Business Sector Market Assessment and Baseline Study: Existing Commercial Buildings Vol. 1

Final Report

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1. Introduction

1.1 Project Objectives

This is the Final Report of the Vermont Business Sector Market Assessment and Baseline Study: Existing Commercial Buildings. It is the first in a set of three reports that characterize the energy-related features and opportunities for cost-effective energy efficiency improvements in Vermont's business facilities. The other two reports address the same topics in regard to commercial new construction and industrial facilities.

The Vermont Department of Public Service (Department or DPS) commissioned these reports and their underlying research as part of its ongoing role to guide and support the design and delivery of energy efficiency programs in Vermont. The Department's goals for the project, in order of priority were to:

- Provide baseline data on current market conditions that will be useful in future evaluations of EEU program effects.
- Identify and provide information about opportunities for achieving increased levels of cost-effective energy efficiency in Vermont for use in program planning and design.

Working together with KEMA, the Department and other stakeholders[1] in the Study further refined the project objectives to include the following.

- Estimate the saturation of key end-uses, end-use technology shares (e.g. fluorescent v. HID lighting), and efficient technology shares (e.g. high performance (super) T8 fluorescent lamps and ballasts v. conventional T8 technology).
- Assess the extent of opportunities to install additional energy-efficient equipment.
- Estimate installed capacity of major end-use equipment groups: lighting power density (w/square feet), KBtu/hour of heat, tons of cooling.

[1] Other stakeholders involved in the design and review of the study included Efficiency Vermont, Burlington Electric Department, and CVPS.

- Estimate the level of adoption of operating and maintenance practices such as commissioning, load control, and various types of preventive measures that enhance energy efficiency.

To address these objectives, KEMA developed and deployed an on-site survey of a stratified random sample of 117 commercial facilities built prior to 2006. In developing this on-site sample, KEMA conducted screening interviews with a random sample of 547 commercial customers. These screening interviews provided basic information on building uses and other features used both to characterize the overall population of existing commercial facilities and to weight the survey results.

To further support program planning efforts, DPS and the other stakeholders requested the development of primary information on the current market share of efficient equipment in the following end-use categories: lighting, packaged HVAC units, motors, and variable speed drives.

1.2 Overview of Data Collection and Analysis Activities

As discussed above, the basic objectives of the on-site survey were to develop information on the saturation and installed capacity of end-uses, end-use equipment types, efficient equipment, and opportunities to install additional energy-efficient equipment in Vermont's existing commercial facilities. KEMA designed the data collection and analysis methods to yield saturation estimates in terms percentage of premises with various end-uses or equipment types. For lighting, heating and cooling measures we also calculated saturation estimates in terms of the percentage of total square feet. This corresponds to methods used by other commercial energy use surveys, as well as the data requirements of energy efficiency potential models.

KEMA designed the study to support disaggregation of results along dimensions of concern to DPS and the other stakeholders, to the extent possible and within the available data collection budget. Specifically, the Department was concerned about identifying any potential differences between facilities in four load-constrained areas (geo-targets) and the balance of the state in terms of energy savings opportunities available. Given the diversity of facilities comprised by the commercial sector, the Department and the program sponsors were interested in differences among key market segments. The sample and data collection procedures were thus designed to support meaningful disaggregation by region (geo-targets v. balance of state) and a limited number of market segments defined by facility use: office, retail, all other commercial, and industrial.[2] Finally, the DPS and stakeholders were interested in the difference between small and large facilities. We provided results for two size groups based on annual kWh consumption.

Table 1-1 summarizes the data collection and analysis activities undertaken for this project. We present detailed descriptions of the methods used for the on-site survey in Section 2 and for the supply channel surveys in Section 8.

Table 1-1
Data Collection and Analysis Activities:
Existing Commercial Buildings

Activity/ Key Objectives	Sample Frame	Sample Size and Other Details
Screening Survey Estimate distribution of commercial customers by size (annual kWh consumption), building type and region. Estimate portion of facility population with major systems upgraded within the past 2 years; 5 years Establish weighting system to expand sample results to the population of commercial facilities Identify customers willing to participate in on-site survey.	Utility billing data compiled by Efficiency Vermont and Burlington Electric Department	**547 completed** stratified by kWh consumption.

[2] Results for industrial facilities are reported in the report: "Final Report of the Vermont Business Sector Market Assessment and Baseline Study: Industrial Buildings.

Activity/ Key Objectives	Sample Frame	Sample Size and Other Details
On-Site Survey Verify link to billing information General facility information: size, configuration, ownership, age, primary use, operating schedule Schedule and extent of recent renovations and equipment replacement Characterize energy-related O&M practices Characterize building shell elements; identify related energy efficiency opportunities. For the following end uses -- indoor lighting, outdoor lighting, heating, cooling, ventilation, domestic hot water, refrigeration – estimate: Saturation of end-use by fuel Share of key equipment types Share of efficient equipment Extent of opportunities for specified efficiency measures	Customers identified by the screening survey	**117 completed** initial target of 120. Sample stratified by size, building type, and region.
Supply Chain Interviews Estimate current sales volumes and/or market shares of energy-efficient equipment or services. Obtain vendor perspectives on customer motivations and barriers to adoption efficient equipment and design, installation & maintenance services Obtain vendor perspectives on the likely course of customer purchases with and without the proposed programs in place. Obtain vendor expectations concerning program participation and effects on their current practices	Dun and Bradstreet iMarket Business Database	**HVAC Contractors** **12** of 15 targeted **Lighting Contractors** **15** of 15 targeted **Motor and VFD Vendors** **5** of 5 targeted

1.3 Structure of the Report and Formats for Display of Results

The remainder of the report is organized as follows.

- ***Section 2: On-Site Survey Methods* –** details the sampling, data collection, data quality control, and analysis methods applied in the on-site survey.
- ***Section 3: Population of Existing Commercial Facilities* –** combines information on facility energy consumption from the billing database with the results of the screening survey to develop a portrait of the population of existing commercial facilities in Vermont, focusing on its distribution by building type, energy consumption, primary heating fuel, presence of cooling systems, and recent energy-related upgrades.
- ***Section 4: Characteristics of the Sample Establishments* –** presents information on the basic characteristics of establishments and facilities in the on-site sample, including: primary use, type of owner, form of tenure, facility size and configuration, primary heating fuel, primary heating and cooling equipment. Where appropriate we compare the characteristics of the on-site sample to those of the larger screened sample.
- ***Section 5: Characteristics of Major Energy Systems* –** presents detailed information on the saturation, fuel shares, technology shares, and efficiency shares of the major end-uses. This section also contains estimates of installed capacity for indoor lighting, heating, and cooling equipment, as well as occupant-reported hours of operation information for lighting. Information is generally reported by customer segment: office, retail, and all other. Where differences between facilities in the geo-target areas and those in the balance of the state are sufficiently large to affect program design, we report on them here. Otherwise, we present this information in the Appendices in Volume 2 of this report.
- ***Section 6: Facility Maintenance and Capital Improvement Practices* –** presents the results of questions concerning sample customer's energy-related maintenance practices and recent improvements to energy-related building and mechanical systems. This information is presented in terms of percentage of total facilities, weighted to the population.
- ***Section 7: Opportunities for Energy Efficiency* –** summarizes findings regarding the presence of opportunities for common energy efficiency upgrades in key energy systems, based on the judgment of the KEMA team's field engineers.

- ***Section 8: Supply Channel Surveys –*** details the methods and results of the surveys of lighting installation contractors, motor vendors, and HVAC contractors. The results of these surveys are reported in terms of market share of the equipment types in question.
- ***Section 9: Conclusions and Recommendations –*** summarizes the findings of the previous sections and explores their implications for the design of programs offered by the Energy Efficiency Utility.
- ***Appendices:*** The appendices included in Volume 2 of this report provide detailed tables of all the results by geotarget vs. rest of state, commercial building type, and by size categories. The results are provided either based on premise weights (used to represent the percent of premises in Vermont), square foot ratio weights (used to represent the percent of commercial square footage in Vermont) or both.

2. On-Site Survey Methods

2.1 Objectives

As discussed in Section 1, the basic goals of the project and the on-site survey were to characterize and quantify cost-effective energy efficiency opportunities in Vermont's stock of existing commercial buildings, and to provide information to support the development of programs to capture those opportunities. To do accomplish this goal, KEMA worked closely with the Department and other stakeholders to balance a number of objectives under constraints of budget and the amount of time deemed feasible to spend on a given customer's site (one day). These objectives are as follows.

