DNV·GL

FINAL REPORT

RI C&I Market Characterization Data Collection Study

National Grid

Date: March 9, 2020

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1 INTRODUCTION

The DNV GL team made up of DNV GL, ERS, Inc., NMR, and PMR conducted the Rhode Island (RI) Commercial and Industrial (C&I) Market Characterization Data Collection Study to help the RI OER and National Grid better understand the state's existing C&I building and equipment stock, support the efficiency potential study and lighting baseline determination, and otherwise identify ways to expand RI statewide energy efficiency initiatives.

The study's goal was to conduct comprehensive on-site assessments of 125 C&I facilities across the state of RI with representation among relevant business types. The study focused on understanding the highest priority electric and natural gas end uses, based on stakeholder feedback and annual energy efficiency program savings. The following end uses were included in this study: lighting, HVAC and motor/drive on the electric side and HVAC, including steam traps and boilers and hot water on the gas side.

This report includes a discussion of study objectives, a population and sample discussion, a summary of site data collection methods, and high-level results at the business level around all non-lighting equipment observed (types, efficiencies, size, etc.). We provided added detail around lighting results to inform a lighting baseline estimate. This includes quantities (and portion) of lamp types observed by the socket and business.

1.1 Study objectives

The study had three primary objectives:

1. Collect data at a statistically selected sample of sites that targeted reasonable representation of 13 market businesses with stratification based on electric consumption within each business.
2. Provide a dataset of information on the lighting, HVAC, and motor/drive system information gathered on the electric side and HVAC, including steam traps and boilers, and hot water on the gas side. This study also included gathering observed on-site generation when available.
3. Provide sufficient detail on observed lighting systems to inform a lighting baseline assessment.

1.2 Organization of report

The remainder of this report is structured as follows:

Section 2: Methodology
Section 3: Results

- Section 3.1: Lighting equipment
- Section 3.2: HVAC equipment
- Section 3.3: Domestic Hot Water equipment (DHW)
- Section 3.4: Steam Traps
- Section 3.5: On-site generation
- Section 3.6: Motors & Drives

2 METHODOLOGY

2.1 Sample design

DNV GL designed a sampled based on 2018 C&I National Grid billing data in RI. The key information required to develop the sample for the on-site assessments included the business type and annual consumption. The key objective of the sample design was to achieve the best precision available within the budget through stratified sampling methods with an effort to represent each building type. There are three stages to the process, including developing the sample frame, the sample design, and the weighting used to expand the results based on the actual sample achieved.

2.1.1 Sample frame

The total population of electric accounts in the billing and tracking database was 62,394 accounts consuming 4.37 billion kWh (as shown in Table 2-1). There were several steps taken to refine the population dataset to the final sample frame. These steps included:

- The DNV GL team removed accounts with little to no energy consumption by taking out accounts with annual consumption of less than 2,000 kWh. This resulted in a decrease of 5,454 accounts in the population consuming a total of 4.1 million kWh (0.1% of RI's consumption). The average usage among these removed accounts was less than 800 kWh at each account.
- The DNV GL team removed accounts noted to be currently inactive in the billing system. This resulted in removing 1,258 accounts with a total consumption of 11.2 million kWh.
- Where available, the DNV GL team used NAICS 6-digit codes to assign accounts into 13 building types. As part of this process, the DNV GL team broke out College/Universities (Campus) from the Education category and divided Healthcare into Hospitals and Non-hospital (healthcare) based on the facility name. There were 28,307 accounts (33.2% of consumption) in the population that did not have a NAICS code. The DNV GL team conducted a manual search to fill the building types for top consuming accounts. This resulted in classifying 133 more accounts from the unknown category with a total annual consumption of approximately 622.7 million kWh.

The final sample frame after these steps is 27,508 accounts, representing 80.8% of the total consumption received. The on-site sample was selected from this group of accounts.

Table 2-1: Population Summary

Description	Total Accounts #	Consumption (kWh)	%Total Billing
2018 C&I Billing Data	62,394	4,337,991,270	100.0%
Accounts with <2,000 kWh	5,454	4,137,386	0.1%
Inactive Accounts	1,258	11,211,934	0.3%
Accounts with Unknown Building Type	28,307	1,441,760,928	33.2%
Unknown accounts added	133	622,678,753	14.4%
Final Population Frame	**27,508**	**3,503,559,775**	**80.8%**

Table 2-2 presents the distribution of the sample frame across 13 business types. We classified these types consistent with CBECs, as defined in Appendix C. From left to right the table shows the number of accounts, consumption, and percent of overall consumption by business type. The sample unit in this design is an account number. The final two columns show the minimum and maximum consumption by type. The minimum consumption is always higher than 2,000 kWh as that was the threshold for inclusion in the

frame, as described above. The data shows that Manufacturing/Industrial, Office, and Retail businesses consume about 61% of total energy in the population frame and Warehouses and Other business types only 0.4% and 2.0%, respectively.

Table 2-2: Population frame with business type classification

Business Type	Accounts	Total Consumption (kWh)	Consumption %	Minimum (kWh)	Maximum (kWh)
Campuses	88	238,572,411	6.8%	2,043	76,078,179
Education	794	163,038,015	4.7%	2,006	14,126,000
Food Sales	707	146,264,313	4.2%	2,000	2,956,000
Food Service	2,381	209,076,586	6.0%	2,000	3,604,500
Healthcare	2,772	212,171,638	6.1%	2,028	9,989,562
Hospitals	129	155,066,072	4.4%	2,027	40,892,398
Lodging	325	76,676,418	2.2%	2,115	6,745,259
Manufacturing/Industrial	3,373	765,993,270	21.9%	2,001	57,121,719
Office	6,926	699,615,932	20.0%	2,001	93,444,624
Other	252	69,645,889	2.0%	2,016	23,551,093
Public Assembly	989	87,936,035	2.5%	2,010	28,819,702
Retail	8,697	664,658,217	19.0%	2,001	25,028,384
Warehouse	75	14,844,979	0.4%	2,331	9,624,000
Grand Total	**27,508**	**3,503,559,775**	**100.0%**		
Unknown*	28,174	819,082,175			

**active accounts only*

2.1.2 Sample design

A state-wide sample size of 125 accounts was targeted to represent the final population frame. The DNV GL team used a proportional allocation of sample points based on the consumption in each business type. The DNV GL team committed at least 6 to each business type and as many as 19 to the largest ones, as shown in Table 2-3 below. To estimate the precision around this study by business type, we assumed an error ratio of 0.6[1] to reflect the amount of variability we might expect in the systems observed. Among business types, precisions ranged from ±24.6% to ±50.6% with an overall estimate of ±11.6%.

This design provides sampling that ensured representation of segments within the overall estimate but was generally sized to provide reasonable overall results at the state level. As mentioned earlier, this study focused on a select series of systems, some of which were not always present or observable at all sites. For example, while the lighting was nearly always present and verifiable, HVAC and DHW measures were not. The combination of small business level sample sizes and low counts of observable systems can produce poor precisions at business and/or technology levels.

[1] 0.6 is the midpoint of the ratio assumed in the Massachusetts market characterization study completed in November 2016.

Table 2-3: Sample allocations

Business Type	Accounts (N)	Total Consumption (kWh)	Consumption %	Error Ratio	Sample (n)	Expected Relative Precision
Campuses	88	238,572,411	6.8%	0.6	7	±28.0%
Education	794	163,038,015	4.7%	0.6	6	±51.3%
Food Sales	707	146,264,313	4.2%	0.6	7	±44.1%
Food Service	2,381	209,076,586	6.0%	0.6	7	±45.7%
Healthcare	2,772	212,171,638	6.1%	0.6	7	±45.1%
Hospitals	129	155,066,072	4.4%	0.6	7	±45.2%
Lodging	325	76,676,418	2.2%	0.6	6	±50.6%
Manufacturing/ Industrial	3,373	765,993,270	21.9%	0.6	19	±29.9%
Office	6,926	699,615,932	20.0%	0.6	19	±27.5%
Other	252	69,645,889	2.0%	0.6	7	±36.0%
Public Assembly	989	87,936,035	2.5%	0.6	7	±42.7%
Retail	8,697	664,658,217	19.0%	0.6	19	±27.3%
Warehouse	75	14,844,979	0.4%	0.6	7	±24.6%
Grand Total	**27,508**	**3,503,559,775**	**100.0%**	**0.6**	**125**	**±11.6%**

The DNV GL team used stratified statistical sampling principles to develop a stratified random sample of the population of C&I accounts in which business type and consumption category served as the strata. This optimized the sample within each building type by increasing the likelihood of selecting larger accounts (by consumption). This table is provided in Appendix A and shows the use of four strata for each building type except healthcare, which only needed three. It also shows the designed inclusion probability of each stratum/building combination. Each stratum 4 was a census stratum with an inclusion probability of 1.

National Grid and the DNV GL team worked together to recruit sites according to the sample design. This included the use of National Grid account managers with existing customer relationships to recruit very large sites (i.e., strata 3 and 4). The DNV GL team used a CATI firm to soft recruit customers and gather contacts that were subsequently scheduled on specific dates by the site auditors. Sites were offered incentives ($200) or an inventory of our findings if they allowed auditors to visit their sites. Despite these efforts, not all strata within each business type were able to be fully completed. This study visited 87 of the 125 targeted, due primarily to the difficulty in recruitment within the available study schedule.

Table 2-4. shows the final sample achieved and resulting case weights by business type and size. The columns include the strata in each business based on size, the final sample achieved, the accounts in the population and total consumption among those accounts. The last two columns show the consumption represented in the sample and the case weight. The attrition between the sample design and final samples achieved introduces limitations in results, particularly at the business level. Three businesses only had 2 sample points (campus, hospitals, and warehouses) and the sample in the warehouse business, in particular, included small businesses. Manufacturing, offices, and retail had the largest sample sizes in the study.

Table 2-4. Final sample achieved and post stratified case-weights

Sector	Strata	Final Sample (n)	Accounts (N)	Total Population Consumption (kWh)	Sample Consumption (kWh)	Case Weight (N/n)
Campuses	1	1	85	72,268,232	7,305,600	85.0
Campuses	2	1	3	166,304,179	65,560,000	3.0
Education	1	2	663	37,340,747	15,140	331.5
Education	2	2	97	52,825,506	468,910	48.5
Education	3	1	34	72,871,762	2,762,400	34.0
Food Sales	1	2	587	32,110,543	48,564	293.5
Food Sales	2	2	91	49,145,370	501,160	45.5
Food Sales	3	2	29	65,008,400	5,027,400	14.5
Food Service	1	2	1,622	52,293,502	102,857	811.0
Food Service	2	2	560	65,693,361	265,441	280.0
Food Service	3	2	199	91,089,723	628,460	99.5
Healthcare	1	1	2,416	41,397,468	42,418	2,416.0
Healthcare	2	1	292	68,032,518	430,560	292.0
Healthcare	3	2	64	102,741,652	1,952,720	32.0
Hospitals	1	1	127	96,706,970	34,030	127.0
Hospitals	2	1	2	58,359,102	40,892,398	2.0
Lodging	1	2	279	17,501,368	110,519	139.5
Lodging	2	2	33	25,466,609	1,547,260	16.5
Lodging	3	1	13	33,708,441	3,849,942	13.0
Manufacturing/Industrial	1	7	3,144	141,628,400	556,888	449.1
Manufacturing/Industrial	2	8	189	245,640,049	6,054,880	23.6
Manufacturing/Industrial	3	2	40	378,724,821	15,998,093	20.0
Office	1	8	6,284	117,243,894	86,380	785.5
Office	2	7	579	209,945,346	2,932,680	82.7
Office	3	2	63	372,426,692	4,303,915	31.5
Other	1	3	252	69,645,889	8,964,182	84.0
Public Assembly	1	3	785	13,466,587	34,368	261.7
Public Assembly	2	2	156	19,107,576	227,800	78.0
Public Assembly	3	3	48	55,361,872	1,634,160	16.0
Retail	1	6	7,586	126,828,191	59,919	1,264.3
Retail	2	3	954	204,123,285	488,213	318.0
Retail	3	1	157	333,706,741	2,481,600	157.0
Warehouse	1	2	75	14,844,979	36,016	37.5
Total		**87**	**27,508**	**3,503,559,775**	**175,404,873**	

2.1.2.1 Participation Rates

National Grid provided C&I annual participation rates of 11% for all programs from 2014 through 2018 except the Upstream program. Since the participation rate of the Upstream program was not readily available, DNV GL team in collaboration with National Grid completed a customer name lookup of all Upstream lighting program participants and compared them with the population (~62,000 accounts) to calculate an average annual participation rate to be 17% for the upstream program. Note that these calculations assumed that there is an overlap of 20% of participants between upstream and non-upstream programs. Overall, program participation was estimated to be 28% of the population in RI.

And, for sample participation, DNV GL used a similar approach of account number and/or customer business name lookup with the program data (including Upstream Lighting) and found 55 out of 87 to be participants (63%).

2.1.2.2 Raking weight methods

The initial results (using case-weights in Table 2-4) showed a response bias that over-represented program participants in the sample weighted results. In order to reduce this bias, DNV GL employed a model-based approach (an iterative process simulated in SAS) to adjust the sample weights known as raking. The raking process produces weight adjustment factors that result in sample weighted kWh as close to the marginal kWh in the population across multiple dimensions.

The raking process included two iterations – the first with 100 iterations and the second with 200. The two runs produced almost no difference in the weights produced. This is likely due to a high convergence criterion that was not achieved (+/- 10,000 kWh on the targeted margins). The order of optimization in this process was business type, business size, and participation rate. Putting them in this order means the weights are best optimized for participation, then size then business type. As part of this process, weights were trimmed to ensure no site had too extreme (high or low) representation in the final results. Seven weights were trimmed based on the criteria provided in the table below. These are standard trim factors for a process of this type.

Trim factors	
1	Individual weights were not increased by more than 5 times their original value or decrease less than 20% of their original value
2	On global basis, no single weight was allowed to be greater than 50 times the average or be lower than 9.1% of the average

Table 2-5 and Table 2-6 show the distribution in the population frame by size and business type respectively. Weight adjustment factors are produced by raking to target the share of population kWh in four dimensions: Business Type, Size (Large, Medium, Small), participation and the combination of Business Type and Size. RI National Grid does not track program participation in size bins, so population participation energy (kWh) was estimated by triangulating what is known from MA (Table 2-7) and RI, and the differences in upstream program participation tracking.

The product of weight adjustment factors and the original case weight produces the final weight of each sampled site. APPENDIX C shows the sampled sites' case weight and final (post-raking) weights. The study results were expanded using the final raked weights. The following tables show the consumption in the population versus that in the sample before and after the raking process.

Table 2-5: Size distribution of population frame

Size (by annual consumption)	% Consumption	Weighted sample distribution prior to raking	Final weighted sample distribution after raking
Small: <500 MWh	31.2%	45.0%	33.0%
Medium: 500 - 4,500 MWh	35.5%	27.4%	35.4%
>4,500 MWh	33.2%	27.6%	31.6%
Total	**100%**	**100%**	**100%**

Table 2-6: Size distribution by business types

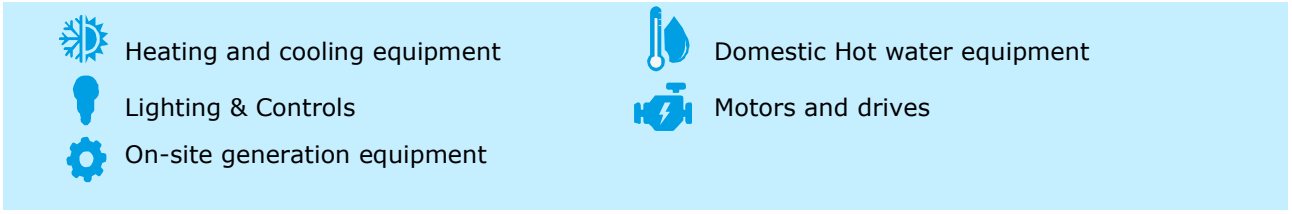
Business Type	% Consumption	Weighted sample distribution prior to raking	Final weighted sample distribution after raking
Campuses	6.8%	18.9%	11.9%
Education	4.7%	2.6%	3.1%
Food Sales	4.2%	2.5%	2.6%
Food Service	6.0%	4.6%	3.3%
Healthcare	6.1%	7.0%	5.5%
Hospitals	4.4%	2.0%	7.5%
Lodging	2.2%	2.1%	2.9%
Manufacturing/Industrial	21.9%	15.9%	21.5%
Office	20.0%	8.8%	21.3%
Other	2.0%	17.4%	3.3%
Public Assembly	2.5%	1.2%	3.5%
Retail	19.0%	16.9%	13.4%
Warehouse	0.4%	0.0%	0.2%
Total	**100%**	**100%**	**100%**

Table 2-7: Participation Rate in MA by size bins

Participation	Estimated % Population Consumption	Weighted sample distribution prior to raking	Final weighted sample distribution after raking
Participant	64.6%	86.4%	64.6%
Non-Participant	35.4%	13.6%	35.4%
Participant	64.6%	86.4%	64.6%

2.2 Data collection

The process for the C&I Market Characterization Data Collection was developed in conjunction with National Grid. The instrument was designed to collect general premise-level information, including building ownership type, operating hours, business-specific characteristics, and extensive information on the major energy end-using equipment within a building. The end-uses include:



These systems represent the electric and gas prescriptive measure end-uses that resulted in the most energy savings for energy efficiency programs according to 2018 program tracking data and likely future savings potential. Refrigeration, compressed air, and other process equipment modules were not captured in this study.

