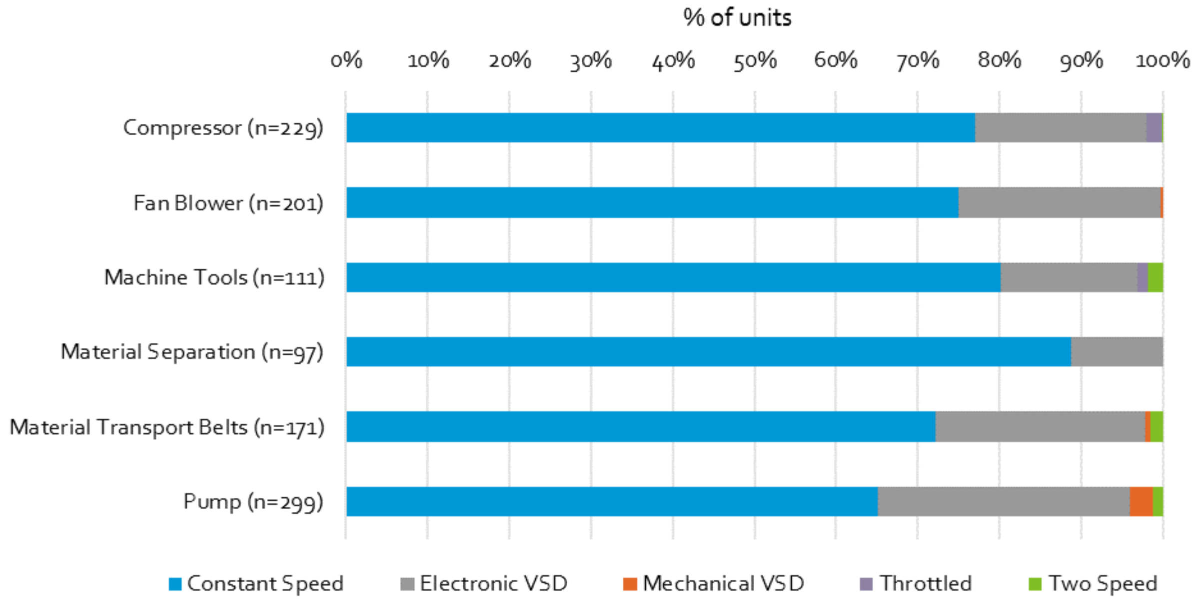


Table 39 shows average surveyed motor horsepower based on the categories provided in the above figures.

Table 39: Average Motor Horsepower (by Control Type, Motor Type, and Service Type)

Control Type	n	Avg. Motor HP
Constant Speed	771	27.5
Electronic VSD/VFD	338	55.8
Mechanical VSD	6	33.2
Throttled	9	9.6
Two Speed	11	3.1
Other	2	15.6
Motor Type	**n**	**Avg. Motor HP**
ODP	873	37.6
TEFC	247	26.2
Service Type	**n**	**Avg. Motor HP**
Compressor	229	58.3
Fan Blower	201	19.5
Machine Tools	111	35.3
Material Separation	97	24.3
Material Transport Belts	172	44.8
Pump	299	25.6
Other	28	21.3

9.3 COMPARISON WITH PRIOR STUDY FINDINGS

The following graphs and tables compare 2023 results with the outputs of the 2018 study. Figure 153 shows the distribution of process type over time, graphed here as the percentage of capacity. Process Heating/Cooking accounted for a much higher share of capacity in 2023, while Pumping capacity decreased substantially from 2018 levels. Metal formation also showed an increased share of process capacity in the 2023 study. Compressed Air, Battery Charger, and Process Ventilation were new process types in the 2023 data collection tool. We caution readers about inferring broader trends from this data as these results are sensitive to the types of large manufacturing facilities sampled. For example, the largest site visited in the 2018 study was a paper mill and the largest site visited in the 2023 study was a steel mill. The pulp/paper and primary metals industries are both incredibly energy intense, but the nature of the loads is different.

Figure 153: Distribution of Process Type (by Capacity), 2023 vs. 2018

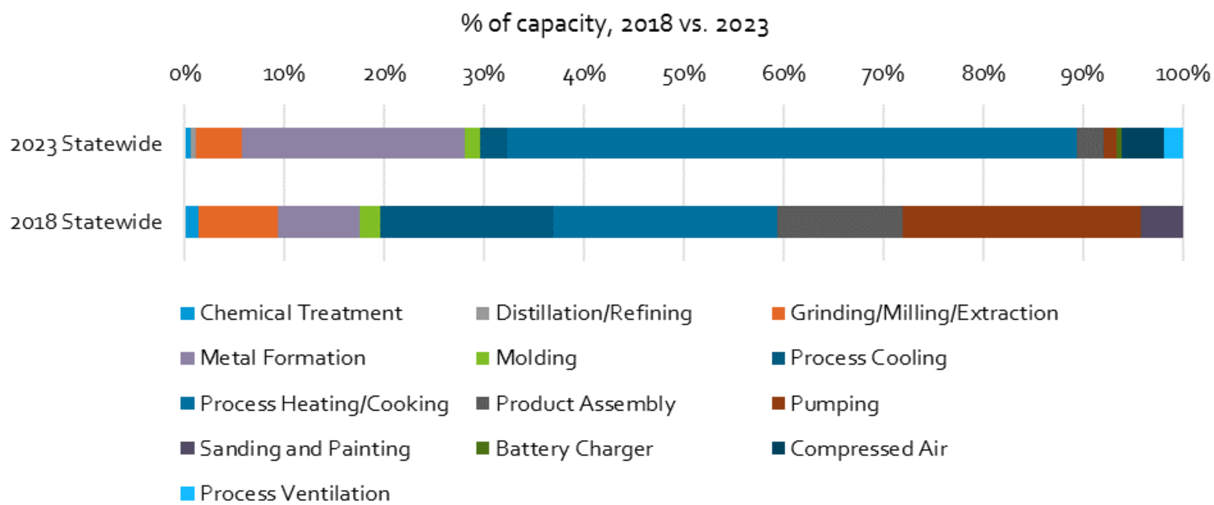


Figure 154 shows the distribution of motor control type over time as a percentage of capacity. The capacity shares of both Electronic VSD (or VFD) and Mechanical VSD controls have grown since 2018. Capacity shares of Electronic and Mechanical VSD doubled from 2018 to 2023. Unlike the changes in Figure 153, which are likely due to variation in industries sampled, we interpret the differences in Figure 154 as a real trend towards variable speed/frequency drives in the Commonwealth's energy intensive motor-driven processes.

Figure 154: Distribution of Motor Control Type (by Capacity), 2018 vs. 2023

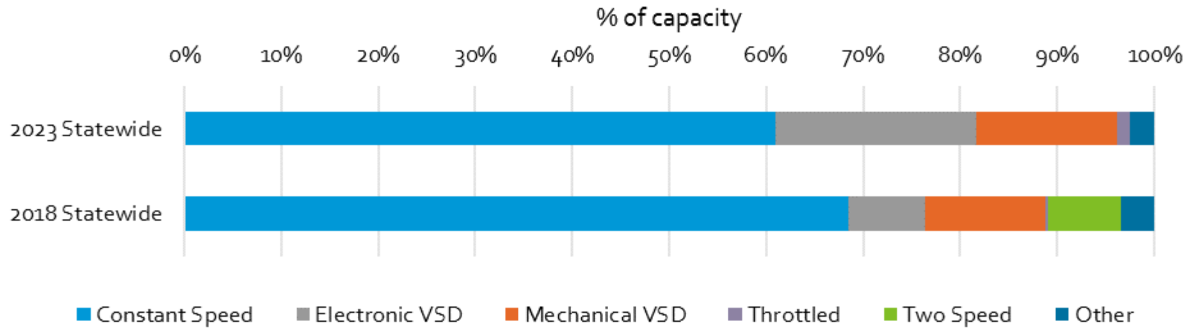
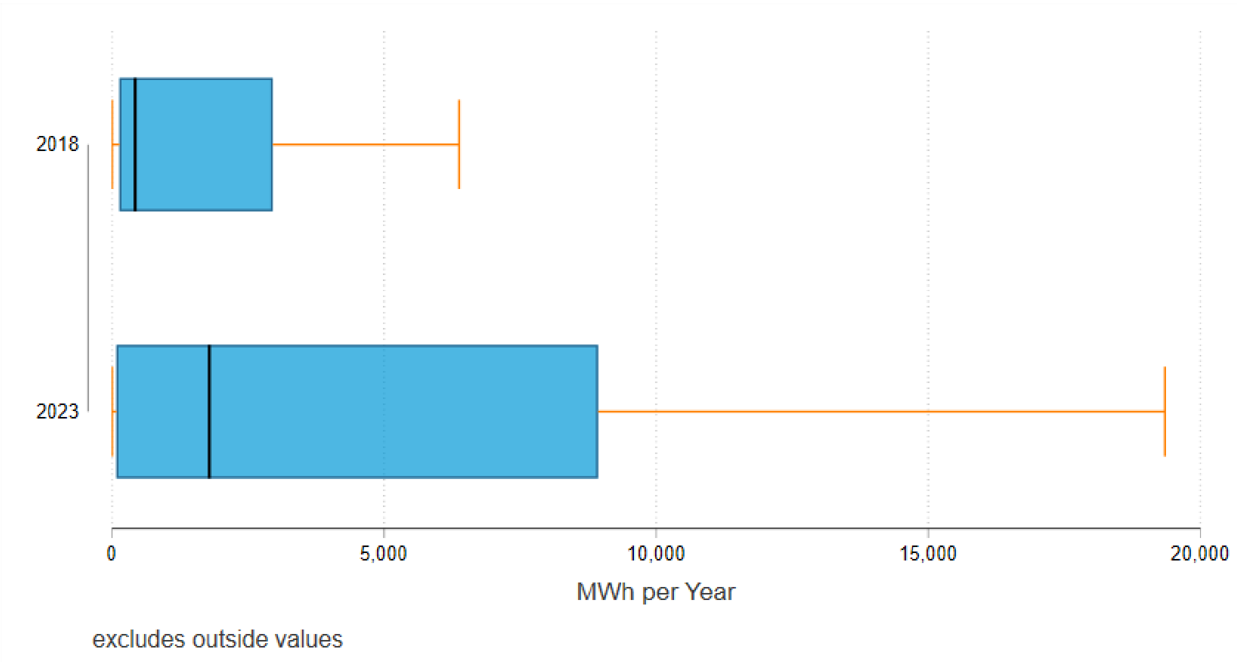


Figure 155 compares the annualized MWh for Industrial sites with processes in the 2018 and 2023 studies. The average in the 2018 non-residential baseline study was 3,836 MWh/year, and the average in this study is 9,851 MWh/year. The difference indicates sites visited in 2023 had much larger process loads, on average, compared to sites visited in 2018.

Figure 155: Annualized MWh for Industrial Sites, 2018 vs. 2023



10 COOKING

10.1 COOKING EQUIPMENT OVERVIEW

This chapter covers equipment for high-volume food preparation, often found in restaurants or cafeterias. Smaller equipment like microwaves and toaster ovens, which are common in offices and break rooms, are discussed in Section 11, which covers Plug Loads. While most businesses do not have commercial cooking appliances, equipment in this chapter can be extremely energy intensive and are thus an important end use to include in the study. Commercial cooking results are organized into the eight appliance categories shown in Figure 156.

Figure 156: Categories for Commercial Cooking Equipment

Most of these appliances are available in both fossil-fuel and electric models, so the fuel shares for each type are a key set of results. Cooking equipment is concentrated in only a few segments, including Restaurant, Grocery, Education (schools), and Health (hospitals). As such, most of the graphs and tables only report results for those segments.

Each industry segment's relative weight in statewide results reflects its share of total, statewide energy used for cooking. Thus, while restaurants make up a relatively small share of total electric sales in Pennsylvania, they represent a large share of the electricity used for cooking and factor heavily in the statewide results for commercial cooking.

10.2 COOKING EQUIPMENT FINDINGS

Figure 157 shows the percentage of surveyed sites with any type of commercial cooking equipment by segment with n-values representing the total number of sites surveyed. Commercial cooking equipment was common in the Restaurant, Religious, Grocery, Education, and Lodging segments.

All Restaurant facilities in the survey had some amount of large, commercial cooking equipment aside from two small coffee shops, whose appliances were included as plug loads. Churches frequently have cooking equipment, with over 60% penetration. Only 45% of Grocery sites had commercial cooking equipment; all had commercial refrigeration, covered separately in Chapter 8, but several convenience stores had only smaller cooking appliances. The Education segment includes K-12 schools and college campuses, but also related buildings such as day care centers and libraries—in the survey, nearly all schools had cooking equipment, while it was largely absent from other sites in the Education segment. The Health and Lodging segments follow a similar trend, with cooking equipment at large hospitals and hotels. Note also that the survey included large industrial sites with cooking equipment—these are included as process equipment in Section 9.