- ***Develop a more detailed and useful quantitative profile of Vermont's population of commercial facilities than is available from other statistical and secondary sources.*** Sources such as Dunn & Bradstreet and the Economic Census provide good detail on the population of business establishments as organizations but little information on facilities and energy use. CBECS provides good information on energy consumption, end-use and fuel saturations, but reports these results at a high level of geographic aggregation. The analysis of the utility databases in conjunction with data collected through the large-sample screening survey provides an opportunity to link current data on consumption and basic utility features to provide a characterization of the facility population that will be useful for program planning.
- ***Develop relatively accurate information on end use saturations, fuel shares, and equipment shares***. Good information on end use saturation, fuel shares, and equipment shares provide the basis for calculations of energy efficiency potential. They also provide a guide and sanity check for estimating total savings available from a given set of measures that apply to a particular end use, fuel, and/or equipment type. Due to the importance of these estimates and multiple observations on which a single saturation fraction relies, the use of experienced, trained field engineers to collect on-site data was necessary.
- ***Develop estimates of installed capacity for key end-uses.*** Estimates of installed capacity support more certainty and detail in developing estimates of potential energy savings than estimates of saturation can provide. Therefore, the on-site survey incorporated methods to estimate installed capacity based on field engineers' observations, to the extent that equipment capacity characteristics could be determined.

For some end-uses such as cooling, it was often difficult to find and record this information during the site visit.

- ***Develop assessments of remaining energy efficiency opportunities based on on-site observation by experienced engineers***. Generally, customers do not have enough information and experience to assess the applicability of various energy efficiency measures in their buildings. Program staff, designers, and installation contractors only get a partial view of opportunities in the course of their work. Therefore, the use of experienced field engineers was required to provide accurate information on the presence of energy efficiency opportunities.
- ***Disaggregate results into meaningful market segments.*** Initially, the Department and other stakeholders requested that the sampling be structured to support the meaningful disaggregation of results along the following dimensions: size (facility's annual electric consumption), region (geo-target v. balance of state), and facility type. The budget available for data collection was not sufficiently large to support meaningful disaggregation by size into more than two categories (high and low, although sampling was based on four consumption categories (small, medium, large and very large) to structure the sample strata and quotas.

2.2 Sampling

2.2.1 Objectives

The key objectives of the sample design were to:

- Provide unbiased representation of the full population of existing commercial facilities.
- Support disaggregation of results by region, building type and size.
- Ensure that small customers were represented even if they accounted for relatively small portions of total energy use and potential savings.

2.2.2 Development of the Sample Frame

KEMA took the following steps to develop and segment the list of customers from which the screening survey sample was drawn. The process described below produced the sample frame used for both the existing commercial facility and industrial facility survey. The population database from which the sample frame was constructed (utility billing data) does not contain reliable information on building type. Nor are commercial customers distinguished from industrial customers by rate codes. Thus, KEMA needed to use the results of the screening surveys to characterize the distribution of the premises among different customer segment, as well as among building types.

- ***Request for billing data***. KEMA obtained billing data for all non-residential accounts from two sources: Vermont Energy Investment Corporation (VEIC) and the Burlington Electric Department (BED). In both cases we received 18 months of historical consumption for all non-residential accounts for April 1, 2006 through September 30, 2007. The data we received from VEIC consisted of the population of non-residential accounts for the utilities that provide energy efficiency program services through Efficiency Vermont and who provide billing data to VEIC. The data from BED consisted of the population of non-residential accounts served by the city of Burlington's municipal electric utility.

- ***Consolidation of billing accounts to premises.*** Because large commercial or industrial customers often have more than one electric account at the same physical address, we aggregated the billing data from the account level to premise level. A premise is defined as a contiguous space occupied by a single business at a given address. This operation yielded a total of 42,656 unique premises using 4,799 GWh.

- ***Adjustments for changes in occupancy***. In cases where the occupant of a premise had changed during the twelve month period for which billing data were available, we summed the 12 month usage of the occupants to determine an annual figure. We used the combined usage of occupants at a single premise as an estimate of size for sampling purposes. In the two cases where combined sites were included in the final sample, we did all analysis on the annualized usage of the current occupant.

- ***Elimination of non-building accounts***. To eliminate traffic lights, cable switch boxes, and other "non-buildings" from the sample frame, we excluded any premise whose consumption fell into the bottom 2.5% of the population. This corresponded to premises with annual consumption of less than 15,040 kWh. This operation yielded a sample frame of 14,995 premises with total annual consumption of 4,679 GWh.

Stratification by size. Next we assigned each premise in the sample frame to one of four size strata. We defined the highest consumption stratum (Very Large) as premises with more than 2.5 million kWh consumed annually. Cut points for the other three strata were calculated using the Delanius-Hodges procedure. Delanius-Hodges creates strata that maximize the efficiency with which a key variable (in this case, consumption) can be sampled. Table 2-1 displays the cut points for the four size strata and the number of premises in each stratum.

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Table 2-2 shows the distribution of premises by size stratum and region (geo-target v. balance of state). Table 2-3 shows the distribution of annual electric consumption by facilities in the various sample segments.

Table 2-1
Consumption Strata for Vermont Non-Residential Premises

Stratum	Lower Bound	Upper Bound
Small	15,040 kWh	59,049 kWh
Medium	59,050 kWh	313,599 kWh
Large	313,600 kWh	2,499,999 kWh
Very Large	2,500,000 kWh	None

*Based on billing data from VEIC and BED.

Table 2-2
Estimated Population of Vermont Non-Residential Premises

	Geo-Target		Balance of State		Total	
Stratum	**Premises**	**Percent**	**Premises**	**Percent**	**Premises**	**Percent**
Small	1,640	57%	6,959	58%	8,599	58%
Medium	794	28	3,479	29	4,273	29
Large	372	13	1,439	12	1,811	12
Very Large	51	2	221	2	272	2
Total	**2,857**	**100%**	**12,098**	**100%**	**14,955**	**100%**

Based on billing data from VEIC and BED.

Does not include premises that fell in the bottom 2.5 percent of overall consumption.

Table 2-3
Estimated Usage (GWh) for the Population of Vermont Non-Residential Facilities

	Total Premises		Geo-Target		Rest of State		Total	
Stratum	**Count**	**Percent**	**GWh**	**Percent**	**GWh**	**Percent**	**GWh**	**Percent**
Small	8,599	58%	49.8	6%	212.4	6%	262.2	6%
Medium	4,273	29	98.3	11	456.0	12	554.3	12
Large	1,811	12	301.5	34	1,115.5	29	1,417.0	30
Very Large	272	2	438.7	49	2,077.1	54	2,515.9	53
Total	**14,955**	**100%**	**888.4**	**100%**	**3,861.0**	**100%**	**4,749.4**	**100%**

Based on billing data from VEIC and BED.

Does not include premises that fell in the bottom 2.5 percent of overall consumption.

2.2.3 Sample Allocation by Size and Geo-Target

After stratifying the sample, we determined how many completed on-site surveys to target within each cell defined by size category and region. The final sample plan reflected a compromise between the goals of minimizing total variance using the Neyman-Pearson allocation and the stakeholders' concern to capture sufficient detail about smaller facilities. Table 2-4 shows the final sample plan (targeted number of completes) and the actual distribution of completed on-site surveys. Overall we exceeded our goal for the number of on-sites conducted. Deviations from sample plan were minor.

Table 2-4
Completed On-Site Surveys
By Size and Geo-Target

	Geo-Target		Balance of State		Total	
Stratum	**Target**	**Actual**	**Target**	**Actual**	**Target**	**Actual**
Small	14	18	16	14	30	32
Medium	16	17	19	15	35	32
Large	23	25	27	32	50	57
Very Large	18	17	22	23	40	40
Total	**70**	**77**	**85**	**84**	**155**	**161**

2.2.4 Sample Allocation by Building Type

In addition to stratifying by consumption and geo-target status, we sought to obtain a reasonable number of completed on-site surveys in each of four building type categories – retail, office, balance of commercial, and manufacturing.[3] We set targets for the number of completed on-sites in each building type based on the results of the screening survey. Table 2-5 shows the targeted distribution of completed on-sites by building type, the actual distribution achieved, and the estimated distribution of the sample frame by building type based on the screening results.

Table 2-5
Population and Participant Distributions
by Building Type

	Target (Sample Plan)		On-site Completes		Estimated Population from Screening Calls	
Segment	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Retail	35	23%	32	20%	4,941	33%
Office	40	26	35	22	3,269	22
Manufacturing	35	23	44	27	2,211	15
Balance of Com.	45	29	50	31	4,535	30
Total	**155**	**100%**	**161**	**100%**	**14,995**	**100%**

A comparison of on-site completes with the population estimates for each building type in Table 2-5 reveals that manufacturing premises were overrepresented in the sample (versus their share of the population), while retail was somewhat underrepresented. On-site survey weights, discussed in the following section, corrected for such over and under-representation in the analysis. Moreover, the overrepresentation of manufacturing in the sample parallels manufacturing's larger share of electricity consumption. Table 2-6 shows total consumption by building type among the 547 premises with which we completed a telephone screening.

[3] Though not included in this report, the sample plan and population estimates were developed for the commercial and industrial sectors together. For results of the Industrial on-site survey, please see: "Final Report of the Vermont Business Sector Market Assessment and Baseline Study: Industrial Buildings.

