2016 Vermont Business Sector Market Characterization and Assessment Study

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Vermont Department of Public Service
112 State Street
Montpelier, VT 05620

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Prepared by:
Mitt Jones
Dave Korn, PE, CEM
Eric Makela
Randy Mead
Monica Nevius, PhD (NMR)
Andrew Rietz
Casey Stevens

Cadmus

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CADMUS

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Introduction

The 2016 Vermont Business Sector Market Characterization and Assessment study provides baseline energy efficiency data for Vermont's business sector facilities as of 2016, largely through primary data collection. Site visits supported extensive characterization of business facilities in existing and new construction within the territory of each Energy Efficiency Utility (EEU) and for the state as a whole. Other study components include remaining potential for existing buildings, code compliance and missed opportunities for new construction, and market actor and participant surveys to evaluate program awareness and the effectiveness of program delivery.

The Vermont Department of Public Safety commissioned the study, selecting the Cadmus team through an RFP process. That team comprised Cadmus as the prime contractor and subcontractors NMR Group, Inc., and Steven Winter and Associations, Inc. NMR carried out most tasks related to market actor and participant surveys and related analysis. Steven Winter and Associates collected data at 100 of the 192 existing building sites.

Purpose of the Study

This study documents current baseline data for existing facilities and new construction throughout Vermont's business sector, in commercial and industrial facilities. The market characterization and assessment provides a milestone for progress made and serves as a roadmap for the remaining opportunities in energy efficiency, code compliance, and building operation. Objectives of the study include:

- Support assessment of demand-side resource potential.
- Document progress installing demand-side measures to improve business sector energy efficiency.
- Document progress toward compliance with 2012 and 2015 Vermont Commercial Building Energy Standards (CBES) in the new construction market.
- Identify opportunities to increase energy efficiency by adding new cost-effective requirements to the Vermont CBES.
- Aid in the development of market intervention strategies.
- Support effective business sector energy efficiency program delivery.

Scope of the Study

The Cadmus team study collected, analyzed, and presented data about business sector energy efficiency characteristics including envelope, lighting, HVAC, refrigeration, and motors and compressed air. Data collection was generally limited to what was observable during on-site data collection, though some data points were collected for some sites from building plans and/or telephone calls. Site visits began in late 2015, with most occurring between January and July of 2016.

The study comprised the following tasks:

- Document the energy-use characteristics of a sample of 192 business sector facilities in existing buildings.
- Document the energy-use characteristics of a sample of 48 business sector facilities in new construction sites and in spaces that have recently undergone major renovation. For the purposes of this report, facilities constructed or renovated in 2012 or later qualify as new construction.
- Characterize the energy efficiency of business facilities for Vermont as a whole and for the jurisdiction of each EEU—Efficiency Vermont (EVT), Burlington Electric Department (BED), and Vermont Gas Systems (VT Gas).
- Provide information necessary to compare the results of this market characterization with those of previous Vermont market characterization studies. In some cases, this involved breaking data down by different facility types than those referenced in the body of this report. In those cases, figures and tables created only for comparison purposes are provided in the appendices of this report.
- Assess compliance with the 2012 and 2015 Vermont CBES in new construction and major renovation projects.
- Identify areas of opportunity for improving energy efficiency in the business sector in Vermont, both with existing buildings and new construction.
- Conduct market actor interviews of electrical distributors, lighting suppliers, lighting professionals, and building decision-makers to identify and assess barriers and opportunities from emerging technologies.
- Conduct participant interviews to assess awareness of and attitudes toward applicable EEU programs.

Organization of the Report

The report is divided into separate sections for existing buildings and new construction, with each section further organizing content to provide subsections on methodology (including sampling), characterization of facilities, remaining or missed opportunities, and (for new construction) code compliance.

An additional section documents market actor and process methodology and findings for all business sector facilities, both new and existing.

Appendices provide survey instruments as well as facility characterization figures and tables that allow direct comparison with the 2011 market characterization reports.

Existing Buildings

Introduction

This section of the report documents the methodology and findings of the existing buildings portion of this baseline energy efficiency study. The Cadmus team collected extensive data on a sample of 192 C&I facilities throughout the state, stratified by EEU, facility size, and facility type. Sample weights were applied to extrapolate findings to represent the populations of existing building C&I facilities in each EEU and the state as a whole.

Study Methodology

The following paragraphs describe the methods used to design and carry out the characterization of C&I facilities in existing buildings in Vermont.

Data Sources

Cadmus obtained data for C&I existing building facilities in Vermont from two different data sources:

- A list of all existing building projects was obtained from InfoUSA.
  - Cadmus identified business facilities located within EVT jurisdiction and removed duplicate records for any business location, sites without valid contact information, and businesses that reported fewer than one employee.
- BED provided a list of existing building ID numbers associated with commercial accounts.
  - Cadmus removed duplicate records for any business location, projects without valid contact information, and businesses that reported fewer than one employee.

Cadmus conducted telephone surveys and site visits for C&I existing buildings in Vermont. We used data on EEUs to draw representative samples for site visits and telephone surveys. Telephone surveys allowed the Cadmus team to obtain information on customer awareness of EEUs and customer behaviors. Primary data collection through 192 site visits provided the majority of existing buildings data presented in this report.

Sampling Approach

Cadmus analyzed business sector facility data from InfoUSA and BED to stratify the population of projects according to facility size and type. The following sections detail the resulting sample design and weighting approach to extrapolate the sample results to the populations of interest.

Sample Design and Weights

Cadmus used stratified random sampling by facility type and energy consumption to obtain a sample that incorporated a broad selection of Vermont building types and sizes. Because of inconsistencies in the best data available for facilities in each EEU, Cadmus also performed post-stratification[1] for the EEU

[1] Post-stratification: stratification after selection of the sample.

populations of existing building C&I projects. We post-stratified the samples by unique combinations of facility-type categories and building-size bins.

To obtain population and sample sizes within strata, we first used facility size information provided by the data sources and verified by the site visits. Cadmus classified facility size into bins specified in Table 1, using facility size as a proxy for consumption. We then applied these categories to stratify the existing facility populations of EVT and BED utilities.

Table 1. Existing Building Size Categories

Square Footage	Facility Size Bins	Facility Consumption Bins
0:2,499	Small	Low
2,500:9,999	Medium	Medium
10,000 +	Large	High

Cadmus used sample weights to produce an accurate representation of results for the population based on what we observed in the sample. We used information from the samples and their populations to calculate weights separately for EVT and BED.

Cadmus calculated sample weights at the strata level using the following equation, where h represents the stratum, w_h represents the weight in each strata, N_h is the population size in each strata, and n_h is the sample size in each strata.

$$w_h = N_h/n_h$$

Cadmus assigned each site the sample weight of the stratum it was classified in specified in Table 2.

Table 2. Existing Building Sample Weights by Post-Strata

EEU	Facility Type*	Facility Consumption	Estimated Population	Number of Completed Sites	Sample Weight**
EVT	Food Sales	Low	144	3	48.0
	Food Sales	Medium	120	4	30.0
	Food Sales	High	86	4	21.5
	Food Service	Low	456	4	114.0
	Food Service	Medium	419	7	59.9
	Food Service	High	145	1	145.0
	Healthcare	Low	16	1	16.0
	Healthcare	Medium	31	4	7.8
	Healthcare	High	37	6	6.2
	Hospital	Low	4	0	NA
	Hospital	Medium	21	1	21.0
	Hospital	High	36	3	12.0
	Lodging	Low	304	9	33.8
	Lodging	Medium	124	2	62.0
	Lodging	High	142	2	71.0
	Manufacturing	Low	265	5	53.0
	Manufacturing	Medium	271	6	45.2
	Manufacturing	High	344	9	38.2
	Office	Low	5743	10	574.3
	Office	Medium	2870	6	478.3
	Office	High	2169	4	542.3
	Other	Low	2933	11	266.6
	Other	Medium	1035	5	207.0
	Other	High	455	3	151.7
	Retail	Low	1816	12	151.3
	Retail	Medium	909	5	181.8
	Retail	High	443	2	221.5
	School	Low	1	1	1.0
	School	Medium	13	3	4.3
	School	High	30	6	5.0
EVT Total			21,382	139	

EEU	Facility Type*	Facility Consumption	Estimated Population	Number of Completed Sites	Sample Weight**
BED	Food Sales	Low	10	2	5.0
	Food Sales	Medium	28	2	14.0
	Food Sales	High	3	1	3.0
	Food Service	Low	24	2	12.0
	Food Service	Medium	86	2	43.0
	Food Service	High	40	1	40.0
	Healthcare	Low	0	0	N/A
	Healthcare	Medium	1	1	1.0
	Healthcare	High	5	1	5.0
	Hospital	Low	1	0	N/A
	Hospital	Medium	2	0	N/A
	Hospital	High	1	1	1.0
	Lodging	Low	3	0	N/A
	Lodging	Medium	7	2	3.5
	Lodging	High	4	1	4.0
	Manufacturing	Low	48	2	24.0
	Manufacturing	Medium	30	5	6.0
	Manufacturing	High	86	1	86.0
	Office	Low	695	0	N/A
	Office	Medium	1213	6	202.2
	Office	High	649	3	216.3
	Other	Low	258	2	129.0
	Other	Medium	215	4	53.8
	Other	High	365	2	182.5
	Retail	Low	41	3	13.7
	Retail	Medium	174	3	58.0
	Retail	High	153	1	153.0
	School	Low	27	0	N/A
	School	Medium	61	4	15.3
	School	High	57	1	57.0
BED Total			4,287	53	
State Total			25,668	192	

* "Other" category includes (3) Food Sales, (1) Food Service, (2) Healthcare, (1) Hospital, (4) Lodging, (2) Schools, (23) Miscellaneous.

** N/A occurs when the stratum was not sampled from.

Using site-level information of weights and energy-saving measures, Cadmus calculated the sample weighted energy-saving measures. We identified formulas for sample weighted means, medians, counts, and proportions[2] and applied these to various energy-saving measures such as counts of lightbulb type

[2] Sampling Techniques, 3rd Edition, Wiley Series in Probability and Mathematical Statistics—Applied by Cochran, William G., 1977

and means of total lighting hours used to obtain population level information on the measures, with 85% confidence and approximately 15% precision for individual measures. Across all projects, we had a target of 90% confidence with approximately 10% precision.

Existing Buildings Telephone Surveys

Cadmus conducted telephone surveys with 221 customers from the existing building population. Table 3 shows the populations and distribution of completed telephone surveys within the sample areas for existing buildings.

Table 3. Existing Building Summary of Telephone Surveys by Area

Area*	Estimated Population	Number of Completed Surveys	Ratio (Completed to Population)
BED	4,287	58	1.4%
EVT	21,381	163	0.8%
Total	25,668	221	0.9%
VT Gas**		118	NA

* BED and EVT populations are mutually exclusive. VT Gas population overlaps BED and EVT.
** Because of insufficient and unreliable population data, VT Gas population estimates are excluded from this table.

Existing Buildings Site Visits

Of the 221 business locations contacted during the telephone surveys for existing building projects, the Cadmus team completed site visits at 192 sites across BED (53), EVT (139), and VT Gas (107). During site visits, field staff collected data including facility type, project cost, and building size (square feet); information on numerous energy-saving measures was also collected at each site.

Table 4 shows the populations and distribution of completed site visits across the sample areas for existing building projects.

Table 4. Existing Building Summary of Site Visits by Area

Area*	Estimated Population**	Number of Completed Sites	Ratio (Completed to Population)
BED	4,287	53	1.2%
EVT	21,381	139	0.7%
Total	25,668	192	0.7%
VT Gas***		107	NA

* BED and EVT populations are mutually exclusive. VT Gas population overlaps both BED and EVT.
** Population estimates are obtained through a list of all existing building projects in Vermont from InfoUSA and BED. Cadmus updated the original list to remove duplicated projects and projects with less than one employee.
*** Because of insufficient and unreliable population data, VT Gas population estimates are excluded from this table.

The Cadmus team maximized the number of site visits completed with respect to time and budget constraints for existing buildings. InfoUSA data provided robust population information on

characteristics such as facility size, facility type, and contact information for the project. Table 5 shows the distribution of the sample of site visits compared to targeted site visits across facility-type populations. Cadmus reports the results of 10 individual facility types for existing building projects.

Table 5. Existing Building Summary of Site Visits by Facility Type

Facility Type	Estimated Population	Number of Targeted Sites	Number of Completed Sites	Percentage of Completed to Target
Food Sales	391	16	16	100%
Food Service	1,170	16	17	106%
Healthcare	90	16	13	81%
Hospital	65	5	5	100%
Lodging	584	16	16	100%
Manufacturing	1,044	27	28	104%
Office	13,339	27	29	107%
Other*	5,261	27	27	100%
Retail	3,536	27	26	96%
School	188	16	15	94%
Total	25,668	193	192	99%

* “Other” category includes (3) food Sales, (1) food Service, (2) Healthcare, (1) Hospital, (4) Lodging, (2) Schools, (23) Miscellaneous.

Final Reporting Segments

Table 6 shows the final reporting segments over EEU areas.

Table 6. Existing Building Final Reporting Segments by EEU

<table>
<tr><th rowspan="2">Original Sample Area</th><th colspan="3">Reporting Segment</th></tr>
<tr><th>BED</th><th>EVT</th><th>VT Gas</th></tr>
<tr><td>A – BED/VT Gas</td><td>x</td><td></td><td rowspan="2">x</td></tr>
<tr><td>B – EVT/VT Gas</td><td></td><td rowspan="2">x</td></tr>
<tr><td>C – EVT/Non-VT Gas</td><td></td><td></td></tr>
</table>

Data Collection Approach

All participants for site visits and telephone surveys were randomly selected according to the stratified sample design. Information on response rates is included below.

Telephone Surveys

The Cadmus team conducted telephone surveys with 220 Vermont existing building businesses that took 2 to 3 minutes on average to complete. Telephone staff attempted to contact the person identified as the building manager or building owner to complete the telephone surveys because of their knowledge about cooling, heating, and lighting equipment at their facility. The survey focused on energy providers and customer knowledge of potential incentives to adopt energy efficiency measures related to their project.

The telephone survey designed for this study allowed the surveyor to categorize each project as one of the following:

- Existing building
- Major renovation completed in 2012 or later
- New construction completed in 2012 or later

The team conducted one round of telephone surveys sampled from the population of existing building projects from December 2015 to April 2016. Table 7 shows the response rates from these survey efforts.

Table 7. Existing Building Telephone Survey Response Rates

	Counts	Percentage of Customers Dialed
Customers Dialed*	712	100%
Reached (Total Reached)	590	82.9%
Reached (Decision-Maker)	295	41.4%
Refused	74	10.4%
Completed	221	31.0%

* Not all customers in the population were dialed because of factors including time, distance to travel, and valid contact information.

Site Visits

The Cadmus team offered survey participants a $100 gift card incentive to participate in the site surveys, ultimately conducting site visits for 192 of the 221 existing building projects reached by the telephone survey. Field staff collected detailed inventories of energy equipment and building characteristics by inspection, including the following qualities:

- Facility size and type based on predetermined categories
- Building envelope information, such as insulation levels and wall and window sizes
- Complete inventories of energy equipment comprising end uses such as lighting, refrigeration, chiller systems, boiler systems, HVAC, ventilation rates, domestic and service hot water, plug loads, and desktop and server IT, data centers, kitchens, laundry areas, renewable energy, control systems, sub-metering and building analytics, and building operations and behavior

Data Analysis Approach

The data analysis performed involved data visualization, descriptive statistics, quality assurance, summary of quantitative results, and result comparisons across data variables to describe C&I facilities in Vermont. All data collected went through rigorous quality assurance and quality control protocols. Data from site visits were reviewed for legitimacy, and a team of analysts filled in missing data using methods of extrapolation and web searching. Cadmus used telephone survey information collected to gain a better understanding of consumer behavior and incentives.

Existing Buildings Commercial and Industrial Market Characterization

This chapter reports weighted estimates of the energy efficiency characteristics of Vermont commercial and industrial facilities in existing buildings. Results are provided for the following facility populations and strata, with weighting applied as necessary to represent each population:

- Statewide population of Vermont C&I facilities
- Population of C&I facilities within each Vermont EEU, including BED, EVT, and VT Gas
- Small, medium, and large C&I facilities, as defined in Table 1
- Ten facility types, as defined in Table 5

The results are based on on-site surveys conducted between September 2015 and July 2016 and, where applicable, telephone surveys conducted between December 2015 and April 2016.

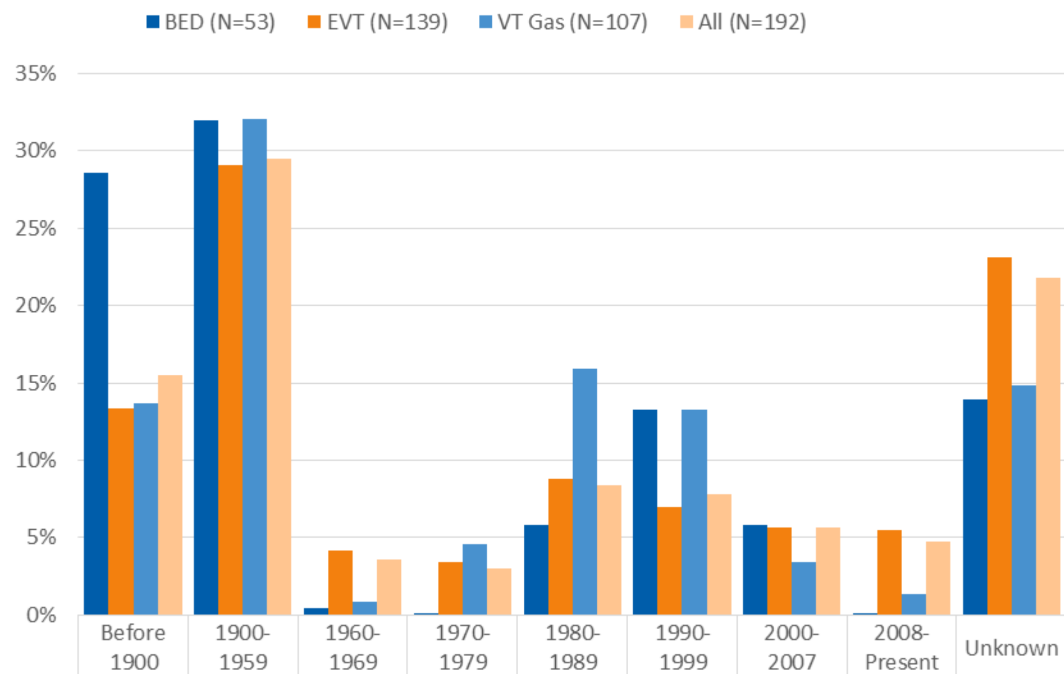
General Building Information

Surveyors collected information regarding general building characteristics such as age, size, operating schedules, and more. The following sections present the results for key building characteristics.

Facility Age

Figure **1** shows the distribution of building construction year by EEU. The majority of buildings in BED territory were constructed prior to 1960 (61%) and approximately half of the buildings in VT Gas territory (47%) were constructed before 1970. Statewide, approximately 16% of all buildings were built prior to 1900, with a significantly higher proportion of BED buildings built in this era (29%) than VT Gas buildings (14%). All three EEU territories saw steady construction of new buildings from 1980 through 2007, with the VT Gas territory having the highest amount of new construction during this period: 32% of VT Gas buildings were built between 1980 and 2007. Only the EVT territory has had significant new construction since 2008.

Figure 1. Year of Building Construction by EEU (N=192)

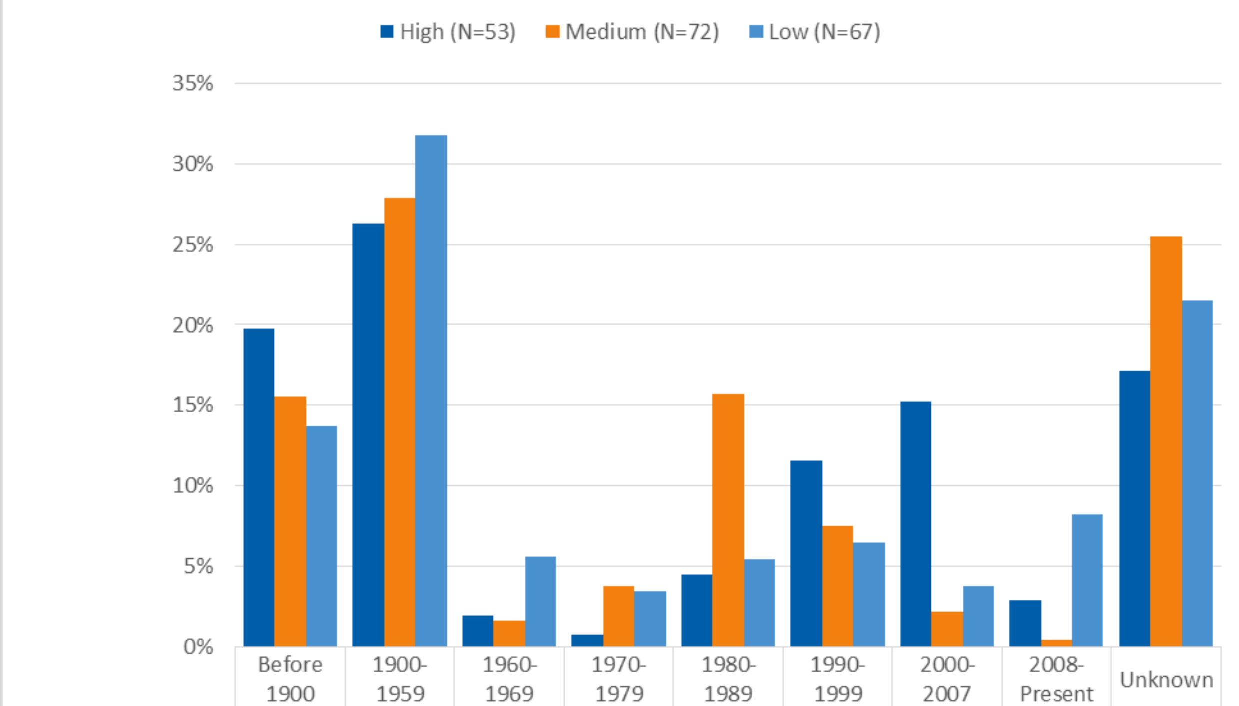


	Before 1900	1900-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2007	2008-Present	Unknown
BED (N=53)	29%	32%	0%	0%	6%	13%	6%	0%	14%
EVT (N=139)	13%	29%	4%	3%	9%	7%	6%	5%	23%
VT Gas (N=107)	14%	32%	1%	5%	16%	13%	3%	1%	15%
All (N=192)	16%	29%	4%	3%	8%	8%	6%	5%	22%

Facility Size

As shown in Figure 2, construction trends tend to vary across facility size strata. In the High strata, 46% of buildings were built prior to 1960 and an additional 27% were built from 1990 to 2007. Outside of those timeframes, only very limited construction was seen in that strata. The Low strata features the most consistent new construction from 1960 through the present, with 3% to 8% of the facilities visited being built in each of those bins. The medium strata features very little new construction after 1960, with the exception of 1980 to 1989, during which time 16% of the facilities visited were built.

Figure 2. Year of Building Construction by Facility Size (N=192)



	Before 1900	1900-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2007	2008-Present	Unknown
High (N=53)	20%	26%	2%	1%	4%	12%	15%	3%	17%
Medium (N=72)	16%	28%	2%	4%	16%	7%	2%	0%	25%
Low (N=67)	14%	32%	6%	3%	5%	6%	4%	8%	22%

Approximately 79% of facilities in existing buildings statewide occupy 10,000 sq ft or less, and roughly 55% occupy 5,000 sq ft or less, as shown in Figure 3. Only 2% of existing building C&I facilities in Vermont are larger than 50,000 sq ft.

Figure 3. Total Square Footage for All Sites (N=192)

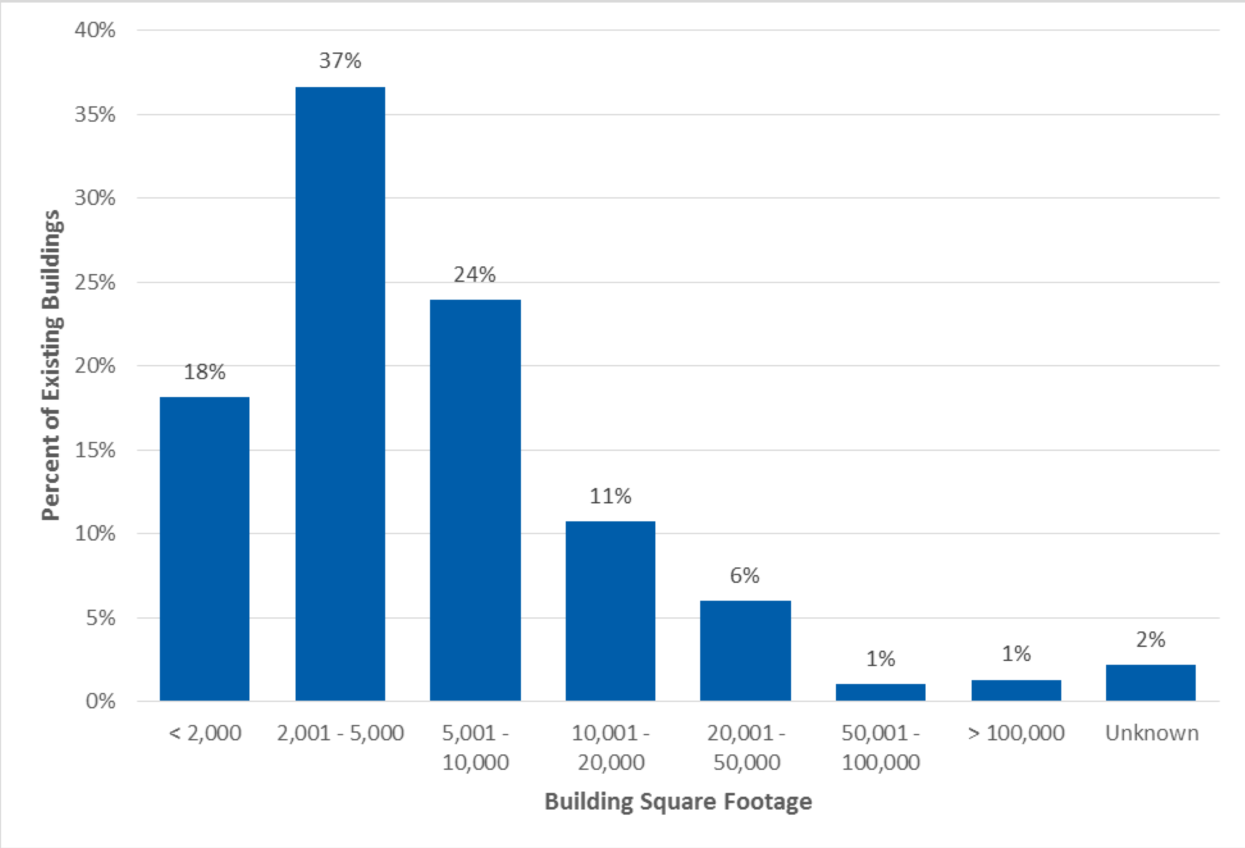


Table 8 shows the square footage by size strata and EEU. Only 2% of facilities statewide occupy more than 50,000 square feet, but these facilities represent 27% of the total square footage statewide.

In BED territory, approximately 46% of the overall square footage is attributed to buildings greater than 50,000 sq ft, compared to 19% of the overall square footage in EVT territory. The opposite is true for buildings smaller than 10,000 sq ft: 45% of EVT's square footage is in buildings smaller than 10,000 sq ft, whereas only 15% of BED's square footage falls in the same range. The VT Gas distribution is most similar to the size distribution of BED buildings except in the 50,001 to 100,000 sq ft range, where the distribution matches the EVT distribution.

Table 8. Total Square Footage by Facility Size and EEU (N=192)

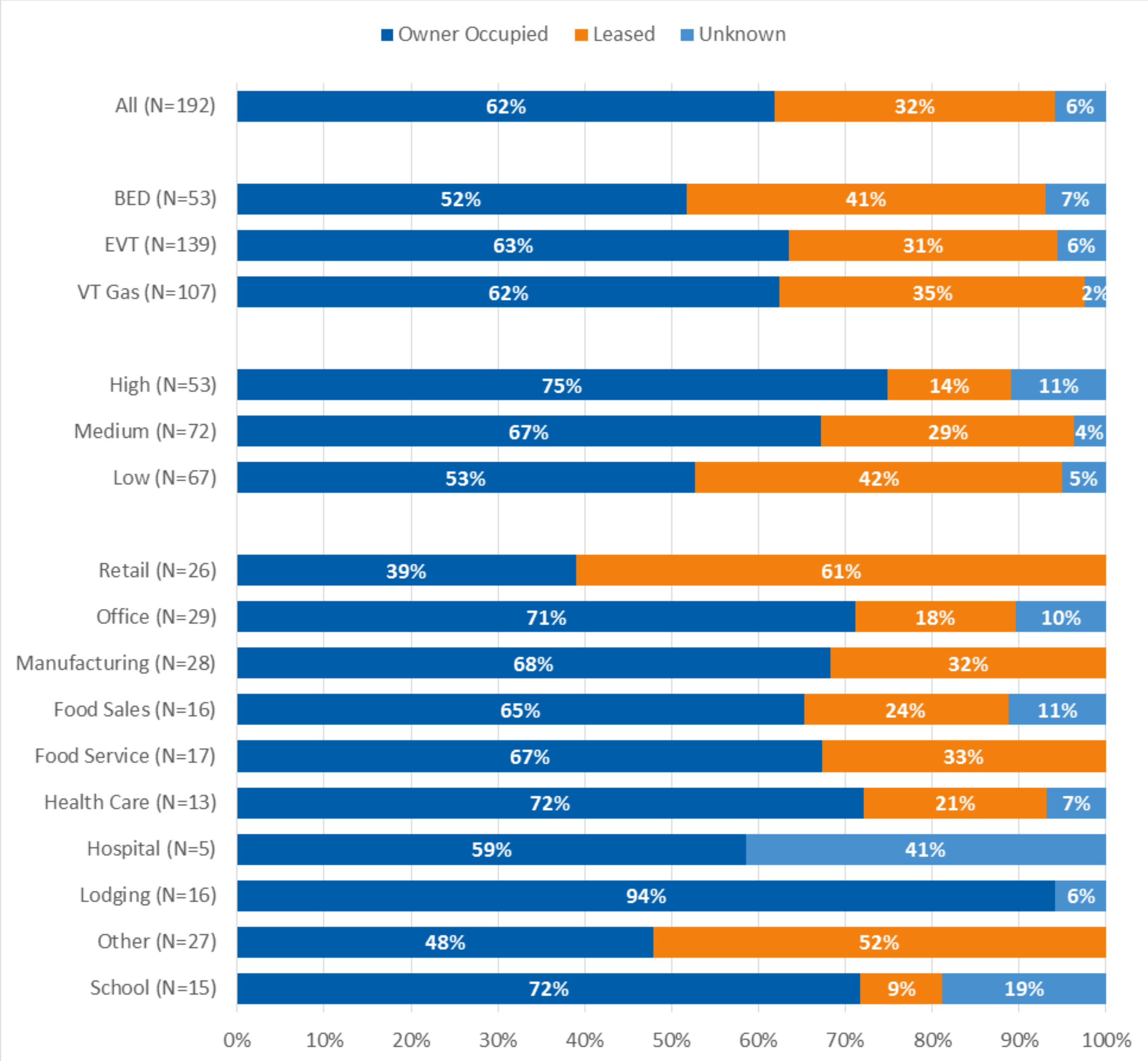
Building Square Footage	Size Stratum			EEU			All (N=192)
	High (N=53)	Medium (N=72)	Low (N=67)	BED (N=53)	EVT (N=139)	VT Gas (N=107)	
≤ 2,000	0%	2%	13%	1%	4%	2%	3%
2,001–5,000	0%	20%	47%	6%	16%	10%	13%
5,001–10,000	7%	37%	40%	8%	25%	10%	20%
10,001–20,000	25%	18%	0%	9%	22%	12%	18%
20,001–50,000	23%	23%	0%	30%	14%	27%	19%
50,001–100,000	12%	1%	0%	1%	10%	10%	7%
> 100,000	34%	0%	0%	45%	9%	30%	20%
Unknown	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%
Mean	23,731	6,792	3,202	17,772	7,099	11,860	8,622
Median	15,000	5,073	2,712	6,154	3,500	3,100	3,750

Facility Ownership

Figure **4** shows that the majority of commercial facilities statewide (62%) are owner-occupied. This is true across all of the strata shown in Figure 4, except for retail and "other" facilities, which are only 39% and 48% owner-occupied, respectively. Other findings from Figure 4 include:

- BED customer are less likely to own their facilities (52%) than either VT Gas or EVT customers (62% and 63%, respectively).
- Smaller facilities are less likely to be owner-occupied (53%) than facilities in the medium (67%) or high strata (75%).
- Lodging facilities have the higher rate of owner occupancy in the state, with an owner occupancy rate of 94%.

Figure 4. Facility Ownership (N=192)



Business Information

Similar to 2011, the estimated mean number of full-time employees in Vermont is 12 (previously 10), and the median is four (previously five), as shown in Table 9. BED and VT Gas territories have the highest estimated average number of employees, with 39 and 18, respectively. As expected, the number of employees correlates well with facility size. Smaller facilities have fewer employees (4) and larger facilities tend to have more (34). The average number of employees is similar between retail, office, and manufacturing facilities, which average 11, 13, and 13 employees, respectively.

Hospitals have the highest estimated average number of employees per facility (167) followed by schools (26) and health care facilities (24). Retail, office, manufacturing, and lodging facilities are all very close to the statewide average of 12 full-time employees.

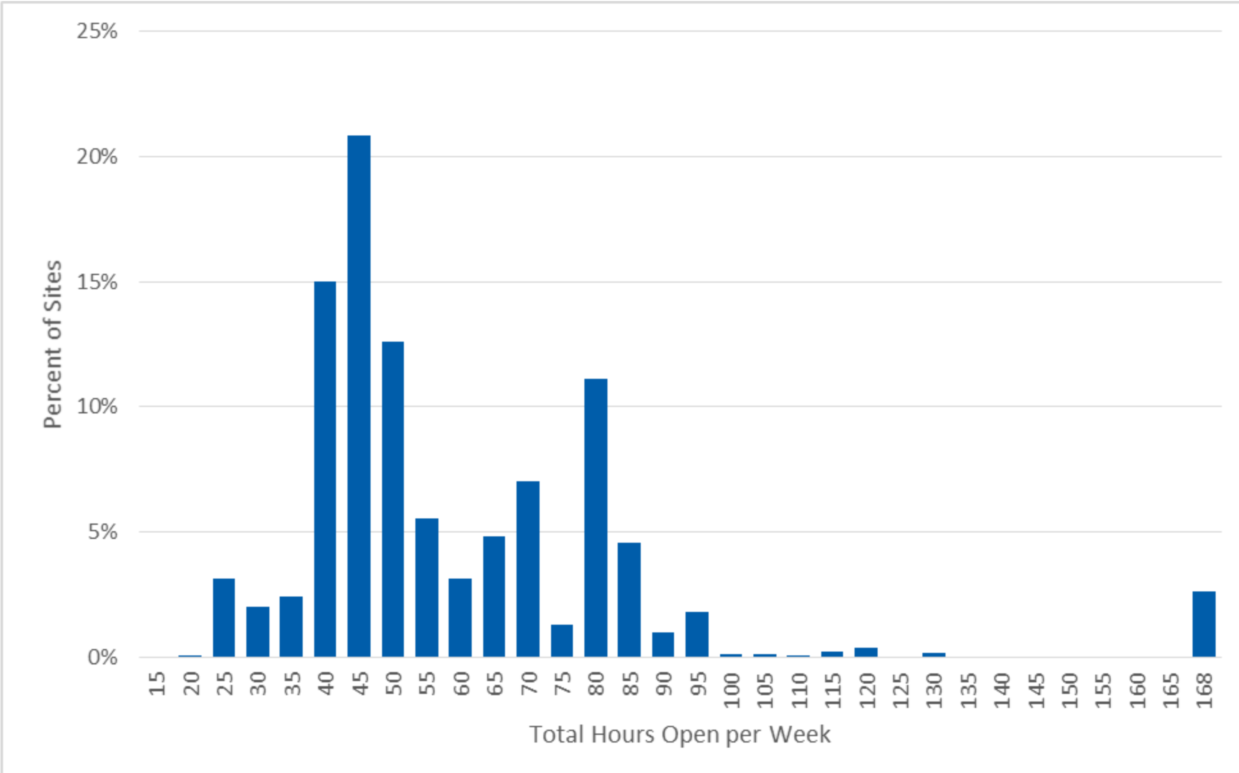
Table 9. Full-Time Equivalent Employees (N=192)

Category	Mean FTEs	Median FTEs	Sites Where Unknown
All (N=192)	12	4	6
BED (N=53)	39	7	1
EVT (N=139)	7	4	5
VT Gas (N=107)	18	4	2
High (N=53)	34	13	5
Medium (N=72)	9	7	0
Low (N=67)	4	4	1
Retail (N=26)	11	4	0
Office (N=29)	13	4	2
Manufacturing (N=28)	13	6	1
Balance of Commercial (N=109)	9	4	3

Business Hours

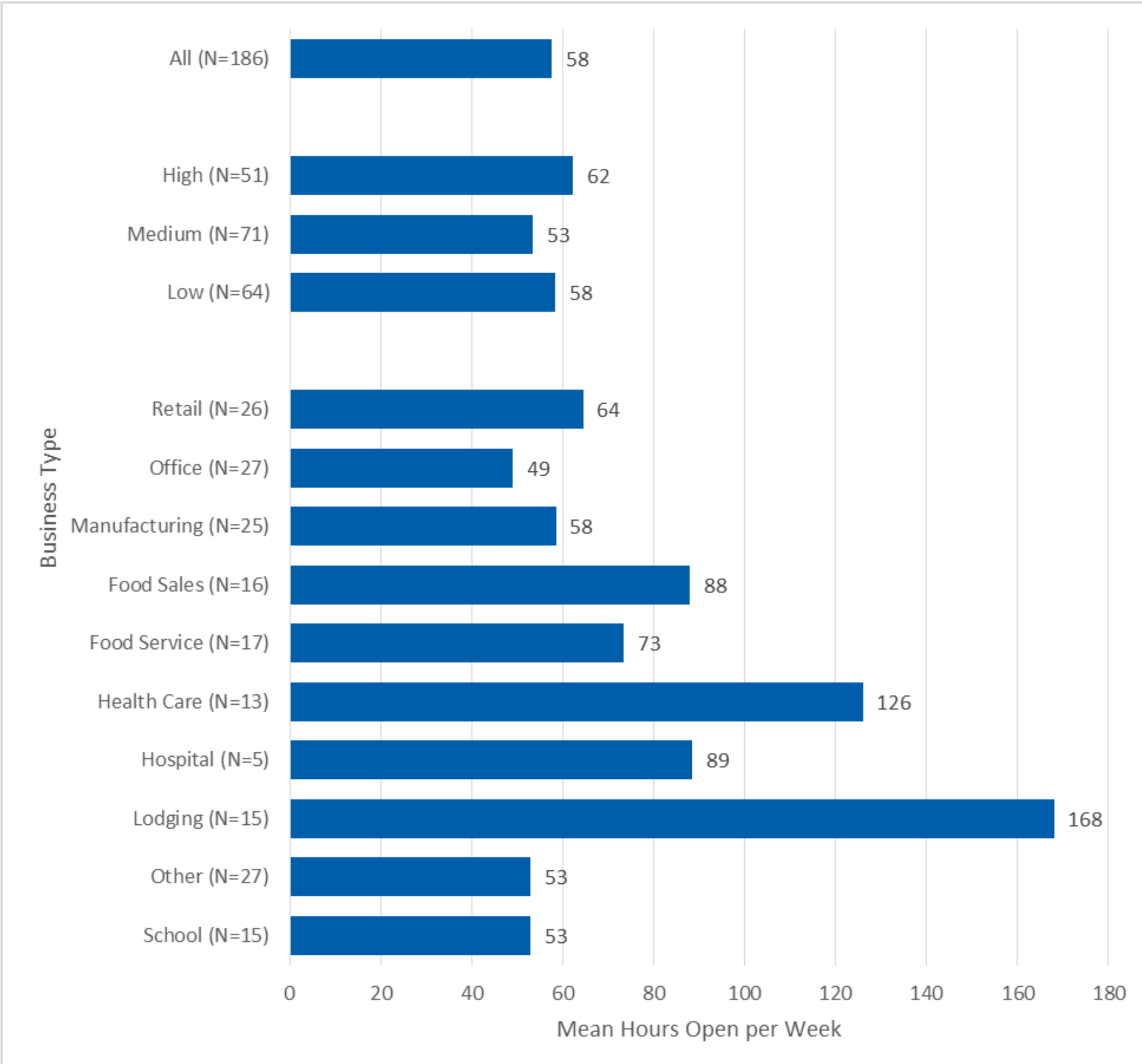
Figure 5 shows the distribution of facility open hours for the existing buildings in Vermont. The majority of sites are open between 20 and 70 hours per week (77% of sites). An additional 20% of facilities are open between 75 and 95 hours per week. Nearly the entire balance (3%) are open 24 hours per day.

Figure 5. Distribution of Weekly Open Hours for All Sites (N=186)



Statewide, the estimated average open hours per week for a commercial or industrial facility is 58 hours, as shown in Figure 6. This is largely consistent regardless of facility size or type. Office buildings tended to have the lowest operating hours (49), while lodging facilities have the highest (168).

Figure 6. Mean Open Hours Per Week by Category (N=186)



EEU Market Characterization—General Building Information

Table 10 shows a characterization summary of general building information for Vermont's EEUs.

Table 10. EEU Market Characterization—General Building Information

Measure/Characteristic	BED	EVT	VT Gas
Facility Age	• Most facilities were constructed before 1960, with some additional construction from 1980 to 2007.	• A large proportion of buildings were built prior to 1960 (42%) with steady construction from 1960 to present. • The only EEU to have new buildings constructed from 2008 to present.	• Approximately 47% of buildings were constructed before 1970. • Highest rate of construction from 1970 through 1999.
Building Size	• Facilities larger than 100,000 sq ft account for 45% of all building area, followed by buildings in the 20,001 to 50,000 sq ft range. • Average facility size of approximately 18,000 sq ft.	• The smallest average building size across all three EEUs, at approximately 7,000 sq ft per facility. • Approximately 67% of the building area in this territory are in buildings smaller than 20,000 sq ft.	• Approximately 40% of facility square footage is attributed to buildings over 50,000 sq ft.
Facility Ownership	• The lowest rate of owner-occupied buildings among the Vermont EEUs (52%).	• 63% facility ownership nearly matches the statewide average of 62%.	• 62% facility ownership matches the statewide average of 62%.
Business Information	• The average number of full time employees (39) is significantly higher than the statewide average of 12. • Average weekly open hours are very similar to the statewide average.	• Average number of full-time employees (7) is lower than the statewide average. • Average weekly open hours are very similar to the statewide average.	• The average number of full time employees (18) is higher than the statewide average of 12. • Average weekly open hours are very similar to the statewide average.

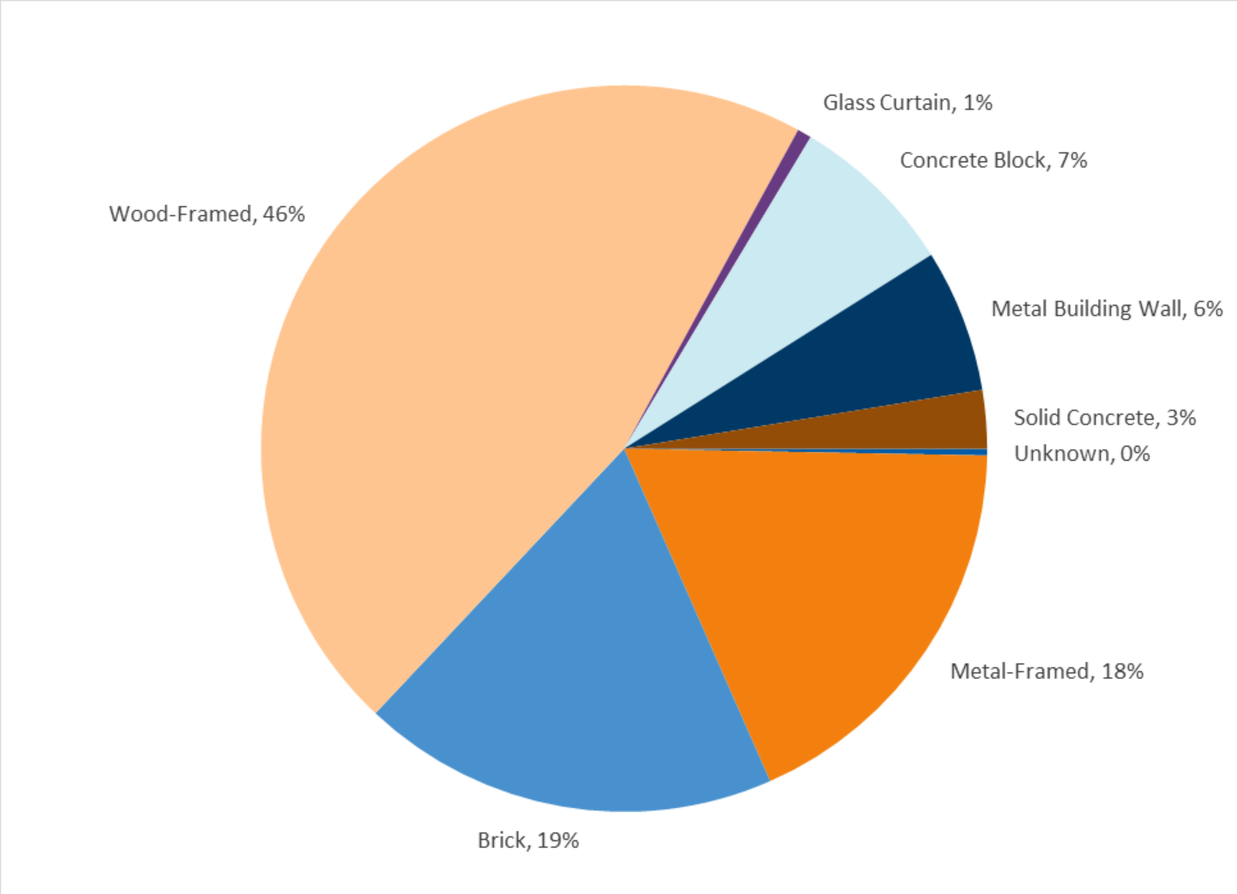
Building Envelope

Cadmus gathered building envelope information during the on-site inspection process. Details about wall, roof, and floor construction and insulation as well as windows were gathered through observation where practical and from building plans where available and accurate. The following sections present the results for each major envelope component.

Exterior Walls

Roughly half of exterior walls in existing building facilities throughout the state use wood framing, at an estimated 46% as shown in Figure 7. Mass walls (brick, concrete block, and solid concrete) together comprise the second most common exterior wall construction, accounting for a combined 29% of exterior walls. Similar to 2011, only 6% of walls are metal building walls (7% in 2011). Metal-framed walls account for more than double their representation in 2011, at 18% of wall observations (8% in 2011).

Figure 7. Frequency of Exterior Wall Construction Types (N=296)



Exterior Wall Insulation Types

During the 2016 site visits, field staff determined wall insulation through visual inspection of the wall, consultation with knowledgeable facility staff, or review of existing building plans. As shown in Figure 8, batt insulation is the most common form of wall insulation and, as in 2011, accounts for 44% of observations. Similar to 2011, a sizeable proportion of walls were identified as being uninsulated during the 2016 site visits. In total, uninsulated walls account for an estimated 39% of C&I facility exterior walls statewide. Following batt insulation, rigid board (9%) and spray foam (5%) are the second- and third-most common wall insulation materials.

Figure 8. Frequency of Wall Insulation Types (N=311)

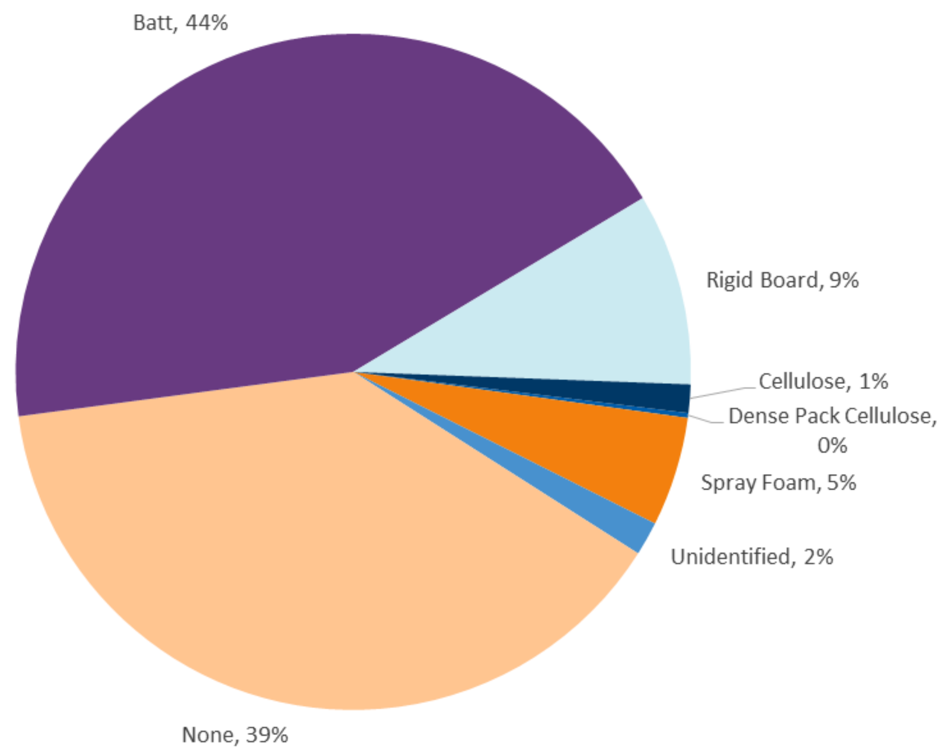
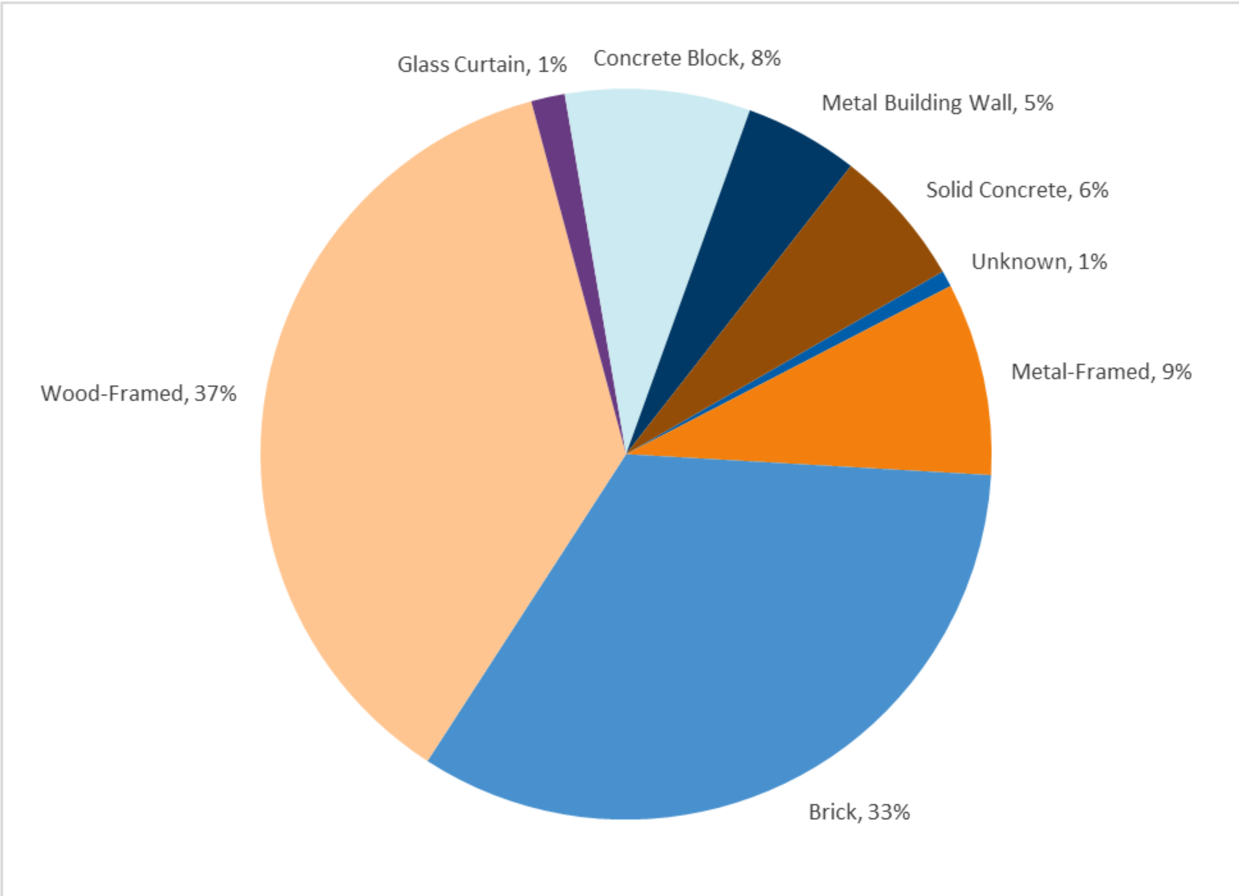


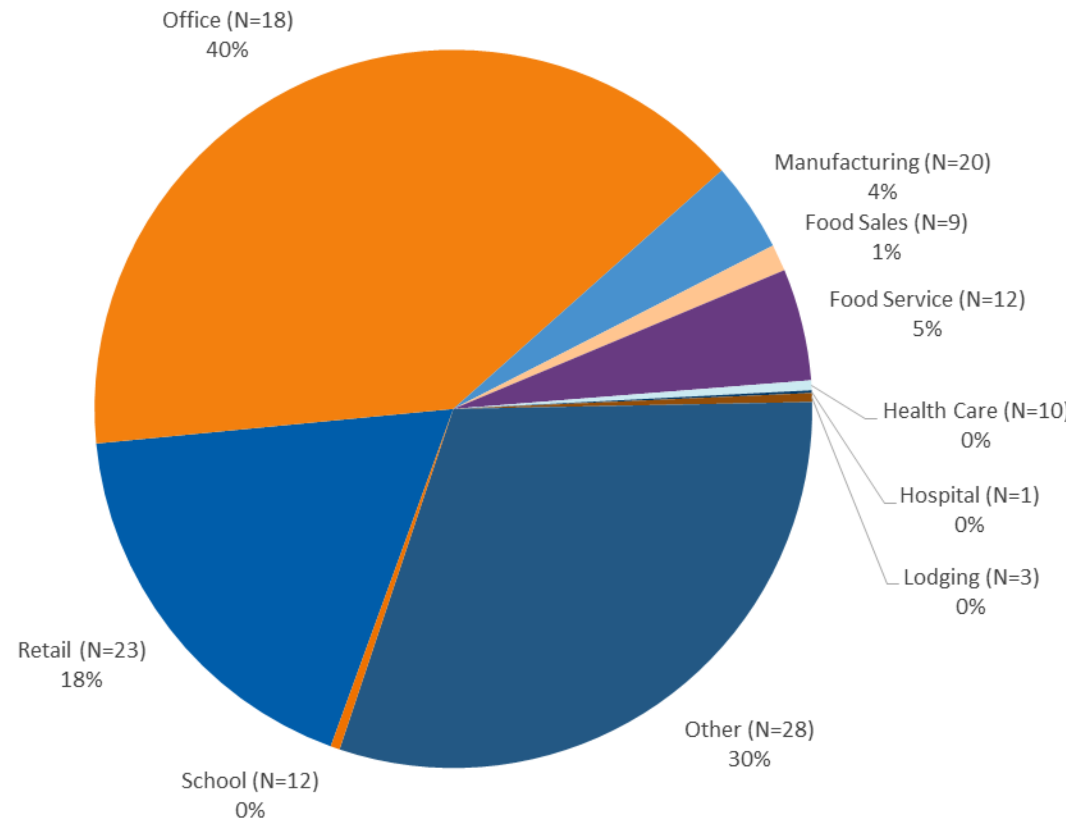
Figure 9 provides a closer look at the incidence of uninsulated walls in Vermont by wall construction type. Wood-framed walls account for the largest estimated percentage of wall type for uninsulated walls statewide, at an estimated 37%. This marks a significant increase from 2011, when wood-framed and other wall types accounted for 14% of uninsulated walls. Mass walls (brick, solid concrete, and concrete block) together account for the largest share of uninsulated walls (47% combined).

Figure 9. Wall Construction Types for Cases with No Insulation (N=136)



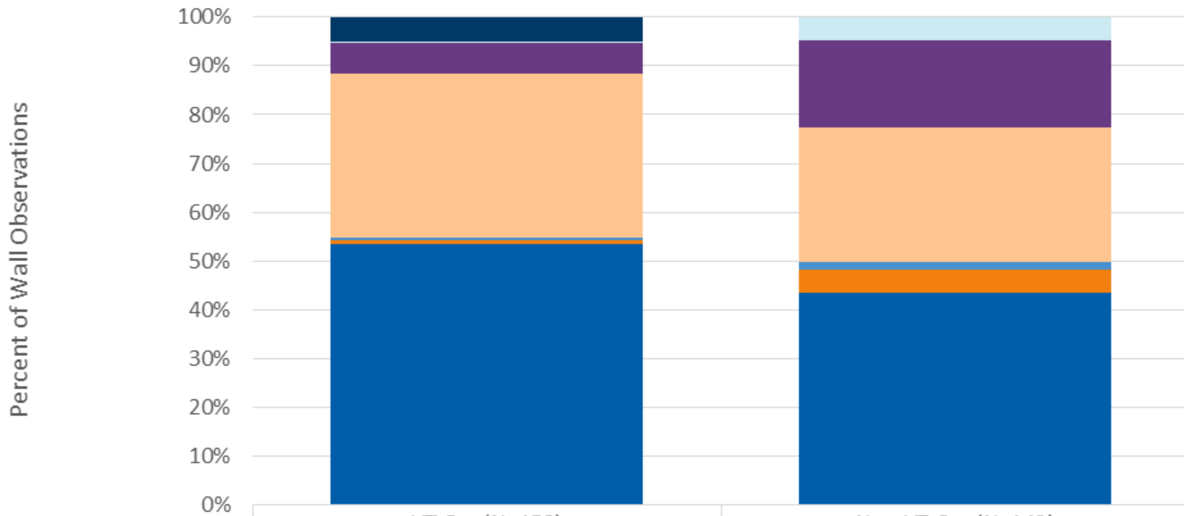
Similar to 2011, manufacturing facilities account for a small proportion of uninsulated walls (4%), as shown in Figure 10. The proportion of retail buildings estimated to have uninsulated walls in unchanged at 18%, but office buildings have a much higher estimated rate of uninsulated walls—40%. Health care, hospital, lodging, and school facilities have the lowest incidence of uninsulated walls among all facility types, with nearly all walls in those facilities being insulated.

Figure 10. Distribution of Facility Types for Cases with No Wall Insulation (N=136)



The predominant type of wall insulation in VT Gas service territory is batt insulation, accounting for an estimated 53% of all insulation. VT Gas facilities have a higher estimated rate of uninsulated walls (34%) than facilities outside of the VT Gas service territory (28%). The most common insulation types in non-VT Gas service territory are batt (44%) and rigid board (18%).

Figure 11. Distribution of Wall Insulation Types—VT Gas vs. Non-VT Gas (N=296)



	VT Gas (N=153)	Non-VT Gas (N=143)
Unidentified	5%	0%
Spray Foam	0%	5%
Rigid Board	6%	18%
None	34%	28%
Dense Pack Cellulose	1%	2%
Cellulose	1%	5%
Batt	53%	44%

Exterior Wall Insulation R-Values

Since 2011, the estimated average wall insulation R-value has increased from R-11 to R-13 (median) and R-10 to R-12 (mean). Mean R-values vary little by size stratum: large facilities have a mean value of approximately 13, and medium and small facilities have a mean value of approximately 12. Median R-values, however, do vary noticeably with facility size. Large facilities have the highest median R-value (R-18), while small facilities have the lowest (R-11).

Figure 12. Wall Insulation R-Values by Facility Size (N=146)

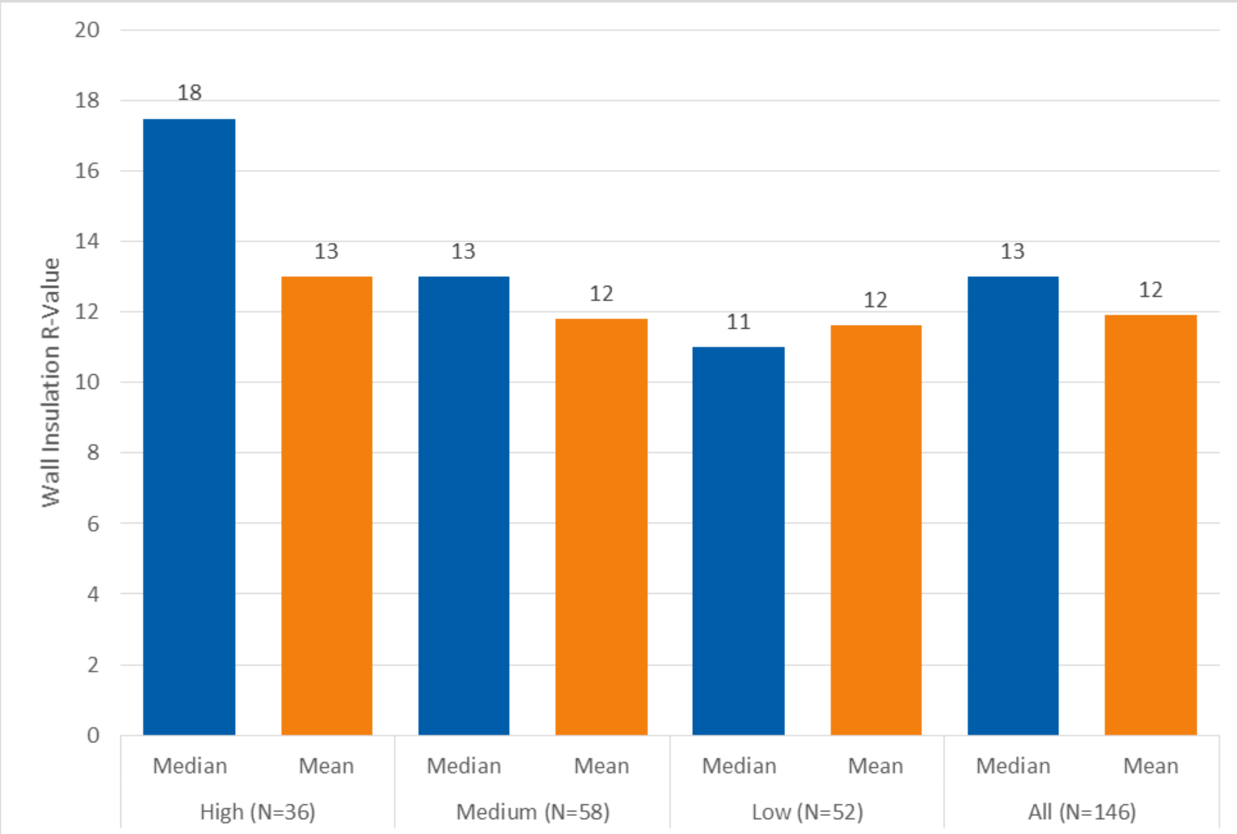
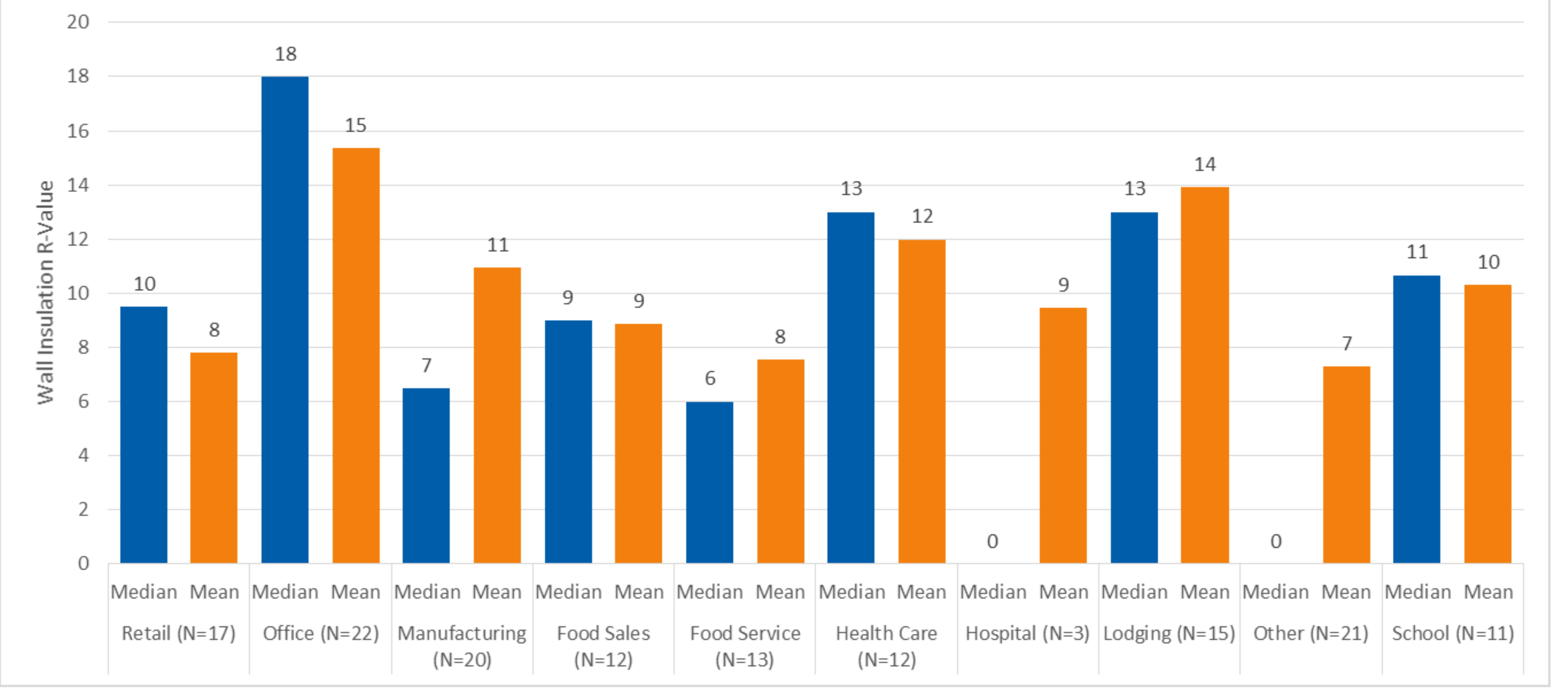


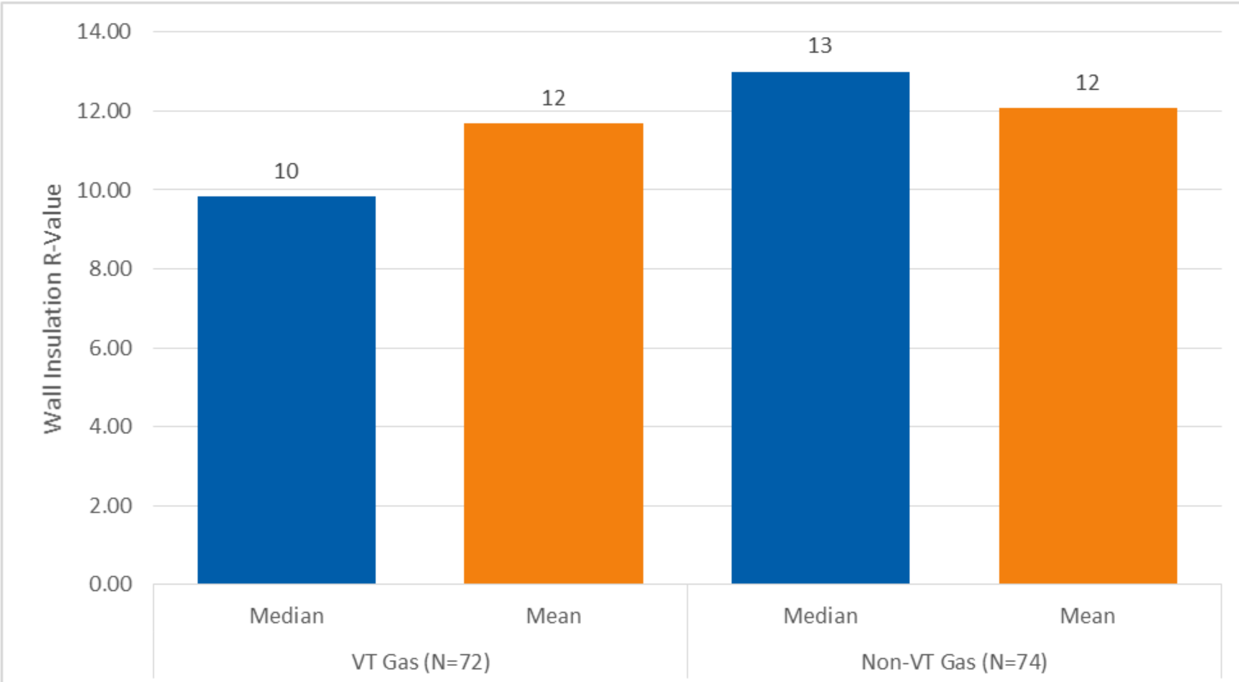
Figure 13 shows a large degree of variation in the mean and median wall R-value by facility type. Office buildings have the highest median R-value across all facility types (R-18), as well as one of the highest mean R-values (R-15). This is an interesting finding, because although office facilities have the highest rate of uninsulated walls among all facility types, insulated offices appear to have the highest R-value among all facility types. The opposite appears to be true for hospitals and schools. These facility types had an extremely low rate of uninsulated walls, but the mean and median R-values for these facility types are typically lower than the statewide average.

Figure 13. Wall Insulation R-Values by Facility Type (N=146)



In contrast to the 2011 study, which found higher mean insulation levels in the VT Gas service territory, the 2016 study estimates essentially equal R-values in VT Gas and non-VT Gas territories.

Figure 14. Wall Insulation R-Values by VT Gas vs. Non-VT Gas (N=146)

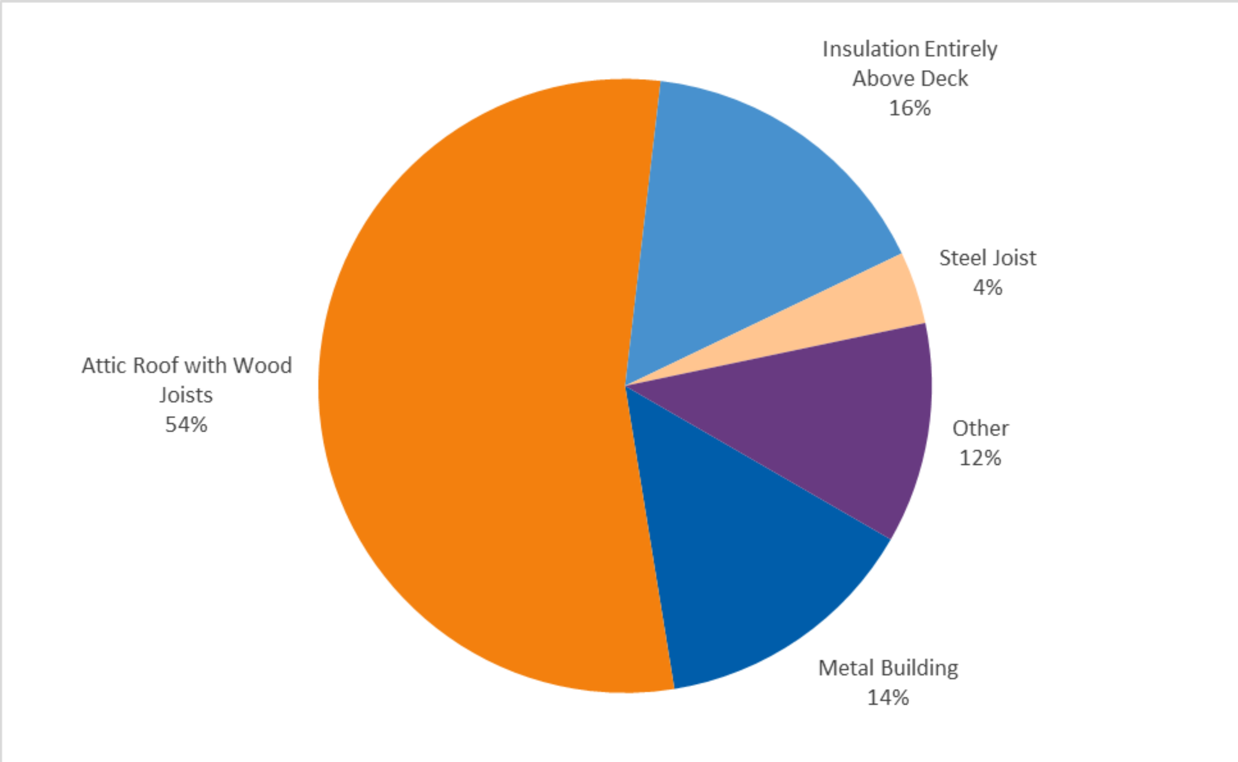


Roofs

Roof Construction Type

The majority (54%) of existing buildings have a roof construction type that falls into the category of 'attic roof with wood joists', as shown in Figure 15. The next largest category is for buildings with insulation entirely above the roof deck, which account for an estimated 16% of C&I existing building roofs statewide. This is approximately half the frequency with which these roofs were estimated in the 2011 study (29%). The balance comprises of metal building roofs (14%), other roofs (12%), and steel joist roofs (4%).

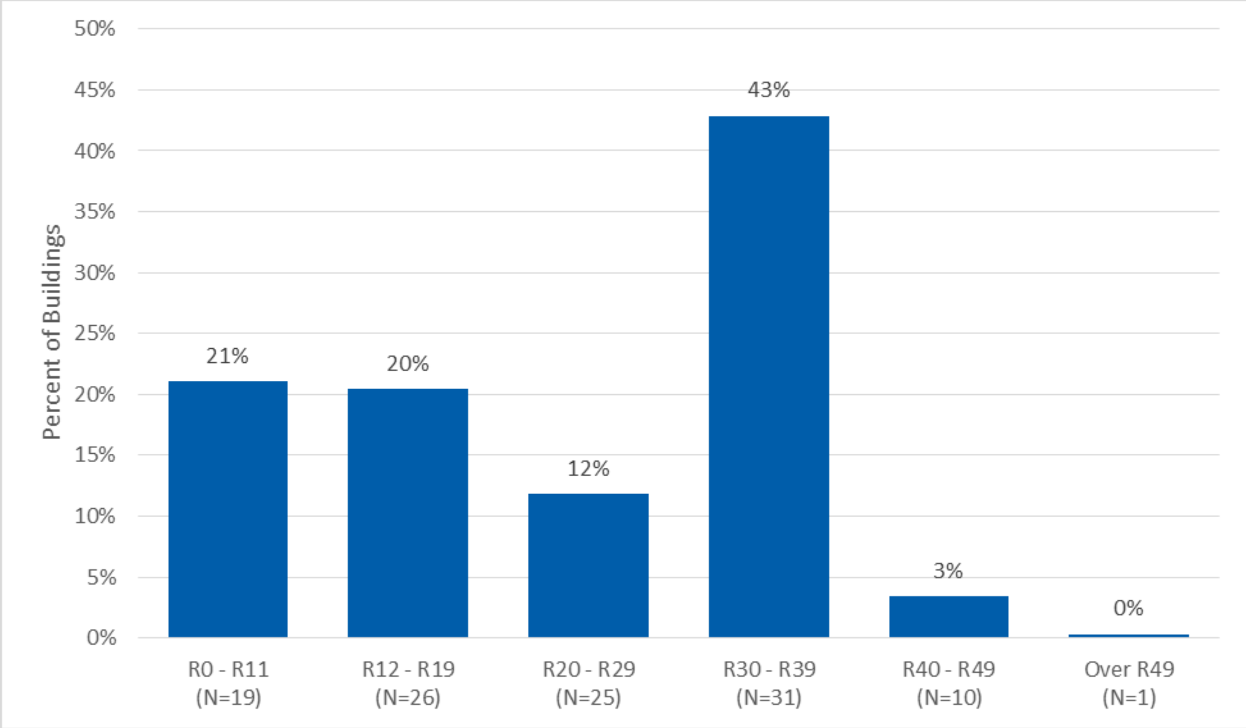
Figure 15. Frequency of Roof Construction Types for all Sites (N=209)



Roof Insulation R-Values

Statewide, approximately half of buildings have roof R-values of less than R30, and nearly half of buildings have a roof R-value between R30 and R39. Approximately 20% of buildings have a roof R-value of less than R11 and another 20% have roof R-values between R12 and R19.

Figure 16. Roof Insulation R-Values by Facility Size (N=112)



Overall, estimated average roof insulation R-value has increased since 2011. The median value has increased from R-15 to R-22 and the mean value has increased from R-14 to R-24. Large facilities appear to have the highest mean R-value in the state (R-26) and the second highest median R-value (R-28). The mean insulation level for medium facilities (R-21) is lower than the statewide average of R-24.

Figure 17. Roof Insulation R-Values by Facility Size (N=112)

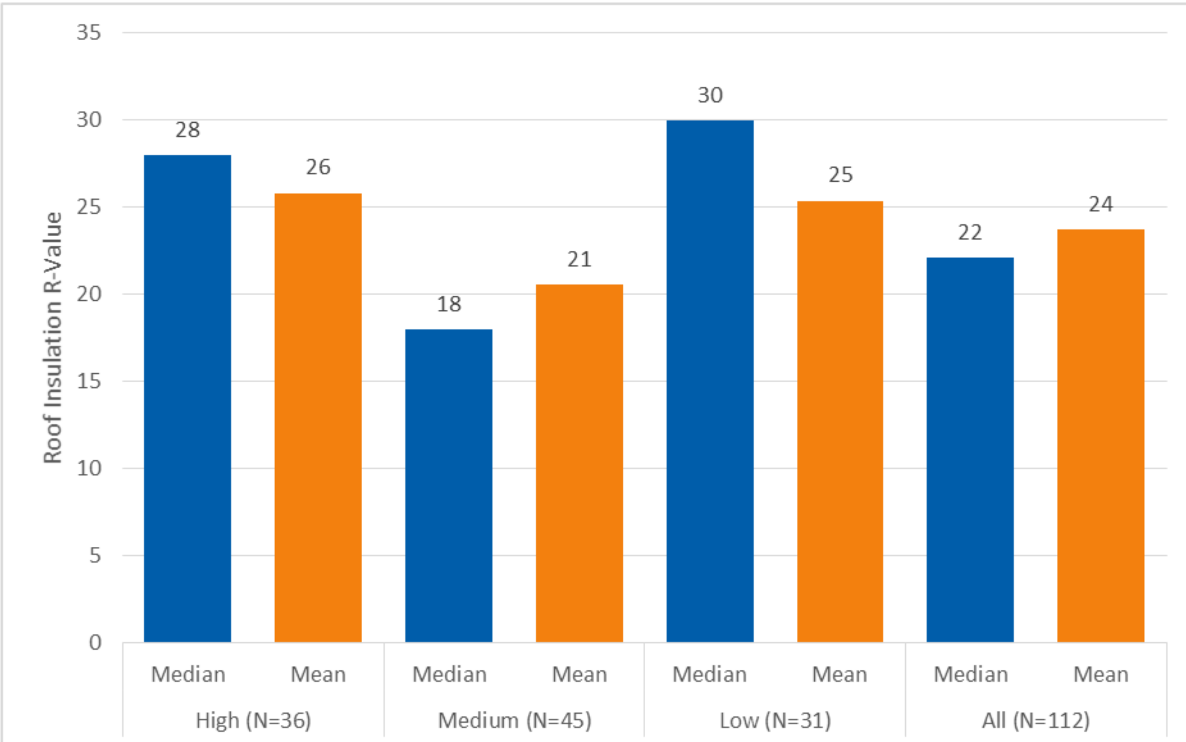
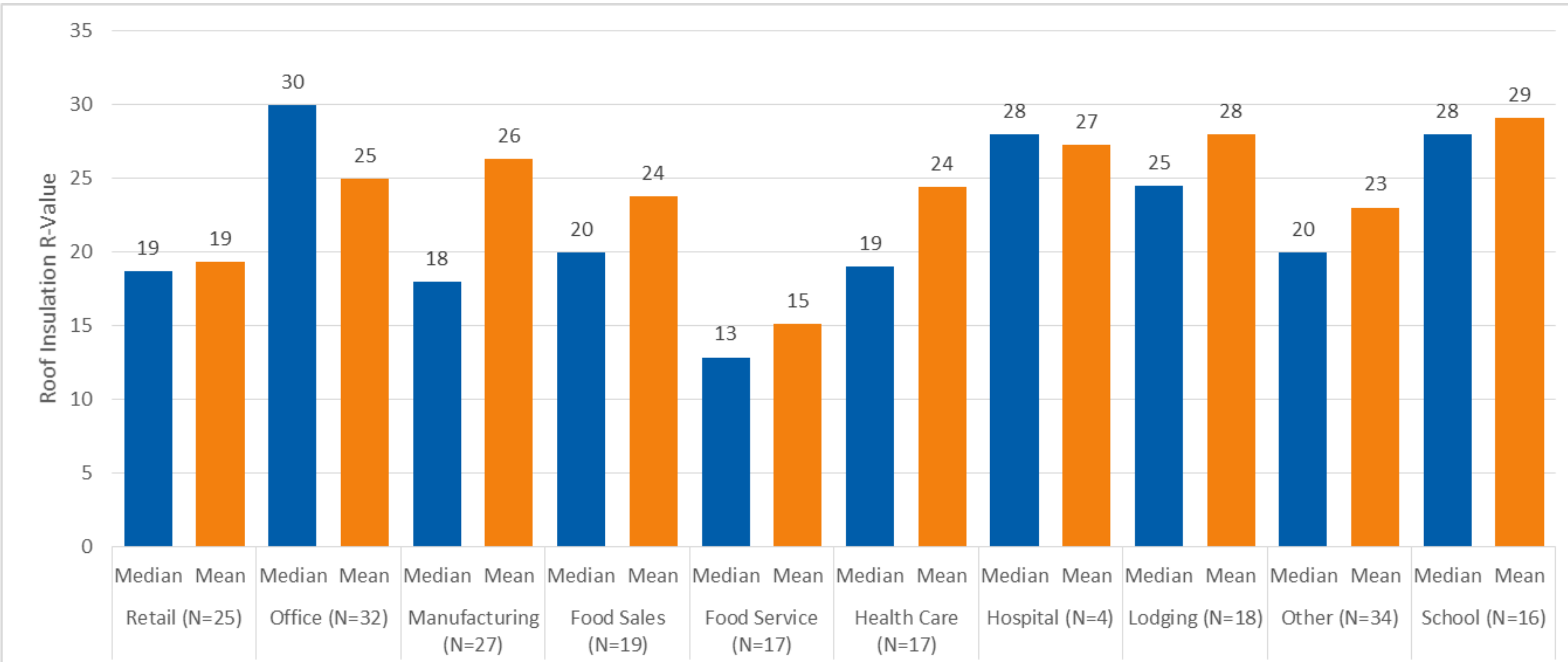


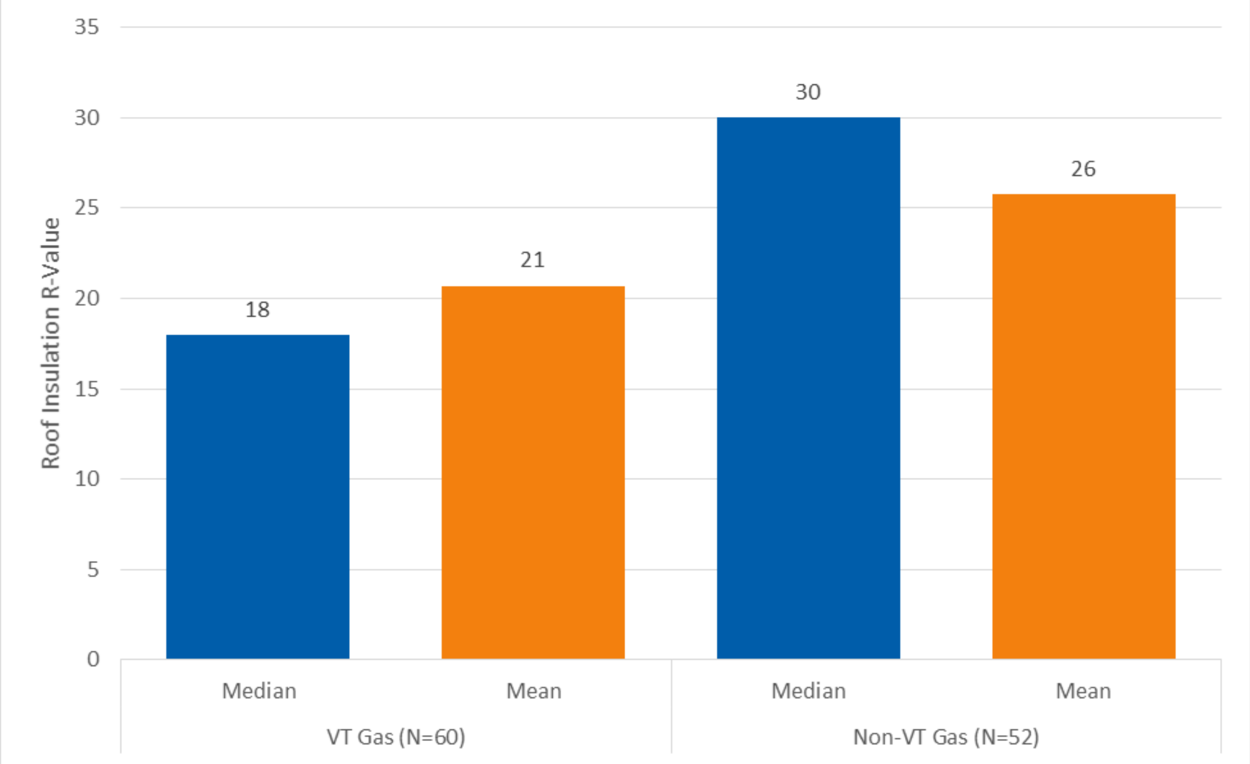
Figure 18 shows roof insulation R-values by facility type. Most of the facility types equal or exceed the statewide mean of R-24, with schools having the highest estimated mean R-value of all facilities (R-29). Office, manufacturing, hospital, and lodging facilities also have higher mean R-values than the statewide average, while the mean R-value in retail and food service facilities (R-15) is lower than the state average. Overall schools, hospitals, and lodging facilities tend to have the highest level of roof insulation.

Figure 18. Roof Insulation R-Values by Facility Type (N=112)



Facilities in the VT Gas service territory tend to be have lower levels of roof insulation than facilities outside the VT Gas territory. As compared to 2011, there has been an increase in the estimated mean and median roof R-values in the VT Gas territory. However, the median R-value in the non-VT Gas territory has doubled from R-15 to R-30, and the mean R-value has increased from R-14 to R-26. It seems unlikely at best that roof insulation values have risen so dramatically in roughly five years; determining the source of the apparent discrepancy may warrant further attention.

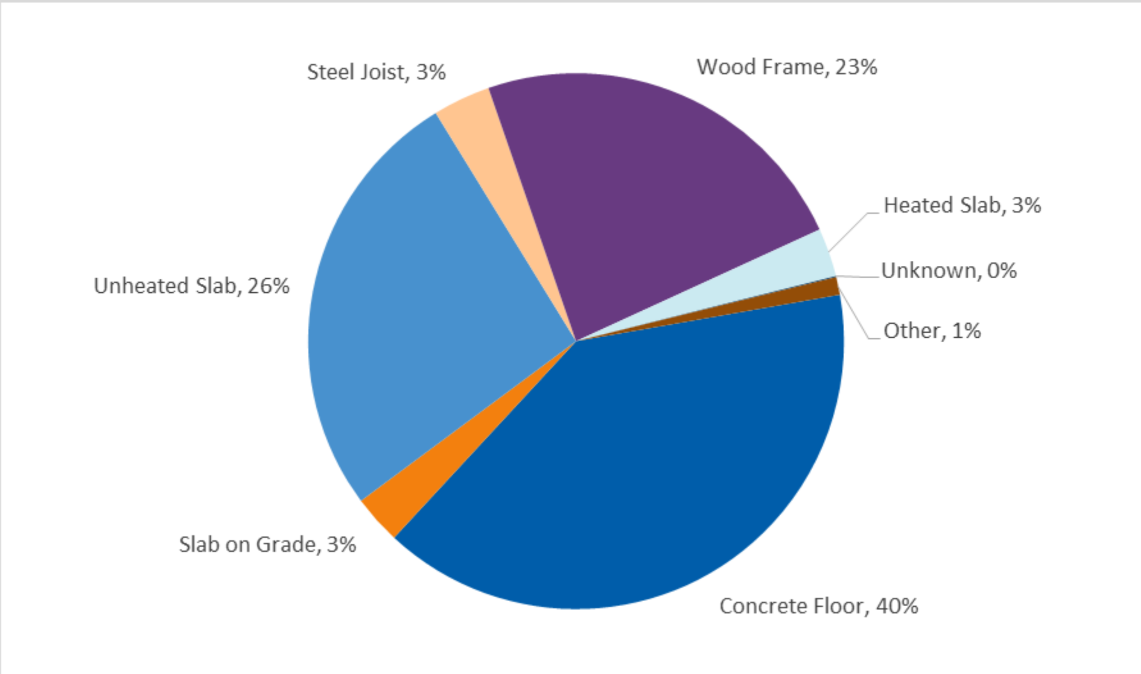
Figure 19. Roof Insulation R-Values by VT Gas vs. Non-VT Gas (N=112)



Floor

Concrete floors are the most common (40%) floor construction type, followed by unheated slabs (26%) as shown in Figure 20. In all, concrete and slab floors account for an estimated 72% of floor construction types. Wood framed floors account for an additional 23%, with steel joist and “other” floor types comprising 3% and 1%, respectively.

Figure 20. Frequency of Floor Construction Types for All Buildings (N=146)



Windows/Fenestration

Double-pane windows rank by far as the most common glazing type encountered in Vermont as shown in Figure 21. Statewide, double-pane windows account for an estimated 85% of all window area, with the balance comprised entirely of single-pane windows. No triple-pane windows were identified during site visits for this study. The ratio of double-pane to single-pane windows is largely consistent across facility size, though medium-sized buildings have a markedly high percentage of double-pane windows (95%).

Figure 21. Area of Window Panes by Facility Size (N=269)

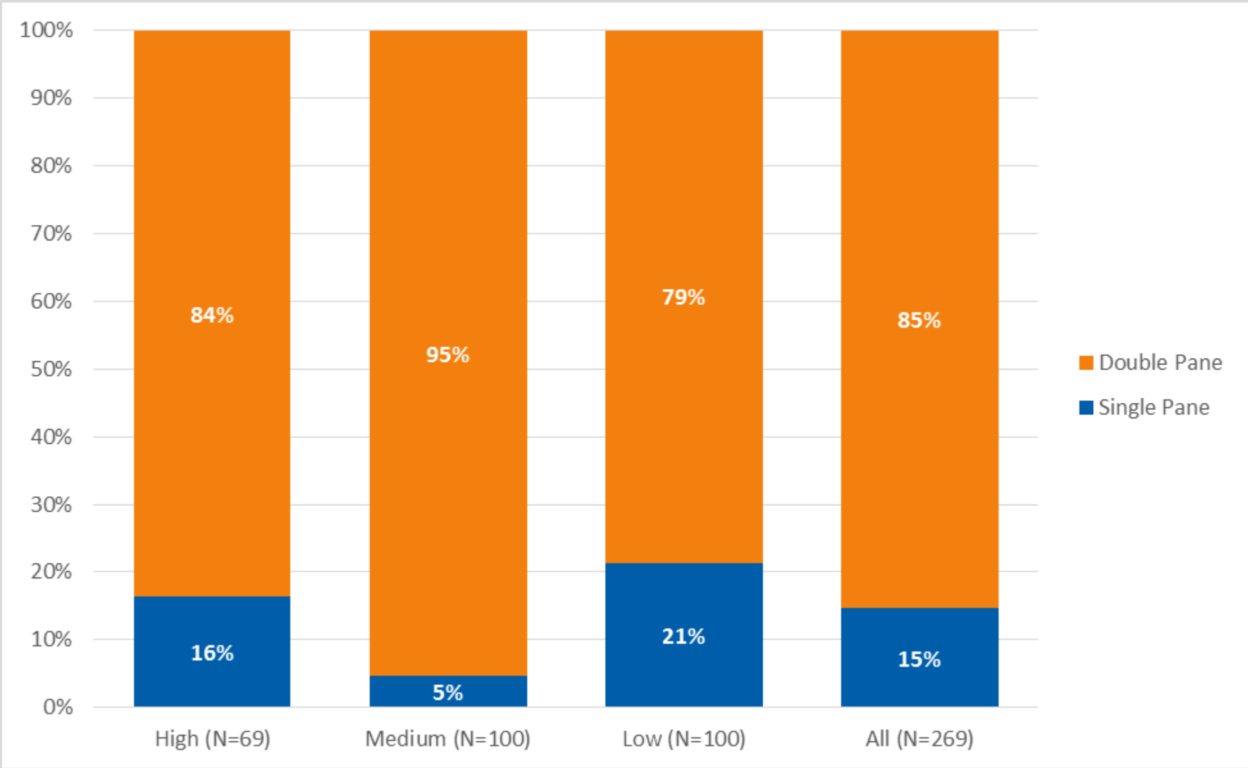


Figure 22 shows that although there is not much variation in the percentage of double-pane windows identified by EEU, VT Gas facilities tend to have a higher percentage of double-pane windows (92%) than non-VT Gas facilities (79%).