Upon approval of the data collection instrument, the DNV GL team initiated the data collection activities in April 2019. At the time, data collection was also getting underway for other National Grid impact studies.

The recruitment efforts in some cases involved coordinating scheduling site visits with these other concurrent studies in order to minimize the burden to customers.

2.3 Data collection instrument

An excel-based spreadsheet was used to collect data on-site. The spreadsheets can be launched on handheld electronic tablet-based applications on iPads. Field staff collected data in iPad forms, and/or regular notes, and photographs to prepare comprehensive site-level data files, supplementing field-collected data with additional research as appropriate (*e.g.,* determining equipment efficiency based on manufacturer model number). APPENDIX A shows screenshots of the instrument. The instruments also included a qualifier question for every equipment item entered, which essentially serves as a source of information for the entry made. The options are:

1. Observed on-site
2. Building Plans
3. Per-onsite contact interview
4. Field staff assumptions

2.4 Site survey

Site visits typically began with a conversation with the site contact to collect key information about the site and to establish the protocols to be followed during the site investigation. Field engineers collected the following information prior to the walk-through:

- Type of facility
- Building area types
- Approximate building square footage and building footprint
- Number of floors and conditioned floors
- Number and type of heating and cooling systems, hot water systems, and controls
- Recent participation in energy efficiency programs through National Grid
- Means of access to any as-built (construction documents) building plans, if available.

During this initial conversation, the field engineer also arranged a time to review the construction documents (if they were only available on site) and arranged an exit conversation. The exit conversation was an opportunity for the field engineer to fill any gaps in the data collected, complete the forms necessary for an incentive payment, and to answer any final questions the site contact might have.

2.5 Walk-through inventory

Following the survey, the site contacts typically escorted the field engineer to mechanical rooms and other limited access areas. After the systems in these spaces were inventoried, the field engineer was usually permitted to conduct the rest of the inventory unescorted. Every effort was made throughout the process to minimize the disruption to the facility and the inconvenience to the site contact.

Mechanical equipment, including HVAC, hot water, and motor & drives information was typically collected first in the presence of the site contact. The field engineer photographed and recorded the quantity and nameplate information for each piece of equipment. The nameplate information collected included size, efficiency, input and/or output capacity, and make and model number. The field engineer queried the site

contact to supplement the data collected with information on the function and/or areas served by each piece of mechanical equipment.

Lighting information collected during the site visit included fixture and lamp counts, types, wattages, and controls. The lighting information was divided up by space type. Spaces were divided into interior and exterior spaces, conditioned and unconditioned spaces, and by each space's function.

For multi-metered buildings, wherein the energy consumption of individual tenants was monitored by a private (not utility-owned) sub-meter, field staff was to:

- Survey all common and other accessible areas
- Survey unique tenant spaces representing a significant percentage of building floor area
- Identify tenants with similar space requirements and floor areas, business hours, and equipment needs, and collect information from a sample of these tenants that was the best representation of the site
- For large facilities and/or facilities with limited access, field staff collected information on approximately 1/3 of the facility. Field staff noted in the data collection instrument that the information is a sampling of the equipment on-site and indicated the percentage sampled. During the data compilation phase, equipment counts were scaled up based on the area surveyed and the total area represented by the sample.
- For campus situations (e.g., colleges and universities, and large hospitals), the DNV GL team developed a sampling protocol similar to that for large facilities, wherein a building or buildings (3 maximum) best representing that campus account were identified based on feedback from the site contact. The information collected from these facilities was then scaled up to represent the premise as a whole.

2.6 Quality check (QC)

The DNV GL team then compiled and analyzed the data from all the site visits. In preparation for the analysis, an extensive quality control (QC) process was used. After being uploaded to the DNV GL On-Site Assessment Master Database, all sites were QC'ed by a senior engineer. The QC reviewer:

- Conducted a review of general site parameters to understand site conditions and the scope of the assessment based on business type and equipment inventoried
- Reviewed notes to look for irregularities about the site visit
- Reviewed each section of the data collection instrument for completeness
- Reviewed large equipment data for accuracy
- Reviewed any sampling procedures performed at the site when access to certain areas could not be obtained

If there were questions, the QC staff would seek clarification from the field surveyor; any identifiable trends or issues that could compromise the quality of the data were discussed with the field team during weekly calls.

During the analysis, the data were verified again to ensure quality and consistency. This involved checking the number of records for each data point once the master dataset was exported for analysis, running a proc-univariate function to look at minimum, maximum and median results for key variables, checking for outliers, and assessing whether or not the means were sensible. Further, we checked for missing values, negative values, and that percentages were correct. Finally, we checked to make sure that the number of

sites or records matched what was expected, ensured there were no duplicate entries, and confirmed that the equipment found in the buildings matched the business type. Once we were comfortable with these results, the DNV GL team proceeded with report development.

3 RESULTS

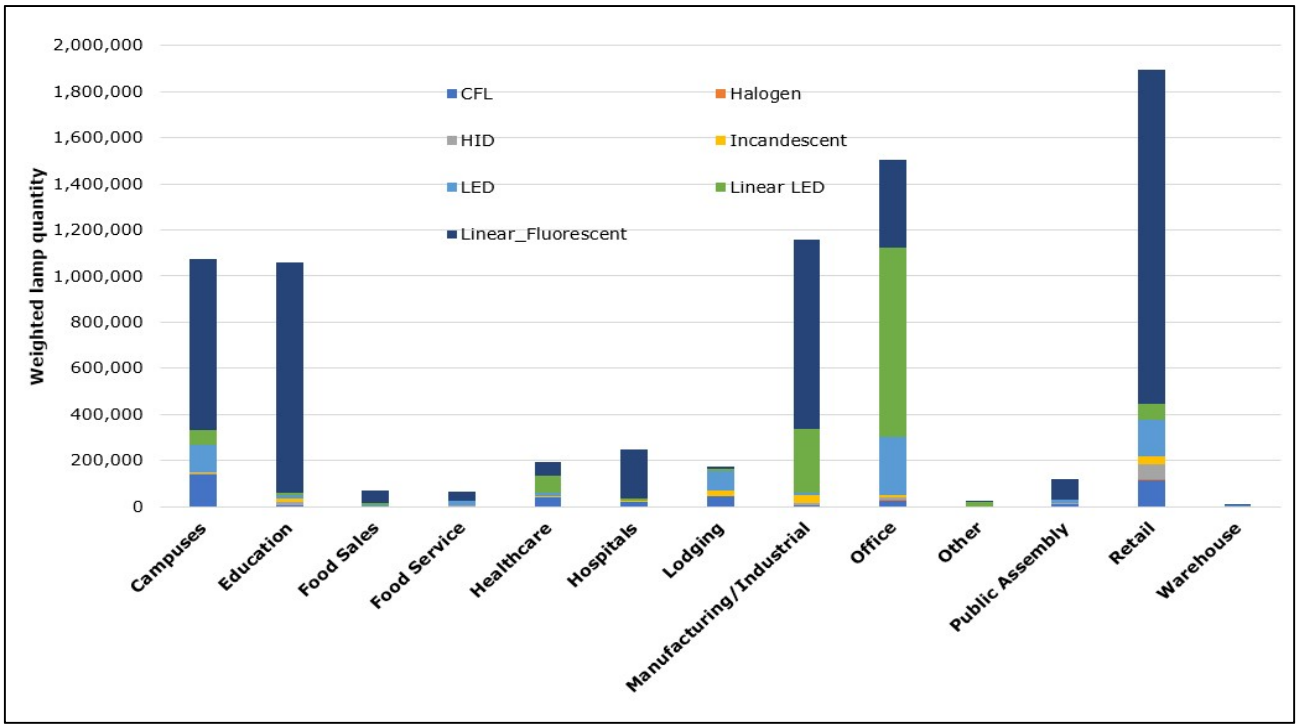
3.1 Lighting equipment

One of the central goals of the C&I Customer On-site Assessments was to document the baseline distribution of existing lighting measures within businesses. Lighting represents one of the largest sources of energy use for many business types. In addition, lighting measures represent a technology of primary interest to energy efficiency programs and is the subject of recent technology code updates.

The lighting data collected during the on-site assessments provide an indication of the progress achieved in replacing inefficient measures with newer, more efficient technologies and also provides information on the current lighting market. These data may also serve as inputs for future potential studies that could provide the PAs with a detailed picture of the remaining achievable lighting energy savings potential. Lighting equipment data collected on-site were classified as one of 7 lighting types: linear fluorescent, Linear LEDs compact fluorescent (CFL), LED (non-linear only), halogen, incandescent and high-intensity discharge (HID). LED lamps used as a replacement for linear fluorescents are referenced in this report as Linear LEDs while non-linear LEDs are treated as a separate lighting category and reported in the ICLH (Incandescent, CFL, LED, Halogen) section. Lighting data installed in indoor and outdoor spaces were analyzed and have been reported separately.

Figure 3-1 below illustrates the estimated count of lamps by business type and lighting technology. This figure provides detail on both the distribution of lamp counts by the business segment and the distribution of lighting technology. The retail business is estimated to have the most lighting systems followed by office and manufacturing businesses.

Figure 3-1: Weighted lamp count by business type and technology



*The results presented above are based on raked weights.

3.1.1 Interior lighting findings

An estimated total of 7.6 million lamps are currently operating in the state. Office, Retail and Manufacturing/industrial facilities have the highest lamp counts. Table 3-1 shows the distribution of interior lighting technologies by business type. For example, an estimated 13.2% of lighting on campuses are CFLs and about 70.3% are linear fluorescent lamps. The last row shows the %lamps of each technology observed. Linear lighting, including linear fluorescents and linear LEDs and TLEDs, accounts for 84.5% of the existing stock of indoor lighting in RI businesses. Our estimate of linear lamps suggests that fluorescent technologies dominate at nearly 66% of the interior lamps in the state and linear LED technologies are estimated to be at an 18.5% saturation. LED bulbs (non-linear) represent 8.9% of lighting observed overall, which is higher than CFLs (5%) and incandescent (1.4%). As noted earlier, there are limitations to business-level results as several only had 2 sample points (campus, hospitals, and warehouses), in particular, included small (size) businesses. It is also important to note that the population for some of these businesses was very small compared to other businesses; for example, there are a total of 75 Warehouses (0.3%) in the population of 27,508 accounts.

Table 3-1: Distribution of interior lamp (counts) technologies by business type

Business Type	Sample size (n)	Total Lamp Count	Incan.	CFL	LED	Halogen	HID	Linear LED	Linear Fluores.	Total	Wtd. Avg.
Campuses	2	1,057,639	0.5%	13.2%	10.1%	0.1%	0.0%	5.9%	70.3%	100.0%	14.4%
Education	5	1,044,172	1.5%	0.2%	1.6%	0.0%	0.0%	0.8%	95.9%	100.0%	14.2%
Food Sales	6	61,916	1.6%	0.5%	6.4%	0.0%	0.0%	15.9%	75.7%	100.0%	0.8%
Food Service	6	63,113	2.9%	1.0%	31.2%	0.7%	0.0%	2.4%	61.9%	100.0%	0.9%
Healthcare	4	186,495	1.2%	18.7%	8.8%	0.0%	0.0%	39.5%	31.8%	100.0%	2.5%
Hospitals	2	245,997	1.0%	8.3%	1.1%	0.0%	0.0%	4.4%	85.2%	100.0%	3.3%
Lodging	5	164,945	13.4%	24.5%	50.9%	0.0%	0.0%	6.4%	4.8%	100.0%	2.2%
Manufacturing/ Industrial	17	1,140,016	2.2%	0.4%	0.8%	0.1%	0.4%	24.2%	71.8%	100.0%	15.5%
Office	17	1,464,583	0.8%	1.5%	15.3%	0.2%	0.1%	56.2%	26.0%	100.0%	19.9%
Other	3	22,990	0.0%	1.1%	0.0%	0.0%	0.0%	75.7%	23.2%	100.0%	0.3%
Public Assembly	8	115,594	0.1%	10.9%	9.0%	0.1%	1.4%	3.1%	75.3%	100.0%	1.6%
Retail	10	1,772,119	1.0%	4.9%	8.9%	0.0%	0.0%	3.4%	81.7%	100.0%	24.1%
Warehouse	2	8,770	6.3%	12.7%	19.9%	0.0%	3.2%	0.0%	57.9%	100.0%	0.1%
Grand Total	87	7,348,349	1.4%	5.0%	8.9%	0.1%	0.1%	18.5%	66.0%	100.0%	100.0%

*All results are based on raked weights

Table 3-2 shows the precisions at the 90% confidence interval around the results provided in Table 3-1. The results in Table 3-1 plus or minus these values provide the high and low boundaries on each estimate. We consider the business results to be useful indicators of trends, but these results often have poor precisions around them. In fact, there are many results where the lower bound of the estimate is less than zero. In these cases, the interval is asymmetrical and can be regarded as an estimate that falls with 90% confidence below the upper bound.

There are three technologies with overall results that experience this asymmetrical precision boundary: halogen, HID, and incandescent. One way to think of the results here (and elsewhere) is if we take the high end of the bound for these three technologies, we get an estimated overall high-end estimate of 4.9% of total sockets with halogen (0.6%), HID (0.7%), and incandescent (3.5%). This suggests that overall there are not many of these technologies to target with efficient alternatives, though there may be businesses where these opportunities are more prevalent. For purposes of estimating potential, one can further consider that the application and use (i.e., operating hours) of these three technologies are likely to be less

than the operating hours of linear lighting systems, the opportunity for energy savings becomes even less lucrative to consider targeting.

Table 3-2: Precision at 90% CI of interior lamps (counts) by technology type & business type

Business Type	Sample size (n)	Total Lamp Count	Incan.	CFL	LED	Halogen	HID	Linear LED	Linear Fluores	Wtd. Avg.
Campuses	2	1,057,639	±7.8%	±39.4%	±35.0%	±3.3%	±2.3%	±27.3%	±53.2%	±40.8%
Education	5	1,044,172	±9.0%	±3.4%	±9.3%	N.A.	N.A.	±6.4%	±14.6%	±25.7%
Food Sales	6	61,916	±8.5%	±4.6%	±16.4%	N.A.	N.A.	±24.5%	±28.8%	±6.1%
Food Service	6	63,113	±11.2%	±6.6%	±31.1%	±5.5%	N.A.	±10.3%	±32.6%	±6.2%
Healthcare	4	186,495	±9.0%	±32.1%	±23.3%	N.A.	N.A.	±40.2%	±38.3%	±12.9%
Hospitals	2	245,997	±11.4%	±32.1%	±12.2%	N.A.	N.A.	±23.8%	±41.3%	±20.9%
Lodging	5	164,945	±25.1%	±31.6%	±36.8%	N.A.	N.A.	±18.0%	±15.7%	±10.9%
Manufacturing/ Industrial	17	1,140,016	±5.9%	±2.4%	±3.6%	±1.5%	±2.6%	±17.1%	±18.0%	±14.4%
Office	17	1,464,583	±3.5%	±4.9%	±14.4%	±1.6%	±1.3%	±19.8%	±17.5%	±15.9%
Other	3	22,990	N.A.	±10.1%	N.A.	N.A.	N.A.	±40.8%	±40.1%	±5.3%
Public Assembly	8	115,594	±1.9%	±18.1%	±16.6%	±1.7%	±6.9%	±10.1%	±25.1%	±7.2%
Retail	10	1,772,119	±5.2%	±11.3%	±14.8%	±0.8%	N.A.	±9.4%	±20.1%	±22.3%
Warehouse	2	8,770	±28.3%	±38.7%	±46.5%	N.A.	±20.4%	N.A.	±57.4%	±4.0%
Grand Total	87	7,348,349	±2.1%	±3.8%	±5.0%	±0.5%	±0.6%	±6.8%	±8.4%	N.A.

Table 3-3 shows the distribution of lamp power (kW) for different technologies by business type. Retail (26%), Manufacturing/Industrial (24%) and Education (14.5%) are the top three power (weighted kW) consuming businesses for lighting equipment. In offices, about 1% of the power (kW) is consumed by linear LED lamps and 37% by linear fluorescents. Overall, 70.3% of the total power is estimated to be consumed by linear fluorescent lamps in the state. shows the relative precision at a 90% confidence interval around the results provided in Table 3-3.