Table 2-6
Estimated Consumption of Premises Participating in the Screener Interview By Building Type

Segment	Annual Consumption (kWh)	Percent of C & I	Percent of Commercial
Retail	500,310,270	12%	24%
Office	475,485,306	12	22
Manufacturing	1,949,342,677	48	0
Balance of Com.	1,142,193,610	28	54
Total	**4,067,331,862**	**100%**	**100%**

The results shown in Table 2-6 indicate that the retail and office sectors each account for about 23 percent of all commercial electric use, with the balance of commercial sector accounting for the remaining 54 percent.

As shown in Table 2-6 the manufacturing sector, in spite of representing only 15% of the premises we screened, accounted for nearly half of the consumption. This is consistent with the findings of the 2006 Vermont Electric Energy Efficiency Potential Study, which found that the manufacturing sector accounted for 47 percent of the electricity consumption in Vermont[4].

2.2.5 Weighting

To adjust for the impact of stratification on the sample, we calculated expansion weights for the completed on-sites in each cell of the Geo-Target x Size x Building Type matrix. The expansion weight for each cell was simply the estimated number of premises in the population (as determined by the billing data) divided by the number of completed on-sites. Including building type in the sample design necessitated the estimation of population counts based on the percentage of screened premises that were each business type and size.

To ensure an adequate number of screened premises for estimation by sub-groupings, the geo-target region and the rest of the state were combined within the business type and size groups to estimate the population for each of the 32 sample cells. For example, small "balance of

[4] www.state.vt.us/psb/document/ElectricInitiatives/GDSTechPotentialStudy.ppt

commercial" premises were totaled to estimate the percent of small customers that are "balance of commercial". This percentage was then applied to the balance of commercial totals for both geo-target and the rest of the state.

Some cells did not include an estimate from the recruiting for business type. In these cases cells were combined for developing the weight.

Table 2-7 lists the expansion weights used in the analysis of existing premise survey data. Cells labeled “n/a” did not have a weight calculated because they did not contain any completed on-site surveys.

Table 2-7
Cell-wise Expansion Weights

	Geo-Target				Rest of State			
Segment	**Small**	**Medium**	**Large**	**Very Large**	**Small**	**Medium**	**Large**	**Very Large**
Retail	129.88	28.68	17.46	1.67	597.80	n/a*	101.31	n/a*
Office	49.80	40.31	12.83	3.34	475.46	88.32	33.08	7.25
Manufacturing	n/a*	289.84	27.79	2.69	n/a*	312.56	28.67	9.55
Balance of Com.	105.94	210.33	8.73	3.62	561.91	184.32	57.89	10.14

*There were no completed surveys in this cell, so weights were not calculated.

2.3 On-site Survey Participant Screening and Recruitment

KEMA used the following procedure to contact, qualify, and recruit customers into the sample.

- ***Allocate sample premises to segments defined by region and size (annual consumption) category.*** This was the first step in preparing the sample for the screening survey. Once KEMA accomplished the allocation, we selected a random sample of premises in each cell with probability of selection proportional to size.

- ***Conduct the screening survey.*** KEMA interviewers contacted representatives of the premises in the screening sample by telephone and administered a short survey. The screening survey’s objectives were to:

- **Verify that the premise was a commercial or industrial facility that had not been constructed within the past two years**. This qualified the facility for inclusion in the sample.

- **Gather information on building use for development of the building type allocation.**

- **Gather basic information about the size, configuration, primary heating fuel, presence of cooling, and recent energy system improvements**. Some of this information was used to develop more precise information about the population of facilities than could be gained through the relatively small on-site sample.

- ***Solicit the respondent's participation in the survey***. KEMA forwarded the contact information for willing survey participants to the field engineers, who arranged the schedule for the on-site directly with the participants.

KEMA continued screening interviews until the quotas for all cells of the initial sample design (Table 5) were filled with willing participants. For most cells, KEMA recruited a number of extra potential participants to account for sample attrition in the scheduling process.

2.4 Data Collection and Quality Control

- ***Collect completed surveys from engineers weekly.*** The surveys were sent to ERS or to KEMA for check-in.

- ***Review completed survey.*** An initial review of the survey was conducted to confirm that the data were provided, the correct site was completed and that energy usage data associated with that premise were correctly tied to the premise.

- ***Coding and data entry.*** All surveys were pre-coded for data entry. At this step some data were corrected for out-of-range codes.

- ***Data cleaning.*** After the data were entered a frequency was run on each of the variables. At this point we identified all remaining out-of-range codes and unusual values. Cross checks of key variables were also run to identify inconsistencies in key variables (such as square footage of areas not adding up to total square footage). For each problem identified we reviewed the paper copy of the survey and resolved any data entry or coding errors that could be identified. When issues could not be resolved from the paper version of the survey we contacted the field engineer, who resolved the issue (based on their notes or recall) or followed up with people at the facility (when possible).

2.5 Data Analysis Approach

We calculated results overall for Vermont commercial buildings as well as by building type and geo vs. non-geo-targeted areas.

Weighting and computation of survey results. KEMA conducted analysis using two different weighting approaches. All analysis was conducted on a premise weighted basis. The respondent premises were weighted to be proportional to their incidence in the population, using the expansion weights discussed above and provided in Table 2-7.

For equipment saturations that are highly related to the square footage of facilities, we used ratio estimation to calculate the percentage of commercial space that had specific characteristics. Ratio estimation was used to determine the penetration of equipment and energy efficiency opportunities for heating, cooling and indoor lighting.

Where the survey seeks responses in the form of a number or percentage — say, the portion of total commercial facility floor space that is illuminated by linear tube fixtures — we calculated survey responses using the combined ratio estimator $\hat{R}_c$:

$$\hat{R}_c = \frac{\sum_h \frac{N_h}{n_h} \sum_i F_{h_i} x_i}{\sum_h \frac{N_h}{n_h} \sum_i x_i},$$

where

i = sample facility,

N_h = number of facilities in the population in size stratum *h,*

n_h = number of facilities in the sample in stratum *h,*

F_{h_i} = Facility *i*'s response (expressed as a number or percentage), and

x_i = Square footage consumption for Facility *i*.

If the question elicited a categorical response (e.g., yes/no), a F_{h_i} was created for each possible response. For the selected response (responses if choose all that apply), F_{h_i} = 1. For the response/s not selected, F_{h_i} = 0.

The use of the combined ratio estimator supports the estimate of a standard deviation and standard error for each variable. For surveys of this type, the ratio approach described above generally yields lower variances (more precise estimates) than mean per unit methods, for a given sample size. The standard errors were used to calculate appropriate measures of precision for various kinds of results. For estimates of totals and ratios, and proportions, we sized the samples to achieve 80/20 confidence intervals.

Treatment of missing data. The on-site visits required engineers to collect detailed information from a wide variety of equipment types. Time constraints, safety, privacy concerns and accessibility all contributed to missing data.

For the majority of the analysis cases missing data were excluded from specific analyses. For example, if five percent of the respondents for which a question applied did not have sufficient information, the analyses were completed on the remaining 95 percent of respondents. The exception to this rule is that analysis of the energy efficiency opportunities treated missing data as “no opportunity,” making the reported ratio the most conservative estimate of the opportunity based on the data collected.

The determination of lighting density was dependent on many individual variables within a single premise. Many premises were missing one or more of the key variables. For these premises we used default values to develop estimates. For example, when the on-site engineer did not report the wattage of a linear tube lamp we substituted an average wattage for a lamp of that type to complete the analysis. This approach tends to underestimate the standard errors. However, dropping spaces with missing data biases the sample by selectively eliminating lamps whose wattage was difficult for the on-site engineers to verify or estimate, such as lamps in high bay settings.

3. Population of Existing Commercial Facilities

This section presents information drawn from a variety of sources to characterize the population of existing commercial facilities in Vermont. Specifically, we use information from the following:

- The Screening Survey;
- The On-site Survey;
- The Dun & Bradstreet database of business establishments; and,
- The U. S. Energy Information Administration's *Commercial Building Energy Consumption Survey.*

The objective of this section is to provide a point of reference for putting the findings of the more detailed facility inventory into perspective and for assessing the plausibility of population estimates based on the screening survey and on-site survey samples.

3.1 Characteristics of Commercial Establishments

Based on the results of the sample frame development tasks described above, KEMA estimates that there are 12,742 commercial facilities in Vermont. This subsection presents information on the characteristics of business establishments that affect energy consumption and interest in energy efficiency.