Figure 22. Area of Window Panes by VT Gas vs. Non-VT Gas (N=269)

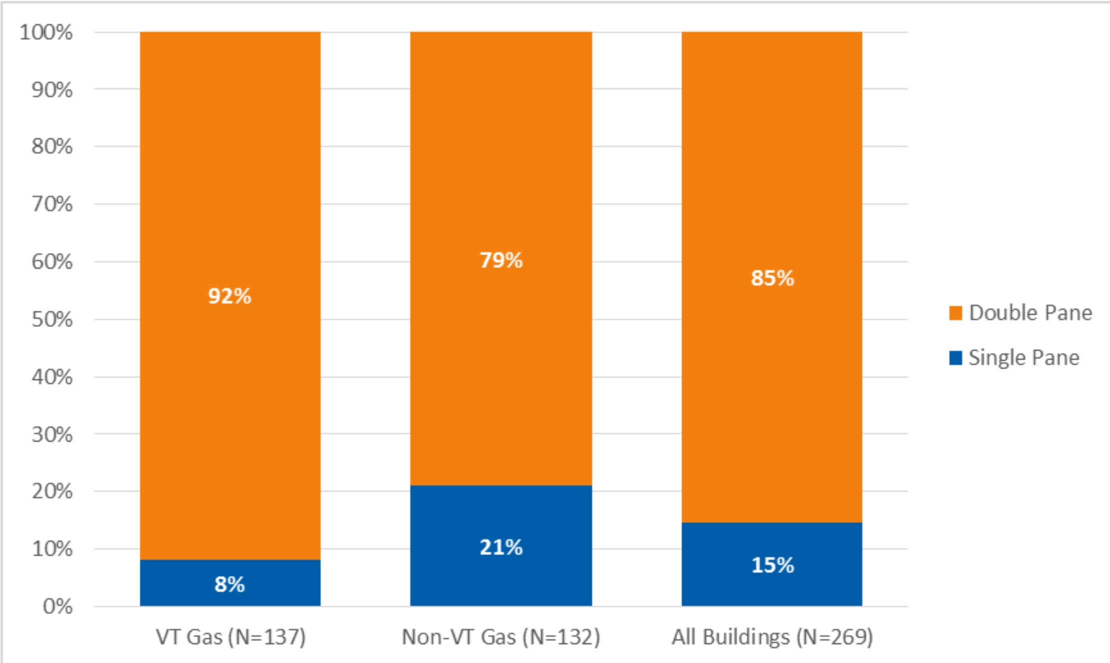
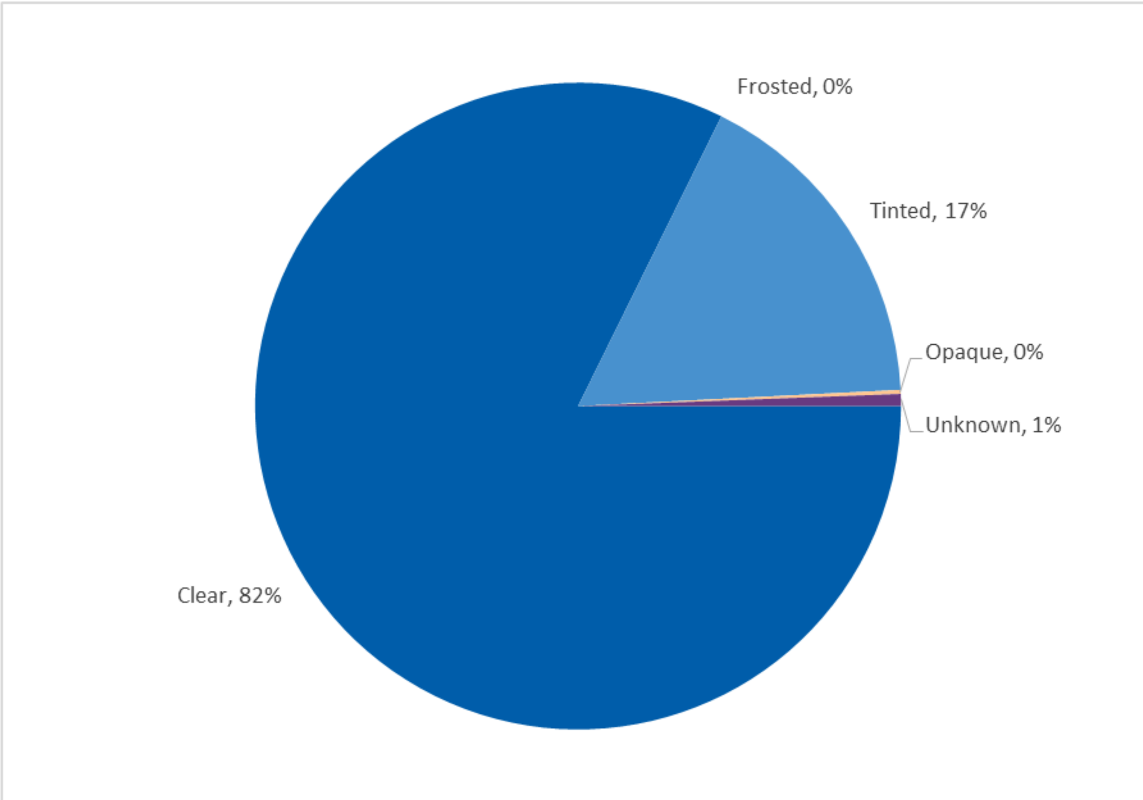


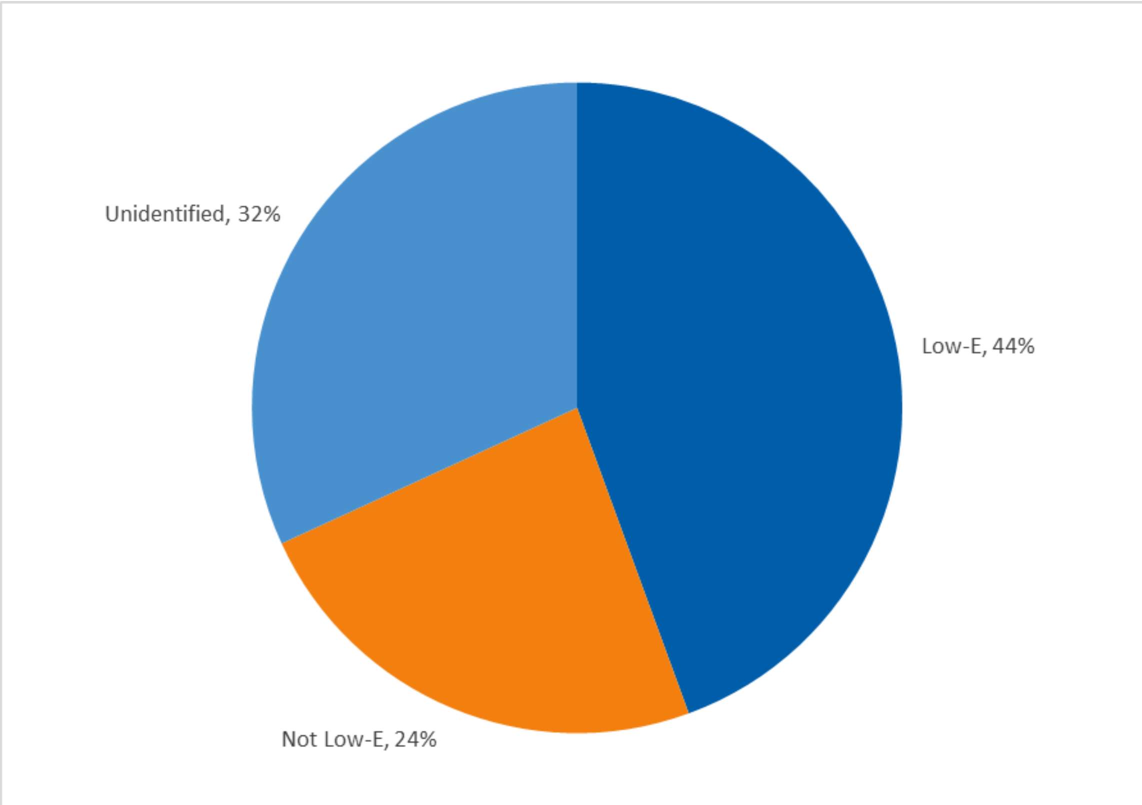
Figure 23 shows that the majority (82%) of windows in Vermont are clear windows. Of the balance, 17% of the windows are tinted and 1% could not be identified.

Figure 23. Distribution of Glazing Types (N=269)



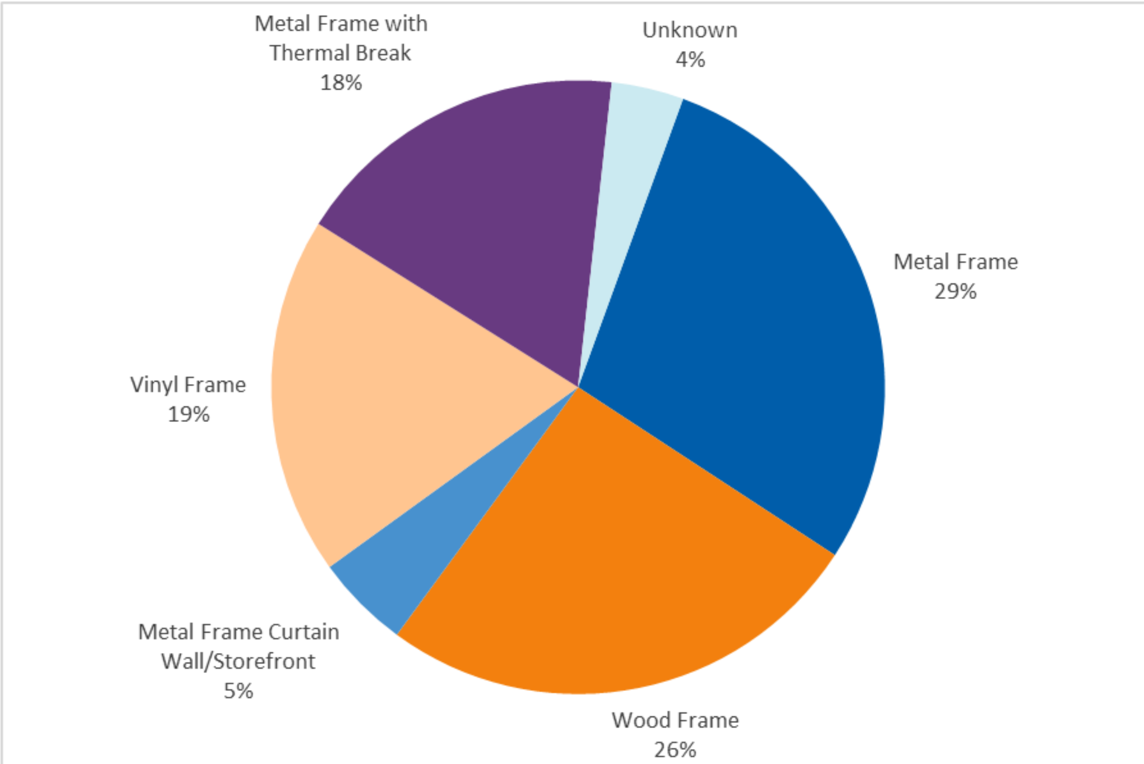
As shown in Figure 24, an estimated 44% of windows have low-E coatings. This is a marked increase from 2011, when only 6% of windows were identified as having low-E coatings. While at least a modest increase in low-E coatings was expected, some of the apparent improvement results from differences in data collection methodology and reporting. For example, Figure 22 reports distribution of glazing type by window area, whereas the 2011 effort reported distribution by number of window panes. In addition, the Cadmus team collected data through direct observation, including through the use of low-E detectors, whereas the 2011 results were based largely on data collected through telephone surveys.

Figure 24. Distribution of Glazing Features (N=269)



Metal-framed windows account for roughly half of installed windows (an estimated 52%). This can be further broken down into metal-framed (29%), metal-framed with thermal break (18%), and metal-frame curtain wall or storefronts (5%). Following metal-frame windows, wood-frame (26%) and vinyl-frame (19%) are the most common.

Figure 25. Distribution of Window Framing Types (N=259)



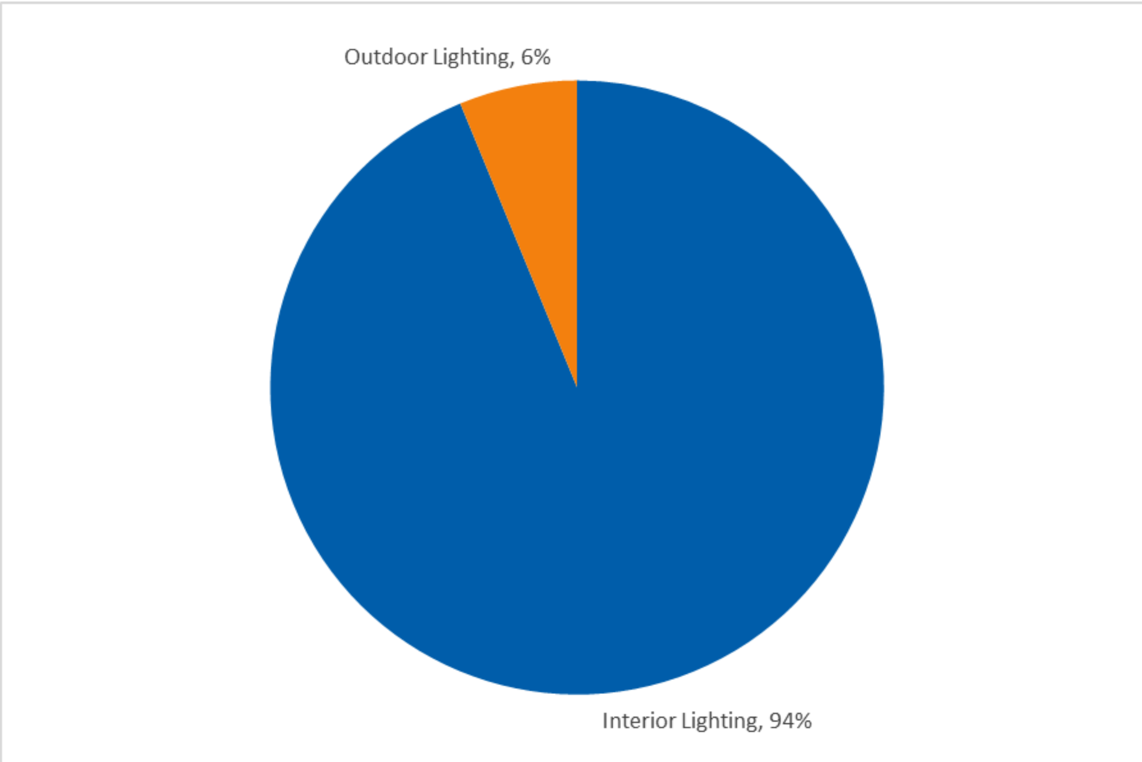
EEU Market Characterization—Building Envelope

Measure/Characteristic	VT Gas vs. Non-VT Gas
Exterior Walls	• The incidence of uninsulated walls in VT Gas territory is similar to the proportion in Non-VT Gas territory (34% and 28%, respectively). • Batt insulation is the most common insulating material used in Vermont's existing C&I building stock, accounting for 53% of insulation in the VT Gas territory and 44% of insulation outside of the VT Gas territory. • The second-most common insulating material is rigid board, accounting for 6% of observation in VT Gas territory and 18% of non-VT Gas territory. • The mean wall insulation levels in the VT Gas service area tend to be similar to the non-VT Gas territory (R-11 in both), as do the median R-values (R-10 vs R-13).
Roofs	• Roof R-values in VT Gas service territory are lower than the values outside of the VT Gas service territory. In VT Gas service territory, the median is R-18 and the mean is R-21.
Windows	• VT Gas facilities have a higher percentage of double-pane windows than facilities in non-VT Gas territory (92% vs. 79%).

Lighting

As in 2011, the majority of lighting in Vermont's existing commercial building stock is located indoors. Figure 26 shows that 94% of all installed lighting (represented by wattage) is indoors. Only 6% of the installed lighting is located outdoors.

Figure 26. Distribution of Indoor and Outdoor Lighting Wattage (N=189)*

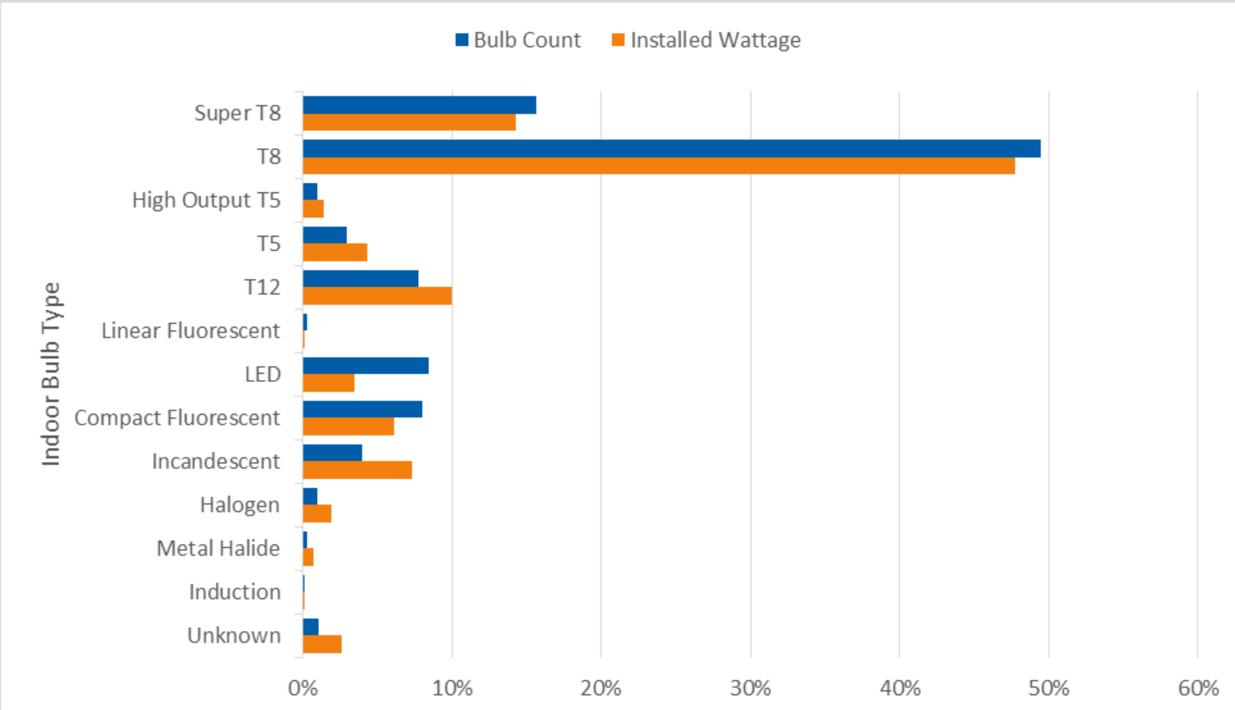


* Presented by percentage installed wattage

Interior Lighting

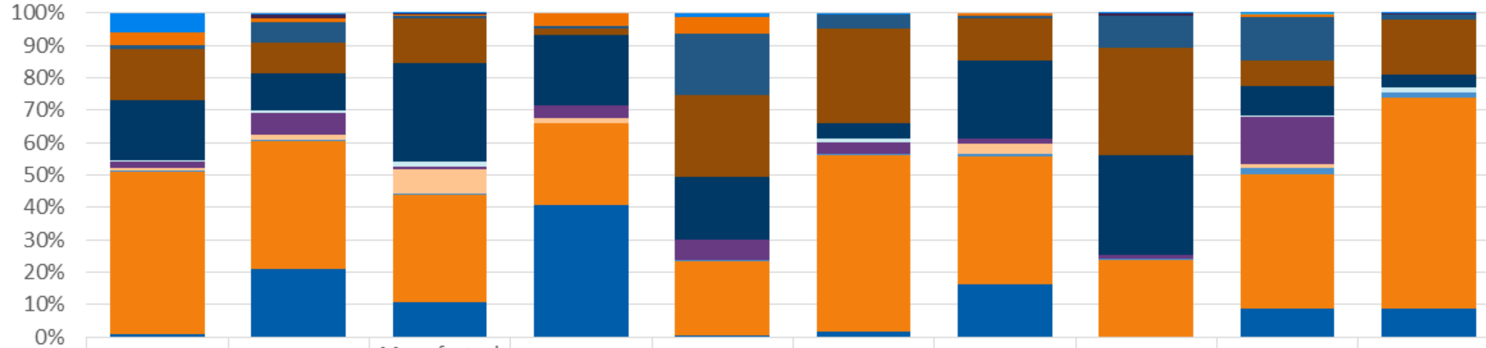
Figure 27 shows the distribution of indoor lamp types by both bulb count and installed wattage. T8 lamps comprise roughly 50% of installed lighting statewide, with Super T8 lamps a distant second at roughly 15%. In contrast with the new construction facilities, T12 lamps still constitute a sizeable proportion of installed lamps—8% by lamp count and 10% by wattage—though at a lower frequency than in 2011: in 2011, T12s accounted for approximately 12% of all lamps and 15% of all wattage. Another interesting change from 2011 to 2016 is that the share of compact fluorescent lamps have nearly halved since 2011, while LEDs have more than doubled. The share of incandescent lamps is also lower in 2016 than in 2011.

Figure 27. Distribution of Indoor Lamp Types—All Sites (N=189)



As shown in Figure 28, T8 and "Super" T8 lamps are the single most common lighting technology across all facility types except for lodging, where LED lamps are the most common (31%). LED lamps also make up a considerable proportion of lamps in retail (25%), manufacturing (29%), and hospitals (24%). Incandescent lamps represent 10% or less of fixtures in all facility types except food service (23%) and "other" facilities (13%). These two facility types also have the highest proportion of T12 lamps across the state: 8% of lamps in food service facilities and 15% of lamps in "other" facilities are T12.

Figure 28. Distribution of Indoor Lamps by Facility Types (N=189)*

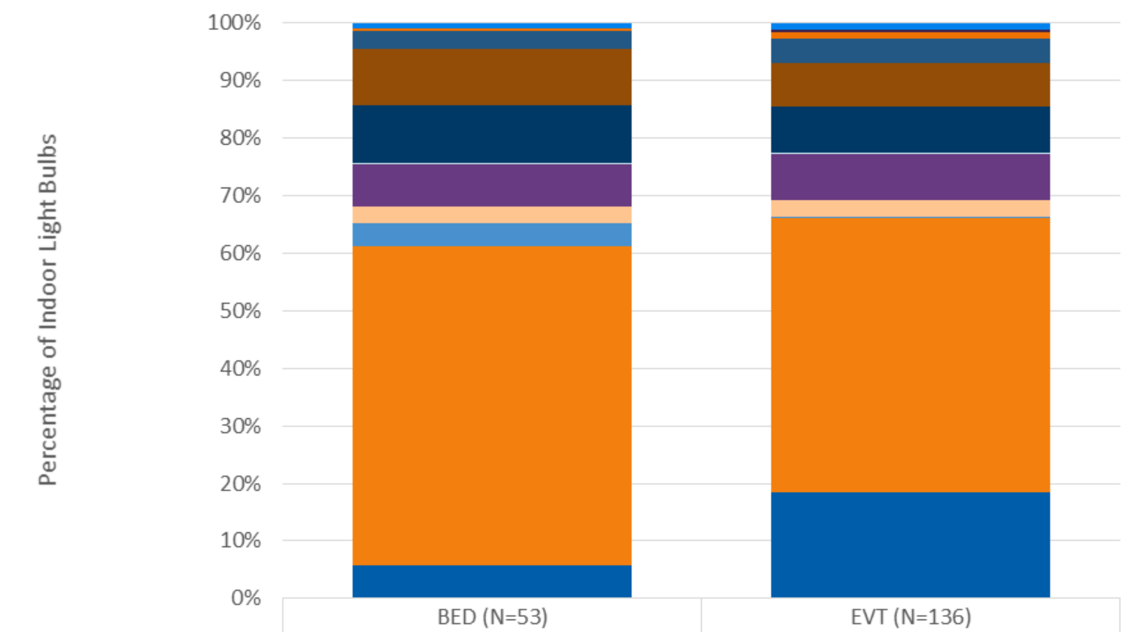


	Retail (N=25)	Office (N=27)	Manufacturing (N=28)	Food Sales (N=16)	Food Service (N=17)	Health Care (N=13)	Hospital (N=5)	Lodging (N=16)	Other (N=27)	School (N=15)
Unknown	6%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Induction	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Metal Halide	0%	1%	0%	0%	0%	0%	0%	1%	0%	1%
Halogen	4%	1%	0%	4%	5%	0%	1%	0%	1%	0%
Incandescent	1%	6%	1%	1%	19%	4%	1%	10%	13%	2%
Compact Fluorescent	16%	10%	14%	2%	25%	29%	13%	33%	8%	17%
LED	18%	11%	31%	22%	19%	5%	24%	31%	9%	4%
Linear Fluorescent	0%	1%	2%	0%	0%	1%	0%	0%	0%	2%
T12	2%	7%	1%	4%	6%	4%	2%	1%	15%	0%
T5	1%	1%	7%	2%	0%	0%	3%	0%	1%	0%
High Output T5	0%	0%	0%	0%	0%	0%	1%	0%	2%	2%
T8	50%	40%	33%	25%	23%	55%	39%	24%	41%	65%
Super T8	1%	21%	11%	41%	0%	2%	16%	0%	9%	9%

* Represented as percentage of fixture counts

Overall, the distribution of indoor lamp types by EEU is very similar for BED and EVT, as shown in Figure 29. The primary difference is that a higher proportion of EVT's T8 lamps are "Super" T8s—20% compared to only 6% for BED.

Figure 29. Distribution of Indoor Lamp Types by EEU (N=189)*



	BED (N=53)	EVT (N=136)
Unknown	1%	1%
Induction	0%	0%
Metal Halide	0%	0%
Halogen	0%	1%
Incandescent	3%	5%
Compact Fluorescent	11%	9%
LED	10%	10%
Linear Fluorescent	0%	0%
T12	8%	10%
T5	3%	4%
High Output T5	4%	0%
T8	59%	59%
Super T8	6%	22%

*Presented as percentage by lamp counts

Table 11 shows that the distribution of linear fluorescent lighting statewide is tilted heavily toward T8 and "Super" T8 lamps, which represent an estimated 66% and 20% of linear fluorescent lamps, respectively. There has been a significant decrease in T12 lamps since 2011, when they represented 17% of all linear fluorescent lamps; they now represent 10%. A lower proportion of T5 and high output T5 lamps were identified in 2016 than in 2011.

As mentioned previously, T12 lamps are most commonly found in food service and "other" facilities. Super T8 lamps represent the majority of linear fluorescent lighting in food sales facilities (58%), and are a significant proportion of the linear fluorescents in offices (27%), hospitals (26%), and manufacturing facilities (20%). Nearly all of the linear fluorescents in retail (92%), lodging (94%), schools (85%), and health care facilities (89%) are standard T8 lamps.

Smaller buildings tend to have less-efficient forms of linear fluorescent lighting than medium or small buildings. They have the largest proportion of T12 lamps (15%). Medium-sized facilities have the highest proportion of "Super" T8 lamps (41%), followed by large facilities (13%).

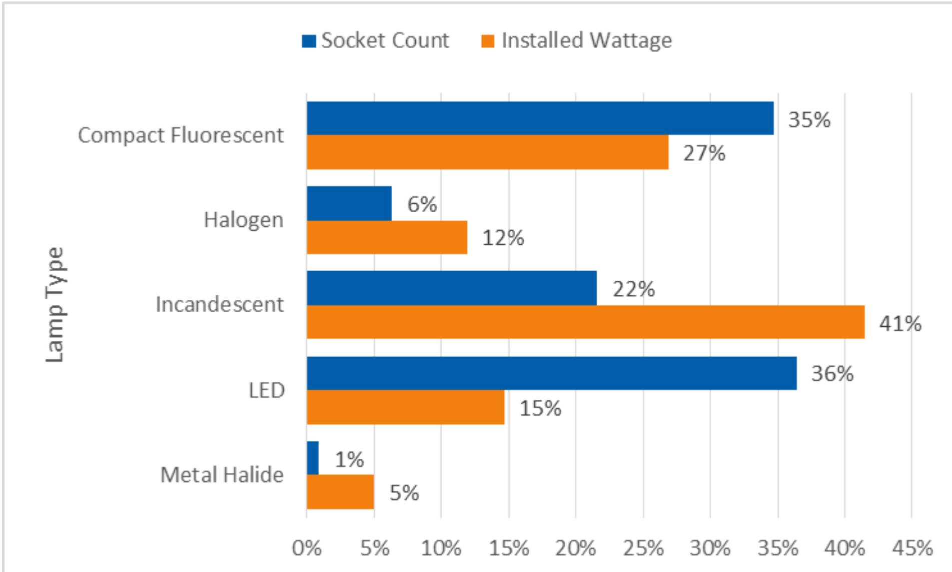
Table 11. Distribution of Linear Fluorescent Lamps*

Category	Super T8	T8	High Output T5	T5	T12	Linear Fluorescent
All (N=189)	20%	66%	1%	2%	10%	1%
EEU						
BED (N=53)	6%	79%	3%	3%	9%	1%
EVT (N=136)	25%	62%	0%	2%	10%	1%
VT Gas (N=106)	24%	59%	1%	4%	11%	1%
Facility Size						
High (N=51)	13%	75%	2%	3%	7%	1%
Medium (N=72)	41%	49%	0%	1%	9%	0%
Low (N=66)	6%	73%	1%	4%	15%	1%
Facility Type						
Retail (N=25)	1%	92%	0%	2%	4%	1%
Office (N=27)	27%	60%	0%	2%	9%	1%
Manufacturing (N=28)	20%	61%	1%	14%	1%	3%
Food Sales (N=16)	58%	35%	0%	2%	5%	0%
Food Service (N=17)	1%	76%	1%	0%	21%	0%
Health Care (N=13)	3%	89%	0%	0%	6%	2%
Hospital (N=5)	26%	64%	2%	5%	2%	0%
Lodging (N=16)	0%	94%	1%	0%	4%	0%
Other (N=27)	13%	60%	3%	1%	21%	1%
School (N=15)	11%	85%	2%	0%	0%	2%

* Presented as percentage fixture counts

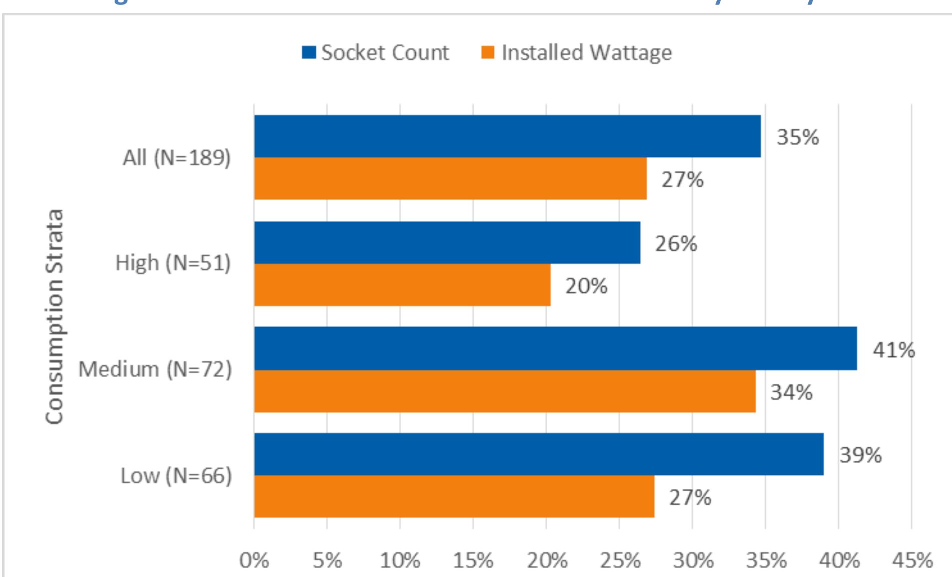
CFLs account for 35% of all screw-based sockets and 27% of the installed wattage in Vermont's existing C&I building stock as shown in Figure 31. LED lamps also account for a sizable proportion of medium screw-based lamps, occupying 36% of screw-based sockets and 15% of the wattage installed in these sockets. Incandescent lamps represent approximately 22% of medium screw-based lamps, but account for over 40% of the power draw of these socket types.

Figure 30. Saturation of Screw-Based Sockets



CFLs represent a smaller proportion of both sockets and installed wattage in large facilities (26% and 20%, respectively), while being more predominantly featured in medium and small facilities.

Figure 31. CFL Saturation of Screw-Based Sockets by Facility Size



LEDs represent a much larger proportion of lamps in large buildings than in small buildings. Because LEDs and CFLs are competing technologies, it appears that large facilities have adopted LEDs in greater numbers than CFLs, as shown in Figure 32.

Figure 32. LED Saturation of Screw-Based Sockets by Facility Size

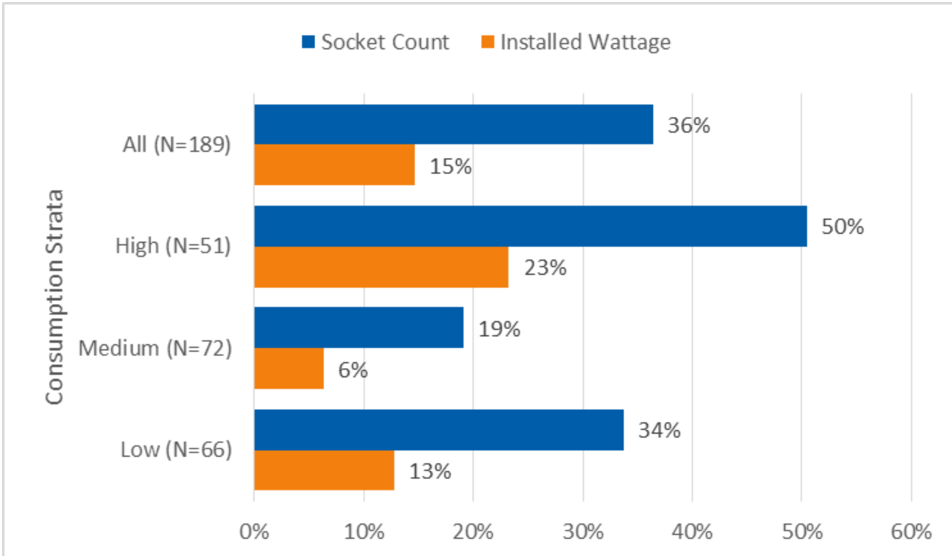
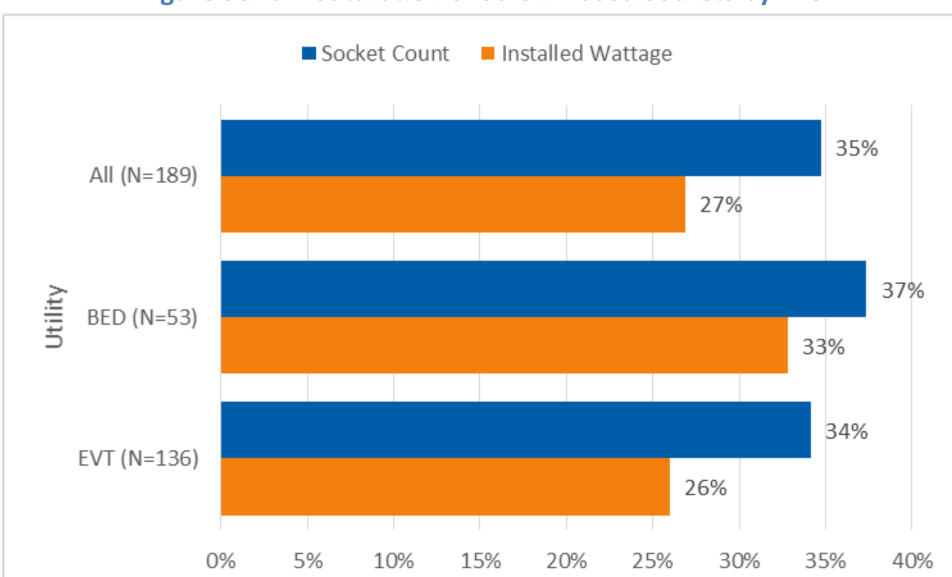


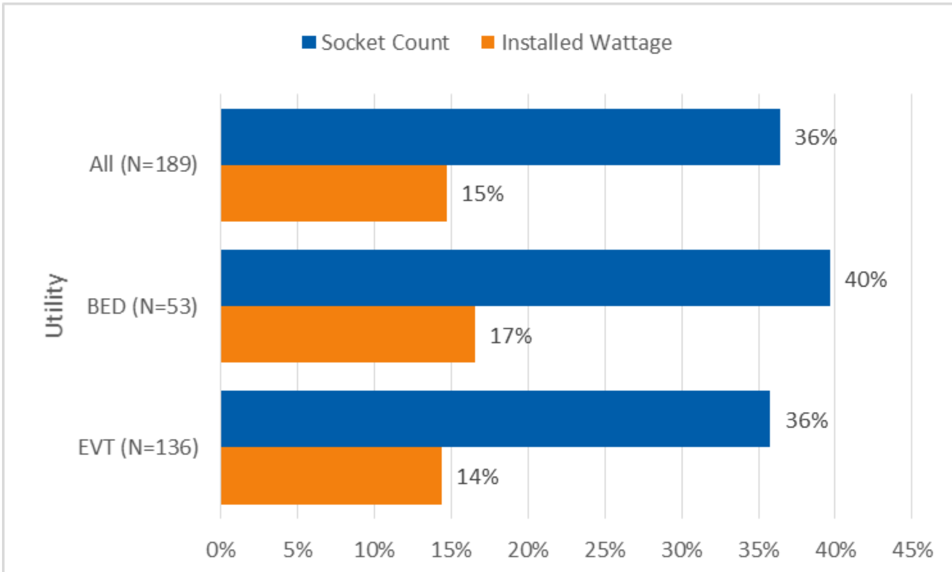
Figure 33 presents the CFL saturation of screw-based sockets by EEU. CFL Saturation by EEU is nearly identical for BED and EVT, but CFLs account for a higher proportion of the installed wattage in BED territory.

Figure 33. CFL Saturation of Screw-Based Sockets by EEU



As with CFLs, LEDs appear to be more prevalent in the BED service territory than the EVT territory as shown in Figure 34.

Figure 34. LED Saturation of Screw-Based Sockets by EEU



Manual on/off switches for indoor lighting were found in all buildings in the 2016 sample as shown in Table 12. Motion / occupancy sensors are the lighting control type with the second highest penetration level in Vermont's existing C&I building stock (31% of facilities). Motion / occupancy sensors are more prevalent in BED facilities (71%) than EVT facilities (21%), and are more commonly found in larger facilities (56%). These controls are also prevalent in schools (83%) and all hospitals (100%).

Timeclock / EMS control systems were predominantly found in the BED service territory (15%), and manufacturing (17%) and food sales facilities (54%). Daylighting controls were only found in the EVT service territory as well as 30% of hospitals, 13% of schools, and 2% of offices. There were no incidences of lighting systems that are left on 24/7 during the 2016 site visits.

Table 12. Penetration of Indoor Lighting Control Types*

Category	Manual Switch	Motion/ Occupancy Sensor	Always On (24/7)	Timeclock /EMS	Dimmer	Daylighting Controls
All (N=189)	100%	31%	0%	4%	4%	1%
EEU						
BED (N=53)	100%	71%	0%	15%	0%	0%
EVT (N=136)	100%	21%	0%	1%	5%	2%
VT Gas (N=106)	100%	35%	0%	7%	4%	0%
Facility Size						

Category	Manual Switch	Motion/ Occupancy Sensor	Always On (24/7)	Timeclock /EMS	Dimmer	Daylightin g Controls
High (N=51)	100%	56%	0%	10%	4%	1%
Medium (N=72)	100%	14%	0%	0%	0%	0%
Low (N=66)	100%	15%	0%	0%	8%	4%
Facility Type						
Retail (N=25)	100%	22%	0%	0%	3%	0%
Office (N=27)	100%	33%	0%	3%	0%	2%
Manufacturing (N=28)	100%	42%	0%	17%	6%	0%
Balance of Commercial (N=109)	100%	30%	0%	4%	11%	1%

* Presented as percentage wattage

Manual switches rank as the most prevalent form of linear fluorescent lighting control across all EEUs and size strata, accounting for an estimated 91% of linear fluorescent lighting controls statewide. Manual switches are followed by motion / occupancy sensors (5% statewide) and timeclock / EMS systems (2% statewide).

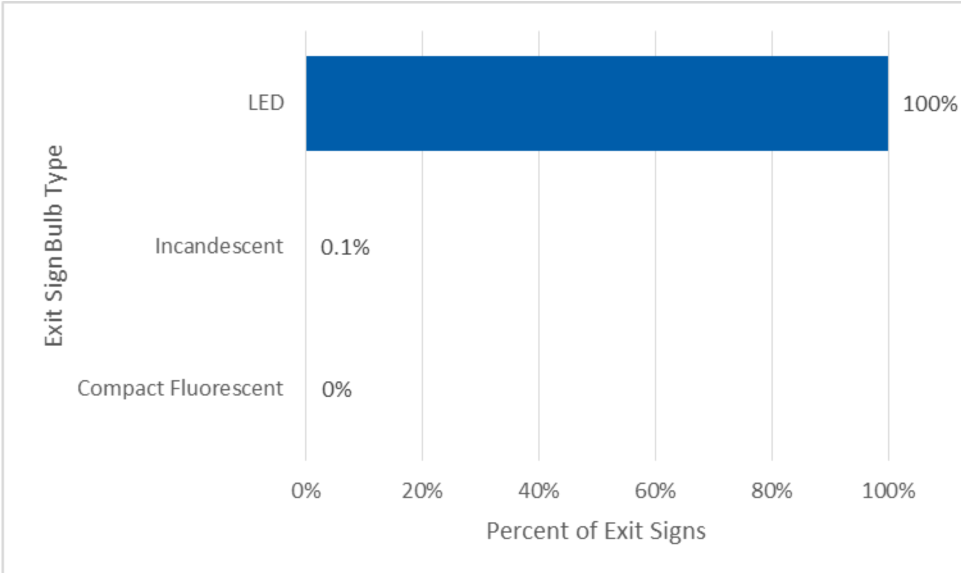
Table 13. Saturation of Indoor Lighting Control Types for Linear Fluorescents Only*

Category	Manual Switch	Motion/ Occupancy Sensor	Timeclock /EMS	Dimmer	Daylighting Controls	No Space Control	Not Identified
All (N=189)	91%	5%	2%	1%	0%	1%	4%
EEU							
BED (N=53)	93%	6%	8%	0%	0%	0%	4%
EVT (N=136)	90%	4%	1%	1%	0%	2%	4%
VT Gas (N=106)	89%	4%	4%	1%	0%	2%	5%
Facility Size							
High (N=51)	85%	7%	5%	1%	0%	1%	7%
Medium (N=72)	95%	2%	0%	0%	0%	2%	3%
Low (N=66)	95%	5%	0%	0%	1%	0%	2%

* Note: Rows may add to more than 100% because of lighting systems with multiple forms of control.

As shown in Figure 35, LED exit signs account for nearly 100% of exit sign lamp types in Vermont. Though the percentage is very small (0.1%), field staff observed a small number of incandescent exit signs identified during the 2016 site visits. No CFL exit signs were observed.

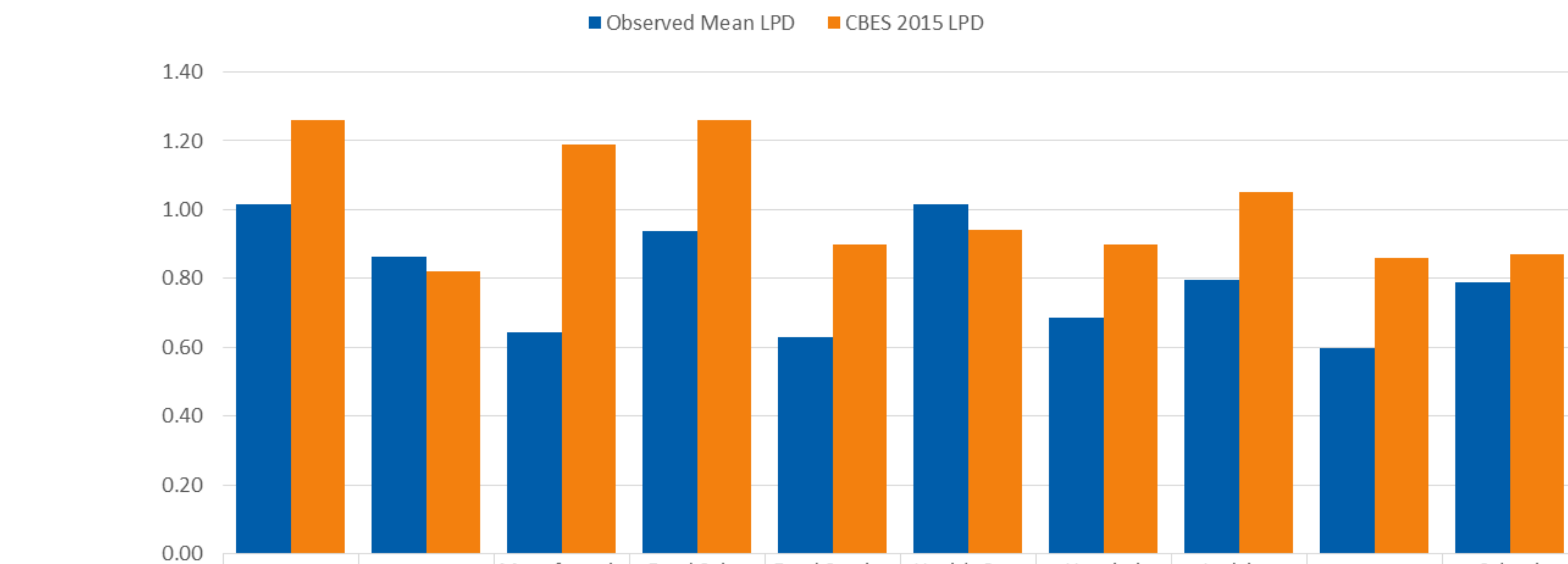
Figure 35. Saturation of Indoor Exit Sign Lamp Types (N=244)



Interior Lighting—Lighting Power Density

Figure 36 shows a comparison of observed lighting power density (LPD) with requirements set forth in the 2015 CBES for each facility type. In most cases, the observed LPD for existing C&I facilities is lower than the code-mandated value, though LPD values exceeded code overall for office and healthcare facilities.

Figure 36. LPD Chart*



	Retail (N=26)	Office (N=29)	Manufacturing (N=28)	Food Sales (N=16)	Food Service (N=17)	Health Care (N=13)	Hospital (N=5)	Lodging (N=16)	Other (N=27)	School (N=15)
Observed Mean LPD	1.02	0.86	0.64	0.94	0.63	1.02	0.69	0.79	0.60	0.79
CBES 2015 LPD	1.26	0.82	1.19	1.26	0.90	0.94	0.90	1.05	0.86	0.87

* There is not a specific LPD requirement for food sale facilities in the 2015 CBES. The requirement shown in the table is for retail facilities.

Exterior Lighting

Exterior Lighting—Lamp Types

The following figures represent the exterior lighting equipment recorded during the 2015-2016 on-site assessments, with the exception of a parking garage surveyed at one of the existing building sites. The parking garage was lit entirely by T8 lamps and represented a large portion of the recorded exterior lighting. The garage represented a possible outlier in the analysis and has been removed from the figures and tables below.

Together, CFLs (30%) and LEDs (22%) represent over half of the exterior lamps identified during the on-site assessments, followed by incandescent (11%), halogen (9%), and metal halide (5%) lamps. Despite only accounting for 5% of lamps, metal halide lamps represent over a quarter (26%) of the installed wattage. A very small number of T12 and induction lamps were identified during the site visits.

Figure 37. Distribution of Outdoor Lamp Types—All Sites (N=189)

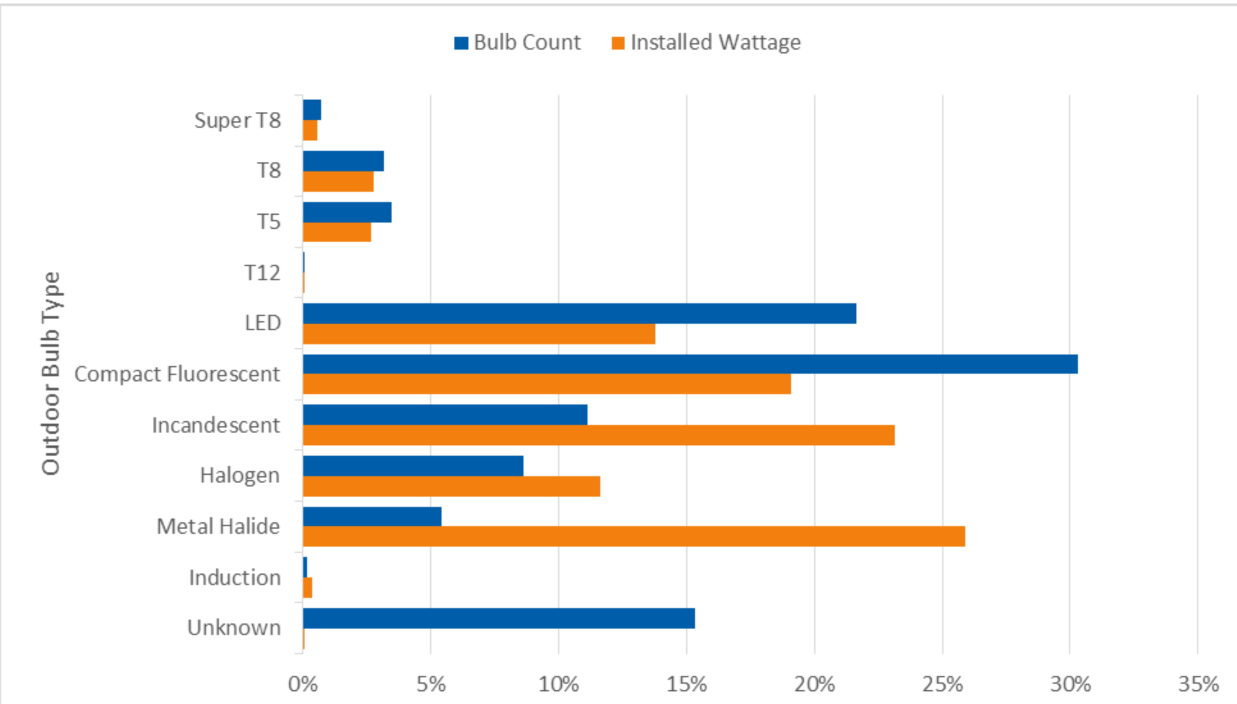
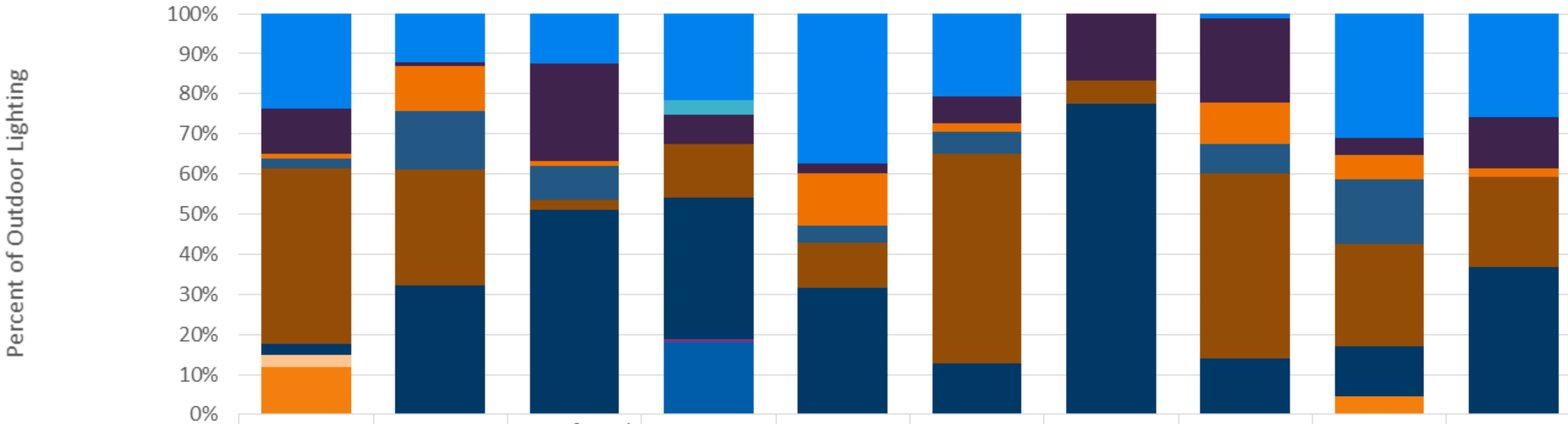


Figure 38 presents the distribution of outdoor lamp types by facility type. CFLs and LEDs are found across all building types, with the highest concentration of CFLs found in healthcare (52%), lodging (46%), and retail facilities (44%). The highest concentrations of LEDs are found in hospitals (78%), manufacturing (51%) and school facilities (37%). Metal halide lamps are found across all facility types, and are most commonly found in manufacturing, lodging, and hospitals.

Figure 38. Distribution of Outdoor Lamp Types by Facility Type (N=189)

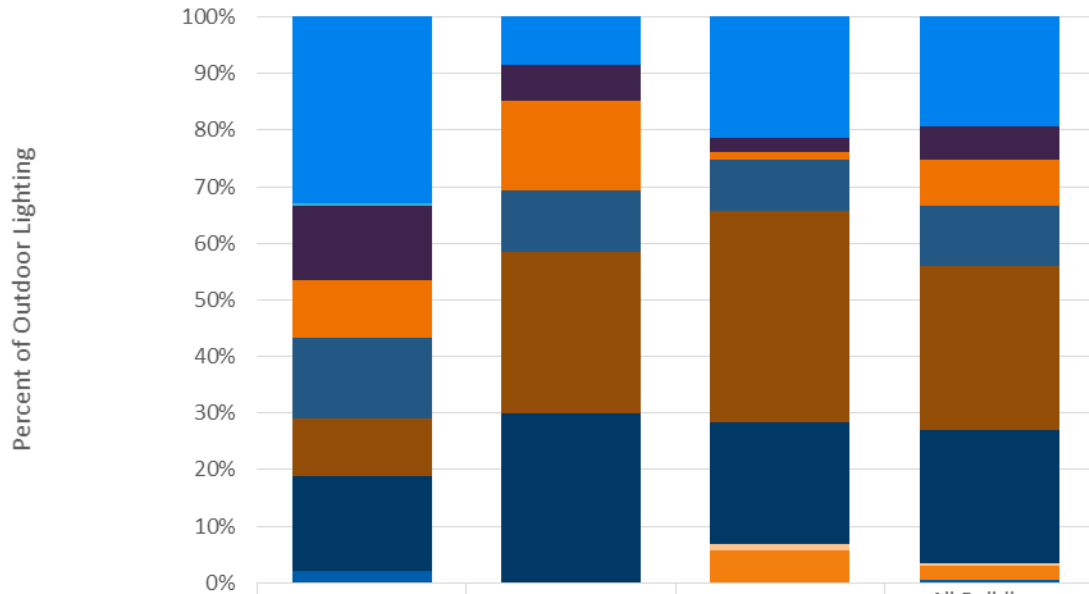


	Retail (N=25)	Office (N=27)	Manufacturing (N=28)	Food Sales (N=16)	Food Service (N=17)	Health Care (N=13)	Hospital (N=5)	Lodging (N=16)	Other (N=27)	School (N=15)
Unknown	24%	12%	13%	22%	37%	21%	0%	1%	31%	26%
Induction	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%
Metal Halide	11%	1%	24%	7%	2%	7%	17%	21%	4%	13%
Halogen	1%	11%	1%	0%	13%	2%	0%	10%	6%	2%
Incandescent	2%	15%	8%	0%	4%	5%	0%	7%	16%	0%
Compact Fluorescent	44%	29%	2%	13%	11%	52%	6%	46%	26%	22%
LED	3%	32%	51%	35%	32%	13%	78%	14%	12%	37%
T12	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%
T5	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%
T8	12%	0%	0%	0%	0%	0%	0%	0%	4%	0%
Super T8	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%

Facility Type

The distribution of outdoor lamp type by size stratum is shown in Figure 39. Medium and small facilities have higher proportions of both LEDs and CFLs than the statewide averages. In larger facilities metal halide, halogen, incandescent, compact fluorescent, and LED all represent similar proportions of the total outdoor lighting, ranging anywhere from 10% to 17% of the total lighting in those facility types. Linear fluorescent lamps are most often found in smaller facilities.

Figure 39. Distribution of Outdoor Lamp Type by Facility Size (N=189)

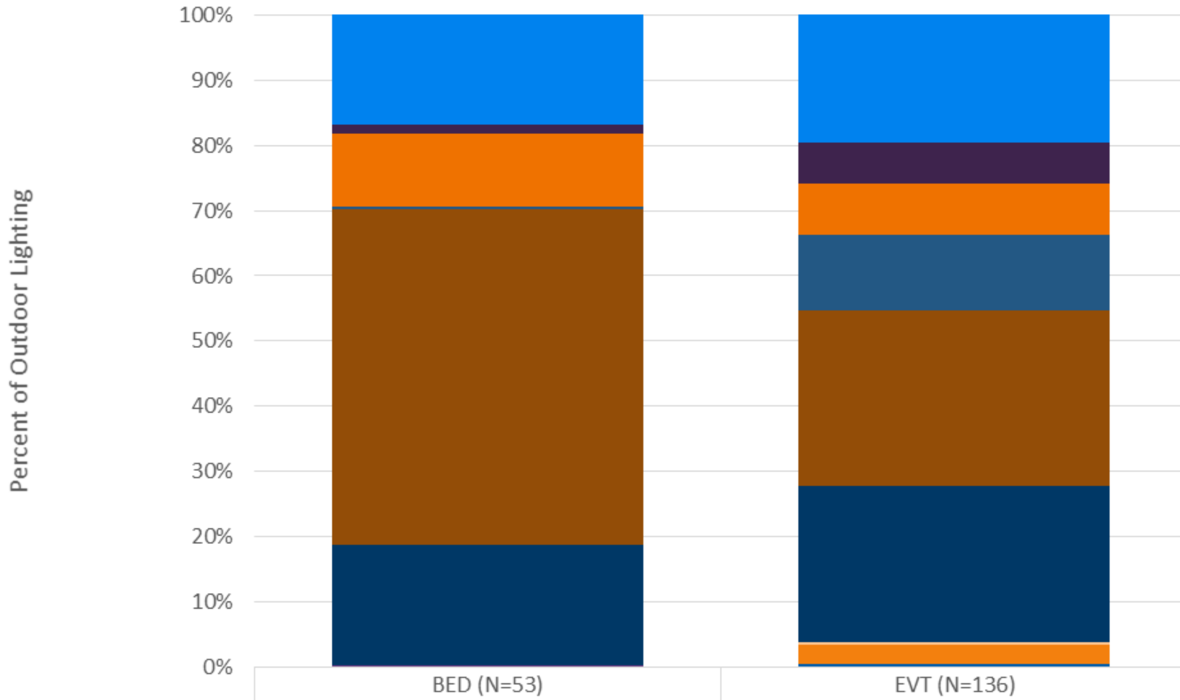


	High (N=51)	Medium (N=72)	Low (N=66)	All Buildings (N=189)
Unknown	33%	8%	21%	19%
Induction	0%	0%	0%	0%
Metal Halide	13%	6%	2%	6%
Halogen	10%	16%	1%	8%
Incandescent	14%	11%	9%	11%
Compact Fluorescent	10%	29%	37%	29%
LED	17%	30%	21%	23%
T12	0%	0%	0%	0%
T5	0%	0%	1%	0%
T8	0%	0%	6%	3%
Super T8	2%	0%	0%	0%

Size Stratum

Over two-thirds of the exterior lighting in the BED service territory is comprised of CFLs (52%) and LEDs (18%). The EVT service territory has a higher saturation of LED lamps (24%) and a lower proportion of CFLs (27%). All told, just over half of exterior lamps in the EVT service territory are either CFLs or LEDs.

Figure 40. Distribution of Outdoor Lamp Types by EEU (N=189)



	BED (N=53)	EVT (N=136)
Unknown	17%	19%
Induction	0%	0%
Metal Halide	1%	6%
Halogen	11%	8%
Incandescent	0%	12%
Compact Fluorescent	52%	27%
LED	18%	24%
T12	0%	0%
T5	0%	1%
T8	0%	3%
Super T8	0%	0%

Exterior Lighting—Control Types

As shown in Table 14, the most common forms of outdoor lighting controls are daylighting controls (34%), manual switches (43%), and timeclock / EMS systems (18%).

Table 14. Saturation of Outdoor Lighting Control Types by Facility Type*

Category	Manual Switch	Motion/ Occupancy Sensor	Always On (24/7)	Timeclock/ EMS	Dimmer	Daylighting Controls	No Space Control	Not Identified
All (N=189)	43%	4%	0%	18%	0%	34%	1%	5%
EEU								
BED (N=53)	40%	1%	0%	23%	0%	19%	0%	18%
EVT (N=136)	43%	5%	0%	17%	0%	35%	1%	4%
VT Gas (N=106)	43%	2%	0%	19%	0%	33%	2%	3%
Facility Size								
High (N=51)	0%	0%	0%	17%	0%	77%	0%	5%
Medium (N=72)	47%	0%	0%	22%	0%	21%	0%	10%
Low (N=66)	67%	11%	0%	14%	0%	16%	2%	0%
Facility Type								
Retail (N=25)	87%	9%	0%	12%	0%	0%	0%	2%
Office (N=27)	48%	4%	0%	8%	0%	44%	0%	0%
Manufacturing (N=28)	14%	1%	0%	23%	0%	63%	1%	0%
Food Sales (N=16)	17%	0%	0%	31%	0%	52%	0%	0%
Food Service (N=17)	28%	1%	0%	51%	0%	17%	0%	4%
Health Care (N=13)	12%	11%	0%	52%	0%	30%	1%	5%
Hospital (N=5)	0%	0%	0%	13%	0%	74%	0%	13%
Lodging (N=16)	6%	0%	0%	2%	0%	70%	0%	22%
Other (N=27)	45%	7%	0%	33%	0%	11%	5%	5%

School (N=15)	5%	0%	0%	3%	0%	88%	0%	5%

Category	Manual Switch	Motion / Occupancy Sensor	Always On (24/7)	Timeclock / EMS	Dimmer	Daylighting Controls	No Space Control	Not Identified
All (N=189)	43%	4%	0%	18%	0%	34%	1%	5%
EEU								
BED (N=53)	40%	1%	0%	23%	0%	19%	0%	18%
EVT (N=136)	43%	5%	0%	17%	0%	35%	1%	4%
VT Gas (N=106)	43%	2%	0%	19%	0%	33%	2%	3%
Facility Size								
High (N=51)	0%	0%	0%	17%	0%	77%	0%	5%
Medium (N=72)	47%	0%	0%	22%	0%	21%	0%	10%
Low (N=66)	67%	11%	0%	14%	0%	16%	2%	0%
Facility Type								
Retail (N=25)	87%	9%	0%	12%	0%	0%	0%	2%
Office (N=27)	48%	4%	0%	8%	0%	44%	0%	0%
Manufacturing (N=28)	14%	1%	0%	23%	0%	63%	1%	0%
Food Sales (N=16)	17%	0%	0%	31%	0%	52%	0%	0%
Food Service (N=17)	28%	1%	0%	51%	0%	17%	0%	4%
Health Care (N=13)	12%	11%	0%	52%	0%	30%	1%	5%
Hospital (N=5)	0%	0%	0%	13%	0%	74%	0%	13%
Lodging (N=16)	6%	0%	0%	2%	0%	70%	0%	22%
Other (N=27)	45%	7%	0%	33%	0%	11%	5%	5%
School (N=15)	5%	0%	0%	3%	0%	88%	0%	5%

* Note: Rows may add to more than 100% because of lighting systems with multiple forms of control.

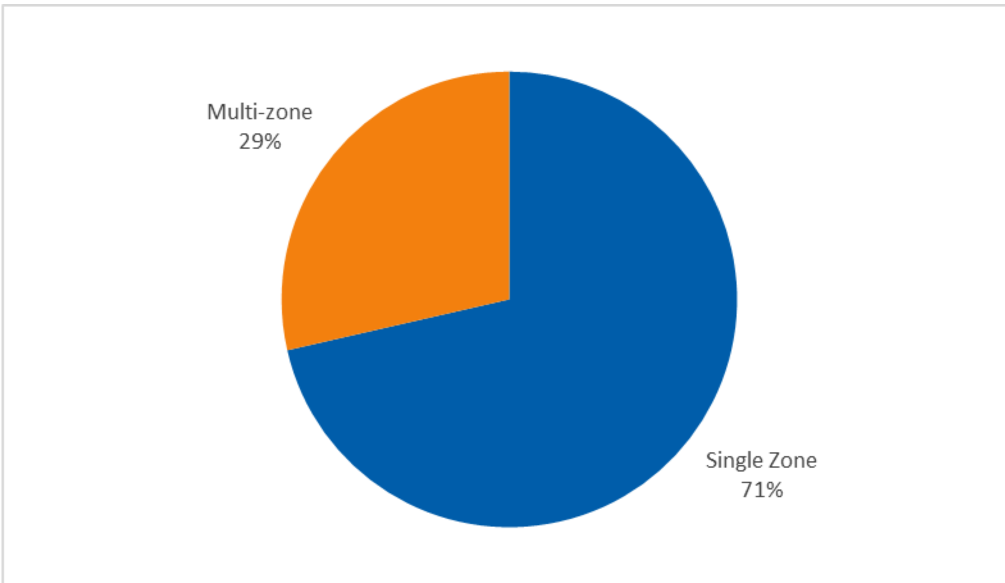
EEU Market Characterization—Lighting

<table>
<tr><th>Lighting Group</th><th>Measure/Characteristic</th><th>BED</th><th>EVT</th></tr>
<tr><td rowspan="5">Indoor Lighting</td><td>T12s</td><td colspan="2">• No significant difference from the statewide average (8%).</td></tr>
<tr><td>T8/"Super" T8</td><td colspan="2">• Represent over half of all interior lighting in both the BED (63%) and EVT (65%) service territories.</td></tr>
<tr><td>CFLs</td><td colspan="2">• Account for approximately 10% of all interior lamps in both BED and EVT service territories.
• Indoor saturation has halved since 2011.</td></tr>
<tr><td>LEDs</td><td colspan="2">• Account for approximately 10% of all interior lamps in both BED and EVT service territories.
• Indoor saturation has increased dramatically since 2011 when LEDs accounted for 1% of BED lamps and 2% of EVT lamps.</td></tr>
<tr><td>Automated Indoor Lighting Controls</td><td>• Manual switches are still the most prevalent form of indoor lighting control.
• Motion/occupancy sensors account for 6% of lighting controls.
• Timeclock / EMS systems account for 8% of lighting controls.</td><td>• Manual switches are still the most prevalent form of indoor lighting control.
• Motion/occupancy sensors account for 4% of lighting controls.
• Timeclock / EMS systems account for 1% of lighting controls.</td></tr>
<tr><td rowspan="3">Outdoor Lighting</td><td>CFLs</td><td>• The second most common form of exterior lighting (8%).</td><td>• Most common form of exterior lighting (27%).</td></tr>
<tr><td>LEDs</td><td>• Third most common form of exterior lighting after T8 and CFL.</td><td>• Second most common form of lighting (22%); double the 2011 proportion.</td></tr>
<tr><td>Automated Outdoor Lighting Controls</td><td colspan="2">• Automated lighting controls are much more commonly found in facilities within EVT's service territory.</td></tr>
</table>

HVAC

Considered by count of systems, an estimated 71% of HVAC systems in Vermont business sector existing building facilities are single-zone systems; only 29% are multi-zone systems, as shown in Figure 41. Single-zone systems are typically considered “simple” systems in Vermont’s 2015 CBES commercial energy code, and multi-zone systems are categorized as “complex” systems.

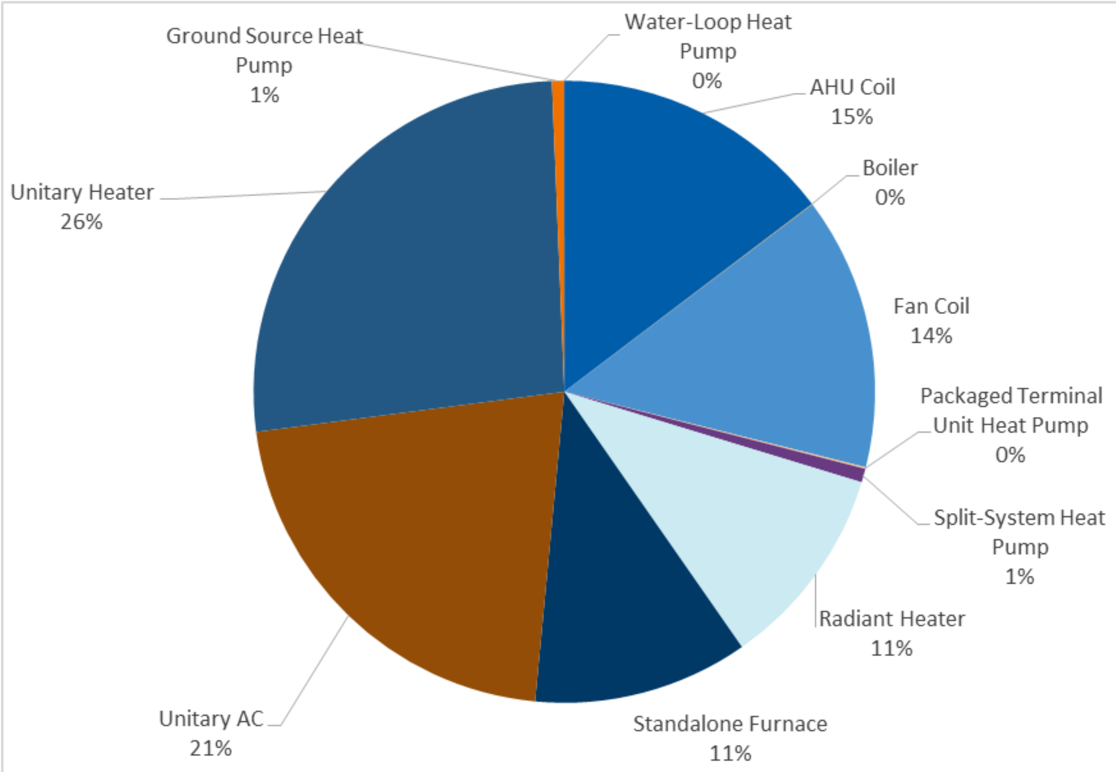
Figure 41. Distribution of Single-Zone and Multi-Zone Systems (N=771)



Single-Zone Distribution Systems

During the 2016 site visits, 640 single-zone HVAC systems were identified, including zonal heating and cooling systems with dedicated controls. Figure 42 shows that the most common equipment type among these 640 systems were unitary heaters (26%) and unitary ACs (21%) followed by air-handling unit (AHU) coils and fan coils (14%). Stand-alone furnaces represent only about 11% of the single-zone HVAC systems by system count, and boilers represent less than 1%, though boilers often heat large zones and represent a much larger share by capacity.

Figure 42. Distribution of Single-Zone Systems (N=640)



The average age of the single-zone systems identified in Vermont's existing building stock is broken out by size strata in Figure 43 below. Statewide, the average system age is approximately 13 years. Systems in medium and small facilities are a little older, averaging 15 years old, while systems in large facilities tend to be a few years newer.

Figure 43. Average Age of Single-Zone HVAC Systems by Facility Size (N=500)

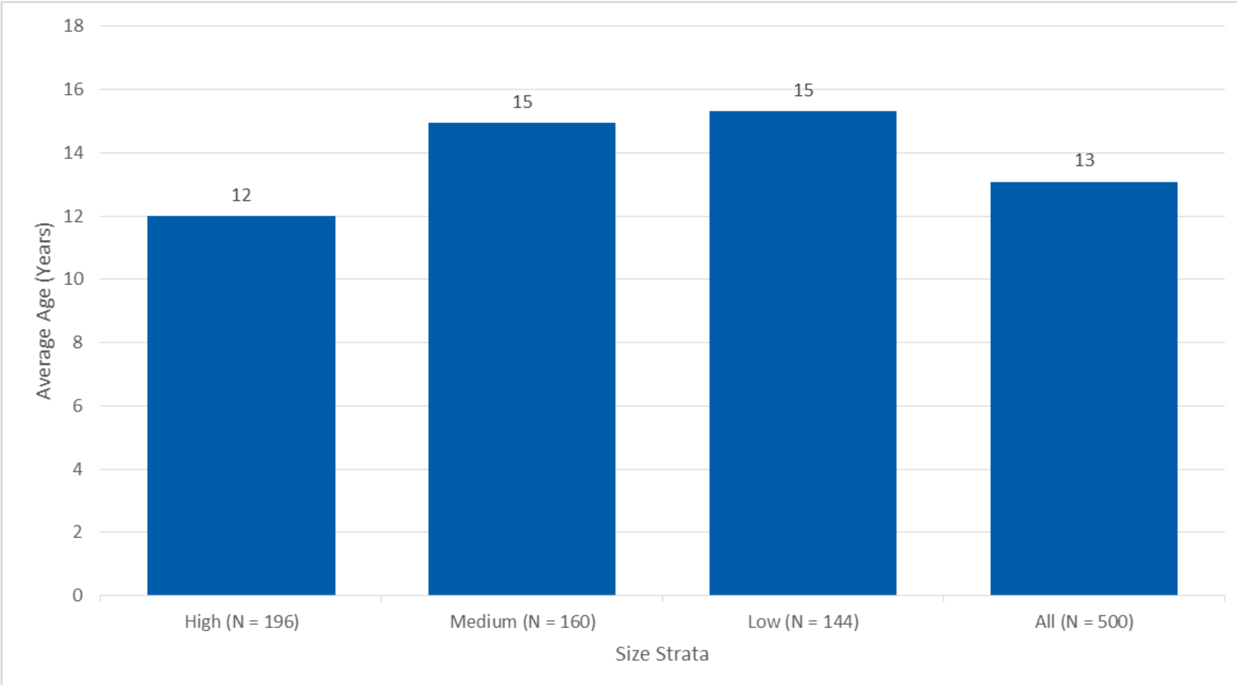
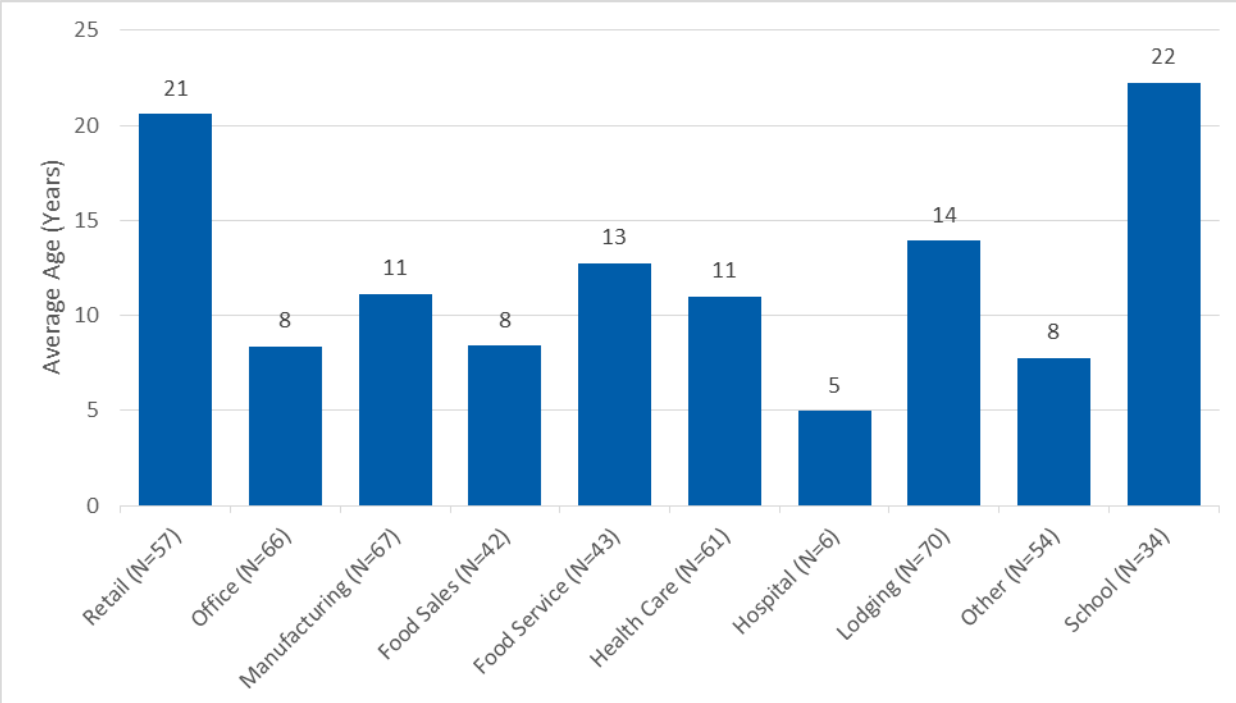


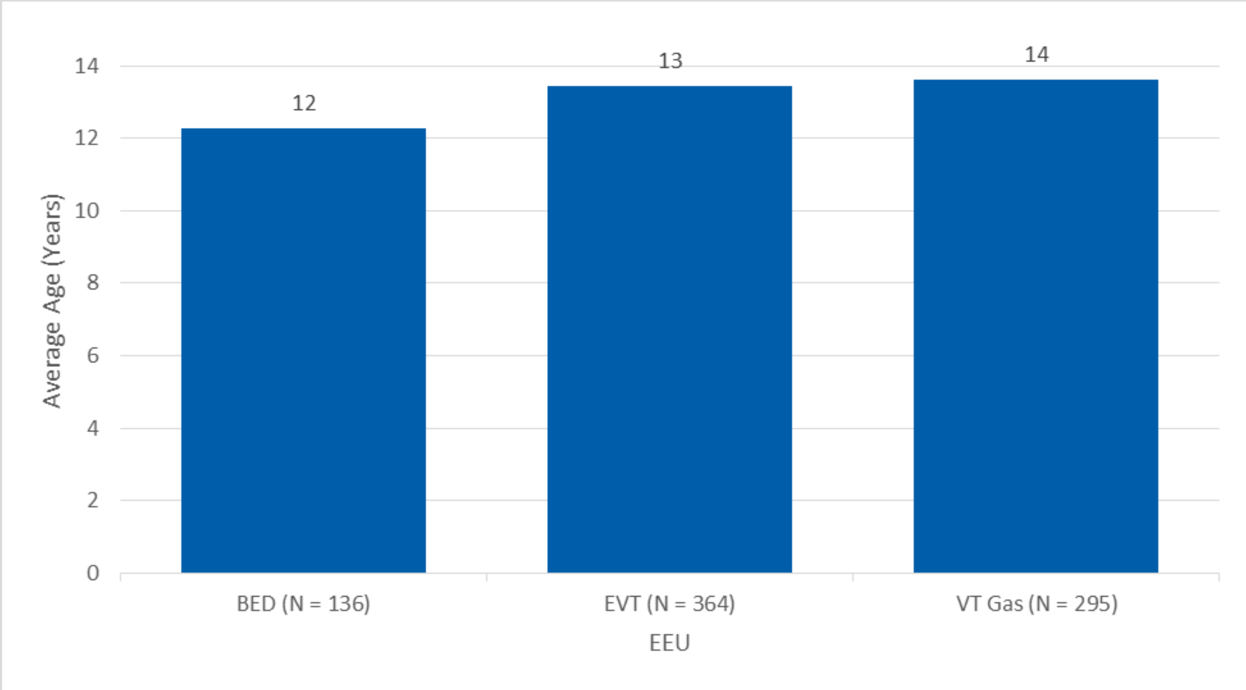
Figure 44 shows the distribution of single-zone systems by facility type. Hospitals have the newest equipment, averaging around five years old, followed by offices and food sales facilities at around eight years. The oldest systems are found in schools (22 years) and retail facilities (21 years).

Figure 44. Average Age of Single-Zone HVAC Systems by Facility Type (N=500)



There is very little difference in the age of single-zone HVAC systems by EEU, as shown in Figure 45.

Figure 45. Average Age of Single-Zone HVAC Systems by EEU (N=500)



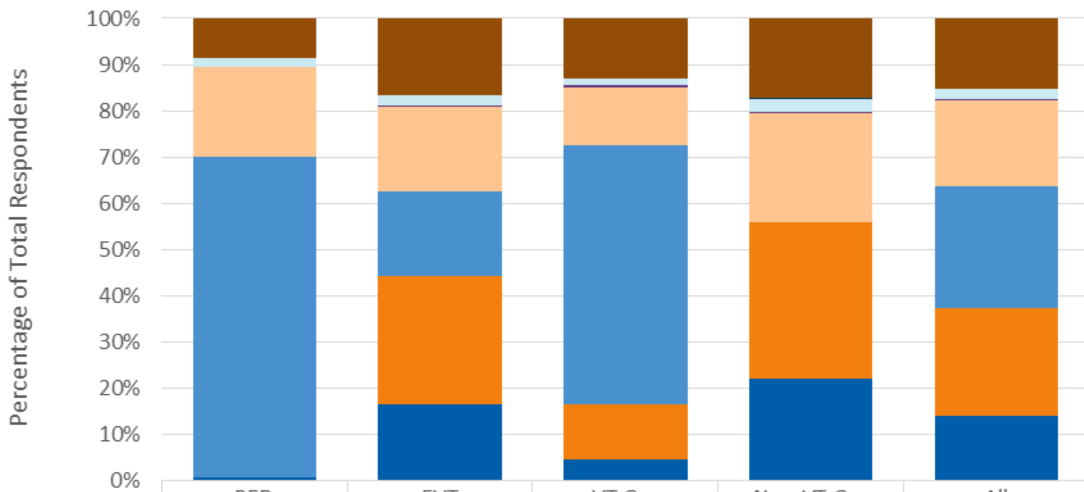
Heating Systems

Heating Fuel Type

Statewide, the most common heating fuel type for systems is natural gas (26%), followed by propane (23%) and electricity (18%). Electricity as a heating source is fairly consistent from one utility region to another, from 12% on the low end (VT Gas territory) to 24% on the high end (non-VT Gas territory).There is considerable variation by utility region, especially with regards to the proportion of gas and propane systems:

- The majority of BED heating systems are natural gas (69%). No systems are heated by propane, and 1% of systems are heated with fuel oil.
- There is a fairly even distribution of natural gas (18%) and fuel oil (16%) in the EVT service territory. Propane accounts for 28% of systems.
- Over half (56%) of the systems in the VT Gas territory are natural gas systems. Propane accounts for 12% and fuel oil for 5%.
- There is a fairly even distribution of electrical heating systems (24%) and fuel oil heating systems (22%) in the non-VT Gas service territory. Propane accounts for 34% of systems.

Figure 46. Heating System Fuel Type by EEU (N=549)



	BED (N = 145)	EVT (N = 404)	VT Gas (N = 329)	Non-VT Gas (N = 220)	All (N = 549)
Unknown	9%	17%	13%	17%	15%
Multiple	0%	0%	0%	0%	0%
Other	2%	2%	1%	3%	2%
Wood	0%	0%	1%	0%	0%
Electricity	19%	18%	12%	24%	18%
Natural Gas	69%	18%	56%	0%	26%
Propane	0%	28%	12%	34%	23%
Fuel Oil	1%	16%	5%	22%	14%

EEU / Area

Heating System Type

Figure 47 shows that boilers comprise the majority of heating system capacity in Vermont, especially in VT Gas service territory and in large facilities. Stand-alone furnaces also comprise a large portion of the state's heating capacity, despite being only a small percentage of single-zone HVAC systems. Radiant heaters are most commonly found in non-VT Gas service territory, as well as smaller facilities. Unitary heaters are found across all three size strata as well as inside and outside the VT Gas territory.

Figure 47. Distribution of Heating System Types by Facility Size and VT Gas Territory

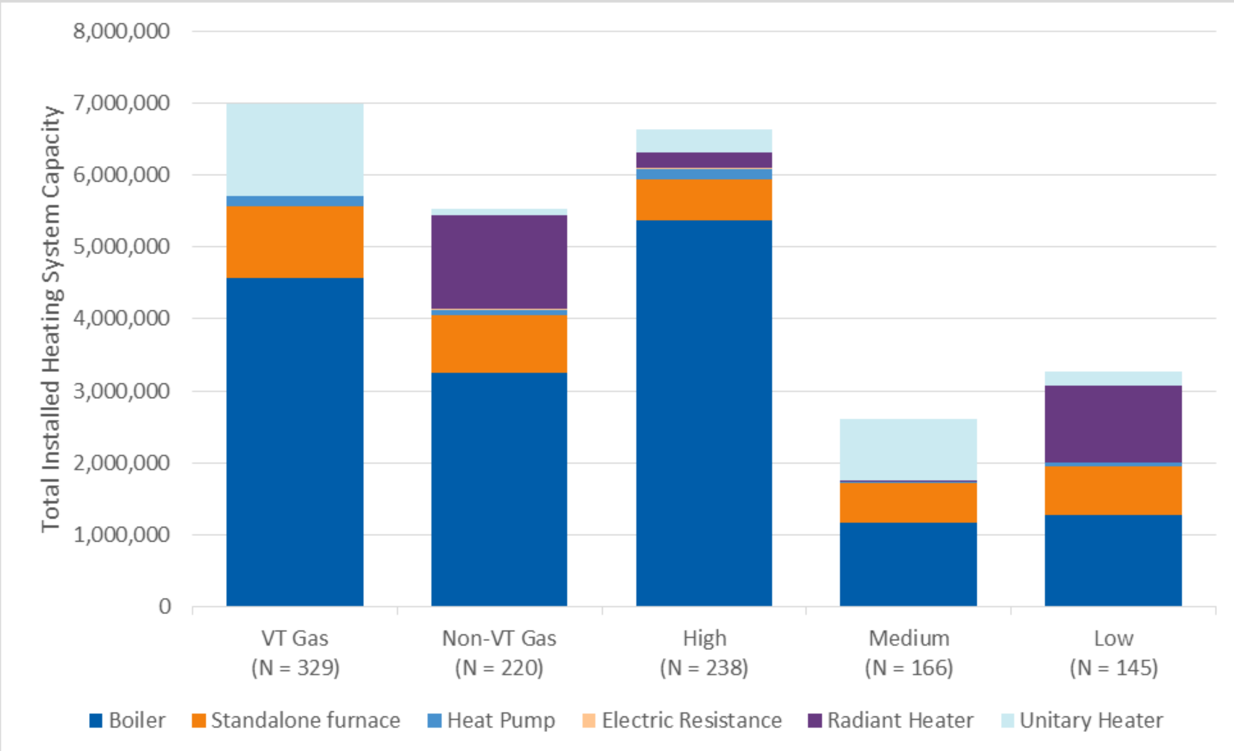


Table 15 shows heating system efficiencies for furnaces, boilers, and heat pumps broken out by CBEs 2015 categories and input capacity thresholds. The statewide average equipment efficiency exceeds energy code for all equipment types except oil-fired steam boilers between 300,000 Btu/h and 2,500,000 Btu/h. There are a number of systems in almost all equipment categories that do not meet the latest version of the CBES.

Table 15. Heating System Efficiency by Type and Code Category

System	Subcategory	Size Category (Input)	Observed Mean Efficiency	Code of Federal Regulation Minimum Efficiency	Percentage of Systems Below/Meet/Above Code	Number of Units
Warm Air Furnaces, gas fired	-	<225,000 Btu/h	90%	78% AFUE or 80% Thermal Efficiency	2%/15%/83%	46
	Maximum capacity	≥225,000 Btu/h	-	80% Thermal Efficiency	No observed systems	0
Warm Air Furnaces, oil fired	-	<225,000 Btu/h	82%	78% AFUE or 80% Thermal Efficiency	0%/0%/100%	14
	Maximum capacity	≥225,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0
Boilers, hot water	Gas-fired	<300,000 Btu/h	87%	80% AFUE	0%/14%/86%	29
		≥300,000 Btu/h and <2,500,000 Btu/h	90%	80% Thermal Efficiency	4%/19%/78%	27
		≥2,500,000 Btu/h	83%	82% Combustion Efficiency	0%/0%/100%	3
	Oil-fired	<300,000 Btu/h	85%	80% AFUE	0%/0%/100%	14
		≥300,000 Btu/h and <2,500,000 Btu/h	84%	82% Thermal Efficiency	63%/0%/38%	8
		≥2,500,000 Btu/h	-	84% Combustion Efficiency	No observed systems	0

System	Subcategory	Size Category (Input)	Observed Mean Efficiency	Code of Federal Regulation Minimum Efficiency	Percentage of Systems Below/Meet/Above Code	Number of Units
Boilers, steam	Gas-fired	<300,000 Btu/h	-	75% AFUE	No observed systems	0
	Gas-fired. All except natural draft.	≥300,000 Btu/h and <2,500,000 Btu/h	80%	79% Thermal Efficiency	17%/0%/83%	6
		≥2,500,000 Btu/h	82%	79% Thermal Efficiency	33%/0%/67%	3
	Gas-fired natural draft	≥300,000 Btu/h and <2,500,000 Btu/h	80%	77% Thermal Efficiency	17%/0%/83%	6
		≥2,500,000 Btu/h	82%	77% Thermal Efficiency	0%/33%/67%	3
	Oil-fired	<300,000 Btu/h	-	80% AFUE	No observed systems	0
		≥300,000 Btu/h and <2,500,000 Btu/h	80%	81% Thermal Efficiency	60%/0%/40%	5
		≥2,500,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0
Water Source Heat Pumps*	68°F entering water	<135,000 Btu/h	4.7 COP	4.3 COP	4%/0%/96%	316
Ground Source Heat Pumps	50°F entering water	<135,000 Btu/h	3.2 COP	3.1 COP	39%/0%/61%	116
Split System Heat Pumps	Air source	<135,000 Btu/h	9.9 HSPF	8.2 HSPF	90% / 0% / 10%	39

* Insufficient information was collected to determine the heat transfer mechanism. The most stringent efficiency standard is used.

Boilers

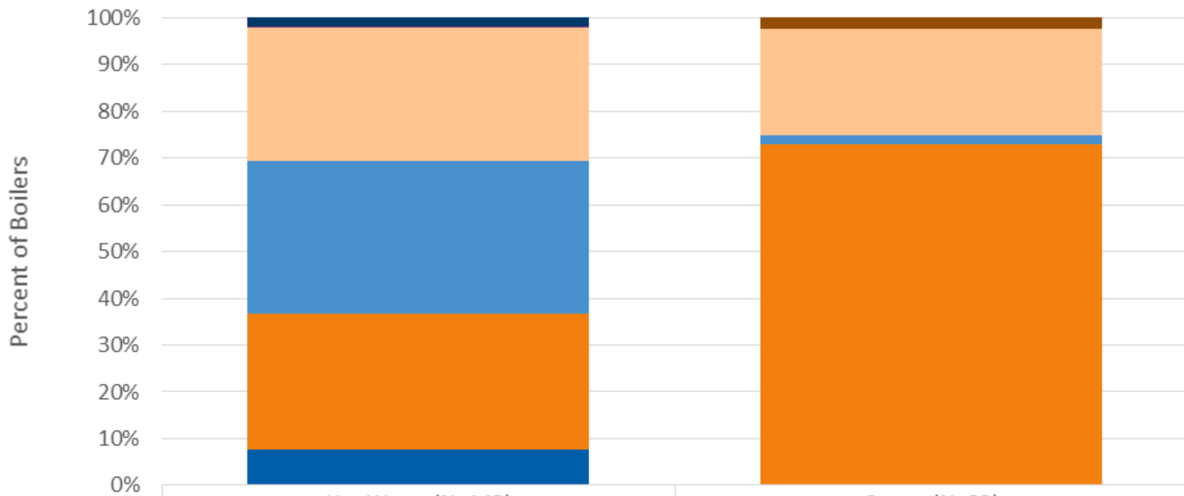
As shown in Figure 48, hot water is the most common boiler delivery medium for most facility types. All boilers systems in retail, manufacturing, food sales, and lodging facilities are hot water systems, as are almost all systems in food service facilities (98%) and schools (88%). Steam systems comprise almost all of the boiler systems in hospitals (99%) and the majority of systems in health care facilities (67%) and "other" facilities (62%).

Figure 48. Boiler Delivery Systems by Facility Type (N=165)

	Retail (N=11)	Office (N=18)	Manufacturing (N=26)	Food Sales (N=6)	Food Service (N=9)	Health Care (N=21)	Hospital (N=11)	Lodging (N=37)	Other (N=8)	School (N=18)
Unidentified	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Steam	0%	35%	0%	0%	2%	67%	99%	0%	62%	12%
Hot Water	100%	65%	100%	100%	98%	33%	1%	100%	38%	88%

Figure 49 shows the distribution of boiler fuel types by delivery system. The majority of the steam boiler systems are fueled by fuel oil (73%) or natural gas (23%). Hot water boilers are predominantly fueled by natural gas (29%), fuel oil (29%), or propane (33%). No electric or wood boilers were identified during the existing building site visits.