Table 3-3: Distribution of interior lamp power (weighted) for technologies by business type

Business Type	Sample size (n)	Power (kW)	Incan.	CFL	LED	Halogen	HID	Linear LED	Linear Fluores	Total	Wtd. Avg.
Campuses	2	29,112	0.8%	10.9%	4.4%	0.1%	0.2%	3.2%	80.4%	100.0%	12%
Education	5	34,722	2.7%	0.1%	0.8%	0.0%	0.0%	0.9%	95.5%	100.0%	15%
Food Sales	6	2,309	2.8%	0.2%	2.9%	0.0%	0.0%	9.2%	84.9%	100.0%	1%
Food Service	6	1,627	6.7%	0.5%	12.8%	1.5%	0.0%	2.1%	76.4%	100.0%	1%
Healthcare	4	3,639	3.8%	14.8%	4.4%	0.0%	0.0%	27.7%	49.3%	100.0%	2%
Hospitals	2	6,200	2.3%	4.1%	0.4%	0.0%	0.0%	4.9%	88.3%	100.0%	3%
Lodging	5	3,355	35.0%	23.2%	25.7%	0.0%	0.0%	5.0%	11.1%	100.0%	1%
Manufacturing/ Industrial	17	57,500	3.3%	0.1%	0.3%	0.2%	2.7%	39.5%	53.9%	100.0%	24%
Office	17	33,403	1.7%	0.9%	9.1%	0.3%	0.5%	50.8%	36.7%	100.0%	14%
Other	3	521	0.0%	0.8%	0.0%	0.0%	0.0%	66.6%	32.6%	100.0%	0%
Public Assembly	8	3,573	0.2%	10.0%	3.4%	0.2%	4.7%	1.6%	80.0%	100.0%	1%
Retail	10	62,431	1.8%	2.7%	2.9%	0.0%	0.0%	6.1%	86.4%	100.0%	26%
Warehouse	2	392	7.1%	5.8%	2.5%	0.0%	17.7%	0.0%	66.8%	100.0%	0%
Grand Total	87	238,784	2.7%	3.0%	3.4%	0.1%	0.8%	19.6%	70.3%	100.0%	100%

*The results presented above are based on raked weights.

Table 3-4: Precision at 90% CI for interior lamp power (weighted) technologies by business type

Business Type	Sample size (n)	Power (kW)	Incan.	CFL	LED	Halogen	HID	Linear LED	Linear Fluores	Wtd. Avg.
Campuses	2	29,112	±10.6%	±36.2%	±23.8%	±4.5%	±4.8%	±20.4%	±46.2%	±38.1%
Education	5	34,722	±11.9%	±2.4%	±6.4%	N.A.	N.A.	±6.9%	±15.2%	±25.9%
Food Sales	6	2,309	±11.1%	±2.9%	±11.2%	N.A.	N.A.	±19.4%	±24.0%	±6.6%
Food Service	6	1,627	±16.8%	±4.7%	±22.4%	±8.2%	N.A.	±9.7%	±28.5%	±5.5%
Healthcare	4	3,639	±15.7%	±29.2%	±16.9%	N.A.	N.A.	±36.8%	±41.1%	±10.1%
Hospitals	2	6,200	±17.5%	±23.2%	±7.1%	N.A.	N.A.	±25.1%	±37.4%	±18.5%
Lodging	5	3,355	±35.1%	±31.0%	±32.2%	N.A.	N.A.	±16.0%	±23.1%	±8.7%
Manufacturing/ Industrial	17	57,500	±7.1%	±1.4%	±2.2%	±1.7%	±6.5%	±19.5%	±19.9%	±17.1%
Office	17	33,403	±5.2%	±3.7%	±11.5%	±2.1%	±2.7%	±19.9%	±19.2%	±13.8%
Other	3	521	N.A.	±8.5%	N.A.	N.A.	N.A.	±44.8%	±44.5%	±4.4%
Public Assembly	8	3,573	±2.6%	±17.4%	±10.5%	±2.4%	±12.3%	±7.3%	±23.3%	±7.1%
Retail	10	62,431	±6.9%	±8.5%	±8.7%	±1.0%	N.A.	±12.5%	±17.8%	±22.9%
Warehouse	2	392	±29.8%	±27.2%	±18.3%	N.A.	±44.4%	N.A.	±54.8%	±4.7%
Grand Total	87	238,784	±2.9%	±3.0%	±3.2%	±0.6%	±1.6%	±7.0%	±8.1%	N.A.

Table 3-5 shows the distribution of lighting technologies for program participants vs non-participants. Among non-participants, approximately 72% of lamps are linear fluorescents compared to 56% observed among their participant counterparts. Linear LED lamps tend to trend in the opposite direction with participants having roughly 23% of lamps as linear LED compared to 16% among non-participants. Halogen, HID and incandescent represent less than 2% of lamps observed overall.

Table 3-5:Technology distribution by EE program participation

Technology Type	Lamp Counts			
	Total Lamp Qty	EE Participant	EE Non-Participant	Overall
CFL	366,419	7.7%	3.3%	5.0%
Halogen	5,882	0.1%	0.1%	0.1%
HID	8,953	0.1%	0.1%	0.1%
Incandescent	105,566	0.7%	1.9%	1.4%
LED	653,958	12.0%	7.0%	8.9%
Linear LED	1,356,063	23.2%	15.6%	18.5%
Linear Fluorescent	4,851,508	56.3%	72.0%	66.0%
Grand Total	7,348,349	100.0%	100.0%	100.0%

*The results presented above are based on raked weights.

Table 3-6 illustrates the distribution of lighting technologies by customer size (consumption). Specifically, each column shows the % of each lighting technology observed within small (<500,000 kWh), medium (500,000 - 4,500,000 kWh), and large (>4,500,000 kWh) customers. Some findings from this table include:

- Customers with more than 4,500 MWh annual consumption have a lower saturation of linear LEDs and higher penetration of linear fluorescent technologies than customers with less than 4,500 MWh of consumption.
- Similarly, large customers (>4,500 MWh) have greater saturation of CFLs than their small and medium counterparts.

Table 3-6: Distribution of interior lamps by technology and business MWh usage

Technology	<500 MWh	500 - 4,500 MWh	>4,500 MWh	Overall
CFL	3.2%	4.5%	11.2%	5.0%
Halogen	0.1%	0.1%	0.1%	0.1%
HID	0.1%	0.2%	0.0%	0.1%
Incandescent	1.8%	1.3%	0.5%	1.4%
LED	7.9%	13.5%	7.6%	8.9%
Linear LED	18.1%	32.4%	6.3%	18.5%
Linear Fluorescent	68.9%	47.9%	74.3%	66.0%
Grand Total	100.0%	100.0%	100.0%	100.0%

*The results presented above are based on raked weights.

3.1.1.1 Linear lighting

Table 3-7 presents the linear technology efficiency distribution within each business (business) and overall. Approximately two-thirds of linear lamps have T8 technology. LED is either integrated into the fixture or present as the lamp technology in an estimated 22% of lighting units. Drawing business level conclusions are difficult due to small sample sizes, although offices with its sample size of 17, shows a high saturation of LED lamp technologies (68.4%) relative to nearly all other businesses. Table 3-8 presents precisions around the business level and overall results for LED integrated fixtures, T12, T5, and T8 technologies. Overall precisions (bottom row) are better than ±10% at 90% confidence interval.

Table 3-7: Interior linear efficiency lamp (counts) distribution by business type

Business Type	Sample Size (n)	Total Lamp Count	LED integrated fixture	Linear LED	T12	T5	T8	Total	Wtd Avg
Campuses	2	805,334	2.7%	5.0%	0.0%	2.1%	90.2%	100%	13.0%
Education	5	1,009,167	0.6%	0.2%	0.2%	0.0%	99.0%	100%	16.3%
Food Sales	6	56,688	7.1%	10.2%	2.4%	0.0%	80.2%	100%	0.9%
Food Service	6	40,568	3.7%	0.0%	0.1%	0.0%	96.2%	100%	0.7%
Healthcare	4	132,938	3.8%	51.7%	3.5%	0.8%	40.3%	100%	2.1%
Hospitals	2	220,438	2.5%	2.4%	1.5%	13.1%	80.4%	100%	3.6%
Lodging	5	18,456	16.4%	40.8%	27.9%	0.0%	14.9%	100%	0.3%
Manufacturing/ Industrial	17	1,093,589	1.7%	23.5%	19.3%	2.5%	53.0%	100%	17.6%
Office	17	1,203,006	18.6%	49.8%	1.3%	0.0%	30.3%	100%	19.4%
Other	3	22,727	59.3%	17.3%	0.0%	0.0%	23.5%	100%	0.4%
Public Assembly	8	90,714	0.2%	3.8%	3.6%	0.0%	92.4%	100%	1.5%
Retail	10	1,508,240	3.4%	0.6%	15.5%	17.2%	63.3%	100%	24.3%
Warehouse	2	5,079	0.0%	0.0%	14.2%	13.0%	72.9%	100%	0.1%
Grand Total	87	6,206,944	5.7%	16.1%	7.7%	5.4%	65.0%	100%	100.0%

*The results presented above are based on raked weights

Table 3-8: Precision at 90% CI of interior linear efficiency lamp distribution by business type

Business type	Sample Size (n)	LED integrated fixture	Linear LED	T12	T5	T8	Weighted Average
Campuses	2	±18.8%	±25.4%	N.A.	±16.7%	±34.6%	±39.1%
Education	5	±5.7%	±3.2%	±3.5%	N.A.	±7.4%	±27.1%
Food Sales	6	±17.3%	±20.3%	±10.4%	N.A.	±26.7%	±6.4%
Food Service	6	±12.7%	N.A.	±1.5%	N.A.	±12.8%	±5.4%
Healthcare	4	±15.7%	±41.1%	±15.0%	±7.2%	±40.3%	±11.9%
Hospitals	2	±18.2%	±17.7%	±14.2%	±39.3%	±46.1%	±21.5%
Lodging	5	±27.2%	±36.2%	±33.0%	N.A.	±26.2%	±4.0%
Manufacturing/ Industrial	17	±5.2%	±16.9%	±15.7%	±6.3%	±19.9%	±15.2%
Office	17	±15.5%	±19.9%	±4.5%	N.A.	±18.3%	±15.8%
Other	3	±46.7%	±35.9%	N.A.	N.A.	±40.2%	±5.7%
Public Assembly	8	±2.5%	±11.1%	±10.9%	N.A.	±15.4%	±7.0%
Retail	10	±9.4%	±4.0%	±18.8%	±19.6%	±25.1%	±22.3%
Warehouse	2	N.A.	N.A.	±40.6%	±39.1%	±51.7%	±3.3%
Grand Total	87	±4.1%	±6.5%	±4.7%	±4.0%	±8.4%	N.A.

Linear technologies have historically been a significant focus of energy efficiency programs in Rhode Island. Table 3-9 presents the estimated distribution of linear lamp technologies within-participant vs non-participant businesses. As might be expected, participants have a much higher saturation of linear LED lamps, moderately higher saturation of integrated LEDs, and much lower saturation of T12s. This study estimates that 11% of lamps in non-participants have T12 technology in them.

Table 3-9: Distribution of Linear lamps by participation

Technology	Participant		Non-Participant		Overall	
	Lamp count	Lamp %	Lamp count	Lamp %	Lamp count	Lamp %
Integrated LED	150,337	7%	203,993	5%	354,330	6%
Linear LED	496,797	22%	504,936	13%	1,001,733	16%
T5	97,485	4%	237,646	6%	335,131	5%
T8	1,430,724	64%	2,604,274	65%	4,034,998	65%
T12	44,864	2%	435,888	11%	480,752	8%
Total	2,220,207	100%	3,986,737	100%	6,206,944	100%

*The results presented above are based on raked weights.

The following tables show results by business and LED vs fluorescent technology. Within linear LED lamps offices comprise the greatest share of lamps of any business type, with an estimated 61% and manufacturing at 20% of the total weighted average lamp count in the state. Healthcare and manufacturers have high saturations of linear LEDs among non-participating facilities. Most linear LED lighting observed among other businesses was installed among participants. Table 3-11 shows the precisions around the results in Table 3-10.

Table 3-10: Distribution of Linear LED lamps by business type and participation

Business type	Lamp Count	LED integrated fixture			Linear LED			Grand Total	Wtd Avg
		Part	Non-Part	Total	Part	Non-Part	Total		
Campuses (2)	62,006	35%	0%	35%	65%	0%	65%	100%	5%
Education (5)	8,055	76%	0%	76%	24%	0%	24%	100%	1%
Food Sales (6)	9,825	14%	27%	41%	18%	41%	59%	100%	1%
Food Service (6)	1,519	100%	0%	100%	0%	0%	0%	100%	0%
Healthcare (4)	73,719	7%	0%	7%	13%	80%	93%	100%	5%
Hospitals (2)	10,776	52%	0%	52%	48%	0%	48%	100%	1%
Lodging (5)	10,559	29%	0%	29%	71%	0%	71%	100%	1%
Manufacturing /Industrial (17)	275,569	5%	1%	7%	7%	86%	93%	100%	20%
Office (17)	822,548	8%	19%	27%	48%	25%	73%	100%	61%
Other (3)	17,395	77%	0%	77%	23%	0%	23%	100%	1%
Public Assembly (8)	3,619	5%	0%	5%	95%	0%	95%	100%	0%
Retail (10)	60,473	18%	67%	85%	15%	0%	15%	100%	4%
Grand Total (85)	1,356,063	11%	15%	26%	37%	37%	74%	100%	100%

*The results presented above are based on raked weights.

Table 3-11: Precision at 90% CI for the distribution of Linear LED lamps by business type and participation

Business type	Lamp Count	LED integrated fixture			Linear LED			Wtd Avg
		Part	Non-Part	Total	Part	Non-Part	Total	
Campuses (2)	62,006	±55.5%	N.A.	±55.5%	±55.5%	N.A.	±55.5%	±24.3%
Education (5)	8,055	±31.5%	N.A.	±31.5%	±31.5%	N.A.	±31.5%	±5.7%
Food Sales (6)	9,825	±23.2%	±29.9%	±33.1%	±25.8%	±33.0%	±33.1%	±5.7%
Food Service (6)	1,519	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	±2.2%
Healthcare (4)	73,719	±20.8%	N.A.	±20.8%	±27.8%	±32.9%	±20.8%	±18.6%
Hospitals (2)	10,776	±58.1%	N.A.	±58.1%	±58.1%	N.A.	±58.1%	±10.3%
Lodging (5)	10,559	±33.2%	N.A.	±33.2%	±33.2%	N.A.	±33.2%	±6.5%
Manufacturing /Industrial (17)	275,569	±9.0%	±4.6%	±10.0%	±10.0%	±13.6%	±10.0%	±16.1%
Office (17)	822,548	±10.9%	±15.7%	±17.7%	±19.9%	±17.2%	±17.7%	±19.5%
Other (3)	17,395	±39.7%	N.A.	±39.7%	±39.7%	N.A.	±39.7%	±10.7%
Public Assembly (8)	3,619	±12.1%	N.A.	±12.1%	±12.1%	N.A.	±12.1%	±3.0%
Retail (10)	60,473	±19.9%	±24.4%	±18.6%	±18.6%	N.A.	±18.6%	±10.7%
Grand Total (85)	1,356,063	±36.5%	±41.6%	±51.1%	±56.0%	±56.2%	±51.1%	N.A.

Table 3-12 shows linear fluorescent results in the same structure as that provided above. Retail, Education, and Manufacturing/Industrial businesses use the highest quantity of linear fluorescent lamps, at 30%, 21%, and 17%, respectively. Office use only 8% of the total linear fluorescent (weighted) lamps. Nearly 95% of the total retail business linear fluorescent lamps are estimated to be from non-participants out of which 65% of them are T8s, 16% are T12s and 14.5% are T5s. The majority of the T8s installed in Campuses (98%), Hospitals (85%), Healthcare (80%) and Offices (61%) are through efficiency programs. Table 3-12 shows the precisions around the results in Table 3-12.

Table 3-12: Distribution of Linear fluorescent lamps by business type and participation

Business type	Total Lamp Count	T5			T8			T12			Grand Total	Wtd. Avg
		Part	Non-Part	Total	Part	Non-Part	Total	Part	Non-Part	Total		
Campuses (2)	743,328	2%	0%	2%	98%	0%	98%	0%	0%	0%	100%	15%
Education (5)	1,001,112	0%	0%	0%	7%	93%	100%	0%	0%	0%	100%	21%
Food Sales (6)	46,863	0%	0%	0%	10%	87%	97%	0%	3%	3%	100%	1%
Food Service (6)	39,049	0%	0%	0%	7%	93%	100%	0%	0%	0%	100%	1%
Healthcare (4)	59,219	2%	0%	2%	80%	10%	90%	8%	0%	8%	100%	1%
Hospitals (2)	209,662	14%	0%	14%	85%	0%	85%	2%	0%	2%	100%	4%
Lodging (5)	7,897	0%	0%	0%	6%	28%	35%	8%	57%	65%	100%	0%
Manufacturing /Industrial (17)	818,020	0%	3%	3%	18%	53%	71%	2%	24%	26%	100%	17%
Office (17)	380,458	0%	0%	0%	61%	35%	96%	4%	0%	4%	100%	8%
Other (3)	5,332	0%	0%	0%	0%	100%	100%	0%	0%	0%	100%	0%
Public Assembly (8)	87,095	0%	0%	0%	6%	91%	96%	3%	0%	4%	100%	2%
Retail (10)	1,447,767	3%	14%	18%	1%	65%	66%	0%	16%	16%	100%	30%
Warehouse (2)	5,079	0%	13%	13%	44%	29%	73%	11%	3%	14%	100%	0%
Grand Total (87)	4,850,881	2%	5%	7%	29%	54%	83%	1%	9%	10%	100%	100%

*The results presented above are based on raked weights.