Figure 157: Penetration of Commercial Cooking Equipment

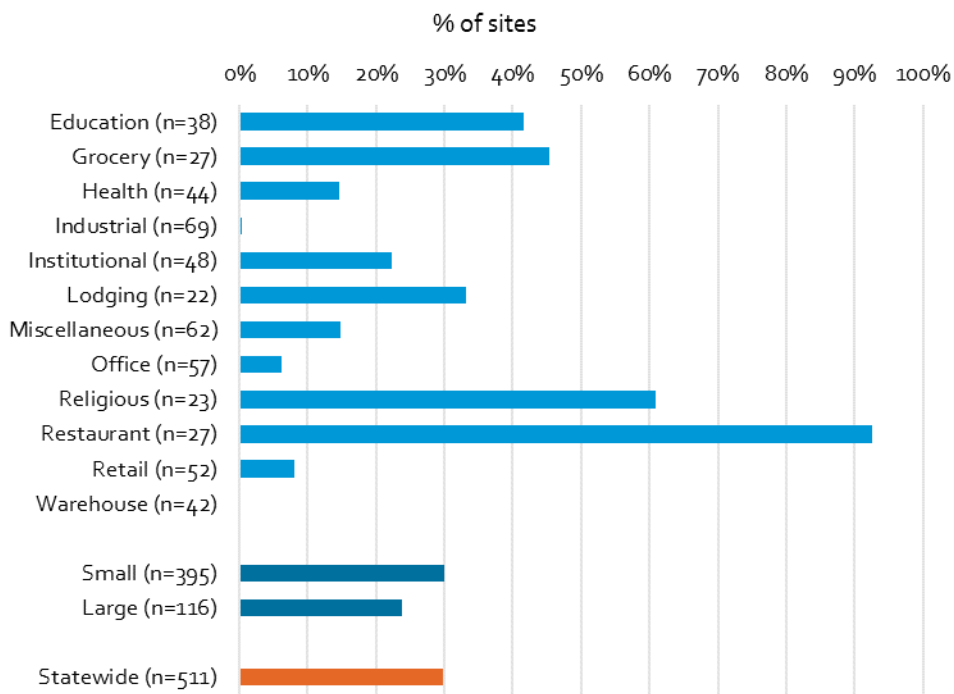


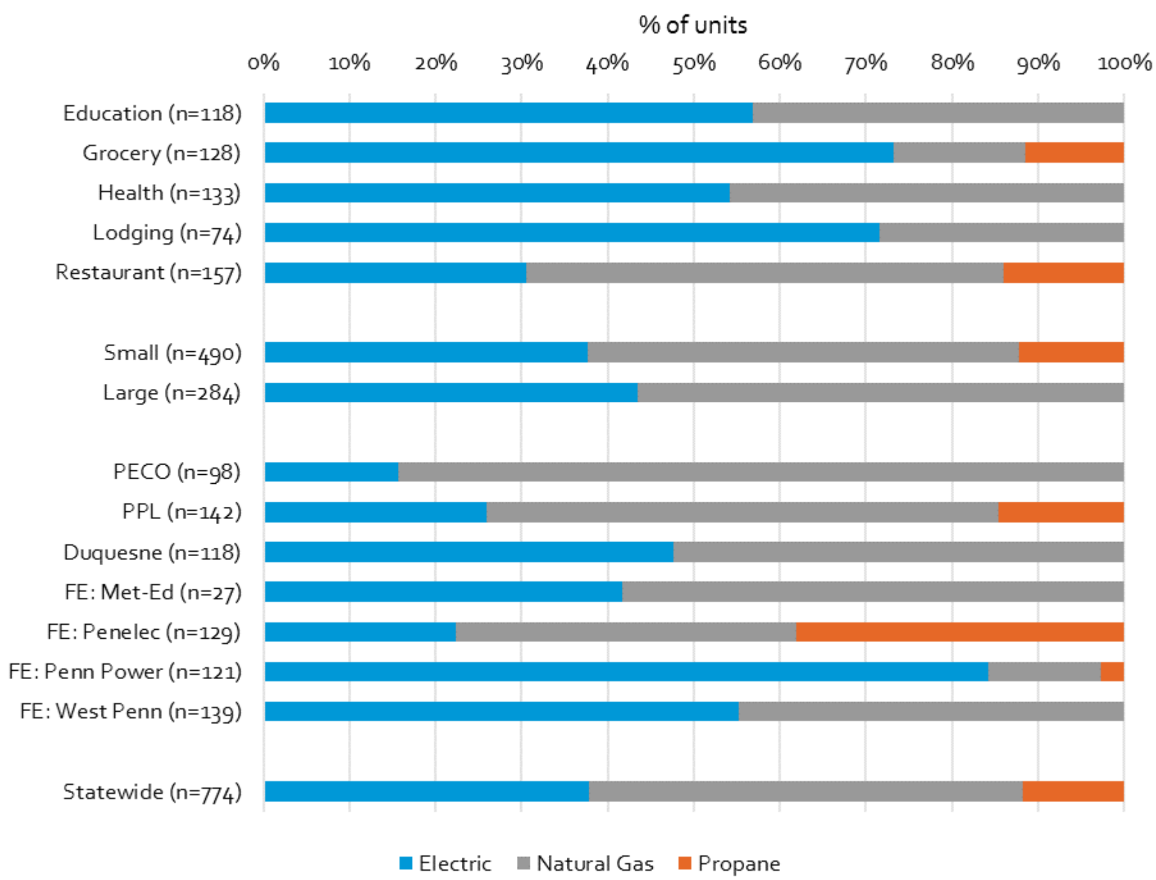
Table 40: Commercial Cooking Equipment Penetration

Category	n	Range	Griddle	Fryer	Standard Oven	Convection Oven	Steam Cooker	Hot Food Holding Cabinet	Commercial Dishwasher
Education	38	23%	-	5%	28%	10%	18%	19%	26%
Grocery	27	22%	-	24%	28%	18%	-	22%	6%
Health	44	15%	7%	1%	11%	-	-	7%	8%
Industrial	69	-	-	-	-	-	-	-	-
Institutional	48	13%	7%	7%	17%	2%	-	3%	5%
Lodging	22	19%	9%	14%	19%	5%	-	9%	9%
Miscellaneous	62	7%	2%	3%	5%	3%	-	3%	2%
Office	57	4%	-	-	4%	-	-	-	-
Religious	23	43%	13%	4%	30%	17%	-	13%	22%
Restaurant	27	59%	33%	67%	59%	26%	22%	33%	37%
Retail	52	4%	4%	6%	4%	2%	-	2%	2%
Warehouse	42	-	-	-	-	-	-	-	-
Small	395	19%	9%	16%	20%	7%	5%	9%	10%
Large	116	17%	6%	10%	17%	10%	6%	11%	11%
Statewide	**511**	**19%**	**9%**	**16%**	**20%**	**7%**	**5%**	**9%**	**10%**

Table 40 above shows the percentage of sites with specific types of cooking equipment. Most of the equipment trends similarly by segment: Restaurants have the highest penetration rate for all eight categories, while Grocery and Education often have commercial kitchens and thus higher penetration rates across all appliance types as well. While some equipment is uncommon or entirely absent in some segments, it is important to note that there are some sites with commercial cooking equipment in nearly every segment.

Figure 158 shows the fuel share across all cooking equipment available in both electric and gas models. This excludes dishwashers, which are all electric. The graph shows a simple percentage of units—it does not reflect the amount of energy provided by each source, but rather the percentage of cooking appliances that are electric, gas-fueled, etc.

Figure 158: Fuel Shares Across All Equipment Types (by Count)

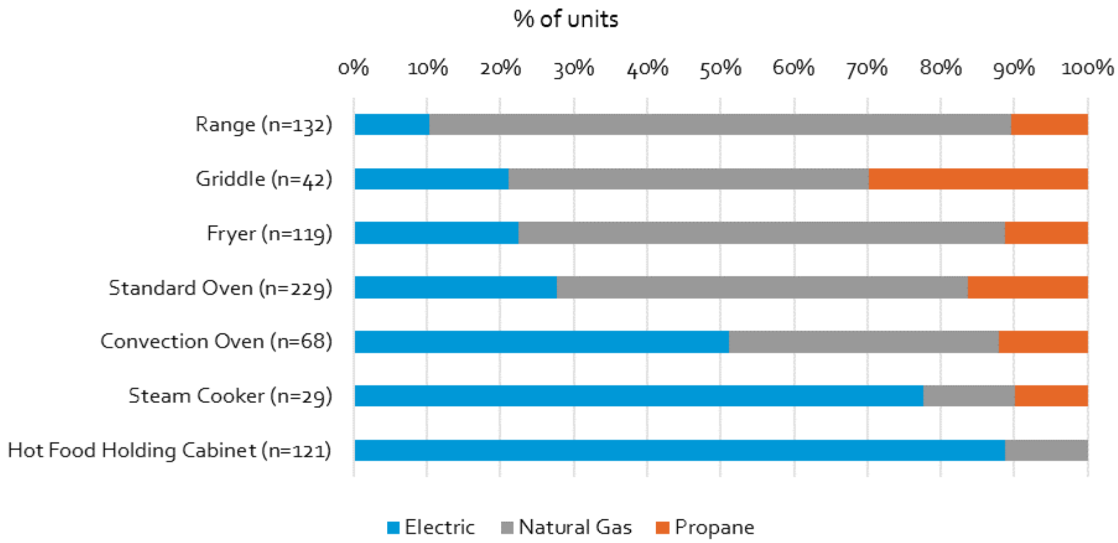


Statewide 38% of commercial cooking equipment is electric. This, however, includes steam cookers and hot food holding cabinets, which are often electric. Fossil fuels power a larger share of the remaining appliances, which are the most energy intense components of a commercial kitchen.

EDC location affects the mix of gas/propane used—PECO, Duquesne, Met-Ed, and West Penn Power, had no propane used for cooking. However, natural gas availability does not have a discernible impact on the choice of electric vs. fossil fuel cooking equipment as the two EDCs with notable propane fuel shares (PPL and Penelec) had among the lowest electric fuel shares.

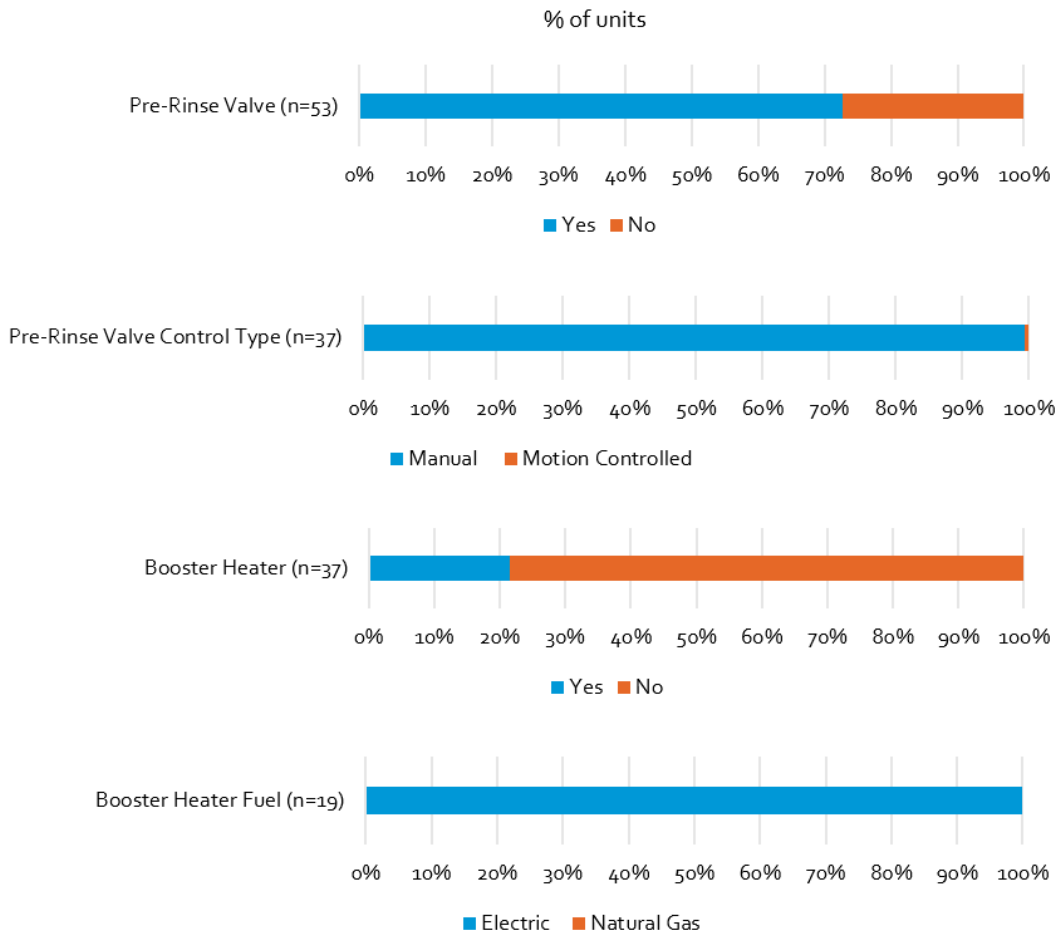
Figure 159 better illustrates the fuel mix, showing the statewide shares for each equipment type. Some of the most energy intensive appliances (range, griddle, fryer) are dominated by fossil fuels, as are standard ovens to a lesser extent. Over half of the convection ovens, steam cookers, and hot food holding cabinets observed were electric.