Distribution by primary economic use. Recall that the sample for the on-site survey was selected without regard to the primary use of the building – such information was not available in the sample frame. Rather, the sample frame was segmented by the electric usage amount, building type, and region and the sample selected to fill those quotas. The distribution by primary economic use was left to chance.[5] Since the primary economic use of the building greatly affects patterns of energy use, we were concerned to establish whether the on-site

[5] The building type groupings that KEMA assigned to each facility were in the sample design were developed from data collected in the screener survey, whereas the more specific primary economic use data was collected during the course of the on-site survey.

sample was, in fact, representative of the commercial facilities in Vermont. To do this we developed Table 3-1, which shows the population weighted distribution of sample facilities by primary economic use and building type category used for this study. It shows the same distribution for establishments counted in the March 2008 County Business Patterns, a product of the U. S. Economic Census.

If the sampling approach has worked as planned, the distributions should be similar although not necessarily the same. As discussed in Section 2, the sample frame for the survey was developed from utility billing account records consolidated to physical premises that appeared to be single business facilities. County Business Patterns are based on analysis of the Employer Identification Numbers (EIN) in the U. S. Business Registry, supplemented by local data collection to identify multiple locations for individual employers. The population of commercial facilities developed from the billing data totals 12,742. The County Business Patterns data development process captures 17,849 establishments in Vermont. However, 9,844 of those (55 percent) employ four or fewer persons.

Table 3-1
On-site Sample by Primary Economic Use and Building Type
Premise-Weighted n = 117

	Building Type				
Primary Economic Use	**Office**	**Retail**	**Balance of Com.**	**All Com.**	**US Census Cty. Bus. Pat**
Retail	1%	24%	1%	27%	22%
Grocery	0%	7%	0%	7%	3%
Office	22%	0%	6%	29%	31%
Restaurant	0%	2%	4%	6%	5%
Warehouse	0%	0%	2%	2%	3%
Hospital	0%	0%	0%	<0.2%	n/a
Other Health	1%	0%	1%	2%	11%[1]
Lodging	0%	0%	3%	3%	5%
School	0%	0%	1%	1%	2%
Assembly	0%	0%	0%	0%	n/a
Other	1%	6%	16%	23%	12%
				12,742	**17,849**

[1] Includes all health care and social services.

The population-weighted (premise weighted) distribution of commercial facilities by economic use developed from the on-site sample closely resembles the distribution of establishments in County Business Patterns. This is especially true for the largest single segments: office and retail. Some discrepancies are expected due to the differences in data sources and classification systems. For example, grocery stores are likely to make up a larger portion of utility customers than of total establishments. Similarly, many establishments listed under 'Other Health' in County Business Patterns are likely to be small practices in leased offices or residential buildings. Based on the results of this comparison, we believe that the on-site sample and the weighting system developed from the billing database and screening surveys yield a representative profile of Vermont's commercial sector facilities.

Distribution by tenure arrangement. Table 3-2 displays the distribution of the on-site sample by tenure arrangement. Projected to the population the sample findings indicate that 76[6] percent of commercial utility customers own and occupy their facilities: 46 percent of facilities are occupied in their entirety by owners; 30 percent are occupied in part by their owners. Thus, the utility customers of record in roughly three-fourths of Vermont's commercial facilities are owners and in position to appropriate both the energy savings and capital appreciation benefits associated with energy efficiency improvements. Another two percent of commercial utility customers lease their facilities in its entirety. These establishments are likely to be directly responsible for their energy bills and thus motivated to make some energy efficiency improvements.

Table 3-2
On-Site Sample by Tenure Arrangement
Premise-Weighted n = 117

	Building Type			
Tenure Arrangement	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Own and Occupy the Entire Facility	22%	56%	52%	46%
Own the Entire Facility and Occupy a Part of It	48	13	36	30
Lease the Entire Facility from another Organization	2	4	0	2
Lease part of the Facility from another Organization	4	25	5	12
Other Ownership Arrangement	21	1	0	6
Unknown	2	2	6	4
Total	100%	100%	100%	100%

[6] The sample findings appear high compared to other studies. This may be due to self-selection bias. KEMA team members initially contacted the person indicated in the utility records as responsible for the bill. Non-occupants responsible for the utility bill (e.g. management company) may have been less likely to agree to the study. We do not, however, have response dispositions at this level of detail.

3.2 Size and Configuration of Commercial Facilities

In this subsection we present information on the size and configuration of commercial facilities as characterized by analysis of the results of the on-site survey.

Distribution by total enclosed floor space. As Table 3-3 shows, the population of commercial establishments in Vermont is characterized by small facilities. Nearly 54 percent are smaller than 5,000 square feet; 31 percent occupy 2,000 square feet or less. The low consumption facilities are predominantly small facilities: 80 percent have less than 10,000 indoor square feet and 58 percent have less than 5,000 square feet. In contrast, 69 percent of high consumption facilities are larger than 10,000 square feet.

Table 3-3
Facility Size and Type – All Space
Premise-Weighted n = 117

	Building Type				Consumption Category[7]	
Facility Size (SF)	**Office**	**Retail**	**Balance of Com.**	**All Com.**	**Low**	**High**
2000 and Under	15%	27%	46%	31%	35%	0%
2001 – 5000	16	35	15	23	23	23
5001 – 10000	40	22	7	21	23	9
10001 – 20000	23	15	16	17	17	24
20001 – 50000	3	0*	8	4	1	29
Over 50000	3	0*	9	4	2	16
Total	100%	100%	100%	100%	100%	100%
Median square feet	6,600	4,200	2,400	4,200	4,200	9,518
Average square feet	13,426	5,108	18,559	12,034	9,518	32,216

- Though one retail facility with square footage between 20,001 and 50,000 square feet was sampled, the premise weighted percent was rounded down to zero. The same is true for retail facilities greater than 50,000 square feet.

[7] The "Low" consumption category includes the "Small" and "Medium" strata, while the "High" consumption category is the combination of the "Large" and "Very Large" strata.

As would be expected, the 'Balance of Commercial' segment is the most diverse. As estimated through the on-site sample, one half of the facilities in this segment are less than 2,400 square feet. On the other hand, the 'Balance of Commercial' segment contains more than three-quarters of Vermont's commercial facilities over 50,000 and has by far the highest average size among the three segments.

Table 3-4 shows the distribution of total enclosed floor space by energy use strata and building type categories. As would be expected, the distribution of total interior floor space is more heavily weighted to large energy use facilities than is the distribution of facilities. However, small energy use facilities account for 30 percent of total indoor space and medium energy use facilities account for an additional 36 percent of indoor floor space. This finding implies that programs must be designed to reach these smaller facilities, as well as larger ones, if overall energy efficiency goals are to be met.

Table 3-4
Percent of Overall Enclosed Floor Space by Energy Consumption and Building Type
Premise Weighted n = 117

	Building Type			
Energy Consumption Strata	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Small	11%	15%	4%	30%
Medium	13	1	22	36
Large	4	2	12	19
Very Large	4	0	10	15
Total	**33%**	**18%**	**49%**	**100%**

Distribution by conditioned floor space. Table 3-5 shows the population weighted distribution of sample facilities by conditioned floor space. As would be expected, the distribution of facilities by conditioned floor space is more concentrated than the distribution of interior space in the smaller size categories. Average conditioned floor space among all commercial facilities is 10,454 square feet, versus 12,034 square feet for total enclosed square feet. Most of this differential is concentrated in the two smallest size categories of the balance of commercial segment, suggesting that small utility buildings account for most of the unconditioned space. There is very little unconditioned interior space in either office or retail facilities.

Table 3-5
Facilities – Facility Size and Type – Conditioned Space
Premise Weighted n = 117

	Building Type			**Consumption Category**		
Conditioned Space (square feet)	**Office**	**Retail**	**Balance of Com.**	**All Com.**	**Low**	**High**
2000 and Under	15%	29%	58%	36%	40%	1%
2001 – 5000	17	35	3	19	18	23
5001 – 10000	39	23	8	22	22	20
10001 – 20000	23	13	14	16	17	12
20001 – 50000	3	0	8	4	1	29
Over 50000	3	0	8	4	2	15
Total	100%	100%	100%	100%	100%	100%
Average square feet	13,384	4,945	14,334	10,455	14,334	10,455

Distribution by number of stories. Table 3-6 shows the population weighted distribution of commercial facilities by number of stories. Only four percent of commercial facilities have four or more stories, with the remainder distributed fairly evenly among one, two, and three stories. There is very little difference among building types in distribution by number of stories. However, the sample contained no retail facilities over three stories.

Table 3-6
Distribution of Commercial Facilities
by Number of Stories
Premise Weighted n = 117

	Building Type			
Number of Stories	**Office**	**Retail**	**Balance of Com.**	**All Com.**
One	23%	38%	36%	34%
Two	42	31	39	37
Three	27	28	19	25
Four or more	4	0	8	4
Total	100%	100%	100%	100%

Distribution by year built. Table 3-7 shows the population weighted distribution of facilities in the on-site sample by year built. Over one-half of the facilities were constructed before 1960; 70 percent were built before 1980. In these facilities, the major mechanical and electrical systems were often replaced at least once. KEMA was unable to obtain reliable data on the year built for facilities that represent 11 percent of the population.