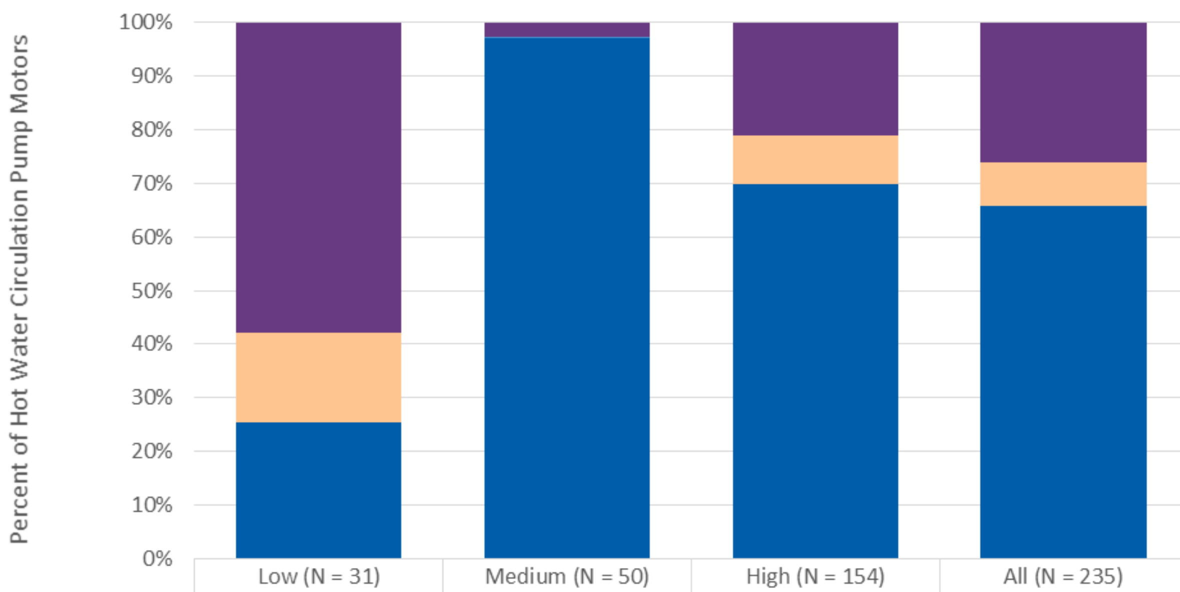
Figure 49. Boiler Fuel Type by Delivery System (N=165)



	Hot Water (N=143)	Steam (N=22)
Multiple	0%	2%
Other	2%	0%
Wood	0%	0%
Electricity	0%	0%
Natural Gas	29%	23%
Propane	33%	2%
Fuel Oil	29%	73%
Unknown	8%	0%

Most of the hot water recirculation pumps statewide are single-speed (66%) as shown in Figure 50. Only 8% of systems are variable speed; there were no two-speed or three-speed pumps identified in the existing building stock. The highest concentrations of variable speed pumps are found in small facilities (17%) and large facilities (9%).

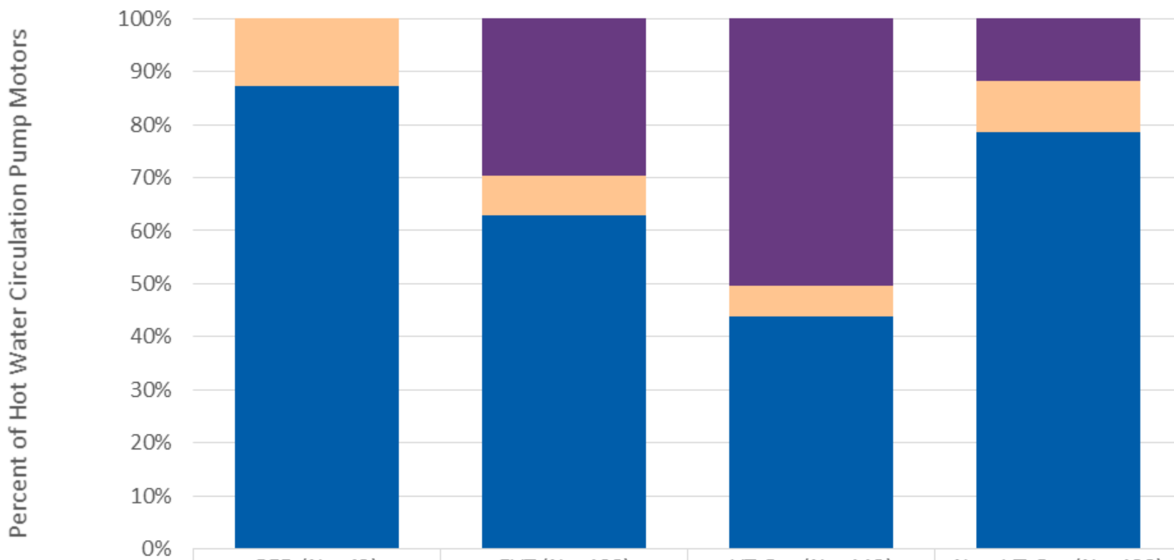
Figure 50. Saturation of Speed Controls for Hot Water Circulation Pumps by Facility Size (N=235)



	Low (N = 31)	Medium (N = 50)	High (N = 154)	All (N = 235)
Unidentified	58%	3%	21%	26%
Variable Speed	17%	0%	9%	8%
Three Speed	0%	0%	0%	0%
Two Speed	0%	0%	0%	0%
One Speed	25%	97%	70%	66%

Single-speed pumps are the most common type of hot water circulation pump identified across all EEUs. Variable speed pumps are also found across all EEUs, as shown in Figure 51. The largest proportions of these equipment are found in the BED service territory (13%) and the non-VT Gas territory (10%).

Figure 51. Saturation of Speed Controls for Hot Water Circulation Pump by EEU

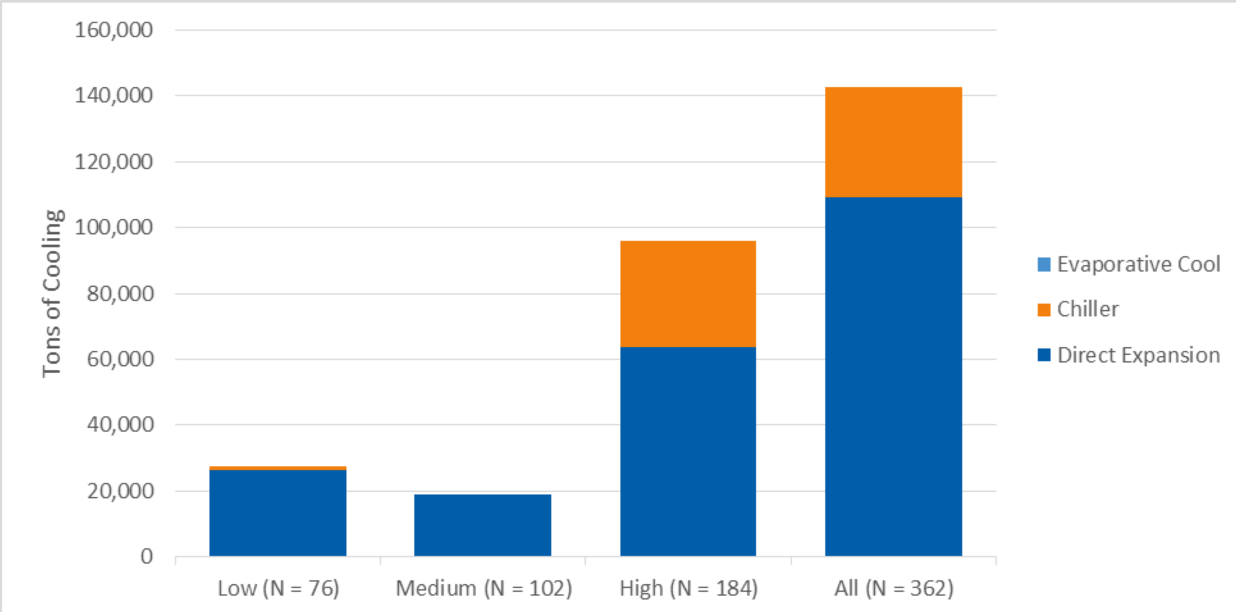


	BED (N = 42)	EVT (N = 193)	VT Gas (N = 113)	Non-VT Gas (N = 122)
Unidentified	0%	30%	50%	12%
Variable Speed	13%	8%	6%	10%
Three Speed	0%	0%	0%	0%
Two Speed	0%	0%	0%	0%
One Speed	87%	63%	44%	79%

Cooling Systems

Direct expansion and chiller systems are the most common cooling systems identified across Vermont's existing building stock, as shown in Figure 52. The majority of the cooling capacity comes from direct expansion systems (approximately 95% of the cooling capacity statewide). No evaporative cooling systems were identified during the 2016 site visits. The majority of the cooling capacity identified in 2016 was found in larger facilities.

Figure 52. Saturation of Cooling System Types by Facility Size (N=362)



The largest proportion of cooling capacity in the state's existing buildings was identified in office buildings, which account for approximately 37% of the state's overall cooling capacity. Retail, manufacturing, hospitals, lodging, and "other" facilities also account for a significant proportion of the cooling capacity in existing buildings. Chiller systems are the primary form of cooling in hospital facilities.

Figure 53. Saturation of Cooling System Types by Facility Type (N=362)

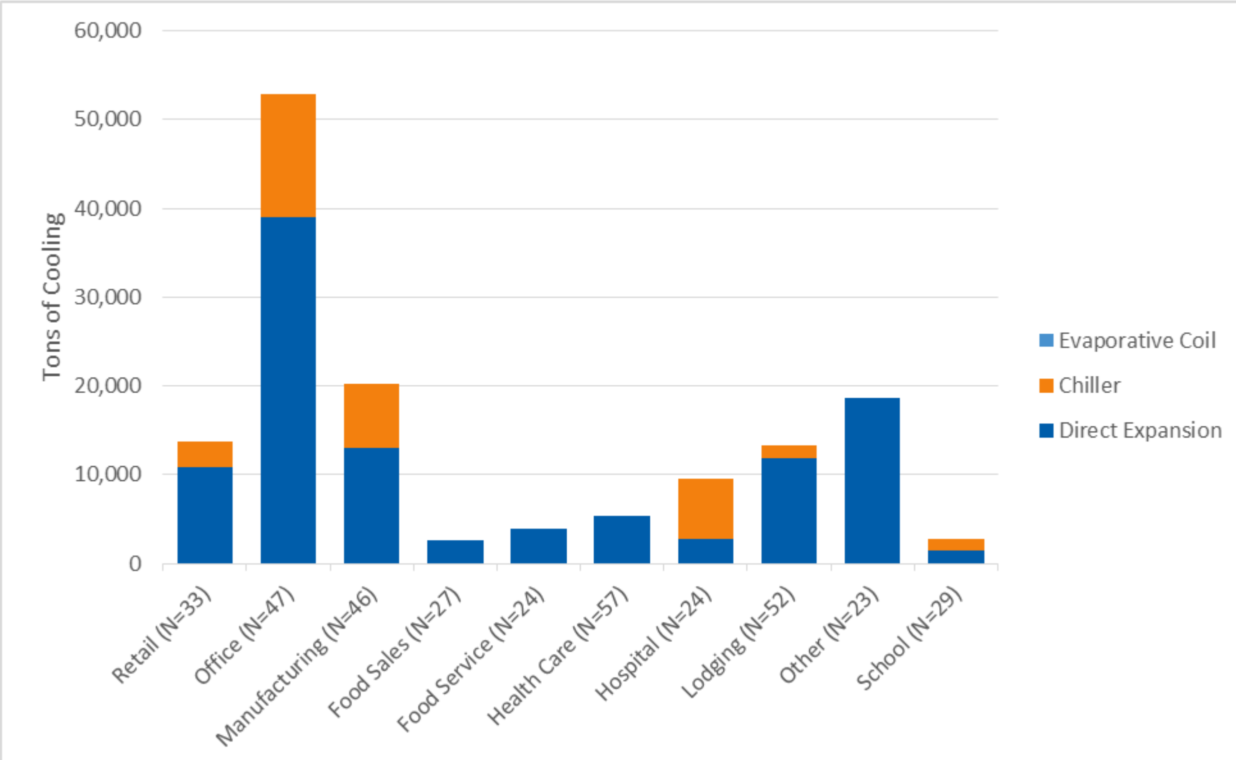


Table 16 compares the cooling efficiency of single-zone HVAC systems to 2015 CBES requirements. Small units (less than 65,000 Btu/h) tend to fall below the CBES code guidelines for these systems. Of the 390 pieces of equipment, approximately 87% fell below the code-required 13 Seasonal Energy Efficiency Rating (SEER). Systems larger than 135,000 Btu/h tend to exceed the CBES requirement of 11 Energy Efficiency Rating (EER); the statewide average is 11.5 EER. Medium-sized units fall in between the other two categories, but as with the units smaller than 65,000 Btu/h, most of these equipment do not meet the 2015 CBES requirements.

Table 16. Cooling Efficiency of Single-Zone HVAC Systems

Statistic	<5.5 tons (65,000 Btu/h) (Code: 13.0 SEER)	≥5.5 tons and <11.25 tons (135,000 Btu/h) (Code: 11.2 EER)	≥11.25 tons (135,000 Btu/h) (Code: 11 EER)
Percentage of Systems Below Code	87%	60%	5%
Percentage of Systems Above Code	13%	40%	95%
Mean EER	10.2	11.1	11.5
Mean SEER	11.7	N/A	N/A
Number of Observed Systems	367	73	6

Table 17 shows the saturation of economizers in cooling systems. The majority of systems identified during the 2016 site visits lacked economizers, leading to estimated percentages of 63% of small units and 53% of large units lacking economizers statewide. Approximately 14% of the units larger than 4.5 tons are estimated to have economizers.

Table 17. Saturation of Economizers in Cooling Systems

Statistic	<4.5 tons	>=4.5 tons
Economizer	9%	14%
No economizer	63%	53%
Unidentified	29%	33%

N=766 Units

Chillers

A substantially smaller number of chillers were identified in this study (19) than in 2011 (51). These units are spread across a variety of facility types, with more than half located in manufacturing facilities and hospitals. An estimated 84% of chillers in Vermont depend on electricity, with gas chillers comprising another 5%.

Table 18. Chiller Fuel Type (N=19)

Chiller Fuel Type	% of Units
Electric	84%
Steam	0%
Gas	5%
Unidentified	11%

N=19 Systems

Most chillers are dedicated to space cooling—an estimated 90% statewide--with an additional 10% used for process cooling. The chiller end use distribution is shown in Table 19.

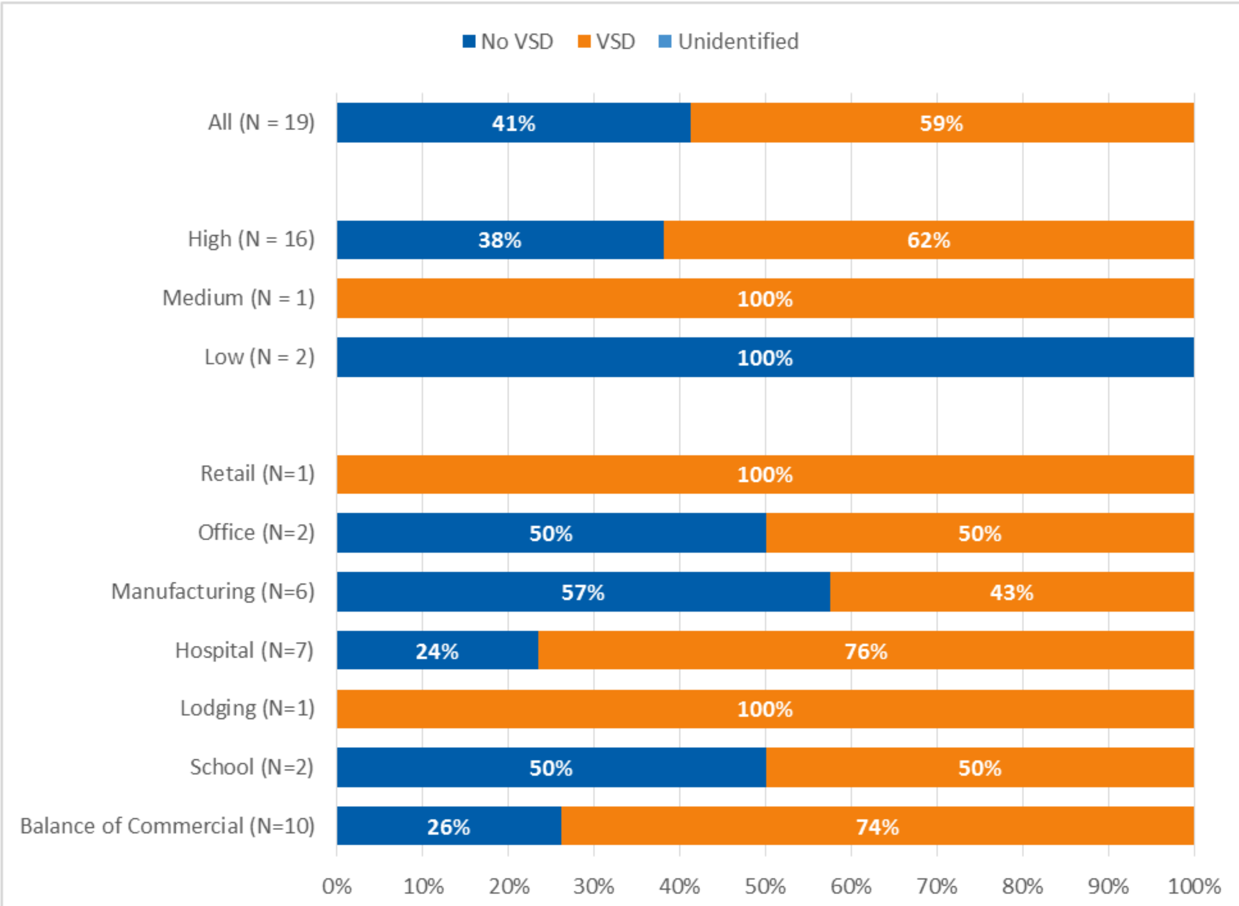
Table 19. Chiller End Uses (N=19)

Chiller End Use	Percentage of Chillers Dedicated to End Use
Space Cooling	90%
Process	10%
Refrigeration	0%
Multiple End Uses	0%
Unidentified	0%

N=19 Systems

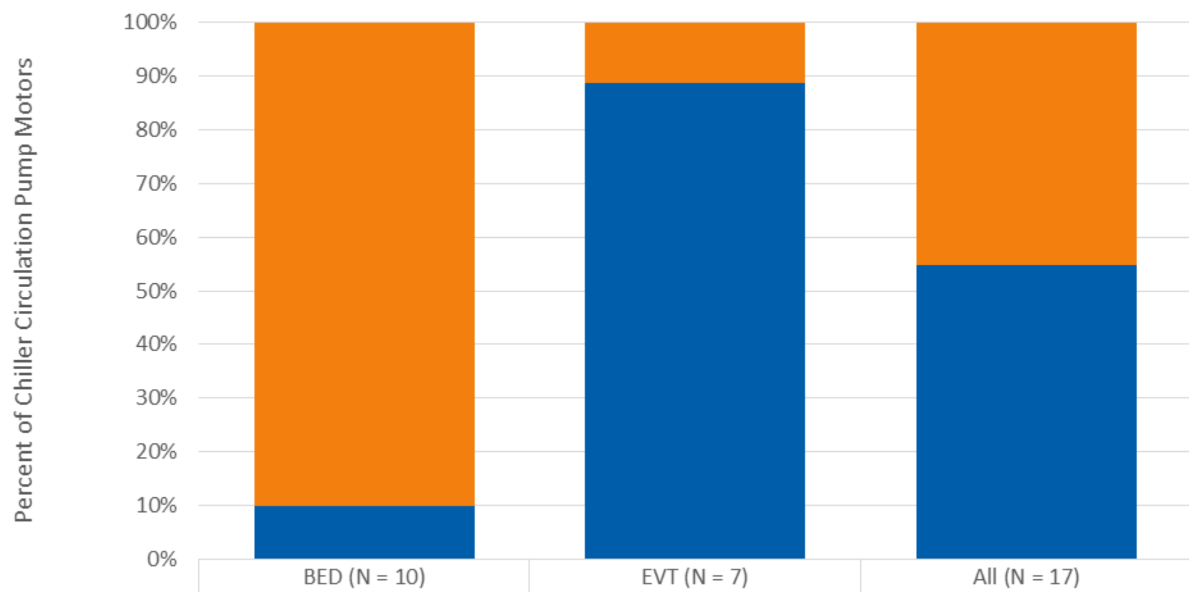
The majority of chillers statewide—an estimated 59%--are equipped with variable speed drive (VSD) controls. This is a significant increase from 2011, when only 4% of chillers were equipped with these controls. VSDs were identified in each of the facility types where chillers were found and in the medium and large size strata.

Figure 54. Saturation of Variable Speed Drive Controls for Chillers



The saturation of speed controls for chilled water circulation pumps, shown in Figure 55, varies considerably between BED and EVT service territories. The majority of chilled water circulation pumps in the BED service territory are variable speed (90%), as compared to an estimated 11% in the EVT territory. Statewide, variable speed controls are found on 45% of chilled water circulation pumps. No two-speed or three-speed pumps were identified in 2016.

Figure 55. Saturation of Speed Controls for Chilled Water Circulation Pumps by EEU

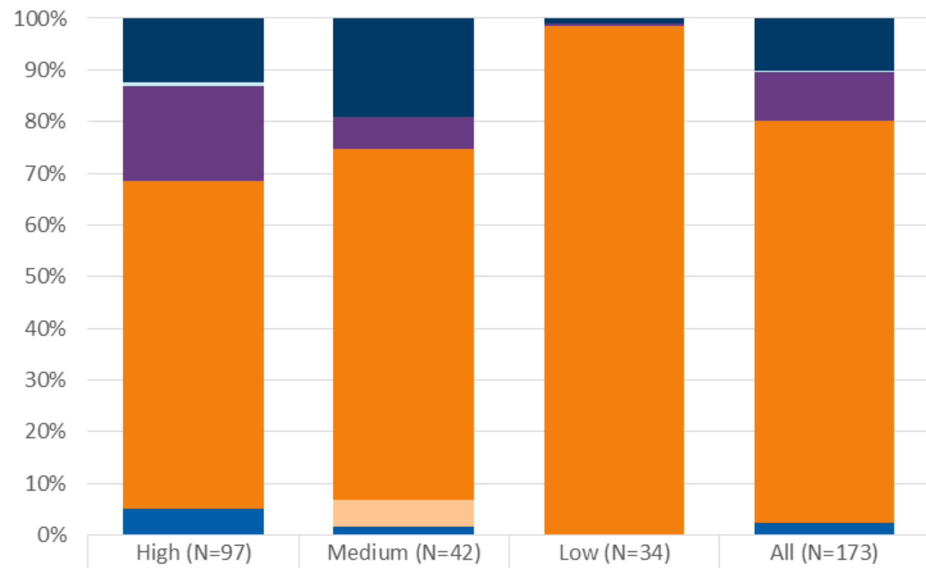


	BED (N = 10)	EVT (N = 7)	All (N = 17)
Unidentified	0%	0%	0%
Variable Speed	90%	11%	45%
Three Speed	0%	0%	0%
Two Speed	0%	0%	0%
One Speed	10%	89%	55%

Multi-Zone Systems

HVAC systems that do not serve a dedicated, single zone are classified as multi-zone systems, or "complex" systems according to the energy code. Figure 56 shows the estimated percentage of systems statewide using each of three distribution types—air, hydronic/steam, and refrigerant. Hydronic systems are the most common distribution systems observed across all size strata, and representing an estimated 72% of multi-zone systems statewide (steam systems represent an additional 9% of systems). The next-most-common multi-zone distribution systems are constant volume refrigeration systems, which represent 10% of systems statewide. These systems are most common in large facilities (13%) and medium-sized facilities (19%).

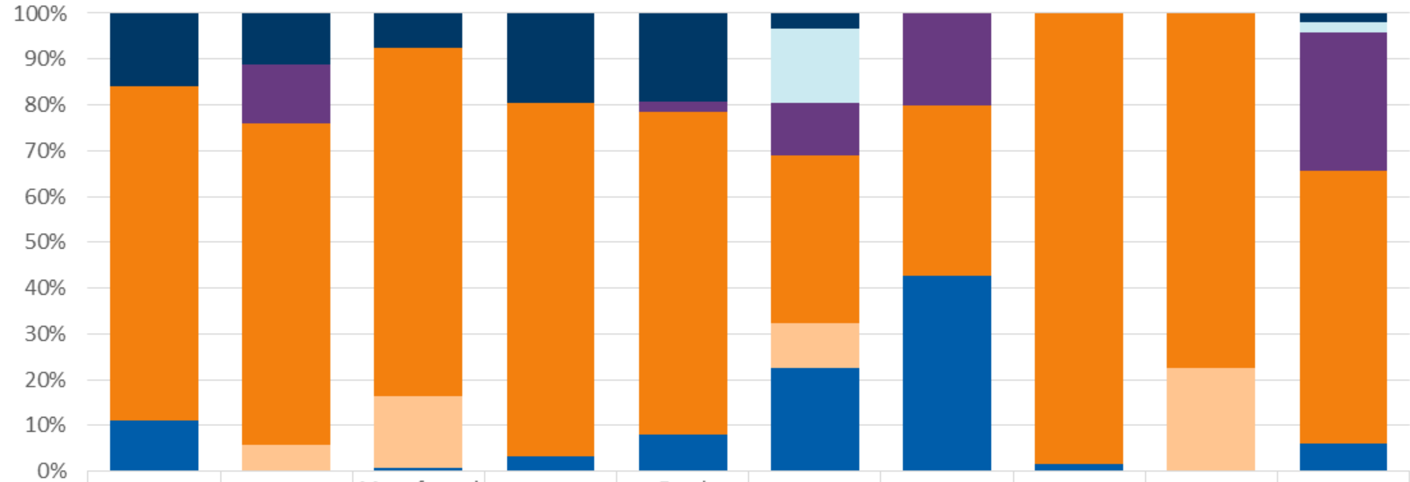
Figure 56. Saturation of Multi-Zone Distribution System Types by Facility Size (N=173)



	High (N=97)	Medium (N=42)	Low (N=34)	All (N=173)
Refrigerant (Constant Volume)	13%	19%	1%	10%
Refrigerant (Variable Volume)	1%	0%	0%	0%
Steam	18%	6%	1%	9%
Hydronic	61%	68%	88%	72%
Air (Multiple)	0%	0%	0%	0%
Air (Constant Volume)	2%	5%	11%	6%
Air (Variable Volume)	5%	1%	0%	2%

Hydronic distributions systems are found in all facility types and represent more than 50% of the distribution systems in all facility types except for health care facilities (42%) and hospitals (37%). Variable air volume systems are most commonly found in hospitals (43%), health care facilities (26%), and retail facilities (11%). Constant air volume systems were most often found in manufacturing (16%) and "other" facilities (22%). No variable volume refrigerant systems were identified during the 2016 site visits, but constant volume refrigeration systems are commonly found in food sales, food service, retail, and office facilities.

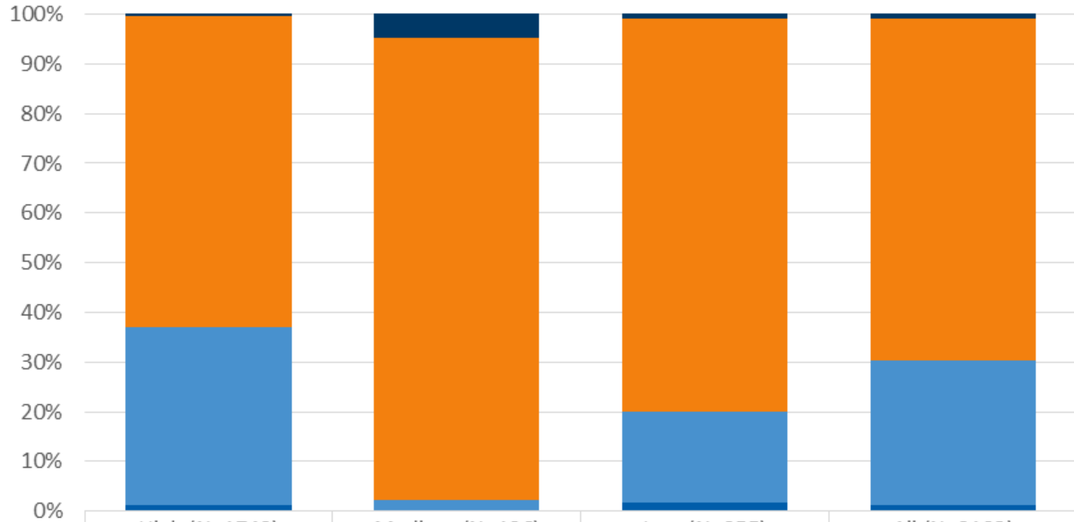
Figure 57. Saturation of Multi-Zone Distribution System Types by Facility Type (N=173)



	Retail (N=10)	Office (N=25)	Manufacturing (N=19)	Food Sales (N=10)	Food Service (N=10)	Health Care (N=28)	Hospital (N=21)	Lodging (N=23)	Other (N=5)	School (N=22)
Refrigerant (Constant Volume)	16%	11%	7%	20%	19%	3%	0%	0%	0%	2%
Refrigerant (Variable Volume)	0%	0%	0%	0%	0%	16%	0%	0%	0%	2%
Steam	0%	13%	0%	0%	2%	12%	20%	0%	0%	30%
Hydronic	73%	70%	76%	77%	70%	37%	37%	99%	78%	60%
Air (Multiple)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Air (Constant Volume)	0%	6%	16%	0%	0%	10%	0%	0%	22%	0%
Air (Variable Volume)	11%	0%	1%	3%	8%	23%	43%	1%	0%	6%

Figure 58 shows the distribution of terminal units by facility size strata. Radiant heaters rank by far as the most common terminal unit, accounting for 69%% of terminal units statewide. Heat pumps represent 29% of hydronic terminal units statewide.

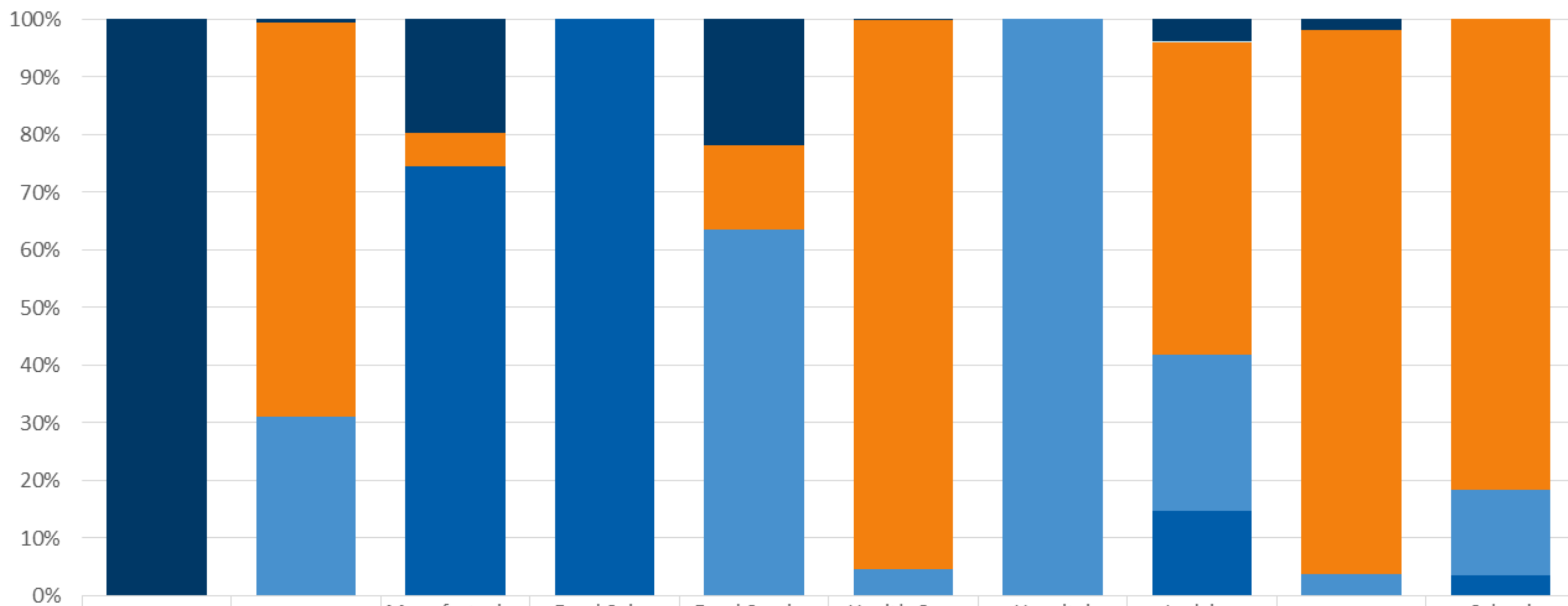
Figure 58. Saturation of Multi-Zone Hydronic and Steam Terminal Units by Facility Size



	High (N=1742)	Medium (N=196)	Low (N=255)	All (N=2193)
Unitary Heater	0%	5%	1%	1%
Unitary AC	0%	0%	0%	0%
Radiant Heater	63%	93%	79%	69%
Heat Pump	36%	2%	18%	29%
Fan Coil	1%	0%	2%	1%

Predominant terminal unit type varies considerably among facility types, as shown in Figure 59. Radiant heaters dominate as hydronic terminal units within office, health care, and school facilities. Heat pumps are appear to be the most common choice for food service and hospitals.

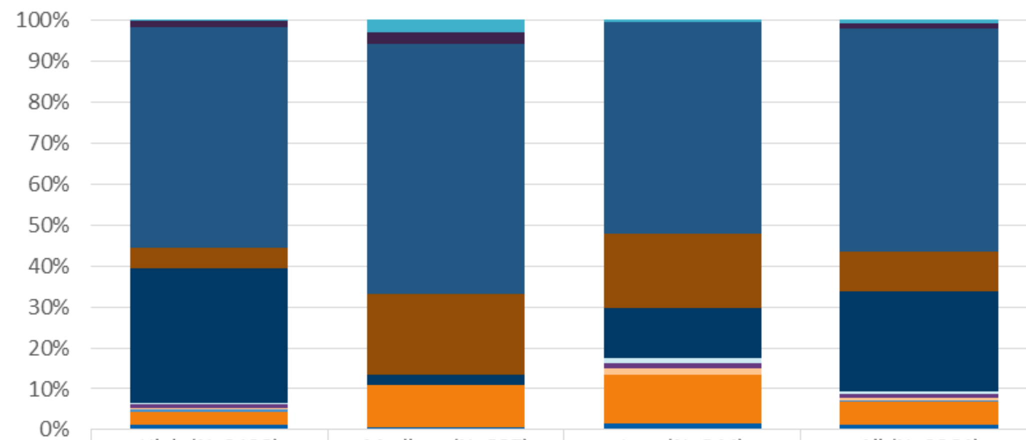
Figure 59. Saturation of Multi-Zone Hydronic and Steam Terminal Units by Facility Type (N=2,193)



	Retail (N=1)	Office (N=445)	Manufacturing (N=25)	Food Sales (N=4)	Food Service (N=18)	Health Care (N=938)	Hospital (N=30)	Lodging (N=301)	Other (N=59)	School (N=372)
Unitary Heater	100%	1%	20%	0%	22%	0%	0%	4%	2%	0%
Unitary AC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Radiant Heater	0%	68%	6%	0%	15%	95%	0%	54%	95%	82%
Heat Pump	0%	31%	0%	0%	63%	5%	100%	27%	4%	15%
Fan Coil	0%	0%	75%	100%	0%	0%	0%	15%	0%	4%

Figure 60 shows the saturation of all major multi-zone equipment by facility size. As discussed previously, radiant heater and heat pump terminal units make up significant proportion of the multi-zone equipment. Pumps and boilers also appear in large numbers, at an estimated 10% and 6% of units statewide.

Figure 60. Saturation of Multi-Zone Equipment by Facility Size (N=2,864)

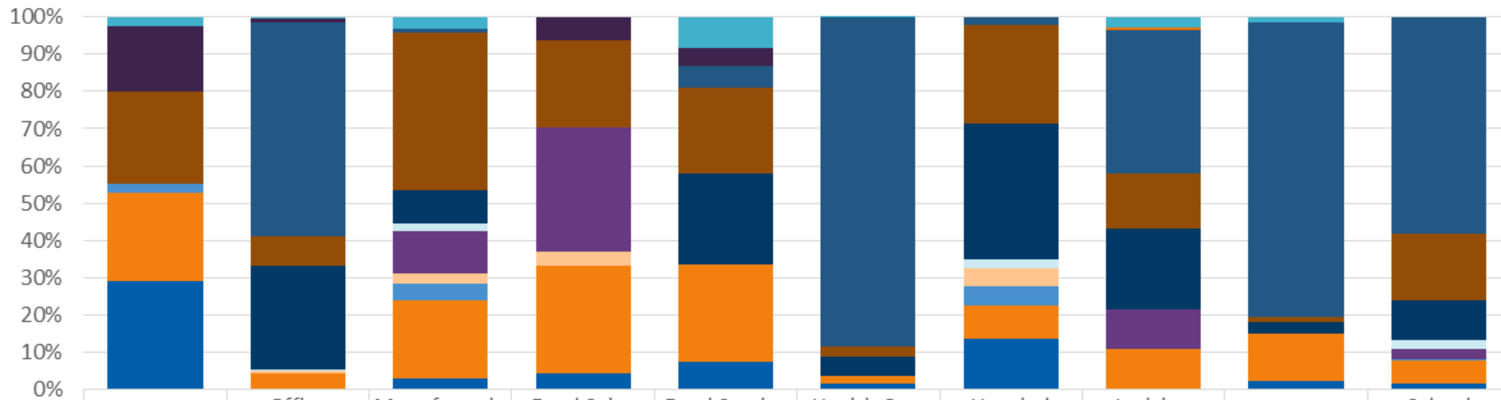


	High (N=2123)	Medium (N=397)	Low (N=344)	All (N=2864)
Unitary Heater	0%	3%	1%	1%
Unitary AC	1%	3%	0%	1%
Standalone Furnace	0%	0%	0%	0%
Radiant Heater	54%	61%	52%	55%
Pump	5%	20%	18%	10%
Heat Pump	33%	2%	12%	25%
Heat Exchanger	0%	0%	1%	0%
Fan Coil	1%	0%	1%	1%
Cooling Tower	0%	0%	1%	0%
Chiller	0%	0%	0%	0%
Boiler	3%	10%	12%	6%
AHU Coil	1%	1%	2%	1%

There is significant variation in the type of multi-zone equipment by facility type. Health care facilities and schools have similar equipment distributions, primarily radiant heater with a mixture of pumps and boilers. Hospitals use diverse sets of equipment including radiant heaters, heat pumps, heat exchangers, cooling towers, chillers, boilers, and AHU coils. Manufacturing facilities have a similarly diverse set of equipment. Other details of note:

- Food sales facilities have the highest proportion of boilers (29%) and fan coils (33%) of all facility types examined.
- Retail HVAC systems primarily comprise boilers, AHU coils, and unitary AC units.

Figure 61. Saturation of Multi-Zone Equipment by Facility Type (N=2,864)

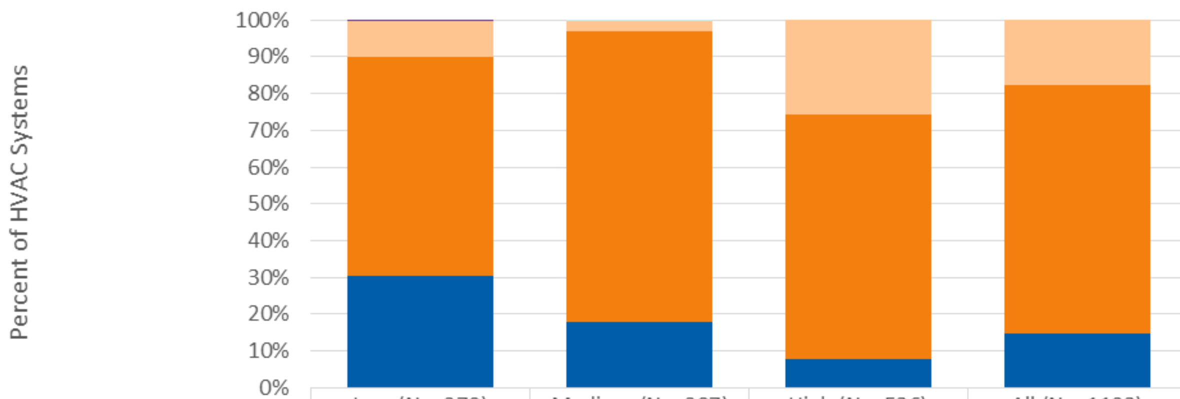


	Retail (N=38)	Office (N=530)	Manufacturing (N=126)	Food Sales (N=26)	Food Service (N=39)	Health Care (N=1008)	Hospital (N=96)	Lodging (N=479)	Other (N=70)	School (N=452)
Unitary Heater	2%	0%	3%	0%	8%	0%	0%	3%	1%	0%
Unitary AC	18%	1%	0%	6%	5%	0%	0%	0%	0%	0%
Standalone Furnace	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Radiant Heater	0%	57%	1%	0%	6%	88%	2%	39%	79%	58%
Pump	25%	8%	42%	23%	23%	3%	26%	15%	1%	18%
Heat Pump	0%	28%	9%	0%	24%	5%	37%	22%	3%	11%
Heat Exchanger	0%	1%	2%	0%	0%	0%	2%	0%	0%	2%
Fan Coil	0%	0%	11%	33%	0%	0%	0%	11%	0%	3%
Cooling Tower	0%	1%	3%	4%	0%	0%	5%	0%	0%	0%
Chiller	2%	0%	4%	0%	0%	0%	5%	0%	0%	0%
Boiler	24%	4%	21%	29%	26%	2%	9%	11%	13%	6%
AHU Coil	29%	0%	3%	4%	7%	1%	14%	0%	2%	2%

HVAC Controls

Figure 62 shows that an estimated 67% of HVAC systems are controlled manually statewide. The two other control types identified in 2016 are EMS (18%) and programmable thermostats (15%). Large facilities have the highest proportion of EMS control systems (26%), and small facilities have the highest proportion of programmable thermostats (30%).

Figure 62. Saturation of HVAC System Control Types by Facility Size (N=1,103)*

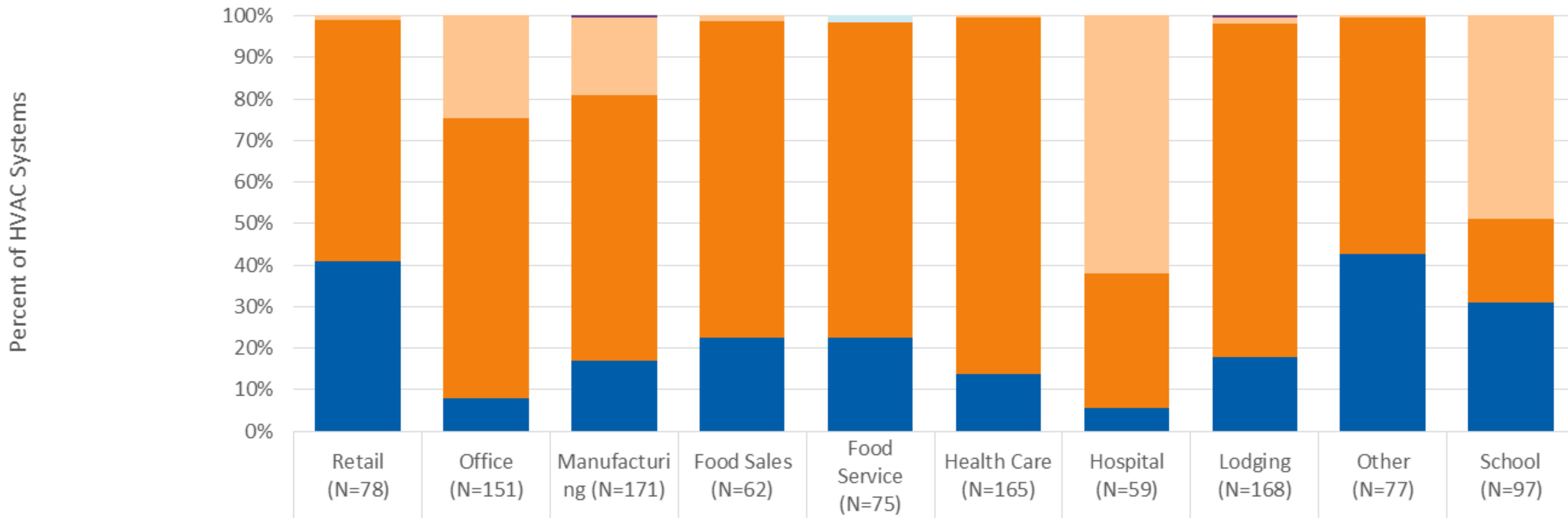


	Low (N = 270)	Medium (N = 297)	High (N = 536)	All (N = 1103)
Unknown	0%	0%	0%	0%
Time Clock	0%	0%	0%	0%
EMS	10%	3%	26%	18%
Always On	0%	0%	0%	0%
Manual	60%	79%	67%	67%
Programmable Thermostat	30%	18%	8%	15%

* Presented by percentage equipment quantity

The highest proportion of EMS systems are found in schools (49%) and hospitals (62%). They are also found with moderate frequency in offices (25%) and manufacturing facilities (19%). Programmable thermostats constitute a significant proportion of control types in retail (41%) and "other" facilities (43%). With the exception of schools and hospitals, manual controls account for more than half of controls in all facility types.

Figure 63. Saturation of HVAC System Control Types by Facility Type (N=1,103)

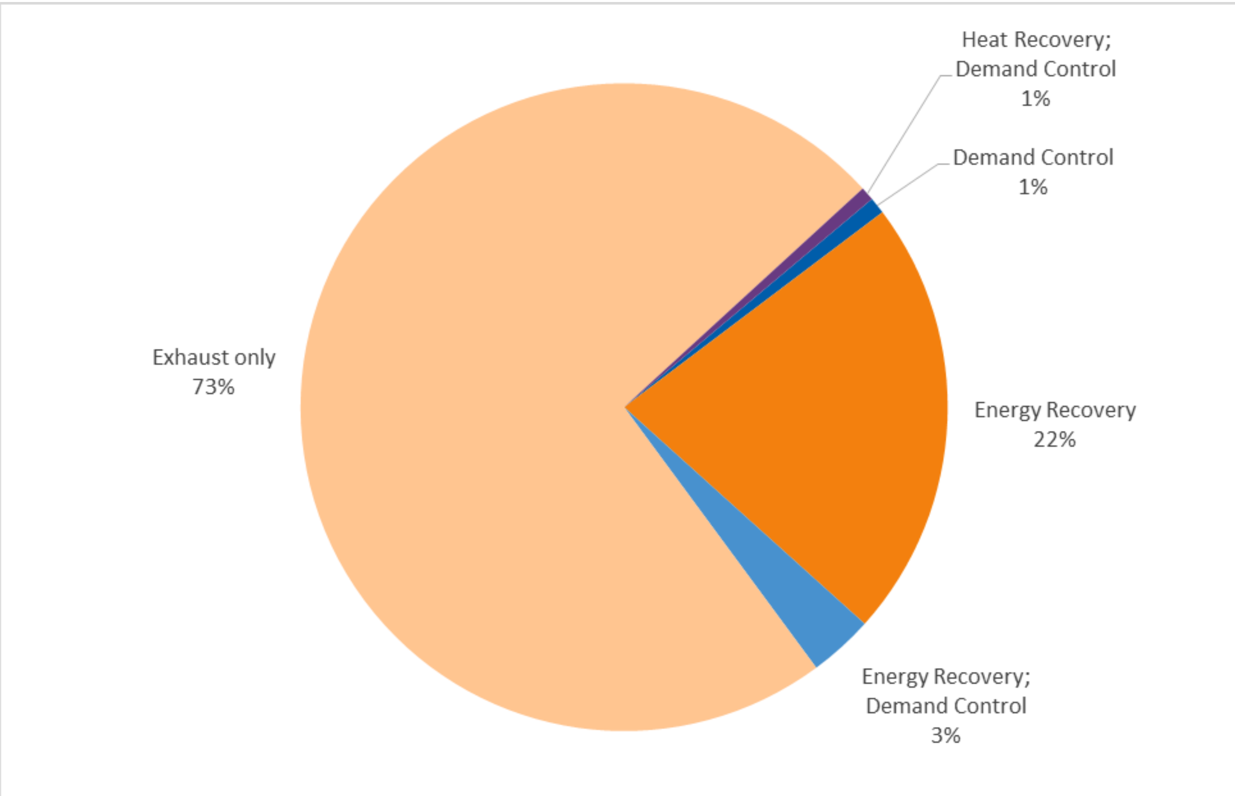


	Retail (N=78)	Office (N=151)	Manufacturing (N=171)	Food Sales (N=62)	Food Service (N=75)	Health Care (N=165)	Hospital (N=59)	Lodging (N=168)	Other (N=77)	School (N=97)
Unknown	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%
Time Clock	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EMS	1%	25%	19%	1%	0%	1%	62%	2%	0%	49%
Always On	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Manual	58%	67%	64%	76%	76%	86%	32%	80%	57%	20%
Programmable Thermostat	41%	8%	17%	23%	22%	14%	6%	18%	43%	31%

Ventilation

Figure 64 shows the distribution of ventilation equipment control strategies identified during the 2016 site visits. The sample size of 1,076 indicates the number of ventilation components identified within the 192 sites visited, and Figure 64 represent the distribution of control strategies for those 1,076 components. The majority of ventilation equipment is operated using an exhaust only strategy (73%). Energy recovery strategies comprise approximately 25% of the ventilation equipment. Demand control strategies are primarily implemented in conjunction with other control types: 1% with heat recovery, 3% with energy recovery, and 1% as a stand-alone system.

Figure 64. Distribution of Ventilation Control Strategies (N=1,076)*

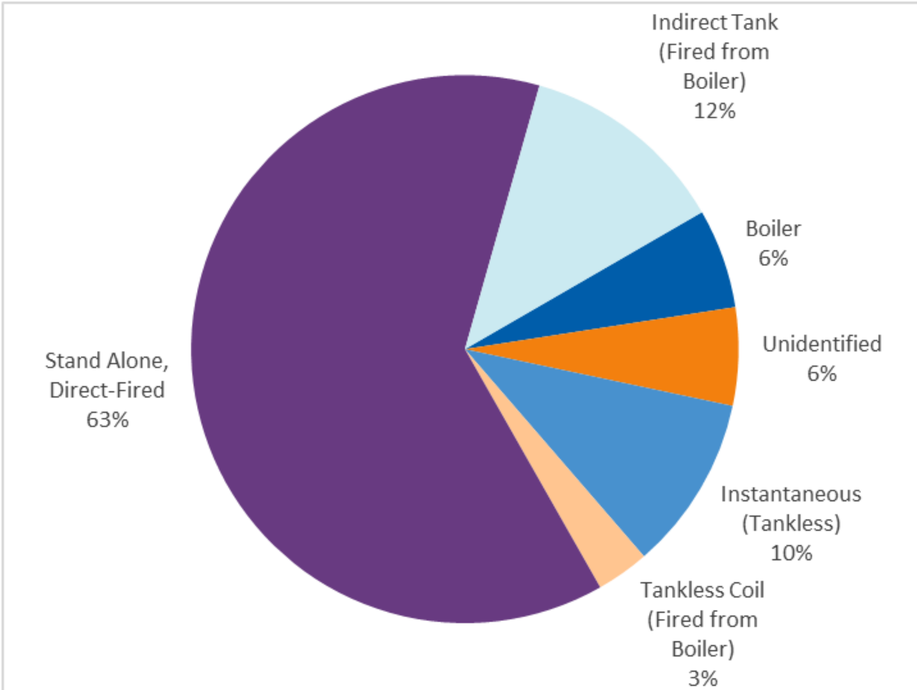


* Presented by percentage equipment quantity

Water Heating

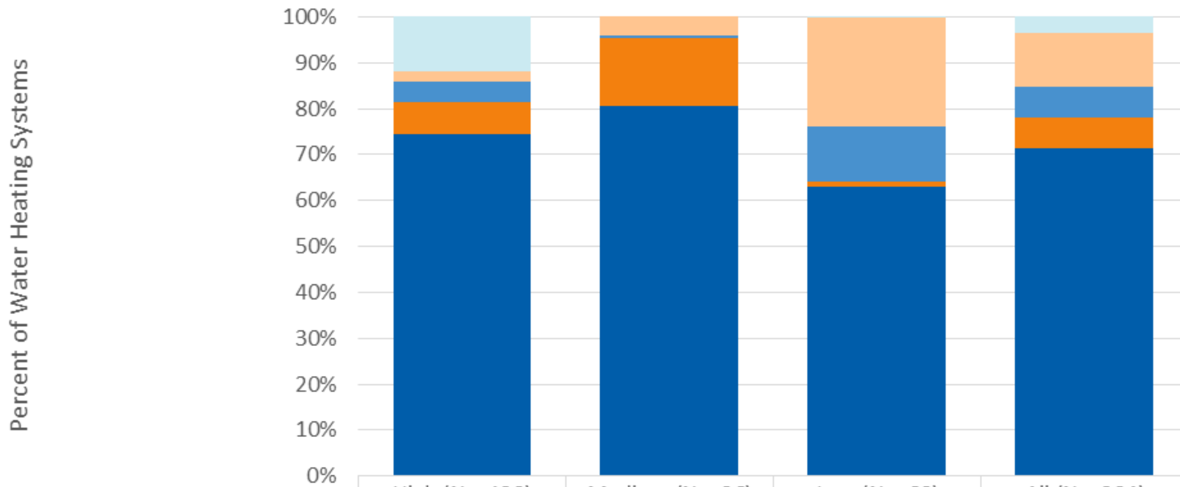
As in 2011, stand-alone, direct-fired water heating systems ranks as the predominant form of water heating equipment, accounting for and estimated 63% of water heating systems statewide, as shown in Figure 65. Boilers systems, which includes dedicated hot water boilers, indirect water heaters heated by boilers, and tankless coils fired from boilers, account for another 21% of water heating systems. Instantaneous water heaters are much more prevalent in the 2016 study than the 2011 study, at 10% and 1%, respectively. No purchased steam systems were identified in 2016.

Figure 65. Distribution of Water Heating Equipment Types—All Sites (N=320 Observations)



Stand-alone direct-fired water heaters are the most common water heating equipment across all size stratum, representing between 60% and 65% of systems. Boiler systems are more common in medium and large facilities than small facilities. Instantaneous systems are much more common in small facilities (22%) than either medium (3%) or large facilities (2%).

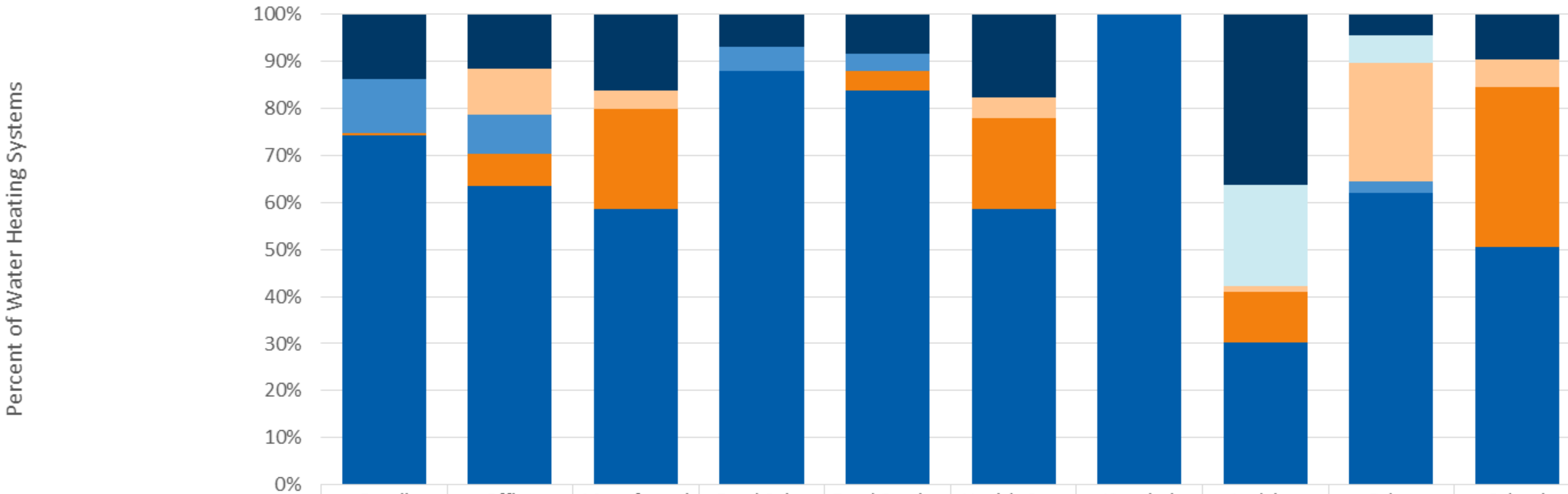
Figure 66. Saturation of Water Heating Equipment Types by Facility Size (N=294)



	High (N = 129)	Medium (N = 96)	Low (N = 69)	All (N = 294)
Tankless Coil (Fired from Boiler)	10%	0%	0%	3%
Purchased Steam	0%	0%	0%	0%
Instantaneous (Tankless)	2%	3%	22%	10%
Unidentified	4%	0%	12%	6%
Boiler	6%	12%	1%	6%
Stand Alone, Direct-Fired	65%	64%	60%	63%

Stand-alone direct-fired systems are common across all facility types, though they represent a much smaller proportion of systems in lodging facilities than the statewide average (30% and 63%, respectively).The predominant form of water heating in lodging facilities is through indirect tanks fired from boilers (36%) and tankless coils fired from boilers (22%). The highest concentration of boilers dedicated to providing hot water are in schools (34%), manufacturing (21%), and health care facilities (19%). Tankless water heaters were only identified in lodging (22%) and “other” facility types (6%).

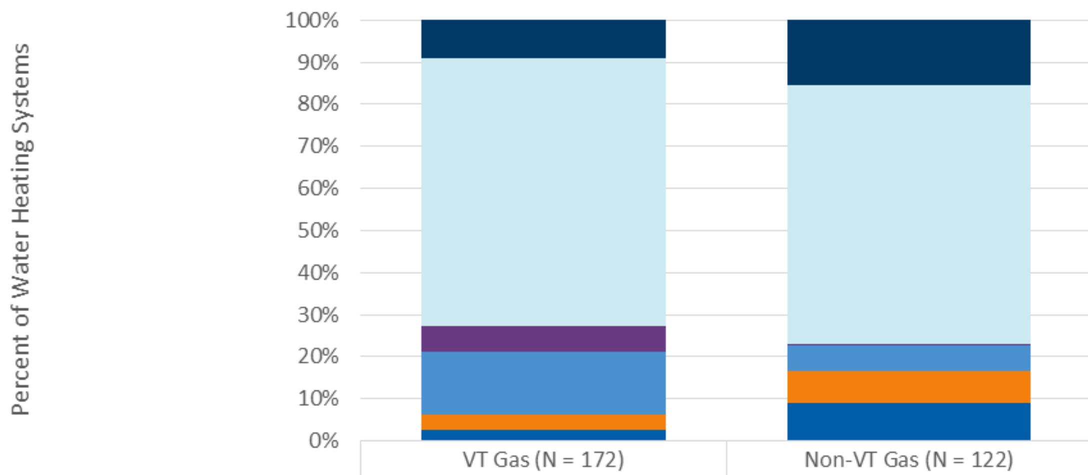
Figure 67. Saturation of Water Heating Equipment Types by Facility Type



	Retail (N=20)	Office (N=35)	Manufacturing (N=33)	Food Sales (N=18)	Food Service (N=21)	Health Care (N=41)	Hospital (N=21)	Lodging (N=50)	Other (N=32)	School (N=23)
Indirect Tank (Fired from Boiler)	14%	12%	16%	7%	8%	18%	0%	36%	4%	10%
Tankless Coil (Fired from Boiler)	0%	0%	0%	0%	0%	0%	0%	22%	6%	0%
Purchased Steam	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Instantaneous (Tankless)	0%	10%	4%	0%	0%	4%	0%	1%	25%	6%
Unidentified	11%	8%	0%	5%	4%	0%	0%	0%	2%	0%
Boiler	1%	7%	21%	0%	4%	19%	0%	11%	0%	34%
Stand Alone, Direct-Fired	74%	63%	59%	88%	84%	59%	100%	30%	62%	50%

The distribution of water heating equipment types is very similar between VT Gas and non-VT Gas territories. VT Gas facilities are more likely to have a tankless coil (6%) than non-VT Gas facilities (0%). Boilers are more common in non-VT Gas territory (9% versus 3%).

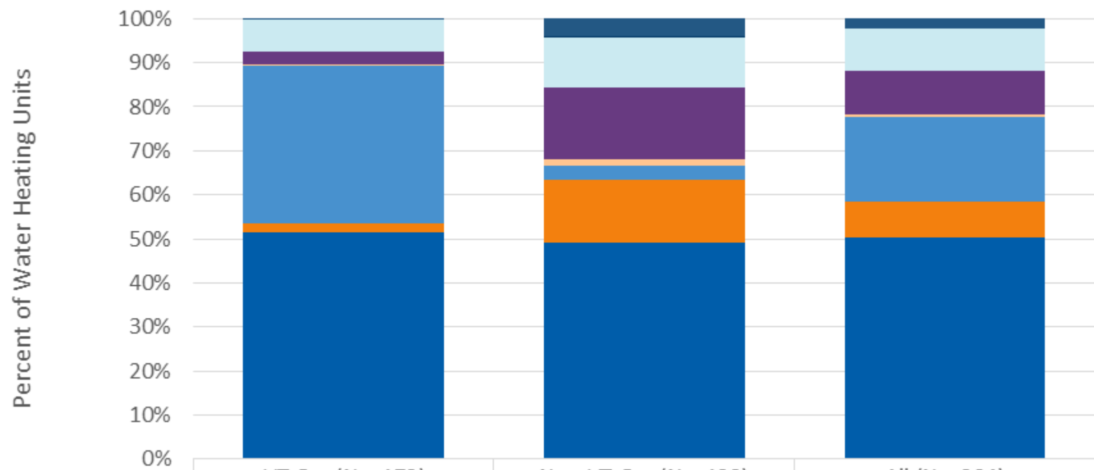
Figure 68. Distribution of Water Heating Equipment Types—VT Gas vs. Non-VT Gas



	VT Gas (N = 172)	Non-VT Gas (N = 122)
Indirect Tank (Fired from Boiler)	9%	15%
Stand Alone, Direct-Fired	64%	62%
Tankless Coil (Fired from Boiler)	6%	0%
Purchased Steam	0%	0%
Instantaneous (Tankless)	15%	6%
Unidentified	4%	8%
Boiler	3%	9%

Figure 66 shows the distribution of water heating fuel types for VT Gas and non-VT Gas territories. The most common fuel types across both territories is electricity, accounting for 51% of VT-Gas facilities and 49% of non-VT Gas facilities. A higher proportion of systems in the VT Gas service territory are heated with natural gas than in non-VT Gas territory (36% and 3%, respectively). The most common fuel types, after electricity, in the non-VT Gas service territory are propane (16%) and fuel oil (14%). No wood-fueled water heating systems were identified in 2016.

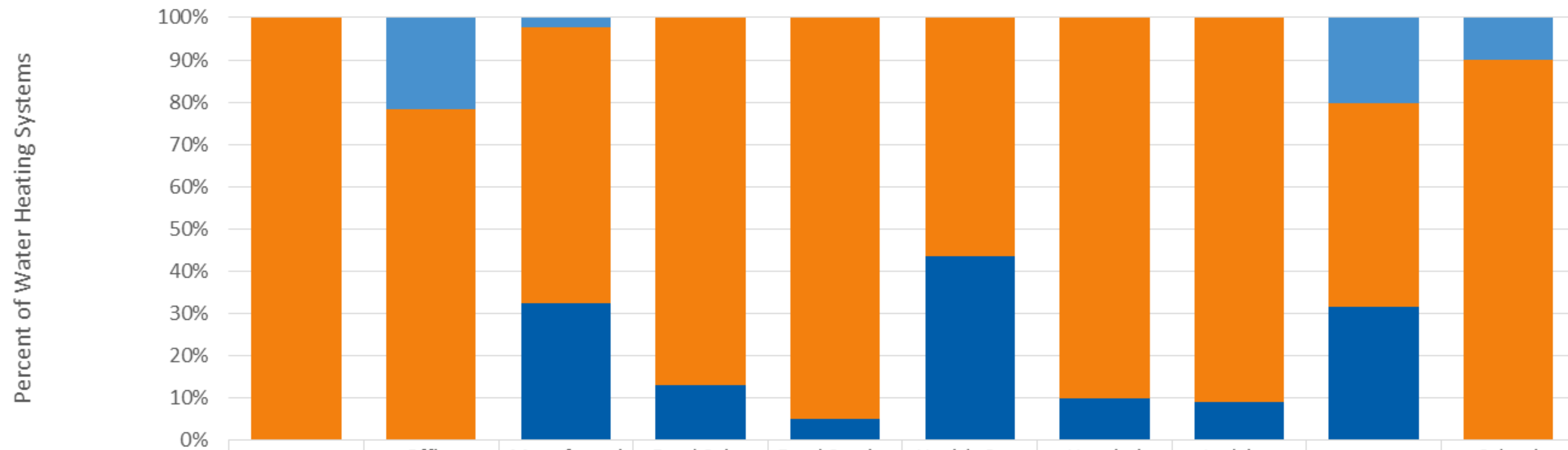
Figure 69. Water Heating Fuel Types—VT Gas vs. Non-VT Gas



	VT Gas (N = 172)	Non-VT Gas (N = 122)	All (N = 294)
Multiple	0%	4%	2%
Wood	0%	0%	0%
Other	0%	0%	0%
Unknown	7%	12%	10%
Propane	3%	16%	10%
Heat Recovery	0%	1%	1%
Natural Gas	36%	3%	19%
Fuel Oil	2%	14%	8%
Electricity	51%	49%	50%

The water heating temperature setting is shown by facility type in Figure 70. Across all facility types, the most common temperature setting is between 110°F and 140°F. Only a small proportion of systems are set below 110°F: 22% of systems in offices, 2% of systems in manufacturing facilities, 20% of systems in "other" facilities, and 10% of school systems. High-temperature systems—systems set to higher than 140°F—are much more common, and are found in all facility types except for retail, office, and schools.

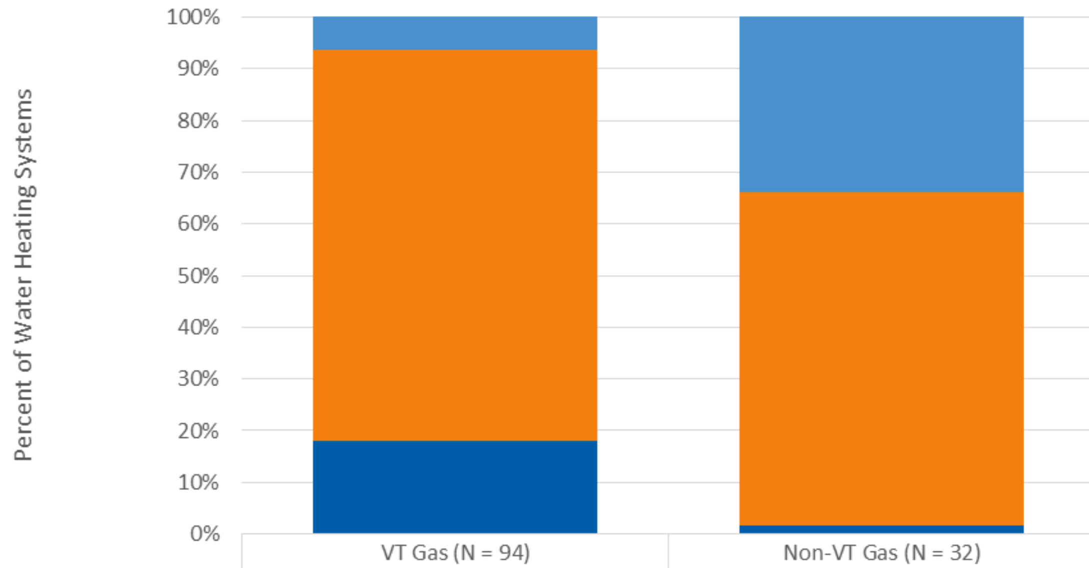
Figure 70. Water Heating Temperature Setting by Facility Type



	Retail (N=5)	Office (N=15)	Manufacturing (N=8)	Food Sales (N=6)	Food Service (N=5)	Health Care (N=20)	Hospital (N=20)	Lodging (N=17)	Other (N=18)	School (N=12)
Low Temp (<110 F)	0%	22%	2%	0%	0%	0%	0%	0%	20%	10%
Medium Temp	100%	78%	65%	87%	95%	56%	90%	91%	48%	90%
High Temp (>140 F)	0%	0%	33%	13%	5%	44%	10%	9%	32%	0%

The majority (76%) of water heating systems in the VT Gas service territory are set in the temperature range of 110°F to 140°F, which is a slightly larger proportion than in Non-VT Gas territory (65%). In the VT Gas territory, water heating systems are more often set above 140°F than below 110°F, while the opposite is true in non-VT Gas territory.

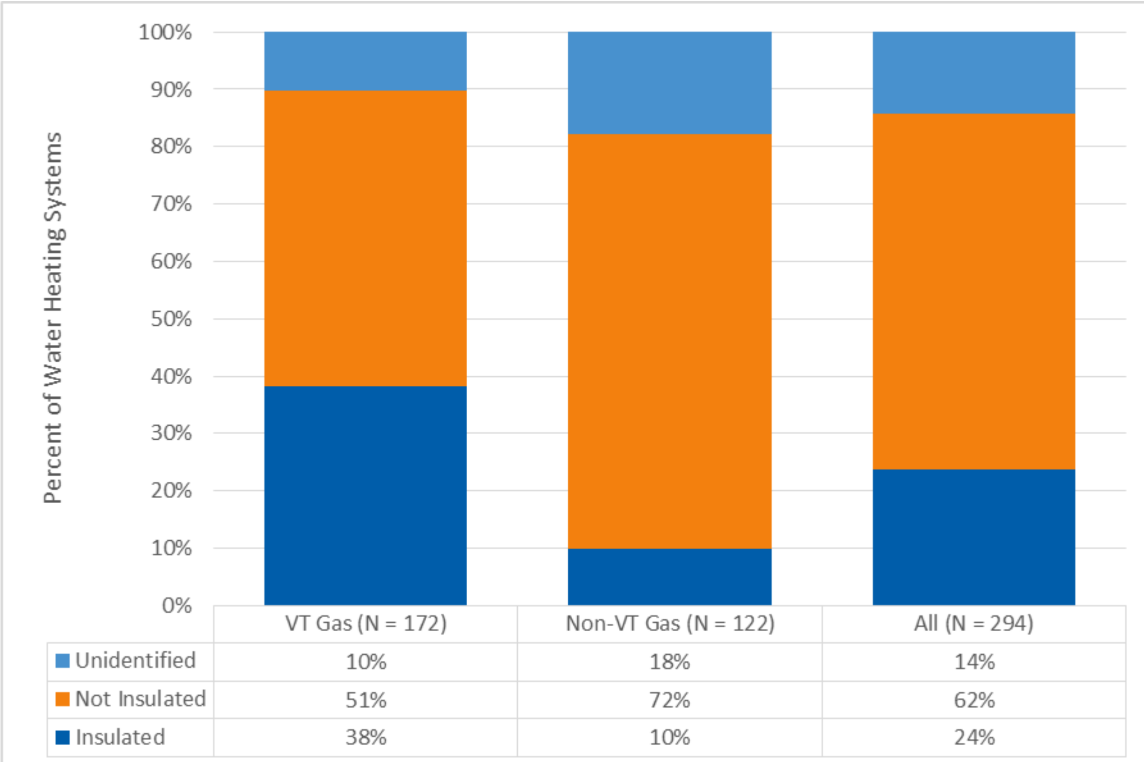
Figure 71. Water Heater Temperature Setting—VT Gas vs. Non-VT Gas



	VT Gas (N = 94)	Non-VT Gas (N = 32)
Low Temp (<110 F)	6%	34%
Medium Temp	76%	65%
High Temp (>140 F)	18%	2%

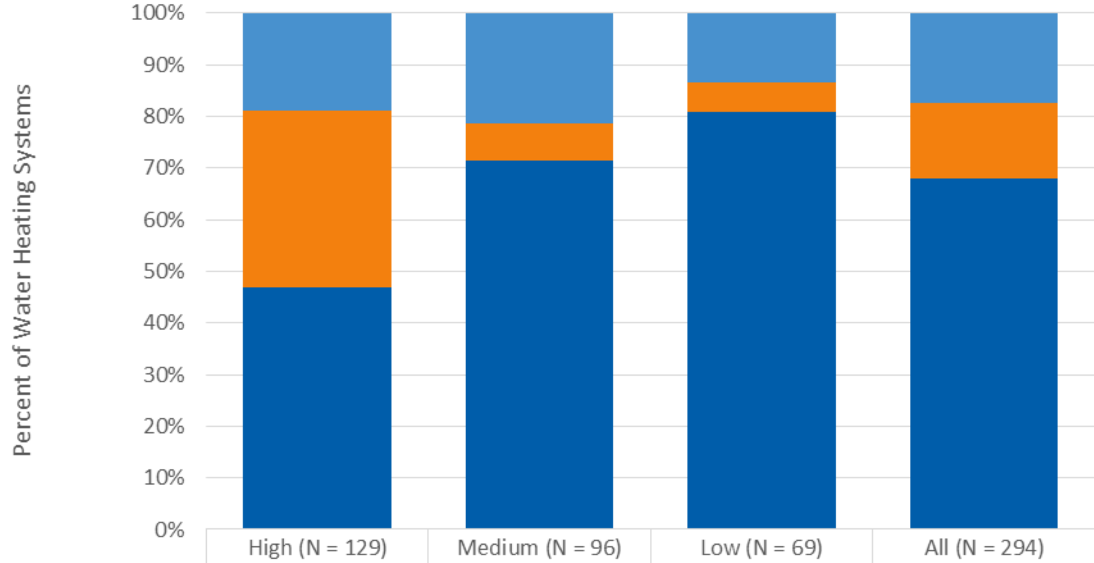
Figure 72 shows the distribution of water heater pipe insulation in VT Gas and non-VT Gas territories. Water heaters in VT Gas territory are more likely to be insulated than similar systems in non-VT Gas territory (38% and 10%, respectively).

Figure 72. Water Heater Pipe Insulation—VT Gas vs. Non-VT Gas



Statewide, most water heating systems (68%) do not use recirculation pumps, as shown in Figure 73. The highest concentration of recirculation pumps is found in large facilities (34%).

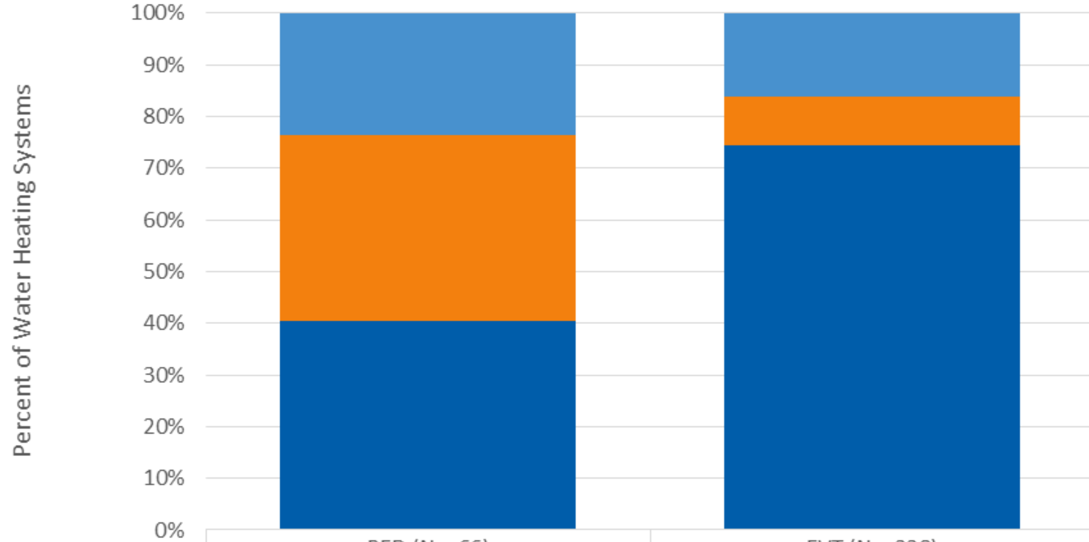
Figure 73. Use of Water Heating Recirculation Pump by Consumption Stratum



	High (N = 129)	Medium (N = 96)	Low (N = 69)	All (N = 294)
Unidentified	19%	21%	13%	18%
Recirc Pump	34%	7%	6%	14%
No Recirc Pump	47%	71%	81%	68%

Figure 74 shows the use of water heating recirculation pumps by EEU. Water heating systems in the BED service territory use a recirculation pump approximately 36% of the time, as compared to 9% in EVT territory. The majority of systems in EVT territory (75%) do not use recirculation pumps.

Figure 74. Use of Water Heating Recirculation Pump by EEU



	BED (N = 66)	EVT (N = 228)
Unidentified	23%	16%
Recirc Pump	36%	9%
No Recirc Pump	40%	75%

EEU Market Characterization—HVAC and Water Heating

Table 20 provides a summary characterization of HVAC and water heating measure for Vermont's EEUs.

Table 20. EEU Market Characterization—HVAC and Water Heating

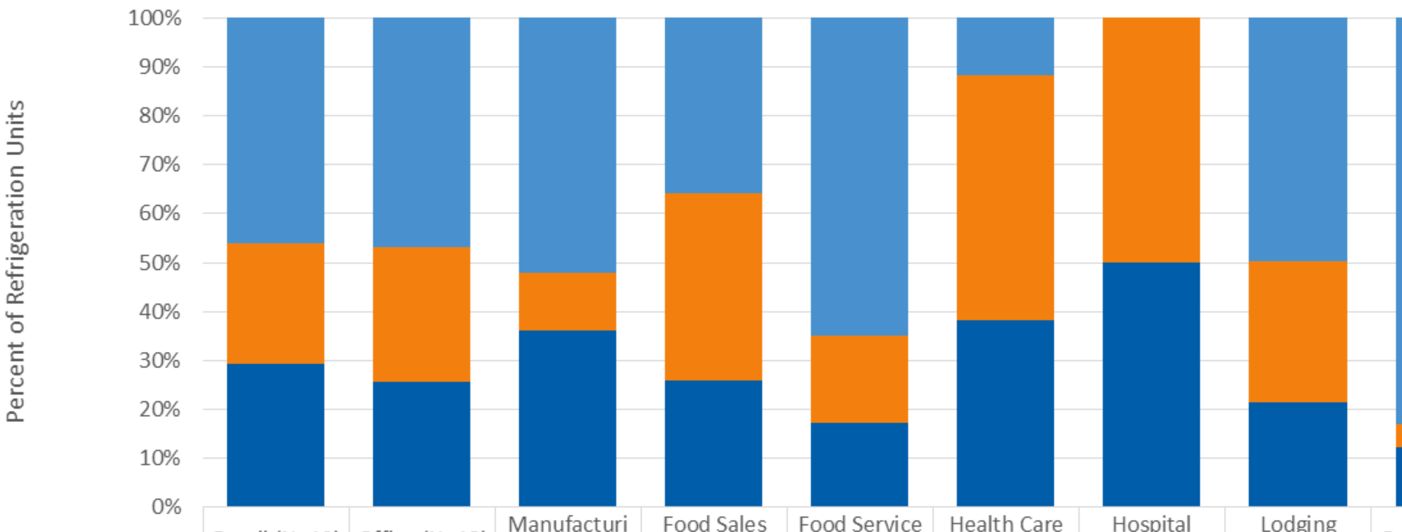
Lighting Group	Measure/Characteristic	BED	EVT	VT Gas
HVAC	Single-Zone HVAC System Age	• There is no significant difference in single-zone HVAC systems age by EEU.		
	Primary Heating Fuel Type	• Natural gas is the primary heating fuel type in BED (69%) and VT Gas territories (56%). • Electricity comprises between 9% and 17% of heating system fuel types in each EEU territory. • The non-VT Gas territory has the highest proportion of fuel oil (22%) and propane (34%).		
	Heating System Type	N/A	N/A	• Boilers are the highest proportion of systems (65%) followed by unitary heaters (18%) and furnace (14%).
	Heating System Efficiency	• With the exception of some large oil-fired boilers, most of the furnaces and boilers in the state meet or exceed 2015 CBES standards.		
	Boiler Delivery Systems	• Water is the primary delivery medium (66%) statewide. However, nearly all (99%) of the boiler heating capacity in hospitals is delivered by steam boilers.		
	Hot Water Circulation Pump Speed Controls	• Highest proportion of single-speed pumps (87%).	• 8% are variable speed pumps.	• Only 6% are variable speed.
	Cooling System Types	• Direct expansion cooling systems comprise approximately 94% of all cooling capacity in the state's existing building stock.		
	Cooling Efficiency of Single-Zone Unitary HVAC Systems (< 5.5 tons)	• The majority of small systems (less than 65,000 Btu/h) do not meet the 2015 CBEs standards. Approximately 95% of systems over 135,000 Btu/h meet or exceed the CBES standards.		
	Saturation of Economizers in Cooling Systems	• Most cooling system are not equipped with economizers. Systems larger than 135,000 Btu/h are equipped with economizers twice as frequently as smaller systems.		
	VSD Controls for Chilled Water Circulation Pumps	• Over half (59%) of chillers are equipped with VSD controls. • VSD controls are found in all facility types, but are not found in small facilities.		
Water Heating	Water Heating Equipment Type	N/A	N/A	• Stand-alone, direct-fired systems comprise 64% of

				systems, followed by instantaneous systems (15%) and indirect tanks fired from boilers (9%).
	Water Heating Fuel Types	N/A	N/A	• Over half (51%) of systems in the VT Gas territory are electric, followed by natural gas (36%).
	Water Heating Pipe Insulation	N/A	N/A	• Water heating systems in VT Gas territory are far more likely to be insulated than in non-VT Gas territories (38% vs. 10%)
	Water Heating Recirculation Pump	• 36% of systems use recirculation pumps.	• Most systems (75%) do not use recirculation pumps.	N/A

Refrigeration

The Cadmus team recorded on-site whether or not an ENERGY STAR® logo was visible on the appliance and, where practical, recorded the make and model number, which were matched to a database of qualifying models. The team identified models as not qualifying only if the database search indicated that the model did not qualify. Refrigerators and freezers were marked ENERGY STAR if the logo was visible on the appliance or if the model number was matched to a previously or currently qualifying model. As shown in Figure 75, facilities with the highest saturation of non-commercial ENERGY STAR units are hospitals (50%), health care (38%), manufacturing (36%), retail (29%), food sales (26%), and offices (26%).

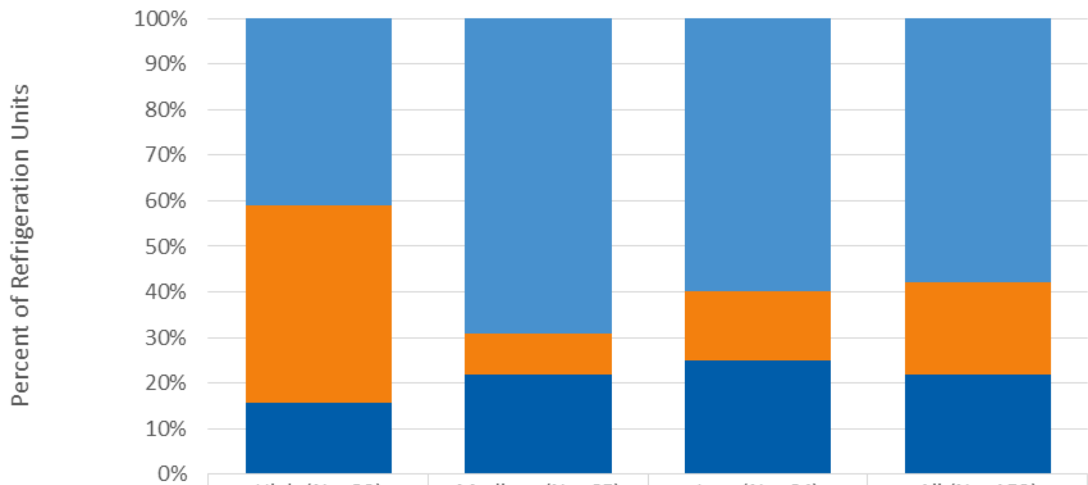
Figure 75. Saturation of Non-Commercial ENERGY STAR Refrigerators and Freezers by Facility Type



	Retail (N=10)	Office (N=18)	Manufacturing (N=18)	Food Sales (N=13)	Food Service (N=23)	Health Care (N=16)	Hospital (N=2)	Lodging (N=27)	Ot
Unidentified	46%	47%	52%	36%	65%	12%	0%	50%	
Non-Energy Star	25%	28%	12%	38%	18%	50%	50%	29%	
ENERGY STAR	29%	26%	36%	26%	17%	38%	50%	21%	

Figure 76 shows saturation of identified non-commercial ENERGY STAR refrigerators and freezers by facility size, with statewide saturation of 22% of all units or roughly 52% after eliminating unknowns. This is substantially lower than the saturation found in the 2011 study (58%) and may reflect differences in data collection protocol.

Figure 76. Saturation of Non-Commercial ENERGY STAR Refrigerators and Freezers by Facility Size

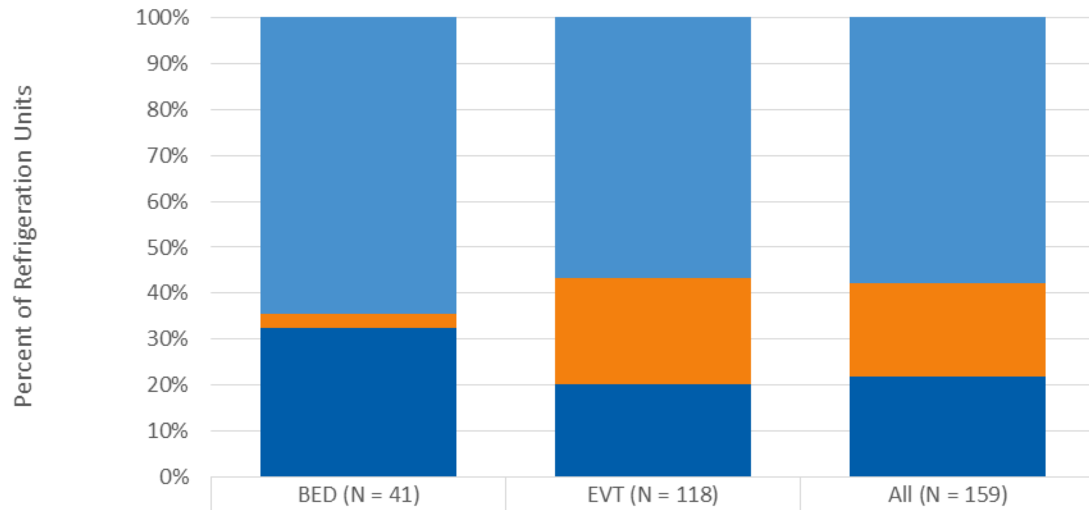


	High (N = 30)	Medium (N = 65)	Low (N = 64)	All (N = 159)
Unidentified	41%	69%	60%	58%
Non-Energy Star	43%	9%	15%	20%
ENERGY STAR	16%	22%	25%	22%

Size Strata

The evaluation team identified 32% of non-commercial refrigerators and freezers as ENERGY STAR models in the BED service territory, compared with 20% for facilities in the EVT territory. In addition, facilities in EVT territory had a substantially greater percentage of units identified as not qualifying (23%).

Figure 77. Saturation of Non-Commercial ENERGY STAR Refrigerators and Freezers by EEU

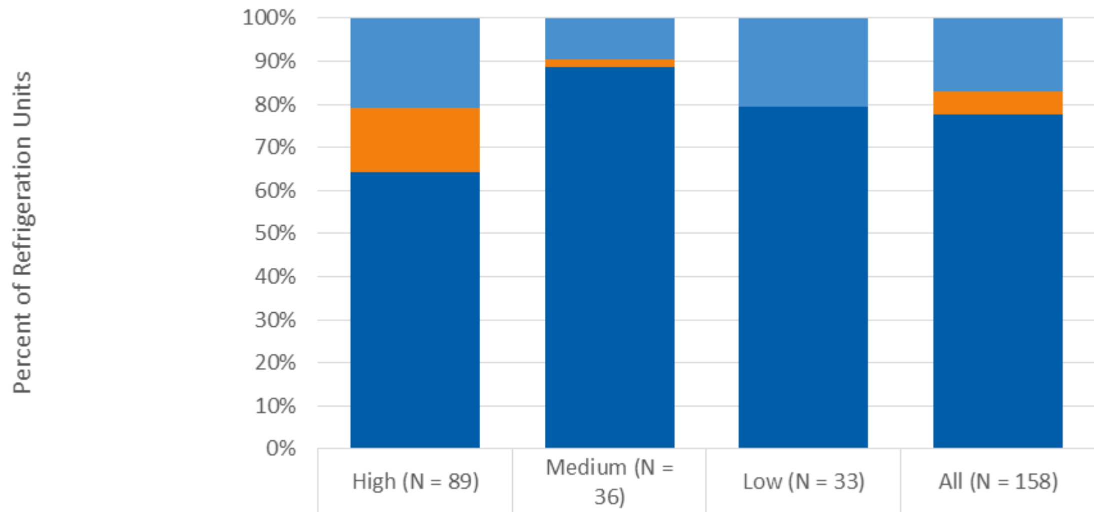


	BED (N = 41)	EVT (N = 118)	All (N = 159)
Unidentified	64%	57%	58%
Non-Energy Star	3%	23%	20%
ENERGY STAR	32%	20%	22%

As in 2011, the 2016 site visits revealed that the majority of refrigeration units in Vermont have anti-sweat heaters that are always on. This represents a large potential for capturing energy savings through anti-sweat heater controls.

The highest saturations of refrigeration units with anti-sweat heater controls were found in the large building stratum (15%).

Figure 78. Saturation of Anti-Sweat Controls on Refrigeration Units by Facility Size

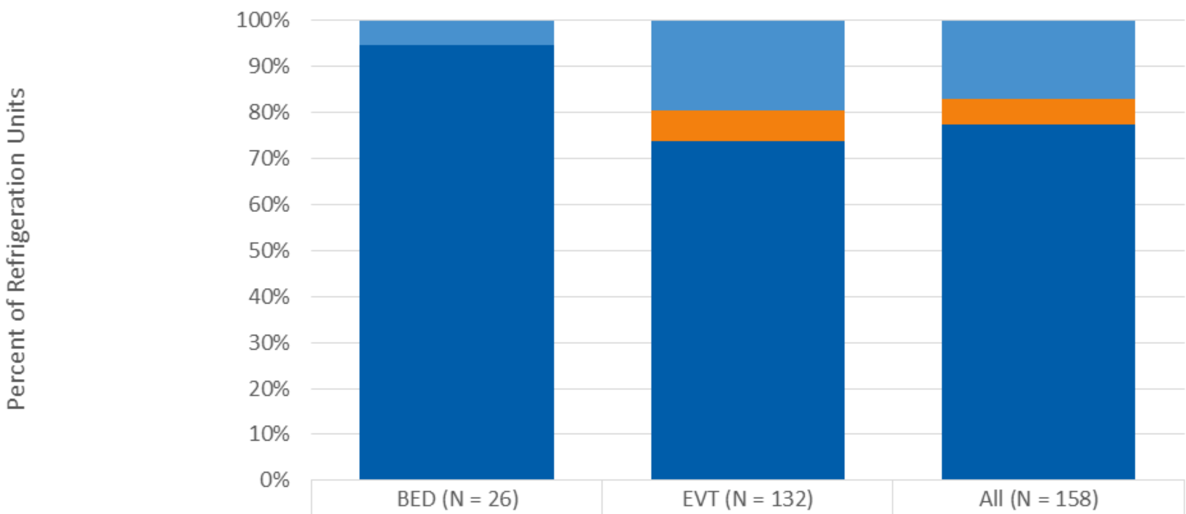


	High (N = 89)	Medium (N = 36)	Low (N = 33)	All (N = 158)
Unidentified	21%	10%	20%	17%
Anti-Sweat Heater Controls	15%	2%	0%	5%
Anti-Sweat Always On	64%	89%	80%	78%

The saturation of anti-sweat controls on refrigeration units, shown in Figure 79, is very similar to the distribution found in 2011. Nearly all (95%) of the units in BED territory have no anti-sweat controls with

5% of systems in that territory unidentified. In the EVT territory, 74% of systems were identified as having controls. Statewide, the proportion is 78%.

Figure 79. Saturation of Anti-Sweat Controls on Refrigeration Units by EEU

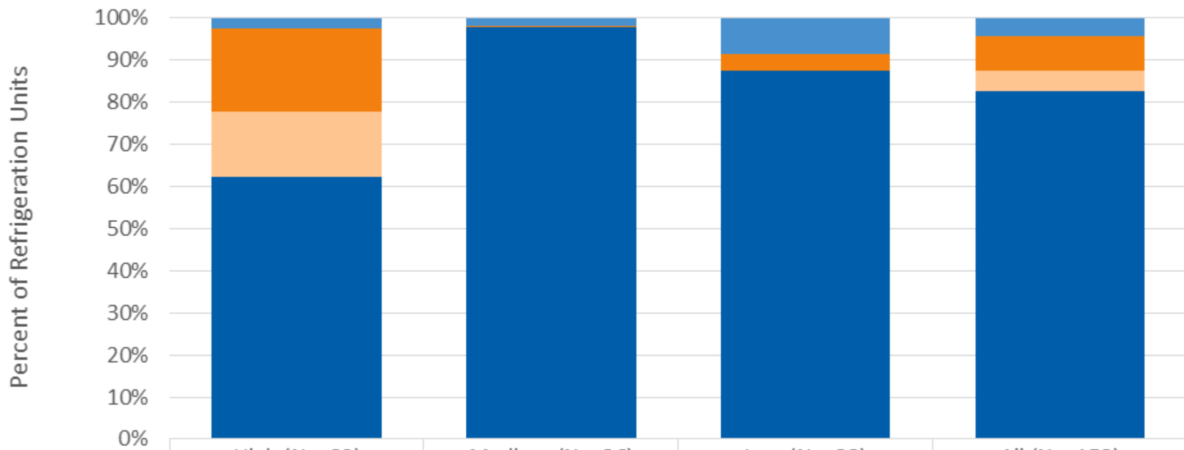


	BED (N = 26)	EVT (N = 132)	All (N = 158)
Unidentified	5%	20%	17%
Anti-Sweat Heater Controls	0%	7%	5%
Anti-Sweat Always On	95%	74%	78%

The saturation of display case door types varies considerably by size stratum as shown in Figure 80. Medium–sized facilities have the highest saturation of glass doors (98%), followed by small (88%) and large buildings (62%). Large buildings have the highest rate of open display cases—cases without doors—at 20%, followed by small facilities at 4%. Display cases with plastic doors were only identified in large facilities (5%).

Since 2011, there has been a marked increase in the number of cases with glass doors in small- and medium-sized facilities. And while the saturation of these equipment is increasing in large facilities, it is still the lowest of all three size strata.