Figure 159: Distribution of Fuel Share by Equipment Type



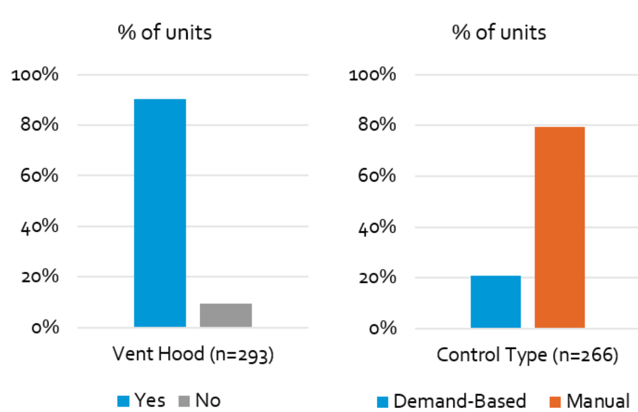
The panels in Figure 160 show the prevalence of optional efficient equipment for dishwashers. While the first panel shows a majority with pre-rinse valves, the flow rates do not meet the Pennsylvania TRM definition of "low-flow" valves. Nearly all the pre-rinse spray valves are manually controlled rather than triggered by motion sensors. Booster heaters were present for just over 20% of units, all of which were electric. Note that while all dishwashers are electric, they can use water heated by a different fuel. Where this is the case, the fuel will show up as the water heating fuel in Section 7, while in this chapter we simply treat the appliance itself as electric.

Figure 160: Optional Equipment for Commercial Dishwashers



The panels in Figure 161 show the penetration of vent hoods in sites with cooking equipment as well as the control types found. Approximately 90% of sites with cooking equipment had some kind of vent hood, and among these almost 80% were manually controlled.

Figure 161: Vent Hoods and Controls for Cooking Equipment



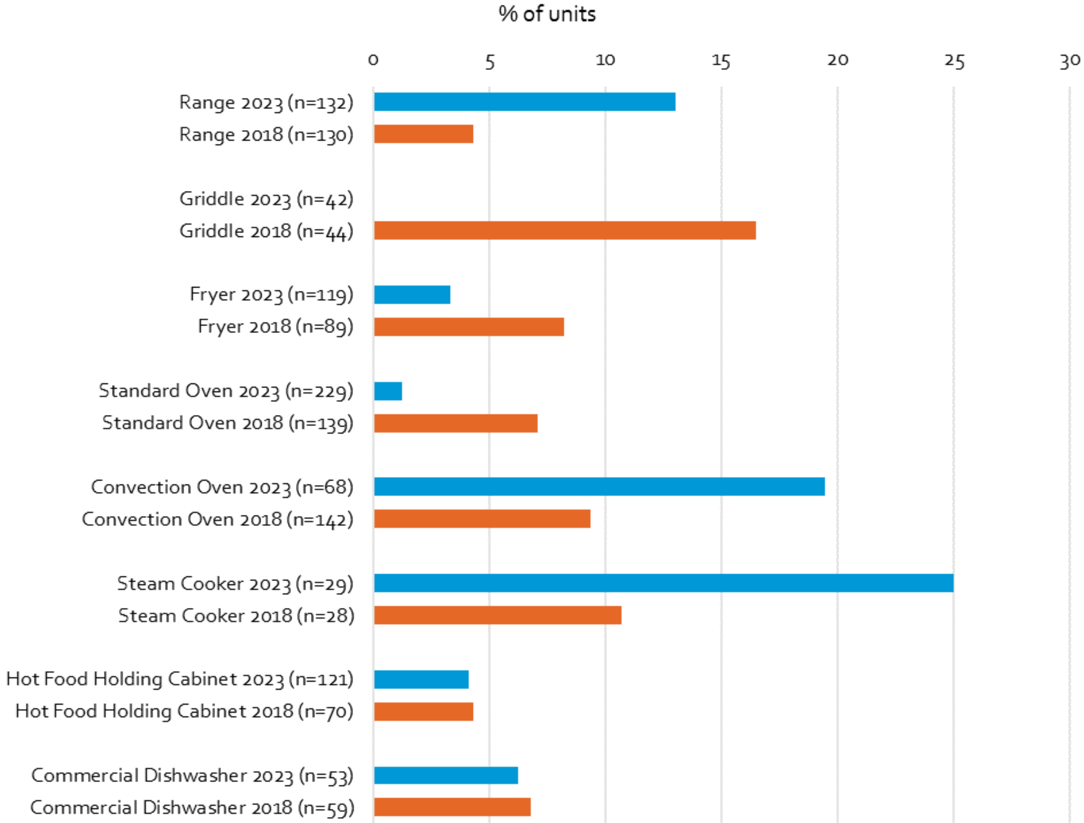
ENERGY STAR ratings are an important distinction for cooking appliances, reported in Table 41 for each equipment type. Unfortunately, this information is difficult to directly observe on site due to inaccessible or in-use equipment. These numbers may have some significance in comparing across appliance types but are more difficult to assess within each category. In the case that the field technician was unclear of the ENERGY STAR status, the unit was entered as non-ENERGY STAR.

Table 41: Percent of Equipment with ENERGY STAR Rating

Kitchen Equipment Type (n=unit)	% ENERGY STAR
Range (n=132)	13%
Griddle (n=42)	0%
Fryer (n=119)	3%
Standard Oven (n=229)	1%
Convection Oven (n=68)	19%
Steam Cooker (n=29)	25%
Hot Food Holding Cabinet (n=121)	4%
Commercial Dishwasher (n=53)	6%

Figure 162 compares these percentages across the 2023 and 2018 non-residential baseline studies. Since the ENERGY STAR information is difficult to observe, the most accurate estimates would likely come from combining the estimates from the two studies. Note that there is too little data here, and the outcome here too noisy, to infer trends over time from 2018 to 2023.

Figure 162: Percent of Equipment with ENERGY STAR Rating, 2023 vs. 2018



11 PLUG LOAD

11.1 PLUG LOAD EQUIPMENT OVERVIEW

This section analyzes additional C&I equipment that runs from standard 120V electrical plugs. Since many devices fit this description, the SWE limited data collection to several common C&I devices listed below, organized by category:

Computers

- Desktop Computers
- Monitors
- Laptops

Computer Infrastructure

- Servers
- Uninterruptable Power Supply

Document Processing

- Office Imaging Units
- Photocopiers
- Printers
- Scanners
- Fax Machines
- Shredders

Televisions (TVs)

Refrigeration & Vending

- Residential Style Refrigerators
- Ice Makers
- Water Coolers
- Vending Machines

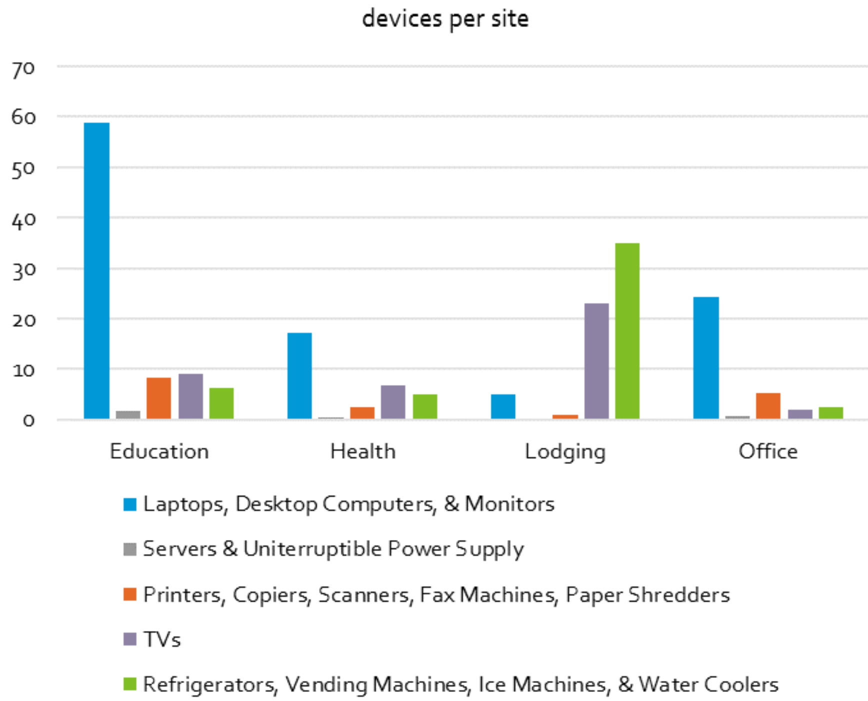
Device types were recorded along with quantities, hours of use, and ENERGY STAR ratings where possible.

11.2 PLUG LOAD EQUIPMENT FINDINGS

Plug load device counts are shown by category in Figure 163 and Figure 164. These figures are not normalized for building size or number of occupants, so sites in segments like Education will tend to have higher counts (see the Section 12: Building Characteristics for building square footage and occupancy by segment).

Figure 163 first shows device counts by category for the four segments with highest counts: Education, Health, Lodging, and Office. Computers in the Education segments were by far the most common of any plug load category. Education sites also had the most document processing devices (printers, copiers, etc.), and a high number of televisions in classrooms. Office sites were often smaller than schools, but large office buildings also had very large numbers of computers. Lodging sites unsurprisingly had a unique mix of devices, with the highest numbers of refrigerators and televisions.

Figure 163: Average Number of Plug Load Devices by Category (Select Segments)



The SWE was able to audit several large hospitals in 2023. Unfortunately, the rich data collected for other end uses in hospitals sometimes precluded a full collection of plug loads, as technicians had limited time in these very large, complex sites. For this reason, plug loads in the Health segment, while high relative to most other segments, are likely underreported. Note that specialized plug loads specific to the healthcare industry were not recorded, since they were so varied and relevant to that segment alone.

Figure 164 reports the average number of devices by category in the remaining segments. Note the different values on the vertical axis from the previous figure, with the highest counts being eight or nine devices per site. Computers were again the most common devices, albeit in much smaller quantities than the Education, Health, or Office segments.

Figure 164: Average Number of Plug Load Devices by Category (Other Segments)

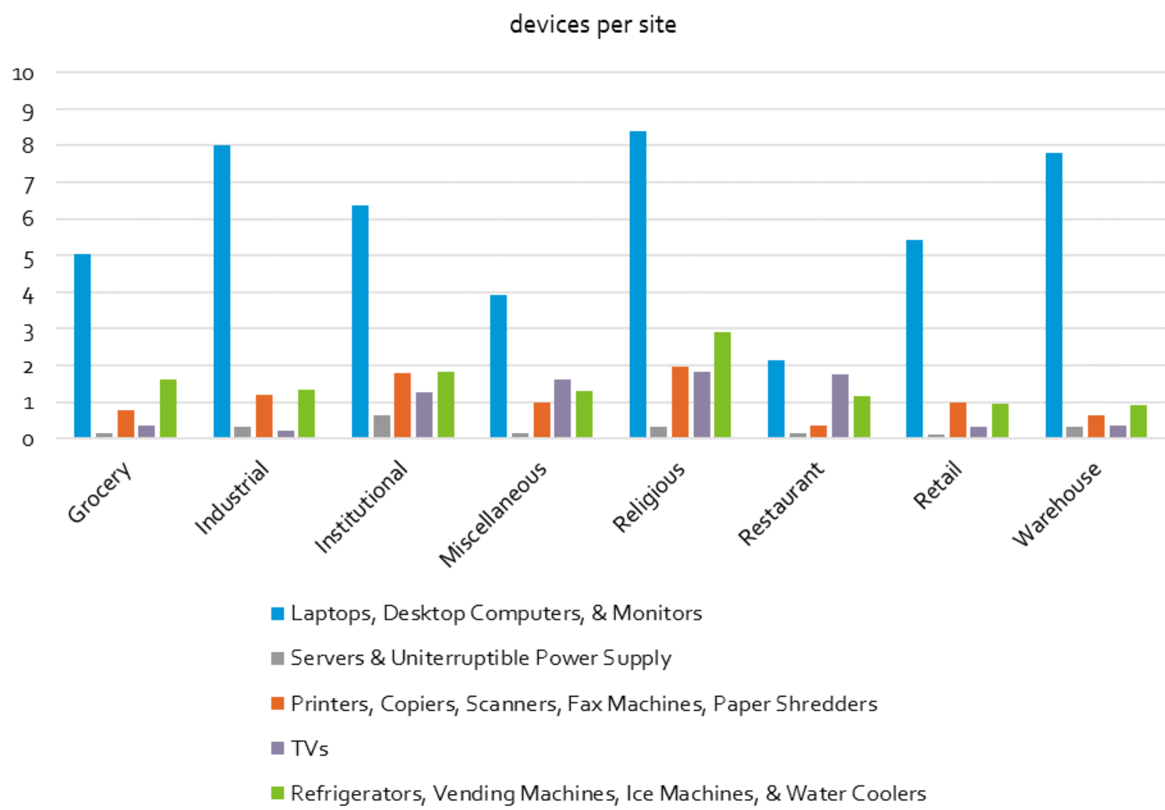


Table 42 reports the percentage of devices that were ENERGY STAR certified. ENERGY STAR certifications are often difficult to observe in practice, so the magnitudes in Table 42 are likely underestimated. The relative magnitudes across categories may yield more information, though these should also be interpreted with caution. As a point of comparison, Table 42 also shows the US Environmental Protection Agency's (EPA) estimated market share of ENERGY STAR devices among 2022 shipments.[8] Plug load types not listed in the 2022 shipment and market share report have a value of Not Available (N/A). All plug load types with the exception of televisions have a higher ENERGY STAR percentage in the 2022 EPA shipment data than in the on-site data collection. The television result is likely due to the fact that the ENERGY STAR specification for televisions changed late in 2022.