Table 3-7
Commercial Facilities
by Year Built
Premise Weighted n = 117

	Building Type			
Year Built	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Before 1900	15%	5%	22%	14%
1900 – 1959	35	51	22	37
1960 – 1969	0	0	31	11
1970 – 1979	15	3	8	8
1980 – 1989	15	18	6	13
1990 – 2000	8	5	0	4
After 2000	4	0	3	2
Unknown	4	18	11	11
Total	100%	100%	100%	100%

Timing and extent of additions and changes in use. In an attempt to develop information on the pace and extent of additions and major renovations, the field engineers asked survey participants to identify the year in which any major changes in use or floor space were made to their facilities. Respondents could report up to two such changes. Table 3-8 displays the results of this question sequence. Unfortunately, 27 percent of the respondents could not provide the information requested. Among those who could provide such information, 59 percent reported at least one major change in use or floors are; six percent reported two such changes. The reported changes were spread fairly evenly over the period from 1960 to the present. Most of the reported changes in use or additions (57 percent) did not involve a change in floor space. However, among those that did, over two thirds resulted in 76 – 100 percent increase in area of the original facility.

Table 3-8
Major Facilities Changes
Premise Weighted n = 117

Year of Major Change in Floor Space or Use	First Reported Change	Second Reported Change
No Changes Made	30%	61%
Before 1960	3	1
1960 – 1979	12	1
1980 – 1989	3	1
1990 – 2000	11	1
After 2000	13	2
Cannot Provide Information	27	32
Percent of Current Floor Space Added		
No Change	57%	93%
0 – 25%	9	0
26 – 50%	3	1
51 – 75%	4	0
76 – 100%	28	5
Don't know	0	1

3.3 Energy-Related Facility Characteristics

This subsection presents information on the energy-related characteristics of Vermont's commercial facilities: primary heating fuel, the presence of cooling, presence of on-site electric generation, and energy intensity. Reported results indicate the presence of equipment at a site, but do not control for the amount of space within the site that was served by that equipment.

Distribution by heating fuel. Table 3-9 shows the population weighted distribution of sample facilities by heating fuel. Fuel oil is the most common heating fuel, accounting for 45 percent of all facilities. The remaining facilities are divided roughly equally between natural gas, electricity, and propane. Ten percent of facilities use other fuels – mostly wood or other biomass products – for heat. The distribution of facilities by heating fuel is similar across building types, though facilities in balance of commercial tend to have more electric and less fuel oil than other building types.

Table 3-9
Facilities by Heating Fuel
Premise Weighted n = 117

	Building Type				Consumption Category	
Heating Fuel	**Office**	**Retail**	**Balance of Com.**	**Total Sample**	**Low**	**High**
Electric	10%	17%	35%	22%	22%	19%
Natural Gas	24	18	20	20	18	40
Fuel Oil	42	61	29	45	47	29
LNG or Propane	24	16	25	21	22	16
Other	2	25	1	10	11	4
	119%	102%	136%	119%	119%	113%

Distribution by heating equipment type present. Table 3-10 shows the percentage of commercial facilities in which various types of heating systems are present. The columns do not add up to 100 percent because multiple heating systems were found in buildings that represent roughly 25 percent of the population. Table 3-11 shows the same information, but weighted by square footage. Comparing the two, it is clear that larger facilities are more likely to have multiple types of heating present. The square footage weighted results should be interpreted as facilities representing “x” percent of the total square footage of Vermont commercial facilities have this type of heating present.

Table 3-10
Heating Equipment by Building Type
Premise Weighted n = 116

	Building Type			
Type of Heating Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Packaged	6%	8%	8%	8%
Split System	24	0	13	11
Electric Baseboard	4	3	29	12
Unit heaters	2	2	2	2
Heat Pumps	1	0	1	1
Hot Water Boiler	66	16	26	32
Steam Boiler	1	25	5	12
Furnace	14	62	45	44
Other	2	2	7	4
Total	**120%**	**119%**	**135%**	**125%**

Table 3-11
Heating Equipment by Building Type
Square Footage Weighted n = 116

	Building Type			
Type of Heating Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Packaged	14%	10%	6%	9%
Split System	41	0	30	28
Electric Baseboard	2	1	6	4
Unit heaters	3	7	15	10
Heat Pumps	6	0	0	2
Hot Water Boiler	70	35	75	66
Steam Boiler	11	15	8	10
Furnace	9	56	56	41
Other	3	7	16	10
Total	**158%**	**130%**	**213%**	**180%**

On a facility basis, furnaces are the most common type of heating equipment, found in 44 percent of commercial facilities. Larger facilities are more likely to have hot water boilers, as they are found in facilities that represent 66 percent of heated space. Furnaces are the predominant heating equipment type in the number of retail facilities and in retail floorspace. Boilers are the predominant type of heating equipment in office facilities, though facilities representing 41 percent of office space have split systems (24 percent of office premises). Electric baseboard heat was observed in facilities representing 29 percent of the population.

Distribution by type of cooling equipment present. Table 3-12 shows the population-weighted distribution of commercial facilities by types of cooling equipment present in the building, while Table 3-13 shows the square footage weighted distribution. The columns add to more than 100 percent because facilities representing roughly 19 percent of the population (and 29 percent of the square footage) had two or more different types of cooling equipment installed. Facilities representing 25 percent of all commercial buildings had no cooling equipment installed[8]. This figure matches the analogous CBECS figure for buildings in the Northeast census region. Split systems are the most commonly found type of equipment, serving facilities that represent 34 percent of the full population and 54 percent of conditioned space. Split systems are especially predominant in office facilities: 64 percent of premises and 62 percent of office space. Chillers are found in only 2 percent of facilities, but those facilities make up almost 10 percent of the total conditioned floor space in the state. Window AC units are most commonly found in retail facilities, where 41 percent of premises have at least one.

[8] Cooling equipment included room air conditioners.

Table 3-12
Cooling Equipment by Building Type
Premise Weighted n = 117

	Building Type			
Type of Cooling Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
None	3%	34%	30%	25%
Packaged AC	9	9	9	8
Split System	64	15	33	34
Chillers	2	1	2	2
Window AC	19	41	8	24
Heat Pump	8	15	22	16
Miscellaneous	0	12	16	11
Total	105%	126%	121%	119%

Table 3-13
Cooling Equipment by Building Type
Square Footage Weighted n = 117

	Building Type			
Type of Cooling Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
None*	1%	34%	8%	11%
Packaged AC	18	16	14	15
Split System	62	29	58	54
Chillers	13	1	9	9
Window AC	17	46	11	19
Heat Pump	17	4	19	16
Miscellaneous	5	3	16	10
	127%	134%	129%	129%

***This means that in buildings presenting 11 percent of all space there is no cooling equipment.

3.4 Patterns of Operating Hours

Median and mean operating hours. As part of the on-site survey, the field engineers posed a series of questions on daily, weekly, and annual hours of operation. In large facilities, these questions were asked about each of the sample spaces surveyed. For these larger sites, the sample space with the most hours of operation was taken to represent the entire facility in the analyses below. Table 3-14 presents mean and median annual hours of operation by building type and by region. For all commercial buildings, the mean annual hours of operation is 3,470 with an 80 percent confidence interval of ± 10 percent. Office facilities have lower annual hours of operation than the other two segments, with a mean of 2,622 versus 3,602 for retail, and 3,940 for the balance of commercial. This relatively high figure likely reflects the inclusion in the segment and the sample of 24-hour facilities such as hospitals and hotels. The balance of commercial sector of commercial also has the most varied hours of operation, as evidenced by the relatively large confidence interval and the large difference between the mean and the median.

Table 3-14
Annual Hours of Operation
by Building Type
Premise Weighted n = 111[9]

	Building Type			
	Office	**Retail**	**Balance of Com.**	**All Com.**
Mean	2,622	3,602	3,940	3,470
80% Confidence Interval	*±272*	*±267*	*±936*	*±347*
Median	2,340	3,432	2,600	2,912

Table 3-15 shows the distribution of commercial facilities by days per week and hours per day of operation. Again, the variability of hours of operation in the balance of commercial segment is apparent in the high concentration of facilities with 8 or fewer hours of operation per day and 24 hour per day operation. Nearly two-thirds of retailers are open seven days a week versus only 19 percent of office facilities. Facilities with long hours of operation offer potential for enhanced cost-effectiveness in energy efficiency measures.

[9] Six respondents did not provide reliable information on hours of operation.

Table 3-15
Hours of Operation
Premise Weighted n = 111

	Building Type			
Days Per Week	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Less Than 5	1%	0%	12%	5%
5	74	1	31	31
6	4	37	3	16
7	20	62	54	48
Total	100%	100%	100%	100%
Hours Per Day				
Less Than 8	3%	0%	25%	10%
8	37	17	6	19
8.1 – 10	55	43	12	35
11 – 12	1	18	15	12
13 -23	3	21	5	11
24	2	0	37	14
Total	100%	100%	100%	100%

3.5 Energy Intensity

Energy use per square foot or the Energy Utilization Index (EUI) is the indicator most commonly used in describing energy use and analyzing relative electric energy efficiency in commercial buildings. Table 3-16 shows the population-weighted EUI for electricity based on data from the on-site sample. For purposes of comparison we show the corresponding EUI from the 2003 CBECS for the Northeast Region, which includes the Middle Atlantic and New England Census Divisions. This is the smallest level of geographic disaggregation for which these data are reported.