Figure 80. Saturation of Display Case Door Types by Facility Size

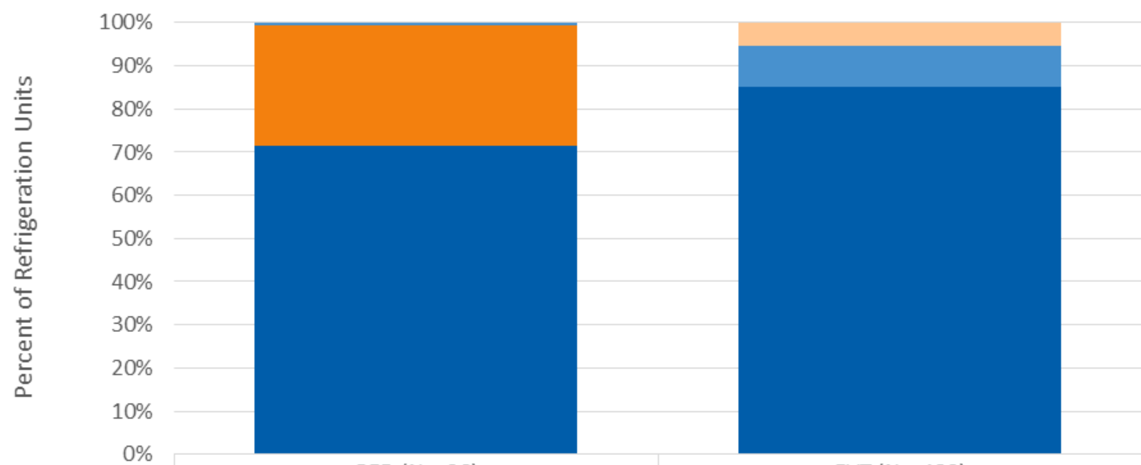


	High (N = 89)	Medium (N = 36)	Low (N = 33)	All (N = 158)
Unidentified	2%	2%	9%	4%
None/Open	20%	0%	4%	8%
Plastic	15%	0%	0%	5%
Glass Door	62%	98%	88%	83%

Size Strata

The saturation of glass display case doors is similar across EEU, as shown in Figure 81. However, there is a much higher proportion of cases without doors in the EVT territory (10%) than in the BED territory (1%).

Figure 81. Saturation of Display Case Door Types by EEU



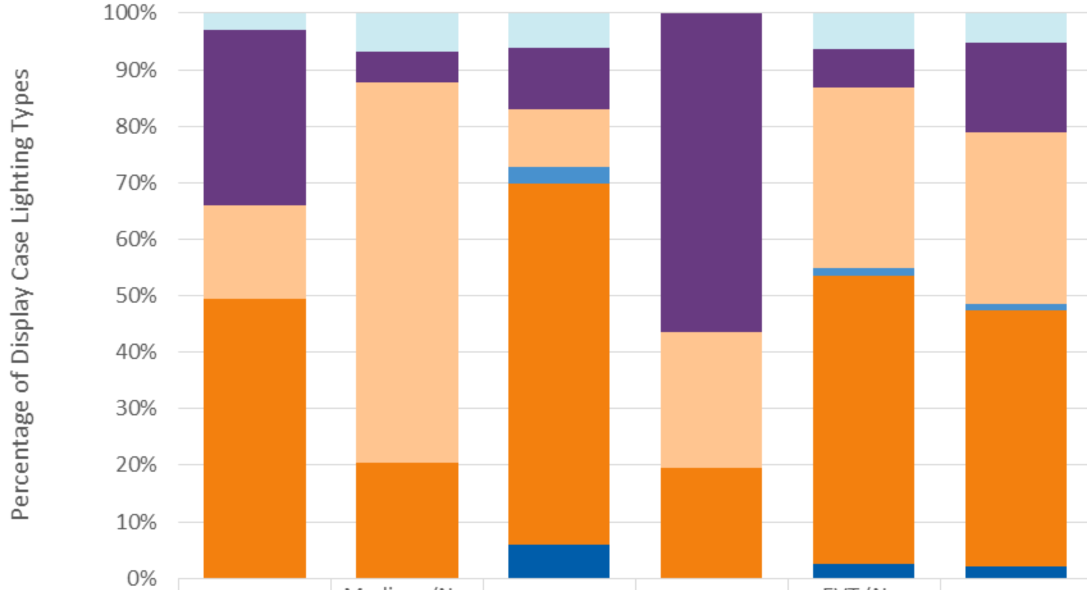
	BED (N = 26)	EVT (N = 132)
Unidentified	0%	5%
None/Open	1%	10%
Plastic	28%	0%
Glass Door	72%	85%

Size Strata

Figure 82 shows the distribution of display case lighting technologies by size and stratum. Statewide, linear fluorescent lighting and LED lighting are most represented: LEDs account for an estimated 31% of installed lighting and linear fluorescents account for 45%. There is considerable variation by facility size and EEU, with equipment in the EVT service territory most closely resembling the statewide average. In the BED service territory, the proportion of LEDs (24%) and linear fluorescents (20%) are similar, but the majority of cases in BED's territory area do not have dedicated lighting.

Display cases in large and small facilities more prominently feature linear fluorescent lighting (49% and 64%, respectively) than LEDs. The highest saturation of LED case lighting is found in medium-sized buildings, where 67% of the case lighting comes from LEDs. Small facilities are the only facilities in which incandescent and CFL case lighting were identified.

Figure 82. Saturation of Display Case Lighting Types by Facility Size and EEU

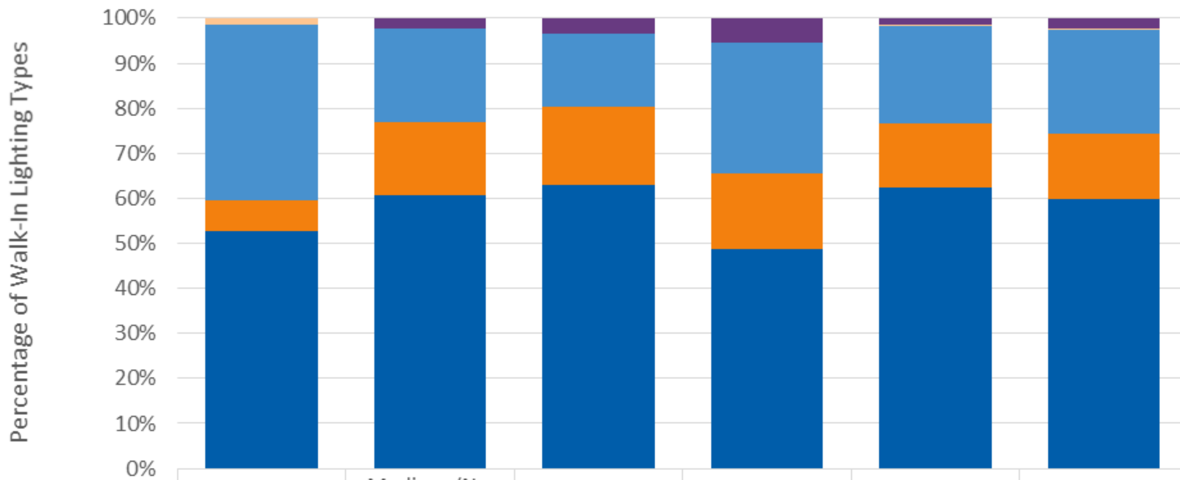


	High (N = 89)	Medium (N = 36)	Low (N = 33)	BED (N = 26)	EVT (N = 132)	All (N = 158)
Unidentified	3%	7%	6%	0%	6%	5%
None	31%	6%	11%	57%	7%	16%
LED	17%	67%	10%	24%	32%	31%
CFL	0%	0%	3%	0%	1%	1%
Fluorescent	49%	21%	64%	20%	51%	45%
Incandescent	0%	0%	6%	0%	3%	2%

Size Strata / EEU

The saturation of walk-in lighting types is shown in Figure 83. Statewide, linear fluorescents are the most common form of lighting (60%), followed by LEDs (23%) and incandescents (15%). This is largely true for each of the EEUs and facility strata as well. The one exception: large facilities have a higher rate of LED lighting (39%) and a lower rate of incandescent lighting (7%).

Figure 83. Saturation of Walk-In Refrigeration Unit Lighting Types by Facility Size and EEU

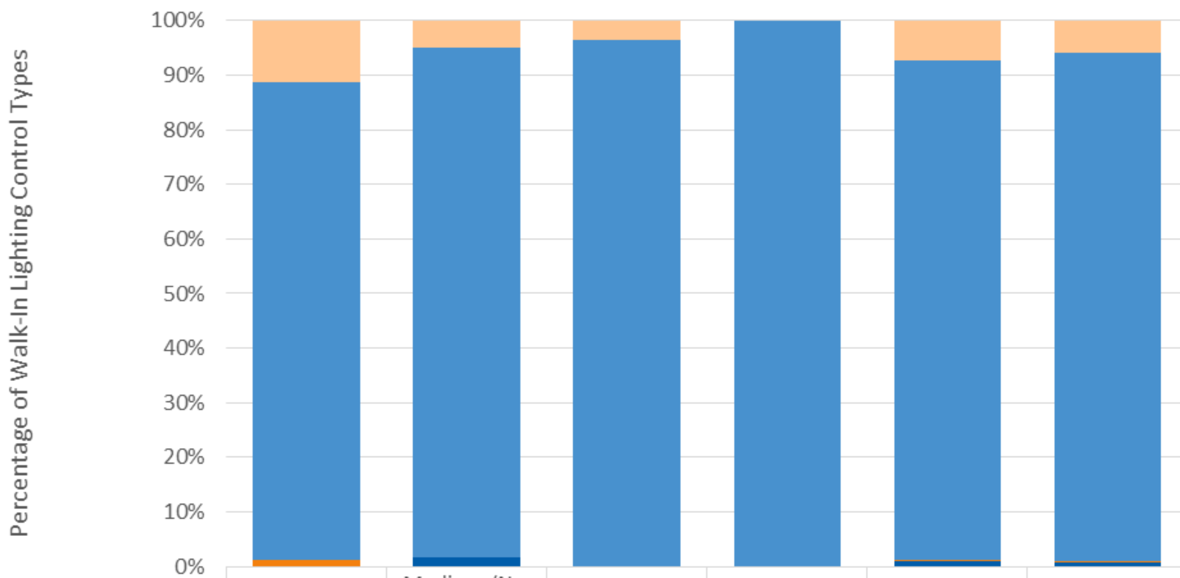


	High (N = 29)	Medium (N = 30)	Low (N = 17)	BED (N = 20)	EVT (N = 56)	All (N = 76)
Unidentified	0%	2%	3%	6%	1%	2%
None	1%	0%	0%	0%	0%	0%
LED	39%	21%	16%	29%	22%	23%
Incandescent	7%	16%	17%	17%	14%	15%
Fluorescent	53%	61%	63%	49%	62%	60%

Size Strata / EEU

Statewide, essentially all walk-in refrigeration lighting is controlled by a wall switch, as shown in Figure 84. This is true across size strata and utility territories. A very small portion (1%) of walk-in lighting systems are on 24 hours per day, and in large facilities, 1% of systems were identified as having occupancy sensor controls.

Figure 84. Saturation of Walk-In Refrigeration Unit Lighting Control Types by Facility Size and EEU (N=76)



	High (N = 29)	Medium (N = 30)	Low (N = 17)	BED (N = 20)	EVT (N = 56)	All (N = 76)
Unidentified	11%	5%	3%	0%	7%	6%
Wall Switch	88%	93%	97%	100%	92%	93%
Occupancy Sensor	1%	0%	0%	0%	0%	0%
24/7	0%	2%	0%	0%	1%	1%

Size Strata / EEU

Across all size strata, the majority of walk-in refrigeration units are not equipped with economizers. Small facilities have the highest saturation of economizers at an estimated 42%, as shown in Figure 85. Figure 85 excludes walk-in freezers, given that economizers do not work well with freezers.

Figure 85. Saturation of Walk-In Refrigeration Unit Economizers by Facility Size (N=60)

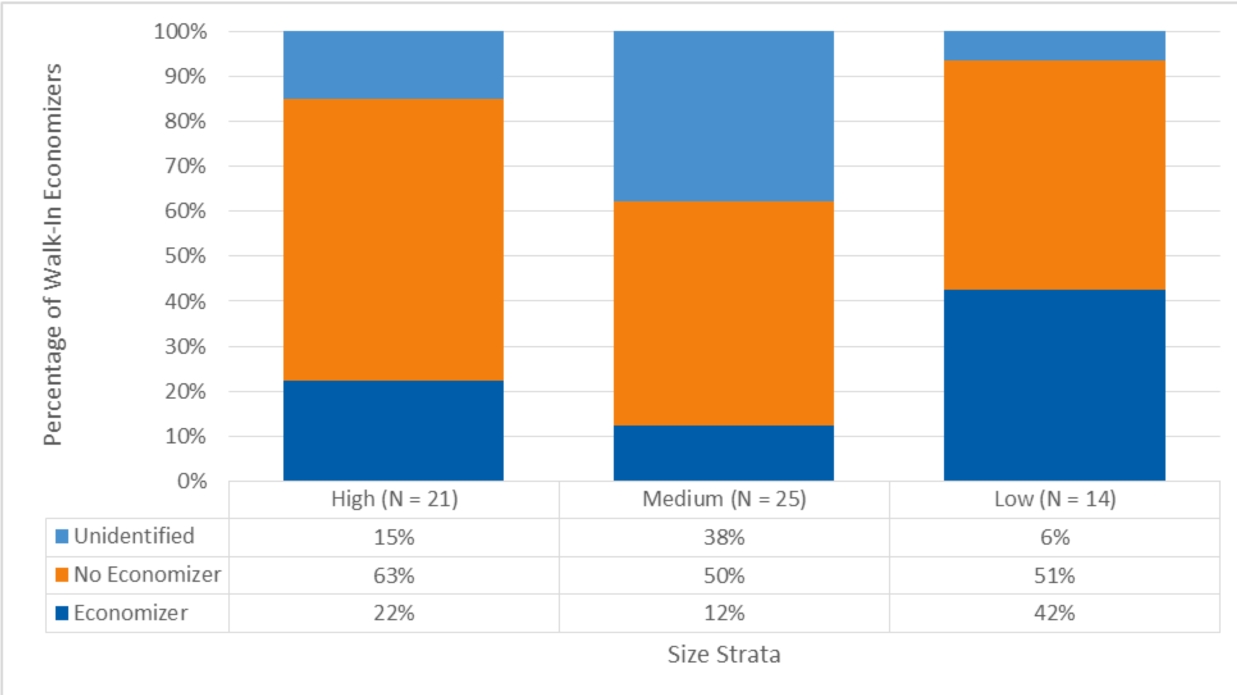
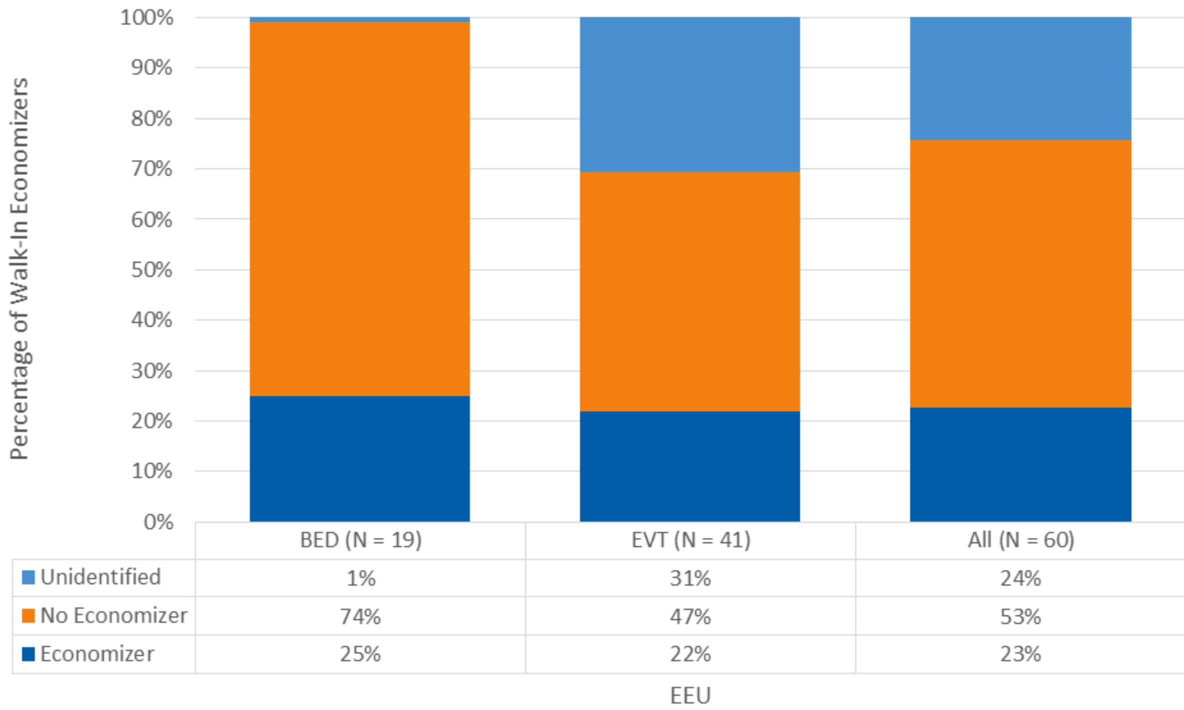


Figure 86 shows saturation of unit economizers by EEU. The estimated percentage of systems with economizers—15% to 19%—is relatively consistent in BED, EVT, and the state as a whole. As with the previous figure, Figure 86 excludes walk-in freezers.

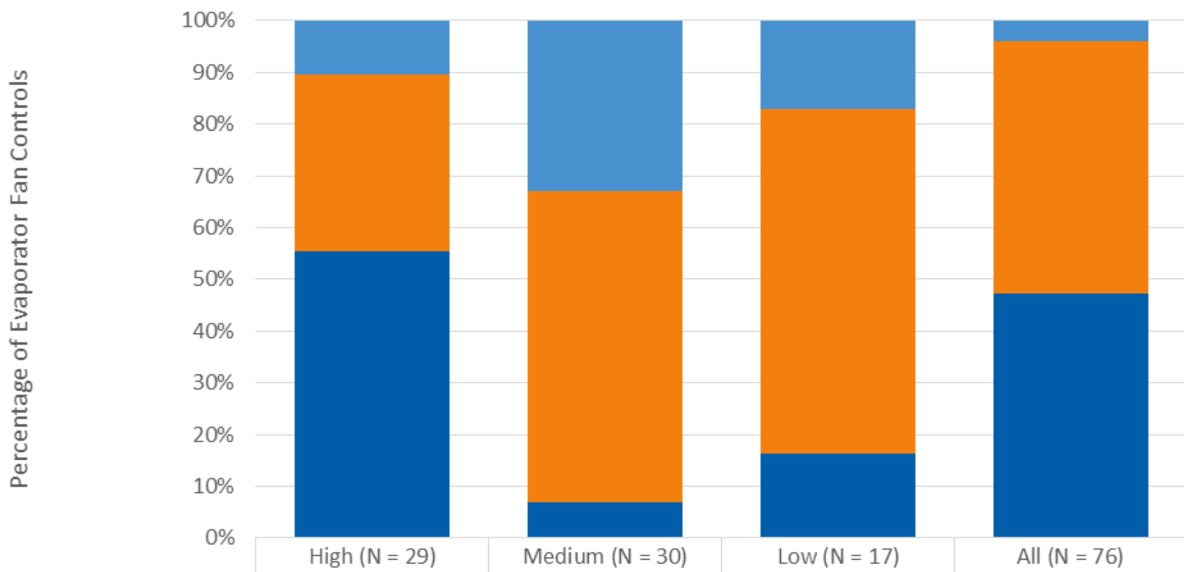
Figure 86. Saturation of Walk-In Refrigeration Unit Economizers by EEU (N=60)



	BED (N = 19)	EVT (N = 41)	All (N = 60)
Unidentified	1%	31%	24%
No Economizer	74%	47%	53%
Economizer	25%	22%	23%

The highest proportion of evaporator fan motor controls are found in large facilities (55%), as shown in Figure 87. Statewide, approximately half of all evaporator fan motors are equipped with motor controls.

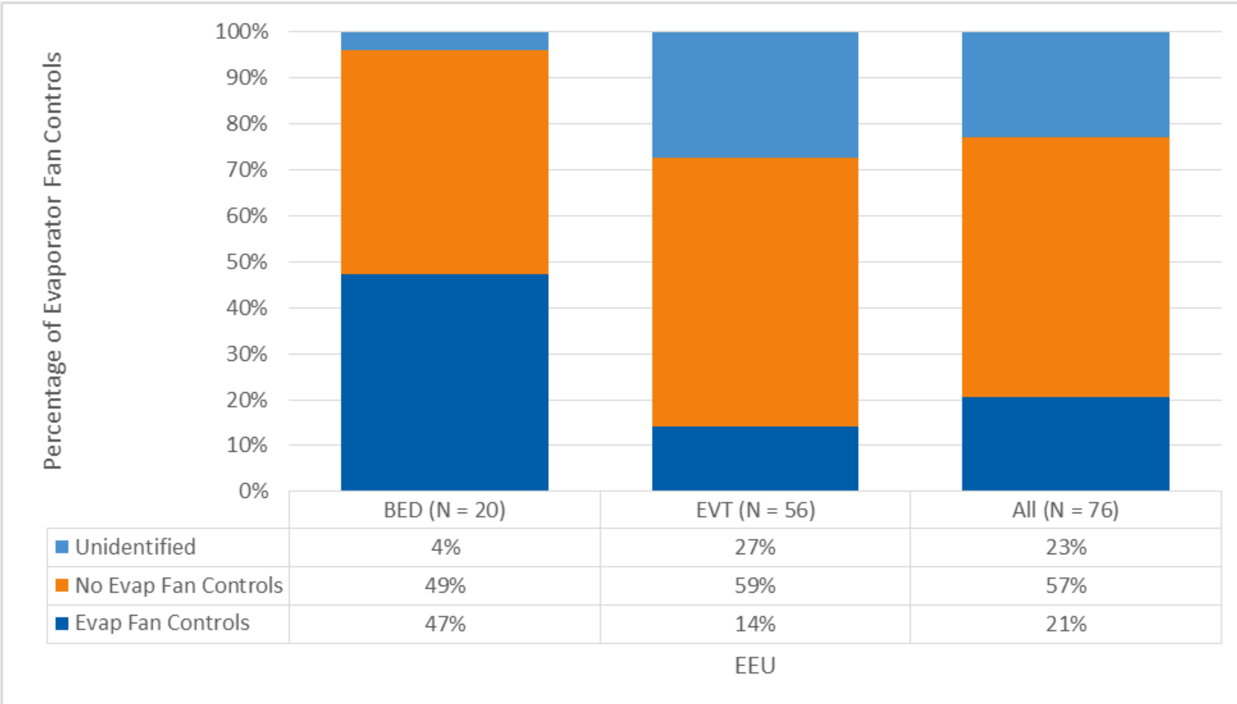
Figure 87. Saturation of Walk-In Refrigeration Unit Evaporator Fan Motor Controls By Facility Size (N=76)



	High (N = 29)	Medium (N = 30)	Low (N = 17)	All (N = 76)
Unidentified	10%	33%	17%	4%
No Evap Fan Controls	34%	60%	67%	49%
Evap Fan Controls	55%	7%	16%	47%

Figure 88 shows the distribution of evaporator fan motor controls on walk-in refrigeration units by EEU. The majority of evaporator fans in EVT territory (59%) do not have motor controls. Nearly half (47%) of the motors in BED's service territory are equipped with motor controls.

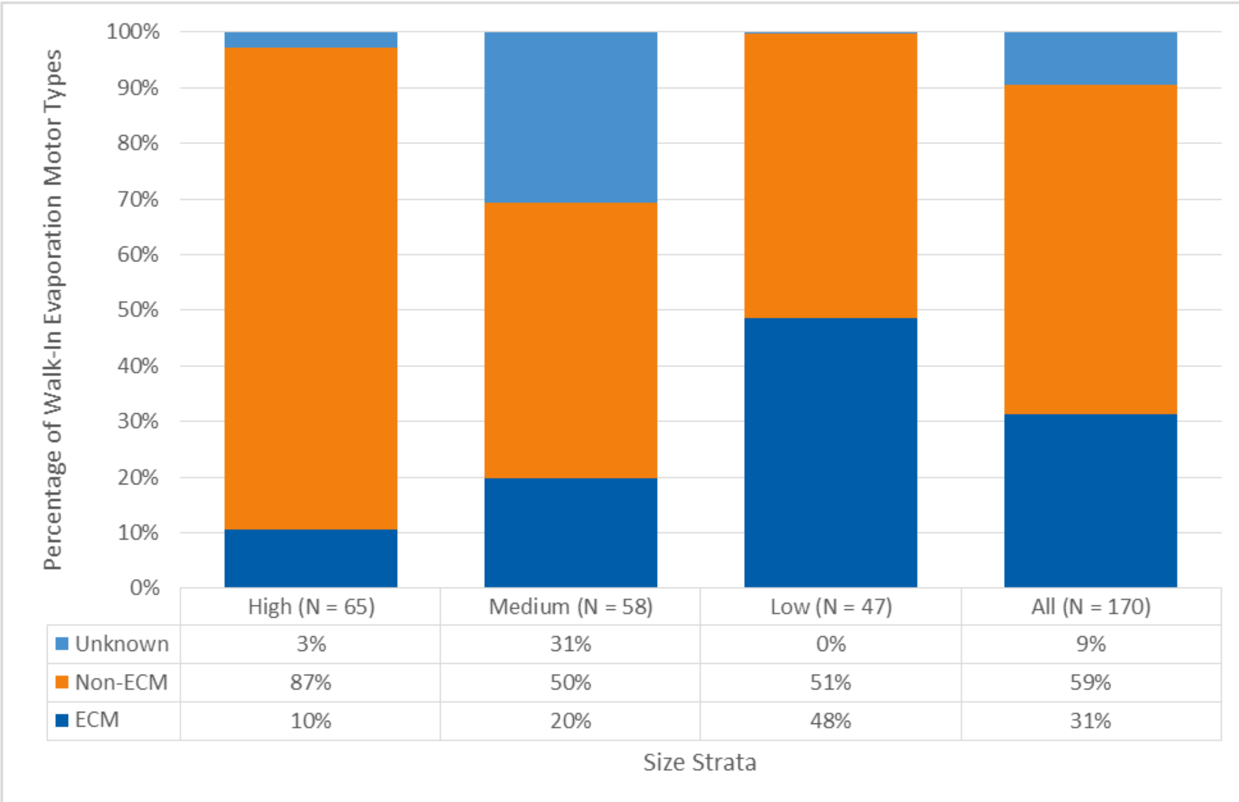
Figure 88. Saturation of Walk-In Refrigeration Unit Evaporator Fan Motor Controls by EEU (N=76)



	BED (N = 20)	EVT (N = 56)	All (N = 76)
Unidentified	4%	27%	23%
No Evap Fan Controls	49%	59%	57%
Evap Fan Controls	47%	14%	21%

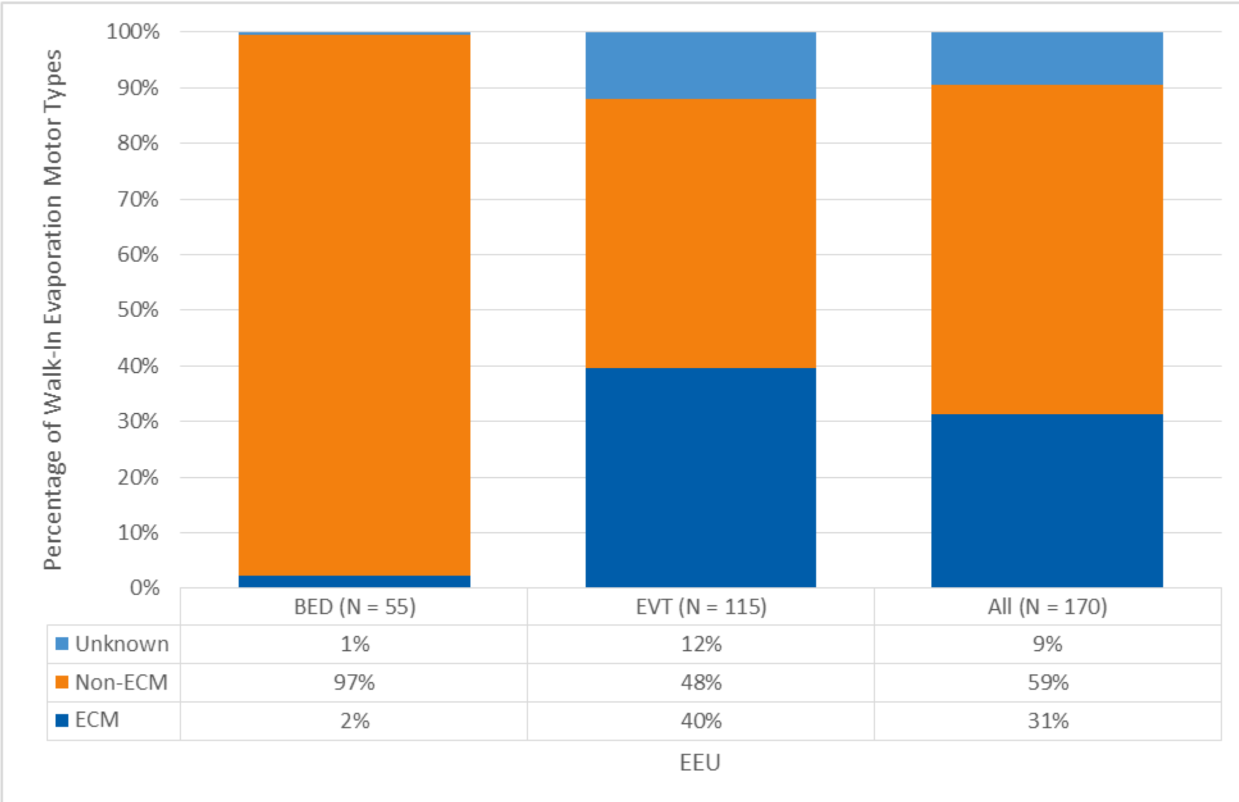
Figure 89 shows the distribution of walk-in refrigeration unit evaporator motor types by size strata. Statewide, electronically commutated motors (ECMs) account for an estimated 31% of all motors. Small facilities have the highest saturation of ECMs (48%), followed by medium-sized facilities at 20%. Approximately 87% of the motors in large facilities are not equipped with ECMs.

Figure 89. Saturation of Walk-In Refrigeration Unit Evaporator Motor Types by Facility Size (N=170)



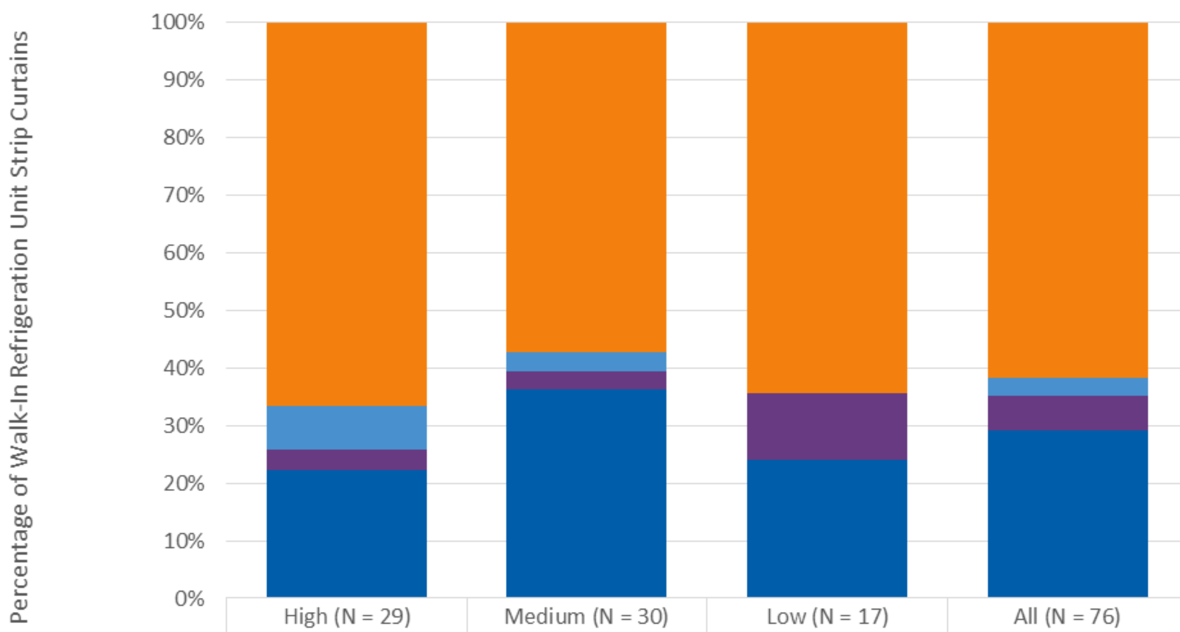
The majority of ECMs were identified in facilities within the EVT service territory, as shown in Figure 90. Only 2% of the motors in the BED service territory were identified as being ECM units.

Figure 90. Saturation of Walk-In Refrigeration Unit Evaporator Motor Types by EEU (N=170)



Statewide, approximately 62% of walk-in refrigeration units are not equipped with strip curtains. This proportion varies little by EEU. Only a small percentage of units are equipped with strip curtains (9% statewide), and one third of those units with strip curtains are also equipped with doors. Approximately 29% of the units statewide have doors; units with doors are most commonly found in medium-sized facilities. The largest saturation of strip curtains is found in small facilities (12%).

Figure 91. Saturation of Walk-In Refrigeration Unit Strip Curtains by Facility Size (N=76)

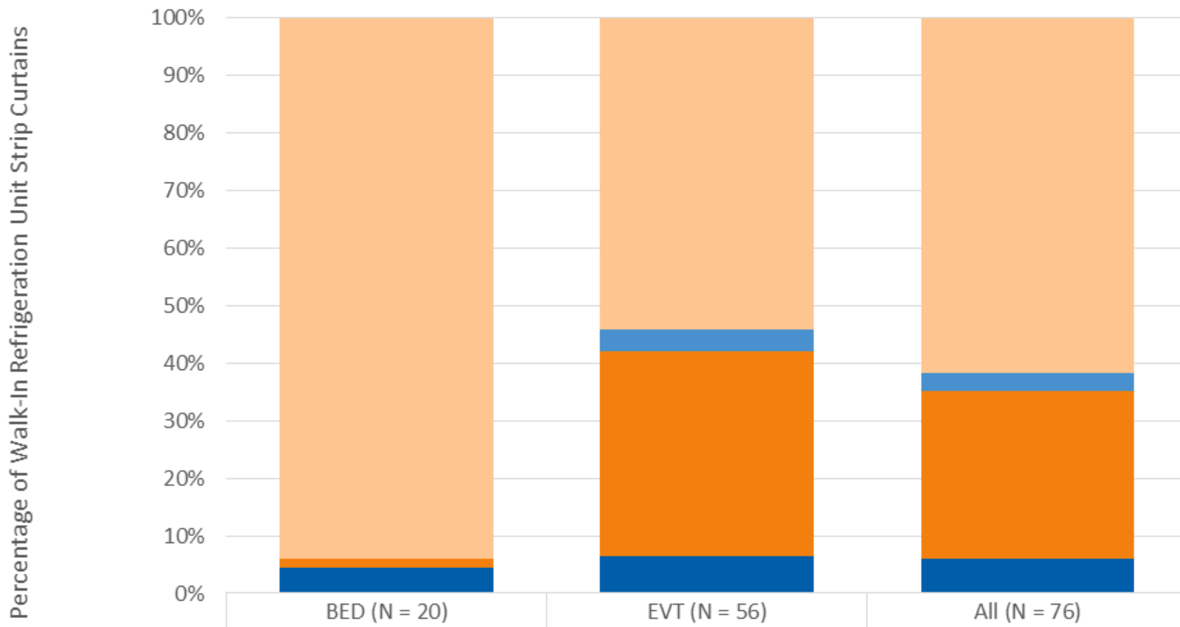


	High (N = 29)	Medium (N = 30)	Low (N = 17)	All (N = 76)
Unidentified	0%	0%	0%	0%
No Strip Curtains	67%	57%	64%	62%
Curtains plus door	7%	3%	0%	3%
Strip Curtains	4%	3%	12%	6%
Door	22%	36%	24%	29%

Size Strata

Most walk-in refrigeration units identified in the BED service territory lacked strip curtains (94%), a significantly higher proportion than the statewide average saturation of 62%. Figure 92 shows that 36% of the walk0in refrigeration units in the EVT service territory are equipped with doors, 6% have strip curtains, and 4% have both.

Figure 92. Saturation of Walk-In Refrigeration Unit Strip Curtains by EEU (N=76)

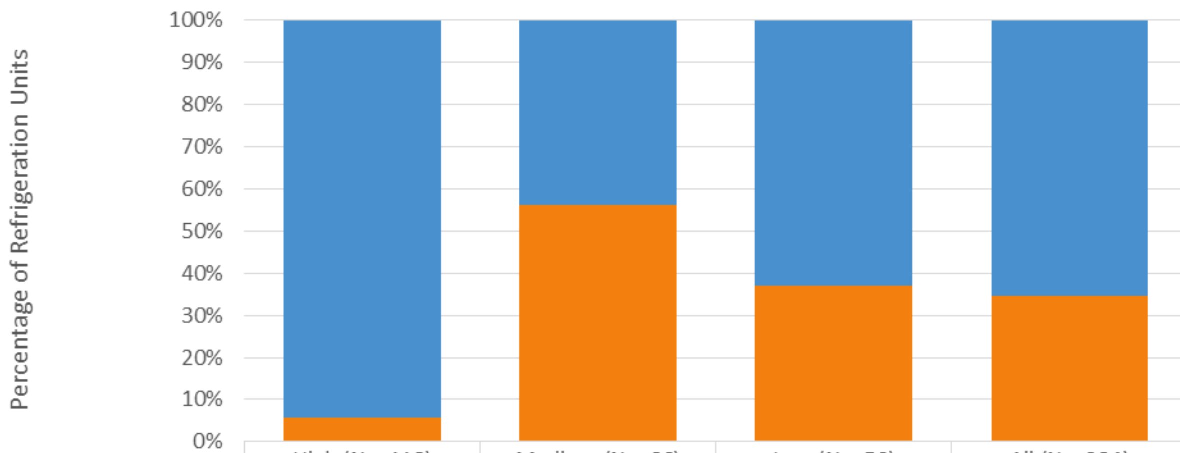


	BED (N = 20)	EVT (N = 56)	All (N = 76)
Unidentified	0%	0%	0%
No Strip Curtains	94%	54%	62%
Curtains plus door	0%	4%	3%
Door	2%	36%	29%
Strip Curtains	5%	6%	6%

EEU

No floating head pressure controls for refrigeration units were identified in 2016, as shown in Figure 93

Figure 93.Saturation of Refrigeration Systems with Floating Head Pressure Control by Facility Size (N=234)

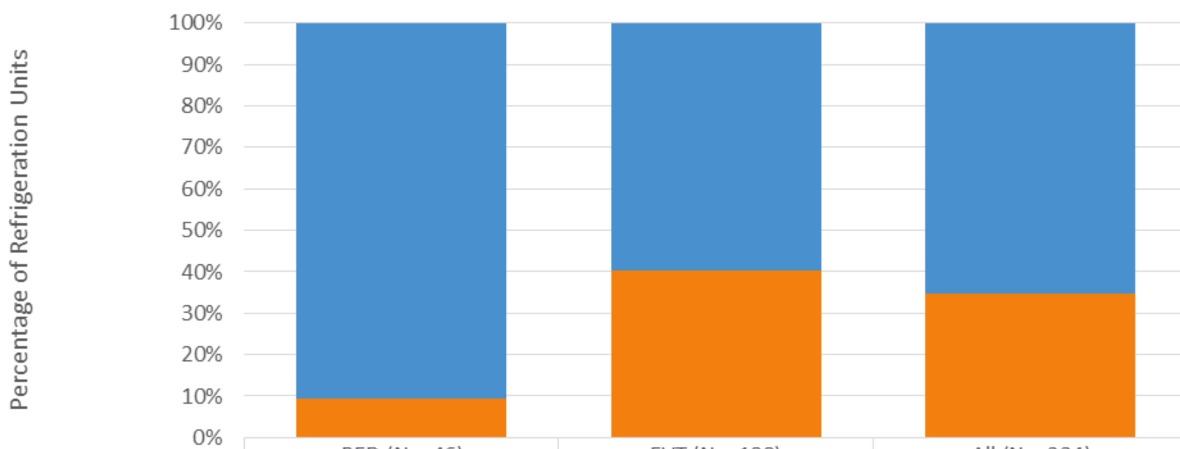


	High (N = 118)	Medium (N = 66)	Low (N = 50)	All (N = 234)
Unidentified	94%	44%	63%	65%
No Pressure Control	6%	56%	37%	35%
Pressure Control	0%	0%	0%	0%

Consumption Strata

Figure 94 shows that no floating head pressure control systems were identified in 2016.

Figure 94. Saturation of Refrigeration Systems with Floating Head Pressure Controls by EEU (N=234)

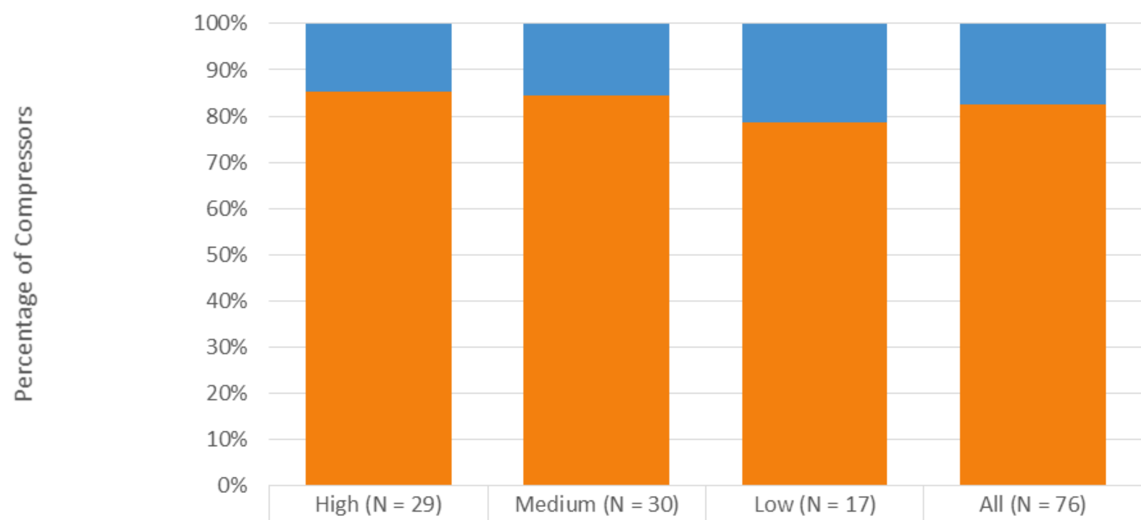


	BED (N = 46)	EVT (N = 188)	All (N = 234)
Unidentified	91%	60%	65%
No Pressure Control	9%	40%	35%
Pressure Control	0%	0%	0%

EEU

Statewide, heat recovery systems were hard to identify. Approximately 83% of walk-in systems were identified as not having heat recovery systems, and another 17% could not be identified. Only one walk-in was identified as using heat recovery in the medium-sized building strata. This system represents less than 1% of all the systems in that strata.

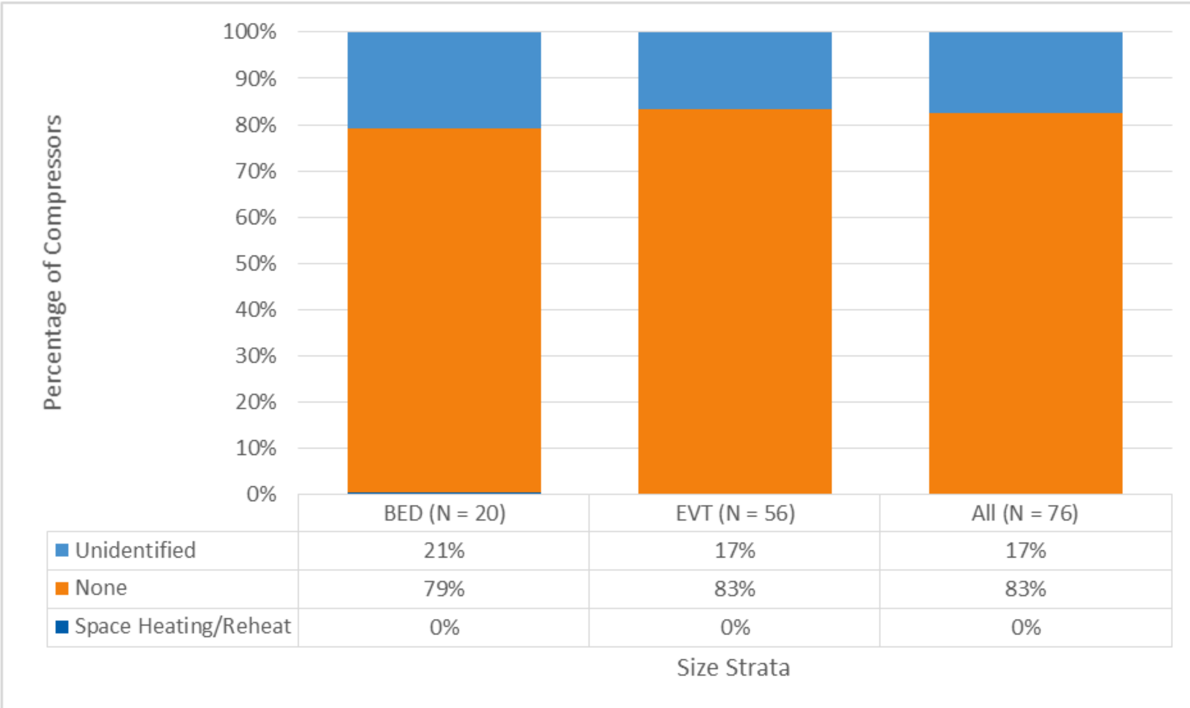
Figure 95. Saturation of Compressor Heat Recovery Types by Facility Size (N=76)



	High (N = 29)	Medium (N = 30)	Low (N = 17)	All (N = 76)
Unidentified	15%	15%	21%	17%
None	85%	84%	79%	83%
Space Heating/Reheat	0%	0%	0%	0%

Figure 96 shows that there is no significant difference in compressor heat recovery systems by EEU. For the majority of compressors, it was identified that there is no heat recovery system. The one unit with a heat recovery system was identified in the BED service territory.

Figure 96. Saturation of Compressor Heat Recovery Types by EEU (N=76)



EEU Market Characterization—Refrigeration

Table 21 provides a summary characterization of refrigeration measures for Vermont's EEUs.

Table 21. EEU Market Characterization—Refrigeration

Measure/Characteristic	BED	EVT
ENERGY STAR non-commercial refrigerators	• Approximately 32% of refrigerators and freezers are identified as ENERGY STAR qualified.	• Only 8% of systems are identified as ENERGY STAR qualified
Anti-sweat heater controls	• The majority of display cases with doors are also equipped with anti-sweat heater controls (95% BED; 74% EVT).	
Doors on reach-in refrigerated display cases	• Nearly 100% saturation of equipment with doors (72% glass; 28% plastic)	• 10% of display cases do not have doors.
Refrigerated display case lighting	• 57% of systems have no lighting, while 24% are LED and 20% are fluorescent.	• Over half (51%) of cases have linear fluorescent lighting and another 32% are LED systems.
Walk-in cooler lighting	• Fluorescent lighting is the highest saturation technology in walk-in refrigeration units, comprising 49% of the lighting in BED's territory and 62% of the lighting in EVT's	

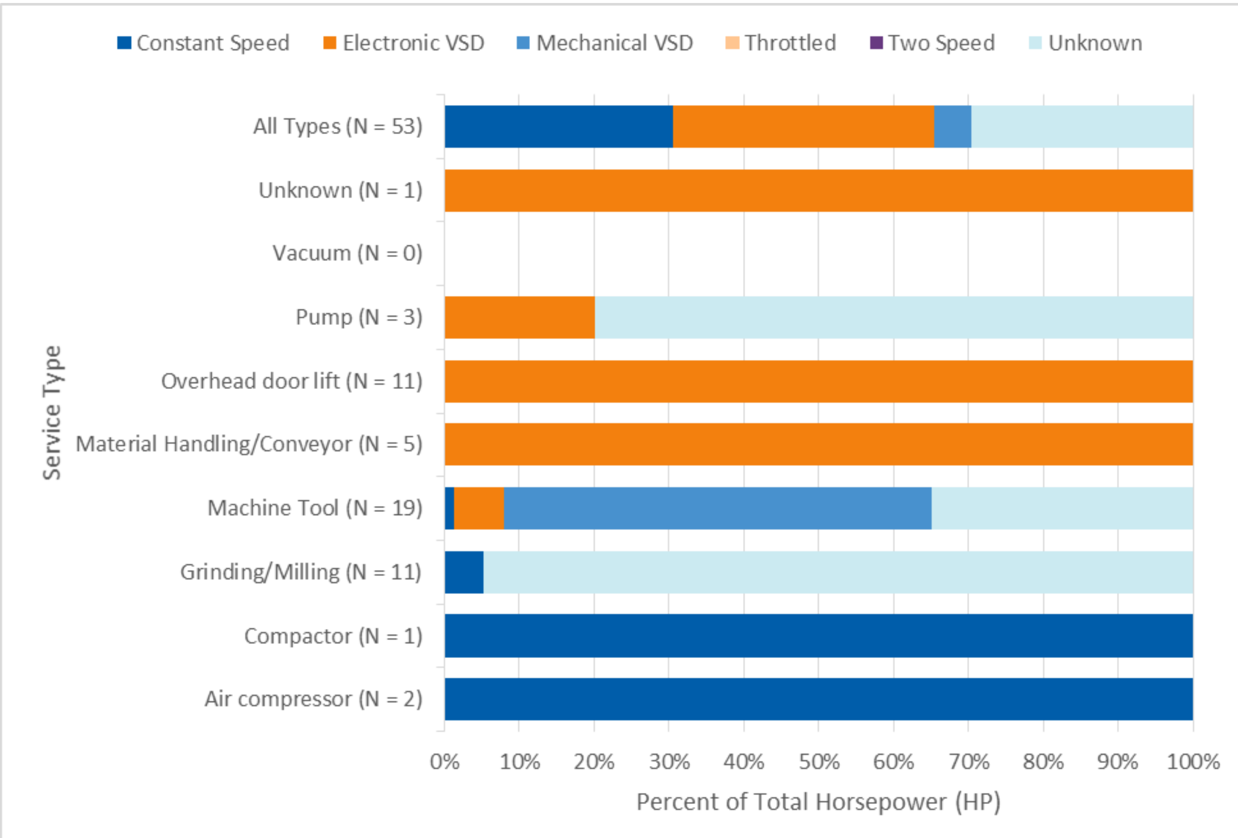
Measure/Characteristic	BED	EVT
	territory. LEDs are more prominent in the BED territory (29% vs. 22%).	
Walk-in cooler lighting controls	• Lighting controls are essentially the same across the state: walk-in refrigeration units are manually controlled by wall switches.	
Walk-in cooler economizers	• Economizers were identified on 25% of walk-in units.	• Economizers were identified on 22% of walk-in units.
Walk-in cooler evaporator fan motor types	• Nearly all (97%) of units are non-ECM units.	• Approximately 40% of the motors were identified as ECM units.
Evaporator fan motor controls in walk-in coolers	• 47% of units are equipped with evaporator fan motor controls.	• Only 14% of units are equipped with evaporator fan motor controls.
Strip curtains on walk-in refrigeration units	• Only 5% of units are equipped with strip curtains; 94% of units do not have strip curtains.	• Approximately 6% of units have strip curtains, 36% have doors, and 4% have both.
Floating head pressure control on refrigeration systems	N/A	N/A
Implement heat recovery on refrigeration systems	• The majority of units did not have compressor heat recovery equipment.	

Motors and Compressed Air

Motors

Figure 97 shows that the largest proportion of process motors in Vermont's existing building stock are electronic VSD motors (35%) followed by constant speed motors (31%). Only 5% of motors were identified as being mechanical VSDs. Field staff could not identify the control types of 29% of the motors.

Figure 97. Distribution of Process Motor Control Types by Service Type (N=53)



Field staff were unable to collect enough information regarding motor efficiency to characterize the efficiency of the population of motors with sufficient accuracy.

Compressed Air

Compressor types vary by application, as shown in Table 22. The majority of compressors are found in manufacturing, health care, and hospital facilities, and the type of compressor varies with the facility type. Single-stage, single-acting reciprocating compressors are most common in the manufacturing facilities, while single-stage double-acting reciprocating compressors are found in the health care facilities. Hospitals have the largest share of two-stage, double-acting and two-stage, single acting reciprocating compressors.

Table 22. Distribution of Air Compressors by Facility Type

Air Compressor Type	All (N=29)	Facility Type									
		Retail (N=1)	Office (N=2)	Manufacturing (N=7)	Food Sales (N=0)	Food Service (N=1)	Health Care (N=5)	Hospital (N=6)	Lodging (N=1)	Other (N=1)	School (N=5)
Reciprocating (Single-stage, single-acting)	24%	0%	0%	66%	0%	0%	40%	0%	0%	0%	0%
Reciprocating (Single-stage, double-acting)	21%	100%	0%	17%	0%	0%	60%	0%	0%	0%	20%
Reciprocating (Two-stage, double-acting)	24%	0%	0%	0%	0%	0%	0%	67%	0%	0%	60%
Reciprocating (Two-stage, single-acting)	10%	0%	30%	0%	0%	0%	0%	33%	0%	0%	0%
Rotary Screw (Two-stage)	14%	0%	70%	17%	0%	0%	0%	0%	100%	0%	20%
Centrifugal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Unknown	7%	0%	0%	0%	0%	100%	0%	0%	0%	100%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
All	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%

Large facilities have the highest proportion of compressors (47%) in the single-stage, single-acting category, as shown in Table 23. Medium-sized facilities have the largest proportion of two-stage rotary screw compressors, and small facilities have the largest proportion of single-stage, double-acting reciprocating compressors.

Only one compressor was identified in the BED service territory—a two-stage, single-acting compressor. Two-stage rotary screw compressors comprise the largest saturation of compressors in the EVT service territory.

Table 23. Distribution of Air Compressors by Facility Size and EEU

Air Compressor Type	All (N=29)	Size Strata			EEU	
		High (N=21)	Medium (N=4)	Low (N=4)	BED (N=1)	EVT (N=28)
Reciprocating (Single-stage, single-acting)	24%	47%	0%	17%	0%	16%
Reciprocating (Single-stage, double-acting)	21%	7%	0%	66%	0%	16%
Reciprocating (Two-stage, double-acting)	24%	18%	0%	0%	0%	4%
Reciprocating (Two-stage, single-acting)	10%	7%	21%	0%	100%	2%
Rotary Screw (Two-stage)	14%	22%	50%	17%	0%	43%
Centrifugal	0%	0%	0%	0%	0%	0%
Unknown	7%	0%	28%	0%	0%	19%
Other	0%	0%	0%	0%	0%	0%
All	100%	100%	100%	100%	100%	100%

Statewide, an estimated 37% of air compressors operated between 50 and 99 hours per week, as shown in Table 24. All of these compressors are used in manufacturing or office facilities. The next largest group of air compressors are operated less than 10 hours per week. These compressors are distributed across offices, manufacturing, health care, hospitals, "other" facilities, and schools. Only 4% of systems operate 24 hours per day, and all of those units are found in food service facilities.

Table 24. Air Compressor Hours of Use per Week by Bin and Facility Type

Hours	All (N=29)	Facility Type									
		Retail (N=1)	Office (N=2)	Manufacturing (N=7)	Food Sales (N=0)	Food Service (N=1)	Health Care (N=5)	Hospital (N=6)	Lodging (N=1)	Other (N=1)	School (N=5)
<10	34%	0%	30%	17%	0%	0%	40%	100%	0%	100%	20%
11 - 49	21%	100%	0%	34%	0%	0%	20%	0%	100%	0%	0%
50 - 99	37%	0%	70%	37%	0%	0%	0%	0%	0%	0%	0%
100 - 167	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
168	4%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
Unknown	4%	0%	0%	12%	0%	0%	40%	0%	0%	0%	80%

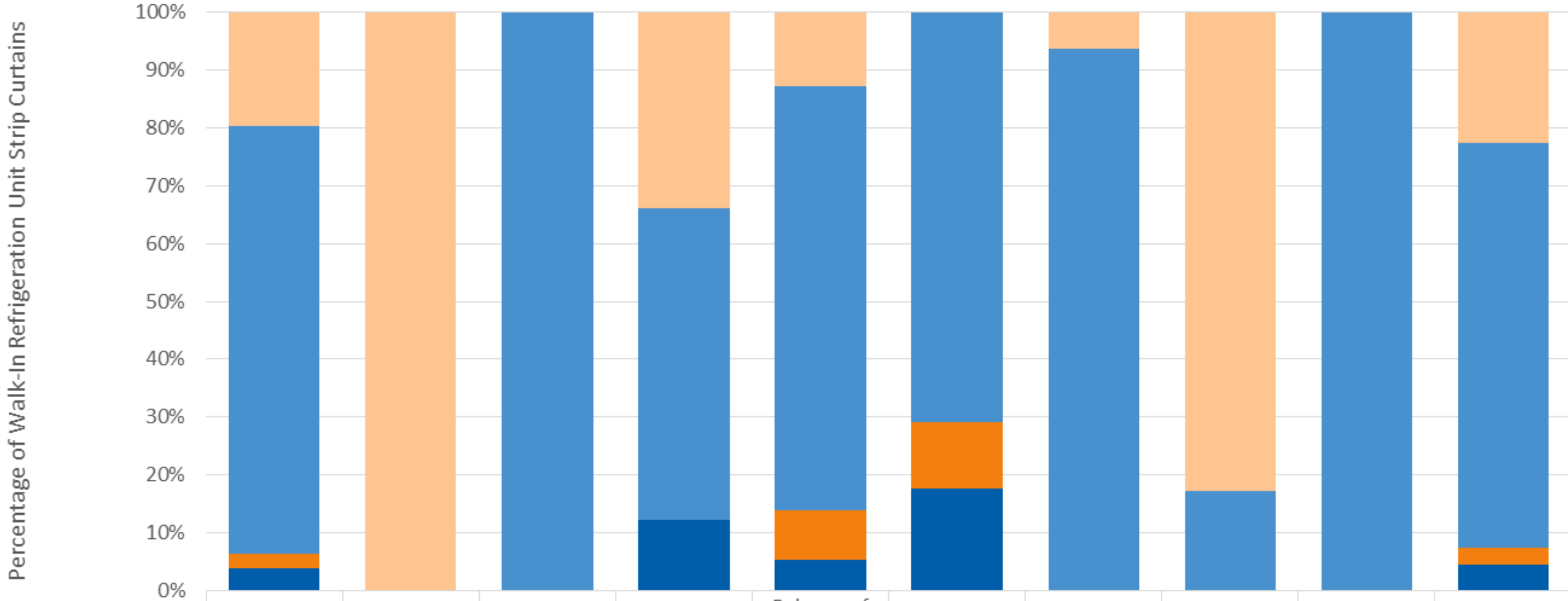
The plurality of compressors in large facilities (33%) and the majority of compressors in medium-sized facilities are operated between 50 and 99 hours per week. The only compressor that operate 24 hours per day are found in the medium-sized facilities. The one compressor identified in the BED service territory is operated fewer than 10 hours per week, while the largest proportion of compressors identified in the EVT territory are operated between 50 and 99 hours per week.

Table 25. Air Compressor Hours of Use per Week by Bin

Hours	All (N=29)	Size Strata			EEU	
		High (N=21)	Medium (N=4)	Low (N=4)	BED (N=1)	EVT (N=21)
<10	34%	25%	43%	17%	100%	25%
11–49	21%	22%	0%	83%	0%	24%
50–99	37%	33%	50%	0%	0%	42%
100–167	0%	0%	0%	0%	0%	0%
168	4%	0%	6%	0%	0%	4%
Unknown	4%	20%	0%	0%	0%	5%

The majority (74%) of air compressors statewide are not equipped with air dryers, as shown in Figure 98. Only 2% of compressors were identified as having continuous air dryers, and only 4% of compressors have cycling air dryers. The largest proportion of both continuous air dryers and cycling air dryers are found in the large facility strata, and are distributed between the manufacturing and “other” facility types. The only compressor located in the BED service territory is not equipped with a dryer.

Figure 98. Saturation of Cycling Air Dryers on Compressed Air Systems



	All (N = 29)	Retail (N=1)	Office (N=2)	Manufacturing (N=7)	Balance of Commercial (N=19)	High (N = 21)	Medium (N = 4)	Low (N = 4)	BED (N = 1)	EVT (N = 28)
Unknown	20%	100%	0%	34%	13%	0%	6%	83%	0%	23%
No Dryer	74%	0%	100%	54%	73%	71%	94%	17%	100%	70%
Continuous Dryer	2%	0%	0%	0%	9%	11%	0%	0%	0%	3%
Cycling Dryer	4%	0%	0%	12%	5%	18%	0%	0%	0%	4%

EEU

EEU Market Characterization—Motors and Compressed Air

Table 26 provides a summary characterization of motor and compressed air measures for Vermont's EEUs.

Table 26. EEU Market Characterization—Motors and Compressed Air

Measure/Characteristic	BED	EVT
Process motor control types	• The plurality (35%) of motors in Vermont's existing building stock are electronic VSDs. • The next largest group (31%) of motors are constant speed motors. • No throttling motors were identified.	
Air compressor types	• Only one compressor was identified in the BED service territory.	• Two-stage rotary screw compressors comprise the largest proportion (43%) of air compressors.
Air compressor hours of use	• Most compressors are operated between 50 and 99 hours per day (37%) or less than ten hours per day (34%). Only 4% of motors are operated 24 hours per day.	
Cycling air dryer on compressed air systems	• Only 4% of compressors statewide were identified as having cycling dryers. Another 3% were identified as having continuous dryers. All of the compressed air dryers were identified in the EVT service territory.	

Assessment of Remaining Potential—Existing Buildings

This chapter provides a brief summary of remaining potential in C&I facilities in existing buildings, which we define for this study as the saturation of inefficient equipment remaining in use. Inefficient equipment can generally be defined as systems or components with energy-use characteristics lower than specified in prevailing energy code—in this case, the 2015 Vermont CBES.

Building Envelope—Remaining Potential

Table 27 summarizes remaining potential for wall insulation, roof insulation, and windows. Uninsulated walls represent a large opportunity for energy savings, though savings from wall insulation often must be considered over a long timeline to appear cost-effective.

Table 27. Remaining Potential Summary for Building Envelope Measures

Building Envelope Measures	Remaining Potential	
	All Buildings	VT Gas
Increase Wall Insulation	An estimated 39% of existing facilities statewide lack wall insulation. Roughly half of these facilities have masonry wall types such as brick, concrete block, or solid concrete, which are more challenging to insulate. An estimated potential of 18% of facilities statewide remains, with these facilities having framed wall construction with no insulation .This potential comprises 40% office, 18% retail, and 30% "other." With an estimated median R-value of 13 among existing buildings with insulated walls, additional potential remains to improve insulation to 2015 CBES levels where economically feasible.	
Increase Roof Insulation	Estimated median roof insulation R-values of R-16 in VT Gas territory and R-22 overall represent ample opportunities for increasing roof insulation to 2015 CBES code levels.	
Upgrade single-pane windows	15%	9%

Lighting—Remaining Potential

As shown in Table 28, considerable potential remains in lighting, including in relatively easy upgrades such a replacing incandescent lamps in screw-based sockets. Automated lighting controls for linear fluorescent lighting and replacing outdoor light also stand out for their high remaining potential.

Table 28. Remaining Potential Summary for Lighting Measures

Lighting Measures		Remaining Potential		
		All Buildings	BED	EVT
Interior Lighting	Replace T8s and T12s in linear fluorescent applications*	76%	88%	72%
	Replace incandescents in screw-based sockets with CFLs and LEDs**	58%	51%	60%
	Install automated lighting controls for linear fluorescent lighting[2]	91%	93%	90%
Exterior Lighting	Replace outdoor lighting with LEDs*	78%	82%	76%
	Install automated outdoor lighting controls**	24%	3%	43%

* Potential expressed as percentage bulb count
** Potential expressed as percentage installed wattage

The potential to install automated lighting controls is high regardless of EEU or facility type.

Table 29 shows that more than half of T8 and T12 fixtures are estimated to be in offices.

Table 29. Distribution of Linear Fluorescent Fixtures by Facility Type

	Facility Type									
Lamp Type	Retail (N=25)	Office (N=27)	Manufacturing (N=28)	Food Sales (N=16)	Food Service (N=17)	Health Care (N=13)	Hospital (N=5)	Lodging (N=16)	Other (N=27)	School (N=15)
Super T8	1%	76%	6%	7%	0%	0%	0%	0%	10%	1%
T8	21%	51%	6%	1%	2%	1%	0%	2%	14%	1%
High Output T5	8%	26%	5%	0%	2%	0%	1%	1%	55%	2%
T5	10%	44%	35%	2%	0%	0%	1%	0%	8%	0%
T12	6%	53%	1%	1%	4%	1%	0%	1%	34%	0%
Linear Fluorescent	11%	52%	22%	0%	0%	2%	0%	1%	11%	2%

HVAC—Remaining Potential

Remaining potential for HVAC upgrades in existing buildings remains generally high, as illustrated in sub-sections below.

Unitary Systems

As shown in Table 30, an estimated 73% of unitary systems (such as rooftop units) with cooling capacities of less than 5.5 tons meet current energy code requirements. For unitary systems with cooling capacity between 5.5 and 135,000 tons, an estimated 60% of systems fall below code.

Table 30. Cooling Efficiency of Single-Zone Unitary HVAC Systems

	<5.5 tons (65,000 Btu/h) (Code: 13.0 SEER)	≥5.5 tons and <11.25 tons (135,000 Btu/h) (Code: 11.2 EER)	≥11.25 tons (135,000 Btu/h) (Code: 11 EER)
Percentage of Systems Below Code	73%	60%	5%
Percentage of Systems Above Code	27%	40%	95%
Mean EER	10.8	11.1	11.5
Mean SEER	12.6	N/A	N/A
Number of Observed Systems	390	73	6

Economizers

Vermont energy code requires economizers on most systems with cooling capacities 4.5 tons or greater and on some smaller systems. As shown in Table 31, study findings estimate that 53% of systems with capacities of 4.5 tons or greater lack economizers. In addition, after weighting is applied, the number of systems not identified as having or not having an economizer is estimated at 33%. With smaller systems—those with a cooling capacity less than 4.5 tons—an estimated 63% lack economizers.

Table 31. Saturation of Economizers in Cooling Systems

	<4.5 tons	>=4.5 tons
Economizer	9%	14%
No economizer	63%	53%
Unidentified	29%	33%

N=788 Systems

Heating Systems

Heating systems by and large meet or exceed 2015 CBES requirements, as shown in Table 32. Boilers with capacities between 300,000 Btu/h and 2,500,000 Btu/h are a notable exception and represent an opportunity for significant savings.

Table 32. Heating System Efficiency by Type and Code Category

System	Subcategory	Size Category (Input)	Observed Mean Efficiency	Code of Federal Regulation Minimum Efficiency	Percentage of Systems Below/Meet/Above Code	Number of Units
Warm Air Furnaces, gas fired	-	<225,000 Btu/h	90%	78% AFUE or 80% Thermal Efficiency	2%/15%/83%	46
	Maximum capacity	≥225,000 Btu/h	-	80% Thermal Efficiency	No observed systems	0
Warm Air Furnaces, oil fired	-	<225,000 Btu/h	82%	78% AFUE or 80% Thermal Efficiency	0%/0%/100%	14
	Maximum capacity	≥225,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0
Boilers, hot water	Gas-fired	<300,000 Btu/h	87%	80% AFUE	0%/14%/86%	29
		≥300,000 Btu/h and <2,500,000 Btu/h	90%	80% Thermal Efficiency	4%/19%/78%	27
		≥2,500,000 Btu/h	83%	82% Combustion Efficiency	0%/0%/100%	3
	Oil-fired	<300,000 Btu/h	85%	80% AFUE	0%/0%/100%	14
		≥300,000 Btu/h and <2,500,000 Btu/h	84%	82% Thermal Efficiency	63%/0%/38%	8
		≥2,500,000 Btu/h	-	84% Combustion Efficiency	No observed systems	0
Boilers, steam	Gas-fired	<300,000 Btu/h	-	75% AFUE	No observed systems	0
	Gas-fired. All except natural draft.	≥300,000 Btu/h and <2,500,000 Btu/h	80%	79% Thermal Efficiency	17%/0%/83%	6
		≥2,500,000 Btu/h	82%	79% Thermal Efficiency	33%/0%/67%	3
	Gas-fired natural draft	≥300,000 Btu/h and <2,500,000 Btu/h	80%	77% Thermal Efficiency	17%/0%/83%	6

System	Subcategory	Size Category (Input)	Observed Mean Efficiency	Code of Federal Regulation Minimum Efficiency	Percentage of Systems Below/Meet/Above Code	Number of Units
		≥2,500,000 Btu/h	82%	77% Thermal Efficiency	0%/33%/67%	3
	Oil-fired	<300,000 Btu/h	-	80% AFUE	No observed systems	0
		≥300,000 Btu/h and <2,500,000 Btu/h	80%	81% Thermal Efficiency	60%/0%/40%	5
		≥2,500,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0
Water Source Heat Pumps*	68°F entering water	<135,000 Btu/h	4.7 COP	4.3 COP	4%/0%/96%	316
Ground Source Heat Pumps	50°F entering water	<135,000 Btu/h	3.2 COP	3.1 COP	39%/0%/61%	116
Split System Heat Pumps	Air source	<135,000 Btu/h	9.9 HSPF	8.2 HSPF	90% / 0% / 10%	39

* Insufficient information was collected in the field to determine the heat transfer mechanism. The most stringent efficiency standard is used.

Additional HVAC and Water Heating Measures

Table 33 summarizes several additional measures where energy efficiency potential remains in HVAC systems and water heating.

Table 33. Remaining Potential Summary for Additional HVAC and Water Heating Measures

HVAC/Water Heating Measures		Remaining Potential*			
		All Buildings	BED	EVT	VT Gas
HVAC	Implement variable speed controls for hot water circulation pumps (space heating)	66%	87%	63%	43%
	Implement VSD controls for chillers	41%	10%	89%	55%
	Automated HVAC system controls	67%			
	Utilize heat/energy recovery systems for ventilation**	83%			
Water Heating	Convert electric water heaters to natural gas or propane	50%			51%

HVAC/Water Heating Measures		Remaining Potential*			
		All Buildings	BED	EVT	VT Gas
	Replace electric water heaters with heat pump models	50%			51%
	Insulate water heating pipes	62%			45%

* No data indicate the value was not calculated for a given stratum.

** Remaining potential includes all systems not observed to be using energy or heat recovery.

Refrigeration—Remaining Potential

As shown in Table 34, considerable potential appears to remain in all refrigeration measures with the exception of installing doors on reach-in refrigerated display cases.

Table 34. Remaining Potential Summary for Refrigeration Measures

Refrigeration Measures	Remaining Potential*		
	All Buildings	BED	EVT
Upgrade non-commercial refrigerators to ENERGY STAR models**	78%	68%	80%
Implement anti-sweat heater controls***	22%	5%	26%
Install doors on reach-in refrigerated display cases	5%	28%	0%
Upgrade refrigerated display case lighting to LED[4]	48%	20%	55%
Upgrade walk-in cooler lighting to LED+	74%	65%	76%
Automated walk-in cooler lighting controls++	100%	100%	100%
Install economizers on walk-in coolers	77%	75%	78%
Upgrade walk-in cooler evaporator fan motors to ECMs	59%	97%	48%
Implement evaporator fan motor controls in walk-in cooler	57%	49%	59%
Implement floating head pressure control on refrigeration systems	100%	100%	100%
Implement heat recovery on refrigeration systems	83%	79%	83%

* Except where stated otherwise, remaining potential includes only units identified as lacking that feature or characteristic.

** Remaining potential includes all units not observed as being ENERGY STAR models, including units with unidentified values.

*** Remaining potential includes all systems not observed to have anti-sweat controls, including units unidentified values.

+ Remaining potential excludes units with no lighting or with unidentified lighting types.

++ Remaining potential includes all systems not observed to have occupancy sensor, including coolers with unidentified lighting controls.

Motors and Compressed Air—Remaining Potential

Determining remaining potential replacing inefficient motors is challenging because of difficulties capturing adequate information during site visits. Table 35 shows significant potential in VSD controls and in implementing cycling air dryers on compressed air systems.

Table 35. Remaining Potential Summary for Motor and Compressed Air Measures

Motor/Compressed Air Measures	Remaining Potential		
	All Buildings	BED	EVT
Replace motors with higher-efficiency models			
Install VSD controls on process motors	31%		
Implement cycling air dryer on compressed air systems	76%	100%	73%

New Construction and Major Renovation

Executive Summary

This section of the report documents the methodology and findings of the new construction portion of this baseline energy efficiency study. The Cadmus team collected extensive data on a sample of 48 new construction and major renovation facilities throughout the state. Sample weights were applied to extrapolate findings to represent the new construction C&I facility populations of each EEU and the state as a whole.

Study Methodology

The following paragraphs describe the methods used to design and carry out the characterization of C&I facilities in new construction in Vermont.

Data Sources

Cadmus obtained data for C&I new construction buildings in Vermont from two different data sources for two separate energy efficiency utilities (EEUs):

- A list of new construction or major renovation projects was obtained from Vermont Department of Public Safety, Division of Fire Safety (DFS) for projects completed after January 1, 2012.
    - Cadmus identified business facilities located in EVT jurisdiction and removed duplicate records for a given site, sites without valid contact information, and projects that were not considered new construction or major renovations.
- BED provided a list of commercial account meter ID numbers issued after January 1, 2012.
    - Cadmus removed duplicate records for any business location, projects without valid contact information, and projects that were not considered new construction or major renovations.

Cadmus conducted telephone surveys and site visits for C&I new construction facilities in Vermont. We used data on EEUs to draw representative samples for site visits and telephone surveys. Telephone surveys allowed the Cadmus team to obtain information on customer awareness of EEUs and customer behaviors. Primary data collection through 192 site visits provided the great majority of existing buildings data presented in this report.

Sampling Approach

Cadmus utilized the data from DFS and BED to classify the population of projects according to facility consumption and type. The following sections detail the resulting sample design and weighting approach to extrapolate the sample results to the populations of interest.

Sample Design and Weights

Cadmus used stratified random sampling by facility type and energy consumption to obtain a sample that incorporated a broad selection of Vermont facility types and consumption. Due to inconsistent data and the relatively small population available for sampling, Cadmus performed post-stratification[3] for the EEU populations of new construction C&I buildings. We post-stratified the samples by unique combinations of facility type categories and facility size bins.

To obtain population and sample sizes within strata, we first used facility size information collected from the site visits and extrapolated facility size to the remaining new construction population by proportionally allocating sites of unknown facility size within known facility types. Cadmus classified facility size into bins in Table 36, using size as a proxy for facility consumption, which we then used to stratify the populations of EVT and BED utilities.

Table 36. New Construction Facility Size Categories

Square Footage	Facility Size Bins	Facility Consumption Bins
0:2,499	Small	Low
2,500:9,999	Medium	Medium
10,000 +	Large	High

Cadmus used sample weights to produce an accurate representation of results for the population based on what we observed in the sample. We used information from the samples and their populations to calculate weights separately for EVT and BED.

Cadmus calculated sample weights at the strata level using the following equation, where h represents the stratum, w_h represents the weight in each strata, N_h is the population size in each strata, and n_h is the sample size in each strata.

$$w_h = N_h/n_h$$

Cadmus assigned each site the sample weight of the stratum it was classified in specified in Table 37.

3 Post-stratification: stratification after selection of the sample.

Table 37. New Construction Sample Weights by Post-Strata

EEU	Facility Type*	Facility Consumption	Estimated Population	Number of Completed Sites	Sample Weight**
EVT	Manufacturing	Low	1	0	N/A
	Manufacturing	Medium	3	1	3
	Manufacturing	High	7	0	N/A
	Office	Low	0	0	N/A
	Office	Medium	6	1	6
	Office	High	8	2	4
	Other	Low	23	3	7.7
	Other	Medium	65	15	4.3
	Other	High	48	14	3.4
	Retail	Low	3	0	N/A
	Retail	Medium	11	0	N/A
	Retail	High	17	4	4.3
	EVT Total		192	40	
BED	Manufacturing	Low	0	0	N/A
	Manufacturing	Medium	0	0	N/A
	Manufacturing	High	0	0	N/A
	Office	Low	2	1	2
	Office	Medium	3	2	1.5
	Office	High	1	1	1
	Other	Low	1	0	N/A
	Other	Medium	8	3	2.7
	Other	High	3	1	3
	Retail	Low	0	0	N/A
	Retail	Medium	0	0	N/A
	Retail	High	1	0	N/A
	BED Total		19	8	
State Total			211	48	

* "Other" category includes (3) Food Sales, (1) Food Service, (2) Healthcare, (1) Hospital, (4) Lodging, (2) Schools, (23) Miscellaneous.
** N/A occurs when the stratum was not sampled from.

Using site level information of weights and energy saving measures, Cadmus calculated the sample weighted energy saving measures. We identified formulas for sample weighted means, medians, counts, and proportions[4] and applied these to various energy saving measures such as counts of lightbulb type and means of total lighting hours used to obtain population level information on the measures with 85% confidence and approximately 15% precision for individual measures. Over all projects, we had a target of 90% confidence with approximately 10% precision.

[4] Sampling Techniques, 3rd Edition, Wiley Series in Probability and Mathematical Statistics – Applied by Cochran, William G., 1977

New Construction/Major Renovation Telephone Surveys

Cadmus conducted telephone surveys with 50 customers from the new construction and major renovation population. Table 38 shows the populations and distribution of completed telephone surveys within the sample areas for new construction facilities.

Table 38. New Construction Summary of Telephone Surveys by Area

Area*	Estimated Population	Number of Completed Surveys	Ratio (Completed to Population)
BED	19	8	42%
EVT	192	42	22%
Total	211	50	24%
VT Gas**		35	NA

* BED and EVT Populations are mutually exclusive. VT Gas population overlaps BED and EVT.
** Because of insufficient and unreliable population data, VT Gas population estimates are excluded from this table.

Table 39 shows that 41 of the 50 (82%) complete telephone surveys were performed on new construction buildings, while eight (16%) were on buildings that had undergone major renovations, and one (2%) was unknown .

Table 39. Summary of Telephone Surveys by New Construction or Major Renovation

Construction Category	All Sites	BED	EVT	VT Gas
New Construction	41	4	37	31
Major Renovation	8	4	4	4
Unknown	1	0	1	0
Total	50	8	42	35

New Construction/Major Renovation Site Visits

Of the 50 facilities contacted during the telephone surveys for new construction projects, Cadmus completed site visits at 48 sites across BED (eight), EVT (40), and VT Gas (35). During site visits, we collected data including facility type, cost of project, facility size (square feet), and information on numerous energy-saving measures at each site.

Table 40 shows the populations and distribution of completed site visits across the sample areas for new construction/major renovation projects.

Table 40. New Construction Summary of Site Visits by Area

Area*	Estimated Population**	Number of Completed Sites	Ratio (Completed to Population)
BED	19	8	42%
EVT	192	40	21%
Total	211	50	27%
VT Gas***		35	NA

* BED and EVT Populations are mutually exclusive. VT Gas population overlaps both BED and EVT.
** Population estimates are obtained through a list of all new construction/major renovation projects in Vermont from DFS and BED. Cadmus updated the original list to remove duplicated projects and projects that were not considered new construction or major renovations based on available information.
*** Because of insufficient and unreliable population data, VT Gas population estimates are excluded from this table.

For projects classified as new construction or major renovation, Cadmus aimed to complete as many site visits as possible. Due to a limited amount of projects and to time and budget constraints, the new construction site visited sample was still relatively small. The data obtained from DFS did not contain consistent population information on building characteristics such as facility size, facility type, or consumption information.

Cadmus researched information provided online to estimate the facility type for each new construction project. We also used data obtained through site visits to extrapolate information and combined our efforts to create a complete and accurate profile of the new construction population. Table 41 shows the distribution of the sample of site visits in comparison to targeted site visits across facility type populations. Cadmus reports the results of four individual facility types for new construction projects.

Table 41. New Construction Summary of Site Visits by Facility Type

Facility Type	Estimated Population	Number of Targeted Sites	Number of Completed Sites	Percentage of Completed to Targeted Sites
Manufacturing	11	12	1	8%
Office	20	12	7	58%
Retail	33	12	4	33%
Other*	147	12	36	300%
Total	211	48	48	100%

* ”Other” includes (3) Food Sales, (1) Food Service, (2) Healthcare, (1) Hospital, (4) Lodging, (2) Schools, (23) Miscellaneous

Table 42 shows that 40 (83%) of the 48 completed site visits were conducted on new construction projects, while 8 (17%) were conducted on major renovation projects. This table shows how these projects are distributed over the EEU areas.

Table 42. Summary of Site Visits by New Construction or Major Renovation

Construction Category	All Sites	BED	EVT	VT Gas
New Construction	40	4	36	31
Major Renovation	8	4	4	4
Total	48	40	8	35

Final Reporting Segments

Table 43 shows the distinction between new construction and major renovation projects over EEU areas.

Table 43. New Construction Final Reporting Segments by EEU

<table>
<tr><th></th><th colspan="3">Reporting Segment</th></tr>
<tr><th>Original Sample Area</th><th>BED</th><th>EVT</th><th>VT Gas</th></tr>
<tr><td>A—BED/VT Gas</td><td>x</td><td></td><td rowspan="2">x</td></tr>
<tr><td>B—EVT/VT Gas</td><td></td><td rowspan="2">x</td></tr>
<tr><td>C—EVT/Non-VT Gas</td><td></td><td></td></tr>
</table>

Data Collection Approach

All participants for site visits and telephone surveys were randomly selected according to the stratified sample design. Information on response rates are included below.

Telephone Surveys

Cadmus conducted telephone surveys with 50 Vermont businesses, which took 2-3 minutes on average to complete. Cadmus attempted to contact the person identified as the building manager or building owner to complete the telephone surveys because of their knowledge about cooling, heating, and lighting equipment at their facility. The survey focused on energy providers and customer knowledge of potential incentives to adopt energy efficiency measures related to their project.

The telephone survey designed for this study allowed the surveyor to categorize each project as one of the following:

- Existing building
- Major renovation completed in 2012 or later
- New construction completed in 2012 or later

Cadmus conducted one round of telephone surveys sampled from the population of new construction/major renovation projects in 2015. Table 44 shows the response rates from these survey efforts.

Table 44. New Construction Telephone Survey Response Rates

	Counts	Percentage of Customers Dialed
Customers Dialed*	102	100%
Reached (Total Reached)	93	91.2%
Reached (Decision-Maker)	52	51.0%
Refused	2	2.0%
Completed	50	49.0%

* Not all customers in the population were dialed because of factors including time, distance to travel, and valid contact information.

Site Visits

A team of Cadmus specialists conducted site visits for 48 of the 50 new construction/major renovation projects reached through the telephone survey. Because of the small population sizes for new construction facilities, our goal was to perform as many site visits as possible. Cadmus collected detailed inventories of energy equipment and building characteristics by inspection, including the following qualities:

- Facility size and facility type based on predetermined categories
- Building envelope information, such as insulation levels and wall and window sizes
- Complete inventories of energy equipment comprising of end uses such as lighting, refrigeration, chiller systems, boiler systems, HVAC, ventilation rates, domestic and service hot water, plug loads, and desktop and server IT, data centers, kitchens, laundry areas, renewable energy, control systems, sub-metering and building analytics, and building operations and behavior.

Data Analysis Approach

The data analysis Cadmus performed involved data visualization, descriptive statistics, quality assurance, summary of quantitative results, and result comparisons across data variables to describe C&I facilities in Vermont. All data collected went through rigorous quality assurance and quality control protocols. Data from site visits were reviewed for legitimacy and a team of analysts filled in missing data using methods of extrapolation and web searching. Cadmus used telephone survey information collected to gain a better understanding of consumer behavior and incentives.

New Construction and Major Renovation Commercial and Industrial Market Characterization

This chapter reports weighted estimates of the energy efficiency characteristics of Vermont commercial and industrial facilities in new construction and major renovations. Results are provided for the following facility populations and strata, with weighting applied as necessary to represent each population:

- Statewide population of Vermont C&I facilities
- Population of C&I facilities within each Vermont EEUs, including BED, EVT, and VT Gas
- Small, medium, and large C&I facilities, as defined in Table 36
- Four facility types—retail, office, manufacturing, and "other" (balance of commercial and industrial)

The results are based on on-site surveys conducted between September 2015 and July 2016 and, where applicable, telephone surveys conducted between December 2015 and April 2016.

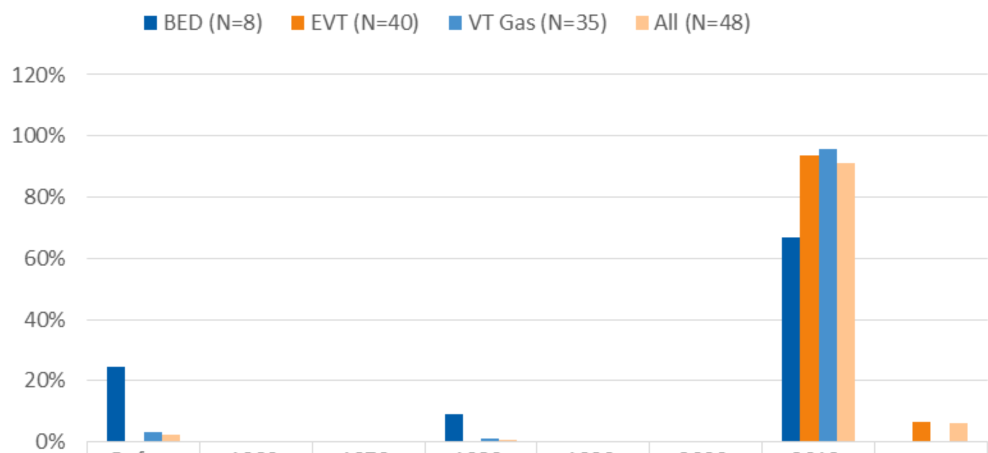
General Building Information

Surveyors collected information regarding general building characteristics such as age, size, operating schedules, and more. The following sections present the results for key building characteristics.

Facility Age

Figure 99 shows the distribution of building construction year by EEU territory. Most buildings (91%) were newly constructed facilities completed since January 1, 2012, and the remaining facilities comprised major renovations of facilities of varying ages. Most (93%) of the buildings in EVT VT Gas (96%) service territories were constructed after 2012.

Figure 99. Year of Building Construction for All Facilities (N=48)



	Before 1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-20011	2012-Present	Unknown
BED (N=8)	25%	0%	0%	9%	0%	0%	67%	0%
EVT (N=40)	0%	0%	0%	0%	0%	0%	93%	7%
VT Gas (N=35)	3%	0%	0%	1%	0%	0%	96%	0%
All (N=48)	2%	0%	0%	1%	0%	0%	91%	6%

Facility Size

Approximately 25% of Vermont’s new and renovated business facilities are between 10,000 and 20,000 sq ft in size, and 58% are smaller than 10,000 sq ft. Approximately 7% of facilities are larger than 50,000 sq ft, as shown in Figure 100.

Figure 100. Total Square Footage for All Facilities (N=48)

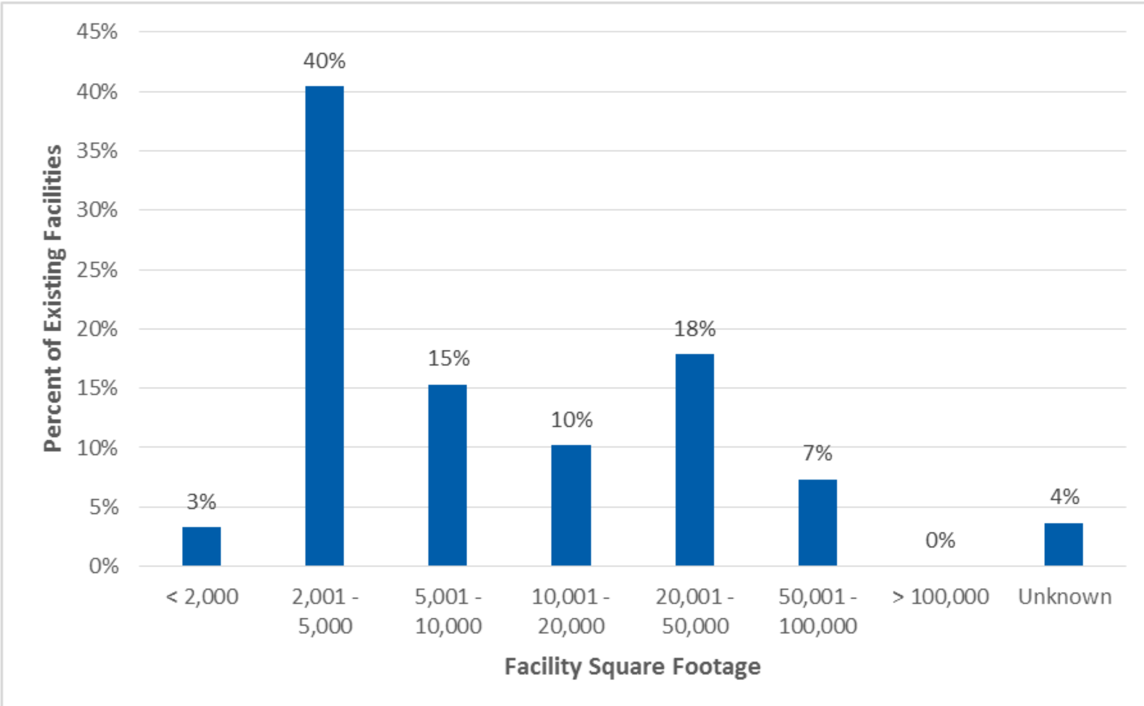


Table 45 shows the proportion of the total sites visited by square footage and EEU. The mean size across all new construction buildings is approximately 21,500 sq ft; the median size is approximately 5,300 sq ft. The distribution by size varies considerably by EEU. BED has the highest proportion of buildings under 2,000 sq ft (36%) and VT Gas has the highest proportion of buildings in the 50,001 to 100,000 sq ft range (10%). EVT has approximately the same proportion of buildings in the 5,001 to 10,000 sq ft range (16%), and the 20,001 to 50,000 sq ft range (18%).

The business facilities visited in the sample for this study tended to be about 25% smaller than those visited for the 2011 study. This is true for the EVT service territory, as well as the state as a whole. The BED sites visited for this study were approximately 70% smaller than the sites visited for the 2011 study, and the average facility size for VT Gas sites is approximately the same, though the distribution of facilities by size has changed.

Table 45. Facility Distribution by Square Footage and EEU

Building Square Footage	BED (N=8)	EVT (N=40)	VT Gas (N=35)	All (N=48)
< 2,000	36%	0%	5%	3%
2,001–5,000	25%	43%	42%	41%
5,001–10,000	16%	16%	15%	16%
10,001–20,000	6%	11%	6%	10%
20,001–50,000	18%	18%	20%	18%
50,001–100,000	0%	8%	10%	7%
> 100,000	0%	4%	3%	4%

Building Square Footage	BED (N=8)	EVT (N=40)	VT Gas (N=35)	All (N=48)
Unknown	0%	0%	0%	0%
Total**	100%	100%	100%	100%
Mean*	7,056	22,985	22,947	21,537
Median*	2,500	6,800	5,200	5,342

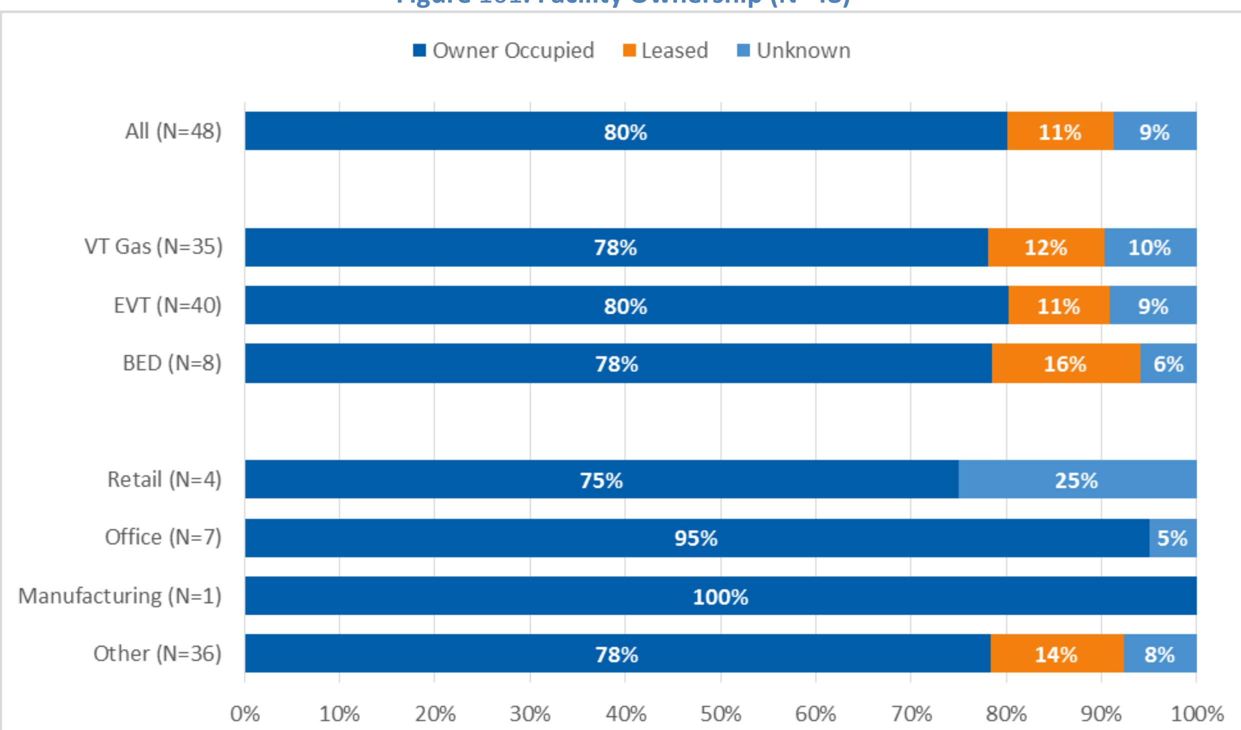
* Values shown are weighted counts, not weighted area.
** Totals may not add to 100% because of rounding.