[8] Environment Protection Agency ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2022 Summary Weblink

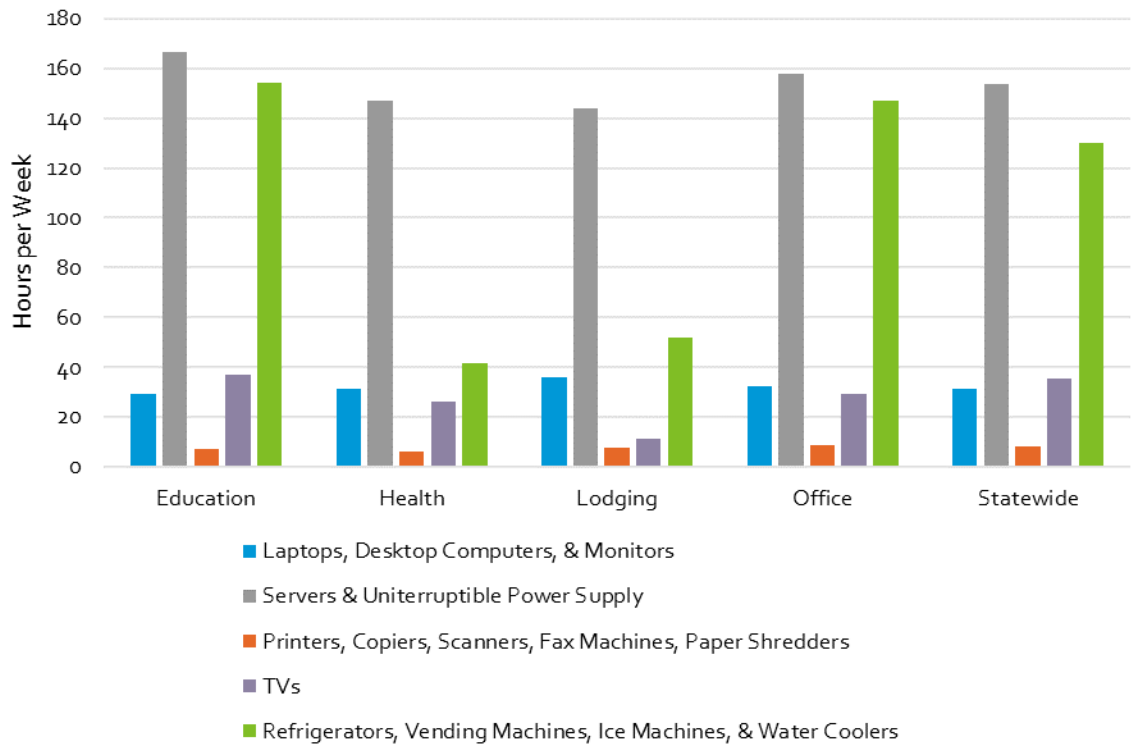
Table 42: Percent of Plug Load Devices with ENERGY STAR Certification

Plug Load Type	% ENERGY STAR (On-Sites)	% ENERGY STAR (2022 Shipment Data)
All-in-one Office Imaging Units (n=564)	12.1	N/A
Ice Makers (n=196)	4.6	28
Laptops (n=4,046)	4.5	71
Monitors (n=8,652)	10.8	65
Non-Refrigerated Vending Machines (n=90)	2.2	27
Paper Shredders (n=267)	0.0	N/A
Personal Computers (n=4,435)	14.7	55
Refrigerated Vending Machines (n=201)	20.6	27
Residential Style Refrigerators (n=2,331)	18.6	66
Servers (n=531)	0.0	19
Standalone Fax Machines (n=87)	0.0	N/A
Standalone Photocopiers (n=58)	51.7	N/A
Standalone Printers (n=1,058)	9.9	N/A
Standalone Scanners (n=67)	1.5	N/A
Televisions (n=3,142)	10.9	1%
Uninterruptable Power Supply (n=65)	0.0	N/A
Water Coolers (n=272)	0.4	39%

While device counts are informative, many sit idle for long hours, especially in the Lodging segment. Wherever possible, on-site technicians collected data from managers on weekly hours of use. These self-reported hours of use are shown by category in Figure 165. Hours are reported as average weekly hours of use (out of a maximum 168). Figure 165 shows only four individual segments—the four categories with largest plug loads. The values in other segments were very similar to the statewide average, which is included in the figure.

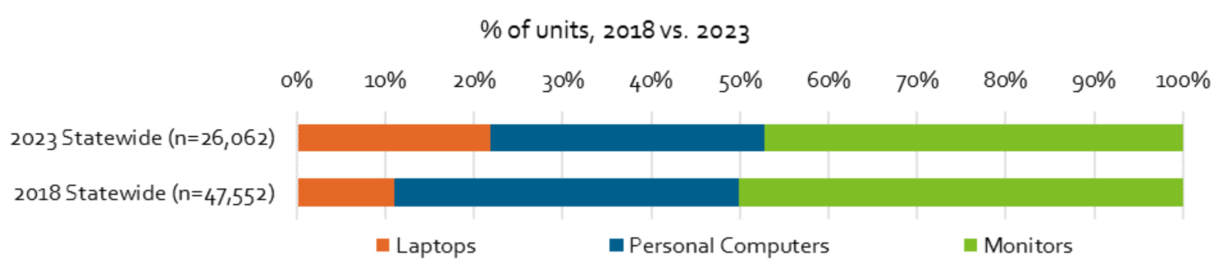
Overall, Figure 165 paints a very different picture of plug loads than Figure 163 or Figure 164. While fewer in number, servers and uninterruptible power supplies run nearly continuously. They likely require much more power when running as well. Refrigerated devices and vending machines are similar, with long runtimes and much more power required per device. Refrigerators in the Health and Lodging sectors are sometimes powered off when not in use, and televisions in the Lodging segment, while common, are used infrequently.

Figure 165: Plug Load Hours of Use by Category (Hours per Week)



It is difficult to discern many trends in the types of devices used over time, as many remain in common use, though possibly with improved technologies, such as televisions. Fax machines decreased in prevalence but were already fairly uncommon in 2018 relative to other devices. Among computers, however, laptops were much more common in 2023, with personal computers and monitors consequently losing shares in that category.

Figure 166: Share of Plug Load Devices in Computer Category, 2018 and 2023



12 GENERAL BUILDING CHARACTERISTICS

12.1 OVERVIEW

In addition to end-use equipment, the SWE collected data on the buildings themselves. This section reports findings on Pennsylvania C&I buildings' size, age, occupancy, and windows, each of which can impact energy use patterns. Building information is further utilized for weights and calculations in other sections of the report, such as EUI.

While we gathered information on aspects of the building that were readily accessible, the scope of the data collection did not include inspecting the interior of walls or other more in-depth engineering tests. Insulation R-values were calculated for some sites, but only when the information was observable or made available by building managers. As such, R-values are not reported here since the final sample size was relatively small.

12.2 BUILDING SIZE

Figure 167 shows each segment's average square footage of buildings per site. For sites with multiple buildings, the square footage totaled across all buildings at the site. Sites in the Education, Lodging, and Warehouse segments were the largest by total square feet, while Restaurant sites were the smallest. Statewide, C&I sites were just over 16,000 sq. ft. on average.

Figure 167: Total Square Footage of Buildings per C&I Site by Segment

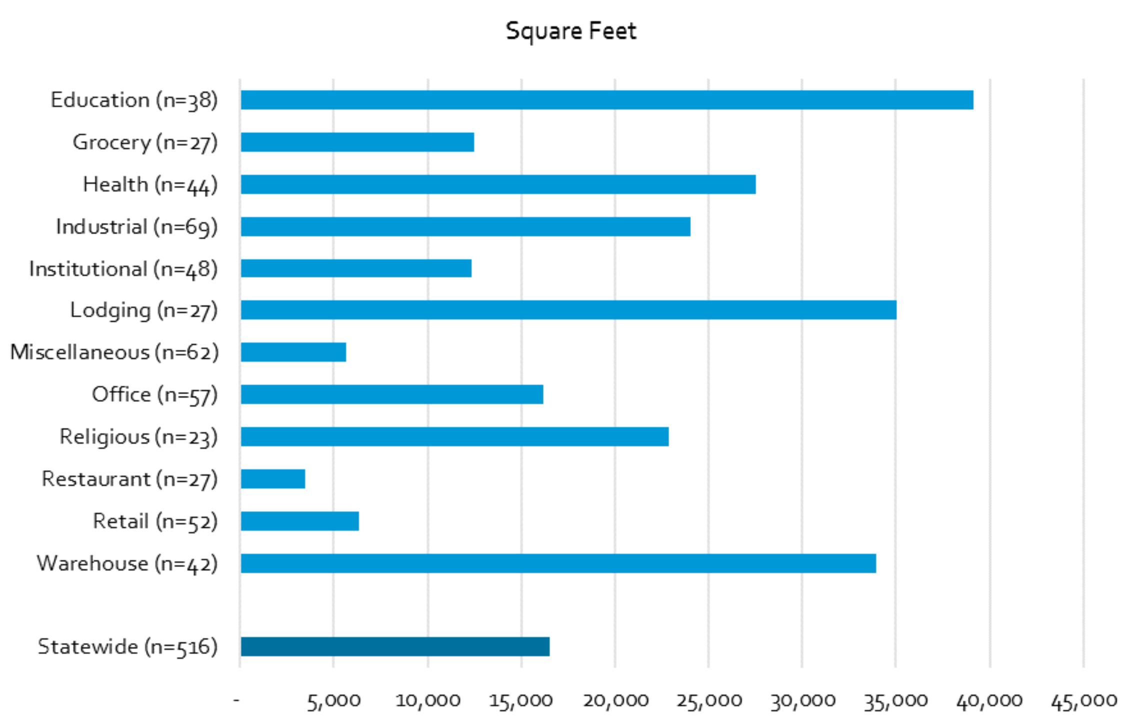
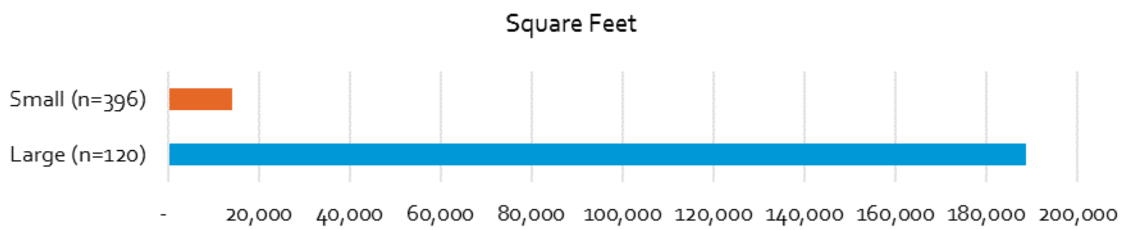


Figure 168 shows average building square footage by sector. While Small and Large C&I sites are differentiated by the service voltage level, the distinction holds for building size as well. Small C&I buildings are not necessarily small at over 14,000 square feet on average, but the Large C&I sites averaged 190,000 square feet of buildings per site. Note that there are far more Small C&I sites in Pennsylvania than Large C&I, so the Small C&I sites weigh heavily in the statewide average above.

Figure 168: Total Square Footage of Buildings per C&I Site by Sector



The distribution of building sizes can be seen from another perspective in Figure 169. The horizontal axis orders each site in the sample from least to greatest square footage. The vertical axis shows the cumulative total square feet in the C&I sample. The smallest 90% of buildings (plotted on the horizontal axis from 0 to 90) only account for 30% of square footage in the sample, while the largest 10% of buildings make up 70% of square footage in the sample. The largest sites are extremely large, such as industrial sites with multiple buildings, hospitals, hotels, office buildings and school campuses.

Figure 169: Distribution of C&I Square Footage in Baseline Study Sample

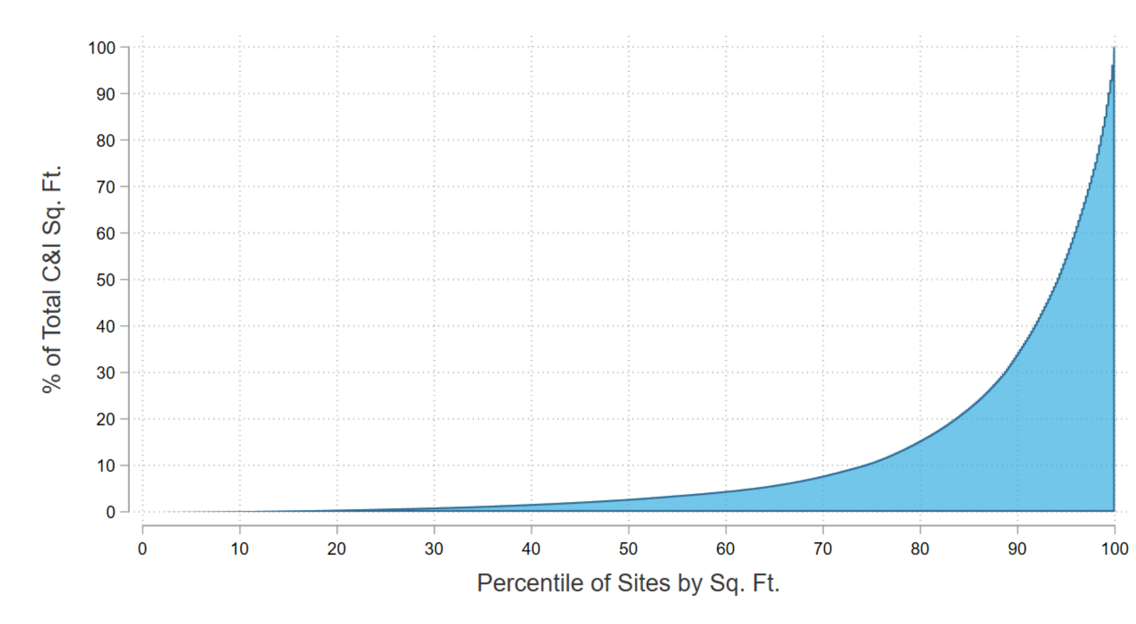


Figure 170 shows the distribution of building sizes by segment and sector. Restaurant, Retail, and Grocery had the most sites under 5,000 square feet, with the smaller Grocery sites coming from gas stations and convenience stores. These smaller Restaurant and Grocery sites can still be quite energy-intense, however. Religious and Warehouse sites were the most likely to fall between 5,000 and 25,000 square feet. Large C&I sites were not only large on average, but over half of the sites had greater than 100,000 square feet.