Table 3-13: Precision at 90% CI of Linear fluorescent lamps by business type and participation

Business type	Total Lamp Count	T5			T8			T12			Wtd. Avg
		Part	Non-Part	Total	Part	Non-Part	Total	Part	Non-Part	Total	
Campuses (2)	743,328	±17.4%	N.A.	±17.4%	±17.4%	N.A.	±17.4%	N.A.	N.A.	N.A.	±41.9%
Education (5)	1,001,112	N.A.	N.A.	N.A.	±18.5%	±18.7%	±3.5%	±3.5%	N.A.	±3.5%	±29.8%
Food Sales (6)	46,863	N.A.	N.A.	N.A.	±19.9%	±22.3%	±11.4%	±3.7%	±10.8%	±11.4%	±6.6%
Food Service (6)	39,049	N.A.	N.A.	N.A.	±16.7%	±16.8%	±1.6%	±1.6%	N.A.	±1.6%	±6.0%
Healthcare (4)	59,219	±10.8%	N.A.	±10.8%	±32.9%	±25.2%	±24.1%	±22.0%	N.A.	±22.0%	±9.0%
Hospitals (2)	209,662	±40.1%	N.A.	±40.1%	±42.0%	N.A.	±42.0%	±14.6%	N.A.	±14.6%	±23.7%
Lodging (5)	7,897	N.A.	N.A.	N.A.	±18.1%	±33.2%	±35.1%	±20.5%	±36.5%	±35.1%	±3.0%
Manufacturing /Industrial (17)	818,020	N.A.	±7.2%	±7.2%	±15.3%	±19.9%	±18.1%	±5.3%	±17.0%	±17.5%	±14.9%
Office (17)	380,458	N.A.	N.A.	N.A.	±19.5%	±19.0%	±8.0%	±7.7%	±1.9%	±8.0%	±10.7%
Other (3)	5,332	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	±3.1%
Public Assembly (8)	87,095	N.A.	N.A.	N.A.	±13.5%	±17.0%	±11.1%	±10.5%	±3.6%	±11.1%	±7.7%
Retail (10)	1,447,767	±9.5%	±18.3%	±20.0%	±5.9%	±24.9%	±24.7%	±1.0%	±19.1%	±19.1%	±23.8%
Warehouse (2)	5,079	N.A.	±39.1%	±39.1%	±57.7%	±52.9%	±51.7%	±36.3%	±20.6%	±40.6%	±3.8%
Grand Total (87)	4,850,881	±2.5%	±3.8%	±4.5%	±8.0%	±8.8%	±6.6%	±1.7%	±5.0%	±5.3%	N.A.

Table 3-14 presents the linear technology efficiency distribution by business annual kWh size and purchase year (2014 through 2019 vs prior to 2014). Overall, purchases of T12, T8, and T5 technologies have decreased substantially between the two periods. Installed T12 technologies have gone down over the past 5 years, although not as much as T8 and T5's. This may be due to the use of left-over stock in facilities, late adopters of efficient lighting trends, or financial barriers. Linear LEDs are a large part of more recently purchased lighting systems, and integrated LED fixtures are clearly increasing over time.

Table 3-14: Interior linear efficiency distribution by business kWh usage and time period

Linear Technologies	T12	T8	T5	LED integrated fixture	Linear LED	Total
Total Lamp Count	**480,752**	**4,034,998**	**335,131**	**354,330**	**1,001,733**	**6,206,944**
Older than 2014						
<500 MWh	51%	57%	63%	11%	2%	46%
500 - 4,500 MWh	36%	3%	15%	0%	0%	6%
>4,500 MWh	3%	20%	5%	6%	0%	14%
Sub Total	89%	81%	82%	18%	2%	65%
2014 to 2019						
<500 MWh	3%	8%	9%	52%	58%	18%
500 - 4,500 MWh	7%	6%	0%	24%	35%	12%
>4,500 MWh	1%	5%	9%	6%	5%	5%
Sub Total	11%	19%	18%	82%	98%	11%
Grand Total	100%	100%	100%	100%	100%	100%
All Stock (all years)	**11%**	**60%**	**8%**	**7%**	**15%**	**100%**

*The results presented above are based on raked weights.

3.1.1.2 Interior incandescent, CFL, LED and halogen (ICLH) lighting

The ICLH section presents information on incandescent, CFL, non-linear LED, and halogen technologies currently installed in businesses in RI. These lighting technologies have been grouped together because these technologies have similar lighting applications. Table 3-15 shows the distribution of incandescent, CFL, LED, and Halogen interior lighting technologies observed by business type while Table 3-16 shows the precisions around those estimates. Given the small sample sizes among the businesses and the relatively small number of these lighting types the business-level results in this section have low confidence but do suggest trends in lighting. Saturation of each technology is in the final overall row and shows an estimate of 58% of these fixture types with LEDs, 32% with CFLs, and 9% with incandescent. The precisions around these overall numbers are reasonable and range from ±1.3% (Halogen) to ±8.7% (incandescent).

Table 3-17 present the installation results in terms of total watts of the installed lamps while Table 3-18 shows the precisions around those estimates. It is important to note that the above mentioned 9% of the incandescent bulbs in Table 3-15 are estimated to consume about 29% of the total power (kW) in ICLH category as shown in Table 3-17 while 58% of the LEDs lamps consume only 36% of the total power. CFL bulbs quantities and total power are close to each other at 32% of counts and 33% of total power (kW) consumption. The larger difference in the saturations by bulb count and fixture wattage relate to the large difference in incandescent wattages and the wattages of LEDs which is the not the case Table 3-1 and Table

3-3 where the incandescent are a much smaller share of the total interior lamps include the large amount of linear lamps.

Table 3-15: Interior ICLH distribution by technology type and business type

Sector Type	Total Lamp Count	Incan.	CFL	LED	Halogen	Total	Wtd. Avg.
Campuses (n= 2)	251,907	2%	55%	42%	0%	100%	22.3%
Education (n= 5)	35,005	45%	6%	49%	0%	100%	3.1%
Food Sales (n= 6)	5,228	19%	6%	75%	0%	100%	0.5%
Food Service (n= 6)	22,545	8%	3%	87%	2%	100%	2.0%
Healthcare (n= 4)	53,557	4%	65%	31%	0%	100%	4.7%
Hospitals (n= 2)	25,559	9%	80%	11%	0%	100%	2.3%
Lodging (n= 5)	146,489	15%	28%	57%	0%	100%	12.9%
Manufacturing/ Industrial (n= 17)	40,768	63%	10%	23%	4%	100%	3.6%
Office (n= 17)	259,996	4%	9%	86%	1%	100%	23.0%
Other (n= 3)	263	0%	100%	0%	0%	100%	0.0%
Public Assembly (n= 8)	23,216	1%	54%	45%	0%	100%	2.1%
Retail (n= 10)	263,879	7%	33%	60%	0%	100%	23.3%
Warehouse (n=2)	3,413	16%	33%	51%	0%	100%	0.3%
Grand Total (n= 87)	1,131,825	9%	32%	58%	1%	100%	100.0%

*The results presented above are based on raked weights.

Table 3-16: Precisions at 90% CI around Interior ICLH distribution by technology type and business type

Sector Type	Total Lamp Count	Incan.	CFL	LED	Halogen	Wtd. Avg.
Campuses (n= 2)	251,907	±16.0%	±57.8%	±57.5%	±6.8%	±48.4%
Education (n= 5)	35,005	±36.6%	±18.1%	±36.8%	N.A.	±12.7%
Food Sales (n= 6)	5,228	±26.4%	±15.3%	±28.9%	N.A.	±4.6%
Food Service (n= 6)	22,545	±18.2%	±11.0%	±22.3%	±9.1%	±9.4%
Healthcare (n= 4)	53,557	±16.5%	±39.2%	±37.9%	N.A.	±17.5%
Hospitals (n= 2)	25,559	±33.9%	±46.6%	±36.0%	N.A.	±17.3%
Lodging (n= 5)	146,489	±26.4%	±32.9%	±36.4%	N.A.	±24.7%
Manufacturing/ Industrial (n= 17)	40,768	±19.3%	±12.1%	±16.8%	±7.7%	±7.4%
Office (n= 17)	259,996	±8.1%	±11.2%	±13.8%	±3.9%	±16.8%
Other (n= 3)	263	N.A.	N.A.	N.A.	N.A.	±1.4%
Public Assembly (n= 8)	23,216	±4.2%	±29.0%	±28.9%	±3.7%	±8.2%
Retail (n= 10)	263,879	±13.1%	±24.5%	±25.5%	±2.1%	±22.0%
Warehouse (n=2)	3,413	±42.9%	±54.5%	±58.1%	N.A.	±6.4%
Grand Total (n= 87)	1,131,825	±5.1%	±8.3%	±8.7%	±1.3%	N.A.

Table 3-17: Interior ICLH distribution by lamp power (kW) and business type

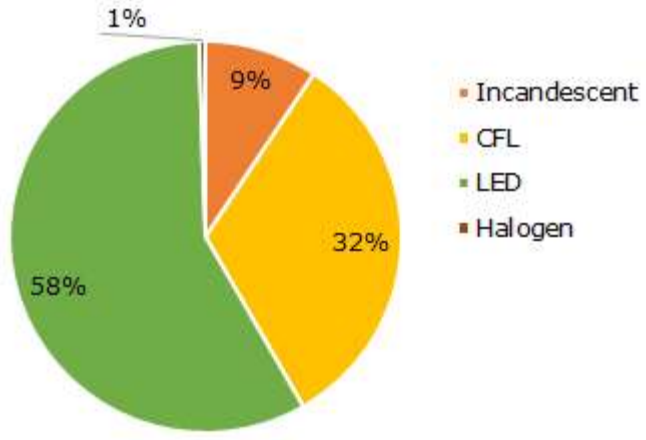
Sector Type	Total Lamp Power kW	Incan.	CFL	LED	Halogen	Total	Wtd. Avg.
Campuses (n= 2)	4,727	5%	67%	27%	1%	100%	21.5%
Education (n= 5)	1,245	76%	3%	21%	0%	100%	5.7%
Food Sales (n= 6)	135	48%	3%	49%	0%	100%	0.6%
Food Service (n= 6)	350	31%	2%	59%	7%	100%	1.6%
Healthcare (n= 4)	837	16%	64%	19%	0%	100%	3.8%
Hospitals (n= 2)	424	34%	61%	5%	0%	100%	1.9%
Lodging (n= 5)	2,815	42%	28%	31%	0%	100%	12.8%
Manufacturing/ Industrial (n= 17)	2,216	85%	3%	8%	5%	100%	10.1%
Office (n= 17)	4,001	14%	7%	76%	2%	100%	18.2%
Other (n= 3)	4	0%	100%	0%	0%	100%	0.0%
Public Assembly (n= 8)	489	1%	73%	25%	1%	100%	2.2%
Retail (n= 10)	4,644	24%	37%	39%	0%	100%	21.2%
Warehouse (n=2)	60	46%	38%	16%	0%	100%	0.3%
Grand Total (n= 87)	21,949	29%	33%	36%	1%	100%	100.0%

*The results presented above are based on raked weights.

Table 3-18: Precisions at 90% CI around Interior ICLH distribution by lamp power (kW) and business type

Sector Type	Total Lamp Power (kW)	Incan.	CFL	LED	Halogen	Wtd. Avg.
Campuses (n= 2)	4,727	±25.7%	±54.7%	±51.6%	±11.1%	±47.8%
Education (n= 5)	1,245	±31.6%	±12.5%	±30.2%	N.A.	±17.0%
Food Sales (n= 6)	135	±33.6%	±11.8%	±33.6%	N.A.	±5.3%
Food Service (n= 6)	350	±31.1%	±10.1%	±33.0%	±17.3%	±8.4%
Healthcare (n= 4)	837	±30.5%	±39.4%	±32.5%	N.A.	±15.8%
Hospitals (n= 2)	424	±55.1%	±56.8%	±26.3%	N.A.	±16.0%
Lodging (n= 5)	2,815	±36.3%	±32.9%	±33.9%	N.A.	±24.6%
Manufacturing/ Industrial (n= 17)	2,216	±14.3%	±6.8%	±10.6%	±8.4%	±12.0%
Office (n= 17)	4,001	±14.0%	±10.3%	±17.0%	±6.0%	±15.4%
Other (n= 3)	4	N.A.	N.A.	N.A.	N.A.	±1.3%
Public Assembly (n= 8)	489	±6.9%	±25.9%	±25.1%	±6.4%	±8.6%
Retail (n= 10)	4,644	±22.2%	±25.1%	±25.3%	±3.6%	±21.2%
Warehouse (n=2)	60	±58.0%	±56.4%	±43.0%	N.A.	±6.1%
Grand Total (n= 87)	21,949	±8.0%	±8.3%	±8.5%	±2.0%	N.A.

Figure 3-2: Saturation of ICLH technologies



*The results presented above are based on raked weights.

Table 3-19 presents the estimated distribution of ICLH lamp technologies within-participant vs non-participant businesses. Participants have roughly the same saturation of LED bulbs while participants have a higher saturation of CFLs and non-participants a higher saturation of incandescent bulbs. This study estimates that 15% of lamps in non-participants have incandescent technology in them.

Table 3-19: Distribution of ICLH lamps by participation

Technology	Participant		Non-Participant		Overall	
	Lamp count	Lamp %	Lamp count	Lamp %	Lamp count	Lamp %
Incandescent	18,964	3%	86,602	15%	105,566	9%
CFL	214,462	38%	151,957	27%	366,419	32%
LED	334,598	59%	319,360	57%	653,958	58%
Halogen	2,320	0%	3,562	1%	5,882	1%
Total	570,344	100%	561,481	100%	1,131,825	100%

*The results presented above are based on raked weights.

Table 3-20 below presents ICLH technologies by program participation and business type. Retail, Office, and Campuses use the highest number of ICLH lamps. As indicated earlier, business-level results are not reliable though we believe them to provide reasonable trends within those with larger sample sizes.

Table 3-20: Distribution of interior ICLH lamp counts by business type and EE participation

Sector Type	Total Lamp Counts	Incandescent		CFL		LED		Halogen		Wtd. Avg.
		Part	Non-Part	Part	Non-Part	Part	Non-Part	Part	Non-Part	
Campuses (n= 2)	251,907	2%	0%	55%	0%	42%	0%	0%	0%	22%
Education (n= 5)	35,005	2%	43%	6%	0%	49%	0%	0%	0%	3%
Food Sales (n= 6)	5,228	19%	0%	0%	6%	52%	24%	0%	0%	0%
Food Service (n= 6)	22,545	8%	0%	3%	0%	18%	69%	2%	0%	2%
Healthcare (n= 4)	53,557	4%	0%	5%	60%	31%	0%	0%	0%	5%
Hospitals (n= 2)	25,559	9%	0%	80%	0%	11%	0%	0%	0%	2%
Lodging (n= 5)	146,489	0%	15%	23%	5%	56%	1%	0%	0%	13%
Manufacturing/ Industrial (n= 17)	40,768	2%	61%	1%	9%	15%	8%	0%	4%	4%
Office (n= 17)	259,996	1%	3%	5%	4%	33%	53%	0%	1%	23%
Other (n= 3)	263	0%	0%	0%	100%	0%	0%	0%	0%	0%
Public Assembly (n= 8)	23,216	1%	0%	9%	46%	32%	13%	0%	0%	2%
Retail (n= 10)	263,879	0%	7%	0%	33%	0%	59%	0%	0%	23%
Warehouse (n=2)	3,413	16%	0%	33%	0%	49%	2%	0%	0%	0%
Grand Total (n= 87)	1,131,825	2%	8%	19%	13%	30%	28%	0%	0%	100%

*The results presented above are based on raked weights.

Table 3-21 presents the ICLH technologies efficiency distribution by business annual kWh size and purchase year (2014 through 2019 vs prior to 2014). Overall, purchases of Incandescent and CFL technologies have decreased substantially between the two periods and, LED and Halogen bulbs have increased in the last 5 years. Installed incandescent technologies have gone down significantly from 75% to 25% over the past 5 years. LEDs are a large part (58%) of more recently purchased lighting systems and are clearly increasing over time.

Table 3-21: Interior ICLH efficiency distribution by business kWh usage and time period

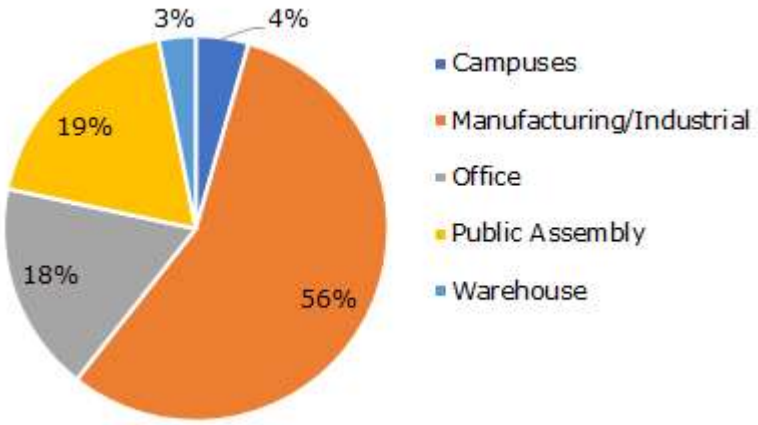
ICLH Technologies	Incandescent	CFL	LED	Halogen	Grand Total
Total Lamp Count	**105,566**	**366,419**	**653,958**	**5,882**	**1,131,825**
Older than 2014					
<500 MWh	57%	24%	24%	9%	27%
500 - 4,500 MWh	14%	0%	0%	21%	2%
>4,500 MWh	5%	39%	16%	15%	22%
Sub Total	75%	63%	40%	44%	51%
2014 to 2019					
<500 MWh	19%	16%	31%	42%	25%
500 - 4,500 MWh	3%	16%	28%	13%	22%
>4,500 MWh	2%	5%	1%	0%	2%
Sub Total	25%	37%	60%	56%	49%
Grand Total	100%	100%	100%	100%	100%
All Stock (all years)	**9%**	**32%**	**58%**	**1%**	**100%**

*The results presented above are based on raked weights.