Facility Ownership

The majority of C&I customers in new construction buildings (80%) own their buildings. Figure **101** shows that the BED sites had the smallest proportion of sites occupied by the owner (78%).

Statewide, the proportion of facilities that are owner-occupied is approximately the same as in 2011, at 80% (76% in 2011). Between 2011 and 2016, the rate of owner occupancy appears to have increased by roughly 20% for both VT Gas and BED, but to have remained the same for EVT.

Figure 101. Facility Ownership (N=48)



Business Information

The average (mean) number of full-time equivalent employees in Vermont's new construction facilities is 19, and the median number of full-time employees is five, as shown in Table 46. This represents a decrease of roughly 33% in the mean number of employees, and roughly a 45% decrease in the median number of employees. This finding aligns well with the findings in Table 45, which found that the facilities visited in the 2016 study tended to be smaller than those visited for the 2011 study.

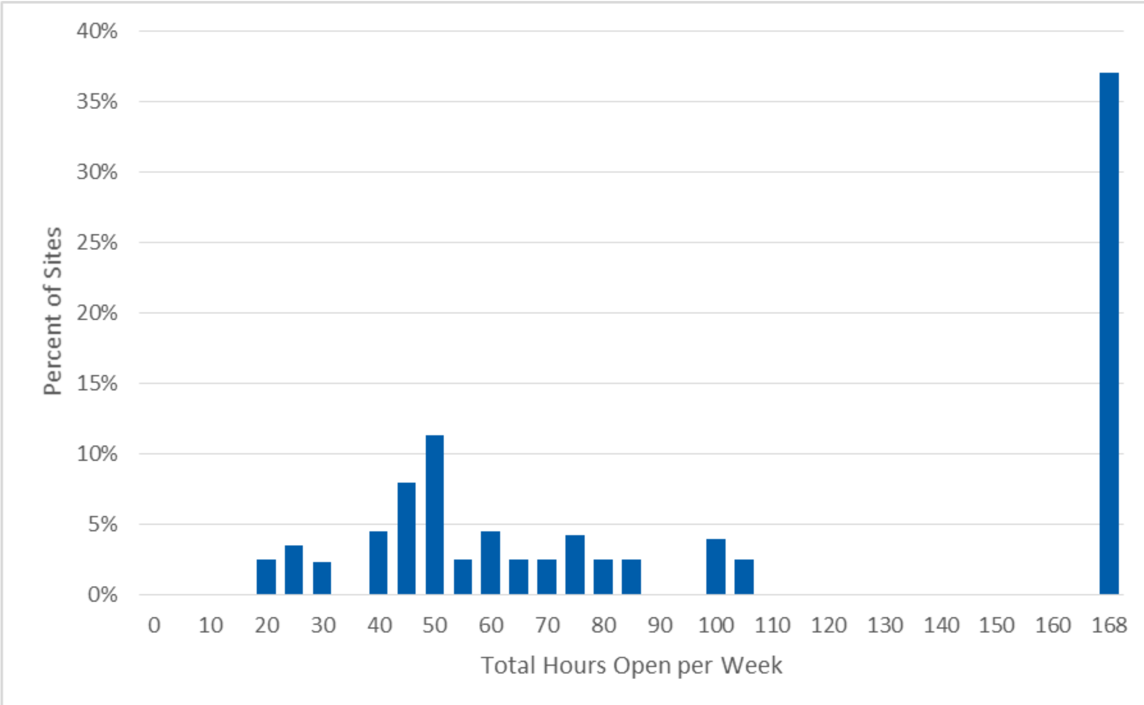
Table 46. Full-Time Equivalent Employees (N=32)

Category	Mean FTEs	Median FTEs
All Buildings (N=32)	19	5
EEU		
BED (N=5)	3	5
EVT (N=27)	20	6
VT Gas (N=23)	24	5
Facility Size		
High (N=14)	42	8
Medium (N=14)	3	5
Low (N=4)	1	2
Facility Type		
Retail (N=3)	16	27
Office (N=4)	24	5
Manufacturing (N=1)	7	7
Other (N=24)	19	5

Business Hours

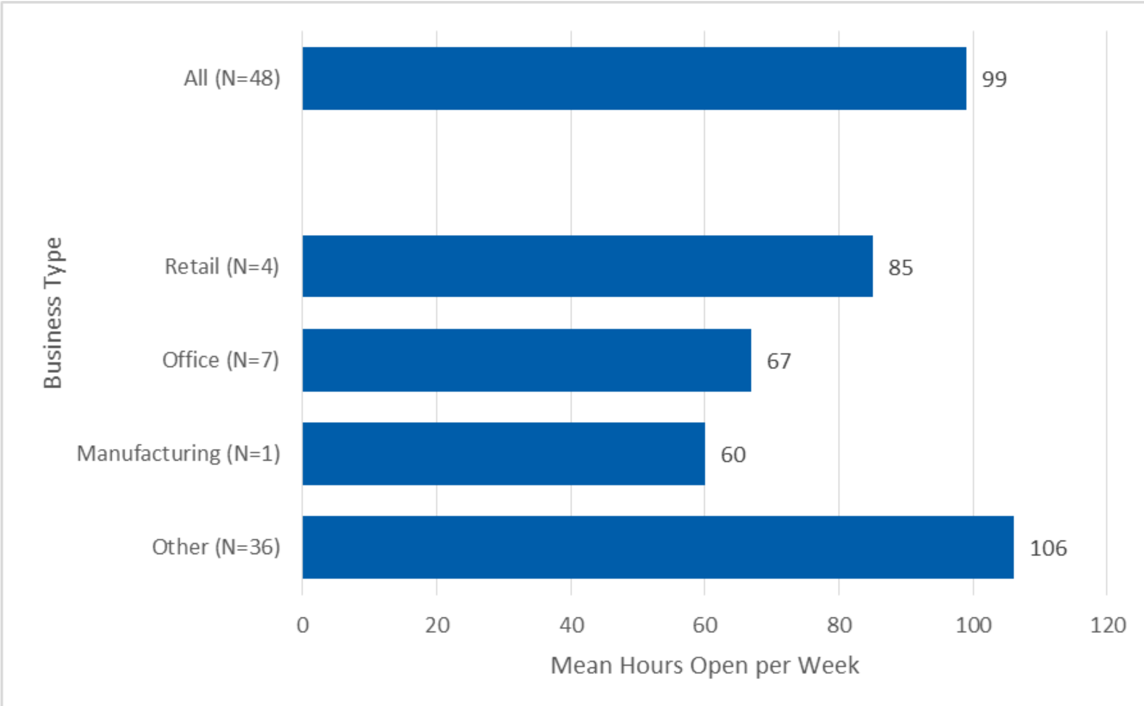
Figure 102 shows the distribution of open hours for new construction C&I facilities in Vermont. Of the sites visited in 2016, 37% are open 24/7. This is nearly triple the value found in 2011 (14%). Another 45% of the sites visited are open between 40 and 85 hours per week.

Figure 102. Distribution of Weekly Open Hours for All Facilities (N=48)



Vermont new construction businesses are open an average of 99 hours per week, as shown in Figure 103. Retail and the balance of commercial and industrial facility types have the highest weekly operating hours at 85 and 106 hours, respectively, while manufacturing and office buildings are the lowest, at 60 and 67 hours per week. Across the state, the 2016 sites tended to be open about 35% longer each week than the 2011 sites.

Figure 103. Mean Open Hours per Week by Facility Type (N=48)



EEU Market Characterization—General Building Information

Table 47 summarizes general building characteristics for facilities in the jurisdiction of each Vermont EEU.

Table 47. EEU Market Characterization—General Building Information

Characteristic	BED	EVT	VT Gas
Facility Age	• Approximately two-thirds (67%) of the buildings were built since 2012. • This jurisdiction showed the largest proportion (25%) of new construction facilities involving major renovations within buildings constructed before 1959.	• Nearly all of the buildings were built since 2012 (93%)	• Nearly all of the buildings were built since 2012 (96%)
Building Size	• The mean square footage for facilities visited for 2016 was roughly 7,000 sq ft. This is a 70% reduction from 2011 (23,000 sq ft). • More than 50% of the facilities visited occupy less than 5,000 sq ft.	• Overall, the mean facility size is roughly 25% smaller than in 2011. • Approximately 43% of all sites visited occupy less than 5,000 sq ft.	• Overall, the mean facility size is roughly the same as in 2011. • Nearly half 45% of facilities occupy less than 5,000 sq ft.
Facility Ownership	• Facility ownership has increased since 2011 (78% vs. 50%).	• Facility ownership is largely unchanged since 2011.	• Facility ownership has increased since 2011 (78% vs. 54%).
Business Information	• Mean full-time employees are lower than for the state as a whole at three employees per site.	• Mean and medium employees are approximately the same as for the state as a whole.	• A mean of 24 full-time employees per facility is higher than the statewide average.

Building Envelope

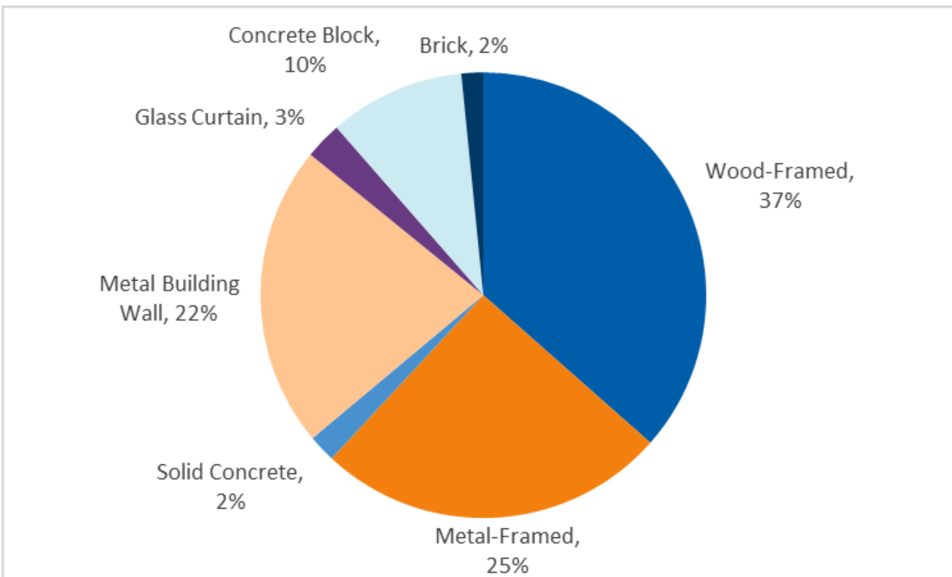
Cadmus gathered building envelope information during the on-site inspection process. Details about wall, roof, and floor construction and insulation as well as windows were gathered through observation where practical and from building plans where available and accurate. In facilities that had undergone major renovation, surveyors recorded information only for the areas that had been affected by the renovation. The following sections present the results for each major envelope component.

Exterior Walls

Exterior Wall Construction Types

Wood-framed walls comprise the largest share of exterior wall construction types by number of observations (36%) followed by metal-framed (25%) and metal building walls (22%). Approximately 14% of exterior walls can be classified as mass walls: concrete block accounts for 10% of all exterior walls while brick and solid concrete walls each account for 2%. Only 3% of new construction facilities are classified as glass curtain buildings. Figure 104 shows the distribution for all new construction facilities.

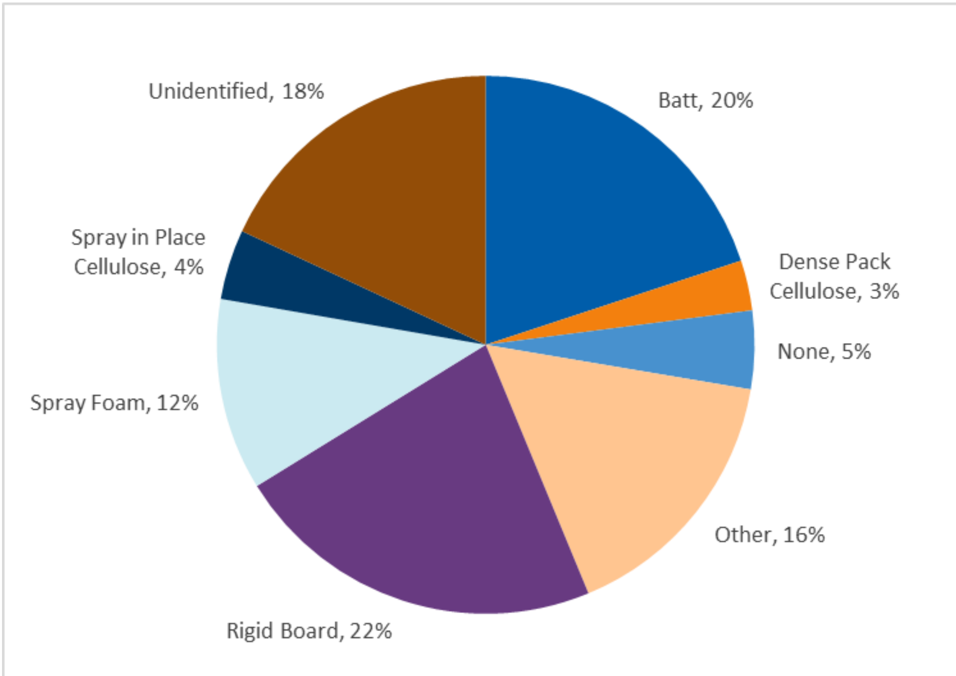
Figure 104. Frequency of Exterior Wall Construction Types for All Facilities (N=43)



Exterior Wall Insulation Types

Surveyors inspected exterior walls, consulted with knowledgeable on-site staff, and/or reviewed as-built plans to determine the insulation types used in the walls. Figure 105 shows that 20% observations of exterior walls have batt insulation, 5% of all walls had no insulation, and that surveyors were not able to identify insulation in approximately 18% of the walls in this study. In 2011, approximately 18% of walls were uninsulated as compared to the 5% of walls in the 2016 study. Uninsulated walls in the sample of visited buildings include glass curtain walls and the concrete block walls of an unconditioned pump house.

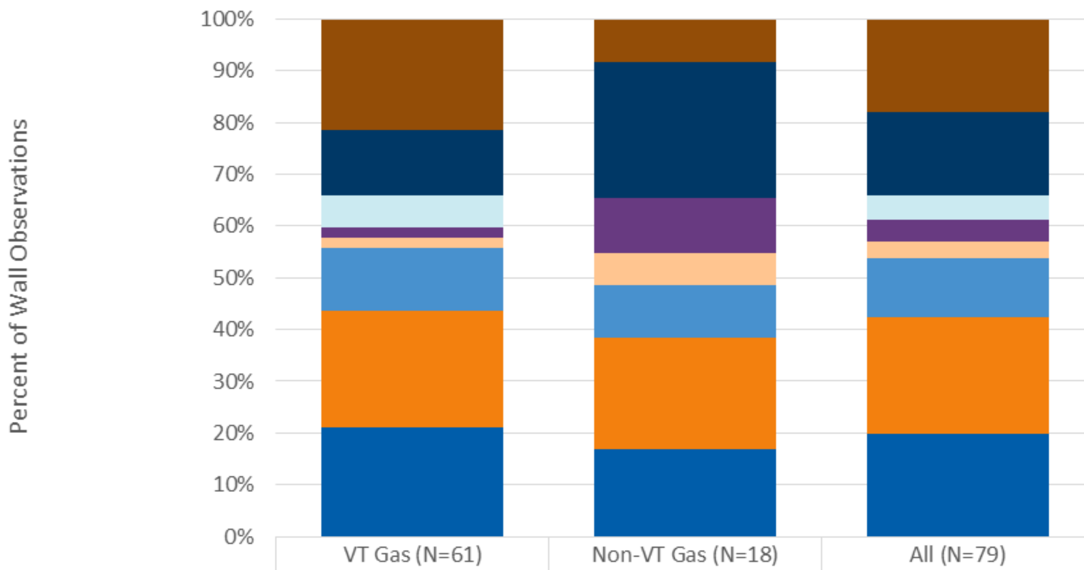
Figure 105. Frequency of Wall Insulation Types (N=79)*



* This figure shows percentage by observations, not area, and represents a combination of cavity and continuous insulation.

Figure 106 shows the wall insulation types for facilities in VT Gas territory versus the rest of the state. The proportion of rigid board, batt, and spray foam insulation types is similar between VT Gas and non-VT Gas areas. VT Gas customers installed very little dense-pack cellulose, though this insulation type accounts for approximately 6% of insulation types in the remainder of the state. VT Gas customers also had a higher incidence of walls without insulation than the rest of the state, which is consistent with the 2011 findings.

Figure 106. Distribution of Wall Insulation Type—VT Gas vs. Non-VT Gas (N=79)*



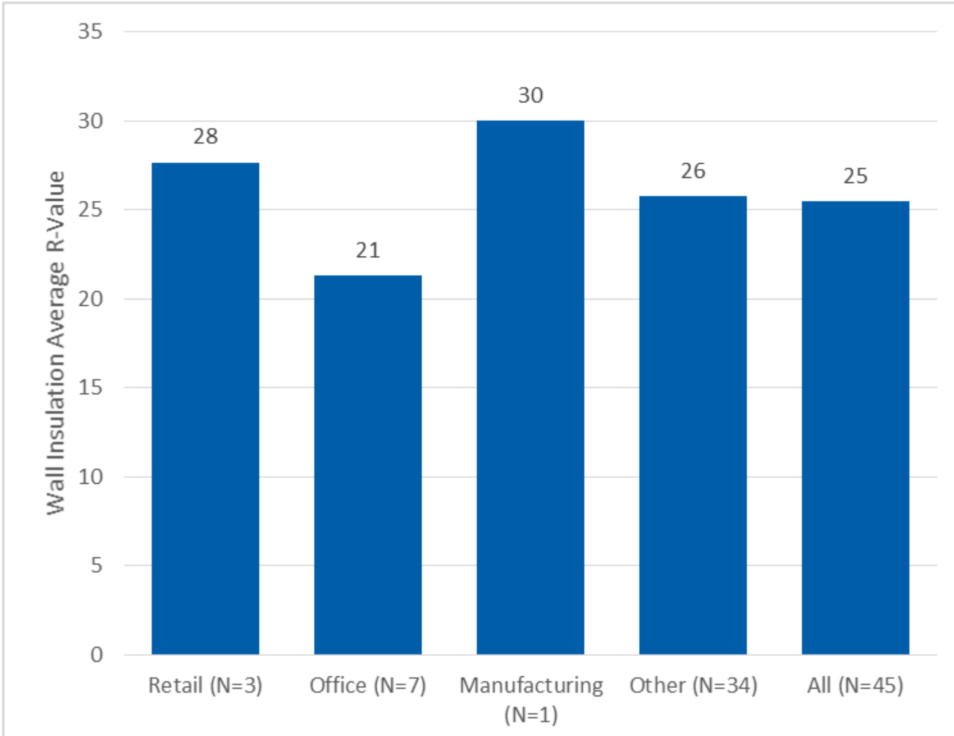
	VT Gas (N=61)	Non-VT Gas (N=18)	All (N=79)
Unidentified	21%	8%	18%
Other	13%	26%	16%
None	6%	0%	5%
Spray in Place Cellulose	2%	11%	4%
Dense Pack Cellulose	2%	6%	3%
Spray Foam	12%	10%	12%
Rigid Board	23%	22%	22%
Batt	21%	17%	20%

* This figure represents a combination of cavity and continuous insulation.

Exterior Wall Insulation R-Values

The average wall insulation R-value for all new construction facilities is R-25, as shown in Figure 107. Office facilities have the lowest average R-value at R-21. The single manufacturing facility visited had an R-value of R-30 and the balance of the commercial and industrial sites had an average R-value of R-26.

Figure 107. Wall Insulation R-Values by Facility Type (N=45)*

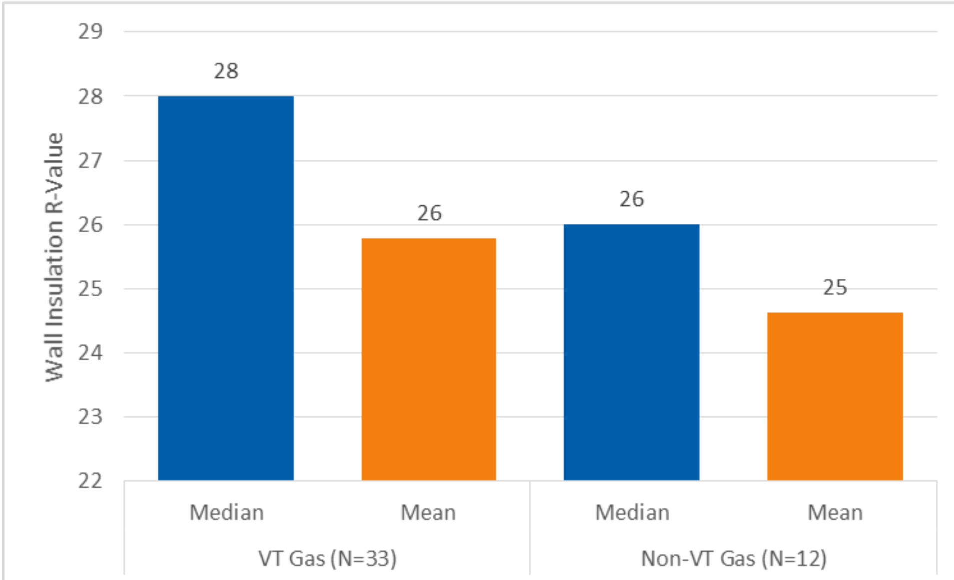


* This figure represents a combination of cavity and continuous insulation.

Mean and median exterior wall R-values in VT Gas service territory are R-26 and R-28, respectively, as shown in Figure 108. The average R-value of facilities in VT Gas service territory are similar to facilities in non-VT Gas service territory, which had a median value of R-26 and a mean value of R-25. These values represent an increase from 2011 in both territories.

The new construction exterior wall R-values generally appear to meet or exceed prevailing energy code requirements at the time of the study (2015 CBES). Code-required cavity insulation R-values vary between R-13.3 for mass walls and R-23 (cavity insulation) for wood-framed walls.

Figure 108. Wall Insulation R-Values by VT Gas vs. Non-VT Gas (N=45)*



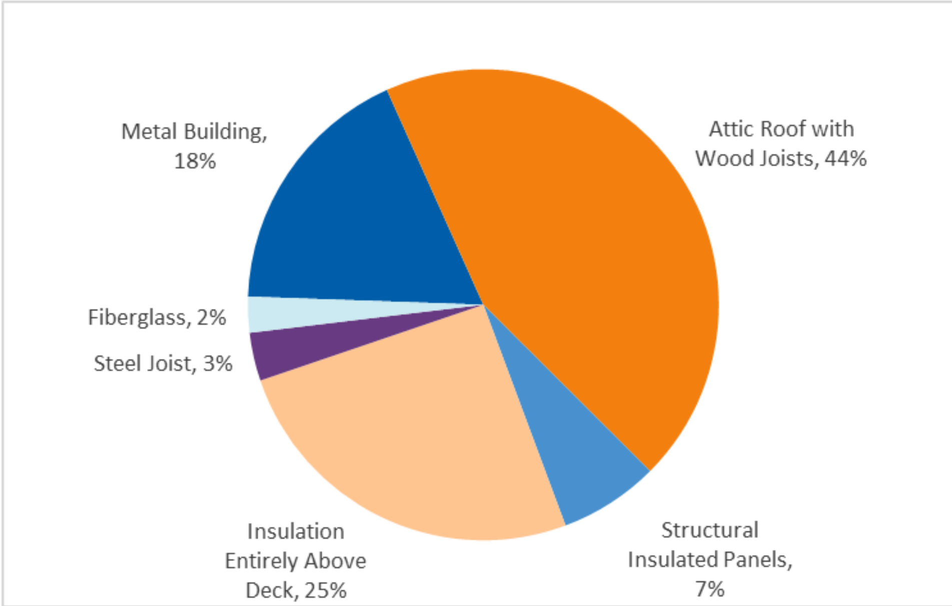
* This figure represents a combination of cavity and continuous insulation.

Roofs

Roof Construction Type

Approximately half (44%) of the new construction facilities in Vermont have a roof construction type that falls into the energy code category of attic as shown in Figure 109. Approximately 25% of all facilities have roofs with insulation entirely above deck, while 18% have metal building roofs. These findings are consistent with the 2011 study.

Figure 109. Frequency of Roof Construction Types for All Facilities (N=44)*

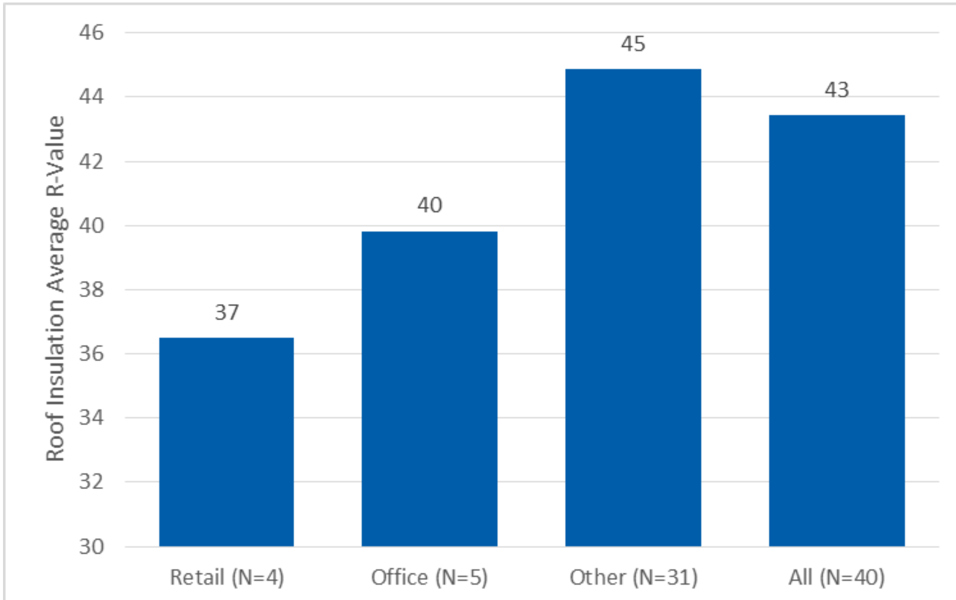


* This figure represents a combination of cavity and continuous insulation.

Roof Insulation R-Values

The average R-value for all new construction roof insulation is R-43, as shown in Figure 110. Both retail and office facilities have roof R-values slightly lower than the statewide average, with values of R-37 and R-40, respectively. Insulation R-value prescribed by the 2015 CBES range between R-30 continuous insulation for roofs classified as insulation entirely above deck and R-49 for the attic and "other" category).

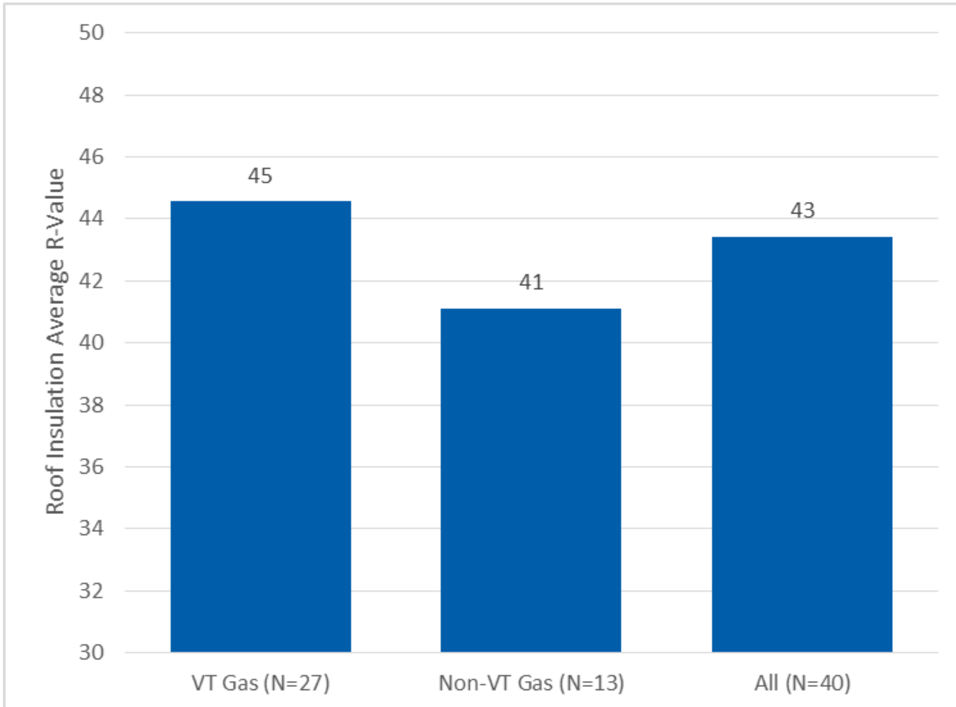
Figure 110. Roof Insulation R-Values by Facility Type (N=40)*



* This figure represents a combination of cavity and continuous insulation.

The roof insulation R-values for facilities in VT Gas territory are higher than in facilities outside of the VT Gas territory, with R-values of R-45 and R-41, respectively. Figure 111 shows the comparison of roof insulation R-values in VT Gas territory versus the rest of the state.

Figure 111. Roof Insulation R-Values—VT Gas vs. Non-VT Gas (N=40)*

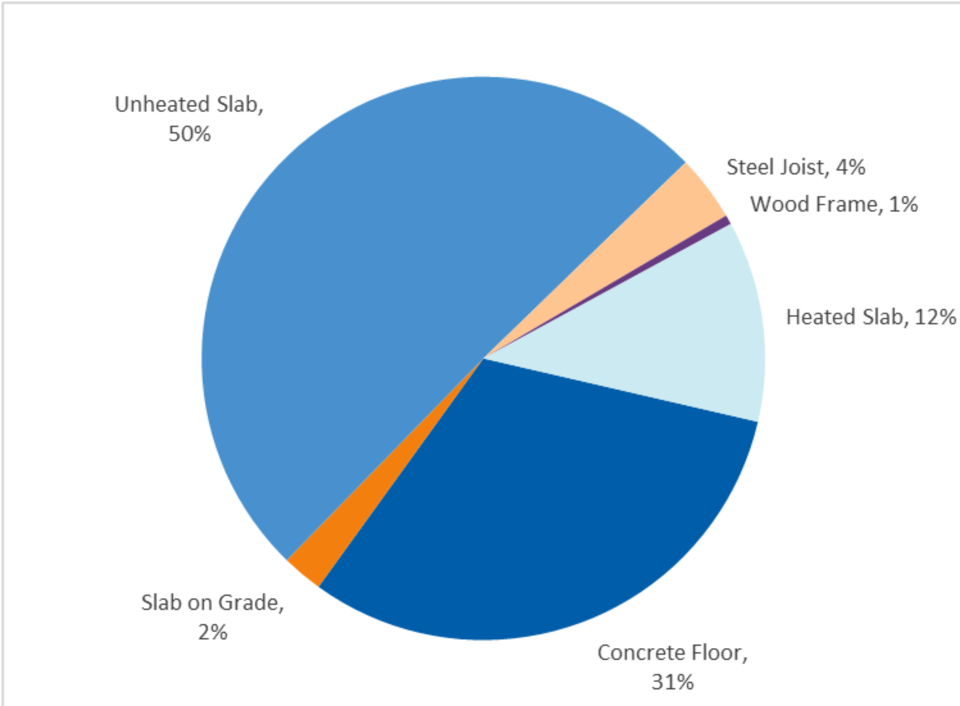


* This figure represents a combination of cavity and continuous insulation.

Floor

Half (50%) floors in Vermont's new construction buildings are unheated slabs. Heated slabs make up a small proportion of the floor construction types in the 2016 study, appearing in 12% of buildings. Figure 112 shows the distribution for all new construction buildings.

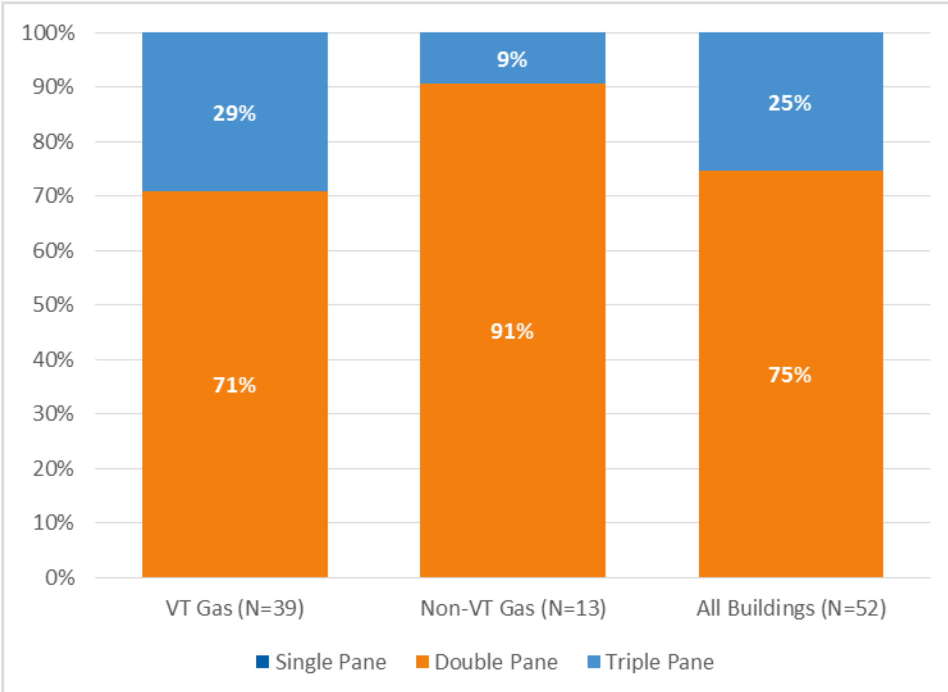
Figure 112. Frequency of Floor Construction Type (N=47)



Windows/Fenestration

Double-pane windows are the most common windows found in new construction buildings, as shown in Figure 113. Statewide, double-pane windows account for 75% of all windows. In the VT Gas service territory, the area of double-pane windows represent approximately two-thirds (71%) of all window area, and triple-pane window represent the remaining 29%. Outside of the VT Gas territory, triple-pane windows account for only 9% of windows. No single-pane windows were identified in the 2016 sample.

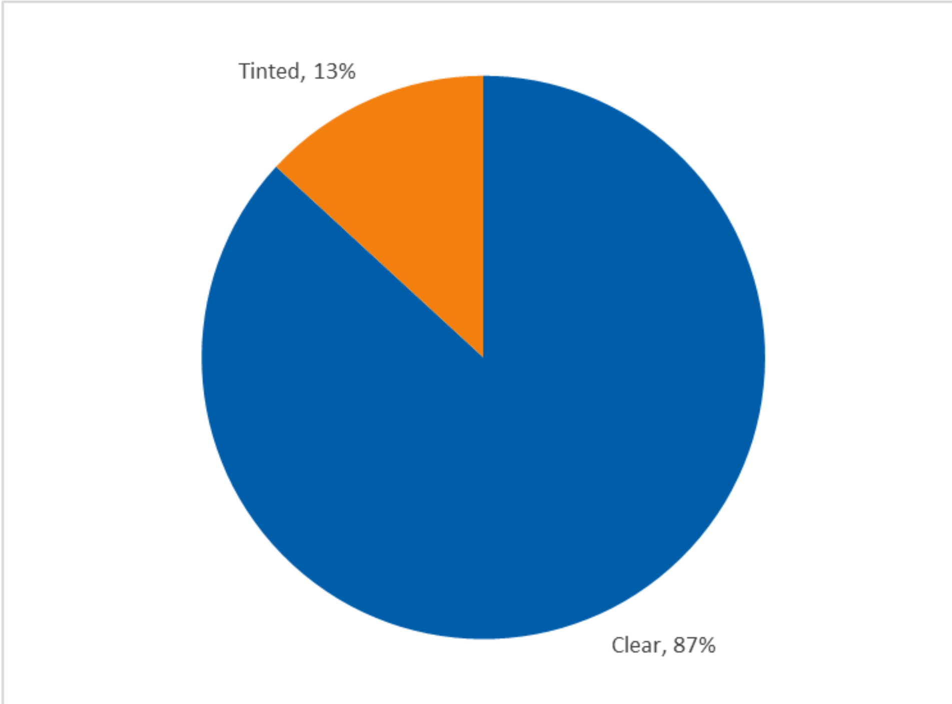
Figure 113. Area of Window Panes—VT Gas vs. Non-VT Gas (N=52)*



*Presented as percentage area of window panes

During the 2016 study, Cadmus identified two primary glazing types in new construction buildings: tinted and clear. As shown in Figure 114, clear windows comprise the majority (87%) and tinted windows make up the balance (13%).

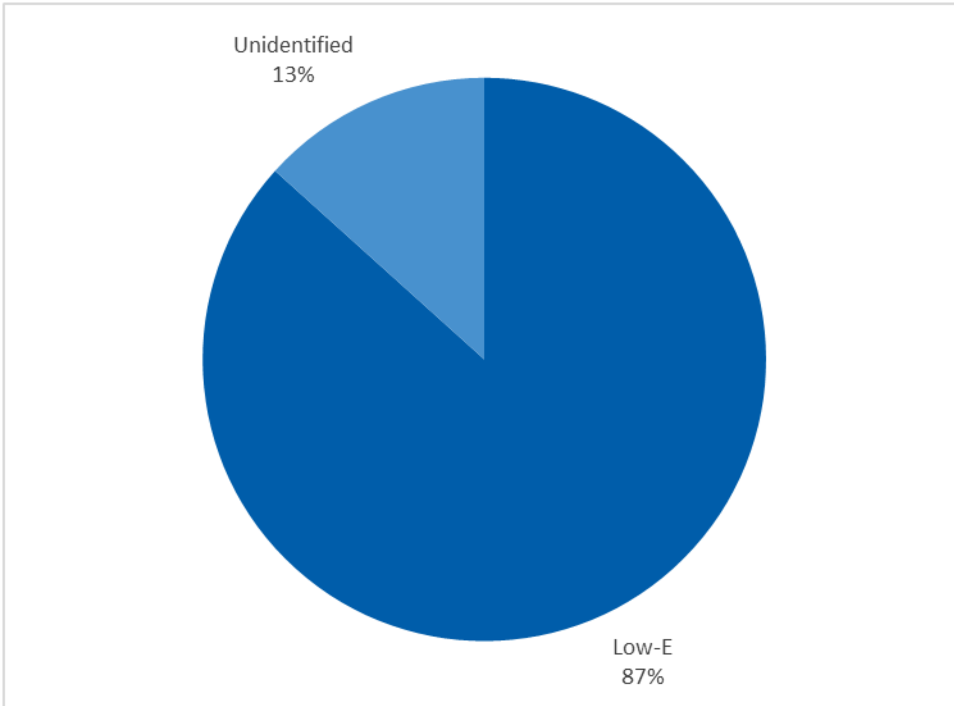
Figure 114. Distribution of Glazing Types (N=52)*



*Presented as percentage area of window panes

Additionally, Figure 115 shows that approximately 87% of the windows in new construction buildings have low-e coatings.

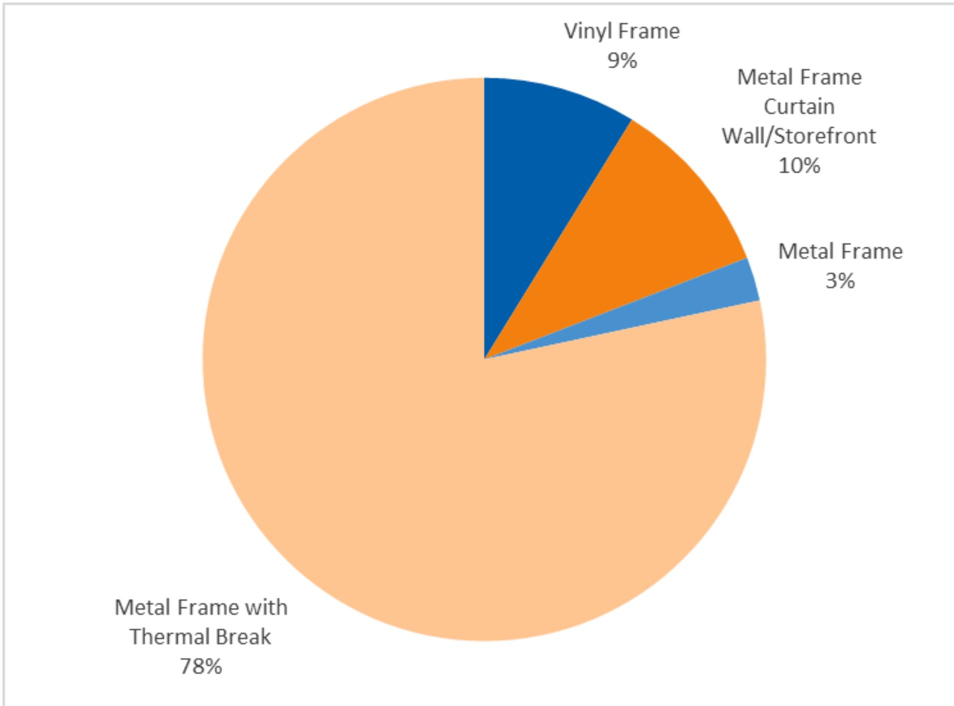
Figure 115. Distribution of Glazing Features (N=52)*



* Presented as percentage area of window panes

The majority (91%) of windows in new construction buildings are metal framed; 78% of all windows are metal framed with a thermal break. The balance of the windows in the new construction sector are vinyl framed. Figure 116 shows the distribution of window framing types for all buildings.

Figure 116. Distribution of Window Framing Types (N=52)*



*Presented as percentage area of window panes

EEU Market Characterization—Building Envelope

Table 48 summarizes building envelope characteristics for VT Gas versus Non-VT Gas service territories.

Table 48. EEU Market Characterization—Building Envelope (VT Gas vs. Non-VT Gas)

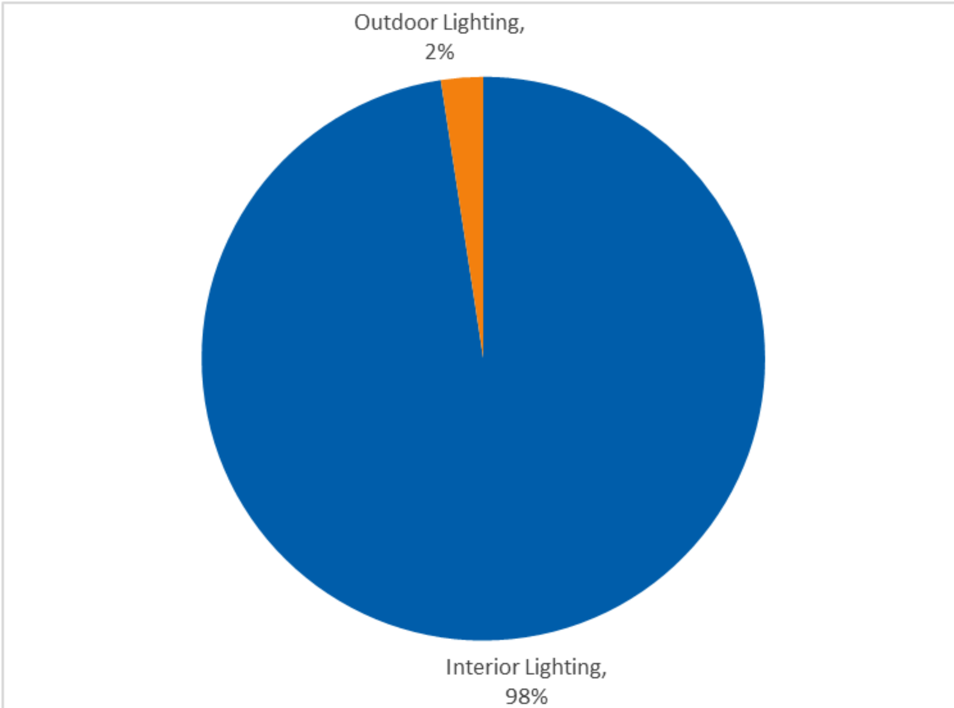
Measure/Characteristic	VT Gas	Non-VT Gas
Exterior Walls	• The share of facilities in the VT Gas territory that are uninsulated is higher than the statewide average (6% vs. 5%). Uninsulated wall types include glass curtain and concrete block. • Facilities in VT Gas territory are more likely to have cavity insulation than buildings in non-VT Gas territory. • The estimated average insulation R-value of buildings in VT Gas territory is approximately the	• No uninsulated walls were identified in facilities outside of the VT Gas service territory. • The most common insulation types are rigid board (22%), batt insulation (17%), and "other" insulation types (26%). • The estimated average wall insulation R-value for facilities that are not in VT Gas territory is approximately R-25.

Measure/Characteristic	VT Gas	Non-VT Gas
	same as in non-VT Gas territory (R-26 vs. R-25)	
Roofs	• The estimated average roof R-value for buildings in the VT Gas territory is approximately R-45, which is higher than the statewide average of R-43.	• The estimated average roof R-value for buildings in the VT Gas territory is approximately R-41. This is slightly lower than the statewide average of R-43.
Windows	• Facilities in the VT Gas territory have the highest incidence of triple-pane windows in the state (29%) by window area. The balance consists entirely of double-pane windows (71%).	• Double-pane windows are the predominant window pane type in non-VT Gas territory, accounting for 91% of the windows, by area. The remaining 9% are triple-pane windows.

Lighting

The majority of lighting in Vermont's commercial and industrial buildings is located indoors. As shown Figure 117, the 2016 study estimates that 98% of all lighting (by wattage) is located indoors, with the balance (2%) located outdoors. In contrast, the 2011 study found that 81% of lighting in sampled facilities was located indoors, with 19% located outdoors.

Figure 117. Distribution of Indoor and Outdoor Lighting Wattage (N=48)*



*Presented as percentage of installed wattage

Interior Lighting

Interior Lighting—Lamp Type

In the 2016 sample, the lamp types with the highest proportions of both bulb counts and installed wattage were T8s, light emitting diodes (LEDs), and Super T8s. In the weighted results shown in Figure 118, the T8 and Super T8 lamps represent 51% and 13% of installed bulbs, respectively, and 42% and 10% of the installed wattage. LEDs account for an estimated 20% of all installed bulbs and 31% of the installed wattage in new construction facilities.

This represents a significant shift from 2011, when LEDs accounted for only 5% of all installed bulbs in sampled facilities. The 2016 sample also includes a much higher percentage of high-efficacy lighting than the 2011 sample. This shift is likely a result of the availability of LED replacements for traditional low-efficacy lamp technologies such as metal halide. Though these LED fixtures can draw hundreds of watts each, they still represent significant power savings over traditional technologies. As in 2011, no T12 lamps were identified during the site visits.

Figure 118. Distribution of Indoor Lamp Types—All Facilities (N=48)

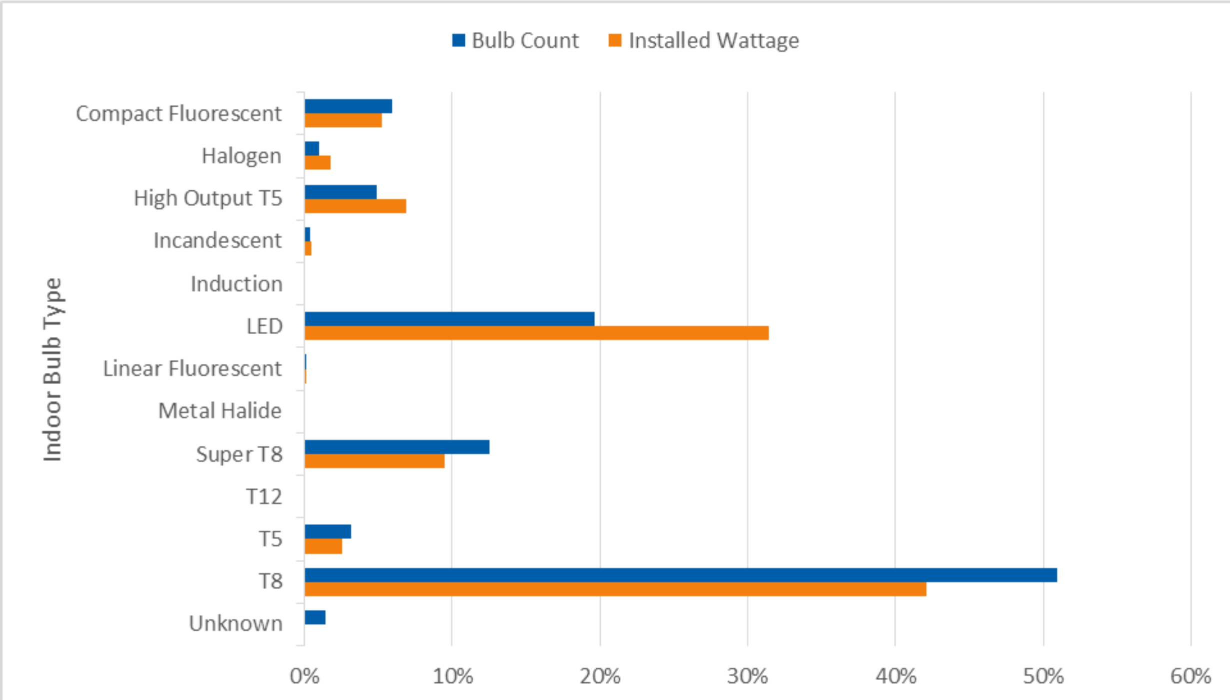
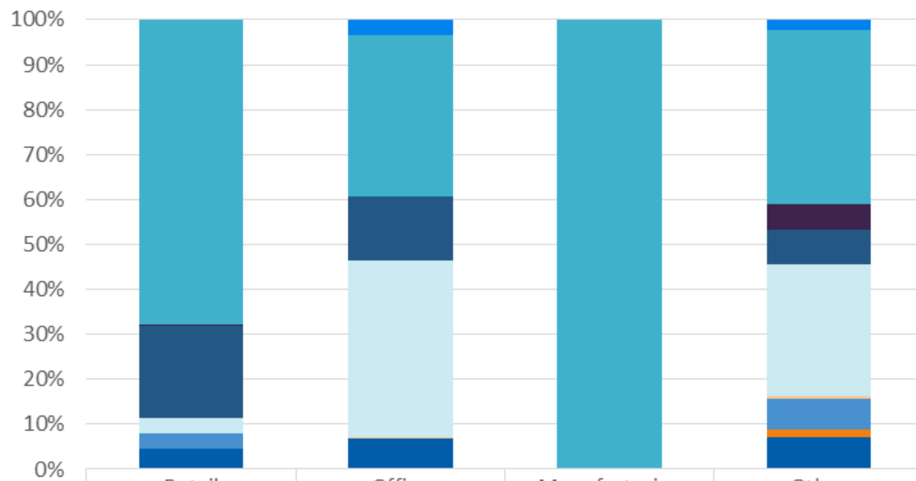


Figure 119 shows the distribution of indoor lamp types by facility type, with weighted distribution shown by percentage of lamp count.

Figure 119. Distribution of Indoor Lamp Types by Facility Type (N=48)*



	Retail (N=4)	Office (N=7)	Manufacturing (N=1)	Other (N=36)
Unknown	0%	4%	0%	2%
T8	68%	36%	100%	39%
T5	0%	0%	0%	6%
T12	0%	0%	0%	0%
Super T8	20%	14%	0%	8%
Metal Halide	0%	0%	0%	0%
Linear Fluorescent	0%	0%	0%	0%
LED	3%	39%	0%	29%
Induction	0%	0%	0%	0%
Incandescent	0%	0%	0%	1%
High Output T5	3%	0%	0%	7%
Halogen	0%	0%	0%	2%
Compact Fluorescent	5%	7%	0%	7%

*Presented by percentage of lamp count

Table 49 shows that Super T8 and T8 lighting accounts for an estimated 18% and 71%, respectively, of all linear fluorescent lighting, while T5 and High Output T5 lamps account for the remaining 11%. No T12 lamps were identified during new construction site visits for this study.

Table 49. Distribution of Linear Fluorescent Lighting*

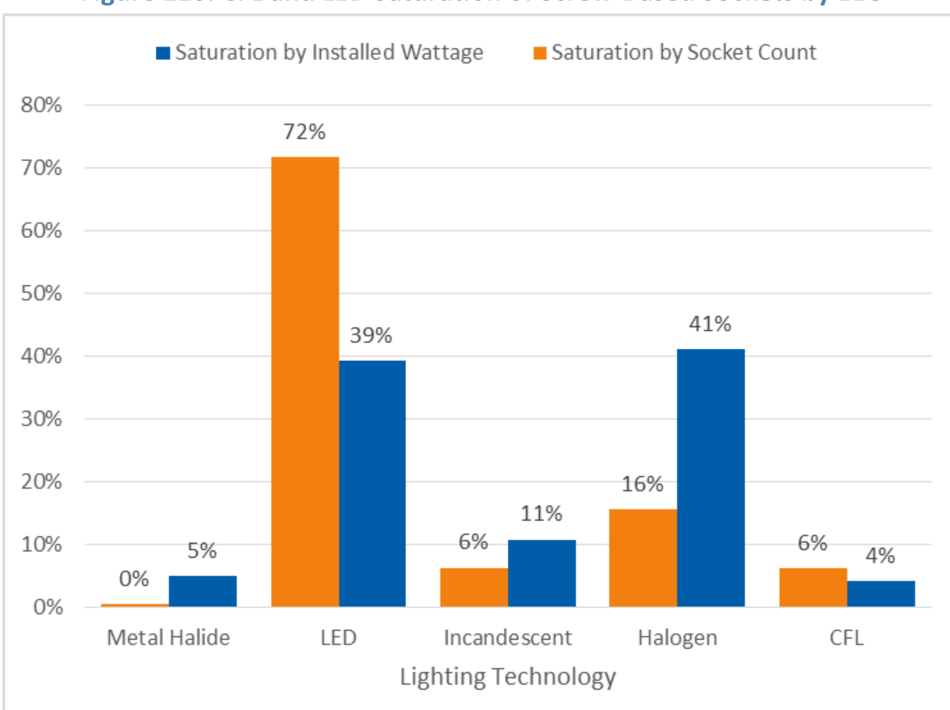
Category	Super T8	T8	High Output T5	T5	T12
All (N=48)	18%	71%	7%	4%	0%
EEU					
BED (N=8)	21%	79%	0%	0%	0%
EVT (N=40)	18%	71%	7%	5%	0%

Category	Super T8	T8	High Output T5	T5	T12
VT Gas (N=35)	21%	63%	10%	6%	0%
Facility Size					
High (N=22)	20%	67%	7%	6%	0%
Medium (N=20)	12%	80%	7%	1%	0%
Low (N=6)	5%	95%	0%	0%	0%
Facility Type					
Retail (N=4)	22%	74%	4%	0%	0%
Office (N=7)	29%	71%	0%	0%	0%
Manufacturing (N=1)	0%	100%	0%	0%	0%
Other (N=36)	13%	66%	11%	10%	0%

* Presented by percentage of lamp count

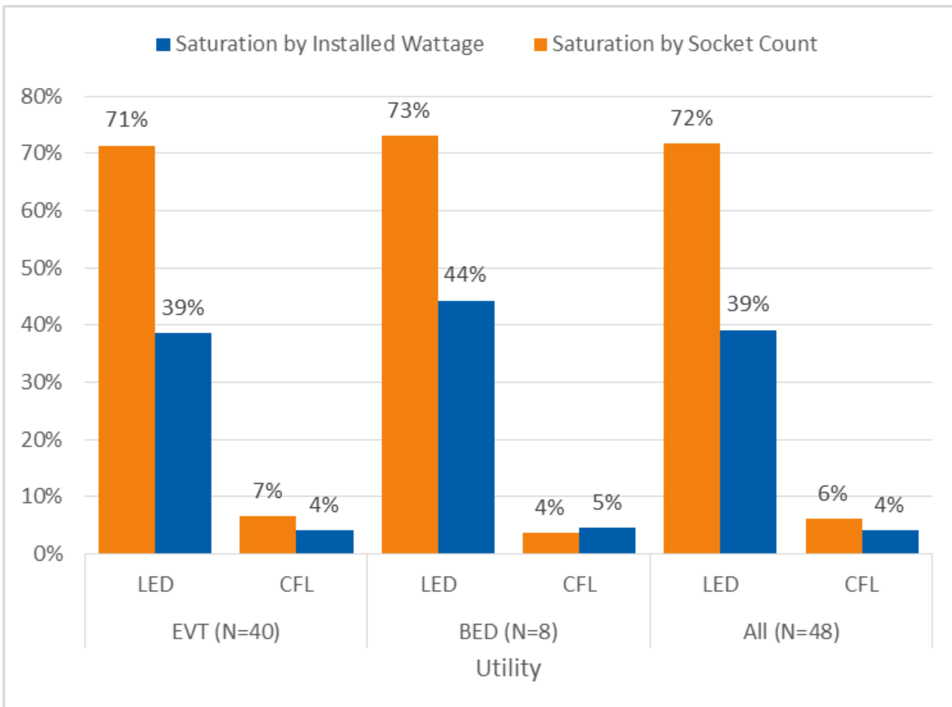
By both socket count and installed wattage, LEDs represent a significant portion of the screw-based lamps in Vermont's new construction building stock. LEDs occupy approximately 72% of screw-based sockets and 39% of the installed wattage. Halogen lamps are the second-most common lighting technology, representing 16% of sockets and 41% of the installed wattage. Compact fluorescent and incandescent lamps each represent approximately 6% of the screw-based sockets, though incandescent lamps represent a significantly larger percentage of total wattage (11% versus 4%, respectively).

Figure 120. CFL and LED Saturation of Screw-Based Sockets by EEU



By socket count, LED lamps represent a significant portion of screw-based lamps[5] in both EVT (71%) and BED (73%) service territories. The saturation of CFLs statewide and in EVT service territory are significantly lower than for LEDs. Statewide, CFLs represent approximately 6% of installed lamp wattage in screw-based sockets.

Figure 121. CFL and LED Saturation of Screw-Based Sockets by EEU



Interior Lighting—Control Types

Weighted results estimate motion and occupancy sensors as the lighting control method found at the largest number of facilities (86%). Manual switches rank a close second with 80% penetration. These values varied considerably from utility to utility. Weighted results estimate that manual switches are present in 98% of BED facilities and only 79% of EVT facilities. Timeclock and energy management system (EMS) lighting controls were used more widely in the EVT territory (an estimated 18% of

[5] Socket type was not explicitly collected during the on-site visits. Instead, fixture and lamp type were used to approximate the screw-based lamp population by excluding lamps and fixtures which do not typically have screw-based options.

facilities) than the BED territory (2%). Dimmers were more widely used in BED facilities (28%) than EVT facilities (7%).

Manual switches have a penetration of approximately 100% in retail, office, and manufacturing facilities but are found in only 67% of the balance of commercial facilities. Motion and occupancy sensors were identified in retail facilities (77%) and office buildings (99%). These two facility types also account for all of the timeclock and EMS lighting control systems in the 2016 study.

Table 50. Penetration of Indoor Lighting Control Types*

Category	Manual Switch	Motion/Occupancy Sensor	Always On (24/7)	Timeclock/EMS	Dimmer	Daylighting Controls
All (N=48)	80%	84%	0%	18%	7%	14%
EEU						
BED (N=8)	98%	68%	0%	2%	28%	0%
EVT (N=40)	79%	85%	0%	18%	7%	15%
VT Gas (N=35)	73%	79%	0%	12%	6%	9%
Facility Size						
High (N=22)	78%	88%	0%	22%	5%	15%
Medium (N=20)	85%	75%	0%	0%	18%	14%
Low (N=6)	82%	49%	0%	2%	0%	0%
Facility Type						
Retail (N=4)	100%	77%	0%	52%	0%	0%
Office (N=7)	99%	99%	0%	42%	0%	0%
Manufacturing (N=1)	100%	0%	0%	0%	0%	0%
Other (N=36)	67%	91%	0%	0%	11%	23%

* Here, penetration represents the percentage of facilities with this type of control somewhere, but the percentage is by wattage. If the control type was found at a facility, the entirety of that facility's lighting load was included in the numerator for this calculation.

Table 51 shows the saturation of indoor lighting control types only for linear fluorescent lighting. The most prevalent control method are manual switches (58%), followed by motion and occupancy sensors (25%). Timeclock and EMS controls account for 5% of the installed wattage, and daylighting controls account for another 1% of the installed wattage.

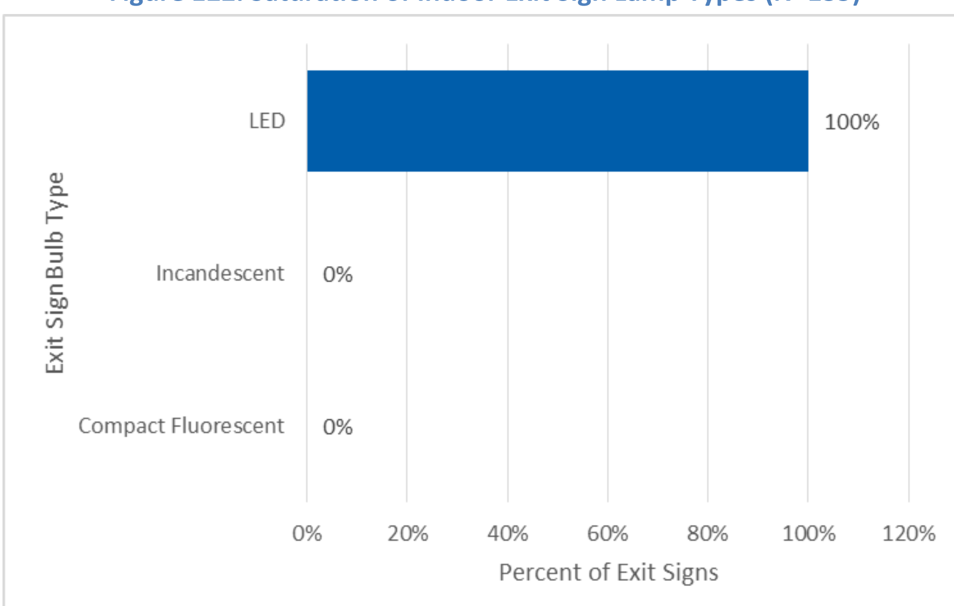
Table 51. Saturation of Indoor Lighting Control Types for Linear Fluorescents Only*

Category	Manual Switch	Motion/Occupancy Sensor	Timeclock/ EMS	Dimmer	Daylighting Controls	No Space Control	Not Identified
All (N=41)	58%	25%	5%	0%	1%	1%	10%
EEU							
BED (N=6)	56%	7%	0%	0%	0%	37%	0%
EVT (N=35)	59%	25%	5%	0%	1%	1%	10%
VT Gas (N=29)	54%	23%	7%	0%	2%	1%	14%
Size Strata							
High (N=20)	52%	25%	7%	0%	1%	1%	13%
Medium (N=16)	72%	27%	0%	0%	1%	0%	0%
Low (N=5)	93%	1%	0%	0%	0%	6%	0%
Facility Type							
Retail (N=4)	63%	5%	11%	0%	0%	1%	20%
Office (N=5)	65%	34%	0%	0%	0%	1%	0%
Manufacturing (N=1)	100%	0%	0%	0%	0%	0%	0%
Other (N=31)	50%	45%	0%	0%	3%	1%	1%

* Presented by controlled wattage

LED lamps account for 100% of the exit signs observed during the 2016 study. This marks a significant increase from 2011 when CFL signs accounted for 43% of exit signs.

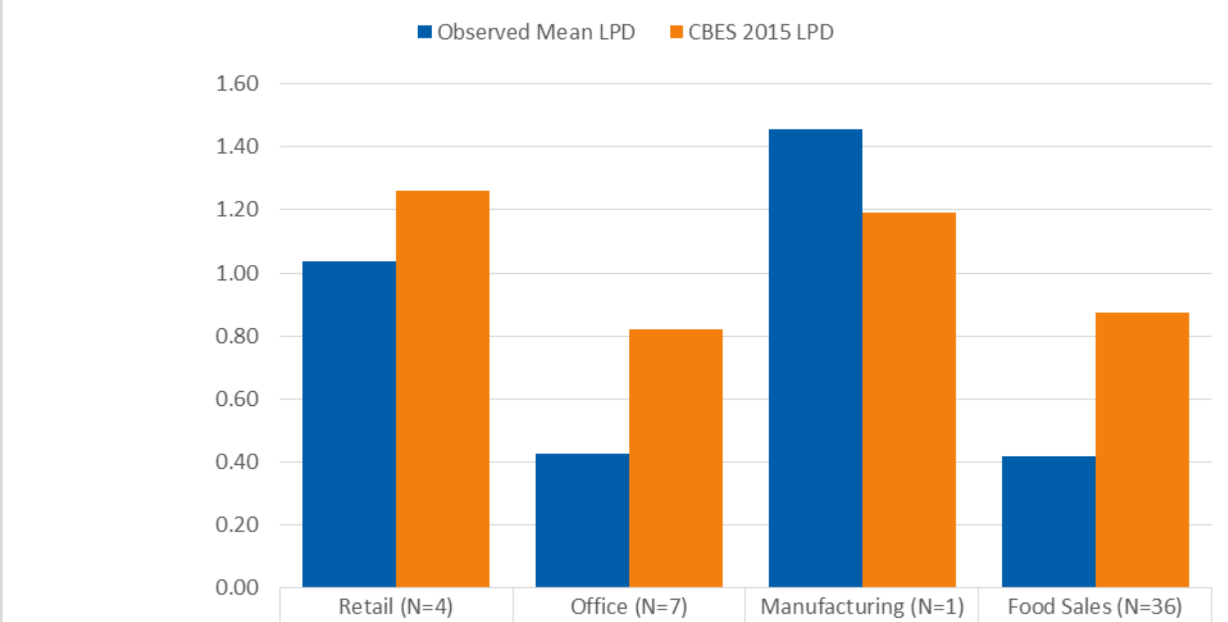
Figure 122. Saturation of Indoor Exit Sign Lamp Types (N=135)



Interior Lighting—Lighting Power Density

Figure 123 shows a comparison of observed LPD and the facility-type LPD requirements set forth in the 2015 Vermont CBES. In most cases, the observed LPD for existing C&I facilities is lower than the code-mandated value. Manufacturing is the only facility type where this is not true.

Figure 123. Lighting Power Density by Facility Type*



	Retail (N=4)	Office (N=7)	Manufacturing (N=1)	Food Sales (N=36)
Observed Mean LPD	1.04	0.43	1.45	0.42
CBES 2015 LPD	1.26	0.82	1.19	0.87

*Only spaces where both area and wattage are known are included in the figure.

Exterior Lighting

Exterior Lighting—Lamp Types

As shown in Figure 124, LED lighting comprises the highest share (59%) of estimated installed outdoor lighting in Vermont's new construction buildings. CFLs each make up approximately 16% of the installed outdoor lighting, with metal halide lighting accounting for only 1% of the installed lamps. Despite only accounting for 1% of installed lamps, metal halide lamps represent 8% of the total installed wattage.

Figure 124. Distribution of Outdoor Lamp Types (N=48)

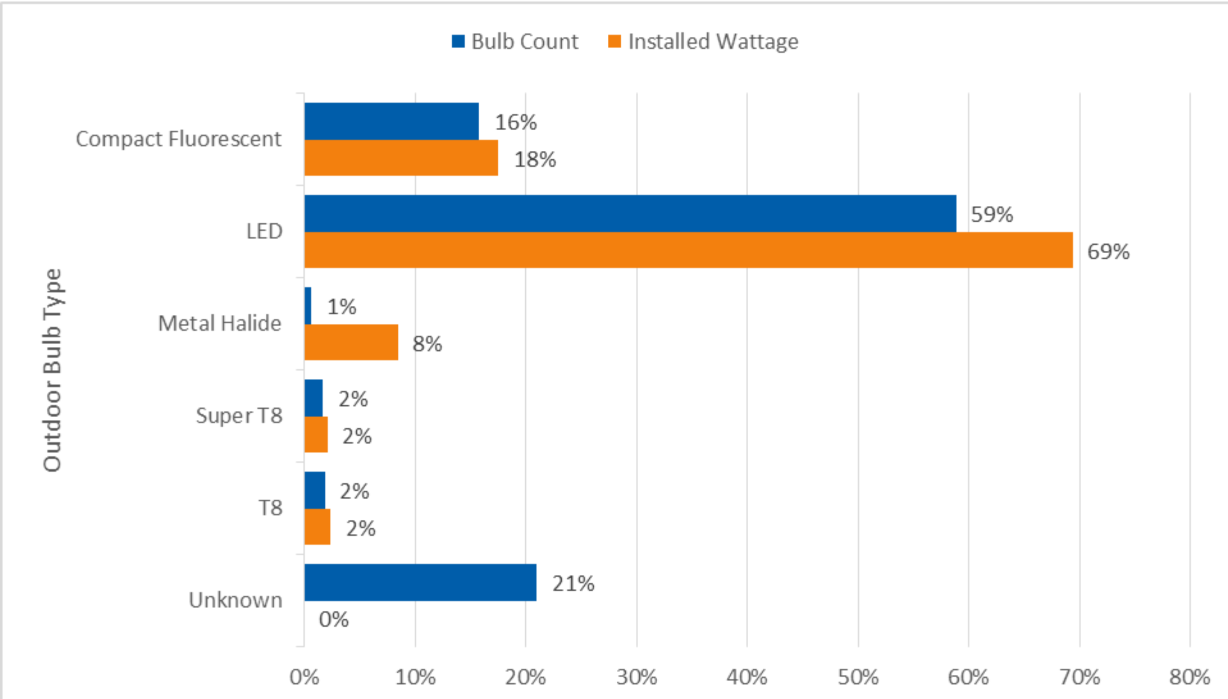


Table 52 shows the distribution of outdoor lighting types by facility type. LEDs are especially prevalent in retail facilities (73% of installed lamps) and office buildings (83% of installed lamps). LEDs account for only 50% of the lamps in other buildings. Compact fluorescents are most common in the balance of commercial facilities and account for roughly 21% of installed lamps.

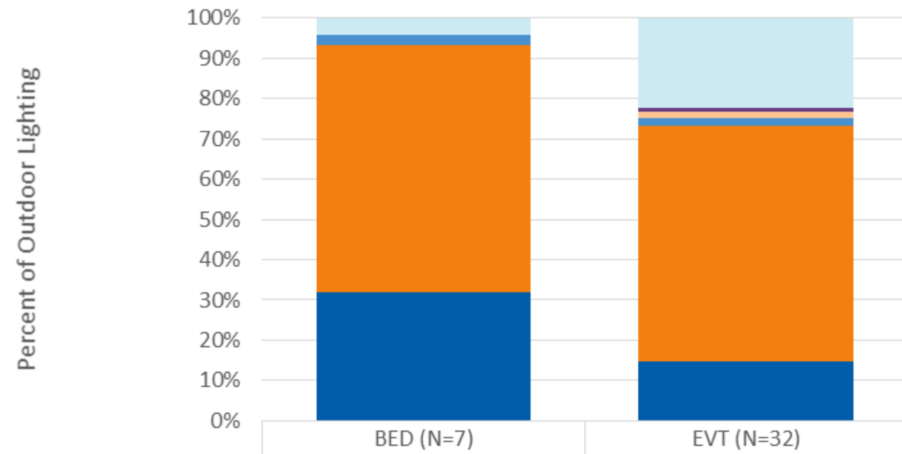
Table 52. Distribution of Outdoor Lamp Types by Facility Type*

Outdoor Lighting Type	All (N=42)	Retail (N=4)	Office (N=6)	Manufacturing (N=0)	Other (N=32)
Compact Fluorescent	16%	8%	1%	0%	21%
LED	59%	73%	83%	0%	50%
Linear Fluorescent	0%	0%	0%	0%	0%
Metal Halide	1%	0%	0%	0%	1%
Super T8	2%	9%	0%	0%	0%
T8	2%	9%	1%	0%	0%
Unknown	21%	0%	14%	0%	28%

*Presented by lamp counts

LED lamps represent roughly the same proportion of outdoor lamps in both BED and EVT service territories at 61% and 59%, respectively. The primary difference between the two territories is the incidence of CFLs as outdoor lighting. In BED territory CFLs represent 32% of exterior lamps as opposed to EVT where they only represent 15% of lamps.

Figure 125. Distribution of Outdoor Lamp Types by EEU*



	BED (N=7)	EVT (N=32)
Unknown	4%	22%
Metal Halide	0%	1%
Super T8	0%	2%
T8	3%	2%
LED	61%	59%
Compact Fluorescent	32%	15%

*Presented by percentage lamp counts

Exterior Lighting—Control Types

Daylighting controls represent the largest proportion of outdoor lighting control types in the state, controlling 50% of all installed wattage, 93% of the installed wattage in BED territory, and 48% of installed wattage in EVT territory. The second most prevalent form of lighting controls are timeclocks and EMS systems, which represent 16% of the lighting control statewide, 0% of controls in the BED territory, and 17% of controls in the EVT territory.

Timeclock and EMS lighting controls are the most prevalent among retail and office facilities, representing 22% and 62% of lighting, respectively. Office facilities also have the largest proportion of their outdoor lighting controlled by manual switches (31%). The one manufacturing facility visited in the study did not have any outdoor lighting identified.

Table 53. Saturation of Outdoor Lighting Control Types*

Category	Manual Switch	Motion/ Occupancy Sensor	Timeclock/EMS	Dimmer	Daylighting Controls	No Space Control	Not Identified
All (N=48)	6%	6%	16%	0%	50%	0%	22%
EEU							
BED (N=8)	0%	0%	0%	0%	93%	0%	7%
EVT (N=40)	6%	6%	17%	0%	48%	0%	22%
VT Gas (N=35)	5%	0%	8%	0%	54%	0%	33%
Size							
High (N=22)	0%	5%	17%	0%	49%	0%	28%
Medium (N=20)	26%	10%	16%	0%	46%	0%	3%
Low (N=6)	6%	0%	0%	0%	89%	0%	5%
Facility Type							
Retail (N=4)	0%	8%	22%	0%	32%	0%	37%
Office (N=7)	31%	0%	62%	0%	0%	0%	7%
Manufacturing (N=1)	0%	0%	0%	0%	0%	0%	0%
Other (N=36)	10%	4%	7%	0%	71%	0%	7%

* Presented as percentage of Installed Wattage EEU Market Characterization—Lighting

Table 54 provides a summary characterization of lighting measures for Vermont's EEUs.

Table 54. EEU Market Characterization—Lighting

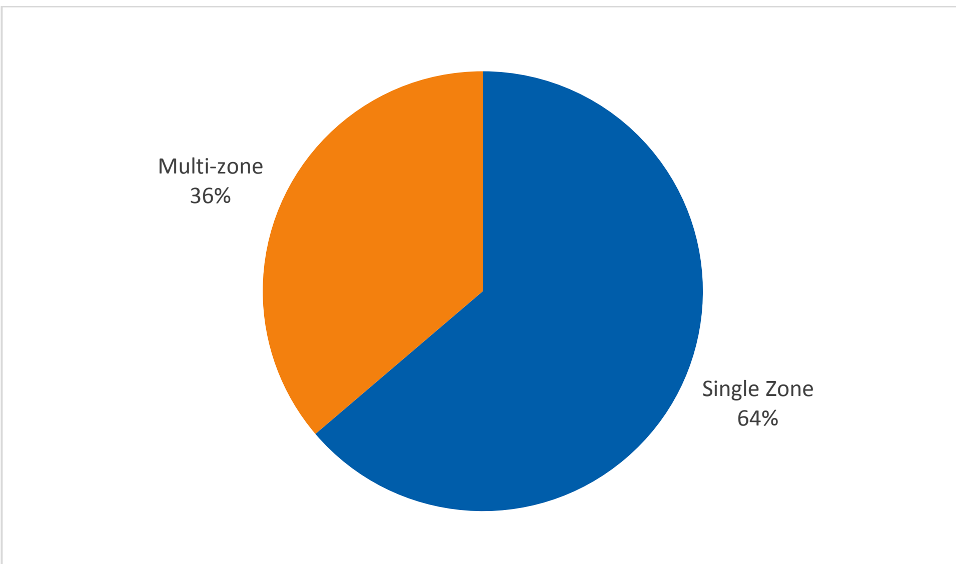
Lighting Group	Measure/ Characteristic	BED	EVT
Indoor Lighting	T12s	• No T12 lamps were identified in the study.	• No T12 lamps were identified in the study.
	T8/HPT8	• T8 and Super T8 represent 100% of linear fluorescent lighting.	• T8 and Super T8 represent 87% of linear fluorescent lighting.
	CFLs	• CFLs represent 28% of installed wattage and 19% of installed lamps; significantly higher than the statewide average.	• CFLs represent only 5% to 6% of lamps and installed wattage in screw-based sockets.
	LEDs	• LEDs represent 28% of all lamps and 27% of the installed wattage. The percentage of installed wattage is higher than the statewide average.	• LEDs represent 21% of all lamps and 32% of the installed wattage. These are roughly the same as the statewide average.
	Automated Indoor Lighting Controls	• Motion and occupancy sensors were found in 68% of facilities; timeclock and EMS systems were only found in 2% of facilities.	• Motion and occupancy sensors were found in 85% of facilities; timeclock and EMS systems were found in 18% of facilities.

Lighting Group	Measure/ Characteristic	BED	EVT
Outdoor Lighting	CFLs	• CFLs are no longer the predominant form of outdoor lighting, representing only 32% of installed lighting.	• The saturation of CFLs has decreased since 2011 to 14% of exterior lighting.
	LEDs	• LEDs are the dominant form of exterior lighting, accounting for 61% of all installed wattage.	• LEDs are the dominant form of exterior lighting, accounting for 59% of all installed wattage.
	Automated Outdoor Lighting Controls	• Daylighting controls account for 93% of the installed wattage in BED service territory.	• Roughly 48% of exterior lighting is controlled by daylight controls, another 17% is controlled by timeclock or EMS controls, and 6% is controlled by motion sensors.

HVAC

Similar to 2011, the majority (estimated at 64%) of HVAC systems in new construction facilities are single-zone systems. The balance (36%) are multi-zone systems. Single-zone systems are typically considered “simple” systems in Vermont’s commercial energy code, and multi-zone systems are categorized as “complex” systems. Each system type has different requirements to comply with the energy code, which affects HVAC systems at time of selection or replacement.

Figure 126. Distribution of Single-Zone and Multi-Zone Systems (N=208 Observations)*

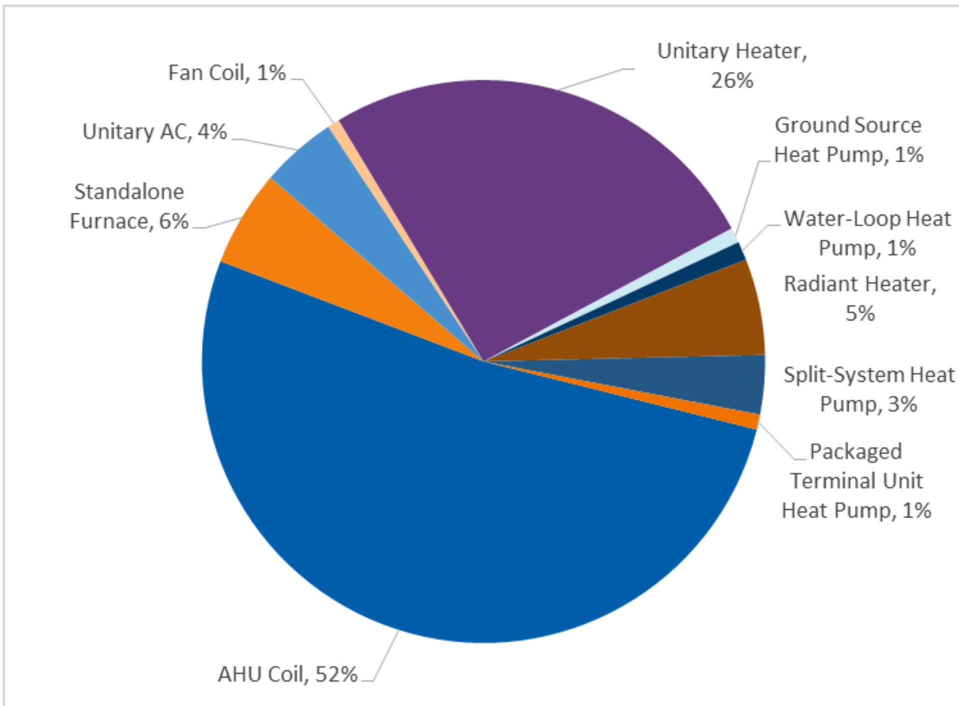


*Presented as percentage of observed systems, not individual components

Single-Zone Distribution Systems

Surveyors identified 131 single-zone HVAC systems during the on-site data collection process. AHU coils account for the majority of the single-zone systems identified, comprising an estimated 52% of systems. Unitary heaters represented 26% of single-zone systems.

Figure 127. Distribution of Single-Zone HVAC Systems (N=131 Observations)*



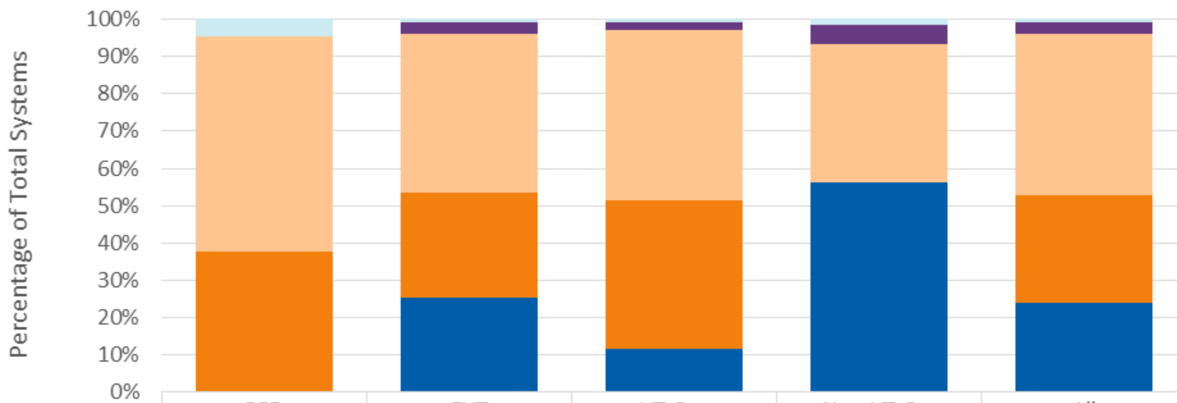
* Presented as percentage of observed systems, not individual components

Heating Systems

Heating Fuel Type

Considered by estimated percentage of installed systems, as shown in Figure 128, the highest percentage of installed systems use electricity (43%) among C&I facilities statewide, followed by natural gas (29%) and propane (24%). The 3% of systems identified as using “other” fuel types primarily used wood-fired boilers. The relatively high percentage of electric systems results partly from the discrete nature of small electric systems, which often consist of a small single-zone system for each space within a facility, and from the classification of water source heat pump (WSHP) terminal units as electric

Figure 128. Heating System Fuel Type by EEU (N=126)*



	BED (N = 11)	EVT (N = 115)	VT Gas (N = 84)	Non-VT Gas (N = 42)	All (N = 126)
Unknown	5%	1%	1%	2%	1%
Other	0%	3%	2%	5%	3%
Electricity	57%	43%	46%	37%	43%
Fuel Oil	0%	0%	0%	0%	0%
Natural Gas	38%	28%	40%	0%	29%
Propane	0%	25%	12%	56%	24%

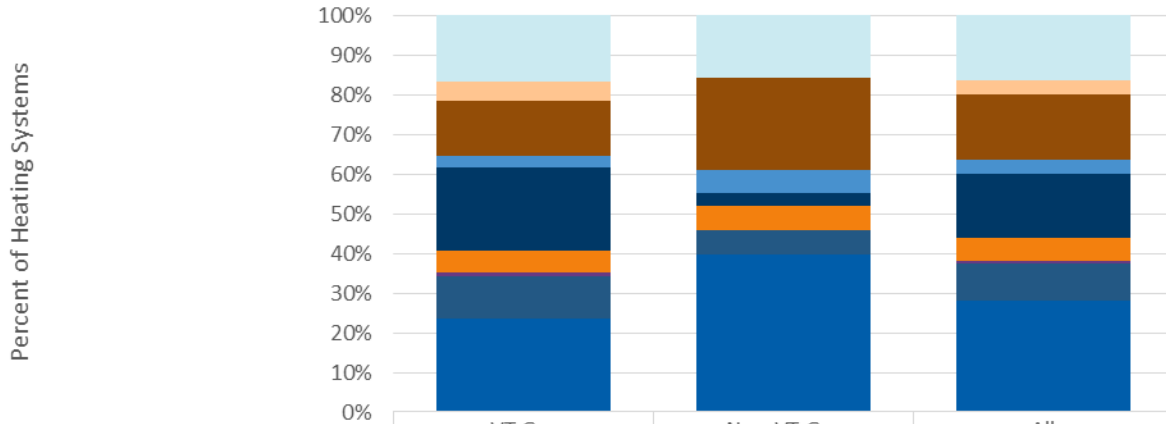
EEU / Area

*Presented as percentage number of systems

Heating System Type

Figure 129 shows that the distribution of heating systems. Boilers rank as the most common heat system in new construction at 28%, followed by stand-alone furnaces (17%), ground source heat pumps (16%), and unitary heaters (16%). The distribution of heating systems is similar for VT Gas and non-VT Gas territories.

Figure 129. Distribution of Heating System Types (N=126)*



	VT Gas (N = 84)	Non-VT Gas (N = 42)	All (N = 126)
Unitary Heater	17%	16%	16%
Electric Resistance	5%	0%	3%
Standalone Furnace	14%	23%	17%
Split System Heat Pump	3%	6%	4%
Ground Source Heat Pump	21%	3%	16%
Radiant Heater	5%	6%	6%
Packaged Terminal Unit Heat Pump	1%	0%	1%
Water Source Heat Pumps	10%	6%	9%
Boiler	23%	40%	28%

*Presented as percentage observation of systems, not individual pieces of equipment

Table 55 shows heating system efficiencies for furnaces, boilers, and ground-source heat pumps, broken out by 2015 Vermont CBES categories and subcategories. All of the furnaces and hot water boilers exceeded the requirements outlined in the 2015 energy code. Most (74%) of the furnaces smaller than 225,000 Btu/h exceed the code minimum efficiency. All hot water boilers observed in new construction buildings exceeded code minimums, with the weighted average efficiency levels significantly exceeding the code requirements.

Table 55. Heating System Efficiency by Type and Code Category*

System	Subcategory	Size Category (Input)	Observed Mean Efficiency	Code of Federal Regulation Minimum Efficiency	Percent of Systems Below/Meet/Above Code	Number of Units
Warm Air Furnaces, gas fired	-	<225,000 Btu/h	94%	78% AFUE or 80% Thermal Efficiency	0%/0%/100%	5

CADMUS

	Maximum Capacity	≥225,000 Btu/h	-	80% Thermal Efficiency	No observed systems	0
Warm Air Furnaces, oil fired	-	<225,000 Btu/h	-	78% AFUE or 80% Thermal Efficiency	No observed systems	0
	Maximum Capacity	≥225,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0
Boilers, hot water	Gas-Fired	<300,000 Btu/h	94%	80% AFUE	0%/0%/100%	10
		≥300,000 Btu/h and <2,500,000 Btu/h	92%	80% Thermal Efficiency	0%/0%/100%	9
		≥2,500,000 Btu/h	94%	82% Combustion Efficiency	0%/0%/100%	5
	Oil-Fired	<300,000 Btu/h	-	80% AFUE	No observed systems	0
		≥300,000 Btu/h and <2,500,000 Btu/h	-	82% Thermal Efficiency	No observed systems	0
		≥2,500,000 Btu/h	-	84% Combustion Efficiency	No observed systems	0
Boilers, steam	Gas-fired	<300,000 Btu/h	-	75% AFUE	No observed systems	0
	Gas-fired. All except natural draft.	≥300,000 Btu/h and <2,500,000 Btu/h	-	79% Thermal Efficiency	No observed systems	0
		≥2,500,000 Btu/h	-	79% Thermal Efficiency	No observed systems	0
	Gas-fired natural draft	≥300,000 Btu/h and <2,500,000 Btu/h	-	77% Thermal Efficiency	No observed systems	0
		≥2,500,000 Btu/h	-	77% Thermal Efficiency	No observed systems	0
	Oil-fired	<300,000 Btu/h	-	80% AFUE	No observed systems	0
		≥300,000 Btu/h and <2,500,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0
		≥2,500,000 Btu/h	-	81% Thermal Efficiency	No observed systems	0

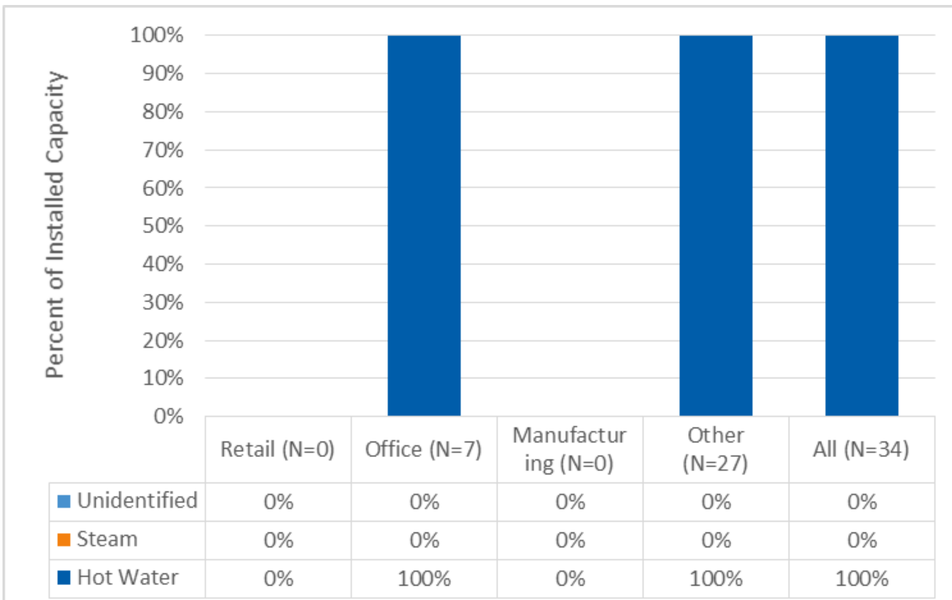
Ground Source Heat Pumps*	50°F entering water	<135,000 Btu/h	4.1 COP	3.7 COP	0%/0%/100%	38

* Note: The most stringent efficiency standard is used.

Boilers

As shown in Figure 130, all boilers observed in new construction buildings use hot water as the delivery medium. No steam boilers were identified in new construction facilities during this study.

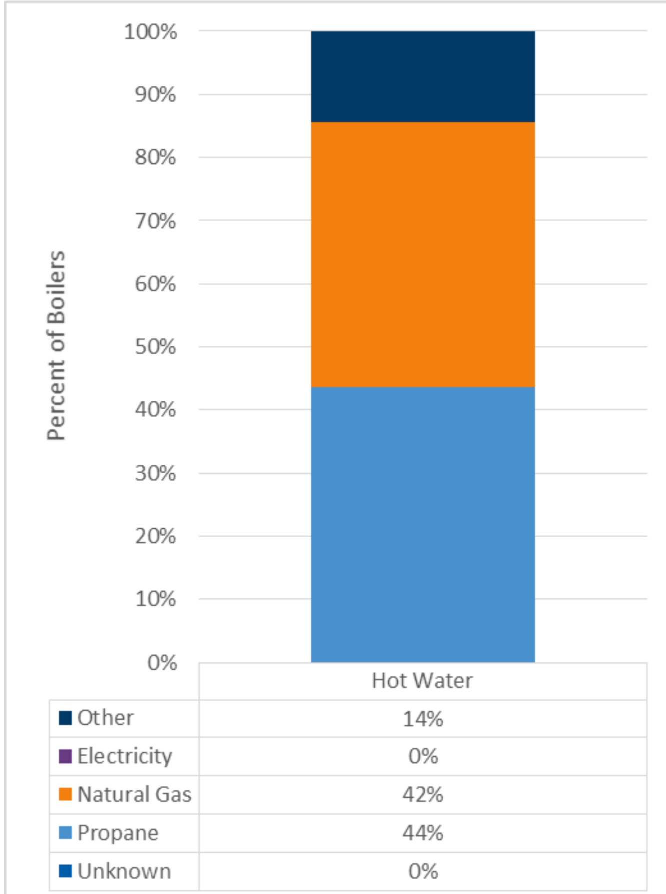
Figure 130. Boiler Delivery Systems by Facility Type (N=34)*



*Presented as percentage of heating capacity

Figure 131 shows the breakdown of boiler fuel type. As in 2011, natural gas and propane are the primary hot water boiler fuel types, at 42% and 44%. The next largest category is wood at 14%.