Figure 170: Distribution of Building Sizes by Segment and Sector

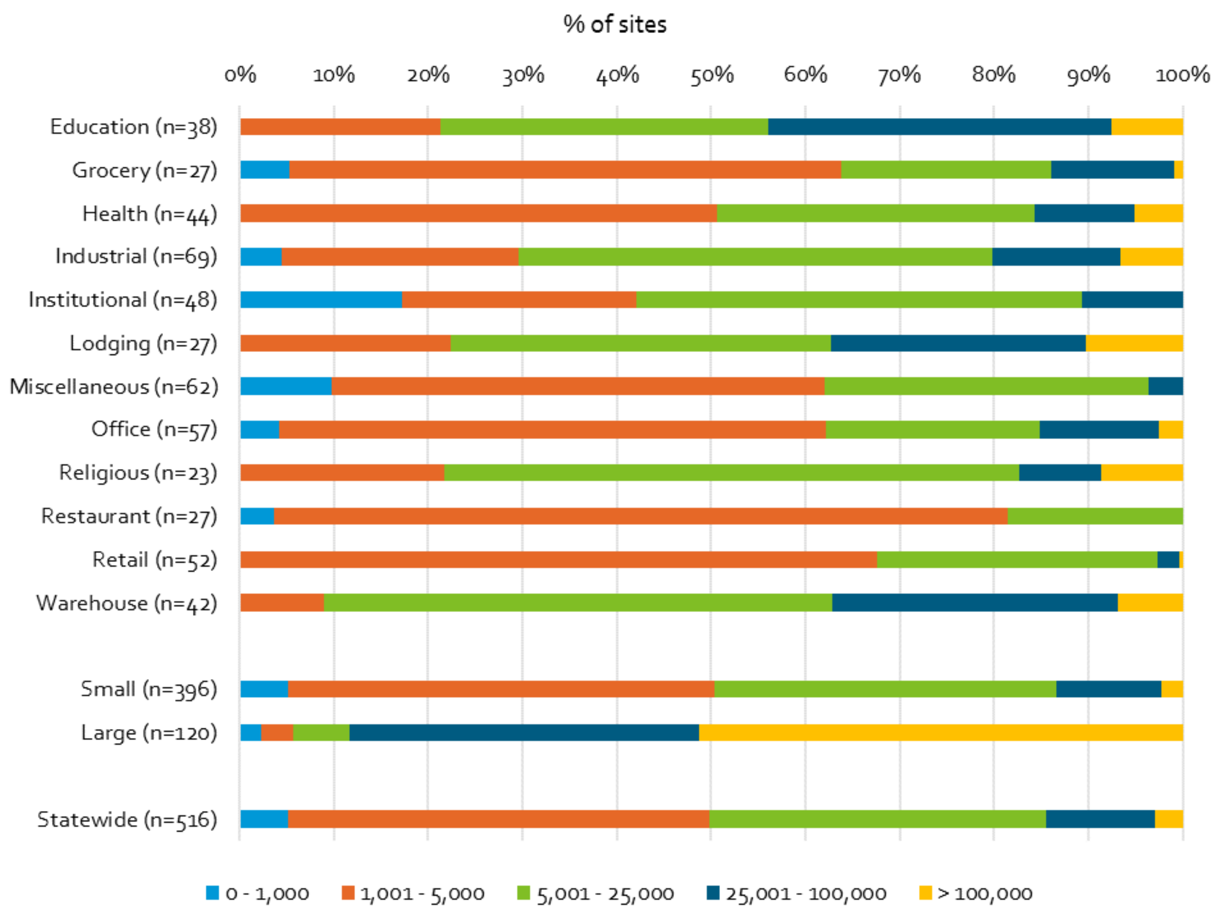


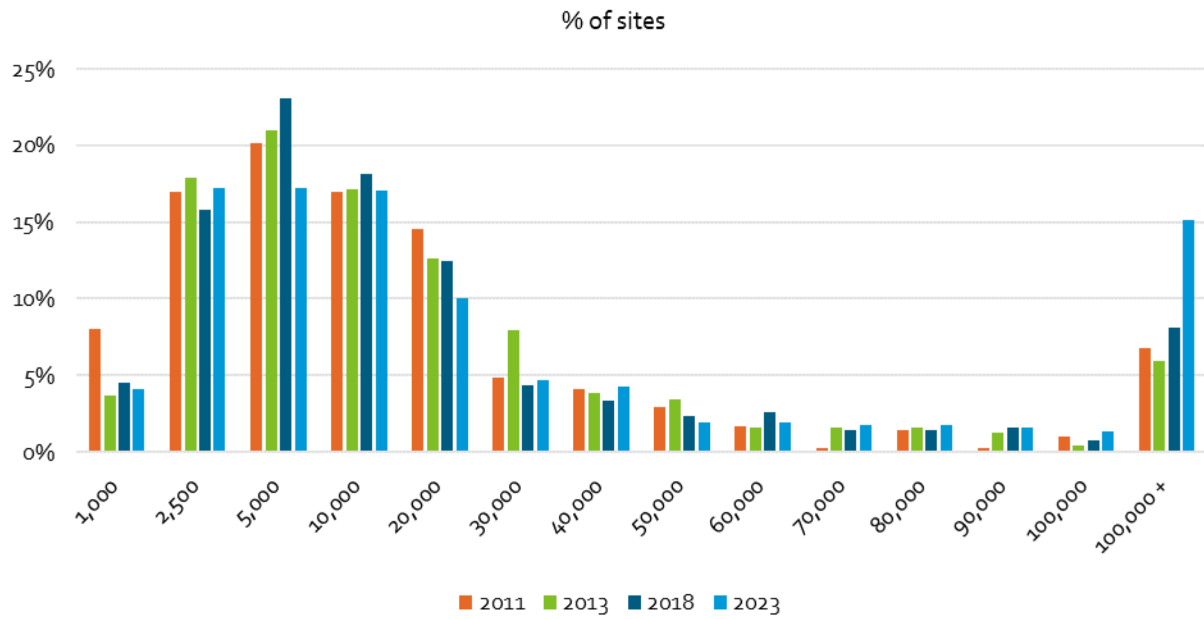
Table 43 gives detail on other aspects of building size, including average number of floors and the average occupancy at given times. Lodging sites had the most floors on average, while Education sites had by far the highest occupancy during normal hours. Buildings in PECO territory were also slightly larger, with more floors and more occupants as well.

Table 43: Average Building Size Characteristics by Sector, Segment, and EDC

Category	Sq. Ft.	Floors	Occupancy (bus. hrs.)	Occupancy (after hrs.)
Education (n=38)	39,131	1.5	183	6
Grocery (n=27)	12,472	1.0	45	3
Health (n=44)	27,541	1.7	49	15
Industrial (n=69)	24,003	1.1	10	2
Institutional (n=48)	12,327	1.4	22	1
Lodging (n=27)	35,025	2.2	58	25
Miscellaneous (n=62)	5,682	1.3	16	1
Office (n=57)	16,155	1.8	22	2
Religious (n=23)	22,892	1.8	74	1
Restaurant (n=27)	3,453	1.1	28	2
Retail (n=52)	6,372	1.1	8	0
Warehouse (n=42)	33,957	1.2	18	1
Small (n=396)	14,119	1.4	23	2
Large (n=120)	188,837	3.2	338	58
PECO (n=70)	22,952	2.0	42	7
PPL (n=75)	15,824	1.4	34	1
Duquesne (n=71)	12,652	1.5	34	1
FE: Met-Ed (n=73)	19,020	1.4	24	3
FE: Penelec (n=73)	22,567	1.2	32	2
FE: Penn Power (n=81)	14,047	1.4	19	3
FE: West Penn (n=73)	12,233	1.3	14	1
Statewide (n=516)	16,539	1.4	27	2

Figure 171 compares buildings sizes across the four Non-Residential Baseline Studies to date. We attribute the increased prevalence of buildings over 100,000 square to enhanced recruiting efforts rather than a trend in building sizes in the Commonwealth. Recruiting efforts for this study included extensive coordination with EDC key account managers to schedule site visits with large managed accounts.

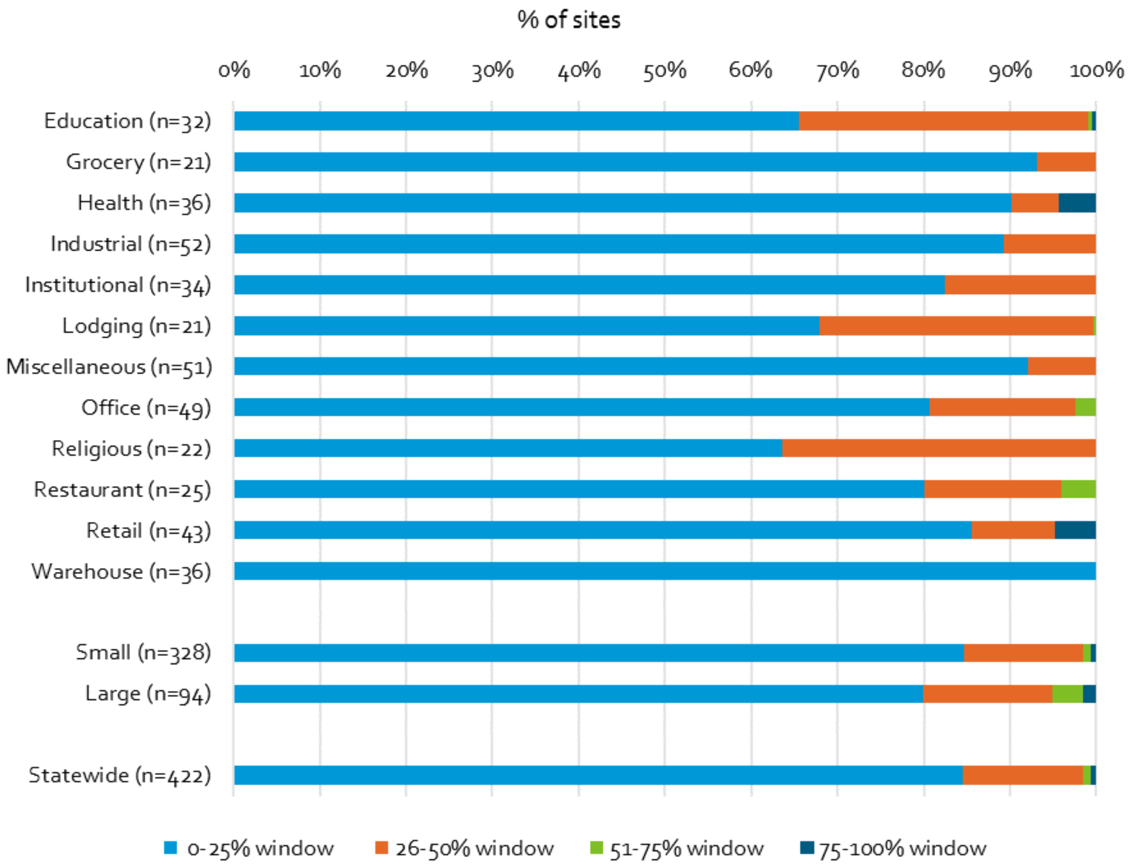
Figure 171: Comparison of Building Sizes Surveyed



12.3 WINDOWS

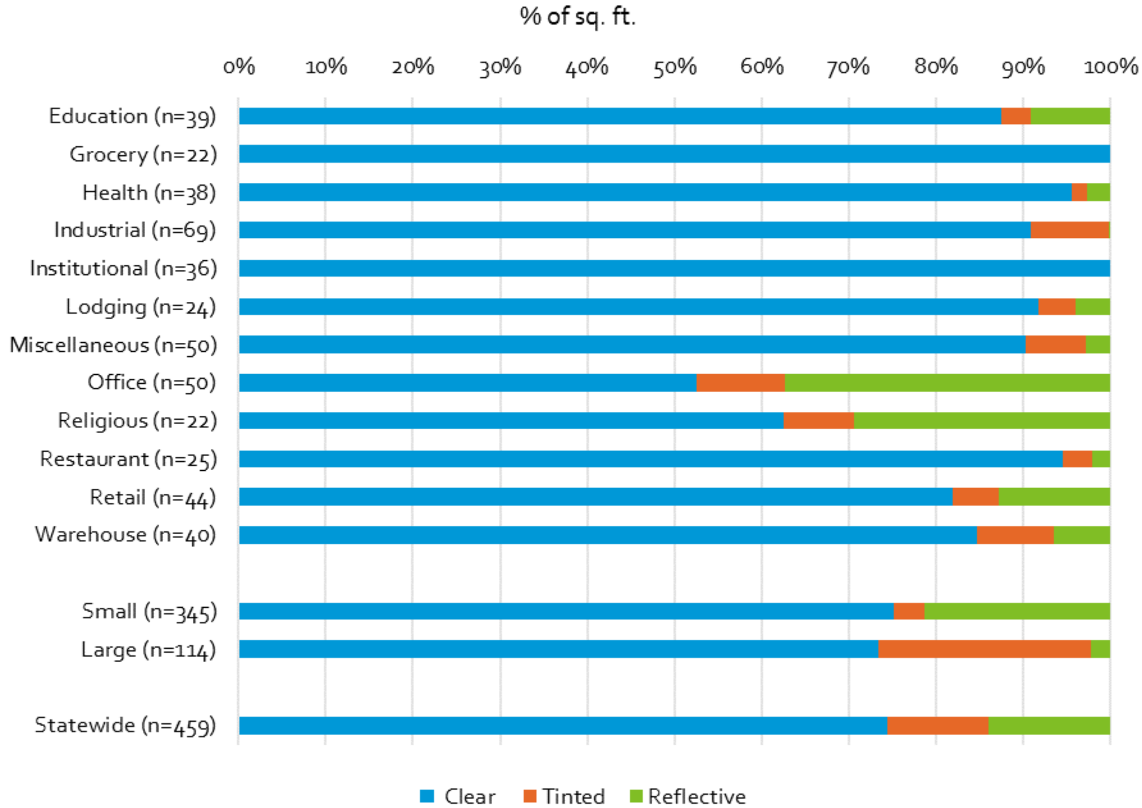
Figure 172 shows the percentage of exterior walls that are windows in four bins. Window space makes up less than 25% of buildings' exterior walls across all segments. The Education, Lodging, and Religious segments had relatively large shares of exterior windows, but only about one third of their buildings had 26-50% window space on exterior walls. A few hospitals and retail stores had over 75% windows on their exterior, but this was very rare statewide.