3.1.1.3 HID

Only 6 out of 87 buildings had HIDs installed for interior lighting and Figure 3-3 shows HID lighting is primarily used in manufacturing/industrial (56%), 32% in the office segment, and the balance in public assembly, warehouses, and campuses. The substantial share of HID lighting in manufacturing is not surprising given that these lamps are frequently used in spaces with high ceilings or as high-bay lighting. The study survey did not include questions on the high bay and low-bay lighting. The low portion in warehouses suffers from there only being two warehouses in this sample that were each very small and likely not representative of warehouses overall. Exterior lighting has more HIDs installed and discussed in the upcoming section.

Figure 3-3: Interior lighting HID distribution of by business type



*All results are based on raked weights

Table 3-22: Interior HID lamps distribution by technology type, lamp power (k) and business type

Sector Type	n	Total Lamp Counts	Ceramic Metal Halide	High-Pressure Sodium	Metal Halide	Total	Total Lamp kW	Ceramic Metal Halide	High-Pressure Sodium	Metal Halide	Total
Campuses	1	398	0%	0%	100%	100%	50	0%	0%	100%	100%
Manufacturing/Industrial	1	5,032	0%	0%	100%	100%	1,573	0%	0%	100%	100%
Office	2	1,581	4%	96%	0%	100%	156	2%	98%	0%	100%
Public Assembly	1	1,664	0%	100%	0%	100%	166	0%	100%	0%	100%
Warehouse	1	278	0%	0%	100%	100%	70	0%	0%	100%	100%
Grand Total	6	8,953	1%	36%	64%	100%	2,014	0%	16%	84%	100%

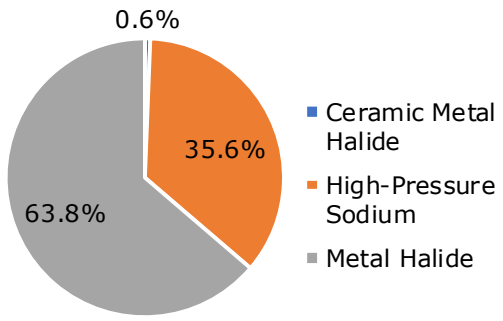
*The results presented above are based on raked weights.

Figure 3-4 presents a distribution of indoor HIDs by lamp type. HID technologies, ranked in order of highest to lowest efficiency include the following lamp types:

- Standard metal halide
- Ceramic metal halide
- High-pressure sodium

Mercury vapor HIDs, the highest efficiency HID choice was not observed in our sample, although metal halide and high-pressure sodium fixtures were observed in 63.8% and 35.6% of these lamps, respectively. Ceramic metal halides were about 0.6%.

Figure 3-4: Saturation of Interior HID lamp technologies



*The results presented above are based on raked weights.

3.1.2 Lighting controls

Table 3-23 displays the distribution of lighting controls across all types of interior lighting. This data indicates that most of the C&I interior lighting in Rhode Island is manually controlled (91%) while 5% are controlled by either EMS, occupancy sensors, or timer.

Table 3-23: Distribution of interior lighting controls

Fixture Control Type	n	%On Lamps Controlled	RP @ 90% CI
24x7	44	1.8%	±3.3%
Advanced lighting controls	1	0.1%	±5.1%
Building EMS (ON/OFF)	2	0.1%	±2.9%
Daylight/Photocell	3	0.0%	±1.2%
Dimmer Switch	9	0.4%	±3.3%
Manual ON/OFF	87	91.4%	±4.9%
Missing	25	1.3%	±3.8%
Timer	3	0.6%	±7.6%
Wall/Ceiling Occupancy Sensor	27	4.3%	±6.4%

*The results presented above are based on raked weights.

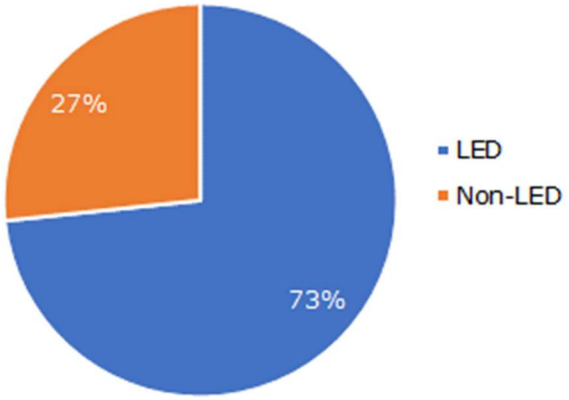
These data indicate that linear, the most common type of lighting in RI businesses (see Table 3-1), are most commonly manually controlled, though a small share of linear technologies is also controlled by occupancy sensors (particularly linear LEDs) or timers (particularly linear fluorescent). The large share of lighting that is manually controlled represents an opportunity for National Grid sponsored programs to educate customers and increase the use of lighting controls.

3.1.3 Exit signs

Figure 3-5 depicts the distribution of exit signs by LED lamp versus non-LED lamp in Rhode Island. Across all business types and business sizes, LEDs are found to be the majority of exit lighting technology at 73%

overall. Replacing exit signs with LED can lead to substantial savings given that these bulbs are required by the Occupational Safety and Health Administration to be on while the building is occupied. Exit signs typically have high annual hours of use, usually 8,760 hours.

Figure 3-5: Distribution of Exit signs by lamp type



*The results presented above are based on raked weights.

3.1.4 Exterior lighting

Table 3-24 illlustrates the lamp share of exterior lighting technologies by business type. Note that we were unable to capture exterior lighting for the two warehouses visited in the sample. The bottom row shows the saturation of each technology in this lighting category. These data indicate that LED (19%), HIDs (42%), and CFLs (17%) are the dominant exterior lamp type overall. Retail establishments have the highest share of many lamp types, including outdoor HIDs lamps at 55%, Incandescent at 14% and CFLs at 24%.

Table 3-24: Distribution of exterior lighting lamp counts by technology type & business type

Business Type	Incan.	CFL	LED	Halogen	HID	Linear LED	Linear Fluor.	Grand Total	Wtd. Avg.
Campuses	0.0%	0.0%	87.5%	0.0%	10.3%	0.0%	2.2%	100%	7%
Education	0.0%	4.5%	0.1%	0.0%	89.5%	5.9%	0.0%	100%	7%
Food Sales	1.0%	5.3%	7.4%	4.2%	0.2%	10.6%	71.4%	100%	4%
Food Service	3.6%	7.3%	9.1%	1.8%	71.8%	3.3%	3.1%	100%	1%
Healthcare	5.4%	47.4%	5.7%	0.0%	41.4%	0.0%	0.0%	100%	3%
Hospitals	14.3%	0.0%	0.0%	0.0%	71.4%	14.3%	0.0%	100%	0%
Lodging	27.7%	27.7%	16.3%	6.0%	7.3%	15.0%	0.0%	100%	3%
Manufacturing/Industrial	40.5%	3.8%	5.6%	5.5%	23.2%	21.4%	0.0%	100%	7%
Office	4.7%	10.0%	68.0%	0.2%	17.2%	0.0%	0.0%	100%	16%
Other	0.0%	11.3%	0.0%	0.0%	0.0%	88.7%	0.0%	100%	2%
Public Assembly	0.0%	0.0%	16.8%	0.0%	78.0%	5.1%	0.0%	100%	1%
Retail	14.1%	23.6%	0.0%	0.4%	54.7%	7.3%	0.0%	100%	49%
Weighted Average	11.7%	16.6%	18.5%	1.0%	41.6%	7.9%	2.8%	100%	100%

*The results presented above are based on raked weights.

Manufacturing is estimated to have the highest share of exterior incandescent (41%). Table 3-25 provides precisions around these results, which are reasonable and range from ±2.0% to ±10.0%, depending on technology.

Table 3-25: Relative Precision at 90% CI for the distribution of exterior lighting lamps by technology type & business type

Business Type	Incan.	CFL	LED	Halogen	HID	Linear LED	Linear Fluor.	Wtd. Avg.
Campuses	N.A.	N.A.	±38.4%	N.A.	±35.3%	N.A.	±17.0%	±29.1%
Education	N.A.	±17.0%	±2.5%	N.A.	±25.2%	±19.4%	N.A.	±20.6%
Food Sales	±7.5%	±16.5%	±19.2%	±14.7%	±2.9%	±22.6%	±33.2%	±13.8%
Food Service	±13.6%	±19.1%	±21.2%	±9.9%	±33.1%	±13.1%	±12.7%	±7.2%
Healthcare	±18.6%	±41.1%	±19.1%	N.A.	±40.5%	N.A.	N.A.	±14.3%
Hospitals	±57.6%	N.A.	N.A.	N.A.	±74.3%	±57.6%	N.A.	±10.1%
Lodging	±32.9%	±32.9%	±27.2%	±17.5%	±19.1%	±26.3%	N.A.	±13.3%
Manufacturing/ Industrial	±20.2%	±7.9%	±9.5%	±9.4%	±17.4%	±16.9%	N.A.	±10.4%
Office	±11.6%	±16.4%	±25.6%	±2.3%	±20.7%	N.A.	N.A.	±20.1%
Other	N.A.	±36.9%	N.A.	N.A.	N.A.	±36.9%	N.A.	±14.4%
Public Assembly	N.A.	N.A.	±27.5%	N.A.	±30.5%	±16.2%	N.A.	±8.3%
Retail	±20.3%	±24.7%	N.A.	±3.5%	±29.0%	±15.1%	N.A.	±29.1%
Weighted Average	±6.5%	±7.5%	±7.9%	±2.0%	±10.0%	±5.4%	±3.3%	N.A.

3.2 HVAC equipment

The C&I Customer On-site Assessments documented the distribution of existing heating, ventilation, and air conditioning (HVAC) equipment that uses electricity and/or natural gas as fuels. HVAC equipment represents a significant fraction of energy use and peak demand within the C&I business. Table 3-26 presents the incidence of heating and cooling equipment and make and model data for the sample by business type.

These data indicate that field data were collected[2] from 87 businesses, cooling information was collected at 83 businesses; At 4 facilities the field staff could not gain access to the cooling equipment and 5 out of 83 facilities that did provide access there was no cooling equipment installed. Heating information was collected from 84 facilities. At 3 facilities the field staff could not gain access to the heating equipment and 1 out of 84 facilities that did provide access had no heating[3] equipment installed. Also, in the 84 facilities, 4 facilities use oil, 1 uses propane, 1 uses waste-oil fired heating equipment. The results presented in this report included electric and natural gas fuel using equipment only.

The final two columns provide information on the number of businesses where make and model information was collected. The make and model information for equipment was analyzed to determine the efficiency of this equipment.

Table 3-26: On-sites by business type and HVAC equipment (unweighted)

Business type	Count of completed on-site surveys	Cooling Sys. info collected	Heating Sys. info collected	Make and model data collected for cooling	Make and model data collected for heating
Campuses	2	2	2	1	2
Education	5	4	4	4	4
Food Sales	6	6	6	5	5
Food Service	6	5	6	4	6
Healthcare	4	4	3	4	3
Hospitals	2	2	2	2	2
Lodging	5	5	5	4	4
Manufacturing or Industrial	17	17	17	15	14
Office	17	15	17	12	14
Other	3	3	3	3	3
Public Assembly	8	8	8	7	6
Retail	10	10	9	7	7
Warehouse	2	2	2	1	1
Total	**87**	**83**	**84**	**69**	**71**

3.2.1 HVAC cooling findings

The DNV GL team identified several important cooling findings during their analysis. Table 3-27 illustrates the distribution of cooling units in RI businesses based upon the on-site data while Table 3-28 shows the precisions around these estimates.

Some key findings (unweighted results):

[2] While it is likely that all or nearly all businesses have heating equipment and nearly all businesses have cooling equipment, the on-site surveyor was not able to collect this information for some facilities.

[3] This account number sampled in this account serves common space only. Heating is provided by the tenant interference/interaction.

- 60% (unweighted) of RI businesses (52 out of 87) use Split/Packaged cooling equipment. The study found that 34% of cooling equipment is split and packaged ACs, 53% are PTACs (packaged terminal air conditioning) and window/wall units, 13% are Heat Pumps and approximately 1% are chillers.
- Chillers were found in 10 sites, while Heat pumps, PTAC/Window units, and Split packaged systems were found in 25, 26 and 52 sites respectively.
- Split/Packaged cooling equipment are common across all size of businesses with reasonable relative precision at 90% Confidence. They are highly concentrated in Office, Retail, Manufacturing, Public Assembly and Healthcare businesses.
- The results also show that 28% of the cooling units are made up of PTACs or Window units. These units are also highly concentrated in lodging, and healthcare facilities.
- Table 3-28 shows reasonable precision for this system type with about 1/3rd (27 out of 87 sites) of the sites using these systems currently.
- Chillers are mostly associated with larger facilities like Public Assembly, Retail, Office, Hospitals, Campus and Manufacturing facilities. A small number of Chillers are found in Education and Lodging.
- Overall the precisions for Split/Packaged systems are reasonable due to higher system sample size, therefore more system-specific results are presented in the sections below.

Table 3-27: Distribution of cooling units (counts) across business types.

Business type	n	Total Units	% Chillers	% Heat Pump	% PTAC/ Window	% Split /Packaged	Total	Wtd. Avg.
Campuses	2	2,814	3.3%	0.0%	16.3%	80.3%	100%	2%
Education	4	31,993	0.2%	0.8%	4.2%	94.9%	100%	21%
Food Sales	6	1,915	0.0%	5.1%	40.4%	54.5%	100%	1%
Food Service	4	3,573	0.0%	0.3%	0.2%	99.5%	100%	2%
Healthcare	4	17,093	0.0%	17.4%	81.3%	1.2%	100%	11%
Hospitals	2	2,705	5.9%	5.0%	69.3%	19.8%	100%	2%
Lodging	5	8,120	0.4%	2.0%	91.5%	6.1%	100%	5%
Manufacturing or Industrial	15	6,084	2.1%	0.9%	73.8%	23.3%	100%	4%
Office	14	16,894	0.1%	43.0%	36.9%	19.9%	100%	11%
Other	3	206	12.6%	43.7%	14.6%	29.1%	100%	0%
Public Assembly	8	1,813	0.9%	6.3%	0.0%	92.7%	100%	1%
Retail	10	59,268	0.1%	10.0%	10.1%	79.8%	100%	39%
Warehouse	1	556	0.0%	0.0%	50.0%	50.0%	100%	0%
Weighted Average	78	153,034	0.4%	11.2%	28.0%	60.5%	100%	100%

*The results presented above are based on raked weights.

Table 3-28: Precisions at 90% CI around the distribution of cooling equipment

Business type	n	Total Units	% Chillers	% Heat Pump	% PTAC/Window	% Split /Packaged	Wtd. Avg.
Campuses	2	2,814	±20.8%	N.A.	±43.0%	±46.2%	±15.6%
Education	4	31,993	±3.4%	±7.1%	±16.5%	±18.1%	±33.4%
Food Sales	6	1,915	N.A.	±14.7%	±33.0%	±33.4%	±7.5%
Food Service	4	3,573	N.A.	±4.8%	±3.4%	±5.8%	±12.4%

Healthcare	4	17,093	N.A.	±31.2%	±32.1%	±9.1%	±25.9%
Hospitals	2	2,705	±27.4%	±25.2%	±53.6%	±46.4%	±15.3%
Lodging	5	8,120	±4.8%	±10.2%	±20.5%	±17.7%	±16.5%
Manufacturing or Industrial	15	6,084	±6.0%	±3.9%	±20.3%	±19.9%	±8.3%
Office	14	16,894	±1.6%	±21.8%	±21.2%	±17.6%	±13.8%
Other	3	206	±31.5%	±47.1%	±33.5%	±43.2%	±3.5%
Public Assembly	8	1,813	±5.6%	±14.2%	N.A.	±15.1%	±6.3%
Retail	10	59,268	±1.6%	±15.6%	±15.6%	±20.9%	±25.3%
Warehouse	1	556	N.A.	N.A.	±82.3%	±82.3%	±9.9%
Weighted Average	78	153,034	±1.2%	±5.9%	±8.3%	±9.1%	N.A.