The Vermont on-site sample EUIs are within the 80 percent confidence level for all building types, with the exception of retail. The data indicate a higher electric energy intensity level for the retail sector than the Northeast Region.

Table 3-16
Electric Energy Utilization Indices
n = 117

	Building Type			**Consumption Category**		
Energy Utilization Index: Full Facility Population	**Office**	**Retail**	**Balance of Com.**	**All Com.**	**Low**	**High**
Electricity: kWh/square feet – Conditioned Space						
Mean for On-site Sample	12.93	19.35	14.75	14.99	6.03	33.11
80% Confidence Interval	±5.6	±9.4	±6.3	±4.5	±1.82	±5.83
CBECS 2003 Northeast	16.50	8.80	10.65	11.5	NA	NA
Electricity: kWh/square feet-All Space						
Mean for On-site Sample	12.89	18.74	11.39	13.03	4.98	32.10
80% Confidence Interval	±5.6	±9.8	±5.6	±3.8	±2.10	±5.58
CBECS 2003 Northeast	16.50	8.80	10.65	11.5	NA	NA

NA = not available

3.6 On-Site Generation

Table 3-17 summarizes the field engineers' observations of on-site generators found in the sample facilities. The key findings that can be taken from this information are as follows.

- **Saturation.** Overall, 18 percent of sample facilities (population weighted) had electric generators on site, with retail facilities having the highest percentage (27 percent). These generators serve 21 percent of total commercial floor space, with very little difference between building types on this dimension.
- **Rated output.** The mean rated output of the generators on-site is 54 kW. Generators found in the office and balances of commercial segments are much larger on average than those in the retail segment: 166 and 96 versus 33 kW.
- **Cogeneration:** Ten percent of the floor space in facilities with on-site generators is served by cogeneration equipment.
- **Input Fuel.** In terms of floor space served, diesel is the most common input fuel for on-site generators. Seventy-two percent of the floor space in buildings with on-site generation is served by diesel generators. Other fuels such as wood and biomass rank second at 12 percent.

- **Operating mode.** Eighty-four percent of all generators installed on-site are currently used to provide emergency back-up power only. Only seven percent are used regularly to reduce peak demand. An additional nine percent are used for intermittent base load generation.

Table 3-17
Saturation and Characteristics of On-Site Generation
n = 116

	Building Type			
	Office	**Retail**	**Balance of Com.**	**All Com.**
Saturation by Facility	6%	27%	17%	18%
Saturation by Floor Space	22%	18%	22%	21%
Weighted by Floor Space, n = 30				
Mean Rated Output (kW)	291	33	253	218
Cogeneration Present	0%	55%	4%	10%
Generator Input Fuel				
Fuel: Natural Gas	0%	0%	10%	6%
Fuel: LPG	5	45	5	10
Fuel: Diesel	95	55	64	72
Fuel: Other	0	0	21	12
Operating Mode				
Emergency	100%	45%	85%	84%
Peak Shaving	0	0	13	7
Base Load	0	0	0	0
Other*	0	55	2	9

*Includes intermittent base load generation

4. Characteristics of the Sample Facilities

In this section we present information on the general characteristics of the organizations and facilities included in the on-site sample and compare their distribution along key characteristics to similar information derived from population data sources such as Dun & Bradstreet and the U.S. Census.

4.1 Characteristics of Organizations in the On-Site Sample

Table 4-1 shows the distribution of the on-site sample by primary economic use and building type.

Table 4-1
On-Site Sample by Primary Economic Use & Building Type

	Building Type				Consumption Category	
Primary Economic Use	**Office**	**Retail**	**Balance of Com.**	**All Com.**	**Low**	**High**
Retail	1	15	1	17	12	5
Grocery	0	8	0	8	6	2
Office	26	0	4	30	18	12
Restaurant	0	6	2	8	3	5
Warehouse	0	0	6	6	1	5
Hospital	0	0	3	3	0	3
Other Health	5	0	3	8	2	6
Lodging	0	0	7	7	2	5
School	0	0	7	7	0	7
Assembly	1	0	0	1	1	0
Other	2	3	17	22	13	9
	35	**32**	**50**	**117**	**58**	**59**

Table 4-2 shows the distribution of sample facilities by size and building type. The distribution of the sites among the square footage size categories resembles the sample allocation by annual electric consumption. Roughly one-third of the sample falls into the small, medium, and large size categories.

Table 4-2
On-Site Sample by Facility Size

	Building Type			
Facility Size (based on SF)	**Office**	**Retail**	**Balance of Com.**	**All Com.**
2000 and Under (Small)	1	4	6	11
2001 – 5000 (Small)	11	15	3	29
5001 – 10000 (Medium)	8	7	3	18
10001 – 20000 (Medium)	6	4	7	17
20001 – 50000 (Large)	6	1	10	17
Over 50000 (Large)	3	1	21	25
Total	**35**	**32**	**50**	**117**

As would be expected, the 'Balance of Commercial' segment is the most diverse. As estimated through the on-site sample, one half of the facilities in this segment are less than 2,400 square feet. On the other hand, the 'Balance of Commercial' segment contains more than three-quarters of Vermont's commercial facilities (more than 50,000 premises) and has by far the highest average size among the three segments.

Table 4-3 shows the distribution of total square footage by energy consumption and building type categories for the facilities included in the sample.

Table 4-3
Space Sampled by Energy Consumption Category and Building Type
(Total Indoor Square Feet)

	Building Type			
Consumption Stratum	**Office**	**Retail**	**Balance of Com.**	**Total Sample**
Small	67,990	49,625	39,605	157,220
Medium	209,860	61,410	249,545	520,815
Large	232,976	86,600	817,490	1,137,066
Very Large	756,018	122,000	1,874,700	2,752,718
TOTAL	**1,266,844**	**319,635**	**2,981,340**	**4,567,819**

5. Characteristics and Installed Capacity of Major Energy Systems

5.1 Indoor Lighting

5.1.1 Saturation and technology shares by floor space served

All space surveyed has indoor lighting equipment. Table 5-1 shows the saturation of the principal indoor lighting technologies. Percentages in the columns will add to more than 100 percent because individual spaces are often served by more than one type of lighting.

T12 fluorescent tube lamps are found in 49 percent of all commercial space and 55 percent of office space. Standard T8 fluorescent tubes are also found in more than 40 percent of space, including more than half of space in both offices and in high electric usage facilities. There are significant opportunities for savings: less than 12 percent of lit space includes T5s or high performance T8s. Both incandescent and compact fluorescent lighting are present in a substantial portion of commercial space, with CFLs found in slightly more space. This indicates that knowledge and some adoption of compact fluorescent is occurring in the commercial sector and that more opportunity for compact fluorescent lamps exists. HID lighting for indoor situations is less prevalent and is primarily found in the 'Balance of Commercial' category, which includes schools and other facilities likely to include this type of lighting.

Table 5-1
Floor Space Served by Lighting Equipment
Square Footage Weighted n = 116

	Building Type			
Indoor Lighting Technology	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Incandescent Lighting	34%	40%	15%	25%
Compact Fluorescent Lamps	32%	37%	25%	32%
T5	1%	10%	6%	5%
Standard T-8	57%	30%	38%	42%
High Performance T-8	14%	3%	3%	6%
Unknown T-8	1%	6%	2%	2%
T-12	55%	44%	47%	49%
Unknown Fluorescent Tube	10%	0%	12%	9%
Other Fluorescent	6%	0%	11%	8%
HID	1%	1%	24%	13%
Quartz	4%	11%	4%	5%
Other	9%	18%	27%	20%

5.1.2 Overall installed capacity

Installed lighting capacity is usually measured by the lighting power density (LPD) indicator, defined as the ratio of the wattage of installed lighting fixtures to square footage lit. Vermont's *2005 Guidelines for Energy-Efficient Commercial Construction* contains standards for maximum LPDs for various building types and individual space types. These guidelines are taken from the current American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 90.1. The maximum LPD for retail buildings (using the whole building approach) is 1.5 watts/square feet; 1.0 watts/square feet for office buildings. Other whole building guidelines range from 0.8 watts/square feet for warehouses to 1.6 watts/square feet for family restaurants and theaters. Efficient lighting layouts and advances in basic fixture technology now permit designers and contractors to meet lighting requirements at LPDs considerably below the ASHRAE standard levels.