Figure 172: Windows as a Percentage of Walls



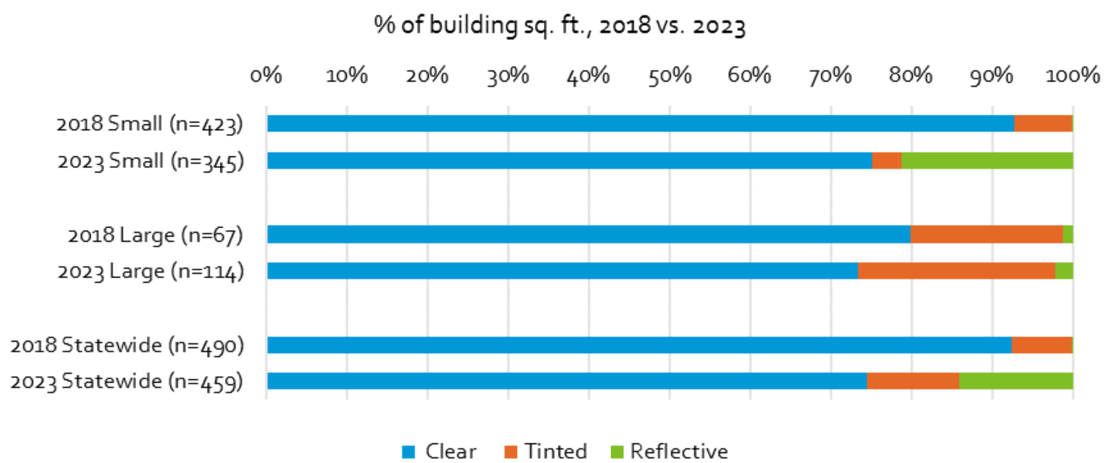
Windows on commercial buildings often have only clear glazing, but they can instead be tinted or reflective to lower energy consumption. Figure 173 shows these three glazing types as a fraction of total building square footage. 75% of the windows were clear, with roughly equal shares of tinted and reflective windows in the remaining share. Large C&I buildings had a significant share of tinted windows, while Small C&I buildings were more likely to have reflective windows.

Figure 173: Window Glazing Types



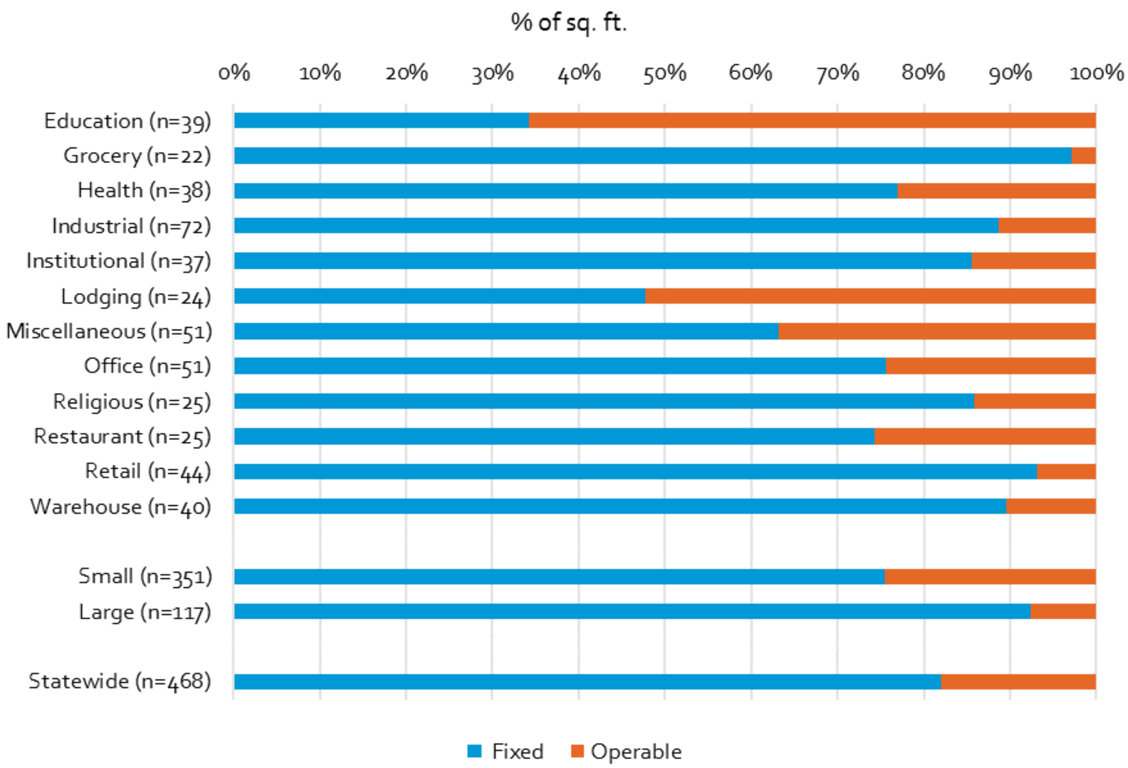
Though most windows at C&I facilities are clear, this percentage was lower in 2023 than in the previous baseline study. Figure 174 shows shares of window glazing types for both studies, with clear windows less common in 2023 in both the Large and Small C&I sectors. Statewide, 92% of facilities had clear windows in 2018, but only 75% in 2023.

Figure 174: Window Glazing Types, 2018 and 2023



The distribution of fixed and operable window types is shown in Figure 175. Over 80% of the windows were fixed, but most windows in the Education and Lodging segments were operable. Operable windows were mainly confined to Small C&I sector sites, with fixed windows making up over 90% of the stock at Large C&I facilities.

Figure 175: Distribution of Window Type



12.4 BUILDING AGE

The SWE recorded buildings' year of construction since building age often affects energy usage. Figure 176 shows the distribution of building age by 20-year bins for each segment and sector. For sites with multiple buildings, the ages were averaged across all buildings at the site.

Most C&I buildings were built after 1960, with roughly 20% built in each of the 20-year windows from 1961-1980, 1981-2000, and 2000 on. Grocery sites were the newest. The Industrial segment was split: many manufacturers have opted for new buildings or green-field sites, but several older spaces were also in use.

Many older buildings in Pennsylvania have been preserved and are still used by C&I customers: over 10% of the C&I facilities statewide are housed in 19^{th} century buildings, including repurposed industrial spaces, old homes, municipal buildings, and churches. 17% of facilities were built from 1901-1940, and another 11% were built from 1941-1960.

Figure 176: Distribution of Building Age

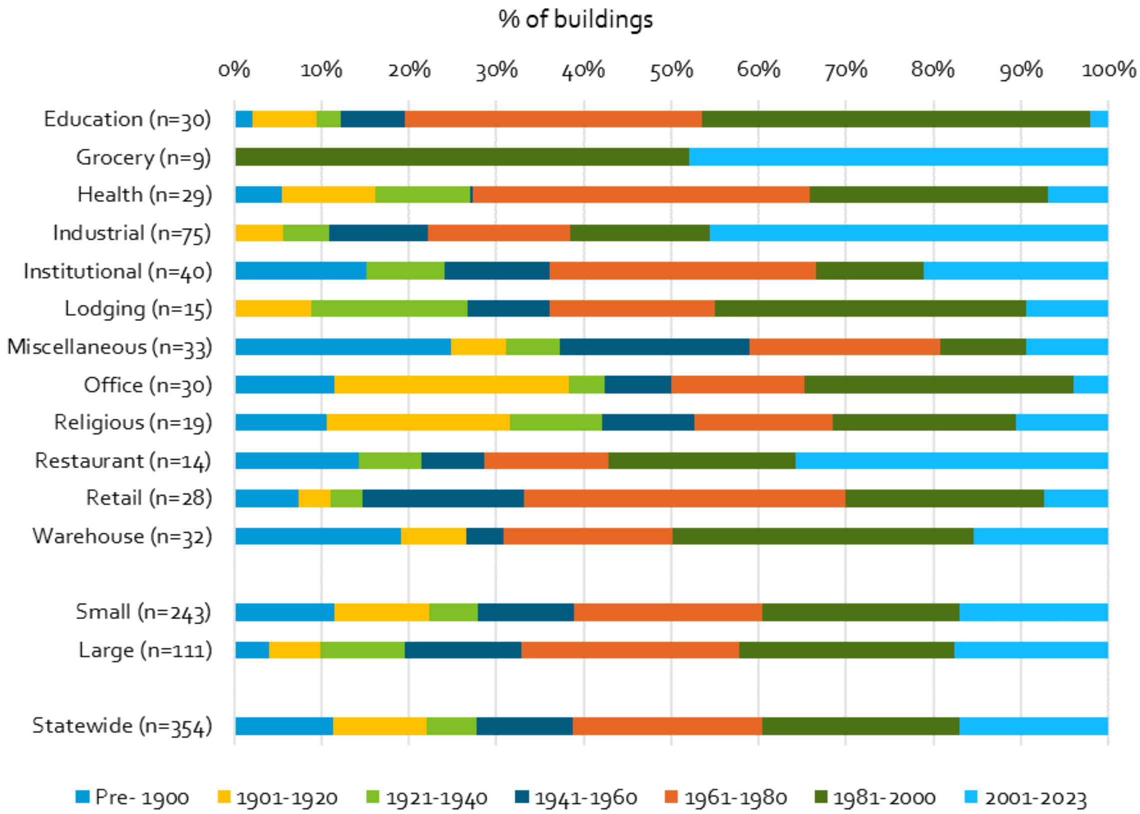
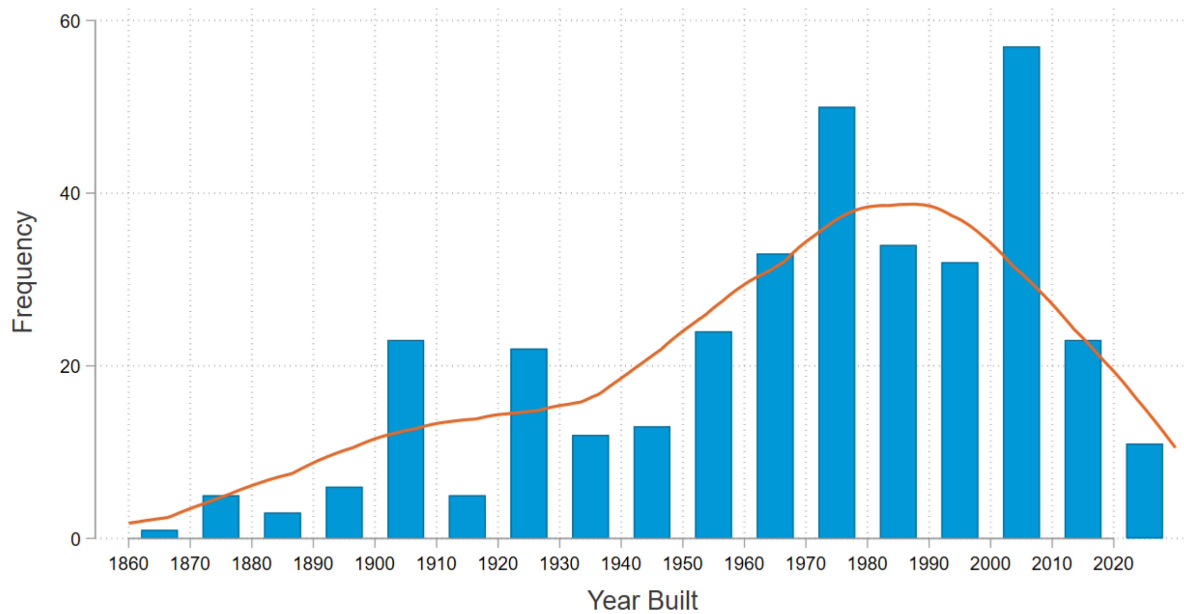


Figure 177 repeats the statewide distribution of building age, plotting the count of buildings built in each decade since 1860. The orange line shows a smoothed trend of construction by decade while the blue bars show the building counts.