3.2.1.1 Cooling capacity and efficiencies

The data collection team gathered information on cooling capacity or tonnage where possible. The average tons (unweighted) per cooling unit by cooling system type. The systems are listed in order of declining average tonnage per unit. These data indicate that Absorption chillers have the largest average tonnage followed by other large HVAC systems. Split and packaged air conditioning (AC) units were the most frequently observed cooling unit in RI businesses. These units are designed to cool a smaller area than chillers but more area than PTAC or Window/wall units. These units were observed to have average capacities between 22 and 5.1 tons per unit and called as commercial AC units in this report. CRAC (computer room air conditioners) were part of the Split/packaged units and averaging 16 tons per unit surveyed. On average, heat pumps were found to be smaller than air conditioning units and typically these units are small and are usually intended to only cool relatively smaller spaces. The study found water source heat pumps, variable refrigerant flow heat pumps and ductless heat pumps. PTAC/Window units were the smallest units found during the survey and the lowest cooling capacity being 1.1 tons per unit surveyed.

Table 3-29: Cooling capacity per unit surveyed, by cooling system type (unweighted)

Cooling Equipment Type	Classification	Average Tons per unit	#Units
Absorption Chiller	Chillers	450	15
Air-Cooled Chillers	Chillers	121	3
Water-Cooled Chiller	Chillers	366	23
Field Assembled DX Unit	Split/Packaged	22	24
CRAC	Split/Packaged	16	30
Single Packaged AC Unit	Split/Packaged	11	40
Split DX System	Split/Packaged	5.1	312
Water Source Heat Pump	Heat Pump	6.1	3
Heat pump, Through wall air, cooled Split	Heat Pump	3.6	199
VRF: Variable Refrigerant Flow Heat Pump	Heat Pump	2.6	109
Ductless Heat pump	Heat Pump	2.0	57
PTAC	PTAC/Window	1.7	30
PTHP	PTAC/Window	1.3	82
Window AC	PTAC/Window	1.1	499

*All results are based on raked weights

Given the smaller share of units observed in the larger capacity units (typically called chillers) and the large sample of split and packaged units, and PTAC/window wall units, it is likely that split and packaged systems

account for the largest share of air conditioning tonnage in RI businesses. These units are the subject of the efficiency analysis presented below. Table 3-30 below shows the weighted cooling tons for all cooling system types in the state. It is important to distinguish between the total number (last row) of cooling units in Table 3-27 and total cooling tons in Table 3-30. For example, approximately 28% (Table 3-27) of the cooling units are PTAC/Window units but the actual tonnage of those units is only 9.7% (Table 3-30) of the total tonnage, approximately while the chillers are only 0.2% of the counts but the actual tonnage is nearly 31.6% of the approximate tonnage in the state.

Table 3-30: Distribution of weighted cooling (tons) across business types.

Business type	n	Total Cooling Tons	Chillers	Heat Pump	PTAC/ Window	Split /Packaged	Total	Wtd. Avg.
Campuses	2	892	Missing†	0.0%	43.0%	57.0%	100.0%	0.2%
Education	4	98,092	2.8%	0.6%	0.7%	96.0%	100.0%	20.1%
Food Sales	6	7,453	0.0%	3.6%	28.0%	68.4%	100.0%	1.5%
Food Service	4	10,946	0.0%	0.3%	0.0%	99.7%	100.0%	2.2%
Healthcare	4	35,610	0.0%	33.5%	60.7%	5.8%	100.0%	7.3%
Hospitals	2	79,889	96.1%	0.3%	1.4%	2.2%	100.0%	16.4%
Lodging	5	25,800	61.0%	1.7%	26.4%	10.8%	100.0%	5.3%
Manufacturing or Industrial	15	56,881	57.3%	0.2%	8.1%	34.4%	100.0%	11.7%
Office	14	65,190	10.6%	36.8%	14.9%	37.7%	100.0%	13.4%
Other	3	16,406	95.1%	0.7%	0.4%	3.9%	100.0%	3.4%
Public Assembly	8	24,508	13.6%	1.4%	0.0%	85.0%	100.0%	5.0%
Retail	10	64,104	Missing†	43.7%	0.1%	56.3%	100.0%	13.2%
Warehouse	1	1,390	0.0%	0.0%	20.0%	80.0%	100.0%	0.3%
Weighted Average	78	487,160	31.6%	13.5%	9.7%	45.2%	100.0%	100.0%

†Missing name plate information; the percent totals assume 0% for missing values.
*Campus data was not included due to missing nameplate information.

3.2.1.2 Split and packaged cooling systems efficiency

The data presented in Table 3-31 estimates that 93% of Split/Packaged AC units and heat pump units in Rhode Island businesses are very small systems (i.e., <65 kBtuh). The second most common size is small commercial units between 65 and 134 kBtuh. Medium and Large systems were about 2% each. The efficiency analysis compared the efficiency levels for the observed units to state adopted[4] cooling standards by system type, capacity, and fuel. Table 3-31 lists the cooling efficiency standards used in the cooling efficiency analysis for the four types of cooling equipment included in this analysis.

The make and model numbers are used to determine the efficiency of the units. The format of the HVAC "make" and model numbers vary tremendously across manufacturers. Each manufacturer has a different numbering scheme, with each letter, number, or dash representing a characteristic unique to the specific manufacturer. The efficiency lookup process incorporated information from manufacturer product specification sheets, web searches, and efficiency databases for high-efficiency units including Energy Star, The Preston Guide, the CEE, and the California Energy Commission eligible product list. For many model numbers, it was not possible to assign an efficiency rating. For example, the model number may be incomplete, or the equipment was old and efficiency information was no longer available. For many model

[4] Federal Standards for C&I equipment- https://ecfr.io//Title-10/pt10.3.431#se10.3.431_197

numbers, the research found that the model number was accurate, but no efficiency information was available. Where appropriate we present missing information in its own category. The following results are based on the 87 sampled site's data collection and the relative precisions calculated above apply.

Table 3-31: Commercial AC Units and heat pump cooling distribution and efficiency standards

System Type	Sample (n)	System Size	Federal Standard Minimum[4]	% Existing Stock (weighted)	%Existing Stock Above Standard
Very small AC or Heat Pump	62	Less than 65 kBtuh	13 SEER[5]	93%	26%
Small Commercial AC/HP	20	65 – 135 kBtuh	11.0 (AC); 10.8 (HP) EER[5]	2%	53%
Medium Commercial AC/HP	14	135 – 240 kBtuh	10.8 (AC); 10.6 (HP) EER[5]	2%	67%
Large Commercial AC/HP	9	240+ kBtuh	9.8 (AC); 9.5 HP; EER[5]	2%	33%
Water Source HP	2	<17 kBtuh	11.2 EER[5]	1%	8%[6]

*All results are based on raked weights

Figure 3-6 shows the distribution of efficiency levels for each of these cooling categories. These data indicate that over 60% of very small-sized commercial air conditioning and heat pump units in C&I facilities in Rhode Island are below[7] federal standards. Given that the Rhode Island TRM lists the expected useful life of a commercial air conditioning unit as 15 years, the study found that many of the air conditioning units that were observed to be below standards were purchased prior to the implementation of these standards.

[5] The efficiency standards for very small sized air conditioning units is regulated in SEER and the standard for larger units is regulated in EER. During the make and model lookup process we found several very small sized air conditioning units where only EER information was available and several large sized units where only SEER information was available. Instead of having these units be categorized as model not found, we used the following conversion to approximate an average EER and average SEER:

$$EER = 1.12 \times SEER - 0.02 \times SEER^2$$

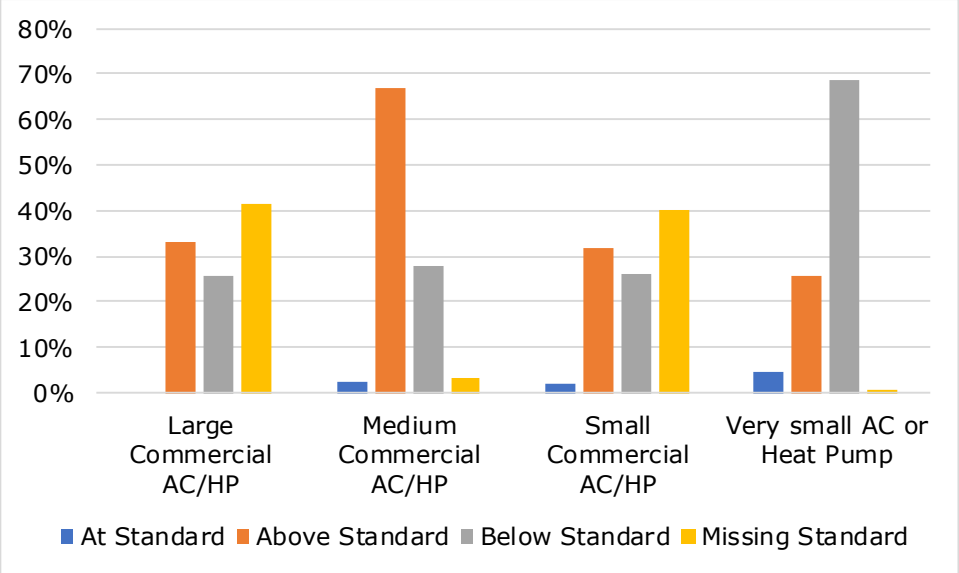
$$SEER = \frac{1.12 - \sqrt{1.2544 - 0.08 \times EER}}{0.04}$$

This equation was sourced from the following website: http://www.powerknot.com/how-efficient-is-your-air-conditioning-system.html.

[6] The other 92% of the water source HP are missing name plates and efficiencies.

[7] Federal energy efficiency standards for C&I https://ecfr.io//Title-10/pt10.3.431#se10.3.431_177

Figure 3-6: Efficiency ratings for split/packaged AC and HP, by system size



*All results are based on raked weights

Table 3-32: Commercial AC and Heat Pump stock age and efficiencies.

System Size	System Age	Above Standard	At Standard	Below Standard	Missing Standard	Total	Wtd. Avg.
Large	>15 years old	50%	0%	50%	0%	100%	0.2%
	<15 years old	42%	0%	2%	56%	100%	1.0%
	Missing	0%	0%	74%	26%	100%	0.4%
	Total	33%	0%	25%	41%	100%	1.5%
Medium	>15 years old	6%	0%	90%	4%	100%	0.3%
	<15 years old	95%	3%	1%	0%	100%	1.2%
	Missing	3%	0%	83%	14%	100%	0.3%
	Total	67%	2%	28%	3%	100%	1.7%
Small	>15 years old	3%	6%	90%	0%	100%	0.4%
	<15 years old	36%	1%	16%	47%	100%	2.6%
	Missing	19%	0%	81%	0%	100%	0.0%
	Total	32%	2%	26%	40%	100%	3.1%
Very Small	>15 years old	0%	0%	98%	2%	100%	46.1%
	<15 years old	59%	10%	30%	0%	100%	38.5%
	Missing	12%	3%	85%	0%	100%	9.0%
	Total	26%	5%	69%	1%	100%	93.7%
Grand Total		**27%**	**5%**	**66%**	**3%**	**100%**	**100.0%**

*All results are based on raked weights

Table 3-32 above, shows that nearly 46% of the stock (Wtd. Avg.) in the very small category was found to be older than 15 years and 69% of very small category- stock is below the standard of 13 SEER. From Table 3-31, 93% of the population in the Commercial AC and Heat Pump category are very small units and therefore have a potential for penetration of high-efficiency equipment in the C&I market.

In the small category, 34% of the small systems are at or above the standard of EER 11 and nearly 40% of the market could not be classified due to the missing model number or efficiency specifications. 26% of the small systems appear to be below current standards.

Medium-sized systems' efficiency distribution shows that about 69% of the stock is at or above the standard of 10.8 EER and nearly a third of the stock is rated below current federal standards. estimates that 33% of the large stock is above the standard of 9.8 EER and the majority of this 41 % of the stock is missing data. However, the sample of large sites is quite small, and the data collected may not be providing a comprehensive picture of the actual stock in the C&I market.

3.2.1.3 PTACs and window units

ASHRAE standard defines efficiencies of PTACs and Window ACs at different capacities of each unit type.

Table 3-33 shows that most of these systems are below the federal requirements. The data also suggests that medium-sized PTACs are widely (n=16) used in the state of RI. A total of 31 unique sites in the sample use PTAC units and about 48% of the weighted population is either above or meeting the required standard efficiency (Table 3-34). These federal standards have been adopted in 2012 and most of these PTACs were installed before 2012.

Table 3-33: PTACs and Window units cooling efficiency standards and distribution of systems

System Type	System Size	n	Federal Standard Minimum[4]	Existing Stock (weighted)
Small PTAC/Window ACs	Less than 7 kBtuh	6	9.0 EER	20%
Medium PTAC/Window ACs	7 – 15 kBtuh	16	13.8-(0.3*Cap kBtuh)	38%
Large PTAC/Window ACs	15+ kBtuh	8	9.3 EER	42%

*Cap= Capacity; All results are combined ratio and case weighted

Table 3-34 shows the distribution of all sizes of PTAC across the state. Nearly 42% of the units observed were large with 47% of them being below standards. 38% of the units are medium sized systems and about 53% of them are at or above standards.

Table 3-34: PTACs/Window stock age and current standards.

System Size	System Age	Above Standard	At Standard	Below Standard	Missing Standard	Total	Wtd. Avg.
Large	>15 years old	0%	0%	10%	90%	100%	15%
	<15 years old	2%	0%	98%	0%	100%	19%
	Missing	100%	0%	0%	0%	100%	8%
	Total	20%	0%	47%	33%	100%	42%
Medium	>15 years old	53%	0%	47%	0%	100%	19%
	<15 years old	53%	0%	47%	0%	100%	14%
	Missing	28%	21%	9%	41%	100%	5%
	Total	50%	3%	42%	6%	100%	38%
Small	>15 years old	0%	0%	0%	0%	100%	0%
	<15 years old	100%	0%	0%	0%	100%	3%
	Missing	99%	0%	0%	1%	100%	17%
	Total	99%	0%	0%	1%	100%	20%
Grand Total		47%	1%	36%	16%	100%	100%

*All results are based on raked weights

3.2.2 HVAC heating findings

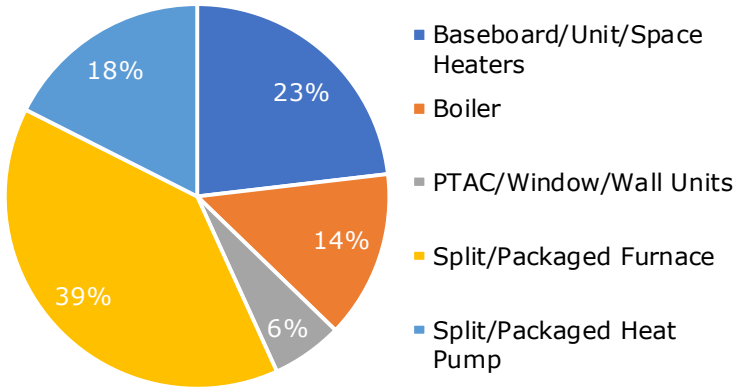
The following section highlights findings from the analysis of the heating equipment data. Heating equipment was analyzed by type of equipment and by fuel. Only electric and natural gas-consuming equipment have been included in this study. For split and packaged heating equipment, an efficiency analysis compared the efficiency of heating units to Federal efficiency standards[8].

The field staff collected information on the type of heating equipment and heating fuel used in Rhode Island businesses. The types of heating equipment included in the study were split into five categories:

1. Split/Packaged Furnace (RTUs, furnaces, etc.)
2. Split/Packaged Heat Pump
3. PTAC/PTHP/Window/Wall Units/CRAC
4. Baseboard/Unit/Space Heaters[9]
5. Boilers (hot water, steam)

Figure 3-7 below shows the weighted percent of various heating units found onsite. 14% of the units found were Boilers which include both steam and hot water boilers and 39% of the unit were split/packaged furnace units which include gas fired warm air duct furnaces.

Figure 3-7: Distribution of heating equipment units



*All results are based on raked weights

The bottom row of Table 3-35 shows the saturation of each heating system estimated in Rhode Island with its relative precision shown in Table 3-36. Split and packaged heating furnace units are the most commonly observed heating sources, representing 39% of heating units. Smaller sized baseboard/space/unit heaters account for 23% of heating units, boilers represent 14% of units, 18% are split and packaged heat pumps and 6% are PTAC/window/wall heating units. Campuses and Hospitals primarily use boilers for heating while retail, food service and sales, education, public assembly and warehouses use more packaged systems than other heating units.

[8] The heating system standards are found in the Code of Federal Regulations at 10 CFR 431.97; https://ecfr.io//Title-10/pt10.3.431#se10.3.431_187;

[9] These units are stand-alone units which use natural gas or electricity for heating fuel.