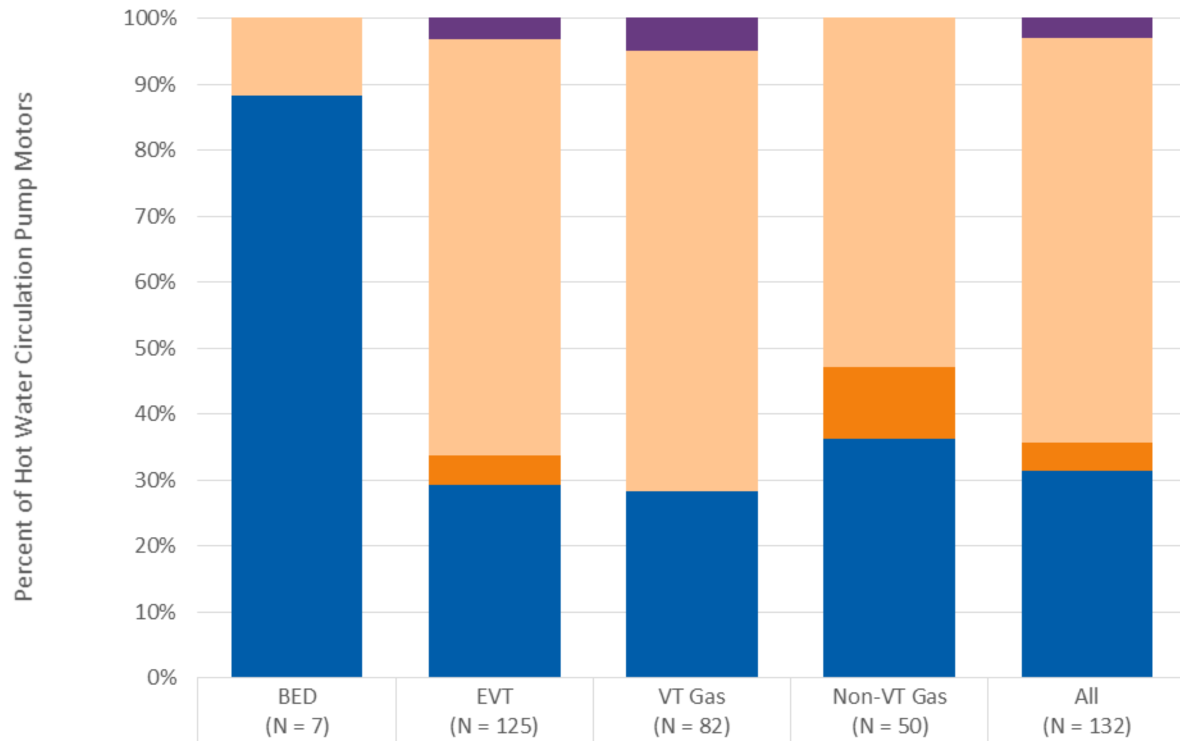
Figure 131. Boiler Fuel Types by Delivery System (N=34)*



* Presented as percentage equipment quantity

Weighted results estimate that nearly two-thirds (61%) of hot water circulation pumps in new construction facilities statewide are controlled by single-speed motors. Approximately one-third (31%) of the hot water circulation pumps are controlled by variable speed motors. VT Gas and non-VT Gas facilities have similar levels of variable speed pump motors (28% and 36%, respectively); however, the non-VT Gas facilities have higher levels of three-speed motors (11%) and VT Gas facilities have higher levels of one-speed motors (67%). However, the saturation of variable speed controls in BED's territory (88%) is much higher than in EVT's territory (29%).

Figure 132. **Saturation of Speed Controls for Hot Water Circulation Pumps by EEU (N=132)**

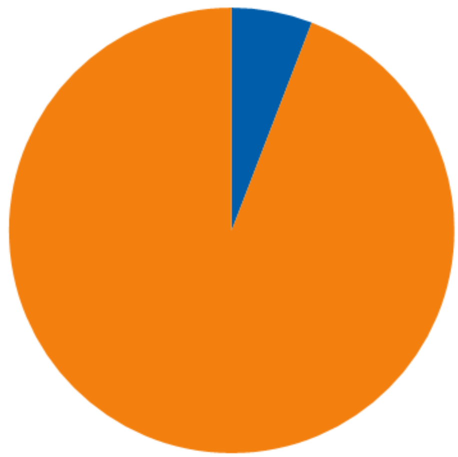


	BED (N = 7)	EVT (N = 125)	VT Gas (N = 82)	Non-VT Gas (N = 50)	All (N = 132)
Unidentified	0%	3%	5%	0%	3%
One Speed	12%	63%	67%	53%	61%
Two Speed	0%	0%	0%	0%	0%
Three Speed	0%	4%	0%	11%	4%
Variable Speed	88%	29%	28%	36%	31%

Cooling Systems

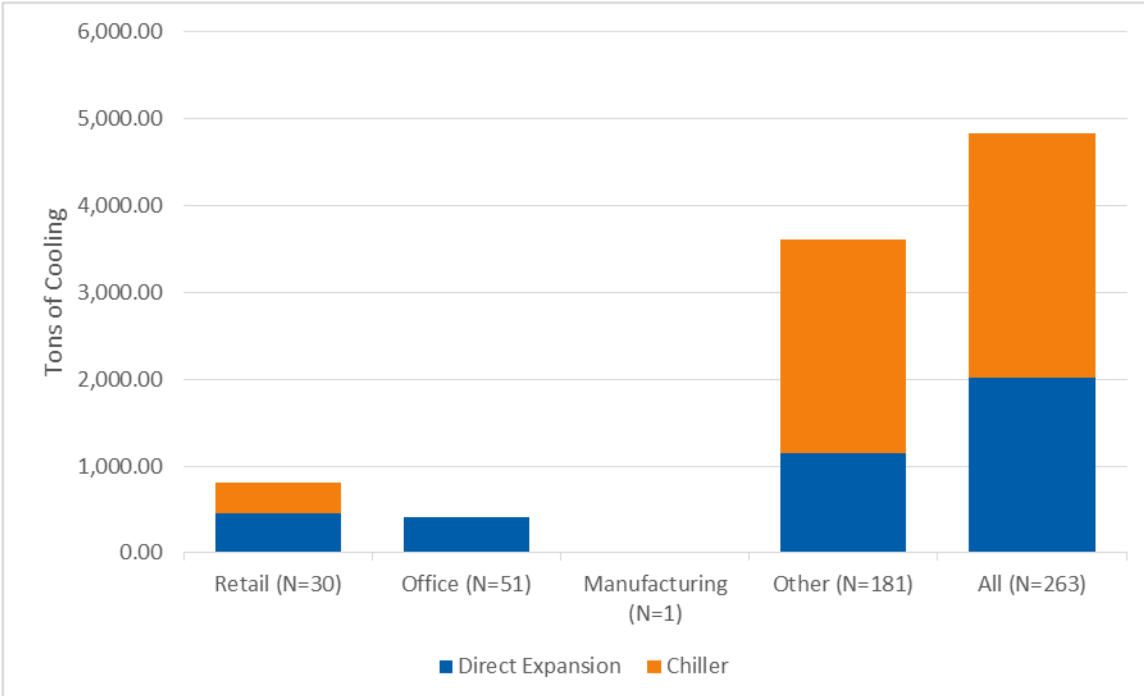
Considered by system type, the most common cooling systems observed in Vermont's new constructions buildings are direct expansion cooling systems. Chillers make up the balance (6%). These results are very comparable to the 2011 findings.

Figure 133. Distribution of Cooling System Types—All Facilities (N=82 Observations)



When taking the capacity of installed systems into account, chillers account for a majority of cooling in new construction statewide, comprising an estimated 58% of cooling capacity. As shown in Figure 134, chillers represent a significant proportion of the cooling capacity in retail and “other” facility types, but were not identified in any of the office buildings or manufacturing facilities visited for this study.

Figure 134. Saturation of Cooling System Types by Facility Type (N=263)*



* Presented by total cooling capacity

Table 56 shows a comparison of the single-zone unitary HVAC systems observed in Vermont's new construction buildings with the most recent building code (2015 CBES). Nearly all of the small systems (less than 5.5 tons) met or exceeded the latest iteration of the building code, and had an average EER of 16.6 with an average SEER of 20.2. Medium-sized systems (between 5.5 and 11.25 tons) met or exceeded code roughly two-thirds of the time, with an average EER value of 15.2. The large systems observed in 2016 all fell below code, with an average EER value of 9.9.

Table 56. Cooling Efficiency of Single-Zone Unitary HVAC Systems

Statistic	<5.5 tons (65,000 Btu/h) (Code: 13.0 SEER)	≥5.5 tons and <11.25 tons (135,000 Btu/h) (Code: 11.2 EER)	≥11.25 tons (135,000 Btu/h) (Code: 11 EER)
Percentage of Systems Below Code	13%	34%	100%
Percentage of Systems Above Code	87%	66%	0%
Mean EER	16.6	15.2	9.9
Mean SEER	20.2	N/A	N/A
Number of Observed Systems	55	6	4

As shown in Table 57, a large proportion of cooling systems in Vermont are not equipped with economizers. Based on observed economizers during site visits and established weighting, an estimated 26% of systems smaller than 4.5 tons are equipped with economizers statewide. That figure rises to 41% with cooling systems larger than 4.5 tons.

Table 57. Saturation of Economizers in Cooling Systems

Statistic	<4.5 tons (65,000 Btu/h)	>=4.5 tons
Economizer	26%	41%
No economizer	8%	22%
Unidentified	66%	36%

Chillers

Table 58 shows that all the chillers identified in new construction facilities are electric chillers.

Table 58. Chiller Fuel Type

Chiller Fuel Type	Percentage of Units
Electric	100%
Steam	0%
Gas	0%
Unidentified	0%

N=7 Systems

Surveyors identified the efficiency level of two of the seven chillers observed chillers. As shown in Table, neither appears to meet 2015 CBES requirements.

Table 59. Chiller Efficiency

Chiller Capacity (Tons)	Observed Full Load Efficiency (kW/Ton)	Observed Part Load Efficiency (kW/Ton)	Code Minimum Efficiency* (kW/Ton)
48	1.17	0.77	Path A: ≤0.610 FL and ≤0.550 IPLV; Path B: ≤0.695 FL and ≤0.440 IPLV
325	0.62	0.35	Path A: ≤0.560 FL and ≤0.520 IPLV; Path B: ≤0.595 FL and ≤0.390 IPLV

* Efficiency information was only available for two of the observed chillers.

As shown in Table 60, the chillers observed in 2016 were split fairly evenly between space cooling (52%) and multiple end uses (48%). All observed chillers in the multiple use category served both refrigeration units and cooling systems.

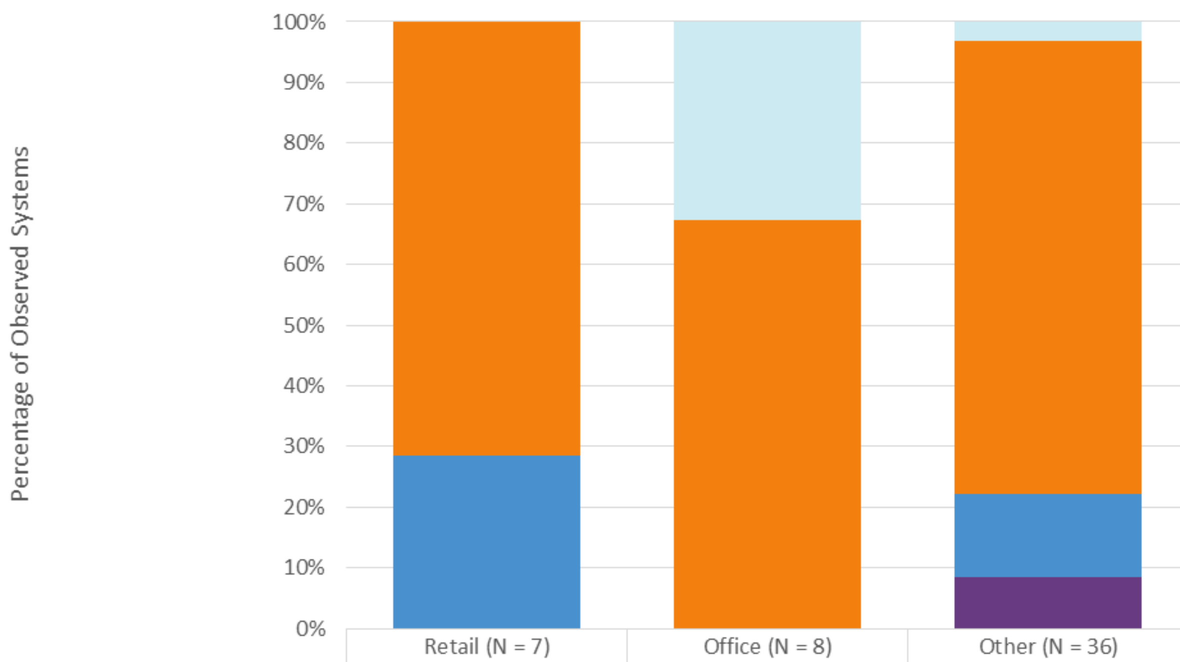
Table 60. Chiller End Uses

Chiller End Use	Percentage of Chillers Dedicated to End Use
Space Cooling	52%
Process	0%
Refrigeration	0%
Multiple End Uses	48%
Unidentified	0%
Total	100%

Multi-Zone Systems

Figure 135 shows that across facility types, the majority of multi-zone HVAC distribution systems are hydronic systems. Most of the remaining systems are constant air volume systems or multi-head split-system heat pumps.

Figure 135. Saturation of Multi-Zone Distribution System Types by Facility Type (N=51)*,**



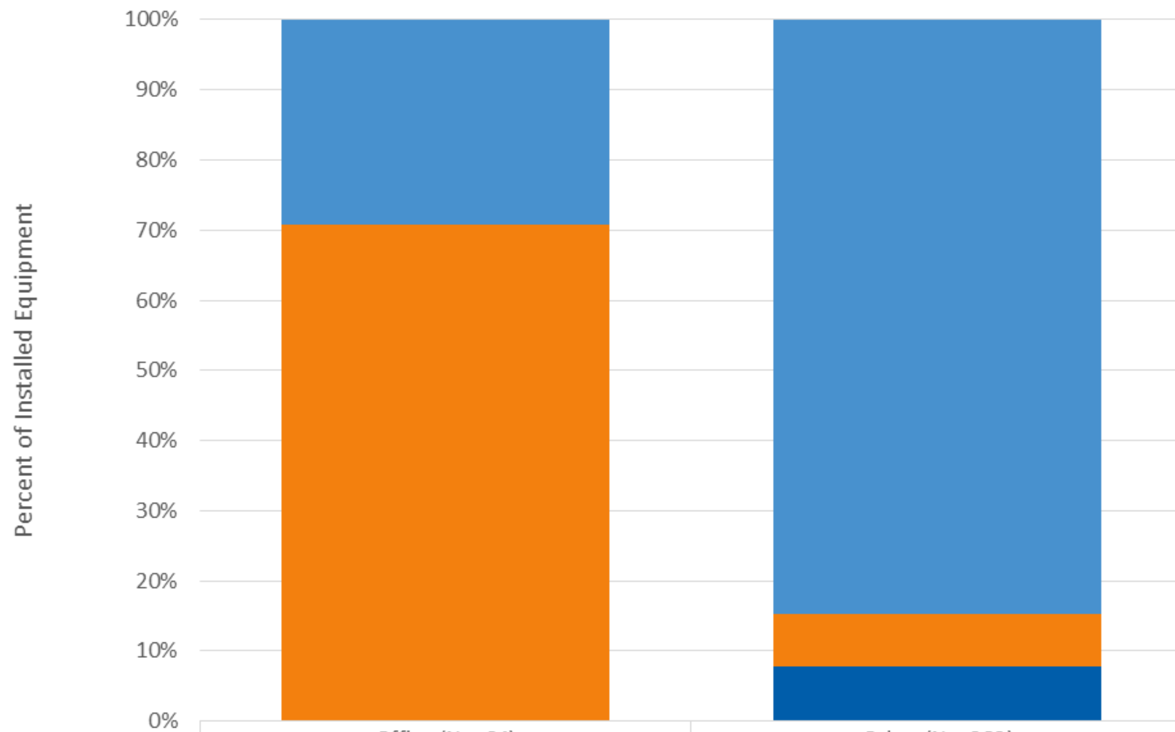
	Retail (N = 7)	Office (N = 8)	Other (N = 36)
Refrigerant (Constant Volume)	0%	0%	0%
Refrigerant (Variable Volume)	0%	33%	3%
Steam	0%	0%	0%
Hydronic	71%	67%	74%
Air (Multiple)	0%	0%	0%
Air (Constant Volume)	29%	0%	14%
Air (Variable Volume)	0%	0%	8%

*Multiple means that the system comprises constant volume and variable volume subsystems.

** Note that this figure only shows the primary distribution medium for the system. The final medium at the point of delivery may be different. For instance, a water loop heat pump is considered part of a hydronic distribution system, even though the final delivery medium is air.

Figure 136 shows the percentage of terminal units for hydronic systems. The most common hydronic terminal units for Offices in new construction and major renovation facilities appear to be water loop heat pumps. Radiant heaters ranked by far as the most common terminal unit in the “other” category. This figure does not show AHU coils served by boilers, chillers, or cooling towers, which are common in retail and some other facilities.

Figure 136. Saturation of Multi-Zone Hydronic and Steam Terminal Units by Facility Type (N=346)

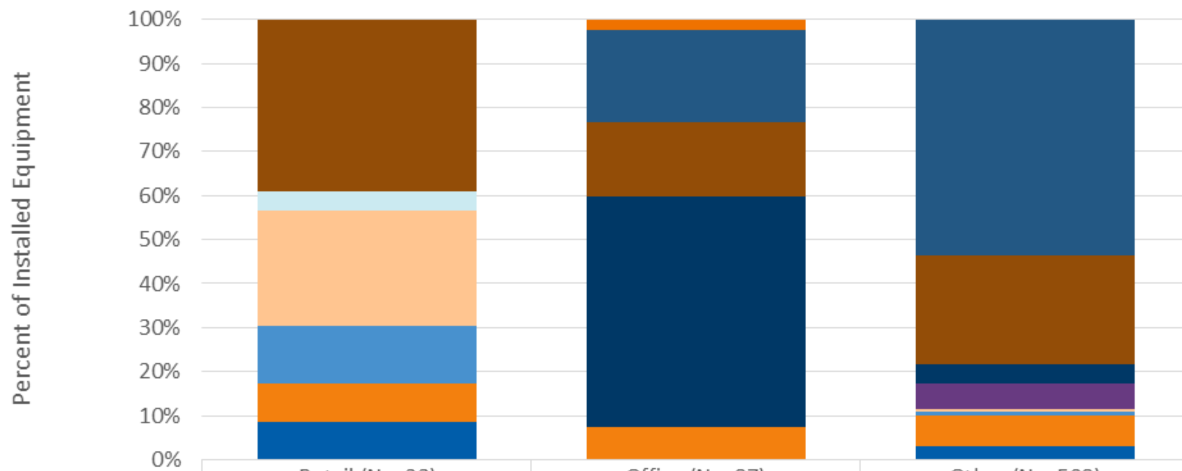


	Office (N = 64)	Other (N = 282)
Radiant Heater	29%	85%
Heat Pump	71%	7%
Fan Coil	0%	8%

*Presented as percentage quantity of installed equipment

Figure 137 shows the estimated the distribution of equipment components identified as part of multi-zone systems. Radiant heaters and pumps are the most common equipment types, with cooling towers representing a sizeable proportion of the equipment in retail facilities. Boilers were identified across all three facility types.

Figure 137. Distribution of Multi-Zone Equipment by Facility Type (N=617)

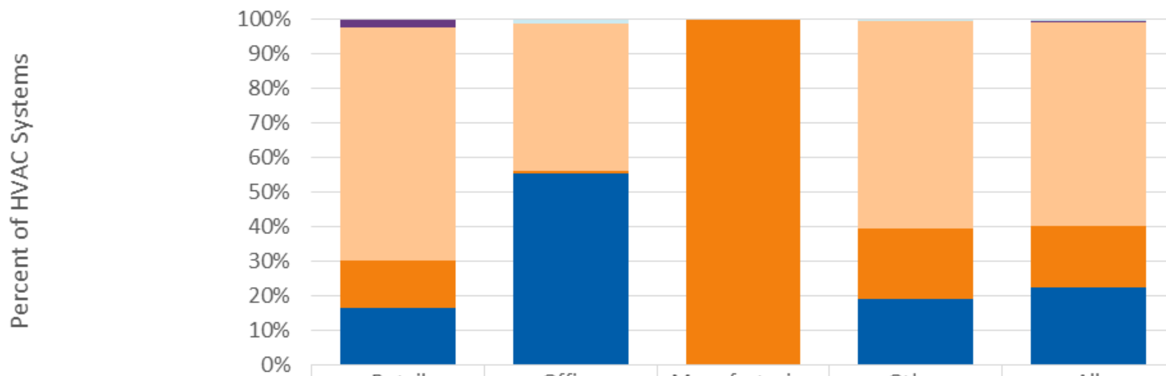


	Retail (N = 23)	Office (N = 87)	Other (N = 508)
Unitary AC	0%	2%	0%
Radiant Heater	0%	21%	54%
Pump	39%	17%	25%
Heat Pump	0%	52%	4%
Heat Exchanger	4%	0%	0%
Fan Coil	0%	0%	6%
Cooling Tower	26%	0%	1%
Chiller	13%	0%	1%
Boiler	9%	7%	7%
AHU Coil	9%	0%	3%

HVAC Controls

Statewide, EMS controls are the predominant form of HVAC system control, comprising an estimated 59% of control systems. Programmable thermostats are the second most common form of HVAC control at 22%, followed by manual controls at an estimated 18%. As in 2011, warehouse/manufacturing facilities rely more than other facilities on manual controls. The distribution of HVAC system control types is shown in Figure 138.

Figure 138. Saturation of HVAC System Control Types by Facility Type

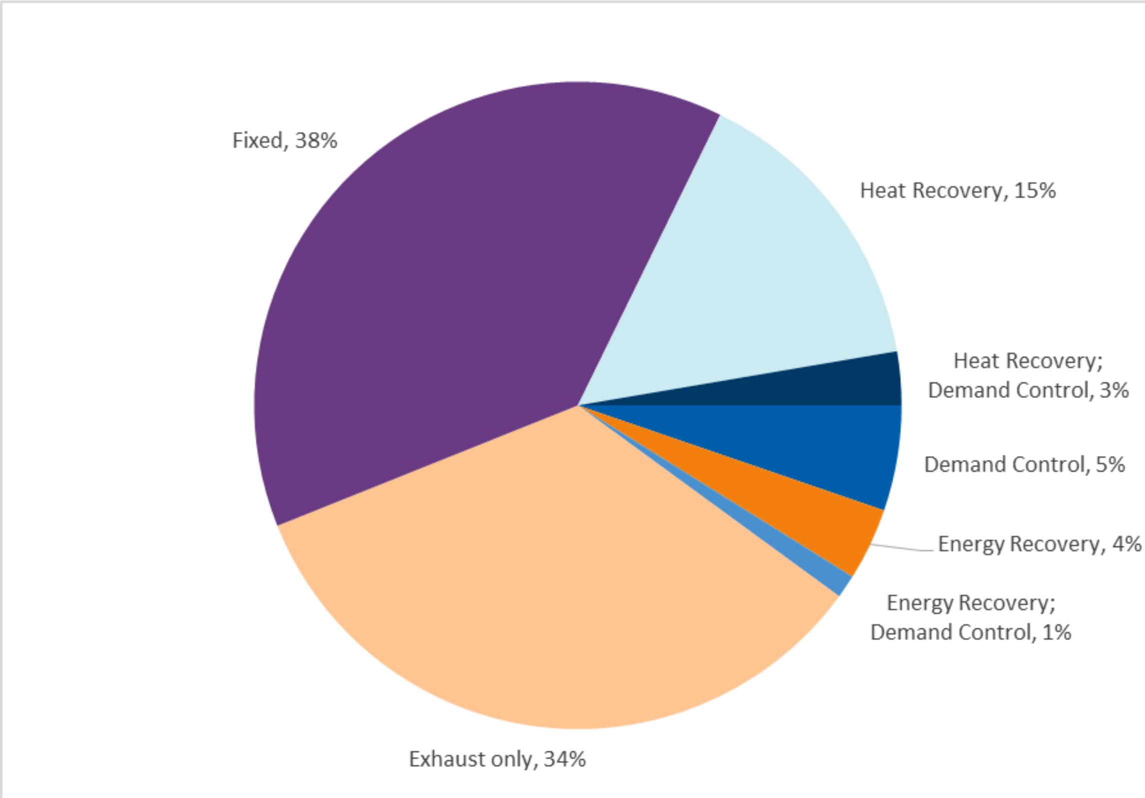


	Retail (N = 43)	Office (N = 40)	Manufacturing (N = 2)	Other (N = 265)	All (N = 350)
Unknown	0%	1%	0%	0%	0%
Time Clock	2%	0%	0%	0%	0%
EMS	67%	43%	0%	60%	59%
Always On	0%	0%	0%	0%	0%
Manual	14%	1%	100%	20%	18%
Programmable Thermostat	16%	56%	0%	19%	22%

Ventilation

Figure 139 shows the distribution of ventilation equipment control strategies identified during the 2016 site visits. The sample size of 1,423 indicates the number of ventilation components identified within the 192 sites visited, and Figure 139 represents the distribution of control strategies for those 1,423 components. During the 2016 site visits, 38% of the ventilation equipment was identified as having a fixed ventilation strategy and 34% was identified as being exhaust-only systems. Heat recovery comprised a similar proportion (18%) in 2016 as it did in 2011 (21%), but there was a drop in the number of systems identified as energy recovery systems (5% total in 2016 as compared to 16% in 2011). Demand control was found in approximately 10% of all systems.

Figure 139. Ventilation Equipment by Ventilation Strategy (N=1,423)



Water Heating

Stand-alone, direct-fired water heating systems rank as the most common water heating system observed in site visits for this study, comprising an estimated 46% of mew construction water heater systems statewide. Boilers account for 35% of water heater systems, and instantaneous water heaters account for 17%. None of the observed systems used purchased hot water.

Figure 140. Distribution of Water Heating Equipment Types—All Facilities (N=104)

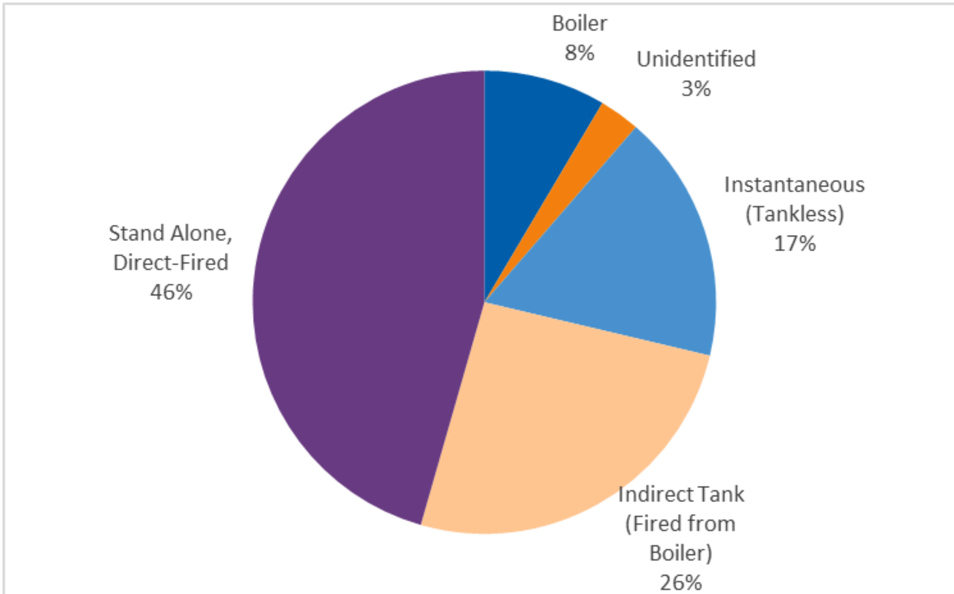
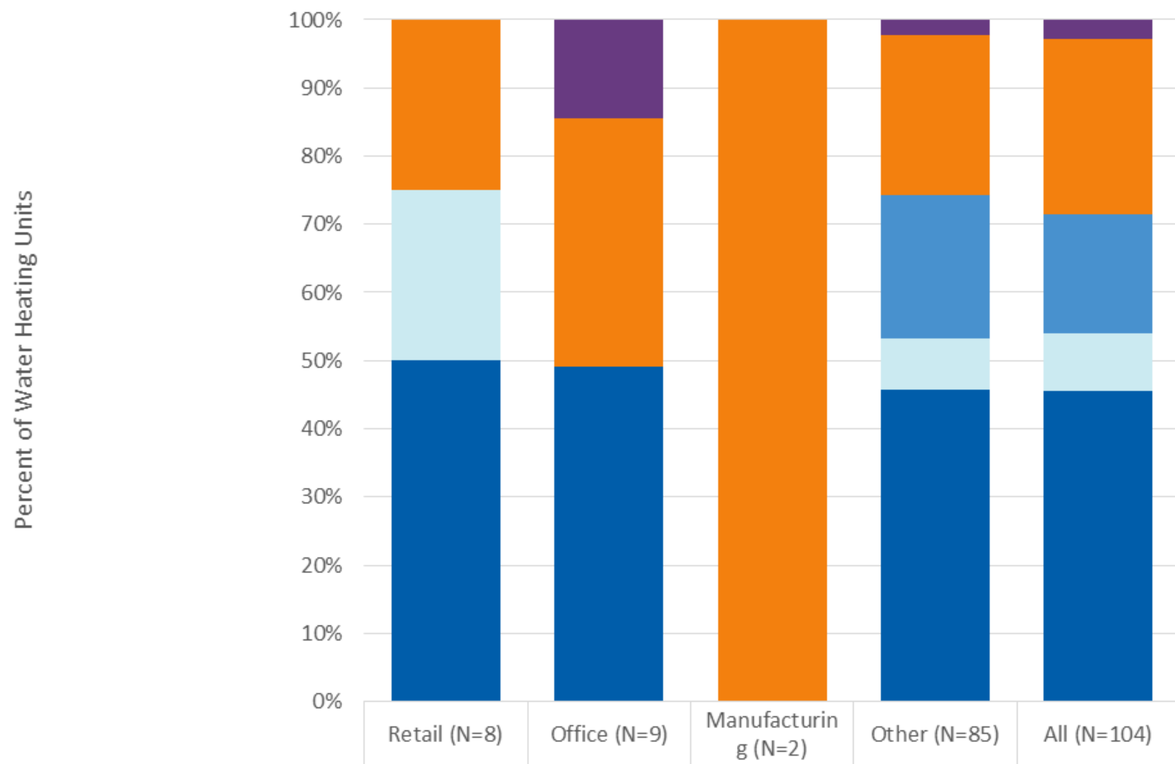


Figure 141 shows the saturation of water heating equipment types by facility type. Stand-alone, direct-fired water heaters are the most common type of system across all facility types except for manufacturing, where surveyors observed indirect tanks fired from boilers. No tankless water heaters were observed in retail, office, or manufacturing facilities.

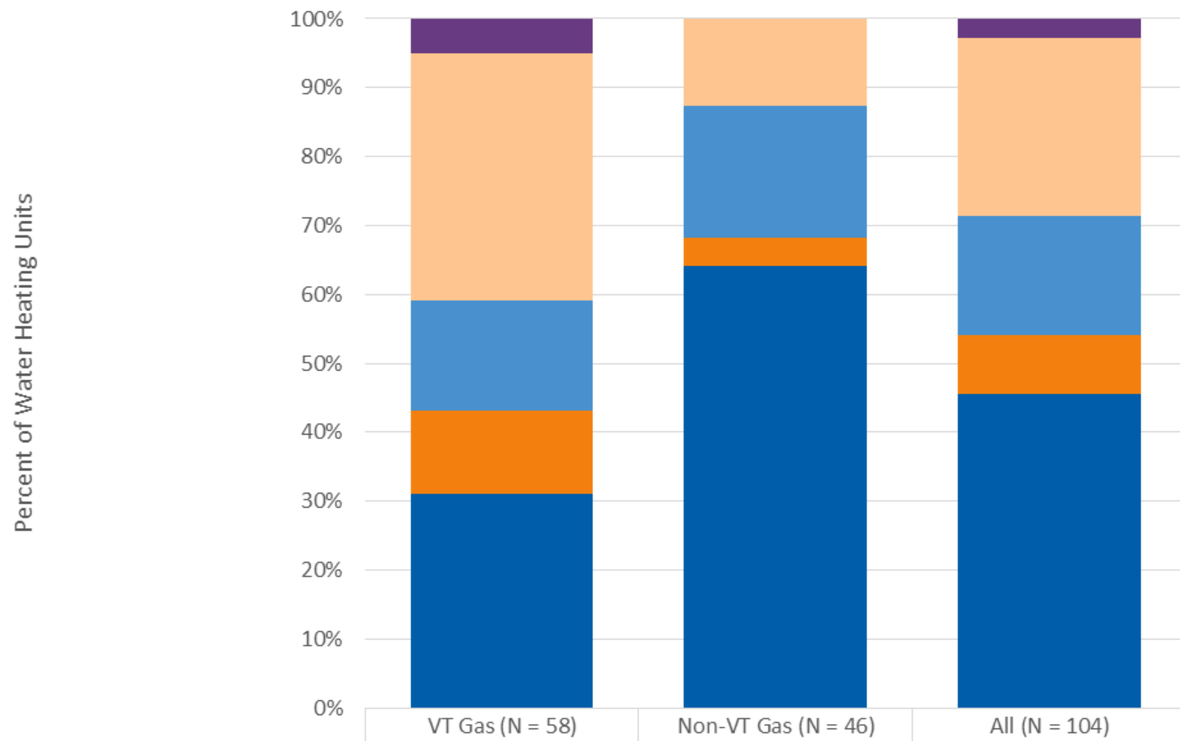
Figure 141. Saturation of Water Heating Equipment Types by Facility Type (N=104)



	Retail (N=8)	Office (N=9)	Manufacturing (N=2)	Other (N=85)	All (N=104)
Unidentified	0%	15%	0%	2%	3%
Indirect Tank (Fired from Boiler)	25%	36%	100%	23%	26%
Instantaneous (Tankless)	0%	0%	0%	21%	17%
Boiler	25%	0%	0%	8%	9%
Stand Alone, Direct-Fired	50%	49%	0%	46%	46%

Figure 142 provides the saturations of water heating system types for VT Gas and non-VT Gas territory. Stand-alone systems are more common in the non-VT Gas territory, representing an estimated 64% of systems as compared to 31% of systems in VT Gas territory. Facilities in VT Gas territory have a higher rate of boilers and indirect tanks fired from boilers, while non-VT Gas facilities have a higher proportion of instantaneous water heaters.

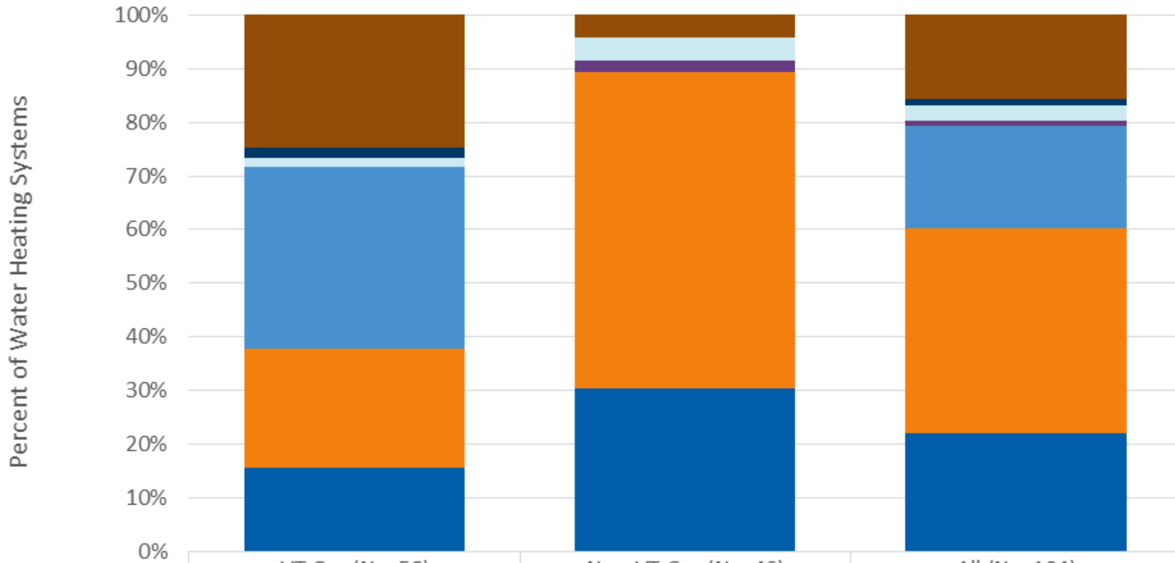
Figure 142. Saturation of Water Heating Equipment Types—VT Gas vs. Non-VT Gas (N=104)



	VT Gas (N = 58)	Non-VT Gas (N = 46)	All (N = 104)
Unidentified	5%	0%	3%
Indirect Tank (Fired from Boiler)	36%	13%	26%
Instantaneous (Tankless)	16%	19%	17%
Boiler	12%	4%	9%
Stand Alone, Direct-Fired	31%	64%	46%

Statewide, the dominant water heating fuel types are propane (22%), electricity (38%), and natural gas (19%). Natural gas is the most common fuel type in the VT Gas service territory, accounting for 34% of the fuel share in these facilities, while electricity is the most common fuel type outside of the VT Gas service territory (59% of fuel share). Propane systems are more common in Non-VT Gas facilities (30%) than in VT Gas facilities (16%). The Cadmus team noted two heat pump waters in the 48 sites visited.

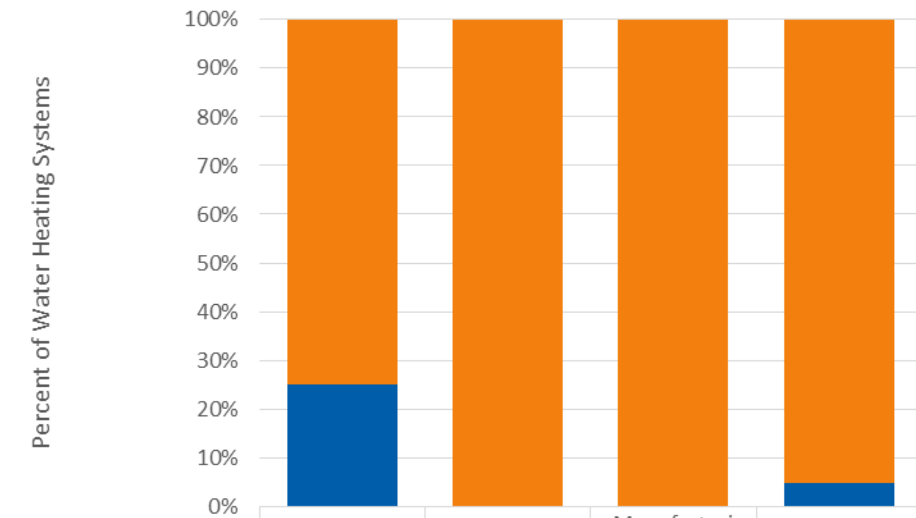
Figure 143. Water Heating Fuel Types—VT Gas vs. Non-VT Gas (N = 104)



	VT Gas (N = 58)	Non-VT Gas (N = 46)	All (N = 104)
Wood	0%	0%	0%
Unknown	25%	4%	16%
Multiple	2%	0%	1%
Other	2%	4%	3%
Heat Recovery	0%	2%	1%
Fuel Oil	0%	0%	0%
Natural Gas	34%	0%	19%
Electricity	22%	59%	38%
Propane	16%	30%	22%

Figure 144 shows the distribution of observed water heater temperature settings by facility type. Nearly all systems (95%) fall into the "Medium Temperature" range of 110˚F to 140˚F. No systems were identified that fall below the "Low Temperature" threshold of 110˚F.

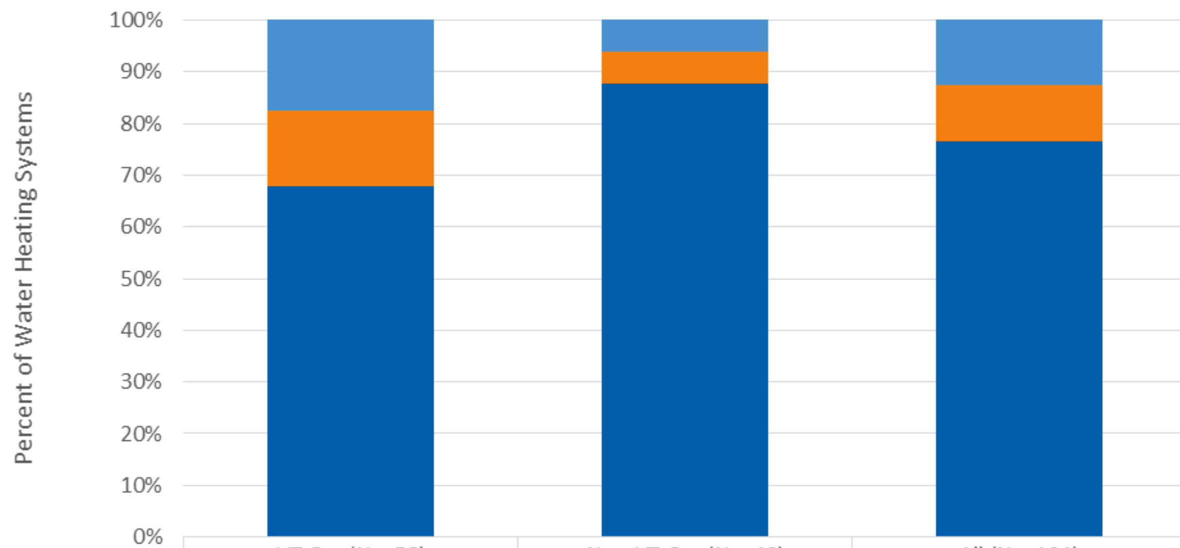
Figure 144. Water Heater Temperature Setting by Facility Type (N=74)



	Retail (N=4)	Office (N=5)	Manufacturing (N=2)	Other (N=63)
Low Temp (<110 F)	0%	0%	0%	0%
Medium Temp	75%	100%	100%	95%
High Temp (>140 F)	25%	0%	0%	5%

Based on observed facilities and established weighting, an estimated 77% of water heating systems have pipe insulation in Vermont's new construction. We estimate that 11 of systems have no insulation, as shown in Figure 145. In VT Gas territory, there are more uninsulated systems (an estimated 15%) than the statewide average, and a lower proportion of systems are insulated (estimated at 68%).

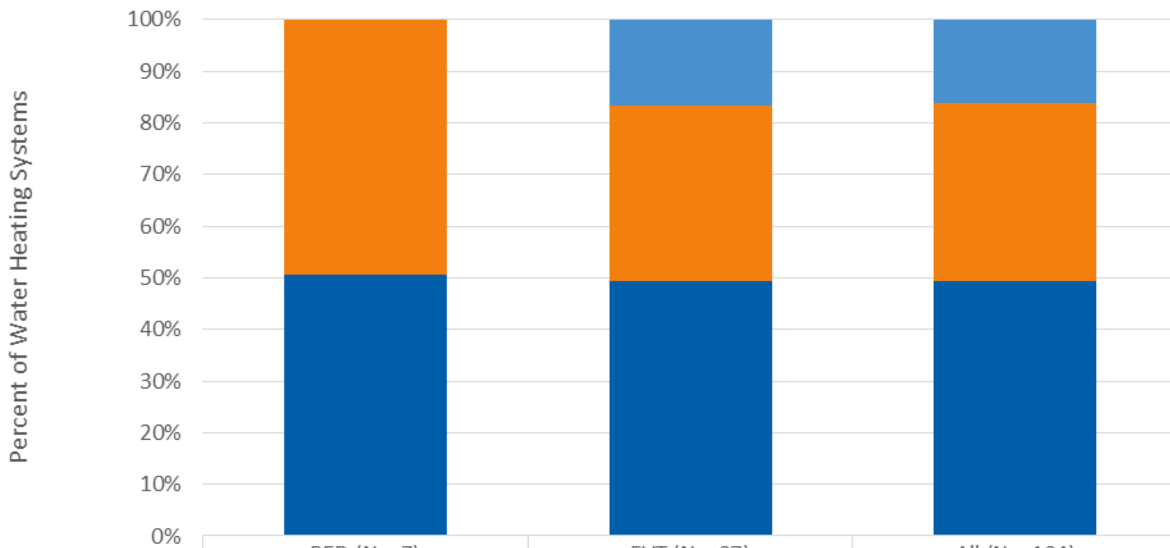
Figure 145. Water Heating Pipe Insulation—VT Gas vs. Non-VT Gas (N = 104)



	VT Gas (N = 58)	Non-VT Gas (N = 46)	All (N = 104)
Unidentified	17%	6%	12%
Not Insulated	15%	6%	11%
Insulated	68%	88%	77%

As shown in Figure 146, an estimated 49% of water heating systems in new construction facilities do not use a recirculation system. This proportion is consistent across BED and EVT service territories.

Figure 146. Use of Water Heating Recirculation Pump by EEU (N=104)



	BED (N = 7)	EVT (N = 97)	All (N = 104)
Unidentified	0%	17%	16%
Recirc Pump	49%	34%	35%
No Recirc Pump	51%	49%	49%

EEU Market Characterization—HVAC and Water Heating

Table 61 provides a summary characterization of HVAC and water heating measures for Vermont's EEUs.

Table 61. EEU Market Characterization—HVAC and Water Heating

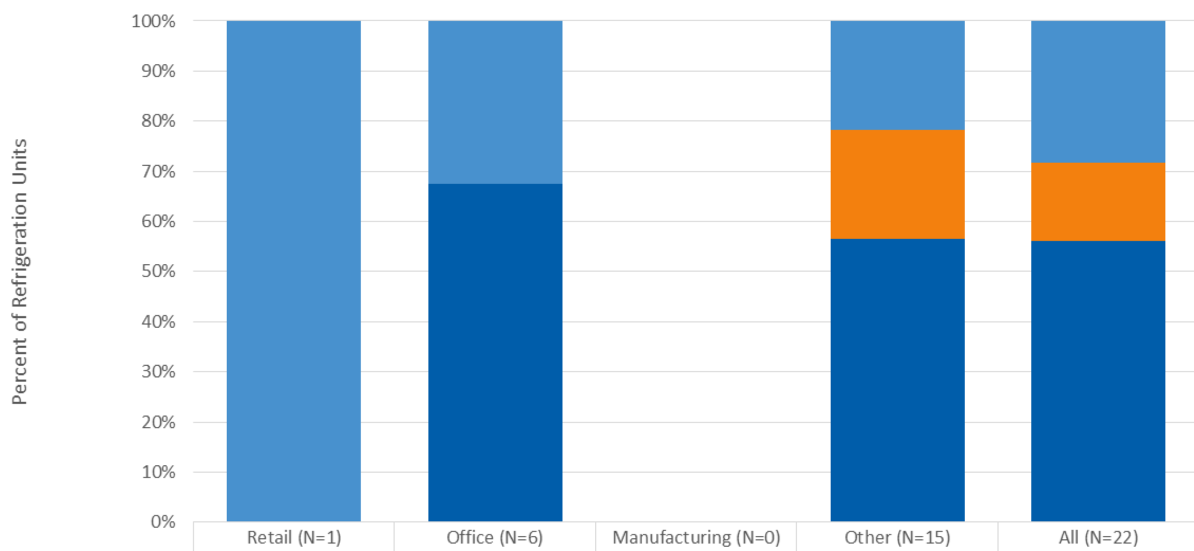
	Measure/ Characteristic	BED	EVT	VT Gas
HVAC	Heating System Types	• Heat pumps and boilers rank as the most common heating systems in Vermont's new construction buildings, comprising 30% and 28% of all systems, respectively. • Stand-alone furnaces account for an additional 17% of systems.		
	Primary Heating Fuel Type	• Electricity is the most common heating fuel type (57%), followed by natural gas (38%).	• Electricity is the most common heat fuel (43%), followed by natural gas (29%) and propane (24%).	• Electricity and natural gas are the primary heating fuels, an estimated 46% and 40% by system count.
	Heating System Efficiency	• All observed boiler and furnace systems exceed the 2015 CBES standards. • Only 8% of water source heat pump units meet the 2015 CBES standards, and 92% fall below the efficiency level.		
	Boiler Delivery Systems	• Al boilers in the new construction sample were identified as having water delivery systems.		
	Hot Water Circulation Pump Speed Controls	• 88% of units are variable speed.	• Most units are single-speed (63%).	• Most units are single-speed (67%).
	Cooling System Types	• By quantity of systems, direct expansion systems are the predominant form of cooling systems in Vermont's new construction building stock (94%).		
	Cooling Efficiency of Single-Zone Unitary HVAC Systems (< 5.5 tons)	• Among small units, the percentage of systems above code is quite high, at 87%.The average EER is 16.6 and average SEER is 20.2. • Medium-sized units meet or exceed code approximately two-thirds (66%) of the time. The average EER is 15.2. • 100% of the observed large systems (greater than 11.25 tons) fell below 2015 CBES standards.		
	Saturation of Economizers in Cooling Systems	• Saturation of systems identified with economizers is low (25%) for units smaller than 4.5 tons, but for larger units the saturation is approximately 50%. However, economizer presence was unidentified in 66% of small units and 36% of large units.		
	Chiller Systems	• Both chillers for which efficiency could be obtained fell below the 2015 CBES code requirements.		
Water Heating	Water Heating Equipment Type	• Stand-alone direct-fired units account for almost half (46%) of installed systems. Boiler and systems fired from boilers represent 35% of systems, and instantaneous systems represent 17%.		
	Water Heating Fuel Types	• Electricity is the primary water heating fuel in the state, followed by propane and natural gas.		

	Water Heating Pipe Insulation	• Approximately 77% of systems have pipe insulation. This proportion is lower in the VT Gas service territory (68%).

Refrigeration

As shown in Figure 147, the Cadmus team identified 56% of non-commercial refrigerators and freezers as ENERGY STAR-qualified, through a combination of on-site inspection and model-number lookups. The team identified 68% of office non-commercial refrigerators as ENERGY STAR-qualified.

Figure 147. Saturation of Non-Commercial ENERGY STAR Refrigerators/Freezers by Facility Type

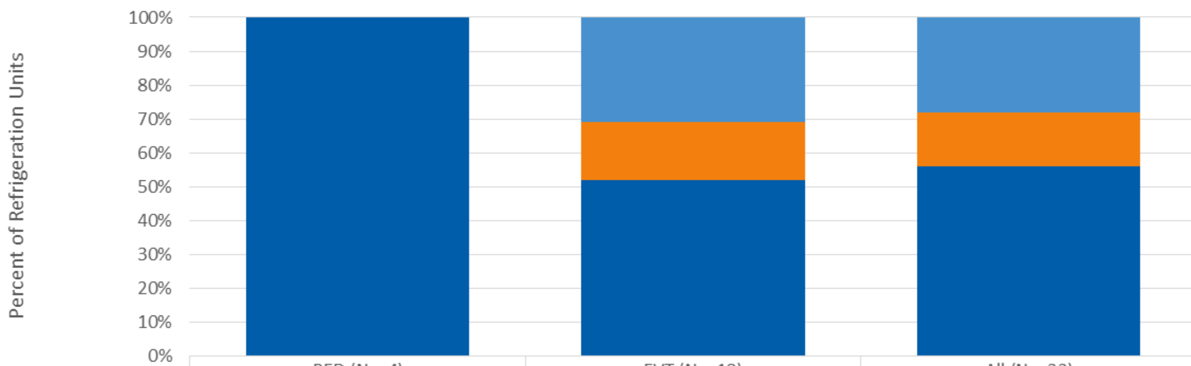


	Retail (N=1)	Office (N=6)	Manufacturing (N=0)	Other (N=15)	All (N=22)
Unidentified	100%	32%	0%	22%	28%
Non-ENERGY STAR	0%	0%	0%	22%	16%
ENERGY STAR	0%	68%	0%	56%	56%

Building Type

The Cadmus team identified all non-commercial refrigerators and freezers found at BED sites, compared with 52% for sites in EVT territory, as shown in in Figure 148. Keep in mind, however, that the sample size of four for BED non-commercial refrigerators and freezers is extremely small.

Figure 148. Saturation of Non-Commercial ENERGY STAR Refrigerators/Freezers by EEU (N=22)



	BED (N = 4)	EVT (N = 18)	All (N = 22)
Unidentified	0%	31%	28%
Non-ENERGY STAR	0%	17%	16%
ENERGY STAR	100%	52%	56%

Table 62 shows that the majority of display case doors (57%) have anti-sweat controls that are always on. A small proportion (28%) are equipped with anti-sweat heater controls.

Table 62. Saturation of Anti-Sweat Controls on Refrigerated Display Case Units (N=14)

Glass Door Anti-Sweat Control Strategy	Percentage of Total Units
Anti-Sweat Heater Controls	28%
Anti-Sweat Always On	57%
Zero Energy Doors	0%
Unidentified	15%
Total	100%

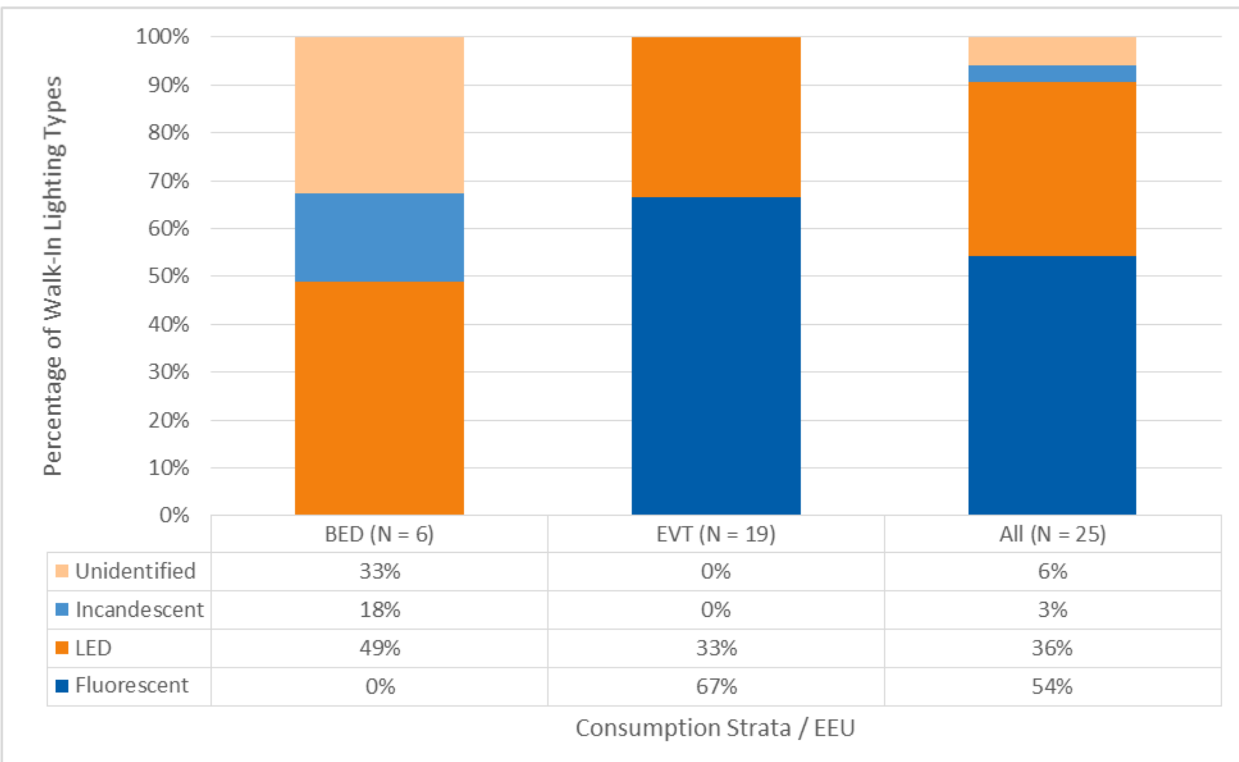
The estimated distribution of display case lighting types is shown in Table 63. Throughout the state, 62% are estimated to be illuminated by fluorescent lamps and 26% by LEDs. Incandescent lighting accounts for 3% of display case lighting.

Table 63. Saturation of Display Case Lighting Types (N=39)

Display Case Lighting	Percentage Total Units
Incandescent	3%
Fluorescent	62%
LED	26%
None	3%
Unidentified	6%
Total	100%

Linear fluorescents are the most common form of walk-in unit lighting statewide (54%), followed by LEDs (36%) and incandescent lamps (3%). There is considerable variation between BED and EVT service territories: the most common walk-in lighting technology in the BED service territory is LED (49%); in the EVT territory, fluorescent lighting ranks as the most common (67%). No fluorescent lighting was identified in walk-in refrigeration units in the BED service territory, as shown in Figure 149.

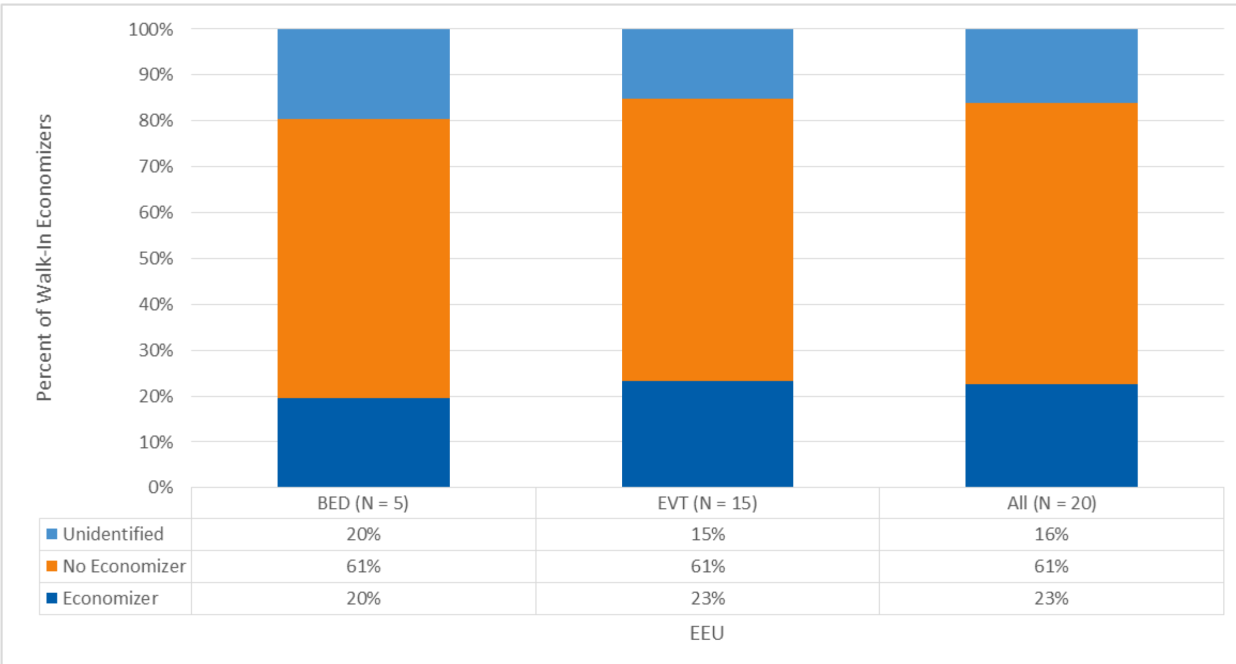
Figure 149. Saturation of Walk-In Refrigeration Unit Lighting Types by EEU (N=25)



As shown in Figure 150, saturation of economizers in walk-in refrigeration units is estimated at 23% in EVT territory and 20% within BED. The EVT findings match those of the 2011 study, which found a saturation of 23% and identified this as an area of significant potential.

As in 2011, the sample size of walk-in refrigeration units in BED jurisdiction is quite small: Sampled facilities in BED territory in 2016 had only six walk-in units, and one of those was a walk-in freezer. The small sample size may not be fully representative of economizers in walk-in refrigeration units in the BED territory.

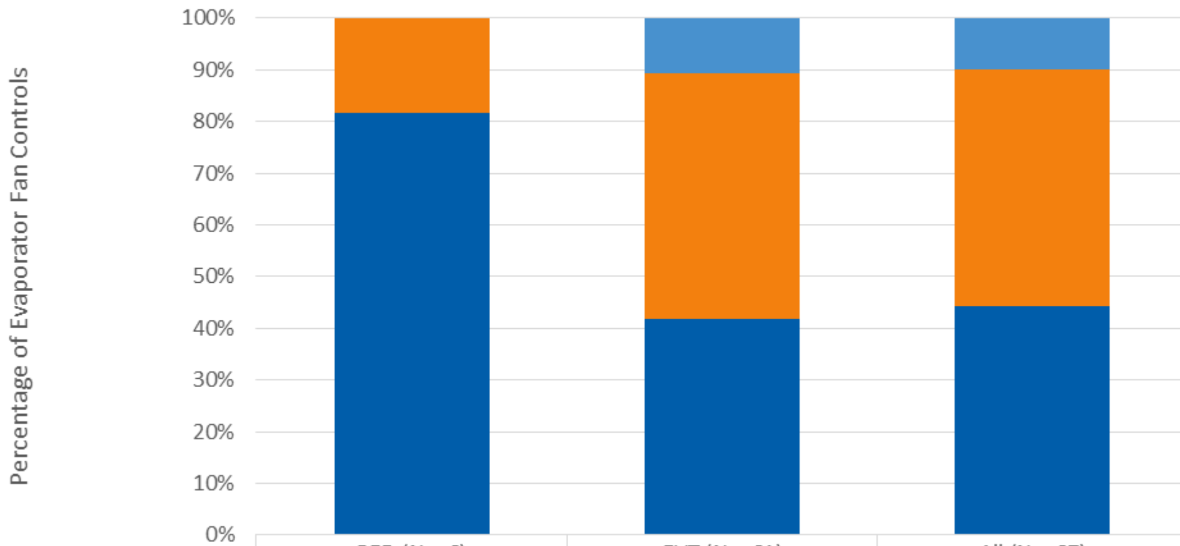
Figure 150. Saturation of Walk-In Refrigeration Unit Economizers by EEU (N=20)*



*Excludes walk-in freezers, which are not good candidate for economizers

Figure 151 shows the distribution of evaporator fan motor controls for walk-in units, by EEU. One significant change from the 2011 study is that a moderate estimated 18% of the walk-in units identified in the BED service territory do not have evaporator fan controls. It is important to note that in both 2011 and 2016, the sample size for BED is quite small. Statewide, approximately half of the walk-in refrigeration units lack evaporator fan motor controls.

Figure 151. Saturation of Walk-In Refrigeration Unit Evaporator Fan Motor Controls by EEU (N=67)



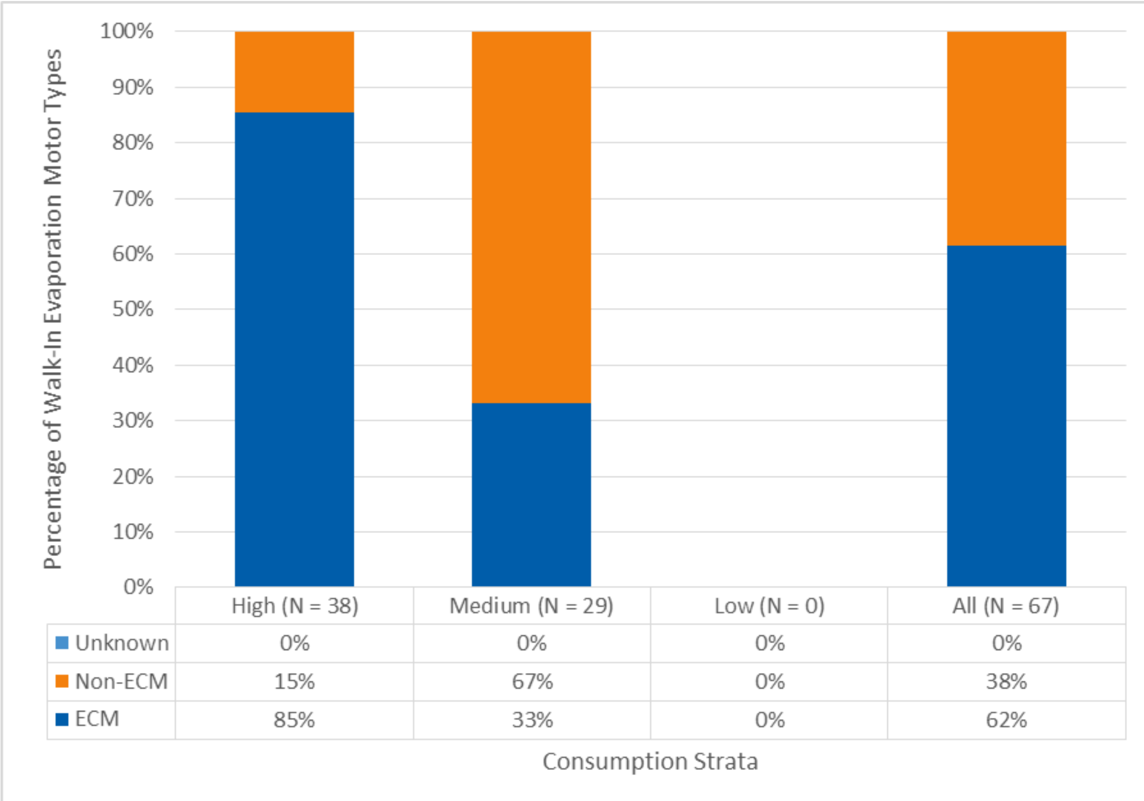
	BED (N = 6)	EVT (N = 61)	All (N = 67)
Unidentified	0%	11%	10%
No Evap Fan Controls	18%	48%	46%
Evap Fan Controls	82%	42%	44%

EEU

*Presented as percentage quantity of motors

ECMs are in use in an estimated 62% of all walk-in refrigeration units statewide, as shown in Figure 152. The highest rate of ECM saturation is found in the Large facility size stratum (85%), followed by the medium-size stratum at an estimated 33%. No walk-in units were identified in the low facility size stratum.

Figure 152. Saturation of Walk-In Refrigeration Unit Evaporation Motor Types by Facility Size

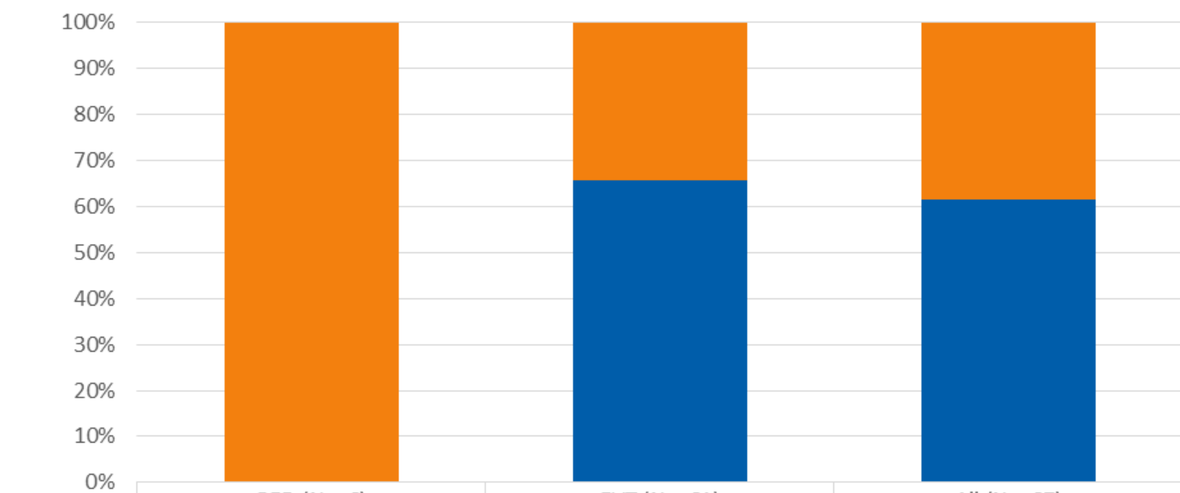


	High (N = 38)	Medium (N = 29)	Low (N = 0)	All (N = 67)
Unknown	0%	0%	0%	0%
Non-ECM	15%	67%	0%	38%
ECM	85%	33%	0%	62%

*Presented as percentage quantity of motors

No ECMs were identified in the BED service territory, as shown in Figure 153, though, as previously, the sample size of walk-in units in the BED jurisdiction is quite small (at six). Over half (66%) of walk-in units in EVT service territory are estimated to be equipped with ECMs.

Figure 153. Saturation of Walk-In Refrigeration Unit Evaporation Motor Types by EEU (N=67)

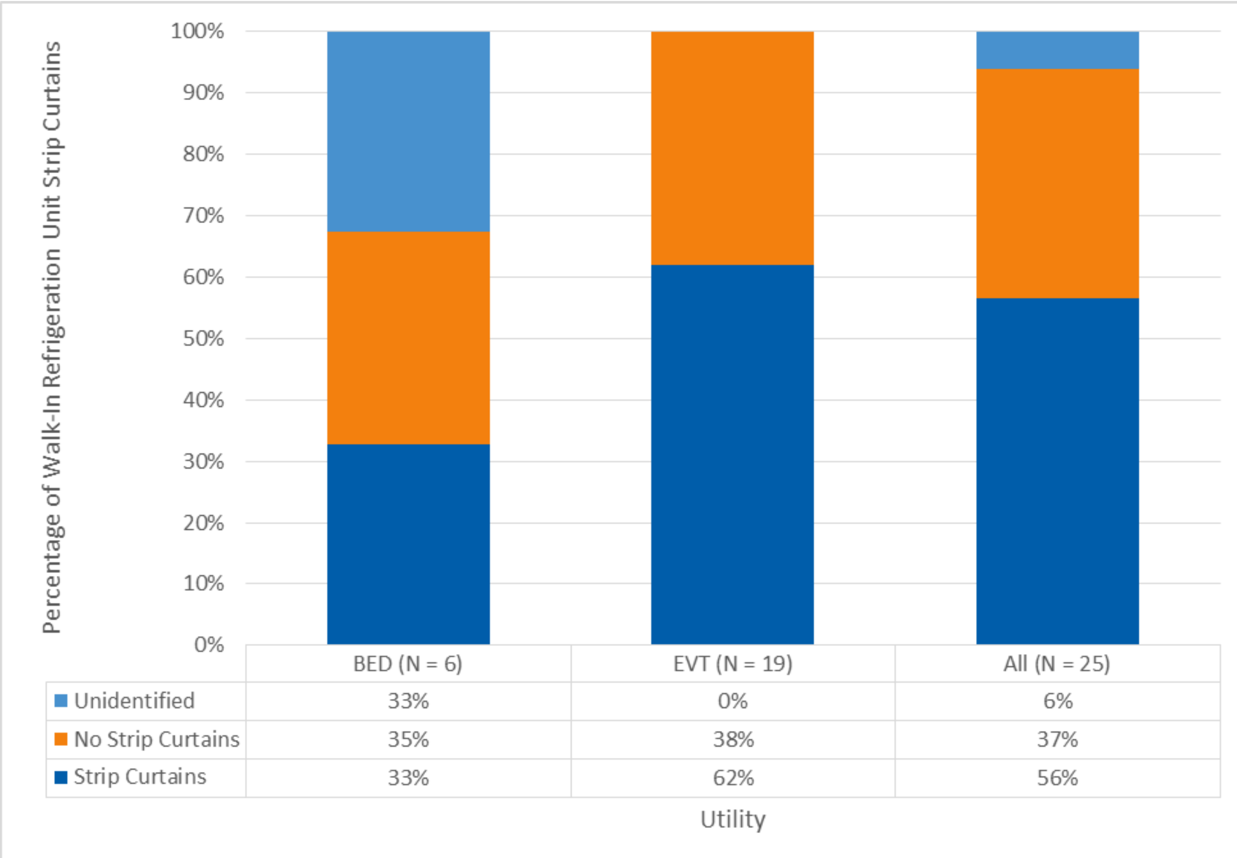


	BED (N = 6)	EVT (N = 61)	All (N = 67)
Unknown	0%	0%	0%
Non-ECM	100%	34%	38%
ECM	0%	66%	62%

*Presented as percentage quantity of motors

Over half of the walk-in coolers in the EVT territory and statewide are equipped with strip curtains (62% and 56%, respectively). Figure 154 shows that similarly, the percentage of walk-ins without strip curtains is very similar between EVT (38%) and statewide (37%).

Figure 154. Saturation of Walk-In Refrigeration Unit Strip Curtains by EEU (N=25)



During site visits for this study, surveyors were not able to determine whether or not refrigeration systems use floating head pressure controls.

EEU Market Characterization—Refrigeration

Table 64 provides a summary characterization of refrigeration measures for Vermont's EEUs.

Table 64. EEU Market Characterization—Refrigeration

Measure/Characteristic	BED	EVT
ENERGY STAR non-commercial refrigerators	• The majority (58%) of refrigerators and freezers identified in BED territory meet the requirements for ENERGY STAR certification.	• Nearly all identified refrigerators and freezers in the EVT service territory did not meet ENERGY STAR requirements.
Anti-sweat heater controls	• Anti-sweat heater controls are estimated to be present in 28% of refrigerated display case units.	
Refrigerated display case lighting	• Only one unit was observed in the BED service territory, and the	• Fluorescent lighting accounts for 62% of refrigerated case lighting,

	display case lighting technology could not be identified.	followed by LED lighting in 27% of systems.
Walk-in cooler lighting	• LED lighting is the dominant lighting type in the BED territory, accounting for 49% of observed technologies. Incandescent lamps account for 18%. • Lighting technology was not be identified in 33% of units.	• Fluorescent lighting in the most common walk-in lighting technology, accounting for 67% of installed lighting. • LEDs account for the remaining 33% of lighting.
Walk-in cooler economizers	• Approximately 18% of systems statewide were equipped with economizers.	
Walk-in cooler evaporator fan motor types	• Almost two-thirds of evaporator fan motors (62%) statewide are ECM units.	
Evaporator fan motor controls in walk-in coolers	• Most (82%) of the BED evaporator fans were equipped with fan controls. • 18% of units did not have evaporator fan controls.	• 42% of evaporator fan motors are equipped with evaporator fan motor controls.
Strip curtains on walk-in refrigeration units	• The saturation of units with strip curtains statewide is estimated at 56%. EVT territory saturation is 62%. (62%) is nearly double the saturation in BED territory.	

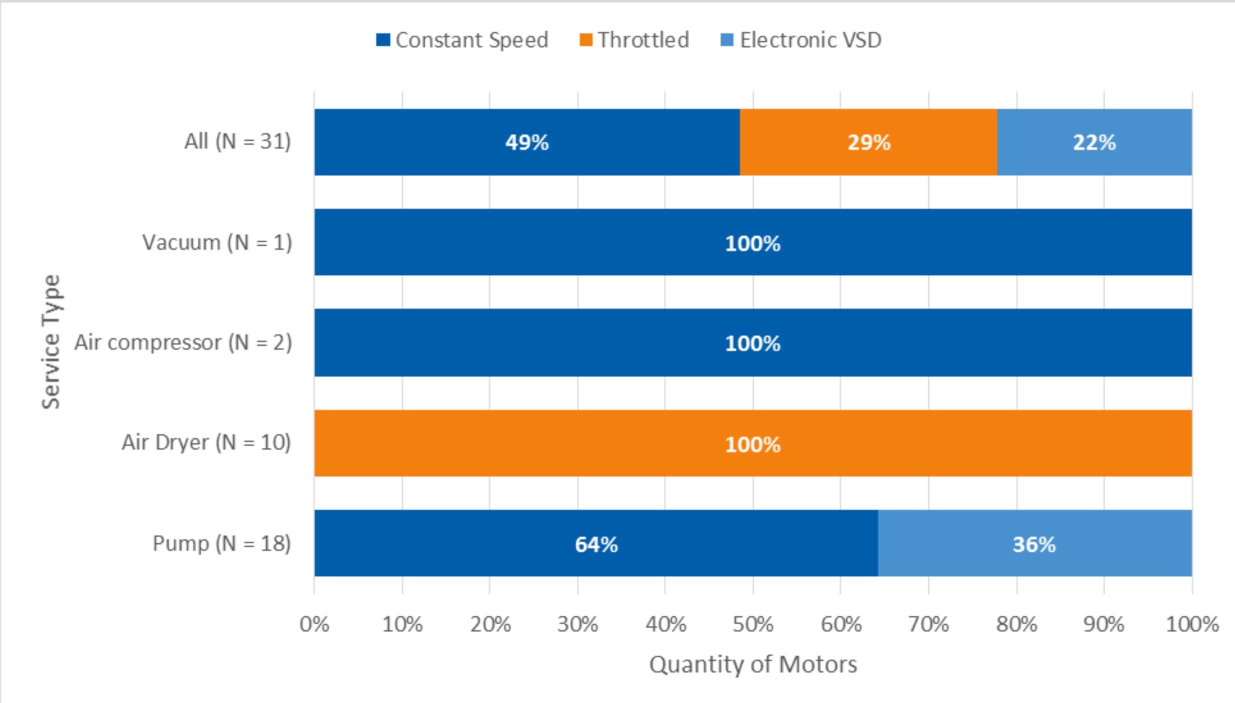
Motors and Compressed Air

Motors

During the 2016 site visits, a total of 31 process motors were identified. Surveyors were able to collect the information necessary to determine the efficiency level of approximately half the motors—14. Of those 14, half met standard NEMA specifications, and the other half were NEMA premium motors.

The estimated distribution of motor control types by service type is shown in Figure 155. Approximately half (49%) of all motors are constant speed, 29% are throttled, and the remaining 22% are equipped with VSD controls. All of the VSD-equipped motors serve pumps.

Figure 155. Distribution of Process Motor Control Types by Service Type (N=31)



Compressed Air

As shown in Table 65, an estimated 62% of l air compressors in use at new construction facilities are reciprocating two-state, double-acting compressors. An additional 12% are centrifugal, with the balance of 26% unknown.

Table 65. Distribution of Air Compressors by Type

Air Compressor Type	All Buildings (N=7)
Reciprocating (Single-stage, single-acting)	0%
Reciprocating (Single-stage, double-acting)	0%
Reciprocating (Two-stage, double-acting)	62%
Reciprocating (Two-stage, single-acting)	0%
Rotary Screw (Two-stage)	0%
Centrifugal	12%
Unknown	26%
Other	0%
All	100%

Table 66 shows the estimated weekly hours of use of air compressors in new construction facilities. Approximately 12% of all air compressors operate 24 hours per day, which is similar to the 10% finding from 2011. However, the majority of the air compressors identified in 2011 (64%) operated less than 10 hours per week, compared to only 15% as estimated by this study. The majority of air compressors identified in 2016 operate between 50 and 99 hours per week.

Table 66. Air Compressor Hours of Use per Week by Bin

Hours	All Buildings (N=7)
<10	15%
11–49	11%
50–99	62%
100–167	0%
168	12%
Unknown	0%

Table 68 shows the distribution of cycling air dryers on compressed air systems. Similar to the 2011 study, only a small portion (12%) of dryers operate continuously. The majority (62%) of compressed air systems identified in 2016 do not have an air dryer. This again is very similar to the 2011 study, which found that 76% of compressed air systems had no air dryer.

Table 67. Saturation of Cycling Air Dryers on Compressed Air Systems

Compressor Air Dryer Type	All Buildings (N=7)
Continuous Dryer	12%
Cycling Dryer	0%
No Dryer	62%
Unknown	26%

3.6.3 EEU Market Characterization—Motors and Compressed Air

Table 68 provides a summary characterization of motor and compressed air measures for Vermont's EEUs.

Table 68. EEU Market Characterization—Motors and Compressed Air

<table>
<tr><th>Measure/Characteristic</th><th>BED</th><th>EVT</th></tr>
<tr><td>Motor efficiency</td><td colspan="2">• Only 22% of motors were identified as having variable speed controls. Nearly half of all motors are constant speed.</td></tr>
<tr><td>Air compressor types</td><td colspan="2">• The majority of air compressors identified are two-stage double-acting reciprocating compressors (62%).</td></tr>
<tr><td>Air compressor hours of use</td><td colspan="2">• Most compressors (62%) operate between 50 and 99 hours per week, 12% operate continuously, and 15% operate less than 10 hours per week.</td></tr>
<tr><td>Cycling air dryer on compressed air systems</td><td colspan="2">• Continuous air dryers were identified on 12% of air compressors. Approximately 62% of air compressors have no air dryer</td></tr>
</table>

Assessment of CBES Compliance

Study Methodology

The Vermont DPS directed Cadmus to measure statewide compliance with the 2011 CBES and the 2015 CBES in newly constructed buildings. Cadmus reviewed the methodology used by Navigant to collect and analyze energy code compliance data during their compliance assessment on the 2005 CBES to ensure consistency between the two studies. Cadmus found that the methodology used is consistent with that developed by the U.S. Department of Energy (DOE) Building Energy Codes Program (BECP)[6] and incorporated the checklists into the on-site survey forms created for the baseline study. We describe the methodology below.

Data Collection

Cadmus reviewed the U.S. DOE commercial energy code compliance data collection tool and incorporated the code related information (e.g. energy code provision numbers, brief description of the feature, etc.) into the Cadmus iPad data collection tool. Cadmus completed the code compliance data collection in conjunction with its site visits for the baseline market study. Data were collected from direct observation wherever possible and secondarily from building plans and specifications reviewed while on site. In a few cases building envelope data was neither observable nor available in the project documentation. In these cases Cadmus conducted interviews with owner's representatives present at the time of construction in an attempt to ascertain the installed materials.

Scoring Compliance

Each energy code measure reviewed as part of the data collection process was evaluated for compliance based on comparing the measure against the prescriptive requirements for that measure in the CBES. This method is consistent with the U.S. DOE Energy Code Compliance methodology[1] if no other energy code compliance documentation was available for review (e.g., COM*check* energy code compliance forms).

The methodology that Cadmus used for scoring compliance with individual requirements follows the methodology used by Navigant and the U.S. DOE. Each provision is assigned a tier weighting based on impact on the energy use of a typical building, with the lowest tier number representing the greatest impact on energy use and therefore given the highest number of weighting points, as shown in Table 69.

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6 *Measuring State Energy Code Compliance (March 2010)* https://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf

Table 69. Tier Weighting Points

Level of Importance	Tier Number	Points
Most Important	1	3
Important	2	2
Least Important	3	1

The data collection team made the following observations when completing the data collection checklist:

- Complied—Energy code provision complied with requirements
- Does not comply—Energy code provision did not comply with the requirements
- Not observable—Verifying compliance or non-compliance was not possible because the feature was inaccessible and, therefore, could not be observed
- Not applicable—the energy feature was not required to be installed as part of the project

Scores were then assigned to each provision based on the assigned tier and on the observation (see Table 70).

Table 70. Energy Code Compliance Scoring Matrix

Measure Observance	Tier	Points Possible	Points Received
Complies	1, 2 or 3	1, 2, or 3	1, 2, or 3
Does not Comply	1, 2, or 3	1, 2 or 3	0
Not Observable	1, 2, or 3	0	0
Not Applicable	1, 2 or 3	0	0

Overall compliance scores for all buildings included in the sample are determined based on the following calculation:

Sum of Points Received/Sum of Points Possible = Compliance Score

Proposed Sample Plan

The overall sample included 48 buildings that were classified as:

Table 71. Compliance Study Occupancy Types

Occupancy Type	Number of Buildings
Manufacturing	1
Office	7
Retail	4
Other*	36
Total	48

* "Other" includes high-rise multifamily, public service, restaurant, schools, and warehouse

Energy Code Compliance Results—2011 CBES

The overall compliance rate with the 2011 VCBES was found to be 92%, as shown in Table 72. This exceeds the U.S. DOE commercial energy code compliance rate of 90% mandated for all states receiving ARRA funding. One general provision was reviewed to ensure that operation and maintenance (O&M) manuals for HVAC systems were on site. The presence of O&M manuals could not be verified in seven of the sites but was confirmed at the remaining 41, providing a compliance rate of 100%.

Compliance rates were heavily weighted toward HVAC code provisions such as minimum HVAC equipment efficiency and duct insulation, as these provisions were typically more readily observed than other energy features in the building during the site visit. The building envelope compliance scores included reviewing insulation R-values and placement, window-to-wall area, and vestibules. The lighting compliance rate accounted for compliance features such as lighting control provisions, automatic lighting shut-off, interior lighting power density, and maximum wattage for exit signs. The primary features for water heating systems included water heater efficiency, limitations on hot water temperature from public lavatories, and time clock controls on circulation pumps.

Table 72. Technical Compliance with 2011 CBES

Category	Points Possible	Points Received	Total Score
General	39	39	100%
HVAC	895	838	94%
Envelope	600	531	89%
Lighting	735	671	91%
Swimming Pool	3	2	67%
Water Heater	240	219	91%
Total	2512	2300	92%

Table 73 provides energy code compliance by occupancy type and demonstrates that 90% compliance was achieved by all occupancy categories reported by this study except retail (84%). Manufacturing had a 95% compliance rate based on all of the code provisions that could be observed as part of the onsite visit including envelope, HVAC, lighting, and water heating measures. Offices were approximately 91% compliant. Areas of non-compliance included not including a vestibule in the design; lack of required lighting controls for daylighting, automatic shut-off, and manual controls to reduce the lighting levels by 50%; and lack of heat traps installed on storage water heating. Non-compliant wall insulation was found in three of the projects in addition to greater than allowed lighting power densities (ALPDs). Non-compliant features in the “other” category were similar to those in the manufacturing, retail, and office facility types.

Table 73. 2011 CBES Compliance by Occupancy

Occupancy Type	Points Possible	Points Received	Total Score
Manufacturing	40	38	95%
Office	392	355	91%
Other	1755	1652	94%
Retail	298	250	84%

Table 74 provides a summary of the features that were found to be non-compliant compared to the 2011 CBES. These measures were compared against the prescriptive requirements of the energy code and also the mandatory measures—those that not allowed to be traded off. Non-compliance with wall insulation had the greatest number of occurrences. This typically occurred in buildings using metal studs for exterior wall systems with insufficient cavity insulation or an insufficient combination of cavity and continuous insulation. In four projects, vestibules were not installed on exterior doors leading from spaces 3,000 sq ft or greater. The maximum glass percentage allowed by the prescriptive approach of 40% window-to-wall ratio was exceeded in three of the buildings.

Economizers accounted for the occurrence of non-compliance with the mechanical provision of the CBES. Economizers are required on all systems with cooling capacities of at least 54,000 Btu/h. HVAC controls that limit simultaneous heating and cooling and that have a 5°F deadband between heating and cooling were not installed in four of the projects. Electric resistance back-up heat was found in one heat pump system, violating a CBES provision that prohibits the use of electric resistant heat in commercial buildings including back-up heat in heat pumps. (Electric resistance heat built into a heat pump may only be used during defrost.)

Shortcomings with lighting controls accounted for the majority of non-compliance for lighting systems. The most common cause of non-compliance was lack of automatic lighting shut-off for buildings greater than 5,000 sq ft. Typically, this is met either by installing occupancy sensors, an automatic lighting control system, or a combination of the two to turn off all lights in the building. Twelve facilities lacked such automatic control. Non-compliance with daylighting control requirements occurred in six projects. Cadmus has found high rates of non-compliance with this requirement in commercial energy code evaluations conducted in several cities and states and has found that this is caused by a lack of knowledge of daylighting zones by both the designer and enforcement personnel. The installed lighting power densities found in all but four projects complied with the maximum ALPDs.

Service water heating features that were found in non-compliance included not installing heat traps on water heaters that are not connected to a circulation loop, and lack of temperature controls on storage water heaters to regulate the temperature to reduce the chance of scalding.

Only one project included a heated swimming pool. In this case there was no timeclock controls on the pool heaters and pumps, resulting in non-compliance with the CBES.

Table 74. Summary of Energy Non-Compliant Energy Code Checklist Requirements for the 2011 CBES

Category	Tier*	CBES Code Requirement	Number of Non-Compliant Sites**
Building Envelope	1	Wall insulation R-value meeting minimum R-value requirements.	14
	3	Vestibules are installed where building entrances separate conditioned space from the exterior.	4
	1	Maximum window area exceeds 40% fenestration to exterior wall area.	3
	3	Freeze protection and snow/ice melting system sensors for future connection to controls.	1
	1	Roof insulation R-value meets minimum R-value requirements.	1
Mechanical Systems	1	Zone controls can limit simultaneous heating and cooling and sequence heating and cooling to each zone.	4
	2	Thermostatic controls have a 5 °F deadband.	4
	1	HVAC Equipment performance.	1
	2	HVAC ducts and plenums insulated.	1
	1	Integrated economizers on cooling systems ≥ 54,000 Bth/h***	7
	2	Heating and cooling to each zone is controlled by a thermostat control.	1
	3	HVAC systems equipped with at least one automatic shutdown control.	1
	3	Setback controls allow automatic restart and temporary operation as required for maintenance.	1
	2	Ducts and plenums sealed based on static pressure and location.	1
Lighting Systems	2	Automatic lighting control to shut off all building lighting installed in buildings >5,000 sq ft.	12
	2	Daylight zones provided with individual controls that control the lights independent of general area lighting.	6
	1	Lighting controls installed to uniformly reduce the lighting load by at least 50%.	4
	1	Interior lighting power density meets the interior lighting power allowance in Table 505.5.2(1) Whole Building	3
	3	Ballasted one- and three-lamp fixtures with >30 W/lamp have two-lamp tandem wired ballasts when >=2 fixtures in same space on same control.	2
	3	Sleeping units have at least one master switch at the main entry door that controls wired luminaires and switched receptacles.	2
	1	Exit signs do not exceed 5 watts per face.	1
Service Water Heating	3	Heat traps installed on non-circulating storage water tanks.	6
	3	Temperature controls installed on service water heating systems <=110 ºF for intended use serving dwelling units and <=90 ºF serving other occupancies.	5
	2	Insulate automatic circulating hot water systems and first eight feet of non-circulating systems without integral heat traps.	4
	3	Public lavatory faucet water temperature <=110 ºF.	2

Pools and Spas	3	Time switches are installed on all pool heaters and pumps.	1

* Tier levels designate level of typical energy impact in commercial buildings where 1 = Highest Impact (3 Points), 2 = Impact (2 Points) and 3 = Lowest Impact (1 Point)
** Non-compliant energy code compliance features ordered from greatest occurrence to least occurrence
*** Economizer non-compliance only for cooling systems where cooling capacity is recorded

Energy Code Compliance Results—2015 CBES

The overall rate of compliance with the 2015 CBES for the building sample was 90%, which meets the U.S. DOE energy code compliance threshold.

Significant changes between the 2011 and 2015 CBES impacted the compliance rates. The maximum window-to-wall ratio that prescriptive code requires was lowered to 30% from 40%. Insulation levels in wall and roof assemblies were also increased. For lighting systems, the ALPD was reduced for most occupancy types, and occupancy sensors were upgraded from optional to required in several space types in commercial buildings. Equipment efficiency for cooling equipment was also increased. These changes were included in determining compliance scores.

For the building envelope, the compliance rates dropped by 1% because of the increase in insulation R-value requirements and the reduction in the allowed window-to-wall ratio. Lighting compliance resulted in the greatest reduction (4%), primarily because of the reduced ALPD and, to a greater extent, the additional requirement for occupancy sensors in several space types in the building. As reported below, only six lighting systems installed in projects did not comply with 2015 ALPD requirements, despite the significant reduction in ALPD between the 2011 and 2015 CBES.

Table 75. Technical Compliance with 2015 CBES

Category	Points Possible	Points Received	Total Score
General	39	39	100%
HVAC	853	808	95%
Envelope	778	687	88%
Lighting	812	705	87%
Swimming Pools	3	2	67%
Water Heating	240	219	91%
Total	2725	2460	90%

Compliance rates for all occupancies lowered between the 2011 and 2015 CBES. Manufacturing experienced the largest drop (18%) primarily as a result of the increased lighting control requirements and increased insulation requirements. The reduction in compliance rates for projects included in the office and “other” category were also a result of the reduction in ALPD and occupancy sensor requirements. Retail compliance changed by 1% because the installed lighting power densities were less than the 2015 ALPD, performing better than expected, and there were very few spaces where occupancy sensors were required but, there were HVAC systems that required economizers that were not found on the systems.

Table 76. 2015 CBES Compliance by Occupancy

Occupancy Type	Points Possible	Points Received	Total Score
Manufacturing	44	34	77%
Office	418	365	87%
Other	1925	1759	91%
Retail	328	272	83%

Table 77 provides a summary of the features that were found to be non-compliant compared to the 2015 CBES. This table reflects those provisions that were found to be non-compliant in the 2011 CBES in addition to the increased stringency of the provisions in the 2015 CBES.

Both wall and roof insulation R-values were increased as part of the 2015 CBES. The increase in insulation levels resulted in more non-compliance for wall systems (14 to 16 occurrences) and 12 additional occurrences for roof insulation. Required roof insulation was increased from R-38 to an R-49 for insulation installed in the framing cavities. Lowering the window-to-wall ratio from 40% to 30% resulted in only one additional occurrence of non-compliance.

Economizers accounted for the greatest occurrence of non-compliance with the mechanical provision of the CBES. Economizers are required on all cooling systems greater than 54,000 Btu/h. The increase in HVAC system also resulted in a high non-compliance rate. The SEER rating for cooling systems less than 65,000 Btu was increased from 13 to 14 SEER. This resulted in four more projects not complying with energy code than with the 2011 CBES.

The 2015 CBES occupancy sensor requirements resulted in the greatest occurrence of non-compliance for the lighting system provisions of the CBES. Thirty of the projects did comply with the requirements. The number of occurrences of non-compliance doubled from three to six for meeting the ALPD requirements. This was a direct result of a significant lowering of ALPD between the 2011 and 2015 CBES.

There were no changes to the occurrences of non-compliance with water heating and swimming pool provision between the 2011 and 2015 CBES.