Figure 177: C&I Buildings Constructed by Decade, 1860-2023



13 ADOPTION RESEARCH

13.1 METHODOLOGY

EDC customers were surveyed to inform key research questions related to EE&C program awareness and their motivations, barriers, and likelihood of adoption. The survey was fielded in two phases to the same set of randomly sampled C&I businesses drawn for the field study recruiting. In the first phase, the site visit screening survey invited all self-identified decision makers to complete these additional questions regardless of whether they were interested in participating in a site visit. After the site visits were completed a second phase follow-up survey was sent to all customers with emails who had not completed the survey previously. This second effort roughly doubled the number of completed surveys to 552.

Table 44 tabulates the number of respondents by study segment as well as the total statewide customer counts within each segment. Some segments with similar end use or economic considerations were combined to ensure sufficient sample for each segment. These segments were used for weighting as well as for analysis and reporting. Table 44 also summarizes the simple population percentage case weights that were applied to adjust the respondent sample to match segment shares in the full population.

Table 44: Population, Respondent and Weight by Segment

Segment(s)	Population Count	Sample Count	Weight
Education, Institutional	63,608	74	1.10
Grocery, Lodging, Restaurant	43,408	68	0.82
Health	22,091	39	0.73
Industrial, Warehouse	98,281	117	1.08
Miscellaneous	82,121	76	1.39
Office	133,486	71	2.41
Religious	21,686	49	0.57
Retail	48,819	58	1.08
Total	**513,500**	**552**	**-**

The survey included direct questions on upgrade-related topics, as well as a choice experiment that presented the respondent possible EE&C program design configurations. A choice experiment, or conjoint, methodology isolates and quantifies the influence of individual factors on a decision. Conjoint studies are a commonly used product-design tool that enables researchers to model uptake likelihood for each combination of factors tested, without having to test each combination directly. A conjoint experiment is the gold standard for product design and is directly applicable to EE&C program design.

To conduct a conjoint experiment, the product or program must be distilled into a set of attributes, each with mutually exclusive levels. Each survey respondent is shown a series of choice sets (one per screen) with multiple design configurations (usually with one level defined for each attribute) simulating a real-world choice the respondent might be faced with. Logistic regression coefficients can be estimated across multiple choice tasks to quantify the respondent's preference for each attribute level, all else equal. These coefficients form a choice model that can be estimated for each respondent. Using results from all participants, the conjoint produces data for dozens of program feature combinations that can identify the optimal design for defined goals, e.g., to maximize uptake or minimize acquisition cost.

For this conjoint experiment, the goal was to identify relative preferences for different program design parameters. This will help to inform adoption curves in the Phase V Energy Efficiency Market Potential Study after survey results are calibrated to real-world program participation data. The choice experiment tested six program design attributes: payback period, installation, equipment performance, sustainability certification, access to financing, and equipment discount or rebate. Importantly, choice experiment questions were framed agnostic of specific end uses, given the diversity in end use applicability to various segments and to enable pooling of preference data across end uses and segments. This design allows for study conclusions to be applied across equipment types. Table 45 shows the attributes and levels tested in the study.

Table 45: Choice Experiment Attributes and Levels Tested

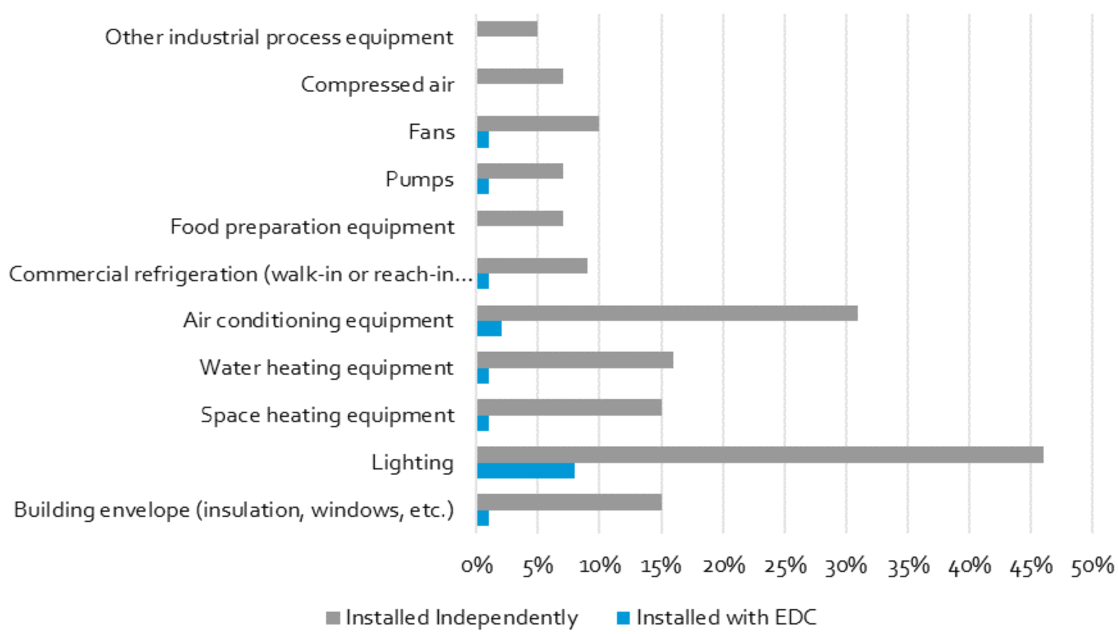
Attribute	Level
Payback Period – After Discount	1 year
	2 years
	5 years
Installation	during business hours
	outside of business hours
Improved equipment performance	No
	Yes
Sustainability certification	No
	Yes
Access to financing	No
	Yes
Equipment discount or rebate	None
	25% of project costs
	50% of project costs
	75% of project costs

13.2 ACT 129 MOTIVATION, BARRIERS, AWARENESS, PARTICIPATION, AND UPGRADE LIKELIHOOD

Act 129 EE&C programs provide financial incentives to customers who install energy saving upgrades. However, most non-residential customers do not participate in programs and there may be a variety of reasons for participating or not participating in programs. Further, installation of energy saving equipment may vary by end use. Better understanding these considerations can inform improvements to future program design to increase participation.

The first set of survey questions asked respondents for which end uses they had installed energy-saving equipment, either independently or through an Act 129 program implemented by their EDC. Figure 178 summarizes the percentage of respondents that reported installing energy-saving upgrades for each end use. Respondents were asked in a preceding question if specialty equipment, including commercial refrigeration, food preparation, pumps, fans, compressed air, and industrial process, was present at their location. Respondents were only asked the installation question for specialty equipment they indicated was present at their location. However, Figure 178 includes all respondents in the denominator to show the rate of installs across all respondents. Independent installations are a missed opportunity, to the extent these installations include code minimum or otherwise less efficient equipment than what is installed through Act 129 programs. Between 5% and 15% of respondents reported independently installing equipment upgrades for most end uses, no more than 2% of respondents reported installing upgrades through an Act 129 program, for all end uses other than lighting. Unsurprisingly, reported installation rates for lighting equipment were much higher than for any end use, whether independently (46%) or through an Act 129 program (8%).

Figure 178: Installation of Energy Saving Equipment by End Use[9,10]

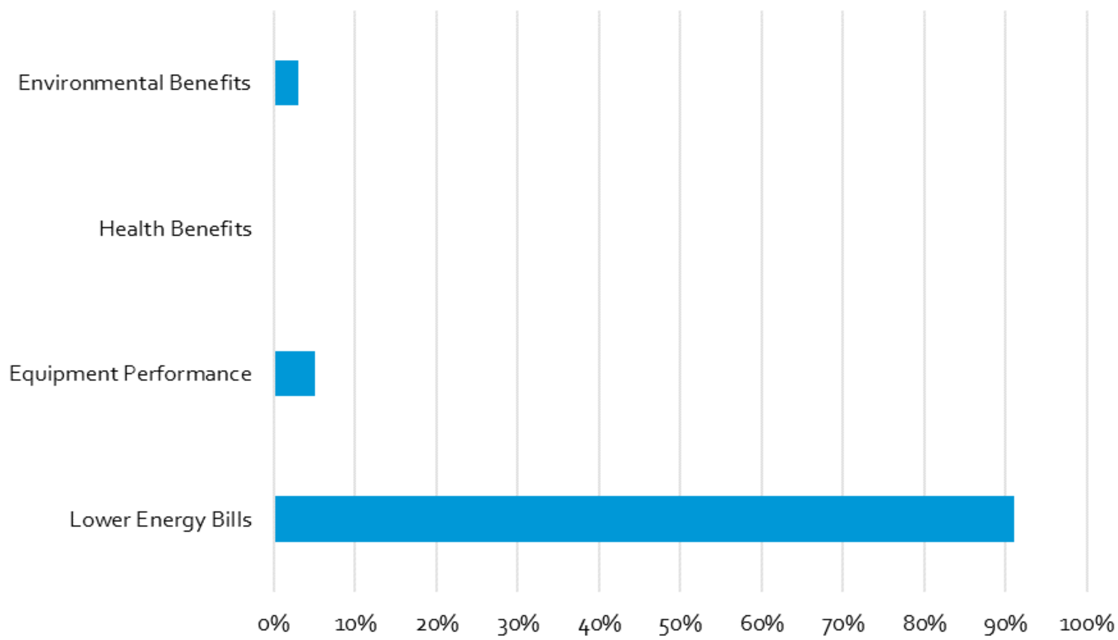


The next set of survey questions was designed to elucidate the motivations behind upgrade decisions as well as the barriers to program participation. Respondents who reported participating in an Act 129

[9] Installed independently: "Has your business recently (in the last five years) installed any of the following energy saving equipment that was NOT associated with [EDC] programs?"
[10] Installed with EDC: "Which of the following energy saving equipment did your business install in association with <EDC> programs?"

program for at least one end use were asked to select their top reason for participating. Figure 179 summarizes the results, showing that lowering energy bills is the top motivator for 91% of respondents. Equipment performance and environmental benefits were the top motivation for 5% or fewer of respondents.

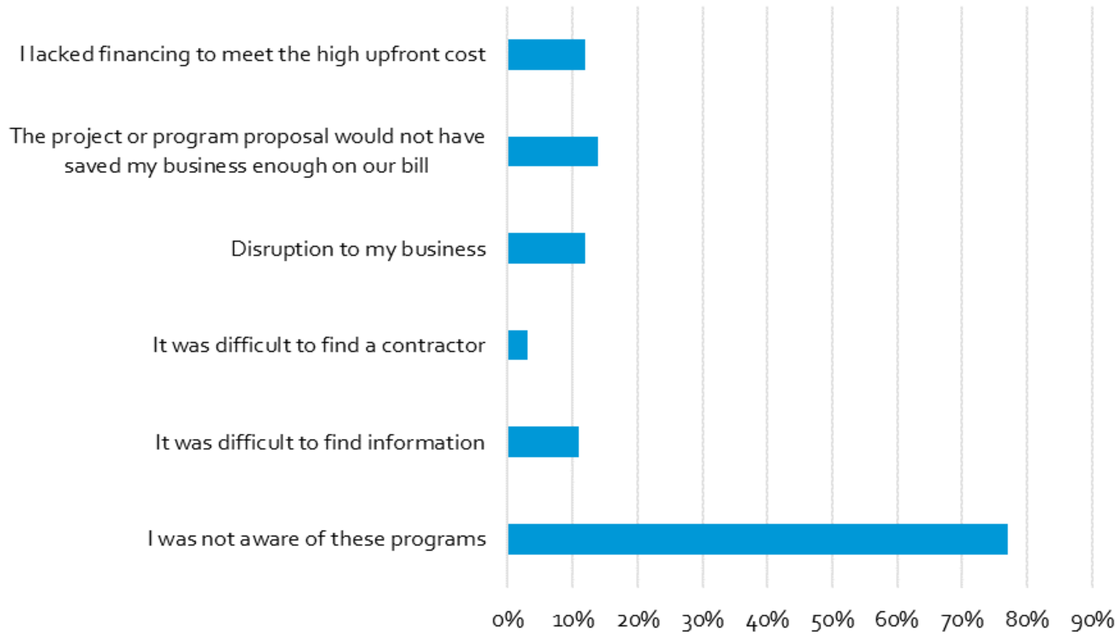
Figure 179: Motivations for Energy Efficiency[11]



Respondents who reported not participating in Act 129 programs were asked to list their reasons for not participating. Figure 180 shows the percentage of respondents that selected each reason. Notably, awareness was by far the most common reason, selected by 77% of participants who hadn't participated. All other reasons, which included both financial and program process barriers, were selected by fewer than 15% of these respondents. This indicates that program awareness is likely the largest barrier and allocating marketing budget to address awareness might reduce this barrier. Among respondents who were aware of Act 129 programs but did not participate, insufficient savings was the most common reason, closely followed by lack of financing and the expected business disruption from equipment installation.

[11] "Which of the following best describes your reason for installing energy saving equipment associated with <EDC> programs?"