Table 3-35: Distribution of heating equipment across business types

Business type	n	Total Qty.	Baseboard/ Unit/ Space Heaters	Boilers	PTAC/ Window	Split/ Pack Furnace	Split/ Pack HP	Total	Wtd. Avg.
Campuses	2	2,618	0%	100%	0%	0%	0%	100%	3.3%
Education	4	15,640	0%	3%	0%	96%	1%	100%	19.8%
Food Sales	6	1,080	28%	0%	1%	62%	9%	100%	1.4%
Food Service	6	3,638	0%	3%	0%	97%	0%	100%	4.6%
Healthcare	3	3,283	0%	5%	0%	5%	91%	100%	4.2%
Hospitals	2	303	0%	56%	0%	0%	44%	100%	0.4%
Lodging	5	5,415	0%	6%	87%	4%	3%	100%	6.9%
Manufacturing/ Industrial	17	7,117	91%	3%	0%	4%	1%	100%	9.0%
Office	17	13,901	40%	9%	0%	21%	30%	100%	17.6%
Other	3	206	15%	13%	0%	44%	29%	100%	0.3%
Public Assembly	8	935	0%	3%	0%	85%	12%	100%	1.2%
Retail	9	24,511	24%	24%	0%	28%	24%	100%	31.0%
Warehouse	2	361	23%	0%	0%	77%	0%	100%	0.5%
Weighted Average	**84**	**79,008**	**23%**	**14%**	**6%**	**39%**	**18%**	**100%**	**100.0%**

*All results are based on raked weights

Table 3-36: Relative Precision at 90% CI for the distribution of the heating system by business type

Business type	n	Total Qty.	Baseboard/ Unit/ Space Heaters	Boiler	PTAC/ Window	Split/ Pack Furnace	Split/ Pack HP	Wtd. Avg.
Campuses	2	2,618	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Education	4	15,640	N.A.	±13.1%	N.A.	±15.3%	±8.2%	N.A.
Food Sales	6	1,080	±30.2%	N.A.	±5.0%	±32.5%	±19.2%	N.A.
Food Service	6	3,638	N.A.	±10.9%	N.A.	±11.5%	±3.9%	N.A.
Healthcare	3	3,283	N.A.	±19.9%	N.A.	±19.9%	±27.4%	N.A.
Hospitals	2	303	N.A.	±57.8%	N.A.	N.A.	±57.8%	N.A.
Lodging	5	5,415	N.A.	±17.6%	±25.0%	±14.9%	±12.4%	N.A.
Manufacturing/ Industrial	17	7,117	±11.1%	±7.2%	N.A.	±8.2%	±3.3%	N.A.
Office	17	13,901	±19.5%	±11.5%	N.A.	±16.3%	±18.3%	N.A.
Other	3	206	±33.5%	±31.5%	N.A.	±47.1%	±43.2%	N.A.
Public Assembly	8	935	N.A.	±9.2%	N.A.	±20.7%	±19.1%	N.A.
Retail	9	24,511	±23.3%	±23.3%	N.A.	±24.7%	±23.5%	N.A.
Warehouse	2	361	±48.9%	N.A.	N.A.	±48.9%	N.A.	N.A.
Weighted Average	**84**	**79,008**	±7.6%	±6.2%	±4.2%	±8.8%	±6.8%	N.A.

*All results are based on raked weights

Table 3-37: Heating efficiency parameters and standards [10]

Classification	Input Capacity [kBtuh]	Sample (n)	Fuel Type	Federal[10] Efficiency Minimum	Efficiency Units	Overall Stock Distribution
Split/Packaged HP	< 65	18	Elec.	7.7	HSPF	22.4%
Split/Packaged HP	≥ 65 and < 135	18	Elec.	3.3	COP	0.0%
Split/Packaged HP	≥ 135	18	Elec.	3.2	COP	0.0%
Water-Source HP	< 135	1	Elec.	4.3	COP	0.1%
Split/Packaged Furnace	< 225	48	Nat Gas	80%	AFUE	54.2%
Split/Packaged Furnace	≥ 225	48	Nat Gas	80%	Thermal Efficiency	3.2%
Steam Boiler	≤2,500	9	Nat Gas	79%	Thermal Efficiency	0.1%
Steam Boiler	>2,500	9	Nat Gas	79%	Thermal Efficiency	0.4%
Hot Water Boiler	≤2,500	20	Nat Gas	80%	Thermal Efficiency	19.5%
Hot Water Boiler	>2,500	20	Nat Gas	82%	Combustion Efficiency	0.1%
					Grand Total	**100%**

*The distribution presented in this table does not include baseboard/unit/space heaters and PTAC/Window/Wall Units data

Table 3-37 presents the current federal standards for heating systems by system type and size. The rightmost column provides the overall stock distribution of the units and sizes observed in this study. Nearly half were natural gas warm air (split/packaged) furnaces of less than 225 kBtuh. 16.6% of the stock was found to be smaller heat pumps that are <65 kBtuh sizes while medium or large air-cooled heat pumps were not observed in the sample. The majority of the Split/packaged furnaces found on site are found to be at or above federal standards and a smaller portion is below standards as shown in Table 3-38. 54% of the large steam boilers (>2,500 kBtuh) observed are below standard and 97% of the smaller (<2,500 kBtuh) hot water boilers are above the federal standards.

Table 3-38: Boilers, Split/Packaged Furnace and Heat pumps Efficiency and Distribution

Unit Type and Size	Qty (Ltd.)	Below Standard	Above or At Standard	Missing	Total
Split/Packaged HP: <65,000	12,094	1%	72%	27%	100%
Split/Packaged HP: Missing	1,724	0%	0%	100%	100%
Water Source HP: <135,000	46	100%	0%	0%	100%
Split/Packaged Furnace: <225,000	29,275	20%	80%	0%	100%
Split/Packaged Furnace: >225,000	1,704	0%	100%	0%	100%
Split/Packaged Furnace: Missing	43	0%	0%	100%	100%
Steam Boiler: ≤2,500,000	53	0%	100%	0%	100%
Steam Boiler: >2,500,000	230	54%	31%	15%	100%
Hot Water Boiler: ≤2,500,000	10,547	3%	97%	0%	100%
Hot Water Boiler: >2,500,000	75	100%	0%	0%	100%

*All results are based on raked weights

[10] Federal energy efficiency standards for C&I https://ecfr.io//Title-10/pt10.3.431#se10.3.431_177

3.3 Domestic hot water heating equipment

During domestic hot water (DHW) data collection, the DNV GL team recorded water heater model numbers and rated inputs where possible. These data, combined with equipment information lookups, were used to characterize the distribution of water heater efficiencies in Rhode Island. Table 3-39 shows the number of sites where model numbers and rated input were gathered.

Table 3-39: DHW unit counts by business types and customers where information was collected

Business	DHW Info Collected	Model# Data Collected DHW	Rated Input Data Collected
Campuses	2	2	1
Food Sales	5	4	4
Healthcare	4	4	4
Hospitals	2	2	2
Manufacturing/Industrial	17	15	17
Other	3	2	3
Public Assembly	8	8	8
Education	4	4	4
Food Service	6	5	5
Office	16	15	15
Lodging	5	5	5
Warehouse	2	1	0
Retail	10	7	7
Total	**84**	**74**	**75**

For the purpose of this study, water heaters were classified as storage, instantaneous or tank-less, boiler/central plant, or district steam and a few sites convert the district steam generated in a boiler to DHW using a heat exchanger. Table 3-40 illustrates the distribution of these system types across businesses in Rhode Island. Storage water heaters were found to represent the vast majority of water heaters (~86%) in the Rhode Island C&I market with a precision of ±6.2% at 90% confidence interval as shown in Table 3-41.

Table 3-40: DHW systems by business types

Business	n	Storage Water Heater	Instantaneous (Tank-less)	Central plant, shared service	Heat Exchanger	Total	Weighted Average
Campuses	2	98%	0%	2%	0%	100%	2.7%
Education	5	89%	4%	8%	0%	100%	1.1%
Food Sales	4	100%	0%	0%	0%	100%	1.5%
Food Service	2	100%	0%	0%	0%	100%	3.5%
Healthcare	17	72%	28%	0%	0%	100%	3.4%
Hospitals	3	80%	0%	0%	20%	100%	1.0%
Lodging	8	100%	0%	0%	0%	100%	3.4%
Manufacturing/ Industrial	4	97%	0%	3%	0%	100%	6.0%
Office	6	93%	7%	0%	0%	100%	19.3%
Other	16	100%	0%	0%	0%	100%	0.3%
Public Assembly	5	97%	3%	0%	0%	100%	0.9%
Retail	2	80%	20%	0%	0%	100%	56.5%
Warehouse	10	100%	0%	0%	0%	100%	0.5%
Weighted Average	84	85.9%	13.6%	0.3%	0.2%	100%	100.0%

*All results are based on raked weights

Table 3-41: Precisions at a 90% confidence interval around DHW systems by business types

Business	n	Storage Water Heater	Instantaneous (Tank-less)	Central plant, shared service	Heat Exchanger	Weighted Average
Campuses	2	±17.1%	N.A.	±17.1%	N.A.	±18.8%
Education	5	±23.4%	±14.1%	±19.5%	N.A.	±7.5%
Food Sales	4	±5.1%	±5.1%	N.A.	N.A.	±9.9%
Food Service	2	N.A.	N.A.	N.A.	N.A.	±21.4%
Healthcare	17	±17.9%	±17.9%	N.A.	N.A.	±7.2%
Hospitals	3	±38.2%	N.A.	N.A.	±38.2%	±9.3%
Lodging	8	N.A.	N.A.	N.A.	N.A.	±10.5%
Manufacturing/Industrial	4	±15.0%	±4.2%	±14.4%	N.A.	±19.5%
Office	6	±17.4%	±17.4%	N.A.	N.A.	±26.5%
Other	16	N.A.	N.A.	N.A.	N.A.	±2.3%
Public Assembly	5	±11.9%	±11.9%	N.A.	N.A.	±7.0%
Retail	2	±46.3%	±46.3%	N.A.	N.A.	±57.7%
Warehouse	10	N.A.	N.A.	N.A.	N.A.	±3.8%
Weighted Average	84	±6.2%	±6.1%	±1.0%	±0.8%	N.A.

About 13.6% of the water heaters are tankless or instantaneous systems. There is a small percentage of central and heat exchanger type heaters that were primarily seen in large education, campuses, hospitals, and manufacturing/industrial facilities.

Figure 3-8 illustrates the distribution of both fuel types collected in this study across the water heater units. Overall, 72% of the water heaters use electricity and 28% use natural gas. The study found other fuel types being used in Rhode Island, but they are not included in this study's data collection effort. The majority of the units observed were electric, smaller (capacity) units and natural gas units that were observed are less in quantity but larger in capacities.

Figure 3-8: Distribution of fuels based on the number of DHW units observed.

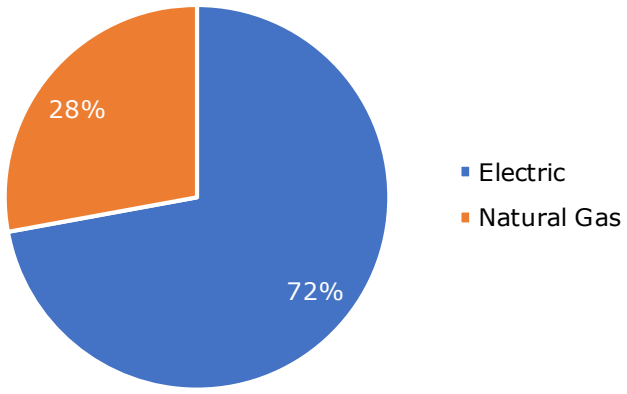


Table 3-42 below shows the federal efficiency standards for water heaters based on fuel type. We estimate 43% of the distribution in Rhode Island are Residential Electric sized storage and Instantaneous water heaters.

Table 3-42: Storage and instantaneous water heater efficiency parameters and standards

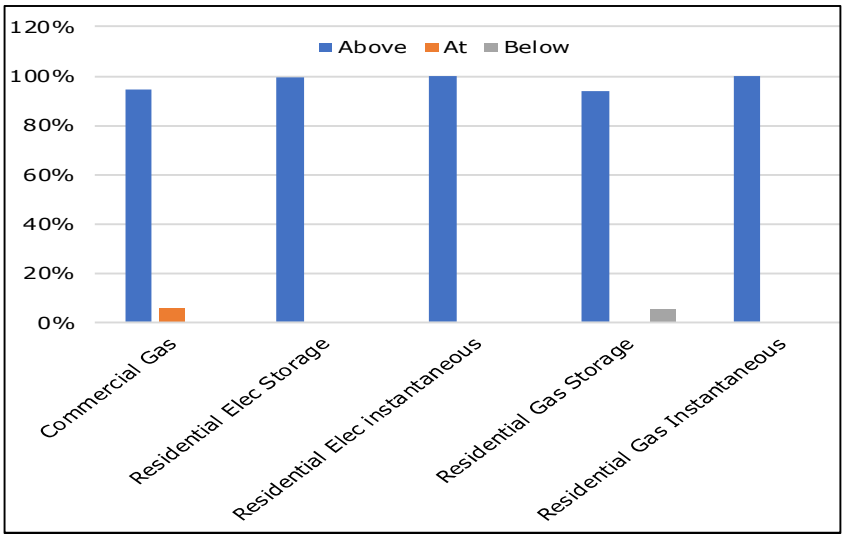
Classification	Sample (n)	Input capacity	Fuel type	Efficiency minimum[11,12]	Efficiency units	Overall stock distribution (weighted)
Residential Storage	12	≥20 gal and ≤55 gal	Nat. gas	0.6483 – (0.0017 × tank cap)	Energy factor	10.5%
Residential Storage	2	>55 gal and ≤100 gal	Nat. gas	0.7897 – (0.0004 × tank cap)	Energy factor	0.1%
Residential Instantaneous	1	<2 Gal and >50,000 Btu/h	Nat. gas	0.81	Energy Factor	1.1%
Residential Storage	22	≥20 gal and ≤55 gal	Elec	0.9307 – (0.0002 × tank cap))	Energy Factor	43.3%
Residential Storage	18	<20 gal	Elec	N/A	N/A	25.4%
Residential Instantaneous	2	<2 gal	Elec	0.91	Energy Factor	0.8%
Commercial Storage	9	All sizes	Elec	N/A	N/A	3.9%
Commercial Instantaneous	6	<10 gal and ≥ 10 gal	Nat. gas	80%	Thermal efficiency	11.9%
Commercial Storage	5	≤155, 000 Btu/h	Nat. gas	80%	Thermal efficiency	0.5%
Commercial Storage	12	≥ 200 KBtuh	Nat. gas	80%	Thermal efficiency	2.5%
Total	75					100%

Figure 3-9 below shows the distribution of water heater system types relative to the federal[11,12] efficiency standards for units, and fuel types, where federal standards are applicable. The majority of the units are either above or at standard. No minimum thermal efficiency is dictated for commercial electric storage water heaters. Residential Storage and Instantaneous water heaters with less than 20- and 2-gallons capacities respectively have no federal standards and therefore not included in the figure below. 5% of the residential gas storage units are below standards.

11 Federal energy efficiency standards (residential) https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8)

12 Federal energy efficiency standards (C&I) https://www.ecfr.gov/cgi-bin/text-idx?SID=a69096e892b13c204bbe6da3a92f8111&mc=true&node=se10.3.431_1110&rgn=div8 (commercial)

Figure 3-9: DHW systems Efficiency and Distribution



*All results are based on raked weights

3.4 Steam traps

Based on the data collected for steam boilers and steam traps, 10 sites use steam for heating, DHW and/or process purposes. The field staff conducted customer interviews to capture steam trap information, and 6 customers provided information on their steam trap systems. In consultation with National Grid, data collection was limited to asking site contacts about the quantity and maintenance practices used for steam traps.

Based on the customer interviews, our analysis of the steam traps data led to the following high-level findings:

- Four out of 6 sites conduct audits regularly
- All 6 sites pay for their own audits without any incentives and 4 customers receive incentives for steam trap replacements, regularly from National Grid. One customer did not have the information on the program-based incentives and if they have ever received any incentives from National Grid.
- Two customers had their last audit about 9-10 years ago, and the other 4 completed audits more recently (approximately 2 years ago).

3.5 On-site generation

The DNV GL team collected information on the on-site generation equipment in Rhode Island non-residential facilities. Of the 87 sites surveyed, 23 had an on-site generation, all 23 of them use emergency generators (EGs) and 2 of those sites also include co-generation.

Our analysis of the on-site generation data led to several high-level findings:

- A total of 32 EGs were found in 23 different sites. We could not access the EGs at 1 site due to ongoing construction work and 1 EG fuel type was unknown.
- The two Cogen systems were found at a hospital and a large campus site. The study did not include questions on system-level details.

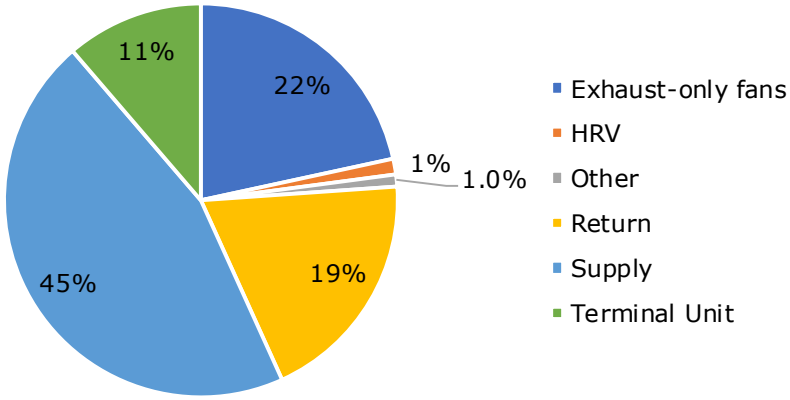
Table 3-43: Distribution of Emergency Generators and their fuel type

Fuel	Number of Sites	Total Units
Diesel	3	5
Multi-fuel	1	3 (1 Natural Gas, 2 Diesel)
Natural Gas	13	17
Oil	3	4
Propane	1	1
Unknown	2	2
Grand Total	**23**	**32**

3.6 Fan Motors & Drives

Fan motors and drives were primarily observed at 19 different sites. Figure 3-10 below shows various motor technologies found. A total of 310 (unweighted) motors were found and the majority (45%) of them are installed on supply fans. Typically, HVAC fan motors and drives are seen in larger buildings.