Table 77. Summary of Energy Non-Compliant Energy Code Checklist Requirements for the 2015 CBES

Category	Tier*	CBES Code Requirement	Number of Non-Compliant Sites**
Building Envelope	1	Wall insulation R-value meeting minimum R-value requirements.	16
	1	Roof insulation R-value meets minimum R-value requirements.	13
	3	Vestibules are installed where building entrances separate conditioned space from the exterior.	4
	1	Maximum window area exceeds 40% fenestration to exterior wall area.	4
	3	Freeze protection and snow/ice melting system sensors for future connection to controls.	1
Mechanical Systems	1	HVAC Equipment performance.	5
	1	Zone controls can limit simultaneous heating and cooling and sequence heating and cooling to each zone.	4
	2	Thermostatic controls have a 5°F deadband.	4
	2	HVAC ducts and plenums insulated.	1
	2	Heating and cooling to each zone is controlled by a thermostat control.	1
	3	HVAC systems equipped with at least one automatic shutdown control.	1
	3	Setback controls allow automatic restart and temporary operation as required for maintenance.	1
	2	Ducts and plenums sealed based on static pressure and location.	1
	1	Integrated economizers on cooling systems ≥ 54,000 and greater[3]	7
Lighting Systems	2	Lighting system shall be provided with occupancy sensor controls.	16
	2	Automatic lighting control to shut off all building lighting installed in buildings >5,000 sq ft.	12
	2	Daylight zones provided with individual controls that control the lights independent of general area lighting.	6
	1	Interior lighting power density meets the interior lighting power allowance in Table 505.5.2(1) Whole Building.	6
	1	Lighting controls installed to uniformly reduce the lighting load by at least 50%.	4
	3	Ballasted one and three lamp fixtures with >30 W/lamp have two lamp tandem wired ballasts when >=2 fixtures in same space on same control.	2
	3	Sleeping units have at least one master switch at the main entry door that controls wired luminaires and switched receptacles.	2
	1	Exit signs do not exceed 5 watts per face.	1
	3	Heat traps installed on non-circulating storage water tanks.	6

Category	Tier*	CBES Code Requirement	Number of Non-Compliant Sites**
Service Water Heating	3	Temperature controls installed on service water heating systems <=110 ºF for intended use serving dwelling units and <=90ºF serving other occupancies.	5
	2	Insulate automatic circulating hot water systems and first eight feet of non-circulating systems without integral heat traps.	4
	3	Public lavatory faucet water temperature <=110ºF.	2
Pools and Spas	3	Time switches are installed on all pool heaters and pumps.	1

* Tier levels designate level of typical energy impact in commercial buildings where 1 = Highest Impact (3 Points), 2 = Impact (2 Points) and 3 = Lowest Impact (1 Point)
** Non-compliant energy code compliance features ordered form greatest occurrence to least occurrence

Comparison to Past Compliance Studies

Compliance rates with the 2011 and 2015 CBES exceed those for the 2005 CBES described in the 2011 Vermont Market Characterization and Assessment Study. The overall compliance rate reported in 2011 was 88% compared to 92% for the 2011 CBES and 90% for the 2015 CBES. Compliance rates increased for HVAC, lighting systems, and service water heating and decreased for building envelope features in the 2011 results. The results were consistent when comparing the 2015 CBES to the 2011 CBES as HVAC, lighting, and HVAC all reported greater compliance rates; envelope showed lower compliance than those reported in the 2005 CBES study The 2005 study did not report compliance with general or swimming pools, but the compliance scores for these represented less than 2% of the total points available and had a minimal impact on the total compliance score.

Assessment of Missed Opportunities

For the purposes of this study, the term *missed opportunities* refers to improvements that might reasonably have been made during construction of the facility, above and beyond attributes required by code. Failure to meet code is considered non-compliance, not a missed opportunity, though missed opportunities are often considered for future code revisions.

Consistent with the 2011 market assessment study, Cadmus adhered to the followed definition of missed opportunities: *Used for the new construction and major remodel markets, to identify measures that could have been reasonably and likely cost-effectively added in the design/ building phase but were not. Missed opportunities may or may not be cost effective to retrofit, now that the building is constructed.*

Cadmus identified missed opportunities by comparing facility attributes collected during site visits against a list of opportunities compiled from past Vermont market assessment studies and current best practices and stretch goals.

Lighting—Missed Opportunities

The installation of switched receptacles for private and open office spaces, high efficacy lighting for multifamily dwelling units, and luminaire level lighting controls on long tube LED and florescent lighting systems represent potential increases in efficiency in sample buildings.

Switched Receptacles

We define the opportunity for installation of switched electrical receptacles as providing occupancy sensor or time-of-day controls for at least 50% of the receptacles in private offices, open offices, conference rooms, rooms used primarily for copying functions, breakrooms, individual workstations, and classrooms. We identified this characteristic, which is not required by the 2015 CBES, as applying to all office and school buildings. This opportunity would effect a minimum of nine (see Table 78) of the buildings in the sample identified as office and school but would also apply to offices in any building designation.

Table 78. Missed Opportunities—Installation of Switched Receptacles

Missed Opportunity	Number of Observations	Percentage of Total Observations*
Install switched receptacles in offices and schools	9	19%

* Based on total number of buildings
Source: Cadmus on-site survey

High-Efficacy Lighting for Multifamily Dwelling Units

This improvement requires 90% of the installed lighting in high-rise dwelling units to meet high-efficacy lighting requirements defined in Table 79, which exceed 2015 CBES requirements.

Table 79. High-Efficacy Lighting Thresholds

Bulb Wattage	Efficacy (luW)
> 40 Watts	90
15–40 Watts	60
5–15 Watts	45
< 5 Watts	30

Typically the efficacies will result in the installation of LED bulbs to meet the requirements. Based on the survey data, 57% of the installed lights would be effected by this opportunity (see Table 80).

Table 80. Missed Opportunities—Installation of High-Efficacy Lighting

Missed Opportunity	Number of Observations**	Percent of Total Observations*
High-efficacy lighting requirements for multifamily	138	57%

* Based on total number of lights surveyed in buildings
** Observations are for none LED lights
Source: Cadmus on-site survey

Luminaire Level Lighting Controls

Another key opportunity with lighting involves luminaire level lighting controls (LLLC), which include occupancy sensor and daylighting controls for each luminaire (long tube), in private and open office arrangements. Estimates show a savings of approximate 40 to 60%over controls required by current energy code.[7] LLLC is recommended for office and school occupancies. Data collected on lighting systems showed no observations of LLLC installed on the lighting systems. Table 81 shows the number of observations that would be effected by this lighting control.

Table 81. Missed Opportunities—Installation of LLLC

Missed Opportunity	Number of Observations**	Percentage of Total Observations*
Luminaire level light control	711	53%

* Based on total number of light fixtures for office and school
** Long tube fluorescents

HVAC—Missed Opportunities

Two HVAC opportunities were identified as opportunities for the sampled buildings—dedicated outdoor air systems (DOAS) and HVAC commissioning.

[7] Luminaire Level Lighting Controls, Northwest Energy Efficiency Alliance. http://neea.org/initiatives/commercial/luminaire-level-lighting-controls

Dedicated Outdoor Air Systems

DOAS decouples the ventilation system from the heating and cooling system. This allows the heating and cooling system to operate only when heating or cooling is needed, reducing run time, and employs separate energy recovery ventilation (ERV) or heat recovery ventilation (HRV) systems to provide ventilation with a much lower energy penalty. DOAS requires an ERV or HRV for each ventilation system and assumes that 100% of the outdoor air is provided to the space without requiring the use of the heating or cooling system to operate. If applied only to single zone systems, the sampled data showed that DOAS could apply to 31 of the installed systems (see Table 82).

Table 82. Missed Opportunities—DOAS

Missed Opportunity	Number of Observations	Percentage of Total Observations*
Dedicated Outdoor Air Systems applied to single zone systems	31	19%

* Based on total number of HVAC systems observed

HVAC Commissioning

HVAC commissioning is currently required in the 2015 CBES but only for buildings greater than 50,000 sq ft, which is significantly larger than the calculated floor area based on the equipment capacity threshold from the 2015 IECC. For this opportunity, we set the goal as providing commissioning for HVAC systems in buildings that have a total cooling capacity of 480,000 Btu/h and/or heating capacity of 600,000 Btu/h for combined service water-heating and space-heating, per the 2015 IECC. For cooling, this results in commissioning buildings with approximately 20,000 sq ft and above versus the current CBES requirement of 50,000 sq ft and above. Table 83 shows the number of buildings that are required to be commissioned under the 2015 CBES and the additional buildings that would be required under the new requirements.

Table 83. Missed Opportunities—HVAC Commissioning

Missed Opportunity	Number of Observations	Percentage of Total Observations*
Buildings currently required to be commissioned under the CBES	5	10%
Require commissioning on HVAC systems in buildings greater than 20,000 sq ft (additional buildings)	8	17%
Total	13	27%

* Based on total number of buildings in sample

Building Envelope—Missed Opportunities

Cadmus considers reduced air leakage a missed opportunity for commercial buildings included in the sample. The opportunity is based on a review of the current testing and air barrier requirements in the 2015 CBES.

Envelope Air Leakage Testing

We define this opportunity as providing air leakage testing and limits for residential and institutional buildings greater than 6,000 sq ft and greater than 40,000 sq ft for all other occupancies. Air leakage should not be greater than 0.40 cfm/sq ft of the building thermal envelope when tested at 75 Pa. The opportunity also includes providing air barrier commissioning for all other buildings. The 2015 CBES requires a maximum leakage rate of 0.50 cfm/sq ft with testing as an option. The envelope testing and envelope air barrier commissioning requirements would apply to all buildings that are heated and/or cooled (see Table 84).

Table 84. Missed Opportunities—Envelope Air Leakage Testing

Missed Opportunity	Number of Observations	Percentage of Total Observations*,**
Air leakage testing for multifamily > 6,000 sq ft	4	9%
Air leakage testing for other occupancies greater than 40,000 sq ft	5	10%
Air barrier commissioning	38	81%
Total	47	100%

* Testing or commissioning does not apply to parking garage

** Observations based on total number of buildings

Water Heating—Missed Opportunities

Water heating systems must comply with the provisions of the 2015 CBES relating to water heater efficiency, piping insulation, and demand response controls on circulation systems. Cadmus considers reduced flow rates for shower heads as a missed opportunity.

New Flow Rates for Shower Heads

This opportunity limits the flow rate for fixed and handheld shower heads to no greater than 2.0 gpm at 80psi (*WaterSe*nse specification). Reducing the flow rate will result in both energy and water savings. The current Federal mandated maximum flow rates is 2.5 gpm. Table 85 provides information on the number of buildings in the sample that would be impacted by this opportunity.

Table 85. Missed Opportunities—Reduced Flow Rate Shower Heads

Missed Opportunity	Number of Observations*	Percentage of Total Observations**
Reduced flow rate shower heads	4	8%

* Number of multifamily buildings

** Observations based on total number of buildings

Refrigeration—Missed Opportunities

Walk-in coolers and freezers can utilize outdoor air to offset energy use by refrigeration systems during colder months of the year. Economizers are recommended for these systems as a missed opportunity

Economizers

This missed opportunity involves installation of economizers on refrigeration systems serving walk-in coolers and freezers. Economizers installed on these systems are especially effective in spaces kept at 38° F or greater. Table 86 shows the number of sampled builders that included refrigeration systems that could benefit from an economizer.

Table 86. Missed Opportunities—Economizers for Refrigeration Systems

Missed Opportunity	Number of Observations*	Percentage of Total Observations**
Economizers on refrigeration systems	22	46%

Source: Cadmus on-site surveys

* Observations based on total number of buildings with refrigeration systems installed

** Observations based on total number of buildings

Market Actor and Process Findings

Executive Summary

Background

The goals of this research were as follows:

1. Inform program planning by obtaining insights about the Vermont markets for commercial lighting and commercial HVAC equipment, and assessing the familiarity with and use of energy management tools among individuals who make decisions about operations or capital improvements of commercial buildings located in Vermont
2. Assess awareness of the Vermont Energy Efficiency Utilities' (EEUs)[8] commercial program services, obtain feedback on the programs, and develop recommendations to enhance the programs

To achieve the first goal, in spring 2016, the Cadmus team conducted telephone interviews with three groups of market actors important to Vermont's commercial programs:

- Building owners, property managers, or operators of large commercial and institutional buildings in Vermont who make decisions about commercial building operation and improvements
- Vermont-based lighting suppliers and lighting professionals such as designers and specifiers
- HVAC designers and specifiers active in the commercial market in Vermont

To achieve the second goal, as part of the telephone recruiting for commercial on-site visits, the Cadmus team asked 234 utility customers who qualified for on-site visits questions about their awareness of and experiences with the EEU commercial programs. In addition, the market actor interviews included questions designed to obtain feedback on the programs.

Organization of the report. In this Executive Summary, we discuss the most important of the findings and deliver recommendations for four key topics. In the main body of the report, we offer detailed findings for each topic. The four topics are as follows:

1. Building benchmarking and other energy management practices
2. Lighting control products and LED fixtures
3. HVAC technologies and systems
4. Program feedback from end users

Research Limitations. The number of interviewees in each group of market actors was small (between eight and 11 per group). In addition, to increase the likelihood that the market actor interviews would

[8] The Vermont Energy Efficiency Utilities, or EEUs, include Vermont Energy Investment Corporation, Vermont Gas Systems, and Burlington Electric Department.

include individuals familiar with the EEU programs who could provide feedback and observations relevant to the programs, as well as for budgetary reasons, the Cadmus team's sample frame for most market actor interviews comprised contacts provided by the EEUs. Given this, the results from market actor interviews may be biased in favor of energy efficiency and should be interpreted with caution.

Building Benchmarking and Other Energy Management Practices

The Cadmus team interviewed a total of eight building decision-makers (i.e., owners, property managers, or operators of large commercial and institutional buildings). Half of the interviewees came from the organizations selected for site visits; the other half came from a list of customers supplied by EVT. The completed sample included a mix of common commercial and institutional property usage categories, and prioritized buildings with large square footage. The Cadmus team asked interviewees about energy upgrades and management practices at specific sites; the area of these properties ranged from 12,258 sq ft (a bank) to 160,000 sq ft (a ski resort). The primary activities undertaken at the sites included banking, higher education, grocery sales, health care/assisted living, municipal offices, music and arts, and skiing. All but one organization owned as well as managed the properties. For the specific sites in question, all organizations were customers of Green Mountain Power and had participated in EVT programs in the previous four years.

Key Findings and Observations

Benchmarking Familiarity, Tools, and Management Strategies

The primary findings related to benchmarking familiarity and management strategies include the following:

- **Benchmarking awareness is relatively low.** Fewer than half of respondents were familiar with the term *building benchmarking* before being read a description, which suggests there is room to improve awareness of the concept and practice.
- **Benchmarking use is relatively low.** Only two of eight respondents said their organizations had benchmarked properties (both have used ENERGY STAR Portfolio Manager), and, of these, only one had benchmarked all its Vermont buildings.
- **Only one organization appears to be maximizing ENERGY STAR Portfolio Manager for operational benchmarking.** This organization uses ENERGY STAR Portfolio Manager both to identify low-performing buildings and to track and monitor scores over time. One staff person is dedicated to monitoring scores and updating building information.
- **Barriers to benchmarking are major impediments for many interviewees.** Some building operators face complicated, costly barriers to benchmarking. Organizations that had considered but not attempted benchmarking cited master metering as the major impediment to benchmarking. Changing building metering is a costly and time-consuming undertaking. Other perceived barriers to benchmarking cited by interviewees include the high cost of the software or systems, too much variability in energy use from tenant to tenant to make benchmarking

worthwhile, and the age of the building. Organizations often noted that facility upgrades were a higher priority than benchmarking.

- **Suggestions for benchmarking support varied by respondent.** According to respondents, programs could help them undertake benchmarking by offering training and education in benchmarking, developing and publicizing case studies of benchmarking by a variety of businesses, and offering financial support to help with the transition from master-metering to individually metered buildings.

Recommendations

The results point to multiple opportunities to encourage Vermont building decision-makers to improve efficiency through better management of their buildings' energy use:

Build benchmarking awareness through marketing and education. Fewer than half of respondents were familiar with the term *building benchmarking*, which suggests there is room to improve awareness of the concept and practice. The Cadmus team expects that program participants would undertake benchmarking at higher rates than nonparticipants. Although all building decision-maker interviewees had participated in EVT programs within the last two years, only two organizations had benchmarked properties, and only one was maximizing its use of benchmarking tools such as ENERGY STAR Portfolio Manager. The findings from this sample of participants suggest that there may be ample opportunity for Vermont commercial building owners to reduce energy consumption through benchmarking and related energy management activities—at least in the private sector. Vermont's EEUs could support this by developing and publicizing case studies of benchmarking by a variety of businesses, offering how-to materials on energy management practices, or providing training days associated with building benchmarking tools. EEUs could also promote the use of building benchmarking on social media platforms and during in-person meetings.

- **Recommendation:** Consider conducting marketing and education activities to increase awareness of building benchmarking and energy management practices.

Provide ENERGY STAR Portfolio Manager training and education. Interviewees often mentioned barriers related to benchmarking software cost, changes in tenancy, and building age as reasons for not benchmarking their buildings. However, ENERGY STAR portfolio manager takes into account these variables and is a free tool. This suggests there is an opportunity to offer additional state-level or EEU-supported trainings or related education about this free resource. This could come in the form of free webinars, partial-day classroom trainings, or downloadable educational materials.

- **Recommendation:** Consider providing trainings and/or education on ENERGY STAR Portfolio Manager's features.

Support conversion to individual metering. Several interviewees mentioned that master metering is a major impediment to benchmarking their buildings because it is costly and time-intensive to switch to individual metering in order to benchmark. The EEUs are in a unique position to provide guidance and technical support to organizations wanting to make this transition.

- **Recommendation:** Consider offering financial and/or technical support to help with the transition from master metering to individually metered buildings.

Consider conducting additional market research to assess the magnitude of the savings opportunity, and possibly also establish a baseline of building management and benchmarking practices. These recommendations are based on input from a very small number of building decision-makers. It would be prudent for the State of Vermont and the EEUs to conduct further research to assess whether these findings hold true for a substantial percentage of building decision-makers in the state, and the likely magnitude of the savings opportunity from the activities described above. Depending on the design of the research, the results may also serve as a measure of baseline building management and benchmarking practices and be used in evaluation.

- **Recommendation:** Consider conducting additional market research with building decision-makers to assess the magnitude of the savings opportunity, and possibly also establish a baseline of building benchmarking and energy management practices.

If subsequent research confirms the opportunities identified by this study for working with decision-makers on benchmarking, then we suggest the following:

Lighting Controls and LED Fixtures

The Cadmus team conducted 11 interviews with a mix of lighting designers (six) and distributors of commercial lighting products (five) active in the state. All interviewees were identified by EVT and had participated in EVT programs.

Key Findings and Observations

Lighting Controls

The primary findings related to lighting controls include the following:

- **The designers and distributors appear to specify lighting controls fairly commonly—with the exception of sun/shade controls for designers and daylight sensors for distributors.** The data offer evidence that these designers and distributors are commonly specifying or stocking lighting controls. Exceptions included designers not commonly specifying sun/shade controls and distributors not frequently stocking daylight sensors.
- **Lack of demand and constant product changes are common barriers that designers and distributors experience with lighting controls.** Most distributors mentioned lack of demand and constant technological advances as stocking challenges. Given this, distributors mentioned that they often prefer to acquire lighting controls on an as-needed basis. A handful of designers mentioned compatibility issues or a trend toward fixtures with mounted controls as obstacles.

- **The market for lighting controls in Vermont has increased in recent years.** All respondents reported selling or specifying more lighting controls in 2015 compared to 2014, but designers reported a greater increase.
- **The lighting controls market is likely to continue to grow over the next two years.** More than four-fifths of all respondents predict the market will continue to grow over the next two years, with most expressing enthusiasm about this trend.
- **The data provide anecdotal evidence that the commercial building market is becoming more receptive to lighting controls, and that the EEUs' program efforts are at least partly responsible.** Increased awareness of lighting controls, in part because of the programs, appears to be one of the key factors related to growth.
- **Lack of training coupled with an ever-changing market for controls are key issues that contractors face when confronted with controls.** Not all contractors are receptive to lighting controls, most likely because of the rapidly changing market and the learning curve associated with new controls.
- **More than half of respondents feel that the price of lighting controls is key barrier, and over one-third suggest continued or increased incentives.** Over one-half of respondents named price as a barrier to the sale or specification of lighting control products, even when taking rebates into consideration. Others disagreed; two distributors noted that rebates were substantial enough to offset the cost of controls. When asked about additional program support needs, over one-third of respondents indicated that EEUs should continue, improve, or expand incentive programs to assist with the cost of lighting controls
- **Other common barriers reported include lack of product standardization and lack of knowledge and awareness.** Respondents described lack of product standardization, lack of customer and contractor knowledge, and awareness as common barriers when selling or specifying lighting control products.
- **Incentives, followed by customer and contractor education, are keys to increasing market adoption of controls.** In addition to increased incentives, more than half of respondents named customer and contractor education as an important area for support from the state and the EEUs. Over one-third of respondents mentioned that lack of contractor familiarity with some lighting control products has led to installation issues, customer concerns, or deterred installation altogether.

LED Fixtures

The primary findings related to LED fixtures include the following:

- **Designers report specifying LED fixtures with integrated controls much more frequently than distributors report stocking these fixtures.** A majority of both designers and distributors report *sometimes* or *frequently* specifying or stocking a wide range of LED fixtures without integrated sensors. However, distributors report stocking LED fixtures with integrated sensors at low rates.

By comparison, designers are much more likely to report specifying LED fixtures with integrated sensors than are distributors to report stocking them.

- **Distributors keep few LED fixtures in stock.** All distributors discussed keeping few LED fixtures in stock, preferring to order them as needed. Respondents most commonly cited rapid advances in the technology as the reason for not specifying or stocking LED fixtures with integrated sensors.
- **Sales and specification of LED fixtures grew between 2014 and 2015.** All respondents reported specifying or selling more LED fixtures in 2015 compared to 2014, but distributors reported a greater increase than designers.
- **Designers and distributors expect the market for LED fixtures to continue to grow.** Close to half of respondents already specify or sell LED fixtures on most if not all projects, and they expect the trend to continue. Other respondents expect the market to continue to grow over the next two years.
- **Decreased cost and rebates are some of the key factors related to growth in LED fixture sales.** Respondents attributed growth to decreased cost, program rebates, and increases in fixture efficiency.
- **Customer and contractor receptiveness to LED fixtures is high, but price, product availability, and product compatibility with lighting controls are key barriers when selling or specifying LED fixtures.** Most customers are generally receptive to LED fixtures, but not all can afford them. Contractor receptiveness has increased as incentives have increased, but product awareness remains an issue. Other barriers include the ability to attract customers, product availability, LED fixture compatibility with lighting controls, and rebate paperwork. According to one distributor, contractors can be wary of LED fixtures with controls if they are unfamiliar with control installation.
- **Most feedback heard by designers and distributors about installed LED fixtures has been positive, although brightness issues were common.** All respondents reported generally positive feedback (or an absence of negative feedback) from customers and contractors about LED fixtures. Customer complaints about brightness were the most commonly reported negative feedback.
- **The majority of distributors feel that incentive levels are excellent or at least adequate for LED fixtures,** while one complained that incentives have been dropping.
- **Some respondents recommended additional contractor training and outreach.** Two respondents, a distributor and a designer, suggested focusing on training and outreach to contractors about the use and installation of lighting controls and of LED fixtures with integrated controls.

Recommendations

Consider higher rebates and incentives for lighting control products. Although most designers and distributors thought the rebate and incentives offered for LED fixtures were excellent, over half thought that price remains a key barrier for lighting control products, and over one-third suggest programs should consider continued or increased incentives for lighting controls.

- **Recommendation:** Consider offering a higher rebate or incentive for lighting control products to offset designer and distributor concerns about price barriers.

Offer additional training and education. As interviewees noted, not all contractors are receptive to lighting controls or LED fixtures, most likely because of the rapidly changing market and the learning curve associated with programing new controls or installing new fixture types. Similarly, not all customer segments have considered lighting control or LED fixture purchases because of barriers of price, awareness, and product standardization challenges (particularly for lighting controls). A majority of lighting interviewees named customer and contractor education in lighting controls as an important way to address barriers to increasing lighting efficiency in commercial buildings. More than one-third of lighting interviewees mentioned that contractor unfamiliarity with some lighting control products has led to installation issues, customer concerns, or deterred installation. Interviewees also noted low contactor awareness of LED fixtures and how to install LED fixtures with integrated controls. Given this, it may be prudent for the EEUs to offer additional classroom or online trainings for contractors who have little experience with these installations, and provide additional information about these technologies, perhaps through case studies, or to customer segments that are traditionally less likely to be aware of or receptive to these technologies.

- **Recommendation:** Consider adding or expanding contractor training in lighting control and LED fixture installation, working to increase customer awareness of the effectiveness of controls for achieving energy efficiency and addressing LED brightness issues.

Encourage further product standardization. Product standardization was a barrier mentioned by one distributor and one designer. Both thought that increased standardization would better allow contractors to understand installation requirements and improve compatibility of controls with fixture types.

- **Recommendation:** If they do not already do so, EEUs should consider participating in or otherwise encouraging efforts to further standardize products, increasing the compatibility of lighting controls with LED lamps and fixtures, and improving ease of installation.

Support the use of LED fixtures with dimming capabilities. Brightness was a common customer complaint from those who have installed LED fixtures. One distributor mentioned that they have learned to provide dimming for LEDs to better accommodate customer needs. EEU programs are well suited to encourage the purchase of LED fixtures with dimmers, whether through incentives or training and education with customers and contractors.

- **Recommendation:** Encourage, or continue to encourage, contractors to offer dimming capabilities on LED fixtures to avoid customer complaints related to brightness levels.

HVAC Technologies and Systems

The Cadmus team interviewed a total of eight HVAC designers and specifiers from a list provided by EVT. All eight provide design and specification assistance for commercial properties in Vermont and, on average, new construction projects represent just over half their work. All of the firms undertake new construction, renovation, and gut rehab for nonresidential projects. For four of the eight firms, new construction projects make up the largest share of their work. The firms ranged in size from 50 to 180 employees.

Key Findings and Observations

Design Process

The primary findings related to respondent experiences with the design process include the following:

- **The way interviewees categorize their gut rehab work is mixed.** Two respondents consider their gut rehab work to be a part of their renovation work and included it in the renovation total work estimates, two consider it to be part of their new construction work and included it in the new construction total work estimates, and three consider it to be a separate category.
- **Over one-fifth of projects involve a commissioning component or agent.** On average, respondents estimated that just 23% of their projects involve a commissioning component or a commissioning agent who is involved throughout the design and construction process. This percentage, plus the fact that some respondents said they wished commissioning were more widespread, suggests there is an opportunity for programs to encourage building end users and HVAC designers and specifiers to commissioning more frequently.
- **Most respondents report that it is typically a mix of both the client and the engineer driving the inclusion of energy efficiency considerations on projects**. On average, clients ask for efficiency considerations to be included on projects 63% of the time. This represents a change from the past, where engineers would typically take the lead and clients would not be as involved, and may indicate market progress.
- **The majority of these firms' projects exceed minimum standards for energy efficiency.** On average, respondents reported that 66% of their commercial projects exceed minimum CBES.
- **These firms typically have considerable control over what HVAC equipment is ultimately installed.**
  - All firms report that being involved in all phases of their projects as well as reviewing contractor submittals allows them to make sure that what they design or specify ends up in a building.
  - Very few firms report that their designs are often altered or made less efficient. Half either never or only very occasionally have their designs or specifications altered in a way that makes the project less efficient, and only one firm reported that their designs were often altered.

- The majority of projects do not have to adhere to pre-determined requirements from the client regarding the HVAC systems for a project. On average, respondents have the freedom to apply the most appropriate HVAC equipment instead of a pre-determined HVAC system on 82% of their projects.

- **According to these firms, Owner's Project Requirements (OPRs) are rare among Vermont commercial buildings.** Three-quarters of firms rarely encounter OPRs. One-half of the firms mentioned that OPRs can have an impact on the technology specified when they do encounter them.
- **Suggestions for additional program support varied, but included incentives, additional equipment, and involving designers earlier in the process.** When asked what support the EEUs or the State could provide to encourage the incorporation of energy efficiency into HVAC design or specification sooner in the process or more frequently (especially in retrofit application), responses ranged from adding more equipment to the rebate program to encouraging the EEUs to get involved as early as possible in the process. As could be expected, "increased incentives" was the most common response.

Technologies Specified and Installed

The primary findings related to respondent experiences with technologies that are commonly specified and installed include the following:

- **All respondents frequently design and specify variable refrigerant flow (VRF) systems.** There was strong consensus about the popularity of VRF systems. Reasons cited include technological advances that have made them viable for Vermont's climate, manufacturer marketing, and the flexibility to install this technology in different applications and facility types. Six respondents cited this as a very popular, even "dominant" HVAC technology. Other frequently or somewhat frequently specified technologies included air-source chillers and water-source heat pumps with a boiler and/or cooling tower.
- **Ice storage is a possible peak load reduction tool for Vermont EEUs—but one with which few firms have experience.** None of the respondents had extensive experience with ice storage. Several respondents said this technology has value for reducing peak loads, but not for energy efficiency.

Code Changes

The primary findings related to respondent experiences with code changes include the following:

- **The findings suggest that Vermont's energy efficiency code has increased the baseline efficiency of HVAC equipment, but could be more uniformly enforced.** Six respondents stated that Vermont's strong energy code has encouraged energy-efficient HVAC systems. Three respondents believe that the code is not enforced uniformly across the state.
- **Recent increased requirements for certain HVAC controls have led to more efficient systems.** The requirements are moving the market toward direct digital control systems, although the

more sophisticated controls increase costs and, because of their complexity, present challenges with some users to operating the system in the most efficient manner.

- **The company mission, personal beliefs, and benefit to the customer are the primary motivations behind why interviewees install above-code equipment.** Most (five of eight) of the respondents say they install high-efficiency HVAC systems because of their company mission/personal preferences or because they believe it will benefit the owner financially over the life of the system.

Program Experience

The primary findings related to respondent experiences with EEU programs include the following:

- **A large majority of respondents provided positive feedback about their experiences with EEU program support.** Seven of eight respondents (88%) mentioned one or more positive ways in which the EEU programs have supported their projects. The incentives as well as information sharing with and knowledge of program staff were mentioned most often as positive program aspects.
- **Suggested program improvement areas commonly included increased incentives and earlier coordination on projects.** Respondents most often mentioned increasing the incentive amounts and encouraging the EEUs to coordinate with HVAC designers and specifiers as early as possible on projects as areas that the EEUs could improve on or change.

Recommendations

Encourage HVAC designers and specifiers as well as building end users to commission buildings with more frequency. Given that respondents, on average, estimate that only 23% of their projects involved a commissioning component, or a commissioning agent who is involved throughout the design and construction process, an opportunity likely exists for EEUs to encourage building end users and HVAC designers and specifiers to utilize commissioning with more frequency.

- **Recommendation:** Where possible, in the early planning stages of a new construction or gut rehab project, program staff should encourage both HVAC designers and specifiers as well as building end users to include a commissioning component or agent.

Include designers early on in project planning. A large majority of respondents provided positive feedback about their experiences with EEU program support. Suggestions varied regarding additional program or state-level support to help encourage energy efficiency upgrades. Beyond offering increased incentives and additional equipment, the most resonant suggestion from firms was for EEU program staff and customers to involve designers and specifiers earlier in a project's planning process. EEU program staff can play a role in helping to connect and engage both the firm and the customer when a project is initiated. Designers and specifiers may have insights that are important to capture early on in project planning.

- **Recommendation:** Where possible, program staff should involve designers and specifiers earlier in the design phase of the process to help ensure designs are realistic and that energy efficiency goals can be successfully met.

Provide contractor education and training on emerging technologies. The interviews suggest a role for EEU programs to provide education or training to help contractors implement emerging HVAC technologies, particularly for the technologies that interviewees expect to become more common over the next few years, such as VRFs, air-source chillers, and ERV. Another educational role to consider is increasing the awareness and understanding of emerging HVAC technologies such as ice storage.

- **Recommendation:** Consider providing or expanding education and support to designers, contractors, and end users for emerging HVAC technologies.

Program Feedback from End Users

The Cadmus team gathered program feedback from end users through a short series of questions fielded by telephone as part of recruiting for on-site visits for the baseline portion of the study. The majority of surveyed customers who reported having participated in an EVT or BED program had installed lighting measures. The majority of surveyed customers who reported having participated in a VT Gas program had installed HVAC measures.

During interviews with building decision-makers, who also participated in the telephone survey, the Cadmus team asked more-detailed questions about program satisfaction.

Key Feedback Findings from Telephone Survey

Survey respondents across all EEUs demonstrated high awareness of the EEU programs. Most customers (84%) are aware of energy efficiency service offerings available to them from EEUs.

The majority of customers are highly satisfied with the equipment, services, ease of participation, and quality of measures provided by each of the EEUs. Ratings are typically clustered between scores of 8 and 10, where 10 is completely satisfied.

The majority of surveyed customers who reported having participated in an EVT or BED program had installed lighting measures. The majority of surveyed customers who reported having participated in a VT Gas program had installed HVAC measures.

EVT Feedback from Building Decision-Makers

All interviewed building decision-makers reported having participated in EVT programs and gave the following anecdotal feedback:

- **All respondents made program-supported efficiency improvements within the last four years.** As noted above, all respondents reported having participated in at least one EVT program.

Lighting was the improvement reported most commonly. Two organizations participated in a new construction program.

- **Rebates and incentives are the primary reason for program participation.** Respondents most often cited obtaining rebates and incentives to help defray the cost of undertaking efficiency upgrades as the primary reason for participating in efficiency programs. However, respondents cited corporate social or environmental commitments slightly ahead of other reasons, including creating management buy-in and obtaining technical expertise.
- **Program satisfaction is high.** The overwhelming majority of respondents is highly satisfied with their program experience with EVT. Half of respondents reported that they had needed help to convince upper management to approve energy efficiency upgrades; all of them found EVT program services and support either helpful or very helpful in this task. The only substantive suggestion for improving programs that respondents offered was to expand the number of in-ground LED lighting products included as part of EVT's lighting program offerings.

Introduction

The research described in this report had two goals. The first was to inform program planning by obtaining insights about Vermont markets for commercial lighting and commercial HVAC equipment, and assessing familiarity with and use of energy management tools among individuals who make decisions about operations or capital improvements of commercial buildings located in Vermont. The second was to assess awareness of the EEUs' commercial program services, obtain feedback on the programs, and develop recommendations to enhance the programs.

To achieve the first goal, in spring 2016 the Cadmus team conducted interviews with the following three groups of market actors important to Vermont's commercial programs:

- Individuals such as building owners, property managers, or operators of large commercial and institutional buildings in Vermont who make decisions about commercial building operation and improvements
- Vermont-based lighting suppliers and lighting professionals such as designers, specifiers, and architects
- HVAC designers and specifiers active in the commercial market in Vermont

To achieve the second goal, as part of the telephone recruiting for commercial on-site visits, the Cadmus team asked utility customers who qualified for on-site visits questions about their awareness of and experiences with the EEU commercial programs. In addition, the market actor interviews included questions designed to obtain feedback on the programs.

Research Limitations. The number of interviewees in each group of market actors was small (between eight and 11 per group). In addition, to increase the likelihood that the market actor interviews would include individuals familiar with the Vermont EEUs'[9] programs who could provide feedback and observations relevant to the programs, and for budgetary reasons, the Cadmus team's sample frame for most market actor interviews comprised lists of contacts provided by the EEUs. Given this, the results from market actor interviews may be biased in favor of energy efficiency and should be interpreted with caution.

[9] The Vermont EEUs include Vermont Energy Investment Corporation, Vermont Gas Systems, and Burlington Electric Department.

Methodology

The Cadmus team conducted in-depth interviews (IDIs) by telephone with market actors in May and June of 2016, and, as part of recruiting for on-site visits, asked utility customers survey questions between December 2015 and April 2016 about program experience. Below, we describe the sampling and disposition for the market actor interviews. The Sampling Approach sections of this report for existing buildings and new construction provide information about sampling for telephone recruiting surveys.

In the process of developing interview guides and sampling plans, to ensure that this portion of the research met current program needs, the Cadmus team obtained input from staff of the Vermont Department of Public Service and staff of the Vermont EEUs (comprising Vermont Energy Investment Corporation [VEIC], VT Gas, and Burlington Electric Department).

Building Decision-Makers

The Cadmus team conducted eight telephone interviews with building decision-makers (i.e., owners, property managers, or operators of large commercial and institutional buildings). Half the interviews were with building owners or managers whose buildings were among the on-site visits. To ensure that program participants were included among the interviewees, the other half of the interviews were with large commercial or institutional building owners or managers selected from a list of contacts provided by Efficiency Vermont. The completed sample included a mix of common commercial and institutional property usage categories, and prioritized buildings with large square footage. (See Firmographics section for more details about building square footage and firmographics of the completed sample.) Interviewers screened the potential interviewees to ensure they were speaking with individuals whose organization managed the property in question (whether or not they owned it), and who were familiar with both the energy efficiency improvements made at the property and the energy management practices for the building. Although more than half of interviewees reported managing multiple properties, the Cadmus team asked interviewees about energy upgrades and management practices at specific sites. Interviewers contacted 25 individuals in total to complete the eight interviews, for a response rate of 33%. Table 87 summarizes the sample disposition.

Table 87. Building Sample Disposition

Sample	Total	On-Site Participants	VEIC Recommended Contacts
Total Sample Contacted	25	14	11
IDIs Completed	8	4	4
Not Qualified	1	1	--
Refused	2	1	1

Lighting Distributors and Designers

The Cadmus team conducted 11 telephone interviews with lighting distributors and designers. The lighting designers and distributors selected for the sample were provided to the Cadmus team by EVT and had participated in EVT programming in the past. Interviewers screened the potential respondents to ensure they were speaking with individuals who were most familiar with the organization's efficient lighting product offerings. To encourage interviewees to take the time to talk, interviewers offered an incentive in the form of a $50 check. Of the original sample of 14 contacts (six designers and eight distributors), the Cadmus team completed 11 interviews, for a response rate of 92%. Two distributors no longer had commercial contracts or business interests in Vermont, and one refused an interview. Table 88 summarizes the sample disposition.

Table 88. Lighting Sample Disposition

Sample	Total	Designers	Distributors
Total Sample Contacted	14	6	8
IDIs Completed	11	6	5
Not Qualified	2	0	2
Refused	1	0	1

HVAC Designers and Specifiers

The Cadmus team conducted eight telephone interviews with HVAC designers and specifiers. The HVAC designers and specifiers selected for the sample were provided by EVT to the Cadmus team. EVT was familiar with these contacts either because they had participated in EVT programming in the past, or because they were known for having design experience with commercial projects in Vermont. The final sample included a mix of large and small HVAC designers and specifiers, with the largest firms prioritized. The interviewers recruited respondents by e-mail and telephone. Interviewers screened the potential respondents to ensure they were speaking with individuals who were most knowledgeable about their organization's work designing or specifying HVAC systems in commercial or institutional buildings in Vermont. To encourage interviewees to take the time to talk, interviewers offered an incentive in the form of an $80 check. Interviewers contacted 13 individuals to complete the eight interviews, for a response rate of 62%. Table 89 summarizes the sample disposition.

Table 89. HVAC Sample Disposition

Sample	Total
Total Sample Contacted	13
IDIs Completed	8
Refused	2

Building Benchmarking and Other Energy Management Practices

A key reason for interviewing building decision-makers was to provide information about the energy management strategies used by Vermont building decision-makers and their familiarity with and use of building benchmarking and benchmarking tools such as ENERGY STAR Portfolio Manager. According to ENERGY STAR, building managers can reduce building energy use by 30% or more through "effective energy management practices that involve assessing energy performance, setting energy savings goals, and regularly evaluating progress. Building-level energy performance benchmarking is an integral part of this effort."[10] A better understanding of current energy management practices should help Vermont EEUs in assessing support for benchmarking as a program opportunity, particularly for organizations like these that may have already undertaken many of the program-supported efficiency upgrades for which they are eligible.

To provide feedback on current programs, the Cadmus team also asked building decision-makers about the process of obtaining management approval to make efficiency improvements and their experience with Vermont energy efficiency programs.

With such a small number of interviewees, it is not possible to generalize these results to the population of commercial building decision-makers in Vermont. If the EEUs find the results sufficiently intriguing to consider offering some form of support to encourage the use of building benchmarking and energy management practices, it would be prudent to conduct market research with a larger sample to help with program design and establish baselines for practices prior to initiating program support.

Firmographics

Most organizations interviewed owned as well as managed the properties, and more than half managed multiple properties.

Table 90 shows that all but one of the organizations owned as well as managed the property in question. A very wide range of primary activities took place at these properties.

[10] ENERGY STAR. 2008. ENERGY STAR Building Manual. April 2008. Accessed September 5, 2016, from https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH2_Benchmarking.pdf.

Table 90. Primary Activities, Ownership, and Management

Primary Activity at Property Interviewed	Property Description	Property Ownership	Manage Property	Leases Space to Tenants?	Data Source
Banking	Banking activities only	Yes	Yes	Yes, but at other properties	VEIC
College	Mixed use (dining, classrooms, dormitories)	Yes	Yes	No	VEIC
Grocery	Mixed-use grocery (banking, bakery, deli, florist, etc.)	Yes	Yes	No	On-Site Participants
Health Care	104-bed facility with 36 long-term residents	No (lease from others)	Yes	No	On-Site Participants
Municipal Office Space	Primarily office space; forensics lab	Yes	Yes	Yes, but at other properties	On-Site Participants
Music and Arts Center	Primarily production of recordings; art studios, café	Yes	Yes	Yes, to artists	On-Site Participants
Assisted Living	14 duplex cottages; main building with three stories	Yes	Yes	No	VEIC
Ski Resort	Seven primary lodges: mixed-use assembly (ski rental, retail, food service, etc.)	Yes	Yes	No	VEIC

The Cadmus team asked interviewees for an estimate of the square footage of the buildings about which they were interviewed, as well as for the total square footage of all properties for which they were responsible. The area of the buildings about which they were interviewed ranged from 12,258 sq ft (a bank) to 160,000 sq ft (a ski resort). Half of the respondents also managed other properties in Vermont. Table 91 summarizes these findings.

Table 91. Square Footage and Total Number of Properties

Primary Activity at Property Interviewed	Total Square Footage at Property Interviewed	Number of Properties Owned in VT	Total Square Footage—All Properties in VT**	Average Square Footage—All Properties in VT**
Banking	12,258*	40	Not provided	4,000
College	22,157*	1 campus, 65 buildings	750,000	Not provided
Grocery	35,913*	17	750,000	44,000
Health Care	64,987*	One	Do not own any property	Do not own any property
Municipal Office Space	86,124*	280	3,500,000	Not provided
Music and Arts Center	52,000*	1	Only one property	Only one property
Assisted Living	64,987*	1	77,200	Only one property
Ski Resort	160,000**	1 property, 7 lodges	160,000	Not provided

* Source: VEIC and Cadmus On-Site Participant records.
** Source: Provided by respondent.

All organizations were customers of Green Mountain Power and all had participated in EVT programs in the previous four years.

Although the Cadmus team's intention was to include decision-makers with buildings served by more than one electric service provider, as Table 92 shows, all eight organizations received electric service from Green Mountain Power. (Customers in the BED service area were included in the original sample frame, but were not responsive to requests for an interview.) Two organizations confirmed that VT Gas provided gas service to their properties. All others used a variety of fuels at their properties, including liquefied petroleum (LP) oil, fuel oil, propane, wood chips, or a mix of different fuels. All organizations confirmed having worked with EVT. All three organizations who reported owning more than one property reported that their other properties were served by a mix of utilities, depending on their location.

Table 92. Utilities Serving Properties Owned by Interviewees

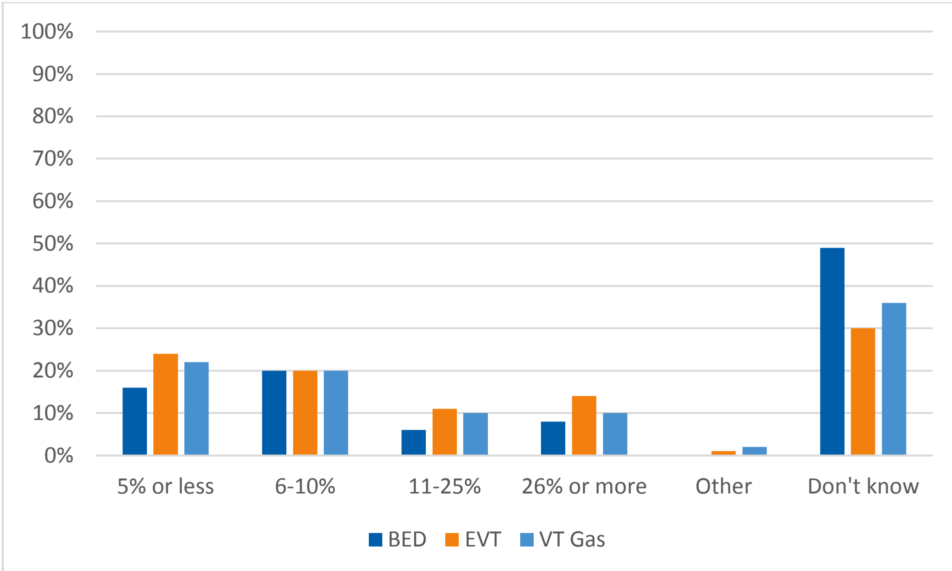
Primary Activity at Property Interviewed	Electric Utility at Property	Fuel Use at Property	Efficiency VT Participant	Utilities—All Properties in VT
Banking	Green Mountain Power	Liquefied Petroleum Gas	Yes	Mix of utilities
College	Green Mountain Power	Fuel Oil	Yes	Only one campus
Grocery	Green Mountain Power	Propane; VT Gas	Yes	Mix of utilities
Health Care	Green Mountain Power	Liquefied Petroleum Gas (kitchen; laundry); VT Gas with oil Backup (for boilers)	Yes	Do not own any property
Municipal Office Space	Green Mountain Power	Wood Chip Heat Plant w/ Backup Propane Boiler	Yes	Mix of utilities
Music and Arts Center	Green Mountain Power	Fuel Oil	Yes	Only one property
Assisted Living	Green Mountain Power	Propane	Yes	Only one property
Ski Resort	Green Mountain Power	Fuel Oil	Yes	Only one property

Building Energy Management

The telephone survey included questions about the percentage of companies' total operating costs that are spent on energy and their self-reported approach to managing energy use and costs.

Figure 156 shows the percentage of the companies' total operating costs that are spent on energy, by EEU. These self-reported operating costs are similar across the three EEUs. More than one-third of the survey respondents did not know the percentage.

Figure 156. Operating Costs Spent on Energy, by EEU



Respondents were asked, "Which of these descriptions most closely matches your organization's approach to managing energy use and costs?" The answer categories were as follows:

- Energy management is a daily part of our operations. We actively monitor and control our usage and costs.
- We review our energy use and costs at least quarterly and consider energy efficiency when we need to purchase new equipment.
- We are concerned about energy costs, but we don't have a systematic approach to managing them.
- We pay the bills but don't actively manage energy use or costs.

Figure 157 shows the self-reported energy management approach for existing buildings and for new construction. The data suggest that companies operating new construction are more inclined to take an active approach to managing the energy use of their buildings than are companies operating existing buildings. About half of respondents in existing buildings report being concerned about energy costs, but not having a systematic approach to managing them.

Figure 157. Energy Management Approach by Existing versus New Construction

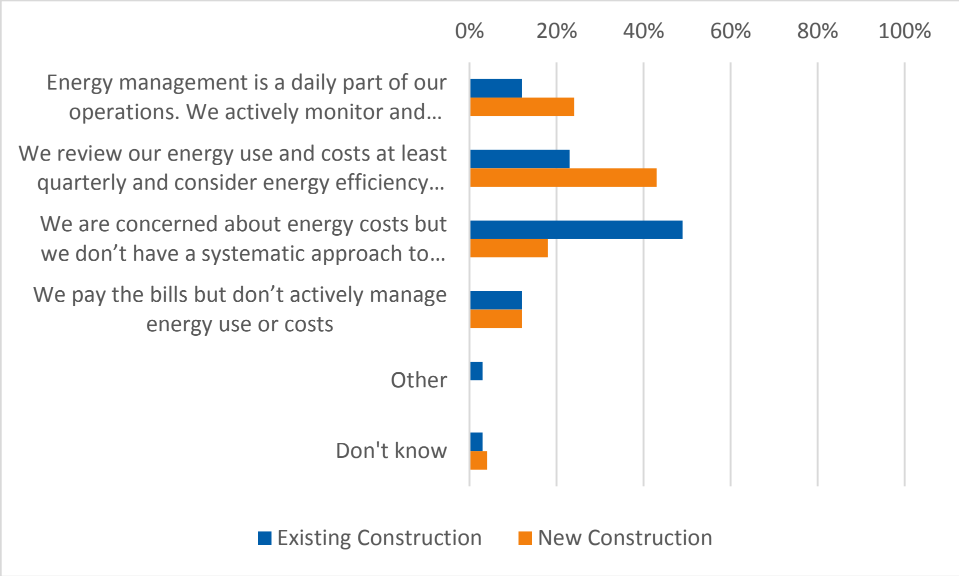
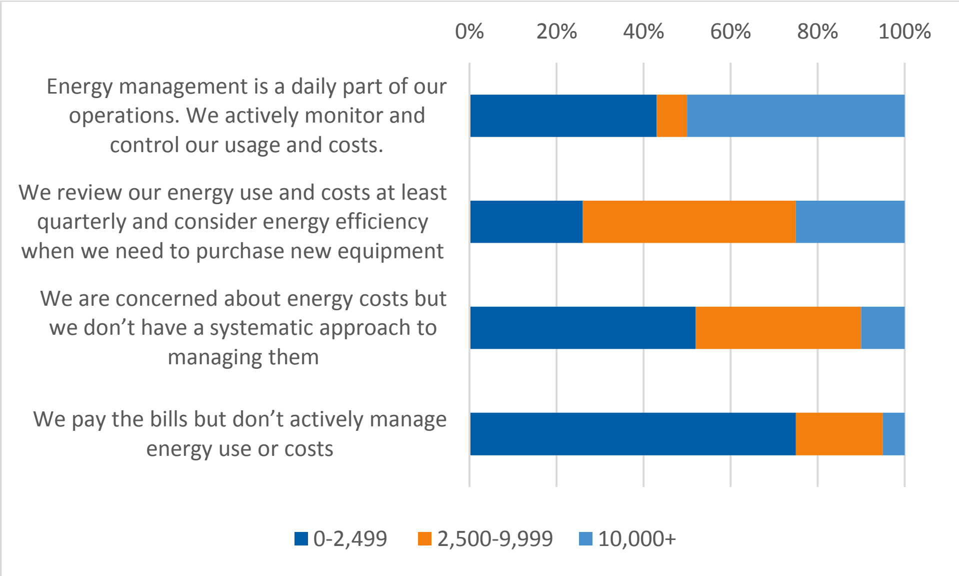


Figure 158 shows the relationship between the approach to energy management and facility size. The data suggest that companies in buildings over 10,000 sq ft are more likely to say that they actively monitor and control their energy costs, whereas those in the smallest buildings are more likely to say that they do not systematically or actively manage their energy costs.

Figure 158. Approach to Energy Management by Facility Size (All EEUs)



Benchmarking Familiarity, Tools, and Management Strategies

Interviewers asked respondents about their use of building energy management tools and strategies.

Familiarity with Benchmarking

Interviewers asked respondents if they were familiar with the term *building benchmarking*. If they were not familiar with the term, the interviewer read them the following description:

> Buildings are benchmarked using energy management software that allows customers to track and assess energy consumption. Typically, benchmarking provides metrics that assess the energy-use intensity and energy performance of the whole building by comparing it to the energy usage of similar buildings. Have you heard of this practice of building benchmarking?

Fewer than half of respondents were familiar with the term *building benchmarking* before being read a description, which suggests there is room to improve awareness of the concept and practice.

Just three of the eight respondents were familiar with the terminology without the interviewer having to read the description. (Three more said they were familiar with it after hearing the description). Two respondents were not familiar with the term.

Table 93. Building Benchmarking Familiarity and Experience

Primary Activity at Property Interviewed	Familiar with Benchmarking	Experience Benchmarking
Grocery	Yes	Yes
Municipal Office Space	Yes	Yes
Banking	Yes	No
College	Yes, after reading description	No
Assisted Living	Yes, after reading description	No
Ski Resort	Yes, after reading description	No
Health Care	No	No
Music and Arts Center	No	No

Experience Benchmarking

Only two of eight respondents said their organizations had benchmarked properties, and of these, only one—the municipal office space manager—had benchmarked all its Vermont buildings. The findings suggest that some building operators face complicated, costly barriers to benchmarking This also suggests that there may be ample opportunity for Vermont commercial building owners to reduce energy consumption through benchmarking and related energy management activities—at least in the private sector.

Interviewers asked respondents if their organizations had any experience with benchmarking their building(s) in the past four years (Table 93). Just two respondents reported that their organizations had benchmarked properties during this period. The municipal office space manager, which operates the largest square footage of all respondents (Table 91), has benchmarked all of the

properties it oversees. The grocery store, which is tied with the college as operating the second largest square footage among the respondents, reported having benchmarked some of its properties. None of the other respondents had benchmarked any of their properties.

Both respondents that have benchmarked buildings use ENERGY STAR Portfolio Manager plus at least one other tool.

Both the municipal office space and grocery store respondents reported using ENERGY STAR Portfolio Manager for benchmarking. The staff at the grocery store supplements ENERGY STAR Portfolio Manager with an unnamed application that analyzes utility bill expenses. The municipal office space manager noted that their organization's staff have energy management systems particular to certain buildings—including SkySpark,[11] which has capabilities similar to ENERGY STAR Portfolio Manager—but it appears that they do not use these other tools as commonly as ENERGY STAR Portfolio Manager. The municipal office space manager is in the process of developing an RFP to get a third party to manage its utility data on a statewide basis. The municipal office space manager noted that the organization would like to be able to use "other very robust tracking systems [that] are incredibly useful" to track and manage energy use at its buildings, but that other tools are also "relatively expensive." By comparison, ENERGY STAR Portfolio Manager is free.

Of the two organizations that have benchmarked, only one—the municipal office space manager—appears to be maximizing ENERGY STAR Portfolio Manager for operational benchmarking.

This organization uses ENERGY STAR Portfolio Manager both to identify low-performing buildings and to track and monitor scores over time, and has a staff person dedicated to monitoring scores and updating building information in ENERGY STAR Portfolio Manager.

Interviewers asked the two respondents who have benchmarked their buildings about how their organizations use the benchmarking scores. The staff member at the grocery store uses benchmarking information only to identify and prioritize stores with energy-saving opportunities. The staff member who manages the municipal office space uses benchmarking to do the following:

- Identify low-performing buildings (and noted that whether this is possible depends on the building)
- Store multiple scores for a building and look at the data over time, which "can sometimes be the most useful application"

The interviewee indicated that the ability to store data may be the most useful application of ENERGY STAR Portfolio Manager, because it is "only as good as the user at the end of the day." They are trying to address this challenge, though, because the municipal office space manager reported that the organization recently hired a program coordinator to routinely monitor its

[11] Additional details about SpySpark can be accessed online: www.skyfoundry.com

buildings' benchmark scores and to update the information in ENERGY STAR Portfolio Manager on a quarterly basis to reflect changes in the building, such as in tenancy or property usage.

The municipal office space manager has not yet widely used ENERGY STAR Portfolio Manager to re-benchmark the organization's buildings when a change is made to a building or to equipment that could affect its energy use, but this is a goal moving forward. In addition, the municipal office space manager conducts monitoring and verification with EVT on a regular basis at many of their buildings.

No Experience Benchmarking

Interviewers asked respondents who had not benchmarked their buildings yet whether they had considered it, what reasons or barriers had stopped them from performing benchmarking, and what assistance or support they might need to encourage them to benchmark their buildings (Table 94).

Master metering is a major impediment to benchmarking for the organizations that have considered, but not attempted, benchmarking. Changing building metering is a costly endeavor. These organizations are approaching it incrementally, so it will be some time before it is complete.

Two organizations with the next-largest total square footage, the ski resort and the college, have considered benchmarking at least some of their buildings, but are impeded by being master-metered. Switching to individual meters for each building is costly, and both organizations are taking a long-term approach. According to the staff at the college:

> We are just beginning to develop a benchmarking strategy. We have meters on several buildings, although we're master-metered as of now so we can't run diagnostics on specific buildings for the time being. Adding more meters to all the buildings and developing a benchmarking schema for all buildings individually is the goal we are just beginning to work toward, though.

The staff at the ski resort reported the following:

> Most buildings are on a master meter. . . . As we have renovated buildings, though, we have begun to install sub-meters, but the lodges are more difficult to get off the master meter. This is something we would like to move toward, but it may not happen until [we do] a major overhaul of all of the existing lodges . . . which would require major and costly renovation.

Other perceived barriers to benchmarking cited by interviewees are the high cost of the software or systems, too much variability in energy use from tenant to tenant to make benchmarking worthwhile, age of the building, and that benchmarking is a low priority compared to facility upgrades. If the first three perceptions are widespread, programs could potentially address them

with marketing and education to spread the word that ENERGY STAR Portfolio Manager is a free resource, and that it takes into account building age as well as changes in tenancy and related space use.

Of the four organizations that had not considered benchmarking, two (the bank and assisted living facility) were familiar with the concept after being read a description. The bank respondent shared its organization's perception that benchmarking systems or software would be costly in terms of time and money. This respondent was apparently unaware that ENERGY STAR Portfolio Manager is a free resource:

> Mainly it's cost. It's also time, resources, and money. The cost of those systems from my experience . . . they're very expensive.

The two respondents who were not familiar with benchmarking before the interview explained that they would be unlikely to consider it:

> I have a two-year history of trying to operate this building. Our energy consumption went down, but the minute you bring in more people it goes up again. There's always going to be volatility in a multi-use center. Some artists use a paintbrush and some artists use power tools. It just depends (music and arts center).

> It's an older building. It's hard to compare our building with others. When this building was built it was built under HUD, and there are many things I would have done differently. We have made many upgrades over the years but have not used benchmarking tools. We may benchmark, though (health care facility).

According to respondents, programs could help them undertake benchmarking by offering training and education in benchmarking, developing and publicizing case studies of benchmarking by a variety of businesses, and offering financial support to help with the transition from master-metering to individually metered buildings.

The staff at the college noted that funding to assist with the process of transitioning away from master-metering would be helpful. The staff at both the health care facility and the bank said training and education could help encourage them to consider benchmarking their buildings, with the staff person at the bank noting the following:

> Training on benchmarking might help us. The biggest issue we've had using the systems is not having the proper training and experience.

The staff person at the music and arts center would find it helpful to see case studies of buildings with similar characteristics and energy usage profiles as theirs, and the staff person at the assisted living center said they would be willing to learn more about benchmarking if information was provided to them.

Table 94. Benchmarking Barriers and Support Needed

Primary Activity at Property Interviewed	Considered Benchmarking	Benchmarking Barriers	Support Needed
College	Yes	• Master metered	Nothing else, besides additional funding
Ski Resort	Yes	• Master metered	Nothing else
Banking	No	• System cost • Lack of resources • Lack of time • Don't know how	Training and Education
Health Care	No	• Have focused their resources on making other necessary upgrades	Training and Education
Music and Arts Center	No	• Don't think the building is amenable because of age, tenancy type	Case studies of similar buildings
Assisted Living	No	• Haven't given it much thought yet	Nothing else

Energy Efficiency Improvements in Leased Spaces

The Cadmus team asked the three respondents who mentioned that they lease at least some of their space to tenants about improvements they have made in leased spaces.

Table 95 shows answers to a series of questions about energy management practices in leased space that interviewers posed to the three organizations that lease out at least some of their space.

These landlords have all made lighting and HVAC energy efficiency upgrades to tenant spaces in the last four years. One made other kinds of upgrades as well.

All three organizations have made energy-efficient upgrades to reduce the energy used in the tenant spaces in their leased spaces in the last four years. Both the bank and the music and arts center staff said they have made lighting and HVAC energy efficiency improvements in their leased spaces, and the staff person who manages the municipal office space said they have made a variety of upgrades that depend on the particular building's needs.

Respondents mentioned the following reasons for making energy efficiency upgrades in tenant spaces in equal numbers: legal requirements, desire to reduce costs, and social and environmental concerns.

It is unusual to find any respondent group—let alone landlords—offering social and environmental concerns as a reason to make energy efficiency upgrades with the same frequency as cost savings or legal requirements. With such a small number of respondents, this outcome is very likely to be

the result of random chance and not because of a systematic difference in how landlords of Vermont commercial buildings value social and environmental concerns.

Barriers to landlords who wish to make efficiency upgrades in leased space include high rates of occupancy and the cost of upgrades.

The music and arts center staff person mentioned that they made what upgrades they could, but that the cost of making additional improvements was a challenge. The staff person who manages the municipal office space said all of their leased spaces are occupied, which can make it a challenge to do work.

All three organizations mentioned EVT as a source of information about efficiency upgrades in lease spaces. They also look to their utilities, to contractors, and to their own staff for this information.

All three of the organizations rely on EVT when looking for information about energy-efficient improvements in their leased spaces. The music and arts center staff person also mentioned relying on Green Mountain Power as well as their contractor to help them make decisions. The staff person who manages the municipal office space noted that they rely on their own staff resources in addition to EVT:

> We have a team of architects and engineers, so we rely on our own staff. We do a lot of research regarding new available technology and best practices in the industry. We also reach out to Efficiency Vermont as well.

Table 95. Leased Space Energy Management Practices

Leased Space Practices	Primary Activity at Property Interviewed		
	Music and Arts Center	Banking	Municipal Office Space
Leases Space to Tenants	Yes, leases part of property	Yes, but at other properties	Yes, but at other properties
Percentage of Space Leased	Less than half	13%	98%
Tenant Primary Activities	Art	Many uses	Many uses
Utility Payments	Owner	Depends on the lease agreement	Owner pays utility; compensated by tenants
EE Upgrades Made	Lighting, HVAC	Lighting, HVAC	Variety of upgrades
EE Upgrade Motivations	Required by law	Cost reduction; social and environmental	Required by law; cost reduction; social and environmental
Barriers	Cost of additional improvements	Nothing mentioned	All spaces are occupied
Sources of Information	EVT; Other utilities; Contractor	EVT	Own staff, EVT
Importance of EE to Tenants	Not asked	Depends on who pays utilities	Not asked

Lighting Control Products and LED Fixtures

A key reason for interviewing lighting designer professionals and electrical distributors of lighting products was to provide information about the market for efficient commercial lighting in Vermont. A better understanding of the market should help Vermont EEUs in assessing their continued support for various types of lighting control products and LED fixtures.

The Cadmus team asked lighting design professionals and electrical distributors of lighting products who are active in the commercial market in Vermont about their experience with lighting control products and LED fixtures, how they market these products to their customers, and the types of support needed to achieve market adoption.

Firmographics

All of the lighting design professionals interviewed had 10 or fewer employees, and the majority of their commercial project work was for the retrofit market. Most of the electrical distributors interviewed had between six and 25 employees, and, in total, likely represented 50% or more of the total commercial market in Vermont.

The most common roles of respondents were owner (designers) and branch manager (distributors), as shown in Table 96. On average, the lighting design organizations interviewed had fewer than four employees working in Vermont, compared to just over 14 employees for distributors (Table 97). Four of the six designers interviewed reported having provided lighting design services for 10 or fewer commercial lighting projects in 2015; overall, an average of 88% of projects were identified by respondents to be retrofits and 12% were new construction (Table 98). After asking distributors to estimate their company's share in the state's commercial lighting market, the Cadmus team estimated that the study covers at least 50% of lighting distributors active in Vermont (Table 99).

Table 96. Roles and Responsibilities of Respondents

Role	Designers (n=6)	Distributors (n=5)
Lighting Design	1	0
Energy Efficiency Program Manger	1	0
Head Engineer	1	0
Owner/Co-Owner	3	1
Branch Manager	0	3
Senior Quotations Manager	0	1

Table 97. Company Size

Number of Employees in Vermont	Designers (n=6)	Distributors (n=5)
1–5	4	0
6–10	2	2
10–25	0	2
Don't Know	0	1
Average	**3.8**	**14.25**

Table 98. Projects Specified by Respondents in 2015 (Designers)

Number of Commercial Projects in Vermont	Percentage of Retrofit	Percentage of New Construction
3	100%	0%
3–4	100%	0%
5–6	100%	0%
10	75%	25%
20	90%	10%
100	60%	40%
Average	**87.5%**	**12.5%**

Table 99. Market Share of Respondents in 2015 (Distributors)*

Number of Employees in Vermont	Market Share
7	5%
9	5%
16	< 5%
25	35–40%
Total	50%+

* Note that one distributor did not respond to this question.

Lighting Controls

The Cadmus team asked respondents a series of questions about lighting control product trends, with a focus on lighting controls specified and stocked, use in commercial projects, marketing, customer and contractor interest and feedback, and barriers to and support needed for market adoption in Vermont.

Lighting Controls Specified and Stocked

The designers and distributors appear to specify lighting controls fairly commonly—with the exception of sun/shade controls for designers and daylight sensors for distributors.

Table 100 shows the frequency with which designers specified and distributors reported stocking certain types of lighting control products.

Most designers reported frequently specifying daylight sensors, exterior motion sensor controls, occupancy sensors, and touch or slide dimmers. The data offer evidence that this group of designers is commonly specifying lighting controls, with the exception of sun/shade controls.

Distributors indicated stocking exterior motion sensor controls, occupancy sensors, and programmable timer controls with the most frequency. Overall, the most noticeable difference between designers and distributors was in regard to daylight sensors; five designers indicated that they *frequently* specified these controls, while no distributors reported frequently stocking daylight sensors.

Table 100. Lighting Control Stocking/Specification Frequency

Lighting Control	Designer (n=6)				Distributor (n=5)			
	Frequently Specify	Sometimes Specify	Seldom/ Never Specify	Don't Know	Frequently Stock	Sometimes Stock	Seldom/ Never Stock	Don't Know
Daylight Sensors (Fixture Mounted, Switch Mounted, Ceiling and Wall Remote Mounted)	5	1	0	0	0	1	2	2
Exterior Motion Sensor Controls	6	0	0	0	3	1	0	1
Integrated (Factory Mounted) Lighting Sensors	2	1	2	1	1	1	1	2
Programmable Timer Controls	3	2	0	1	3	0	0	2
Occupancy Sensors (Fixture Mounted, Switch Mounted, Ceiling and Wall Remote Mounted)	5	0	1	0	3	1	0	1
Touch or Slide Dimmers	4	0	1	1	2	0	0	3
Sun/Shade Controls	1	1	3	1	1	1	1	2

Distributors were more likely than designers to mention obstacles to stocking or specifying lighting control products. Most distributors mentioned lack of demand and constant technological advances as stocking challenges. Given this, distributors mentioned that they often prefer to acquire lighting controls on an as-needed basis. A handful of designers mentioned compatibility issues or a trend toward fixtures with mounted controls as obstacles.

Four out of five distributors cited lack of demand and rapidly evolving technology as obstacles to maintaining stock of lighting control products. Although most respondents spoke generally about the controls market, one distributor specifically identified fixtures with integrated controls as difficult to stock because of demand issues and technology changes. One larger distributor indicated a preference to order stock from headquarters or directly from the manufacturer on an as-needed basis because of lack of demand:

> We don't stock many controls due to lack of demand. . . . Each branch stocks what is in demand in that area. If there were more interest in a particular control type, we would communicate with our headquarters about stocking it.

A designer cited compatibility issues between controls and fixtures as a reason for not stocking either touch or slide dimmers or sun controls. Another designer described a trend toward fixture-mounted sensors that combine occupancy and daylighting, as they provide the deepest savings with minimal labor, which appeases both the customer and contractor.

Lighting Controls in Commercial Projects

Percentage Sold or Specified. The Cadmus team asked designers what percentage of their commercial projects in 2015 included lighting controls, and asked distributors what percentage of their sales to commercial buildings in 2015 included lighting controls (Table 101).

The market for lighting controls in commercial applications in Vermont appears to have been growing. Designers estimated that lighting controls were specified in close to all of their projects (95%) in 2015, but distributors estimated that less than two-fifths of the commercial projects they sold lighting products to included lighting controls. All respondents reported selling or specifying more lighting controls in 2015 compared to 2014, but designers reported a greater increase (12.5% versus 8%).

Across the six designers interviewed, respondents reported specifying lighting controls in an average of 95% of commercial projects in 2015. (The median was 100%). Designers reported an average increase of 12.5% in the number of projects in which they specified lighting controls from 2014. (The median increase was 0%.)

Across the five distributors interviewed, respondents reported selling lighting control products to less than 36% of total commercial projects in 2015 (median of 20%). Distributors reported an average increase of 8% in sales of lighting control products to the commercial market since 2014 (median increase of 5%).

Table 101. Lighting Controls Sold or Specified in Commercial Projects

Commercial Projects on Which Designers Provided Design Assistance (n=6)		Sales of Lighting Products Distributors Know Were Included in Commercial Buildings (n=5)	
Average Percentage of Projects that Included Lighting Control Products in 2015	95%	Average Percentage of Lighting Control Products Sold for Use in Commercial Buildings in 2015	Less than 36%
Range	80%–100%	Range	Less than 10%–100%
Median	100%	Median	20%
Average Percentage Change from 2014	12.5%	Average % Change from 2014	8%
Range	0%–50%	Range	0%–20%
Median	0%	Median	5%

Reasons for Change

Interviewees commonly attributed growth in the use of lighting controls in commercial applications to increasing contractor and customer awareness of controls (attributable, in part, to programs), available rebates, improvements in technology, and the high rate at which designers say they are specifying lighting controls.

All respondents noted that the percentage of lighting controls sold or specified for commercial projects either held steady or increased from 2014 to 2015. As seen in Table 102, among the designers reporting an increase, all three mentioned improvements in lighting control technology and one cited the role of rebates as reasons for this increase. Among the four distributors reporting an increase, three pointed to growing awareness surrounding lighting controls by customers and sales professionals as a reason for this increase. Two distributors cited rebates, one of whom credited EVT's role, in particular:

> A continued push by Efficiency Vermont to talk more about lighting controls and make sure the customer is aware of the incentive [has led to this increase]. I'd say [the increase from 2014 to 2015 is] more driven by Efficiency Vermont than customer request.

Interview results suggest that designers are driving change by specifying controls in commercial projects. By comparison, distributors report selling lighting controls at rates substantially lower than designers report specifying them (95% versus less than 36%). One distributor directly attributed the increase in sales of lighting controls for installation in commercial buildings to more engineers, architects, and others in the field specifying lighting controls.

Table 102. Reasons for Increase in Specification and Stocking of Controls

(Multiple Response)

Reasons for Increase	Designer (n=3)	Distributor (n=4)
Improvements in Technology	3	0
Growing Awareness of Controls	0	3
Rebates	1	2
Specified More Often	0	1

Changes Expected in the Next Two Years

More than four-fifths of all respondents predict the market will continue to grow over the next two years, with most expressing enthusiasm about this trend. Of the five respondents who said lighting controls were included in 100% of their commercial sales and designs in 2015, two designers expected the market to stabilize and perhaps slow, while the other two (one distributor and two designers) predicted the market would continue to grow (Table 103). The other six respondents indicated selling or specifying lighting controls at lower rates; all expected an increase over the next few years. More than one in four respondents expressed enthusiasm about the direction of the market, with one designer noting:

> Whole building control might be where things are going—like a school or industrial site where an "energy czar" could view where energy use is occurring throughout the whole building.

And another distributor reported:

> I expect sales to increase, simply because as technology is evolving, we're starting to see lighting control products you can control with your smartphone. Who doesn't have a smartphone in their hand six hours a day?

Two respondents were skeptical about continued progress in lighting controls. One designer thought the cost of lighting controls would stabilize and slow market growth:

> Someone who installed systems this year rather than two years ago has seen a dramatic decline in prices, but [I am] not sure that it will continue over the next two years.

A distributor predicted a modest increase of sales (5% per year) over the next two years, and indicated that dramatic changes would not be possible unless there is a greater effort to promote controls and/or train contractors. Another distributor expected sales to increase in the next two years *if* codes and standards mandating more controls were adopted.

Table 103. Expected Market Trends 2016–2017

Lighting Control Market 2016–2017	Designer (n=6)	Distributor (n=5)
Expect Market Growth	4	5
Predict Market Stabilization/Stagnation	2	0

Marketing Energy Efficiency

Most (nine of 11) distributors and designers actively encourage the use of lighting controls when marketing energy efficiency. As shown in Table 104, four of five distributors and five of six designers interviewed stated that when marketing energy efficiency to their customers, they actively encouraged the purchase of lighting control products. One distributor believed all projects mandated controls, and, therefore, felt it was an act of compliance rather than encouragement. A designer also indicated that lighting control requirements under state energy codes were part of the conversation with customers when discussing energy efficiency.

Although most designers stated they actively encouraged the specification of lighting control products, one designer expressed reservations, indicating that lighting control products were only specified "where warranted," and that, because of price, the company did not believe in installing controls in every room.

Among designers actively encouraging lighting controls, a focus on smart controls as a means to achieve payback on the lighting investment was cited by one designer as a reason for encouraging their use. As part of the generally positive trend surrounding the specification of lighting control products, one designer discouraged customers from doing projects *without* controls:

> It's irresponsible if we do not [encourage customers to consider lighting control products] because new technologies are inherent to being controlled. Very often, with existing lighting products, situations are over-lit from the beginning, and without controls, there's nothing people can do about it.

Table 104. Encouragement for Use of Lighting Controls

Encouragement of Controls	Designer (n=6)	Distributor (n=5)
Actively Encourage Use of Controls when Marketing Energy Efficiency	5	4
Only Encourage Controls as an Act of Code Compliance	1	1

Customer and Contractor Interest

Respondents provided a variety of feedback when asked whether some commercial customers or contractors are more receptive than others when purchasing or installing lighting control products (Table 105).

Customer Interest

Interest in lighting controls varies. The customers most likely to purchase them are those who are most committed to energy reduction or those with higher-end projects.

Because price can be a barrier to the installation of lighting controls, one designer found that only the most committed customers chose lighting controls, and others were satisfied with just upgrading to LED lighting products. Another designer noted that customers with more basic applications (e.g., factories) are not as interested in lighting controls, whereas customers with higher-end projects expect lighting controls and may choose their designer accordingly.

A designer with a relatively negative outlook on lighting control applications overall stated that experienced customers preferred to avoid controls because of inconsistency and their potential for failure.

Some customers may not be receptive to lighting control products unless they are provided guidance. For example, one distributor noted that LEED-certified building owners may be more aware of lighting control products than others. Other customers may be attracted to different types of control methods. A designer indicated that wall-mounted occupancy sensors, for example, might be specified if fixture-mounted sensors were not a good fit and the customer preferred a wall switch for manual control.

Certain customers, such as hospitals, were more likely to have reservations about lighting controls because of potential maintenance issues or safety concerns. A distributor noted that one recent customer specifically requested no controls over concerns that the plant was too complex for occupancy sensors to properly monitor the area, and safety could be compromised if lights went out while someone was present in a space. In this case, the distributor recalled EVT to inquire why no controls had been quoted, but noted that the company had complied with the customer's request.

Contractor Interest

Not all contractors are receptive to lighting controls, most likely because of the rapidly changing market and the learning curve associated with new controls.

Eight respondents addressed the effects of product sophistication and increased awareness on contractors' receptiveness to lighting controls:

> When you start getting into fancier lighting controls, [contractors] tend to balk; [we] need to get them on board with more sophisticated lighting controls. As far as the basic lighting controls, that's pretty much the way they go now. Very few [lighting controls contractors we] have worked with have old-fashioned switches on walls. . . . They like it old-fashioned because it's easier to understand, but contractors who don't follow this trend will find themselves left out of the market.

One designer expressed frustration with pushback on controls specification:

> [Contractors] have a more difficult time grasping things they have never done before, so sometimes it takes a little bit of time to convince a contractor that it's the best way to go. Very often, when someone value-engineers a project after it's already been developed, controls are one of the first things they take out, which is very irresponsible.

Another distributor concurred:

> There are some contractors who get it, they understand the value, understand how to install them, especially as they become a little more complex than controls used to be.

Four respondents spoke to the benefits of experience in the lighting control market. One distributor spoke to contractors who are more receptive to controls:

> There are a handful of contractors who are more comfortable and receptive to lighting control products because they have had experience with them and have worked through initial challenges already.

One distributor felt smaller contractors were better suited to adjust to the market:

> Now that these contractors are comfortable with the controls, they typically promote them. Medium to smaller contractors are the ones who have done a lot of lighting control product upgrades, possibly because they have more flexibility to try new things.

Table 105. Receptiveness to Lighting Controls (Multiple Responses; n=11)

Concern Categories	Customer Receptiveness	Contractor Receptiveness
Price	1	0
Product Inconsistencies	1	0
Product Sophistication/Awareness	1	9
Experience/Installation Concerns	3	4
Customer/Contractor Size and Flexibility	1	1
Application Fit/Safety Concerns	2	0

Barriers

Respondents described the higher cost of installation when lighting controls are included in a project, lack of product standardization, and lack of customer and contractor knowledge and awareness as common barriers when selling or specifying lighting control products. Although over one-half of respondents mentioned the upfront cost of lighting controls as a key barrier, two interviewees suggested that the programs are largely offsetting the initial cost of controls.

The initial purchase price and the higher cost of lighting installation when controls are included in a project were the most commonly cited barriers to increasing the sale or specification of lighting controls. Contractor and consumer awareness was a close second (Table 106). Over one-half of respondents (one distributor and five designers) named price as a barrier to the sale or specification of lighting control products. Others disagreed; two distributors noted that rebates were substantial enough to offset the cost of controls. One designer described his cautious approach to the specification of lighting controls:

> You wouldn't put $250 worth of controls (which is a typical cost) in a space that has one CFL and LED—so you put them where they make economic sense for the building owner.

Another designer noted that it can be more expensive for electricians to install more sophisticated control systems, making it harder for customers to realize the cost benefit of lighting controls as labor costs increase.

Product standardization is another lighting control barrier, but was cited with less frequency than other barriers. Product standardization was cited as a barrier by one distributor and one designer. Both thought that standardization would help contractors to understand installation requirements and improve compatibility of controls with fixture types. One distributor noted:

> There are so many controls out there, and it would be nice if controls were more standardized. This would allow contractors to better understand their installation requirements. Compatibility of controls with fixture types is a related issue. There is a wide array of products available, and it is changing rapidly. There are constantly new models being introduced to the market. It's hard for [distributors] to stock the wide variety of controls that are out there, and hard for contractors to keep up, too.

A designer cited compatibility issues between dimmers and fixtures to justify the choice not to specify touch or slide dimmers or sun/shade controls. A distributor also mentioned difficulty in matching up controls and LED fixtures.

One small-scale designer mentioned lack of lighting control standards as a barrier to control specification. This designer reported spending a great deal of time reading case studies and other resources, and emphasized that established industry standards would be very helpful when specifying controls to give designers a shorthand for choosing trusted products.

Close to half of respondents cited the need for continued or enhanced customer and contractor education about lighting controls. Nearly one-half of respondents (three designers and two distributors) cited customer and contractor education as an issue**.** One distributor reported:

> Another barrier to overcome is customer and contractor appreciation/awareness of the value that lighting control[s] will bring to the market. Customer education and contractor awareness-building are needed.

Some respondents found that if the customer has not been educated on use of the lighting control system, they will feel that the product has failed them, leaving them with a negative outlook on controls and an inability to fully realize the energy-saving potential of the controls. One designer noted that at many commercial installation sites, maintenance positions have high turnover and that, even in cases where training has been provided, the employee might leave abruptly without sharing knowledge—a problem for large facilities, in which lighting control systems are often quite sophisticated.

One distributor alluded to installation challenges as a barrier, and another noted that some contractors may not even be willing to install control systems:

> With all due respect to some of the smaller contractors (we are a rural state) . . . some of them don't want to be bothered with having to install controls. Not just an occupancy sensor as opposed to a wall switch; I find everyone seems to do that. If it becomes part of a system where they may not know exactly how these things go in, there are some contractors who say, "No, I'm just going to put in this fixture and move on."

However, other distributors found no issue with contractors regarding lighting controls, or found that experienced contractors are more receptive because they have already worked through initial challenges.

Table 106. Lighting Control Barriers (Multiple Responses)

Barriers Identified	Designer (n=6)	Distributor (n=4)
Price	5	1
Product Standardization	1	1
Education/Awareness	3	2

Lighting Control Feedback

Respondents provided a variety of perspectives when asked what feedback they have received from customers and contractors about lighting control products (Table 107).

Nearly all designers and some distributors have heard positive feedback about lighting controls from customers.

Although distributors were unable to report conclusively on customer feedback, five out of six designers indicated customer feedback was largely positive. One designer, however, mentioned that while improvements to lighting controls were positive from an industry standpoint, sales proved difficult because some customers are wary from prior experiences with lighting controls. Another concurred:

> In the early days of controls being implemented, putting the wrong controls scheme in the wrong situation has made lights go off when they shouldn't go off, wave your arms at your

> desk—which has given the controls aspect of things a negative review in the beginning. [It] goes back to the person installing or designing or laying out a control scheme not being aware of how things work in a space.

More than one in four respondents (two distributors and one designer) stated that no feedback was good feedback, with one distributor noting:

> Very little feedback—if they use them they think they're great, and we don't hear back from them.

And another designer reporting:

> If everything's fine you hear nothing—when people complain it's because they didn't learn how to use it. When people have a dolly system they know how to fix it, but with these occupancy sensors they may not know how to use them. If something's broken, we hear it all.

Over one-third of respondents (three designers and one distributor) mentioned that contractor unfamiliarity with some lighting control products has led to installation issues or customer concerns, or deterred installation altogether.

One designer mentioned that as integrated controls have come onto the market, contractors are increasingly willing to work with lighting controls:

> They were used to installing sensors and power packs, etcetera, that were a lot more cumbersome and harder to wire and put in than today's fixture that you can get complete with integrated sensors in every fixture.

Although distributors and designers alike have noted technology is improving, they recognized this has not always been the case. As one designer pointed out:

> Historically, controls **have** meant callbacks from the customer. If [the contractor] does receive callbacks, it can be costly for them from a labor standpoint.

Table 107. Lighting Control Feedback (Multiple Responses)

Feedback Areas Identified	Designer (n=6)	Distributor (n=4)
Price	1	0
Improvements in Tech	1	0
Learning Curve	2	1
Past Product Failure	3	0
Positive Feedback	5	3

Support for Market Adoption

Although one distributor felt the current level of support was sufficient, most respondents provided constructive feedback on the types of support and targets for support needed to encourage the market adoption of lighting control products in Vermont (Table 108).

Respondents identified incentives as key to the market adoption of lighting controls, requesting that lighting rebate programs be sustained or expanded. Over one-half of respondents named customer and contractor education as an important area for support from EVT, whereas a handful of respondents thought that no further support was needed.

Education. Over half of respondents (two designers and four distributors) cited the need for more education for all parties involved, especially contractors and customers.

One distributor recalled attending a training session co-hosted by EVT and a manufacturer that was well-attended by distributors—but with few contractors in attendance:

> Contractor education is always a challenge, except for the ones on the cutting edge who look forward to these opportunities. It's tough to get a contractor to stop his work. . . . My understanding amongst competitors in town is that it's tough to get contractors to come to a distributor-sponsored event.

Another distributor suggested extending the rebate program beyond customers to the contractor:

> A lot of the rebates offered are for the end user, and it doesn't incentivize the contractor to learn about the product, install it, and troubleshoot it. I suggest providing the contractor with a $100 or $200 incentive for the labor. You may not need to offer it long term, [but] it could help get the contractors over the initial learning curve.

A designer indicated the need for access to webinars, manufacturer resources, and independent lighting research in order to maximize designer impact on the efficient lighting process.

Incentives. Over one-third of respondents (four designers) indicated that EVT should continue, improve, or expand incentive programs to assist with the cost of lighting controls:

> High first cost is a real barrier to customers. Customers always understand the first cost, [but they] only understand payback about half of the time.

A second designer emphasized that high cost was especially relevant given that incremental reductions in energy efficiency have lengthened the payback period:

> Obviously, it's going to be about incentives. . . . Especially when there was a big jump from metal halide to fluorescent, companies would expect paybacks in the one- to two-year range, which was very easy to do. But to go from fluorescents to LEDs to adding controls, etcetera, it becomes a little bit longer of a payback, and people aren't used to that, so

> that's where Efficiency Vermont can subsidize that particular piece, that delta, that allows [the customer] to do the right thing to get a payback that's palatable.

A third designer at an independent consulting firm suggested reinstating EVT's RELIGHT program, which was suspended at the beginning of 2016. The designer reported successfully participating in the program for several years:

> [Electrical firms and distributors] do projects, but there's a conflict of interest because they're trying to install the project and make a good profit based on the installation, or the representatives are recommending projects based off what they rep. There are a lot of projects where the client is not willing to pay for a designer [and opts for "free" design from the lighting company representative]. [Efficiency Vermont] needs to figure out how to promote use of designers more, instead of just relying on electricians or manufacturers.

<u>No Further Support Needed.</u> Nearly one-fourth of respondents (one distributor and two designers) stated that no additional support was needed, making suggestions as to how support could be modified. One designer lamented the potential outcome of too much support for lighting control adoption, suggesting that support be tempered in light of changes in overall saturation:

> It's not that the other lighting incentives are so effective, it's that the designer who designs by the latest recommendations . . . knows that you don't need as many controls because you're not installing as many watts. [Electrical lighting fixture and control] supply houses love controls—[they mean] bigger sales. People install way too much light and that's the necessity of controls, but controls are becoming less and less viable as light is going down over the years.

Although many respondents indicated price was a barrier to the wider adoption of lighting controls and praised EVT's existing incentives, one designer pointed out one downside to the program:

> One of the inherent problems found in Vermont is that they have been very aggressive in energy savings over the years. So they've taken out the T12s and put in the T8s, and taken out the T8s and put in the super T8s, and now they're taking out T8s and putting in LEDs. The problem is every time you do those incremental changes you remove a certain amount of power from the space . . . [and] what ends up happening is you've already reduced the power consumption in a space over the last ten years to 50%, you only have 50% of that number to work with, and in some cases the cost of completely taking out that 50% or dimming that 50%--there's not enough delta in savings to cover the cost of the retrofit.

Table 108. Support for Market Adoption of Lighting Controls (Multiple Responses)

Support Needs Identified	Designer (n=6)	Distributor (n=5)
More Education	2	4
Increased Incentives	4	0
No Further Support Needed	2	1

LED Fixtures

The Cadmus team asked respondents a series of questions about LED fixture trends, with a focus on LED fixtures specified and stocked, their use in commercial projects, marketing, customer and contractor interest and feedback, and barriers to and support needed for market adoption in Vermont.

LED Fixtures Specified and Stocked

Distributors report stocking LED fixtures with integrated sensors at low rates. By comparison, designers are much more likely to report specifying LED fixtures with integrated sensors than are distributors to report stocking them. Two-thirds of the six designers (four) reported frequently or sometimes specifying high-bay LED fixtures with integrated sensors, and half (3) reported this for other kinds of LED fixtures with integrated sensors (troffer, surface, suspended, and low-bay fixtures). Of the four distributors who were aware of what LED fixtures they stock, all seldom or never stocked high-bay LED fixtures with integrated sensors, and three-quarters (3) seldom or never stocked other kinds of LED fixtures with integrated sensors. **A majority of both groups report *sometimes* or *frequently* specifying or stocking a wide range of LED fixtures *without* integrated sensors, however.**

Table 109 shows the frequency with which designers and distributors specified or stocked certain types of LED fixtures.

Table 109. LED Fixture Specification/Stocking Frequency

LED Fixture	Designer (n=6)				Distributor (n=5)			
	Frequently Specify	Sometimes Specify	Seldom/Never	Don't Know	Frequently Stock	Sometimes Stock	Seldom / Never	Don't Know
High-Bay Fixtures	3	1	2	0	3	0	1	1
High-Bay Fixtures with Integrated Sensors	2	2	2	0	0	0	4	1
Surface & Suspended Linear Fixtures	3	2	1	0	4	0	0	1
Troffer Fixtures	5	0	1	0	4	0	0	1
Troffer, Surface & Suspended, & Low-Bay LED Fixtures with Integrated Sensors	2	1	3	0	1	0	3	1

Similar to lighting control products, all distributors discussed keeping few LED fixtures in stock, preferring to order them as needed. Respondents most commonly cited rapid advances in technology as the reason for not specifying or stocking LED fixtures with integrated sensors.

In explaining why Vermont branches were not stocked with integrated LED fixtures, one large distributor expressed caution about stocking a product that was not yet widely popular. When these fixtures are needed, stock is moved from a central hub or product is ordered directly from the manufacturer.

A second distributor also indicated that fixtures with integrated controls were mostly ordered on a project basis, and that the company did not maintain more than a token stock. That distributor noted issues with technology changing before products can be delivered to the customer, leaving the company to absorb the cost:

> The reason [the fixtures with integrated controls] are mounted in my office and not the customer's [is] before we could move the product . . . it was updated to a Generation Two from a Generation One product. In a matter of months, the product we had on our shelves became obsolete and the factory would not take it back because it was an outdated SKU number.

A third distributor recognized that integrated fixtures are expensive to inventory:

> If [the customers] want a sensor mounted on them, they can do it in the field. If they don't want a sensor, then we have [those fixtures] for them in stock.

Another distributor also mentioned that stocking fixtures with integrated sensors deterred customers from purchasing LED fixtures:

> If you sell them with a sensor, you have to add whatever the sensor price is. Even though [the customer] gets a rebate, they see the cost and say, "Oh no, we don't need that."

Designers also echoed distributors' concerns about LED fixtures with integrated sensors. One designer specified lighting sensors and controls and acknowledged EVT's incentive program, but recommended against the installation of fixtures with integrated sensors in discussion with clients. Some designers only specified integrated fixtures for certain types of projects or applications, which sometimes fell outside a designer's target market.

Short product life cycles were also cited as a barrier to stocking LEDs by one distributor:

> If I have three dozen of a product on the shelf and it doesn't move, we're stuck with them; if I have three dozen and someone needs four dozen, I can't get an extra dozen because they've been replaced with something else. We will stock anything that can be returned, and moved easily.

LED Fixtures in Commercial Projects

Percentage Sold or Specified. The Cadmus team asked designers what percentage of their commercial projects in 2015 included LED fixtures and asked distributors what percentage of their sales in 2015 included LED fixtures (Table 110).

Sales and specification of LED fixtures grew between 2014 and 2015. All respondents reported specifying or selling more LED fixtures in 2015 compared to 2014, but distributors reported a greater increase than designers. However, designers specified LED fixtures more frequently (over 90%) than distributors reported selling them to commercial buildings (over 80%).

The six designers reported that an average of 92% of commercial projects they designed had LED fixtures (median of 100%). Among the five distributors, an average of 83% of commercial buildings they made sales to included LED fixtures (median of 77.5%). Most designers reported no change in the percentage of LED fixtures specified in 2015 compared to 2014, although one reported a 50% increase.

Table 110. LED Fixtures in Commercial Projects

Commercial Projects on Which Designers Provided Design Assistance (n=6)		Sales of Lighting Products Distributors Know Were Included in Commercial Buildings (n=5)	
Average Percentage of Projects that Included LED Fixtures in 2015	92%	Average Percentage of LED Fixtures Sold for Use Commercial Buildings in 2015	83%
Range	60%–100%	Range	60%–100%
Median	100%	Median	77.5%
Average Percentage Change from 2014	8%	Average Percentage Change from 2014	20%
Range	0%–50%	Range	0%–60%
Median	0%	Median	10%

Reasons for Change

Respondents attributed growth to decreased cost, rebates, and increases in fixture efficiency. The three respondents who offered an explanation for the change they observed between 2014 and 2015 credited a decrease in the cost of LED fixtures, rebates, and an increase in fixture efficiency (Table 111).

Table 111: Reasons for Increase in Specification and Stocking of LED Fixtures

Reason for Percentage Change 2014–2015	Designer (n=2)	Distributor (n=1)
Decrease in LED Fixture Cost	2	1
Rebates	1	0
Increase in Fixture Efficiency	1	0

Changes Expected in the Next Two Years

Close to half of all respondents already specify or sell LED fixtures on most if not all of their projects, and they expect the trend to continue. All other respondents expect the market to continue to grow over the next two years.

Nearly one-half of respondents (four designers and one distributor) reported that they specified for or sold LED fixtures to 100% of their commercial projects as of 2015. All five respondents expected that number to hold steady (Table 112). To quote a designer, "It will be an LED world until they find something better." The remaining respondents (two designers and four distributors) predicted that number would continue to increase over the next year or two. One distributor predicted a 5% to

10% increase per year "as long as the rebates remain available," and another expected fluorescent fixtures to be completely phased out in three to four years.

Table 112. Expected Market Trends 2016–2017

LED Fixture Market 2016–2017	Designer (n=6)	Distributor (n=5)
Expect Market Growth	2	4
Predict Market Stabilization/Stagnation	4	1

Marketing Energy Efficiency

Similar to lighting controls, most (10 of 11) distributors and designers encourage LED fixture purchases when marketing energy efficiency.

The majority of respondents (10 of 11) indicated that they encourage, or strongly encourage, the purchase or specification of LED fixtures when marketing energy efficiency to customers. The one designer that did not encourage customers to include LED fixtures in their projects cited fixture compatibility, cost, and health concerns related to LED strobe as reasons. This designer did, however, express enthusiasm for the specification of LED fixtures for exterior use, and reported highly positive feedback from customers on these exterior fixtures.

Customer and Contractor Interest

Compared to lighting controls, designers and distributors reported fewer differences in customer and contractor receptiveness to LED fixtures (Table 113).

Most customers are generally receptive to LED fixtures, but not all can afford them. Contractor receptiveness has increased as incentives have increased, but price to the customer can still be a disincentive, and product awareness remains an issue.

Customer Interest. A distributor noted that customers that are LEED certified are very receptive to LEDs, but acknowledged that, especially with the rebates from EVT, most customers are generally receptive to LED fixtures. However, it appears the rebates do not guarantee universal accessibility; another distributor reported that, while "everyone is interested in hearing about the LEDs, not everyone is able to afford them—even with the rebates."

Contractor Interest. One distributor noted that some contractors appreciated that the long life expectancy of an LED translated into fewer return visits for replacements, and these contractors were more likely to install LEDs. Three respondents cited awareness as a factor in contractor receptiveness to LED fixtures. One designer said even when contractors are receptive to LED fixtures, their knowledge might be outdated:

> I was called into jobs where the electrician specified a[n] LED fixture that was state-of-the-art three years ago, but there are better, cheaper choices now. But that's not [the

contractors'] main business, so they may not know about the updated fixture. If [contractors] are used to installing a fixture, they may continue to install that fixture, even when there are better choices [available].

A distributor spoke on the effect of incentives on the market:

> Compared to the lighting control question, even the smallest of contractors doesn't care whether he's installing fluorescent or LED, and we do find the incentives have made a big difference. As that transition has occurred over the past two or three years, the availability of incentives to bring the cost of an LED closer to the cost of a fluorescent has been a major factor in our ability to sell LEDs.

Another distributor reported that some contractors can be resistant to encourage their customers to install LED fixtures because they do not want to deal with the incentive paperwork or take on the role of salesperson in addition to installer:

> Contractors, for the most part, are receptive to LED fixtures unless they are too lazy to do the rebate paperwork, in which case they may not recommend them to their customers. If we find out from our customers that this is the case, we will front the money ourselves.

Table 113. Receptiveness to LED Fixtures

(Multiple Responses; n=11)

Concern Categories	Customer Receptiveness	Contractor Receptiveness
Price	3	1
Awareness	4	4
Rebates Create Extra Work	0	1
Product Sophistication/Quality	1	0

Barriers

Respondents provided a variety of feedback when asked what barriers, if any, they face when selling or specifying lighting control products (Table 114).