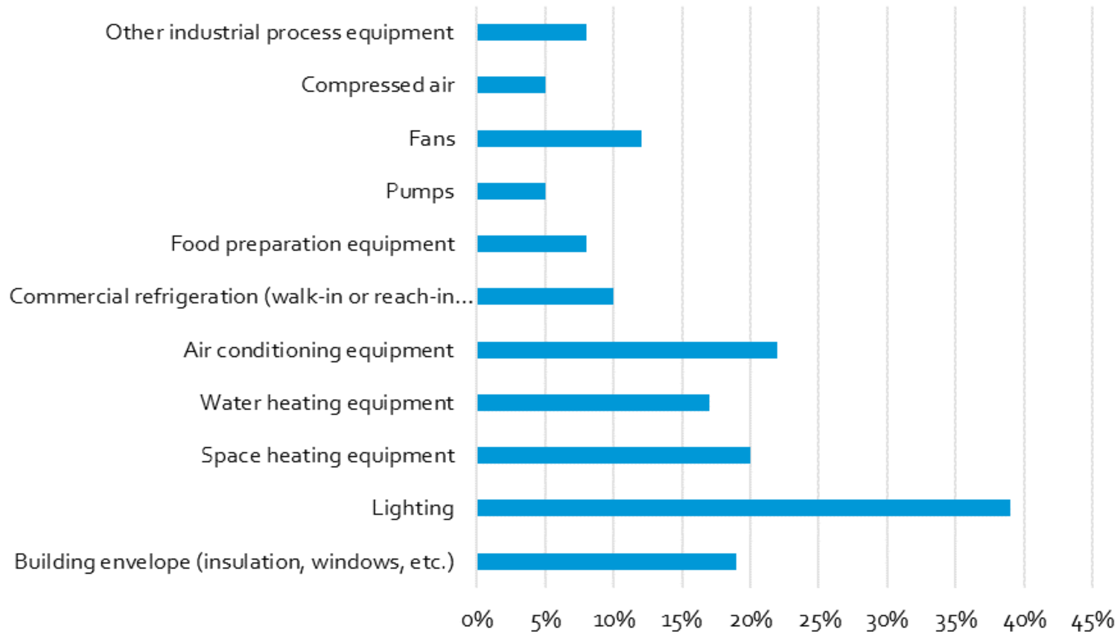
Figure 180: Barriers to Efficient Purchasing Decisions[12]



Finally, respondents were asked about their plans for upgrading their equipment. Figure 181 shows the percentage of respondents who expect to upgrade each type of equipment in the next three years. This question was framed to exclude replacements due to equipment burnout. As with the questions on past installations, the figure shows the percentage across all respondents, regardless of whether the respondent reported having the end use. Also as with the retrospective questions, lighting is by far the most common end use, with 39% of respondents expecting to upgrade their lighting in the next three years. This is followed by air conditioning, heating, and space heating equipment which between 19% and 22% of respondents expect to upgrade.

[12] "Which of the following best describes your reason(s) for not participating in <EDC> programs that help customers like you reduce your energy usage? Select all that apply."

Figure 181: Upgrades Expected in the Next Three Years[13]



The questions described above can be summarized holistically as an upgrade program conversion funnel with the following stages:

1. **Retrospective installations**: Has your business recently (in the last five years) installed any of the energy saving equipment that was NOT associated with [EDC] programs?
2. **Prospective installations**: Are you considering upgrading any equipment in the next three years to improve efficiency or performance?
3. **Program awareness**: Has your business participated in Act 129 programs in the past five years OR are you aware of Act 129 programs? Includes respondents who had either participated in the past or that did not state awareness as a barrier to participation.
4. **Program participation**: Have you participated in the program in the last five years?

Table 46 shows the share of respondents overall represented under each step in this upgrade conversion funnel. The table also includes results by segment, EDC, sector, and statewide to give more detailed insight on how different areas compare for these program awareness questions. Most notably, while past and planned installations are somewhat higher for Large C&I respondents than for Small C&I, program awareness and past participation are much higher. 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

[13] "Are you considering upgrading the following equipment in the next three years to improve efficiency or performance?"

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 46: Upgrade Conversion Funnel Summary

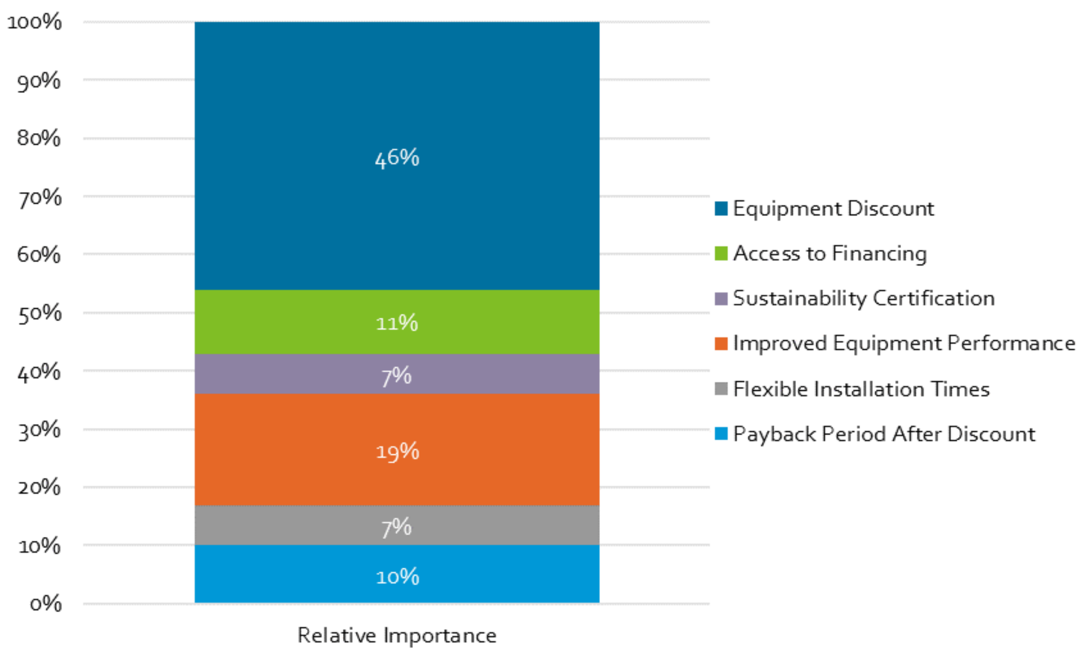
Segment	Past Independent Installation	Plans for Future Installation	Program Awareness	Past Program Participation
Education, Institutional (n=74)	65%	51%	35%	19%
Grocery, Lodging, Restaurant (n=68)	75%	59%	25%	9%
Health (n=39)	64%	59%	41%	18%
Industrial, Warehouse (n=117)	81%	68%	38%	17%
Miscellaneous (n=76)	75%	62%	21%	4%
Office (n=71)	65%	54%	37%	6%
Religious (n=49)	71%	67%	16%	8%
Retail (n=58)	71%	67%	14%	5%
EDC				
PECO (n=59)	77%	59%	50%	24%
PPL (n=99)	72%	53%	38%	14%
Duquesne (n=78)	75%	67%	35%	9%
FE: Met-Ed (n=68)	66%	62%	22%	6%
FE: Penelec (n=98)	72%	60%	23%	7%
FE: Penn Power (n=73)	67%	59%	29%	8%
FE: West Penn Power (n=77)	68%	61%	16%	4%
Sector				
Small (n=497)	70%	58%	27%	7%
Large (n=55)	85%	75%	62%	33%
Statewide (n=552)	**71%**	**60%**	**30%**	**10%**

13.3 WILLINGNESS TO PAY

The choice experiment section of the survey, described above, was used to quantify the relative effect of the attributes tested on respondent likelihood to prefer, or not prefer, an EE&C program design in the survey setting. Attribute preferences provide a measure of how much each attribute influenced respondent choices, given the levels tested in the survey. Relative importance values for each attribute sum to 100% since they represent components of a single decision. Figure 182 summarizes the relative importance of each attribute in the study. Because there are six attributes, the average importance is about 17%; attributes with greater importance have above average importance and vice versa.

Equipment discount was by far the most influential attribute, influencing 46% of the participation decision. All other attributes were close to average importance (improved equipment performance), or far below average performance. However, finance related attributes are interrelated: access to financing, payback period after discount, along with rebate or discount magnitude comprise 67% of the participation decision. All remaining attributes influence the remaining third of the decision: equipment performance, sustainability certification and installation time.

Figure 182: Choice Experiment Attributes and Relative Importance



A key output of the conjoint survey analysis is the relative impact of research attributes on energy efficiency program participation preferences. Figure 183 shows estimated design preferences for all combinations of the attributes tested as part of the survey. For analysis purposes, we define a baseline offering (shaded) to resemble a typical existing program design as closely as possible within the constraints of the model. This baseline serves as an anchor point to interpret the remaining results. The participation likelihood in each cell corresponds to a program offer consisting of that specific attribute level and the baseline levels for all other attributes. This allows differences between cells to be interpreted as the marginal effect of each level on the likelihood of participation holding all other attributes constant.

Figure 183: Relative Impact of Research Attributes on EE Program Participation Preferences

Attribute	Level	Base Level	Pref Share	% Change Over Base
Payback Period - after discount	1 year		34%	6%
	2 years	✔	32%	0%
	5 years		24%	-26%
Installation	during business hours	✔	32%	0%
	outside of business hours		31%	-3%
Performance	No	✔	32%	0%
	Yes		41%	28%
Certification	No	✔	32%	0%
	Yes		34%	6%
Financing	No	✔	32%	0%
	Yes		35%	11%
Discount or rebate	None		17%	-46%
	25% of project costs	✔	32%	0%
	50% of project costs		43%	34%
	75% of project costs		49%	54%

Within the context of the survey, 32% of respondents said that they would participate in the baseline program if it was made available to them. Several caveats are necessary for this important result. The most important caveat is that the participation likelihood suffers from "hypothetical bias" that often exists with stated preference surveys since there is often a difference between what survey respondents say they will do and what they will actually do. Hypothetical bias is generally positive, meaning that survey respondents would be prone to overstate their true likelihood of participating in energy efficiency program. As shown in Table 46, 30% of respondents reported being aware of Act 129 programs and 10% reported participating in the past five years. It follows that a third of respondents who report being aware of these programs also report participating. In the survey setting all respondents are made aware of the programs to some degree so it is notable that this real-world participation rate is similar to the preference share for the baseline program design within the context of the survey.

Despite the limitations of quantifying absolute participation likelihood, changes in participation likelihoods can be analyzed to estimate the relative influence of different program attributes. Figure 183 shows that increasing the payback period to five years could reduce enrollment likelihood—compared to the likelihood of enrolling with two-year payback—by about a quarter (26%), while shortening payback period to one year could increase the likelihood of enrolling in an energy efficiency program by 6%.

The magnitude of discount or rebate has the most substantial impact on participation likelihood and the choice experiment results suggest that there is a minimum amount of discount needed to attract interest in energy efficient programs. There is a very large increase in preference between 0% and 25% of project costs that participation likelihood for a program with no rebate or discount might be about half compared to the likelihood of participating in a program with a 25% rebate or discount. In contrast, there is a substantial 34% preference increase for doubling of a rebate or discount (from 25% to 50% of project costs). Increasing the rebate, or discount, to 75% yields an even higher but diminishing relative increase in preference.

Among the other economic related attributes and levels, relative impacts on preference were relatively small except for the meaningful 26% decrease in uptake expected by increasing payback period (net of the rebate or discount) from two years to five years. Among the non-economic related attributes, only improved equipment performance is expected to meaningfully impact program participation. Specifically, measures that have improved equipment performance as well as energy savings are expected to yield 28% higher participation rates relative to measures that offer energy savings alone. This choice data will be calibrated to real-world program participation data to inform adoption curves in the Phase V Energy Efficiency Market Potential Study.

APPENDIX A – TABLE OF ACRONYMS

Table 47 lists each of the acronyms used in this report and the phrase it is used to represent.

Table 47: Table of Acronyms

Acronym	Phrase
AC	Air Conditioner
BTU	British Thermal Units
C&I	Commercial And Industrial
CBECS	Commercial Buildings Energy Consumption Survey
CEER	Combined Energy Efficiency Ratio
CFL	Compact Fluorescent Lamp
CFS	Commercial Food Savings
CHP	Combined Heat and Power
CO_2	Carbone Dioxide
COP	Coefficient of Performance
DHW	Domestic Hot Water
DLC	Duquesne Light Company
DSA	Demand Side Analytics, LLC
DX	Direct Expansion
ECM	Electronically Commutated Motors
EDC	Electric Distribution Company
EE&C	Energy Efficiency and Conservation
EER	Energy Efficient Ratio
EFLH	Equivalent Full Load Hours
EIA	U.S. Energy Information Administration
EMS	Energy Management System
EPA	U.S. Environmental Protection Agency
ERV	Energy Recovery Ventilators
EUI	Energy Use Intensity
FE	FirstEnergy
FE: ME, Met-Ed	Metropolitan Edison Company
FE: PN, Penelec	Pennsylvania Electric Company
FE: PP, Penn Power	Pennsylvania Power Company
FE: WPP, West Penn	West Penn Power Company

GPY	Gallons Per Year
GWh	Gigawatt Hour
HID	High-Intensity Discharge Lamp
HP	Horsepower
HRV	Heat Recovery Ventilators
HVAC	Heating, Ventilation, And Air Conditioning
IECC	International Energy Conservation Code
kBTU	Kilo British Thermal Units
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt Hour
LED	Light-Emitting Diode
LPD	Lighting Power Density
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
PPL	PPL Electric Utilities Corporation
PTAC	Packaged Terminal Air Conditioner
PUC	Public Utility Commission
RTU	Roof Top Unit
SEER	Seasonal Energy Efficiency Ratio
SIC	Standard Industrial Classification
SWE	Statewide Evaluation Team
TCU	Transportation, Communications, And Utilities
TEFC	Totally Enclosed Fan-Cooled
TRM	Technical Reference Manual
TV	Television
VFD	Variable Frequency Drive
VRF	Variable Refrigerant Flow
VSD	Variable Speed Drive