The LPDs presented in this report were calculated from survey data detailing the number, type and wattage of the lamps found in sampled facilities. It was not always possible to collect complete information for each lighting type present in a sampled space. In cases where partial information about the lamps was known, values were used to fill in missing data. The results reported should be considered a minimum LPD estimate: information was only collected for all the lamps that the surveying engineer had time to catalogue, so some small lighting groups may have been overlooked.

Correcting for missing data. Our LPD estimates for individual light types represent the average LPD for the given light type in spaces that have that type of light. In some cases the light type and number of lamps were known, but Watts per lamp was not estimated on-site. In these cases, KEMA used an average Watts per lamp based upon the lighting type and (if the data allowed) the ballast type. This was the only type of correction used in estimating the lighting specific LPDs and it was used in less than seven percent of cases. More than one third of these cases were LED lighting, which is a very small percentage of overall lighting. If, after this correction the wattage for the lighting group was still unknown, then the entire space was dropped from the analysis of that light type.

The overall LPD estimates included a further correction for missing data. When presented with a lighting group for which the wattage was impossible to calculate, the estimated LPD from the technology specific LPD analysis for that light type and building type was used to estimate the wattage for the lighting group with missing information. Using the observed average technology and building specific LPDs in this way keeps the overall distribution of light types in the LPD analysis consistent with the technology shares of the lit square footage and provides more accurate results than dropping the spaces with insufficient data from the analysis entirely. This correction was employed in 15 percent of cases.

Lighting Power Density Results. Table 5-2 displays the mean observed LPDs (premise weighted) by building type, the 80 percent confidence interval around the estimated mean, and the maximum LPD for the corresponding building types in the Vermont *Guidelines.*[10] The key findings to be drawn from the information presented in Table 5-2 are as follows.

[10] Maximum LPDs for the balance of commercial segment and all commercial are the weighted average maximum LPDs for the building types contained in those categories, using the whole building approach.

- The observed mean LPD for all commercial facilities is lower than the weighted average maximums contained in the Vermont *Guidelines*.
- The observed LPDs in the office segment are about the same as the maximum standards in the Vermont *Guidelines*.

Table 5-2
Overall Lighting Power Density
Premise Weighted n =115

	Building Type			
Indoor Lighting Technology	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Mean Lighting Power Density (w/square feet)*	1.00	1.00	0.72	0.85
80% confidence interval	*±0.19*	*±0.13*	*±0.12*	*±0.12*
Maximum standards per Vermont Guidelines	1.00	1.50	1.13	1.21

*Default values were used for the analysis of LPD when full information was unavailable for a site. These values are provided in the Appendix, table 245.

- Observed LPDs in the retail sector are roughly two-thirds of the guidelines. KEMA has encountered low LPDs for retail facilities in other studies. The most common cause is that smaller retail facilities tend to be lit by overhead fluorescent fixtures only, where ASHRAE guidelines assume the use of task and display lighting as well.
- The observed Balance of Commercial LPDs is lower than the standard.

5.1.3 Installed capacity by fixture type

Table 5-3 shows the average installed lighting capacity (w/square foot) by fixture type in spaces where the fixture type is present. The key findings to be drawn from the information presented in Table 5-3 are as follows.

- Where installed, fluorescent tube and HID lighting have the highest Watts per square foot, especially in offices. This is primarily due to their use as area rather than task lighting.
- Incandescent lamps have a relatively high LPD, at 0.34 watts per square foot, with compact fluorescent lamps at 0.11 Watts per square foot. Since CFLs provide roughly 4-5 times the lumens, per watt, CFL lighting is providing slightly more lumens than incandescent lighting in spaces where each is used.

While there appears to be a significant market segment that has already adopted efficient equipment and designs, and there is an equally significant segment that has not, despite a decade of consistent promotion by utilities and the EEU[11]. Substantial improvement in the overall LPD will require that the facilities in the lagging segment be identified through program operations and targeted for program assistance.

Table 5-3
Lighting Power Density (w/square footage) by Type
Premise weighted n = 115

	Building Type			
Indoor Lighting Technology	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Incandescent Lighting *n=48*	0.18	0.36	0.53	0.34
Compact Fluorescent Lamps *n=53*	0.03	0.06	0.19	0.11
T5 *n=3*	0.39	-	0.02	0.09
Standard T8 *n=53*	0.44	0.57	0.35	0.44
High Performance T8 *n=14*	0.65	0.75	0.20	0.51
Unknown T8 *n=10*	0.68	0.25	0.11	0.22
T12 *n=54*	0.50	0.75	0.38	0.53
Unknown Fluorescent Tube *n=6*	1.24	-	0.41	0.82
Other Fluorescent *n=18*	0.11	-	0.15	0.14
HID *n=10*	0.70	1.17	0.54	0.65
Quartz *n=7*	0.08	0.05	0.38	0.16
Other *n=23*	0.02	0.24	0.00	0.06
Overall Lighting Power Density*	**1.00**	**1.00**	**0.72**	**0.85**

*LPDs reported in this table represent the average LPD of spaces where a lighting technology was found. The overall LPD is not the sum of the technology specific LPDs, rather it is the population weighted sum of all Watts divided by the population weighted total square feet of spaces where wattage could be estimated.

[11] As shown in Section 7, on-site engineers identified substantial opportunities to increase the efficiency of linear tube lighting, much with up-grades to standard T-8 lighting.

Ninety-five percent of indoor lighting is controlled by manual on/off switches, 91 percent of lighting is used for area lighting. This suggests that lighting controls represent an untapped resource of energy savings. In retail and office space, incandescent and CFL lamps are used for area lighting in more than 95 percent of the space where they are present, whereas in balance of commercial more than 25 percent of the space that has incandescent and CFL lamps uses them for task lighting.

5.1.4 Additional Indoor Lighting Details

Usage. Over ninety percent of all lighting wattage in Vermont commercial buildings is area lighting. The only other significant use of lighting is task lighting, which makes up seven percent of overall lighting watts and 17 percent of balance of commercial lighting.

Age. On average, lighting fixtures in Vermont commercial facilities are seven years old. T12 fixtures are the oldest, averaging almost 13 years old, while High Performance T8s are the newest at just less than three years in age. Table 5-3 has the average age, of light fixtures in Vermont commercial facilities weighted by estimated lamp wattage. The data is not shown by building types due to small sample sizes.

Table 5-4
Indoor Lighting Fixture Age by Watts
Wattage weighted n = 98

Indoor Lighting Technology	**All Com. Age in Years**
Incandescent Lighting *n=49*	7.2
Compact Fluorescent Lamps *n=50*	5.8
T5 *n=6*	3.8
Standard T8 *n=48*	6.0
High Performance T8 *n=13*	2.9
Unknown T8 *n=10*	7.3
T12 *n=49*	12.7
Unknown Fluorescent Tube *n=10*	11.6
Other Fluorescent *n=17*	6.1
HID *n=12*	8.7
Quartz *n=8*	2.8
Other *n=25*	5.8
Overall Age	**7.5**

Ballast Types. Most of the lamps in Vermont have electronic ballasts, including all HP T8s, all T5s all unknown T8s and 85 percent of standard T8s. T12s, unknown fluorescents and HIDs are the lamp types that are most likely to have ballasts that are not electronic. T12s mostly have standard magnetic ballasts and are the only lamp type that makes significant use of "energy saving magnetic ballasts".

Table 5-5
Indoor Lighting Ballast Type by Watts
Wattage weighted n = 107

Indoor Lighting Technology	Standard Magnetic	Energy Saving Magnetic	Electronic	Other	None
T5 *n=7*	0%	0%	100%	0%	0%
Standard T8 *n=56*	3%	1%	85%	0%	12%
High Performance T8 *n=14*	0%	0%	100%	0%	0%
Unknown T8 *n=11*	0%	0%	100%	0%	0%
T12 *n=54*	66%	21%	6%	2%	5%
Unknown Fluorescent Tube *n=11*	48%	0%	40%	0%	12%
Other Fluorescent *n=19*	30%	5%	61%	0%	4%
HID *n=12*	38%	0%	15%	0%	47%
All Light Types Overall*	**18%**	**5%**	**35%**	**0%**	**41%**

***Overall totals include light types not included in this table**

Control Types. Though 12 percent of lighting watts in offices are controlled by motion/occupancy sensors, ninety-three percent of lamp wattage in Vermont commercial facilities are controlled by manual on/off switches, including 99 percent of retail lamps. This suggests that considerable electric savings could be realized through the introduction of automated lighting controls.

5.2 Outdoor Lighting

Overall, 81 percent of commercial facilities have some type of outdoor lighting (population weighted) as shown in Table 5-6. Results presented for outdoor lighting are based on estimated installed wattage.

Saturation by percent of all facilities. The majority of outdoor lighting wattage illuminates parking lots (51 percent of watts). Walkway lighting draws the next largest amount of power at 28 percent. Building façade lighting accounts for 16 percent of outdoor lighting wattage in offices and high use facilities, but is less than 10 percent of wattage in other building types and low use facilities.