Price, product compatibility, the ability to attract customers, product availability, and rebate paperwork are common barriers when selling or specifying LED fixtures, with price most commonly reported.

Two distributors and one designer cited price as a barrier to the sale or specification of LED fixtures. As one designer explained, energy savings calculations depend on a variety of factors, and it can be difficult to convince the customer that the retrofit or new product will pay for itself. Two more distributors and a designer indicated that price would be an issue if incentives were not in place:

> I find very few barriers in selling LED lights—it's been a big part of what I've done over the past three years. It's a little scary because, as an owner, I find the fact that you're selling all

> these LED products is wonderful . . . but I don't find it good organic growth for a company. . . . If those incentives were to go away tomorrow, fixture sales would drop dramatically.

One designer reported compatibility of LED fixtures and lighting controls as a barrier, and a distributor cited fixture availability, emphasizing that it was difficult to stock all fixtures because there are too many different types. Standardization was also mentioned by a designer in regard to customer receptiveness to LED fixtures (see the "Customer and Contractor Interest" section for additional information):

> Some [customers] want to standardize on a certain manufacturer or fixture. I try to impress upon them that first, if you don't bid, you won't get the best prices; and secondly, LEDs last five to seven years. If you standardize on a fixture, by the time you replace it, it will be an obsolete technology, so it doesn't make a lot of sense to standardize in those cases. Lighting now is not one-size-fits-all . . . so it's almost impossible to standardize. When we do a design, we know there's more than one manufacturer for the design we're proposing, unless it's for a particular architectural project.

Two respondents identified the types and targets of program support to be barriers to capturing clients or specifying certain products. Again referencing the RELIGHT program, a designer spoke about the challenges of attracting customers:

> [Some customers] are going to electrical distributors who offer "free" design, and it's hard to compete with free. My customers understand the difference and are looking for the value of a lighting design.

A distributor reiterated that rebate paperwork can discourage contractors from promoting LED fixtures (see the Customer and Contractor Interest section above for more details).

Table 114. LED Fixture Barriers

Barriers Identified	Designer (n=3)	Distributor (n=4)
Price	1	2
Compatibility	1	0
Difficulty Attracting Customers	1	0
Fixture Availability	0	1
Rebate paperwork	0	1

LED Fixture Feedback

All respondents reported generally positive feedback (or an absence of negative feedback) about LED fixtures from customers and contractors. Customer complaints about brightness were the most commonly reported negative feedback.

One exception, according to a distributor, was LED fixtures with controls, as contractors can be wary of controls if they are unfamiliar with installation (Table 115).

Another distributor described a typical adjustment period in which the company might hear complaints from a customer who has retrofitted from fluorescent to LED:

> It's a huge change going to a new lighting technology, they perceive it as a lot brighter, but after two weeks the concerns generally go away. . . . I encouraged the owner to sit tight for a couple of weeks, if you want to we can come in and install dimmers, but we never heard another word about it.

A designer also mentioned brightness as a common element of customer feedback:

> One thing we've learned with LEDs is to provide dimming; even though the output of an LED is the same as fluorescent, LEDs always look brighter. Because LEDs are inherently dimmable, we can put in lighting and then use dimming to accommodate more peoples' needs or desires.

One designer recalled negative feedback in cases when a fixture was incorrectly specified by electricians or distributors, and the respondent was called in to the project after the fact because the customer did not use a designer up front.

Table 115. LED Fixture Feedback (Multiple Responses)

Feedback Areas Identified	Designer (n=6)	Distributor (n=5)
Positive Feedback	4	3
Brightness	2	1
Product Failure Concerns	1	0
Installation Challenges	1	1

Support for Market Adoption

Most respondents provided constructive feedback on the types of support and targets for support needed to encourage the market adoption of LED fixtures in Vermont (Table 116).

Four of 11 distributors and designers praised EVT's lighting program efforts.

The majority (four of five) of distributors feel the incentives are excellent or at least adequate, while one complained that incentives have been dropping. Two designers suggested increasing incentives, one specifically to help customers who already have fairly efficient lighting thanks to the programs to achieve even greater levels of lighting efficiency.

Two respondents, a distributor and a designer, suggested focusing on training and outreach to contractors about the use and installation of lighting controls and of LED fixtures with integrated controls. Another designer suggested expanding business incentive programs to include smaller-sized businesses.

Incentives. Three distributors praised EVT and, in particular, the incentive structure:

> I think Vermont does a bang-up job on support, in terms of dollars, rebates—Vermont is four-plus years ahead of other states, even Massachusetts.

One distributor encouraged EVT to simply "maintain a respectable rebate level," and another expressed support for EVT while also hoping for incentives to be raised:

> Certainly, the financial component is key to being able to continue to market LEDs, to give people the incentive (no pun intended) to put in LEDs or change from fluorescent to LEDs. . . . I couldn't be happier, other than the fact they keep lowering incentives, and certainly that slows the process down a bit.

Two designers indicated that incentives should be modified or expanded. One designer felt that EVT has been too successful, and now there is need for additional support—financial or otherwise—so customers can continue to see a return on the energy efficiency investment as they achieve higher levels of efficiency over time:

> If a customer still has metal halides or T12s, going to LEDs is super easy. If it's their third or fourth time doing a project with Efficiency Vermont and they're attempting to reduce power from more recent technologies (i.e., super T8s), it gets difficult to reduce power more.

Training, Education, and Outreach. A distributor emphasized the need for training and outreach to contractors regarding the use and installation of lighting controls, including LED fixtures with controls. A designer also named outreach to customers and contractors as a necessary element to EVT programming, alongside the rebates.

Program Priorities. One designer perceived renewable energy programming in the state was favored over the efficient lighting industry, to the detriment of overall energy savings, and recommended an increase in incentives for efficient lighting solutions:

> In Vermont, there's a disproportionate amount of money going into the renewable energy field rather than the amount of money that could be used for energy conservation. The lowest energy use is the energy you don't use—so yes, you can produce it with solar power, but if you can make a dramatic reduction because of spending more on LED lighting, you may not need that solar panel. Energy efficiency has taken a back seat to renewable energy, and there needs to be a shift.

Customer Awareness of Health Impacts. The designer with the negative outlook on the current state of LED technology expressed concern that poorly made LEDs pose a health threat if they flicker or strobe. This designer thought EVT was not interested in discussing this negative aspect of LEDs and hoped the Department of Health would be interested in an awareness campaign.

More Inclusive Programming. Lastly, a small-scale designer noted that there are many small businesses in Vermont with energy efficiency needs, but EVT provides programs for larger commercial applications. This designer suggested expanding business incentive programs to be more inclusive of small businesses, especially those with small budgets for lighting projects, as well as published standards and accessible information regarding the compatibility and cost of LED fixtures and lighting controls:

> There are so many options now [for lighting fixtures], and they can't put everything online. Is there a way to get the price quote quicker online?. . . I find a fixture that works for the application, but I don't know the price, so I have to call. If [the price] is too high, I have to specify another fixture. If I could see a ballpark price before I start, that would be really helpful.

Table 116. Support for Market Adoption of LED Fixtures

Additional Support Needs Identified	Designer (n=6)	Distributor (n=5)
Incentives	2	1
Training/Education/Outreach	1	1
Program Priorities	1	0
Consumer Awareness of Health Impacts	1	0
More Inclusive Programming	1	0
No Additional Support Needed	0	3

HVAC Technologies and Systems

A key reason for interviewing HVAC designers and specifiers was to provide information about the market for efficient commercial HVAC in Vermont. A better understanding of commercial HVAC market trends should help Vermont EEUs in assessing their continued support for various types of HVAC products as program opportunities.

The Cadmus team asked HVAC designers and specifiers active in the commercial market in Vermont about the design process used for their commercial HVAC projects, as well as details about technologies and systems specified and installed, the impact of recent code changes, and experiences with efficiency programs.

Firmographics

All eight interviewees provide design and specification assistance for commercial properties in Vermont, and, on average, new construction projects represent just over half of their work.

Roles and Responsibilities. All companies interviewed provide design and specification assistance for commercial properties in Vermont. Half of the interviewees are professional engineers who work on design/build projects, and the other half are owners or other executives who oversee and also work on design/build projects.

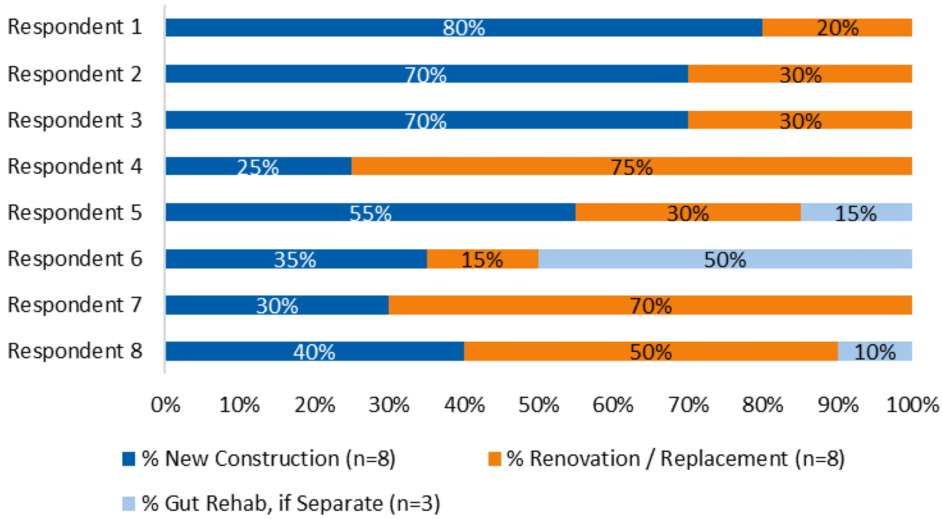
Firm Size. The Cadmus team interviewed firms ranging in size from a sole proprietor to a firm with over 180 employees in Vermont, with an average of about 50 employees.

Project Types. All of the firms undertake new construction, renovation, and gut rehab nonresidential projects.

On average, interviewees reported that new construction projects represent about half of their work (51%). For four of the eight firms, new construction projects make up the largest share of their work.

Two respondents consider their gut rehab work to be a part of their renovation work and included it in the renovation total, two consider it to be part of their new construction work and included it in the new construction total, and three consider it a separate category and reported it this way. The latter three reported that gut rehab projects represent an average of 25% of their firm's work (Figure 159).

Figure 159. Percentage of Work by Project Type



Over one-fifth of projects involve a commissioning component or agent. As shown in Table 117, on average, respondents estimated that 23% of their projects involve a commissioning component or an agent who is involved throughout the design and construction process (range of 10% to 47% and median of 25%). Two respondents commented that they would like to see commissioning agents involved in more projects. One respondent who reported that about 10% of his firm's projects were commissioned noted that whether a project is commissioned varies based on the project type:

> If it's new construction, or a LEED-certified building, you'll typically have an outside commissioning agent verify that it's done properly. But if you are just replacing ductwork, furnaces, not a redesign, we don't have an outside engineering firm verifying our work.

Table 117. Percentage of Projects Commissioned

Projects	Percentage Commissioned (n=8)
Average Percentage	23%
Range	10%–47%
Median Percentage	25%

Design Process

Energy Efficiency Drivers

Most respondents find that it is typically a mix of both the client and the engineer driving energy efficiency considerations on projects. As seen in Table 118, when asked whether it is typically the client or the engineer who drives the inclusion of energy efficiency considerations on projects, one respondent said the engineer is typically the primary driver, and the rest (seven of eight respondents) said it is typically a mix of both the client and the engineer driving the inclusion of energy efficiency considerations.

One respondent noted that he tries to consider energy efficiency even if the client does not:

> If the client isn't focused on [energy efficiency], then I will try to drive it.

Another respondent finds that both the client and the engineering firms now drive the inclusion of efficiency considerations in projects:

> There isn't a project that goes out now that doesn't have energy efficiency considerations. It's gradually come to this point over the last 15 years.

Table 118. Primary Drivers of Energy Efficiency

Primary Drivers	Who Encourages Energy Efficiency (n=8)
Both Client and Engineer	7
Engineer	1

Clients request energy efficiency on over three-fifths of projects. As shown in Table 119, on average, respondents reported that clients ask for energy efficiency considerations to be included on 63% of commercial projects (range of 10% to 100% and median of 65%).

One respondent finds that 100% of his clients ask about energy efficiency considerations:

> Everybody wants to know what they can do for more efficient equipment and how much they're going to get back.

A respondent who reported that clients request efficiency on 65% of projects noted an increase in the number of clients asking for efficiency over time:

> Even 10 years ago, [clients asked for energy efficiency] less than 30% of the time.

A respondent who reported that efficiency is requested by clients on more than 50% of projects mentioned that cost considerations can be a concern for some. Another respondent who reported that clients ask for efficiency on only 10% of projects said he was not concerned because he thought that code requirements in Vermont are high-efficiency oriented now anyway.

Table 119. Percentage of Customers Requesting Energy Efficiency

Clients	Percentage Requesting Energy Efficiency (n=8)
Average Percentage	63%
Range	10%–100%
Median Percentage	65%

The majority of these firms' projects exceed CBES requirements. As shown in Table 120, on average, respondents reported that 66% of the commercial projects their firms undertake exceed minimum CBES in Vermont (range of 10% to 90%, and median of 75%).[12]

One respondent noted that it is a company goal to encourage clients to go beyond code, and mentioned the challenges of doing so in some instances:

> As a goal, we try to encourage people to go at least 30% beyond code. It's fairly easy to do in most cases; over 90% of our projects exceed that. What we have been noticing as the code has ramped up is that it's a little harder [to go beyond the code]. We have to look at the low-hanging fruit to try to achieve that.

Another respondent noted that they do not always actively discuss with a client when their project exceeds code as long as it meets their budget. Another pointed out that some commercial projects by nature exceed CBES requirements if they are required to adhere to Vermont's Land Use and Development Act (Act 250), which requires developments of a certain size to address environmental and community impacts.[13]

Table 120. Percentage of Projects Exceeding CBES Requirements

Projects	Percentage Exceeding CBES (n=8)
Average Percentage	66%
Range	10%–90%
Median Percentage	75%

Design and Specification Assurance

Interviewee firms typically have considerable control over what HVAC equipment is ultimately installed. All firms report that being involved in all phases of their projects as well as reviewing contractor submittals allows them to make sure that what they design or specify ends up in a building. Interviewers asked respondents to describe how they go about making sure that what their firm designs or specifies actually ends up in a building. Close to three-fifths (five of eight respondents) said they are involved with all phases of their projects, which allows them to control what is installed, with one respondent noting:

> It's easier for us because we're a design/build firm compared to a plan and spec firm, where the engineer does the HVAC design and then multiple contractors bid on the cost, and try to save money on the equipment. What I put on the plans is what my guys install.

[12] More information about CBES can be found on the Vermont Department of Public Service website: http://publicservice.vermont.gov/energy_efficiency/cbes

[13] More information on Act 250 can be found on the Vermont Natural Resources Board webpage: www.nrb.state.vt.us/lup/

Another respondent reported similar experiences:

> The only buildings I design are ones that [our firm] builds, so I own it through the whole process. I specify it, we go through the submittals, and we install it. It's pretty easy for me to ensure that what I specify goes in.

Close to two-fifths (three of eight respondents) said they review the technologies and plans that contractors submit to help ensure that what they design and specify ends up being installed. One respondent described the process in the following way:

> Sometimes we do get substitutions from the contractor, but they make sure they meet their specifications. It's pretty rare for this process [of reviewing contractor submittals] to not happen.

Another respondent noted that when they provide all services for a project, they can review contractor submittals to make sure they meet their design criteria, but pointed out that there are some projects where they do not have full control:

> When we are working on a project where we are providing the full services (construction, administration) we will review all the submittals for the equipment. The process involves comparing what they specify to what the contractor is proposing to make sure it meets the same performance requirements. We do get involved in some projects where we don't have construction administration of our work (about 10% to 20%). On about 80% of projects, we make sure it complies with the spec.

Design Alterations

Very few firms report that their designs are often altered or made less efficient. Interviewers asked respondents how often the design or the specification their firm develops for a particular installation is altered in a way that makes it less energy efficient (Table 121). One respondent said their designs are *often* altered, but close to two-fifths (three of eight respondents) report that their designs are *never* altered, with one respondent noting that it does not occur because they are involved in all aspects of the project:

> It doesn't happen. We're one-stop. We budget it, price it, design it. It doesn't go out to bid or get value-engineered. With our in-house resources, we are able to guarantee a price early on. We think it's an advantage of our method.

The respondent who had previously noted that very few of his clients' request energy efficiency on their projects cited this reason for never being forced to be less efficient:

> It's never altered. It's so rare that someone wants to go above code requirements, and I can't go below the code, so it can't be altered to be less efficient.

Close to two-fifths (three of eight respondents) reported that their designs are *sometimes* altered to be less efficient. The client (n=2) or a mix of the client and the construction manager (n=1) typically alter the designs because of budget constraints, with one respondent reporting:

> That typically happens when there are budget crunches. It may not be specifically related to mechanical or electrical, but when it's over budget, at that point, the project needs to be pared back. The first place the client looks . . . is typically in the mechanical and electrical side of things.

Another respondent said when his clients ask him to alter his design, he will explain the payback period to them in hopes of dissuading them from altering it. Another respondent noted that his designs may be altered when "the reality of what [the client] wants versus what they can afford sets in."

Table 121. Projects Altered to Be Less Efficient

Project Altered to Be Less Efficient (n=8)	Who Alters Project (n=5)	Why Altered (n=5)
Often (n=1)	Client or General Contractor	
Sometimes (n=3)	• Client (n=2) • Mix of Client and Construction Manager (n=1)	Budget Constraints
Not Very Often (n=1)	Client	
Never (n=3)	--	--

Design Freedom

The majority of projects do not have to adhere to pre-determined HVAC systems. As shown in Table 122, on average, respondents reported that their firm has the freedom to apply the most appropriate HVAC equipment instead of a pre-determined HVAC system on 82% of their projects (range of 50% to 100%, and median of 84%). Two noted that the client typically does not have a pre-determined system in mind, with one stating:

> The customer often doesn't know, and assumes you are giving them the best option. If they have a budget, and it is over, they are more likely to ask about what is being specified.

One respondent said clients typically ask them to present an option that meets the code requirements and an option that goes beyond it, and about 50% of clients choose the higher-than-minimum-efficiency option.

Two respondents did not provide a percentage estimate and instead stated that they work with clients to find a solution that will fit their needs and budget, with one respondent noting:

> We will provide one or two options to meet their basis of requirements, and along with that we might give them operating cost and first cost. Then [we will] try to collaborate with them to

> come up with the best system for what they want to spend. . . . Some clients will take the path of investing more money to get a better system, and others will just look at the first cost.

Table 122. Projects with Freedom to Specify Most Appropriate HVAC Equipment

Projects	Percentage with Freedom to Specify (n=6)
Average Percentage	82%
Range	50%–100%
Median Percentage	84%

Owners Project Requirements

According to these firms, OPRs are rare among Vermont commercial buildings. As shown in Table 123, three-quarters (six of eight respondents) either do not *very often* encounter OPRs (four respondents, 10% of projects) or they encounter them only occasionally (two respondents, range of 15% to 35% of projects). One respondent said they typically encounter an OPR when they work with a commissioning agent, and noted:

> OPR leads us down the path of the appropriate system that the owner is looking for. It's always going to result in a happier customer at the end of the job.

Another respondent most often encounters OPRs on LEED projects, and two noted that it is more common for them to have informal verbal agreements with clients about OPRs.

Two respondents encounter OPRs on all of their projects, with one respondent noting that if a client does not have an OPR, they would work with them to come up with one, and the other respondent stating that they try to follow the LEED approach on all of their projects.

The Cadmus team also asked respondents how, if at all, OPRs impact the HVAC system design and specification task. Close to two-fifths (three of eight respondents) reported that OPRs often drive the HVAC system design and specification. One respondent who said OPRs typically come up in LEED projects noted that they work closely with the client from the beginning to ensure their system design adheres to their requirements:

> [An OPR] can drive where we go with the system. It is a checkpoint. Usually the OPR comes from the owner and their commissioning agent. If we've done our homework on the upfront side, we've worked hand-in-hand to develop a system that will meet that requirement. . . . On occasion we'll get the OPR pretty late in the game, in which case if we've done our due diligence we would know what the owner's looking for.

One-half of the firms mentioned that OPR requirements can impact the technology specified, with one respondent stating:

> System efficiency is probably not affected, but the system selection is certainly affected.

Another respondent mentioned that when customers specify something in the OPR, it is often because they have an interest in new high-efficiency technology

Table 123. Owner Project Requirement and HVAC Impacts

Frequency	OPR Included (n=8)	Impacts on HVAC (n=8)
Frequently	Two respondents (100% of projects)	• Drives system design (n=1) • Specifies equipment selected (n=1)
Occasionally	Two respondents (15%–35% of projects)	• Drives system design (n=1) • Specifies equipment selected (n=1)
Not Very Often	Four respondents (10% of projects)	• Drives system design (n=1) • Specifies equipment selected (n=2) • Minimal impact (n=1)

Support Needed for Renovation

Suggestions for additional program support on renovation projects varied, with incentives mentioned most often, followed by respondents who thought no additional support was needed beyond what is already being provided.

Respondents provided a variety of feedback when asked what the Vermont EEUs or the State of Vermont could do to encourage building decision-makers (such as owners, operators, and managers) to take energy efficiency into consideration more often when replacing existing HVAC equipment with something more efficient than what was there before (Table 124). One-half of respondents mentioned increasing incentives would help encourage building decision-makers to make more efficient choices, with one respondent noting that the incentives give them a chance to discuss high efficiency with the client.

Another respondent mentioned a desire to see more prescriptive rebates listed on the EVT website:

> There are fewer rebates than there once was, and many have been reduced. I used to be able to go to the Efficiency Vermont website and show the customer what rebate they would receive; now the rebates and incentives are becoming more custom.

Another respondent encouraged the programs to expand to other equipment types and also requested that EEUs improve their reaction time when reaching out to them about the programs.

Table 124. Support Needed—HVAC Replacement (Multiple Response, Count of Responses)

EEU or State-Level Support	Replacement (n=8)
Increase incentives	4
Nothing else beyond what they're already doing	2
Add back prescriptive rebates	1
Add more equipment to rebate/upstream program	1
Change codes to allow electric heat as backup	1
Coordinate on projects earlier	1
Speed up response times	1
Take other fuel sources into account in addition to electric	1

Support Needed to Incorporate Energy Efficiency Sooner or More Often

Suggestions for additional program support needed to incorporate energy efficiency sooner or more often also varied. "Incentives" was mentioned with the same frequency as those who thought no additional support was needed beyond what is already being provided.

The Cadmus team also asked respondents for feedback about what the Vermont EEUs or the State of Vermont could do to encourage building decision-makers or construction managers to incorporate energy efficiency into the HVAC design or specification process sooner or more frequently (Table 125). Again, "increased incentives" was a common response (three of eight respondents), with one respondent noting the importance incentives have for customers even when they are aware of energy efficiency considerations:

> Owners are more educated than they once were [about energy efficiency], but we still need to have [an] initial talk with them. . . . They often will not do what is right for energy. If they're not getting incentivized, most owners will go with the bare bones that meets energy code rather than what exceeds it.

One of the three respondents who felt that the state and EEUs could not do anything beyond what they are already doing felt differently about the choices clients typically make:

> It pretty much goes without even being said that everybody does the highest efficiency possible.

One respondent mentioned the importance of EEU staff engaging in projects in their very early stages:

> We have found the best way to engage Efficiency Vermont is to try to get them engaged as early in the process as possible . . . so they know what is being done with the basis for design and how decisions for design were made. Often. they'll mention some options to us that haven't been considered.

Table 125. Support Needed—Efficiency Sooner or More Often (Multiple Response, Count of Responses)

EEU or State-Level Support	Sooner or More Often (n=8)
Increase incentives	3
Nothing else beyond what they're already doing	3
Behavior comparison with commercial customers	1
Increase code enforcement	1
More senior engineers at EVT	1
EEUs to engage very early in process	1

When the Cadmus team asked respondents if there are different types of support needed for existing buildings, new construction, or gut rehab, one-half of respondents thought that it did not vary, with one mentioning, "everybody's looking for efficiency," and another stating that "better incentives are better for everyone." Another respondent thought that their projects were driven more by the owner or general contractor than by whether it was new construction, retrofit, or gut rehab.

Offering higher incentives to meet renovation's unique challenges was mentioned by one respondent:

> Renovations may require a stronger incentive due to [the mentality of] "If it ain't broke, don't fix it." In new construction and gut rehab, it's easier to make those decisions since you are installing new equipment anyway.

Another respondent felt similarly about the relative ease of installing higher efficiency equipment in new construction projects, noting the following:

> With new construction [it is] new equipment, so the customer is more likely to choose higher efficiency. With renovation, the customer may choose to leave equipment until its end of useful life. Overall, it comes down to budget, and the support the incentive can provide is useful to both existing buildings and new construction.

Technologies Specified and Installed

The interviewers asked the respondents a series of questions about their experiences with various HVAC technologies and their thoughts on market trends.

Frequency of Specification

The interviewers read the respondents a list of HVAC technologies and asked them how often they designed or specified each (Table 100).

All respondents said their firms *frequently* install variable refrigerant flow systems, and commercial air-cooled rooftop units (RTUs) were the next most *frequently* specified technology.

Two respondents commented that there were few buildings in Vermont of a size to require units over 20 tons in capacity for RTUs, however. Ground source heat pumps and ice storage were the most rarely specified technologies, with six and eight respondents, respectively, saying that they *seldom* or *never* specified these. Three respondents had *never* installed an ice storage system, and three had seen them installed only once in the last 10 years.

Table 126. HVAC Technologies Specified and Installed

Technology	Frequently	Sometimes	Seldom/Never
Variable Refrigerant Flow (n=8)	8	-	-
Commercial Air-Cooled Rooftop Units (RTUs) (n=8)	6	2	-
Air Source Chillers (n=8)	4	2	2
Water Source Heat Pumps (WSHPs) with a Boiler and/or Cooling Tower (n=8)	3	3	2
Biomass (n=8)	2	2	4
Water Source Chillers (n=8)	1	3	4
Ground Source Heat Pumps (GSHPs) (n=8)	1	1	6
Ice Storage (n=8)	-	-	8

Most Commonly Specified

The interviewers then asked the HVAC designers and specifiers to identify the single type of equipment they most commonly specified, and whether this differed by facility size or use.

The most prevalent answer, from four respondents, was that their firms chose the best system for the particular application. Three respondents named WSHPs with a boiler and/or cooling tower as the most common type of equipment (Table 127). Two each cited air source heat pumps (ASHPs) and variable refrigerant flow systems, and one said RTUs were the most common technology for that firm.

Discussing variations in specifying system types by building use or size, none of the respondents cited any differences in their specified equipment by building use. The respondents did say that there were differences in which technologies they recommended for buildings of different sizes:

- Three respondents said they more frequently specify WSHPs for large buildings. Two said they commonly specified RTUs for large buildings as well.
- For VRF systems, two cited their flexibility for use in many types of buildings. One said VRF systems were good for historic renovations or other buildings with space constraints. One said they most commonly recommended VRF for small buildings.
- One respondent said he most commonly specified ASHPs for buildings of 6,000 to 25,000 sq ft.

Table 127. HVAC Technologies Most Commonly Specified

Technology	Count (n=8)
Water Source Heat Pumps (WSHPs) with a Boiler and/or Cooling Tower	3
Air Source Heat Pumps (ASHPs)	2
Variable Refrigerant Flow	2
Commercial Air-Cooled Rooftop Units (RTUs)	1

Market Trends

The interviewers asked the respondents for their insights into the general market trends for a list of HVAC technologies. Table 128 presents the respondents' assessments of the trends in popularity and efficiency for various system types.

Variable Refrigerant Flow: There was strong consensus about the popularity of VRF systems. Six respondents cited this as a very popular, even "dominant" HVAC technology. Two credited part of this popularity to improvements in VRF technology that allows them to provide heat in Vermont's climate without a backup system.

Ventilation Strategies: The respondents also agreed about the popularity of ventilation strategies. Six of the HVAC designers said ventilation strategies are increasing in popularity, specifically ERV units and demand control ventilation. One said, "You don't do a job without an energy recovery unit. Some of the newer technologies on the heat recovery are incredible. When you start seeing 90 to 92% efficiencies on design days in Vermont, that's pretty effective." Another stated, "[An ERV] tends to be something I'm able to sell to an owner even if not required by code."

Ground Source Heat Pumps: There was less consensus about this technology. Two respondents said GSHPs are on an upward popularity trend, two said demand would remain steady, and one said GSHPs are decreasing in popularity. Three respondents cited the high cost and/or uncertainty in digging wells for GSHP as a barrier to greater popularity.

Air Source Chillers: There was also a mixed response regarding market trends for air source chillers, with two respondents saying their popularity is increasing, one saying there is steady demand, and three saying that they are decreasing in popularity. One respondent said part of the market for air source chillers had been taken by VRF, but that the efficiency of the technology is increasing.

Ice Storage: Four respondents said ice storage would remain steady at a state of low demand, though one saw them on an upward trend in the market. Four respondents said they are useful for situations where the customer needs to reduce their peak load.

Commercial Air-Cooled RTUs: Two respondents see the popularity of RTUs as steady, while one sees demand increasing. There was near-universal agreement (seven respondents), however, that RTUs on the market are increasing in efficiency.

Water Source Chillers: Five respondents agreed that, like ice storage, water source chillers would see a steady, low demand. Two cited a scarcity of large buildings in Vermont, which are the best application for water source chillers, as a reason for the low demand.

WSHPs with a Boiler and/or Cooling Tower: There was some disagreement about WSHPs. Four respondents said their popularity is decreasing, and three said there will be steady demand for this technology. Three respondents said WSHPs were being superseded in the market by VRF or ASHP systems, driven by the recent improvements in cold weather performance for these technologies.

Biomass: Two respondents said demand for biomass systems is decreasing, while one said it is increasing. One of the respondents said it is unfortunate that they are not more popular, but that low fossil fuel costs reduce demand for them, a reason also cited by another respondent. Another said there were more manufacturers of biomass boilers entering the market and driving prices down. One respondent said their firm installs fewer biomass units because they are moving away from fossil fuel systems in general. This respondent also said it was difficult for customers to receive timely service for biomass units in Vermont.

Table 128. Market Trends for HVAC Technologies

Technology	Trend (n=8)*			
	Popularity Increasing	Popularity Steady	Popularity Decreasing	Efficiency Increasing
Variable Refrigerant Flow	6	-	-	-
Ventilation Strategies/ERVs/Demand Control Ventilation	6	-	-	1
Ground Source Heat Pumps (GSHPs)	2	2	1	-
Air Source Chillers	2	1	3	1
Ice Storage	1	4	-	-
Commercial Air-Cooled Rooftop Units (RTUs)	1	2	-	7
Water Source Chillers	-	5	1	1
Water Source Heat Pumps (WSHPs) with a Boiler and/or Cooling Tower	-	3	4	-
Biomass	1	-	2	-

* Note that not all respondents commented on all technologies.

Barriers Encountered

The responses were diverse when the interviewers asked the respondents to describe barriers they have encountered with any of the previously discussed technologies or system types (Table 129). A lack of any notable barriers was the only repeated response, from two of the respondents.

Four respondents mentioned barriers related to VRF systems:

- **Code does not allow electric backup heat for VRF or ASHP systems:** At cold temperatures, the coefficient of performance (COP) is approximately one, which is equivalent to standard electric heat. This requires installation of a fossil fuel-based backup heating system that could otherwise be avoided. The respondent stated that "in the state of Vermont we have roughly 30 to 35 hours a year where we're below -13°F [temperature at which electric backup heat would be required]. Of those, there's only about eight [hours] in the 8 a.m. to 5 p.m. timeframe."
- **Cost for larger buildings**: One respondent stated that VRF systems are not the lowest cost option for larger buildings, but that he hoped that increased competition in the market would drive prices down.
- **Unrealistic expectations for cold-weather performance**: This respondent feels that recent manufacturer advertising for VRF systems overstates the capabilities for their performance in very cold weather and underplays the risks of installing a VRF without a backup heating system. "They say the system will provide all the heat you need down to -15°F, what about -20°F? When you need the heat the most, you have no heat. Once it shuts off, they won't restart until temperature is much warmer. That is not being conveyed properly by the manufacturers' advertising campaigns."
- **Complexity of controls**: This respondent feels that the complexity of VRF controls sometimes makes them difficult for the owner to operate in an efficient manner. In a related comment regarding HVAC control systems in general, another respondent stated that the diversity of manufacturers and standards for HVAC controls and building automation systems often makes it complicated to integrate the two.

Table 129. Barriers Encountered with HVAC System Types

(Multiple Response, Count of Responses)

Barriers	Count (n=8)
None	2
Code does not allow electric backup heat for AHSP or VRF systems	1
High VRF cost in larger buildings	1
Misconceptions about the capabilities of VRF systems.	1
Complexity of VRF controls	1
Cost of drilling wells for GSHPs	1
Mismatch with load profile and utility rate structure for ice storage	1
Noise and size of air or water source chillers	1
Integrating equipment control with building automation systems	1

Code Changes

The interviewers asked the respondents for their thoughts on HVAC-related code changes in Vermont and about the reasons why they design high-efficiency HVAC systems.

Effects of Code Changes on Projects or System Selection

The findings suggest that Vermont's energy efficiency code has increased the baseline efficiency of HVAC equipment, but could be more uniformly enforced.

The respondents were largely positive in their responses when asked about the effects of recent code changes in Vermont on their projects and the systems they design or specify (Table 130). Six of the respondents said Vermont's strong base code requirements lead to energy-efficient system designs. As one respondent noted:

> Vermont has a great code, one of the highest energy codes in the country. It's really hard to say "We're going to give you a code-compliant building" and feel guilty about it. They're getting a good building and good efficiency systems.

Three of these six respondents made the related comment that the job of convincing a client to choose more energy-efficient equipment is easier because of the strong code requirements. One commented that recent changes had made it easier to comply with ventilation requirements.

On the negative side, three respondents stated that code changes increased project costs. Three respondents also contended that code enforcement is not uniform across the state or mentioned there did not seem to be coordination between the energy code and HVAC system requirements imposed for Act 250 projects. They felt that this created uncertainty for them and their clients and an un-level playing field when competing against firms that would exploit a lack of code enforcement: "If it was harder to break the rules, less people would break the rules." One respondent stated that published versions of the code do not always appear in a timely manner: "We might not have a hard copy until six, nine, 12 months after it goes into effect."

Table 130. Effects of Code Changes on Projects/Systems (Multiple Response, Count of Responses)

Effect of Code Changes	Count (n=8)
Vermont's strong code leads to energy-efficient HVAC systems	6
Strong base code makes it easier to convince clients to choose efficient systems	3
Increases costs	3
Codes are not enforced uniformly across the state/Act 250 issues	3
Easier now to comply with ventilation requirements	1
Codes are not always published in a timely manner	1

Effects of New Code Requirements for Controls on System Efficiency

The recent code changes that have increased the requirements for certain HVAC controls have led to more efficient systems.

Half of the interviewees stated that recent increases in code requirements for controls in HVAC systems have led to increases in efficiency (Table 131). Two respondents said the requirements are moving the market toward direct digital control systems, though with added costs for the client (two respondents), and offered the caveat that efficiency gains of these controls depend on how the occupant actually uses them, which is not regulated by code and cannot be controlled by the installer (one respondent). One comment showed strong support for new requirements for feedback controls on economizers: “A great move. Most economizers don’t work; when they don’t work or fail, we don’t know about it. If that code results in failing economizers being corrected, it will be a huge benefit in this climate.”

Table 131. Effects of New Control Requirements on Efficiency (Multiple Response, Count of Responses)

Effect of Control Requirements	Count (n=8)
Increases system efficiency	4
Moving the market to direct digital control	2
Increases system cost	2
Code for controls less important than how occupant uses controls installed	1
Hard to find code-compliant controls for smaller single-zone systems	1
Requirements for feedback controls on economizers is beneficial	1

Reasons for Designing High-Efficiency Systems

Most (five of eight) of the respondents install high-efficiency HVAC systems because of their company mission/personal preferences and because they believe it will benefit the owner financially over the life of the system.

A majority (five of eight) of the respondents cited their company mission or personal preference as a primary reason for designing high-efficiency systems, as shown in Table 132. One respondent noted:

> It’s a personal mission. Most of my design peers here share that idea. Give the owner the best building possible for the amount of money they have to spend. The definition of best building is the building that uses as little energy and is as efficient as possible.

An equal number cited the financial benefit to the owner over the life of the system. Several respondents said customers request high-efficiency systems and cited the benefits of efficient HVAC for the environment. One respondent mentioned a mix of these reasons:

> I wouldn’t consider doing anything but [installing high-efficiency systems]. It’s obviously good for the environment. It’s good for the owners in the long run. There will be a payback. It’s a no-brainer.

Two respondents said code requirements were one of the primary reasons for designing high-efficiency systems.

Table 132. Primary Reasons for Designing High-Efficiency Systems (Multiple Response, Count of Responses)

Reasons	Count (n=8)
Company mission/personal preference	5
Financial benefit for owner	5
Customer request	3
Good for the environment	3
Code requires it	2
Makes for a better building	1

Program Feedback from HVAC Market Actors

All eight respondents reported that they have had interactions in the last three years with EVT. Five respondents reported having experience working with BED, and four with VT Gas. The Cadmus team asked respondents about their experiences with efficiency programs, including both positive aspects as well as any aspects they would change or improve on.

Positive Aspects of Efficiency Programs

A large majority of respondents (88%) provided positive feedback about their experiences with EEU program support.

Interviewers asked respondents about what aspects of the EEU program(s) worked well from their perspective (Table 133). Nearly all respondents (88%) mentioned some positive aspects, with information sharing by and knowledge of EEU program staff (four respondents) and program incentives (three respondents) mentioned most often. One respondent noted that "Efficiency Vermont is a great resource for information" and another stated that "Vermont Gas has worked very well when we've dealt with them. It's pretty straightforward. You give them the information and they come back to you."

Another respondent described positive experiences working with BED and VT Gas:

> I find Burlington Electric to be very progressive, pushing for energy efficiency, providing incentives. . . . Vermont Gas is very open. You can present a case for an efficient option; if an owner is on the fence, they will often be cooperative and kick in an incentive to push them over the fence.

Other aspects of programs that respondents noted as working well included EVT's code trainings and interpretations and identifying additional savings opportunities. Specifically:

> I find them [code trainings] to be very approachable. I often go to them for a code interpretation. They are generally very knowledgeable about efficient technology and willing to answer questions as they come up.

Another respondent mentioned information sharing and program knowledge as positive aspects:

The incentives encourage the customers and the Efficiency Vermont staff often point out areas of savings that they may not have suggested to the client otherwise.

Table 133. Positive Aspects of EEU Programs (Multiple Response, Count of Responses)

Aspects	Positive Aspects of Program (n=8)
Information sharing/knowledge	4
Incentives	3
Code training and interpretation	1
Expanding savings for fuels beyond electricity	1
Instant rebates for customers	1
Straightforward	1

Efficiency Program Aspects to Change or Improve Upon

Respondents most often mentioned increasing the incentive amounts and encouraging the EEUs to coordinate with HVAC designers and specifiers as early as possible on projects as areas that programs could improve on or change.

Interviewers asked respondents about what aspects of the program(s) they would change or improve on if they could Table 134). Responses were varied, with increasing incentive amounts and getting programs involved as early as possible mentioned with the most frequency (by two respondents each).

One respondent who has worked with EVT and BED found that getting program staff involved early in projects is important:

> Usually Efficiency Vermont or Burlington Electric Department is supportive and not steering the design. We will present a system to get their support. If we get the energy staff on board early enough, it's helpful through the process. The owner is interested in making sure they receive the incentive.

Feedback about involving EVT early in the process was mentioned by another respondent:

> I deal with Efficiency Vermont the most. In an ideal scenario we bring them on basically as soon as the project becomes real. We try to keep them up to date with the design as it goes through so that when it comes time for them to review the design they know what's coming. Ideally, I personally have the opportunity to run ideas past them prior to final construction documents. I find that I always get good feedback from them, suggestions. Their knowledge base is vast. They're a good resource for us. . . . It seems pretty clean and smooth for me personally most of the time.

One respondent said they would like to see programs target rural areas more specifically and expand incentives to propane-fired equipment.

Expanding upstream incentives to other products was mentioned by a respondent who had experience primarily working with EVT:

> Continue to expand the upstream program to other equipment. [It has] worked so well on equipment implemented so far. Lighting and smart pumps have been hugely successful. There's other products out there that could come into that program.

Post-installation follow-ups to make sure the equipment that gets a rebate or incentive actually gets installed was mentioned by one respondent. Another suggested providing additional incentives to customers after a year:

> If the system could be reviewed after a year, [the customer] could receive more money if it was still operating at the intended efficiency. That is [currently] done more on LEED projects to get certifications.

Another respondent thought the EEUs should more strongly encourage or train contractors to inform all customers about the rebate process, especially smaller customers. The same respondent also suggested discontinuing contractor incentives and giving everything to the customer because "We have seen customers who think we are getting a kickback."

One respondent mentioned communication challenges they have faced with EVT:

> The whole aspect of Efficiency Vermont talking to the client and then talking to us and then talking to the client—90% of the time in Vermont you don't have clients that are very savvy. You don't have a large facilities group that understands what Efficiency Vermont is telling them.

The same respondent thought that EEU programs in Vermont should be more comprehensive and fuel-neutral:

> So much has been pushed on lighting. There's really nobody that's advocating the building envelope to any great degree. If we really want to push efficiency, it's got to be all-inclusive and incentives have to be all-inclusive and not just electricity or gas, because that's what we have.

Table 134. EEU Program Aspects to Change or Improve (Multiple Response, Count of Responses)

Aspects	Aspects to Change or Improve (n=8)
Increase incentive amounts	3
EEUs to get involved as early as possible	2
Create a point person for each project	1
EVT communication issues	1
Encourage contractors to ensure customer receives incentives	1
Expand upstream incentives to other products	1
Nothing else beyond what they're already doing	1
Post-installation follow-up	1
Programs should be more comprehensive, fuel-neutral	1
Review system after a year and provide additional incentives	1
Stop offering contractor incentives	1

Program Feedback from End Users

Program Experience of Building Decision-Makers

The Cadmus team asked building decision-maker interviewees about their experience participating in efficiency programs, including efficiency improvements made, reasons for participating, how supportive the program was in helping to convince upper management to make the improvements, other program support that might have been needed, and their overall satisfaction.

All respondents had made some program-supported efficiency improvements within the last four years. Lighting was the improvement reported most commonly. Two organizations participated in a new construction program.

Interviewers asked respondents to confirm or describe any improvements they had made in the past four years for which they had received technical assistance or an incentive from their EEU; Table 135). Lighting was the most commonly reported improvement (made by five of eight organizations), followed by HVAC program improvements (three of eight organizations). Two organizations (the bank and the college) reported making weatherization upgrades. The college made biomass upgrades, the health care facility installed new circulation pumps, and the music and arts center installed new windows. Two interviewee organizations, the grocery store and the municipal office space, undertook new construction projects that incorporated efficiency improvements for which they received program incentives and technical support.

Table 135. Program Improvements Made in the Last Four Years

Primary Activity at Property Interviewed	Biomass	Circulation Pumps	HVAC	Lighting	New Construction	Weatherization	Windows
Banking			1	1		1	
College	1		1	1		1	
Grocery					1		
Health Care		1					
Municipal Office Space					1		
Music and Arts Center			1	1			1
Senior Assisted Living				1			
Ski Resort				1			
Total	1	1	3	5	2	2	1

Respondents most often cited obtaining rebates and incentives to help defray the cost of undertaking efficiency upgrades as the reason for participating in EEU efficiency programs. However, respondents cited corporate social or environmental commitments next most frequently. Other reasons respondents cited for participating in EEU programs included to create management buy-in and to obtain technical expertise.

As Table 136 shows, the most common reason that respondents gave for participating in efficiency programs was rebates and incentives (five of eight respondents), followed by social and environmental concerns (three of eight respondents). The staff at the bank noted that both the rebates and social and environment concerns were motivating factors for them:

> Rebates are a primary reason—we are a financial institution, so we're in the business of saving money. But it's a social and environmental concern to us as well.

The staff at the ski resort described their parent company's commitment to carbon reduction as a primary reason for program participation:

> Our corporate parent company is very committed to reducing our carbon footprint, and they are very proactive about participating in energy efficiency and renewable energy programs.

The staff at the college mentioned both the rebates/incentives and the program's ability to create buy-in from management as the main reasons for participating in the program, stating:

> There are a number of reasons, including the rebates and incentives themselves. Also, working with Efficiency Vermont and designers that are excited about the improvements and can help us understand the long-term benefits of upgrading our many buildings (which are in various states of maintenance) helps us create buy-in from management who sign off on the work.

The staff at the music and arts center said they participated because the conditions of their permit mandated they make efficiency improvements and because they needed the expertise that the program provides. The municipal office space was owned and managed by a state department that is mandated to make upgrades, but department staff noted that it is also "the right thing to do."

Table 136. Primary Reasons for Participation in Efficiency Programs

Primary Activity at Property Interviewed	Rebates/ Incentives	Social/ Environmental Commitment	To Create Management Buy-in	Mandated to Make Upgrades	In Need of Expertise to Make Upgrades
Banking	1	1			
College	1		1		
Grocery	1				
Health Care	1				
Municipal Office Space		1		1	
Music and Arts Center				1	1
Assisted Living	1		1		
Ski Resort		1			
Total	5	3	2	2	1

Half of respondents needed help convincing upper management to approve energy efficiency upgrades. All of these respondents found EEU program services and support either *helpful* or *very helpful* in this task.

Interviewers asked respondents how helpful EEU program services and support were in convincing upper management to approve the work. Two of the eight respondents said they were the primary person responsible for making the decisions about what improvements to make, while two said their management did not need much convincing. Of the remaining four respondents, all said EEU program services and support were *helpful* or *very helpful* in convincing upper management (Table 137).

The staff at the assisted living center described the importance of the EEU program's support to receiving corporate approval:

> We have had a good relationship with Efficiency Vermont over the years, and they have wonderful incentives. When they started the LED program, it gave us the opportunity to convert to more efficient lighting. Otherwise it would have been difficult to receive corporate approval.

As did the staff at the college:

> Efficiency Vermont's support was very helpful in convincing upper management to approve the work. Their input helped create clarity about the energy savings, and helped generate interest.

Table 137. Program Help in Convincing Upper Management to Make Improvements

Primary Activity at Property Interviewed	Very Helpful	Helpful	Management Did Not Need Convincing	Respondent Primary Decision-Maker
Banking		1		
College	1			
Grocery	1			
Health Care			1	
Municipal Office Space				1
Music and Arts Center				1
Assisted Living	1			
Ski Resort			1	
Total	3	1	2	2

The overwhelming majority of respondents are highly satisfied with their program experience.

When interviewers asked how satisfied respondents were with their program experience overall, all but one respondent said they were very satisfied (seven of eight respondents), and one respondent said they were satisfied. The staff at the assisted living center noted:

> Very satisfied. It would have been very difficult to convince corporate to make the upgrades without the rebates.

The only substantive suggestion for improving programs that respondents offered was to expand the number of in-ground LED lighting products eligible for EVT's lighting program offerings.

When asked about what other services or support the EEU program could have provided that would have helped their organization in the decision-making process *at the time they made the improvements*, three-quarters (six of eight respondents) said nothing else was needed. However, the staff at the college said they would like EVT to include more qualifying lighting products in the program, stating:

> They've been great to work with and very supportive. One thing we ran into was that one of the lighting technologies we used didn't have the right testing to qualify for the rebates, and it was disappointing that they didn't qualify even though they were very efficient lighting.

The staff at the music and arts center said they could have used more advice from the program about what the appropriate HVAC system would have been for their particular building.

The staff at the ski resort noted:

> I can't think of anything else—Efficiency Vermont has been very helpful to us. We think of them as a partner.

Interviewers asked respondents if there was anything else the utilities could do to help encourage their organization's upper management to allow staff to spend time focusing on saving energy in their building(s). All respondents said there was nothing else they could think of beyond what the utilities already do. The staff at the college mentioned:

> I think Efficiency Vermont is already doing everything that it can. They have been a great help to us in "selling" the projects we've worked on to our management.

The staff at the bank also noted that they thought EVT was doing all it could to help their projects move forward:

> There is nothing different that they could do. We have a small team that is committed [to work with upper management]. Efficiency Vermont is helpful in sub-metering and identifying savings opportunities.

Program Experience of Telephone Survey Participants

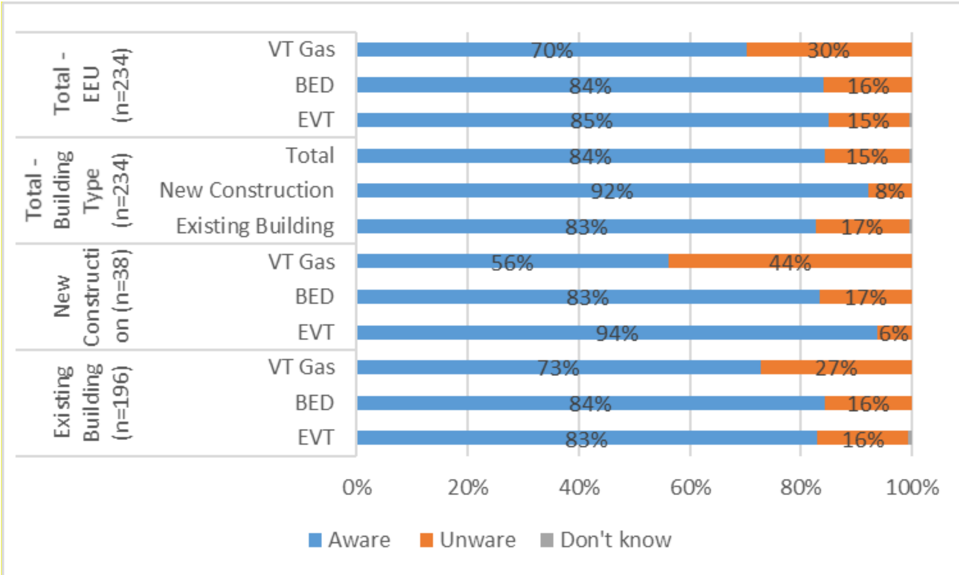
A telephone survey conducted with 234 customers across all EEU areas focused on program awareness and participation and EEU satisfaction.

Program Awareness and Participation

Program Awareness

Survey respondents across all EEUs demonstrated high awareness of the programs. As shown in Figure 159, most customers (84%) are aware of energy efficiency service offerings available to them from EEUs. EVT claims the highest percentage, with 85% of customers indicating awareness of offerings. BED follows closely behind EVT, with 84% of customers indicating awareness. Close to three-quarters (70%) of customers in the EVT service area are aware of service offerings. Customers in new construction were 9% more likely to indicate awareness than those in existing buildings (92% new construction; 83% existing buildings).

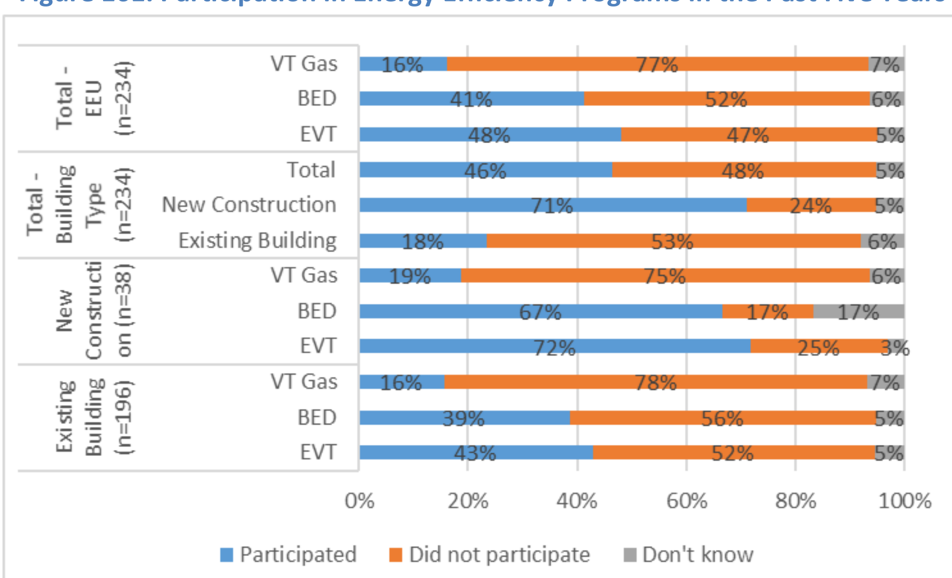
Figure 160. Awareness of Energy Efficiency Service Offerings



Program Participation

Close to one-half (46%) of businesses recall having participated in some form of energy efficiency program in the last five years, as shown in Figure 161. EVT customers claim the highest participation rate of 48%, and over two-fifths (41%) of BED customers report participating in energy efficiency programs in the past five years. Less than one-fifth (16%) of VT Gas customers report participating in the past five years, however. Although nearly three-quarters (71%) of customers in new construction buildings recall participating in programs in the past five years, less than one-fifth (18%) of participants in existing buildings recall participating in programs.

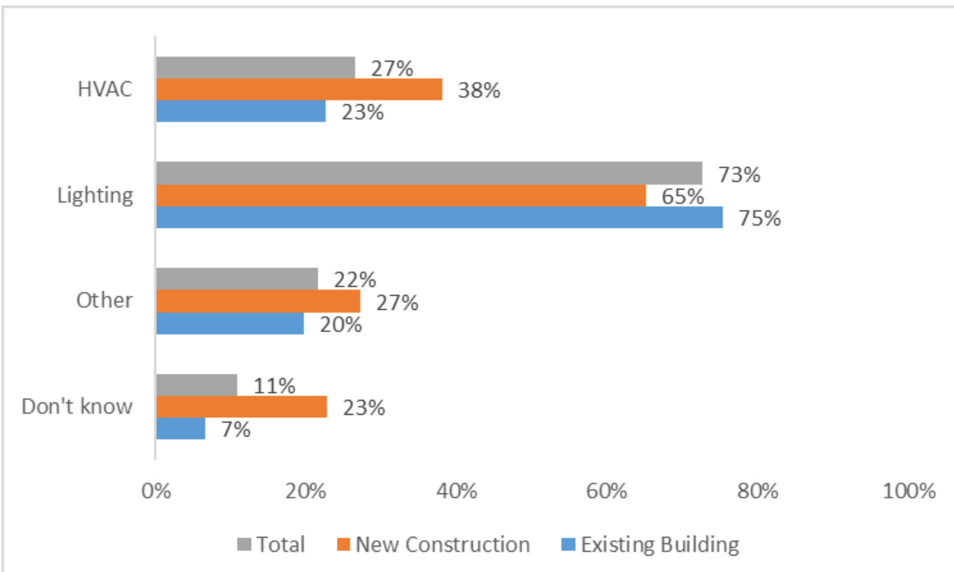
Figure 161. Participation in Energy Efficiency Programs in the Past Five Years



Energy Efficiency Improvements Implemented with Program Support

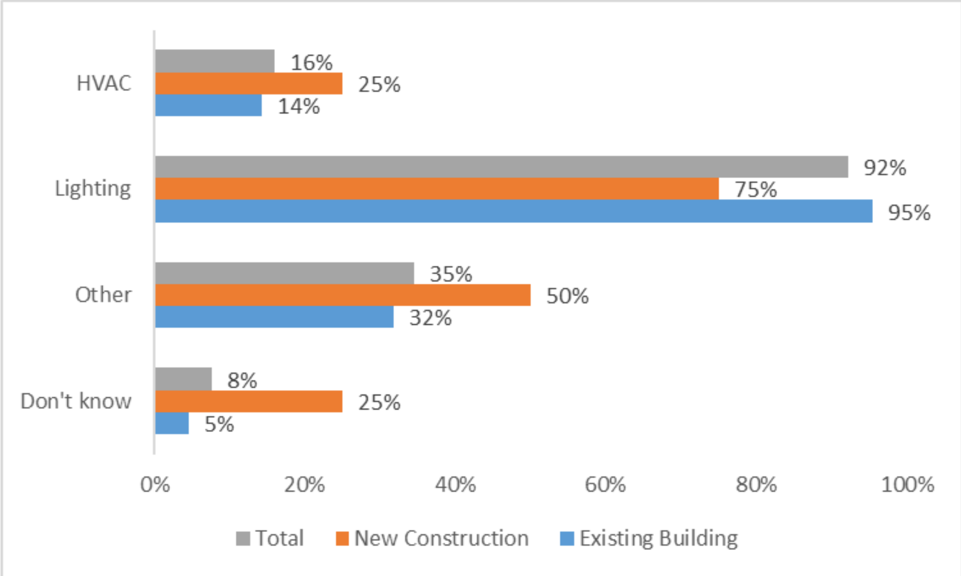
The majority of surveyed customers who reported having participated in an EVT or BED program had installed lighting measures. The majority of surveyed customers who reporting having participated in a VT Gas program had installed HVAC measures. Close to three-quarters (73%) of customers who participated in EVT programs implemented lighting measures, as shown in Figure 162. Lighting measures were implemented by more customers in existing buildings (75%) than customers in newly constructed buildings (65%). Over one-quarter (27%) of customers who participated in EVT programs implemented HVAC measures, with more customers in new construction buildings reporting this (38% new construction customers; 23% existing building customers). Over one-fourth (22%) indicated they implemented "other" measures, such as weatherization work.

Figure 162. Type of Energy Efficiency Improvements Implemented with Technical/Financial Assistance from EVT (n=86)



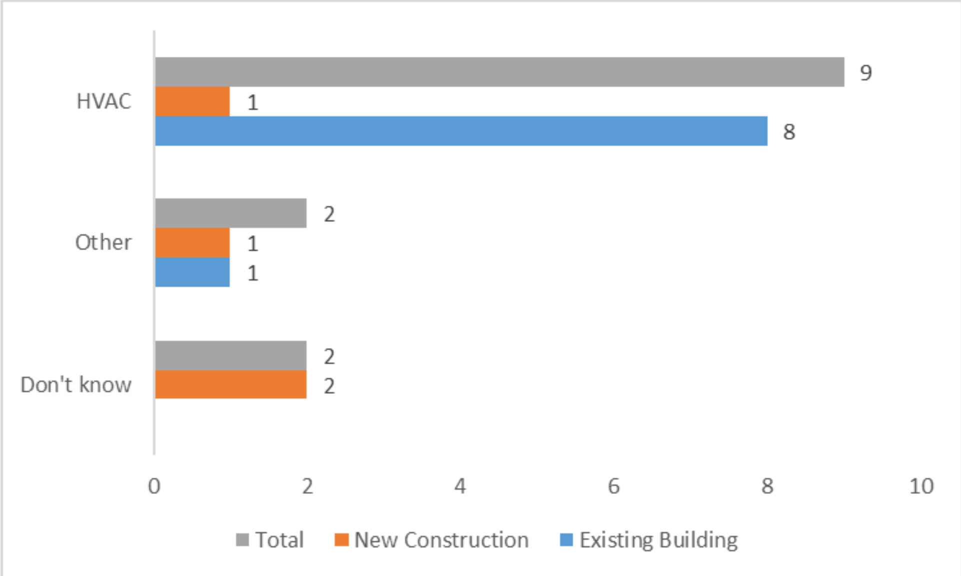
Most (92%) customers who participated in BED programs implemented lighting measures, as shown in Figure 163. Lighting measures were implemented by more customers in existing buildings (95%) than customers in new construction buildings (65%). Over one-third (35%) indicated they implemented "other" measures, such as kitchen equipment replacement and weatherization work.

Figure 163. Type of Energy Efficiency Improvements Implemented with Technical/Financial Assistance from BED (n=26)



Most customers (60%) who participated in VT Gas programs implemented HVAC measures, as shown in Figure 164. HVAC measures were implemented by more customers in existing buildings (67%) than customers in new construction buildings (33%). One-third (33%) indicated they implemented "other" measures, such as kitchen equipment upgrades.

Figure 164. Type of Energy Efficiency Improvements Implemented with Technical/Financial Assistance from VT Gas (n=12)*



* Count of respondents

EEU Satisfaction

Satisfaction with EVT Services

Figure 165 through Figure 169 provide customer satisfaction ratings related to energy efficiency services provided by EVT. **The majority of customers are highly satisfied with the equipment, services, ease of participation, and quality of measures provided by EVT.** Ratings are typically clustered between scores of 8 and 10, where 10 is completely satisfied. Slightly lower scores were reported for the time taken to process the application and issue the incentive payment, the quality of the technical support or services provided through the program, and the level of incentive for the equipment installed.

Figure 165. Overall Satisfaction with Quality of Measures by EVT

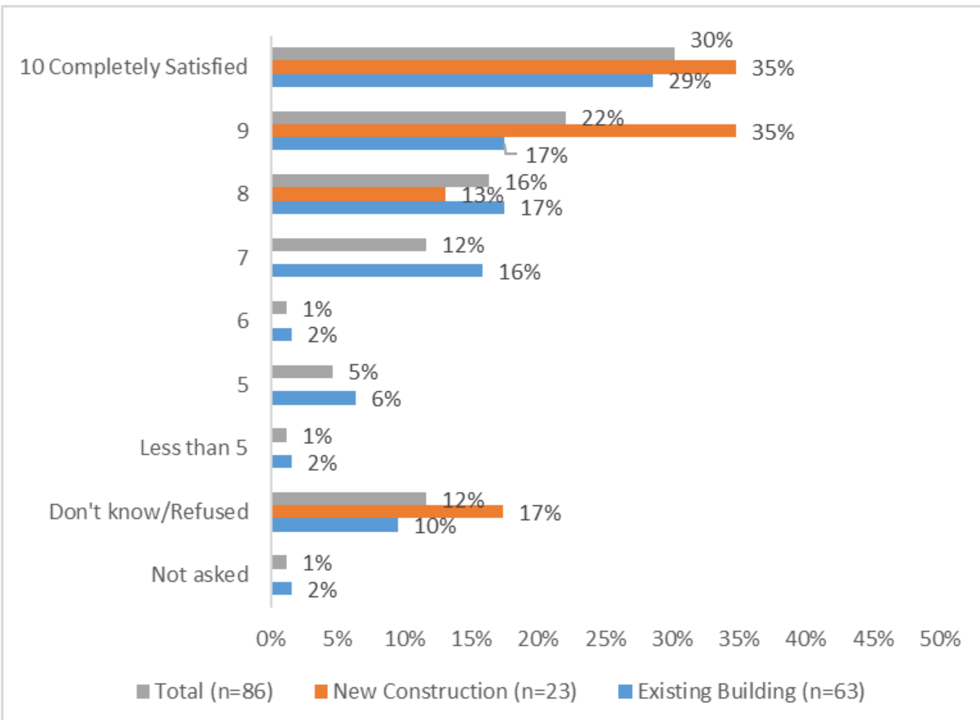


Figure 166. Overall Satisfaction with Quality of Technical Support or Services Provided by EVT

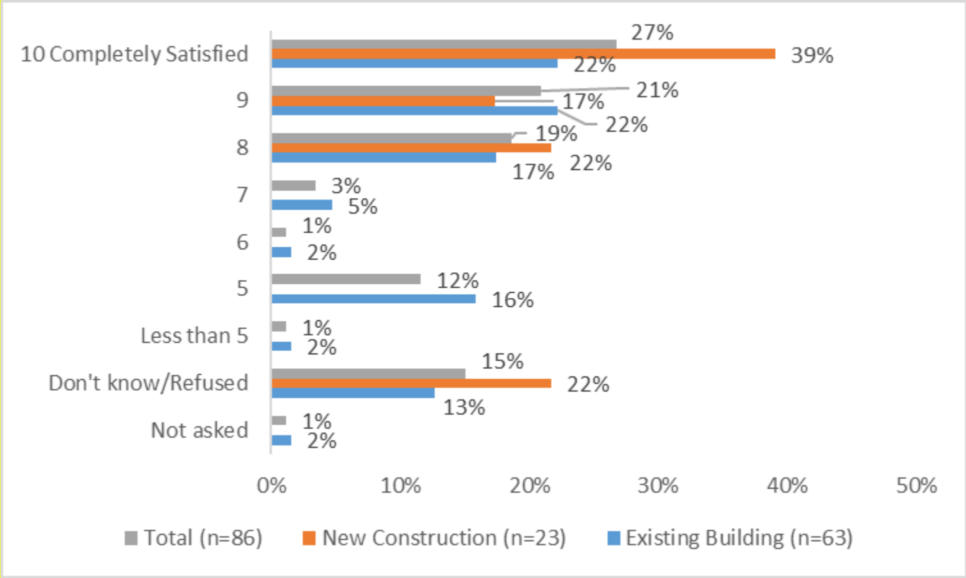


Figure 167. Overall Satisfaction with Time It Took from Application through Receipt of Incentive with EVT

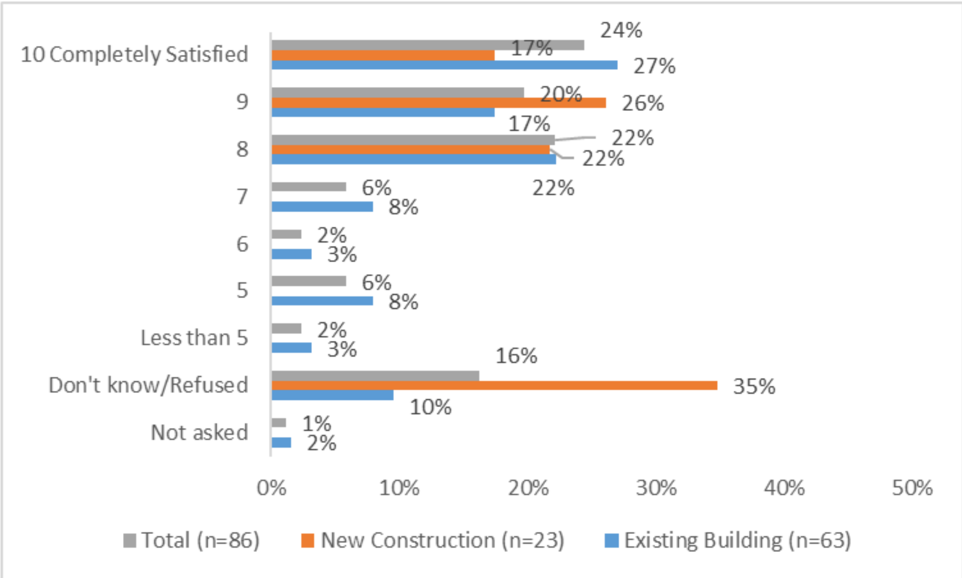


Figure 168. Overall Satisfaction with EVT's Level of Incentive for Equipment Installed

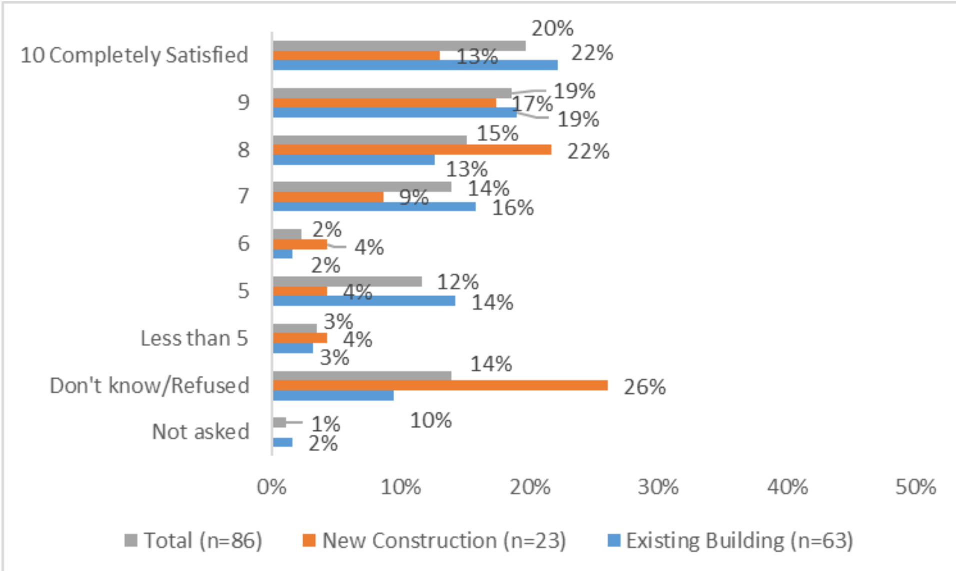


Figure 166 shows that over three-fifths (67%) of customers in the EVT service area rated their overall satisfaction with EVT's programs at an 8 or above, with 7% indicating they were completely satisfied.

Figure 169. Satisfaction with Overall EVT Program(s)

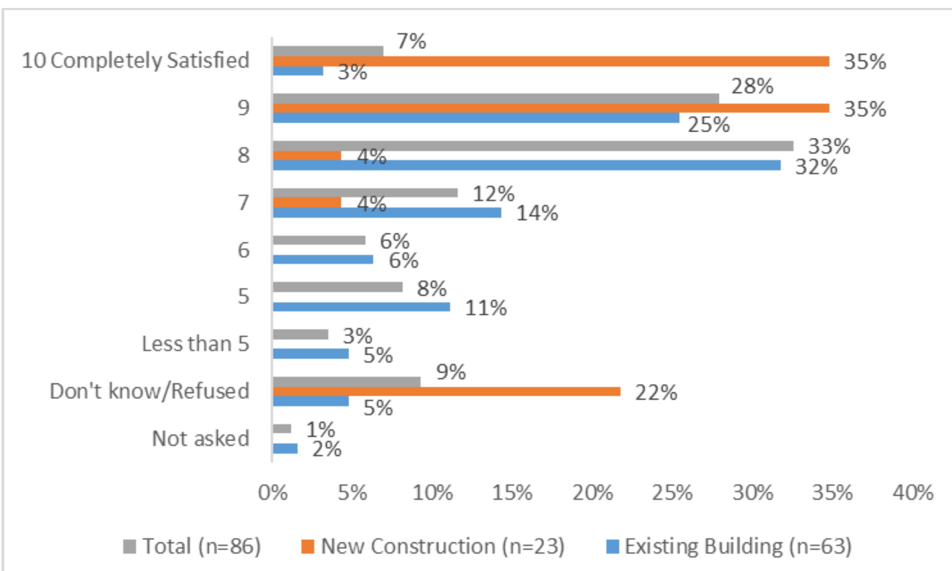


Table 138 shows satisfaction with EVT programs by facility size and type. The results do not vary significantly from the aggregated responses. The majority of EVT customers, regardless of facility size or type, provide a rating of eight or higher on the satisfaction scale.

Table 138. Satisfaction with EVT Programs

	10 Completely Satisfied	9	8	7	6	5	Less than 5	Don't Know	Not asked
All Buildings (n=86)	28%	33%	12%	6%	0%	8%	3%	9%	1%
Facility Size									
Small - Up to 2,499 sq ft (n=21)	29%	14%	14%	5%	0%	24%	5%	10%	
Medium - 2,500–9,999 sq ft (n=28)	18%	50%	18%	0%	0%	0%	0%	11%	4%
Large - 10,000–39,999 sq ft (n=22)	41%	41%	5%	9%	0%	5%	5%	5%	
Extra large - 40,000+ sq ft (n=15)	27%	27%	7%	13%	0%	7%	7%	13%	
Facility Type									
Food Sales (n=7)	2	2	0	0	0	1	1	0	1
Food Service (n=2)	0	1	0	0	0	1	0	0	0
Health Care (n=8)	3	2	1	2	0	0	0	0	0
Hospital (n=4)	2	2	0	0	0	0	0	0	0
Lodging (n=9)	2	3	1	0	0	1	1	0	0
Manufacturing (n=10)	4	2	0	2	0	0	1	1	0
Office (n=11)	1	5	4	0	0	0	0	1	0
Other (n=22)	36%	27%	9%	5%	0%	9%	0%	9%	0%
Retail (n=7)	2	1	1	0	0	1	0	2	0
School (n=6)	0	4	1	0	0	1	0	0	0

Satisfaction with BED Services

Figure 170 through Figure 174 provide customer satisfaction ratings related to energy efficiency services provided by BED. **The majority of customers are highly satisfied with the equipment, services, ease of participation, and quality of measures provided by BED.** Ratings are typically clustered between scores of 8 and 10, where 10 is completely satisfied. Slightly lower scores were reported for the time taken to process the application and issue the incentive payment and the level of incentive for the equipment installed.

Figure 170. Overall Satisfaction with Quality of Measures by BED

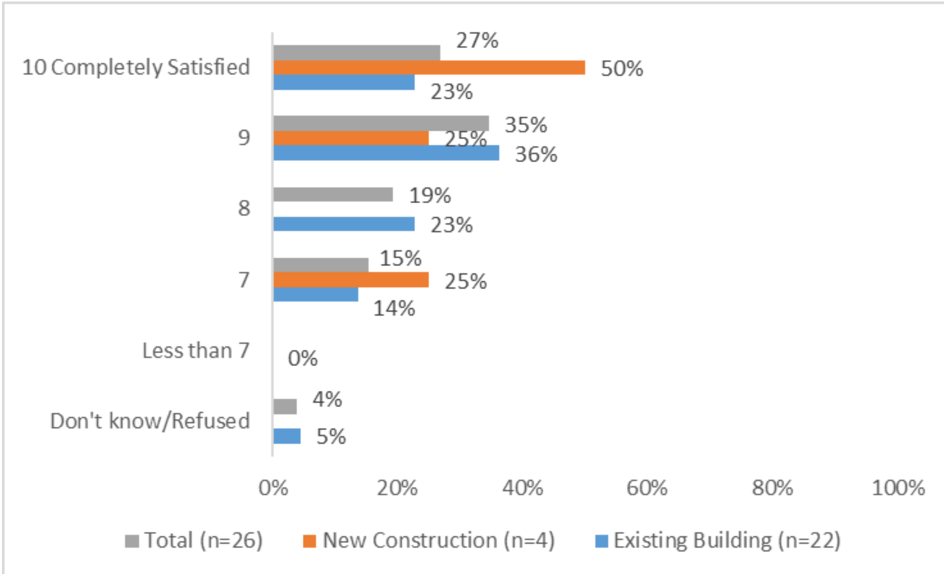


Figure 171. Overall Satisfaction with Quality of Technical Support or Services Provided by BED

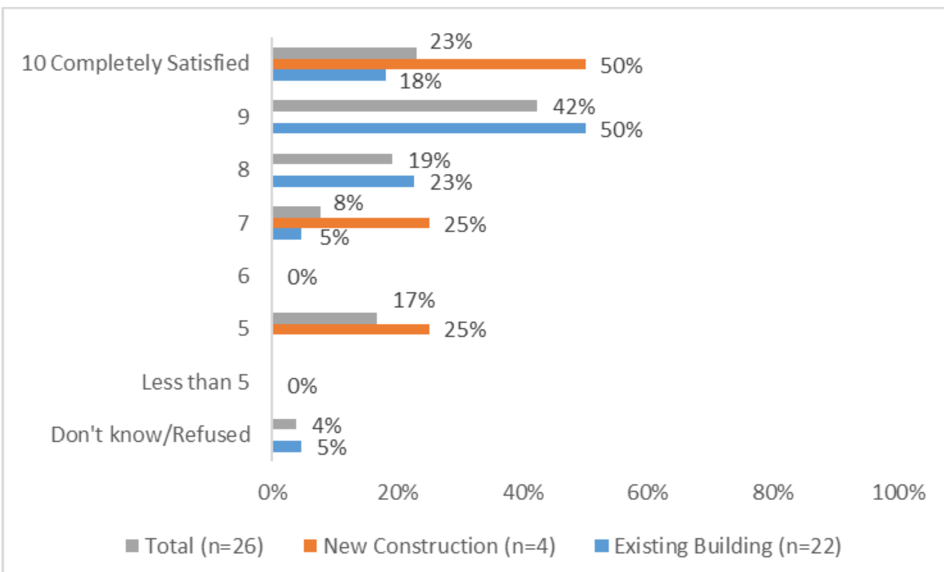


Figure 172. Overall Satisfaction with Time It Took from Application through Receipt of Incentive with BED

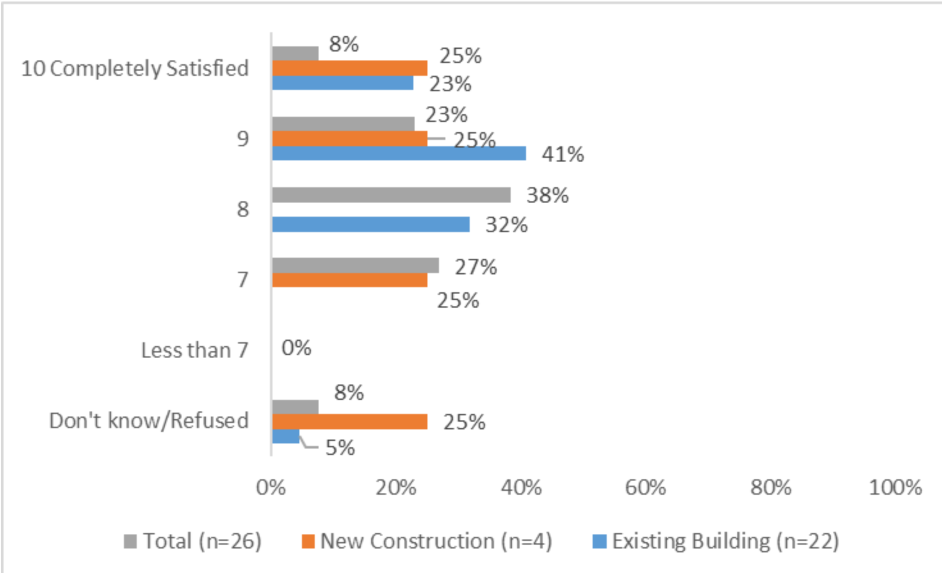


Figure 173. Overall Satisfaction with BED's Level of Incentive for Equipment Installed

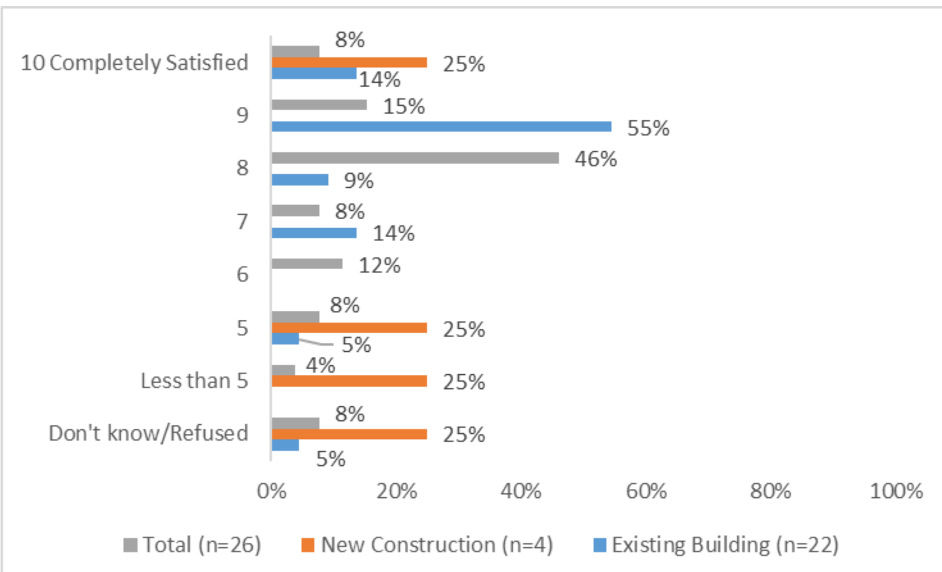


Figure 171 shows that the vast majority (88%) of customers in the BED service area rated their overall satisfaction with BED's programs at an 8 or above, with 35% indicating they were completely satisfied.

Figure 174. Satisfaction with Overall BED Program(s)

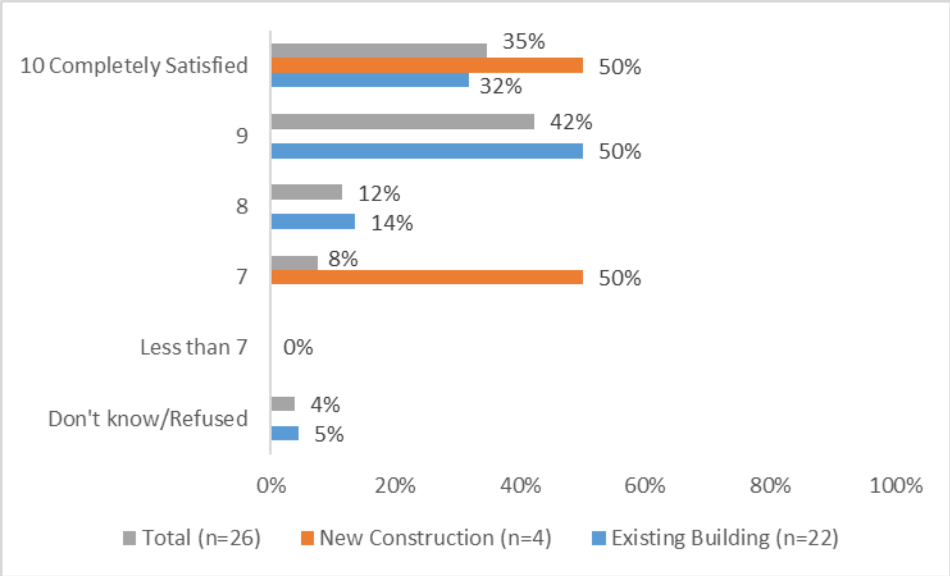


Table 139 shows satisfaction with BED programs by facility size and type. The results do not vary significantly from the aggregated responses. The majority of BED customers, regardless of facility size or type, provide a rating of 8 or higher on the satisfaction scale.

Table 139. Satisfaction with Burlington Electric Programs

	10 Completely Satisfied	9	8	7	Less than 7	Don't Know
All Buildings (n=26)	9	11	3	2	0	0
Facility Size						
Small - Up to 2,499 sq ft (n=4)	1	1	1	1	0	1
Medium - 2,500–9,999 sq ft (n=8)	3	4	0	1	0	0
Large - 10,000–39,999 sq ft (n=12)	3	6	2	1	0	0
Extra large - 40,000+ sq ft (n=2)	2	0	0	0	0	0
Facility Type						
Food Sales (n=2)	1	0	0	0	0	1
Food Service (n=1)	0	1	0	0	0	0
Hospital (n=1)	0	1	0	0	0	0
Lodging (n=1)	1	0	0	0	0	0
Manufacturing (n=4)	2	1	1	0	0	0
Office (n=3)	0	1	1	1	0	0
Other (n=5)	2	1	1	1	0	0
Retail (n=1)	0	1	0	0	0	0
School (n=8)	3	5	0	0	0	0

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Satisfaction with VT Gas Services

Figure 175, Figure 176, Figure 177, Figure 178, and Figure 179 provide customer satisfaction ratings related to energy efficiency services provided by VT Gas. **The majority of customers are highly satisfied with the equipment, services, ease of participation, and quality of measures provided by VT Gas**. Ratings are typically clustered between scores of 8 and 10, where 10 is completely satisfied. Slightly lower scores were reported for the time taken to process the application and issue the incentive payment and the level of incentive for the equipment installed.

Figure 175. Overall Satisfaction with Quality of Measures by VT Gas

(Count of Respondents)

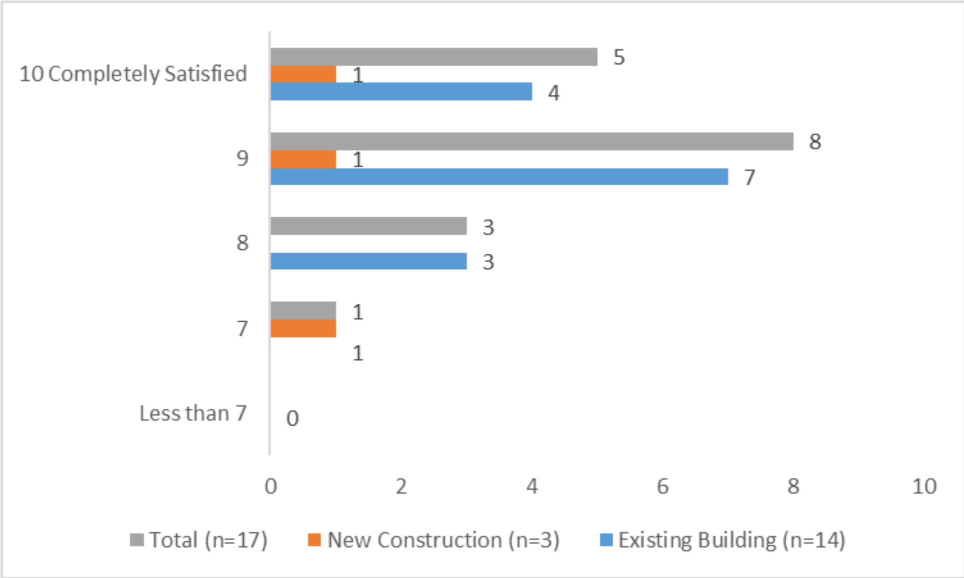

Figure 176. Overall Satisfaction with Quality of Technical Support or Services Provided by VT Gas

(Count of Respondents)

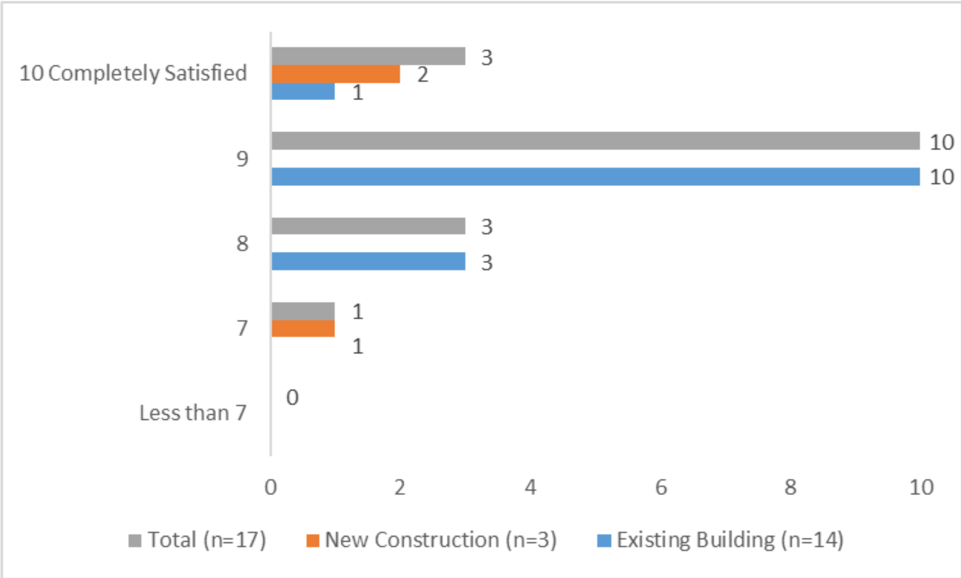

Figure 177. Overall Satisfaction with Time It Took from Application through Receipt of Incentive with VT Gas

(Count of Respondents)

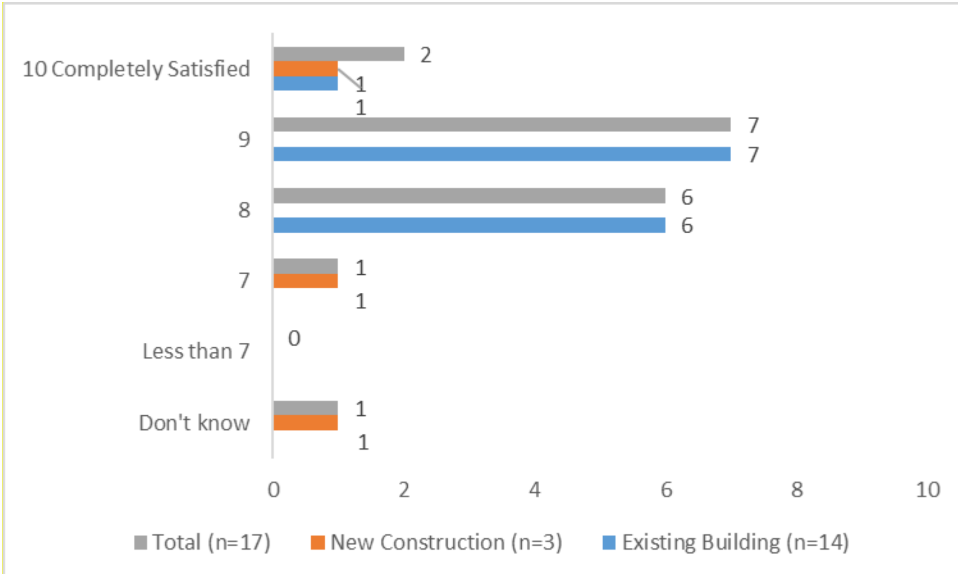

Figure 178. Overall Satisfaction with VT Gas's Level of Incentive for Equipment Installed

(Count of Respondents)

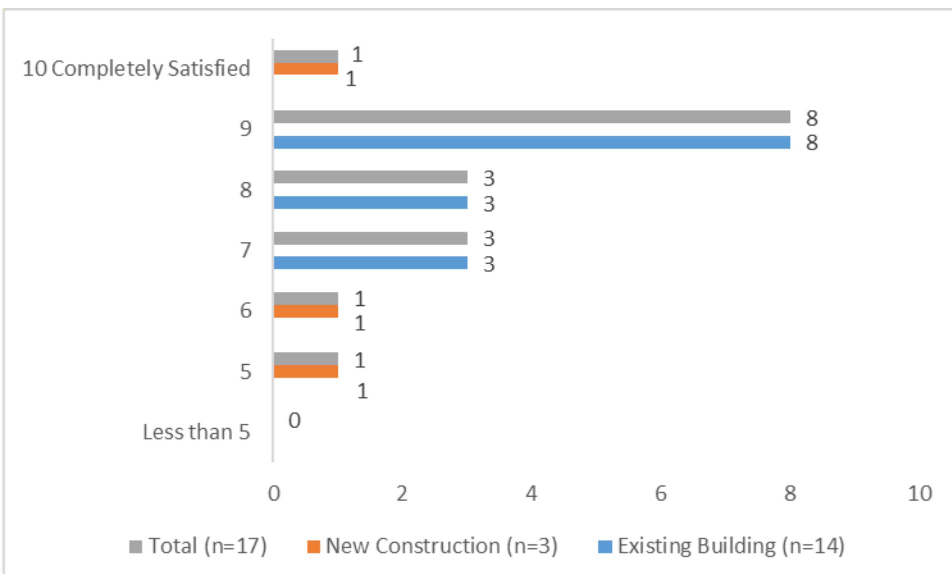

Figure 179 shows that the majority (15 of 17) of customers in the VT Gas service area rated their overall satisfaction with VT Gas programs at an 8 or above, with five customers indicating they were completely satisfied.

Figure 179. Satisfaction with Overall VT Gas Program(s)

(Count of Respondents)

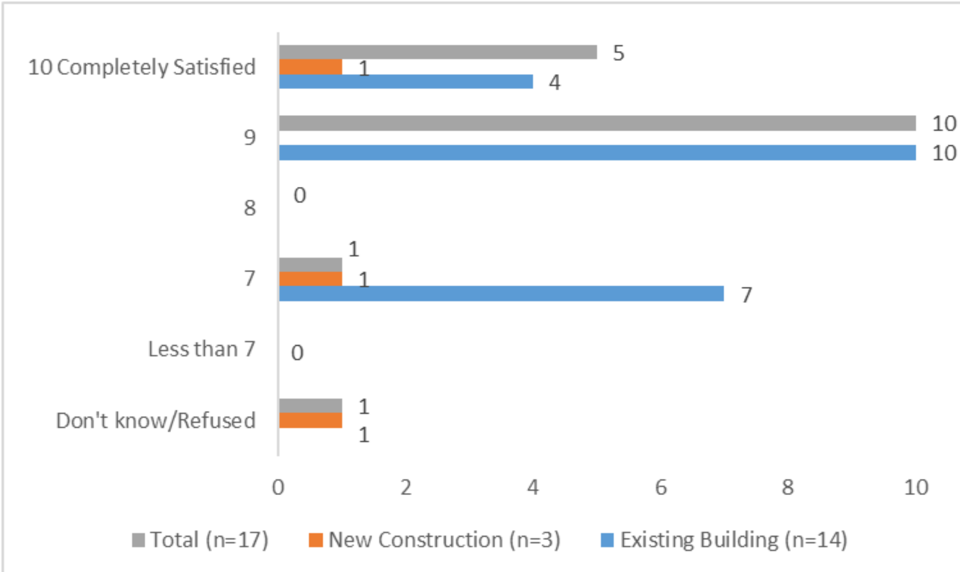

Table 140 shows satisfaction with VT Gas programs by facility size and type. The results do not vary significantly from the aggregated responses. The majority of VT Gas customers, regardless of facility size or type, provide a rating of eight or higher on the satisfaction scale.

Table 140. Satisfaction with VT Gas Programs

	10 Completely Satisfied	9	8	7	Less than 7	Don't Know
All Buildings (n=17)	5	10		1		1
Facility Size						
Small - Up to 2,499 sq ft (n=2)		2				
Medium - 2,500–9,999 sq ft (n=6)	1	4				1
Large - 10,000–39,999 sq ft (n=6)	2	3		1		
Extra large - 40,000+ sq ft (n=3)	2	1				
Facility Type						
Food Service (n=1)		1				
Lodging (n=1)	1					
Manufacturing (n=1)		1				
Office (n=1)				1		
Other (n=4)	1	2				1
Retail (n=1)		1				
School (n=8)	3	5				

Appendix A: Existing Buildings Survey Instruments

A document available as a separate attachment provides survey instruments used for existing buildings recruiting and data collection.

Appendix B: Existing Buildings Figures and Tables with Four Facility Types

A document available as a separate attachment provides Figures and Tables with four facility types, to facilitate direction comparisons with the 2011 Vermont Market Characterization and Assessment Study, Existing Buildings.

Appendix C: New Construction Survey Instruments

A document available as a separate attachment provides survey instruments used for new construction recruiting and data collection.

Appendix D: New Construction Figures and Tables with 10 Facility Types

A document available as a separate attachment provides Figures and Tables with 10 facility types, to facilitate direction comparisons with the 2011 Vermont Market Characterization and Assessment Study, New Construction.