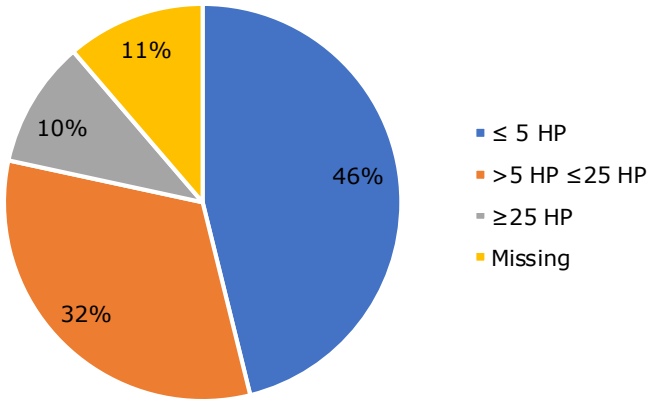
Figure 3-10: Distribution of fan motors (unweighted)



The field staff also verified if there are any variable speed or frequency drives (VSD or VFD) installed on each of the motors. 50% (unweighted) of the motors found did not have any VSD/VFDs installed on them, 35% had either VSDs or VFDs installed and 11% of the motors were missing information on the drives.

Figure 3-11 below illustrates the distribution of motors by size in HP. 46% of the motors installed are less than or equal to 5 HP and 10% of the motors found were greater than 25 HP. About 32% of the fan motors are between 5 and 25 HP while about 11% of the motor capacities weren't observed due to missing name plates or accessibility issues.

Figure 3-11: Distribution (unweighted) of motors by size (HP)



APPENDIX A. BUSINESS TYPE CLASSIFICATION DEFINITIONS

The building type classifications used in this report closely follow the definitions used for CBECS.

Business type	Definition	Includes
Education	K-12 buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings	elementary or middle school, high school, preschool or daycare, adult education, career or vocational training
Campuses	College or university facilities located on or as part of an education campus including non-classroom buildings	college or university buildings
Food sales	Buildings used for retail or wholesale of food	a grocery store or food market, gas station with a convenience store, convenience store
Foodservice	Buildings used for preparation and sale of food and beverages for consumption	fast food, restaurant or cafeteria, bar, catering service or reception hall
Health care (outpatient)	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building)	medical office (see the previous column), clinic or other outpatient health care, outpatient rehabilitation, veterinarian
Hospitals	Buildings used as diagnostic and treatment facilities for inpatient care	Hospital, an inpatient rehabilitation
Lodging	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings	motel or inn, hotel
Manufacturing or Industrial	Buildings that are industrial or manufacturing based	manufacturing or industrial, wastewater or water treatment, assembly, brewery/winery/distillery, chemical production
Office	Buildings used for general office space, professional office, or administrative offices	administrative or professional office, government office, mixed-use office, bank or other financial, police station, fire station
Other	Buildings that are agricultural or other miscellaneous buildings that do not fit into any other category	Agriculture, airplane hangar, crematorium, laboratory, telephone switching, energy/telecommunications, data center or server farm

Business type	Definition	Includes
Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls	social or meeting, recreation (e.g. gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports), entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club), library, funeral home
Retail	Buildings used for the sale and display of goods other than food	retail store, rental center, dealership or showroom, enclosed mall, strip shopping center
Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage)	refrigerated warehouse, non-refrigerated warehouse, distribution or shipping center

APPENDIX B. DATA COLLECTION INSTRUMENT

Table 3-44: General site information

Question	Answer
Site ID	RIM16570
Electric Utility Account Number	1234567890
Specify total number of buildings under this account	1
Total number of buildings surveyed	1
Stratum	2
Business Name	XXXXXX
Contact Name	Mr.X
Account Address	1 Main St
Account City	Atown
Account State	RI
Account Zip	000000
Contact Phone 1	123-456-7890
Contact Phone 2	
Contact Email	xxx@yyy.com
Survey Date	5/1/2019
Choose Facility type (use building definition for reference)	*Office*
Approximate Building Built Year	2005
Approximate Building Area (ft^2)	10,000
Approximate occupant count in the building	NA
If Hospital/Hotel, total bed counts	NA
Number of shifts/day	1
How many floors in the building?	5
Number of conditioned floors	5
Have you recently participated in any energy efficiency program through your utility provider? Yes/no	*Yes*
If yes, choose a program (or enter name if not on the list)	Small Business
If Other	
Choose year of participation?	2016
Approximate % Space Surveyed (to be filled after the site-visit)	100
Other Comments/Notes	

Table 3-45 Lighting inventory

Fixture Type #	Question	Example
	Enter Area ID (for proxy expansion)	1
	Equipment Qualifier	Observed on Site
	AGE (years)	10
	Choose Interior/Exterior	Interior
	Space Name	Classroom/Lecture/Training
	If Other (specify space-type)	
	Space Area (ft^2)	2000
	Conditioned Space?	Yes
1	Lamp Type	Linear_fluorescent
1	If Other (specify lamp-type)	
1	Lamp Description	T8
1	Fixture Length (Ft) for linear fixtures only	4
1	Number of Lamps	2
1	Lamp linear feet (Strip lighting)	
1	Enter Wattage per lamp (or per feet)	28
1	Fixture Quantity	12
1	Ballast	Electronic
1	Fixture Control Type?	Daylight/Photocell
1	Notes	6 fixtures controlled by Daylight, rest on manual
2	Lamp Type	Exit_Sign
2	If Other (specify lamp-type)	
2	Lamp Description	LED
2	Fixture Length (Ft)	
2	Number of Lamps	1
2	Lamp linear feet (Strip lighting)	
2	Enter Wattage per lamp (or per feet)	4
2	Fixture Quantity	2
2	Ballast	ChooseOne
2	Fixture Control Type?	24x7
2	Notes	

Table 3-46: DHW inventory

Question	DHW System 1	DHW System 2
Select Equipment Qualifier	Observed on-site	Observed on-site
Enter Area ID (if multiple, enter all)	Architecture Building	
Choose DHW Type	Storage Water Heater	
If other (DHW type)		
Choose Condensing/Non-Condensing Unit	Non-Condensing Unit	
Choose DHW fuel type	Natural Gas	
Choose DHW service type	DHW only	
Enter DHW manufacturer name		
Enter DHW model number		
Enter DHW manufactured year		
Enter DHW quantity		
Enter DHW tank capacity (gallons)		
Enter DHW rated input capacity		
Choose DHW input capacity units		
Enter DHW efficiency (EF or AFUE %)		
Enter approximate % pipe insulation		
Comments		

Table 3-47: Furnace inventory

Furnaces & Boilers	System 1	System 2
Equipment Qualifier	*Observed on-site*	
Enter Area ID (if multiple, enter all)		
Choose furnace/boiler type	*Warm air duct furnaces, gas fired*	
If other (furnace/boiler type)		
Enter manufacturer name		
Enter boiler/furnace manufactured year		
Enter boiler/furnace model number		
Enter boiler/furnace Output Btu/h		
Select Condensing or Non-Condensing		
Choose efficiency #1 units (AFUE, Et, Ec)		
Enter efficiency #1 value		
Choose efficiency #2 units (AFUE, Et, Ec)		
Enter efficiency #2 value		
Enter boiler/furnace quantity		
Enter approximate area (sq.ft.) served		
Comments		

Table 3-48: Chiller inventory

CHILLERS	System 1	System 2
Select Equipment Qualifier	*Observed on-site*	*Building plans*
Enter Area ID (if multiple, enter all)		
Choose equipment type	*Water-Cooled Chiller*	*Air-Cooled Chillers*
Enter Chiller manufacturer name		
Enter Chiller model number		
Enter Chiller manufactured year		
Enter Chiller total capacity (tons)		
Choose efficiency units		
Enter Full load efficiency		
Enter IPLV value		
Enter Chiller quantity		
Economizer (yes/no)		
Choose refrigerant type		
Chilled Water Pump (CHWP) #1 Model Number		
CHWP#1 HP /pump		
CHWP#1 name plate efficeincy		
CHWP#1 VFD/VSD		
CHWP#1 type (primary/secondary/backup)		
CHWP#1 quantity		
Chilled Water Pump (CHWP) #2 Model Number		
CHWP#2 HP /pump		
CHWP#1 name plate efficeincy		
CHWP#2VFD/VSD		
CHWP#2 type (primary/secondary/backup)		
CHWP#2 quantity		
Enter Condenser water primary pump model number		
Enter Condenser water primary pump quantity		
Enter Condenser water primary pump HP/pump		
Enter Condenser water pump motor name plate efficiency (%)		
Condenser water pump VFD or VSD?		
Enter approximate area (sq.ft.) served		
Comments		

Table 3-49: Packaged units inventory

Packaged Unit	System 1	System 2	System 3
Select Equipment Qualifier	*Observed on-site*		
Enter Area ID (if multiple, enter all)			
Select Cooling equipment type			
Enter Manufacturer Name			
Enter model number			
Output Btu/h- *enter value*			
Enter quantity			
Cooling efficiency #1 (IPLV, IEER)- *enter value*			
Select efficiency unit #1			
Cooling efficiency #2 (IPLV, IEER)- *enter value*			
Select efficiency unit #2			
Choose heating equipment type			
Choose heating fuel type			
Economizer (yes/no)			
Enter approx.manufactured year			
Choose refrigerant type			
Enter approximate area (sq.ft.) served			
Hydronic Cell/Other Central Heating Equipment			
Hydronic Cell Type			
ydronic cell capacity (kW or kBtuh: specify)			
Enter Quantity			
Enter approx.manufactured year			
Enter approximate area (sq.ft.) served			
Comments/Notes			

Table 3-50: Heat pumps inventory

Heat Pumps	System 1	System 2
Select Equipment Qualifier	*Building plans*	*Building plans*
Enter Area ID (if multiple, enter all)		
Choose Heatpump type	*Ductless Heat pump*	*VRF: Variable Refrigerant Flow Heat Pump*
Enter manufacturer name		
Enter model number		
Enter Output Btu/h		
Enter Cooling efficiency #1 value		
Choose Cooling efficiency unit #1 (SEER/EER)		
Enter Cooling efficiency #2 (IPLV, IEER)		
Choose Cooling efficiency unit #2		
Heating efficiency (COP, HSPF)		
Choose Heating efficiency unit		
Choose Heating equipment type		
Enter Quantity		
Economizer (yes/no)		
Enter Heat Pump manufactured year		
Choose refrigerant type		
Enter approximate area (sq.ft.) served		
Comments		

Other equipment types that were collected included PTAC's and PTHPs, Heat Rejection, Steam Traps, and Power Generation.

APPENDIX C. FINAL WEIGHTS

Sector	Site ID	Size	Participant/ Non-Participant	Case Weights	Final weight
Campuses	RIM10007	Large	Participant	3	1.5
Campuses	RIM10205	Large	Participant	85	43.4
Education	RIM10223	Small	Participant	331.5	375.5
Education	RIM10326	Small	Non-Participant	331.5	15,020.3
Education	RIM10917	Small	Participant	48.5	54.9
Education	RIM10969	Medium	Participant	34	10.4
Food Sales	RIM10019	Medium	Participant	14.5	2.8
Food Sales	RIM11042	Small	Non-Participant	293.5	620.0
Food Sales	RIM11122	Small	Participant	293.5	47.6
Food Sales	RIM11600	Small	Non-Participant	45.5	96.1
Food Sales	RIM11604	Small	Non-Participant	45.5	96.1
Food Sales	RIM11686	Medium	Participant	14.5	2.8
Food Service	RIM11743	Small	Participant	811	43.4
Food Service	RIM11828	Small	Non-Participant	811	1,735.1
Food Service	RIM13373	Small	Participant	280	15.0
Food Service	RIM13900	Small	Participant	99.5	5.3
Food Service	RIM13914	Small	Participant	99.5	5.3
Healthcare	RIM10033	Medium	Participant	32	60.8
Healthcare	RIM14144	Small	Non-Participant	785.5	417.2
Healthcare	RIM14199	Small	Participant	2416	89.9
Healthcare	RIM16553	Small	Participant	48.5	1.8
Healthcare	RIM16570	Small	Non-Participant	292	155.1
Healthcare	RIM16810	Medium	Participant	32	60.8
Hospitals	RIM10040	Large	Participant	2	6.3
Hospitals	RIM16920	Small	Participant	127	133.9
Lodging	RIM16974	Small	Non-Participant	139.5	101.7
Lodging	RIM17031	Small	Participant	139.5	22.6
Lodging	RIM17239	Medium	Participant	16.5	20.9
Lodging	RIM17240	Medium	Participant	16.5	20.9
Lodging	RIM17272	Medium	Participant	13	16.5
Manufacturing/Industrial	RIM10054	Medium	Participant	23.625	3.9
Manufacturing/Industrial	RIM17323	Small	Participant	449.1428571	28.4
Manufacturing/Industrial	RIM17399	Small	Non-Participant	449.1428571	628.9
Manufacturing/Industrial	RIM17454	Small	Non-Participant	449.1428571	628.9
Manufacturing/Industrial	RIM17459	Small	Non-Participant	449.1428571	628.9
Manufacturing/Industrial	RIM17527	Small	Participant	449.1428571	28.4
Manufacturing/Industrial	RIM17561	Small	Non-Participant	449.1428571	628.9
Manufacturing/Industrial	RIM17577	Small	Participant	449.1428571	28.4
Manufacturing/Industrial	RIM20474	Medium	Participant	23.625	3.9
Manufacturing/Industrial	RIM20522	Medium	Non-Participant	23.625	156.7
Manufacturing/Industrial	RIM20545	Medium	Participant	23.625	3.9
Manufacturing/Industrial	RIM20546	Medium	Participant	23.625	3.9
Manufacturing/Industrial	RIM20575	Medium	Participant	23.625	3.9
Manufacturing/Industrial	RIM20600	Large	Participant	20	24.4
Office	RIM20762	Small	Non-Participant	785.5	1,723.4
Office	RIM20812	Small	Non-Participant	785.5	1,723.4
Office	RIM20844	Small	Participant	785.5	57.7
Office	RIM20851	Small	Non-Participant	37.5	82.3
Office	RIM20887	Small	Non-Participant	785.5	1,723.4
Office	RIM20939	Small	Participant	785.5	57.7
Office	RIM21035	Small	Non-Participant	785.5	1,723.4
Office	RIM21051	Small	Non-Participant	785.5	1,723.4

Office	RIM26925	Small	Non-Participant	82.71428571	181.5
Office	RIM26927	Medium	Participant	82.71428571	190.3
Office	RIM26968	Small	Participant	82.71428571	6.1
Office	RIM26984	Small	Participant	82.71428571	6.1
Office	RIM27106	Small	Non-Participant	82.71428571	181.5
Office	RIM27190	Medium	Participant	82.71428571	190.3
Office	RIM27316	Medium	Participant	82.71428571	190.3
Office	RIM27505	Medium	Participant	31.5	72.5
Other	RIM10092	Large	Participant	84	12.9
Other	RIM27585	Small	Non-Participant	84	29.3
Other	RIM27648	Small	Non-Participant	84	29.3
Public Assembly	RIM10097	Medium	Participant	16	3.8
Public Assembly	RIM27817	Small	Participant	261.6666667	42.4
Public Assembly	RIM27860	Small	Non-Participant	261.6666667	42.9
Public Assembly	RIM27925	Small	Non-Participant	261.6666667	42.9
Public Assembly	RIM28577	Small	Participant	78	12.6
Public Assembly	RIM28578	Small	Participant	78	12.6
Public Assembly	RIM28727	Small	Non-Participant	16	2.6
Public Assembly	RIM28728	Medium	Non-Participant	16	151.2
Retail	RIM28797	Small	Non-Participant	1264.333333	5,814.4
Retail	RIM28813	Small	Non-Participant	1264.333333	5,814.4
Retail	RIM28875	Small	Non-Participant	1264.333333	5,814.4
Retail	RIM28911	Small	Participant	1264.333333	145.4
Retail	RIM28977	Small	Non-Participant	1264.333333	5,814.4
Retail	RIM28979	Small	Non-Participant	1264.333333	5,814.4
Retail	RIM36353	Small	Participant	318	36.6
Retail	RIM36380	Small	Participant	23.625	2.7
Retail	RIM36397	Small	Participant	23.625	2.7
Retail	RIM36525	Small	Participant	318	36.6
Retail	RIM36559	Small	Participant	280	32.2
Retail	RIM36776	Small	Participant	318	36.6
Retail	RIM37295	Medium	Participant	20	7.0
Retail	RIM37312	Medium	Participant	157	55.0
Retail	RIM37352	Medium	Participant	31.5	11.0
Warehouse	RIM37457	Small	Participant	37.5	277.5