Table 5-6
Outdoor Lighting by Business Type and Consumption Category
Premise weighted n = 117

	Building Type			**Consumption Category**		**All Com.**
	Office	**Retail**	**Balance of Com.**	**Low**	**High**	
Premises with known outdoor lighting wattage	79%	72%	91%	80%	87%	81%
Outdoor Lighting Use Type (based on installed wattage) n=89						
Parking lots	45%	56%	52%	50%	56%	51%
Parking garages	0	0	1	0	2	1
Advertising	3	10	1	5	3	4
Building Façade	16	8	9	9	16	11
Walkway lighting	18	26	36	30	23	28
Unknown location	18	0	1	0		5
	100%	100%	100%	100%	100%	100%

Installed capacity and technology shares. The field engineers identified and counted 1,130 watts of lighting installed per facility with outdoor lighting, with an 80 percent confidence interval of 300 watts. There was relatively little variation among building types on this figure. Table 5-6 shows the distribution of total outdoor lighting wattage by lamp type. High Intensity Discharge technologies account for the largest portion of outdoor lighting installed capacity at 52 percent: Most of the wattage is found in standard metal halide fixtures, with slightly smaller fraction of power being used by high pressure sodium fixtures. Standard metal halide fixtures are most common in high consumption facilities (37 percent of their overall wattage); high pressure sodium fixtures have a greater share of watts in low consumption facilities with 24 percent of watts. Outside of HIDs, Incandescent and quartz technologies make up most of the remaining watts and are most commonly employed in low consumption facilities as shown in Table 5-7 below.

Table 5-7
Outdoor Lighting Installed Capacity by Lamp Type
Wattage weighted n = 89

	Building Type			Consumption Category		
Watts by Lamp Type	**Office**	**Retail**	**Balance of Com.**	**Low**	**High**	**All Com.**
HID	38%	56%	60%	47%	64%	52%
*Mercury Vapor**	*0*	*0*	*8*	*1*	*10*	*3*
*Standard Metal Halide**	*20*	*49*	*14*	*22*	*37*	*26*
*Pulse Start Metal Halide**	*1*	*0*	*2*	*0*	*3*	*1*
*High Pressure Sodium**	*17*	*6*	*35*	*24*	*14*	*21*
*Low Pressure Sodium**	*0*	*0*	*0*	*0*	*0*	*0*
Fluorescent	2	13	7	7	9	8
Incandescent / Quartz	47	30	33	40	26	36
Other lamp type	13	1	0	6	0	4
	100%	100%	100%	100%	100%	100%

*Subset of HID, Percents indicate the percent of overall watts.

5.2.1 Outdoor Lighting Details

Age. The age of the fixture was estimated for 85 percent of the wattage represented. Overall the average age of outdoor fixtures, weighted by their wattage, is a little over nine years. Incandescent/Quartz fixtures are generally older, at an average age of nearly 11 years compared to nine years for HID. The average fluorescent fixture has only been in place for 5 years.

Controls. Lighting controls are used far more frequently for outdoor lighting than for indoor, with only 31 percent of outdoor lighting controlled by manual on/off switches. Photocell systems of various types control 40 percent of watts, while controls that include a timing mechanism are used to control 28 percent of watts.

Table 5-8
Outdoor Lighting Controls by Business Type
Wattage weighted n = 89

Control Type	Building Type			Consumption Category		All Com.
	Office	Retail	Balance of Com.	Low	High	
Manual On/Off Switch	30%	39%	25%	32%	26%	31%
Motion/Occupancy Sensor	7	6	8	9	3	7
Photocell	29	11	51	27	45	32
Time clock	25	37	5	25	9	21
Photocell/Time clock	10	7	5	6	9	7
Photocell with dimming	0	0	3	0	4	1
EMS	0	0	2	0	3	1
	100%	100%	100%	100%	100%	100%

Ballasts. Identification of ballasts for outdoor lighting proved problematic. Engineers were only able to identify the ballasts on lights representing roughly one third of the total watts that had ballasts. Of those identified, the vast majority were standard magnetic ballasts. We do not have information on the types of ballasts for the remaining 70 percent of ballasted outdoor fixtures.

5.3 Cooling

5.3.1 Saturation and Technology Shares

Saturation and technology shares by floor space served. Table 5-9 shows the percentage of total indoor and conditioned commercial floor space that is served by cooling equipment. For all facilities in the commercial sector, we estimate that 47 percent of total indoor floor space is served by cooling equipment, as is 55 percent of total conditioned space. The first figure is somewhat lower than the CBECS estimate of the saturation of cooling equipment: 58 percent for the New England region. Most of this discrepancy appears to occur in the balance of commercial segment.

Table 5-9
Percent of Floor Space Served by Cooling Equipment
n = 117

	Building Type			
Served by Cooling Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Percent of Total Indoor Floor Space	56%	55%	41%	47%
Percent of Conditioned Floor Space	57%	57%	52%	55%

These figures are based on the actual space served by the cooling equipment, which is why they are lower than the percentages in Section 4.

Table 5-10 displays the saturations of various types of HVAC equipment; in terms of percentage of known tons (eight percent of units were missing information on tonnage). Split system HVAC units account for the highest saturation, with particularly high concentrations in low consumption facilities. Other system types have relatively equal saturation, with packaged HVAC systems having a particularly high concentration in retail and heat pumps being most often found in offices. Most chiller based systems are found in large consumption facilities, especially in the balance of commercial segment.

Table 5-10
Percent of Overall tons by Cooling Equipment Type
Premise Weighted n = 74

	Building Type			Consumption Category		All Com.
Type of Equipment Installed	**Office**	**Retail**	**Balance of Com.**	**Low**	**High**	
Packaged HVAC units	9%	36%	11%	2%	31%	14%
Split system HVAC units	56	45	62	81	23	58
Chillers	5	0	19	1	27	12
Window AC	5	14	3	7	2	5
Heat pumps	23	5	1	8	12	9
Miscellaneous Cooling	2	0	3	0	5	2
	100%	100%	100%	100%	100%	100%

Installed capacity. KEMA field engineers recorded information on the installed capacity of cooling equipment in tons. Table 5-11 summarizes findings from these for all space served by cooling equipment of any kind. We present these results in terms of number of square feet served per ton of installed capacity, which is a typical formulation used as a rule of thumb for sizing commercial HVAC installations. Installed capacities of one ton per 400 to 600 square feet are typical in New England.[12] The average cooled area per ton shown in Table 5-11 falls within this range, while the average conditioned feet per ton are far higher. In other words, space that is cooled (except for retail) has systems sized within this range, but much of the conditioned space is not cooled. This is expected for Vermont, one of the northernmost states in the region. High consumption facilities tend to have larger sized systems per square footage cooled.

Table 5-11
Installed Cooling Capacity
n = 71

	Building Type			Consumption Category		
	Office	**Retail**	**Balance of Com.**	**Low**	**High**	**All Com.**
Indoor square feet per ton of AC installed	946	839	1,130	1,171	814	1,026
Conditioned square feet per ton of AC installed	944	808	835	912	804	868
Cooled square feet per ton of AC installed	485	691	468	478	550	506
80% confidence interval for cooled feet per ton	*±157*	*±247*	*±88*	*±104*	*±145*	*±87*

Age of Equipment. Table 5-12 displays the average age of various types of HVAC equipment. Cooling equipment in retail facilities is significantly older than that in other commercial facilities. There was no significant difference in the age of equipment between the low and high consumption facilities.

[12] This is equivalent to 56 – 84 watts/square meter.

Table 5-12
Average Age in years by Cooling Equipment Type
Conditioned Square Footage Weighted n = 99

	Building Type			Consumption Category		
Type of Equipment Installed	**Office**	**Retail**	**Balance of Com.**	**Low**	**High**	**All Com.**
Packaged HVAC units	13.0	14.9	5.2	9.9	7.3	7.4
Split system HVAC units	3.3	21.4*	7.6	6.5	8.1	6.6
Window AC	7.6	11.3	6.9	10.2	7.1	7.7
Heat pumps	9.1	6.6	4.5	9.7	8.6	8.7
Overall	**7.3**	**16.1**	**6.9**	**6.8**	**7.7**	**7.3**

*** n= 4**

Built-up Air Handling Equipment. Facilities representing 26 percent of the total conditioned space have external air handling systems installed. Of these, roughly half (45 percent) have variable speed drives installed on circulating fans. Only built-up, external air handlers were looked at as separately from the air conditioning systems, as discussed above.

5.4 Chillers

The field engineers observed 13 chillers in 10 facilities. Given the custom nature of chiller installations and the huge potential variety of components, configuration, and controls, it is not possible to generalize in any meaningful way from this small sample to the population of facilities with chillers. Also, the field engineers were often unable to observe such important system features as installed cooling capacity or compressor type due a number of factors: lack of access to chiller locations, absence of facility equipment schedules, and occupant's lack of knowledge of the system in question. Table 5-13 summarizes information from selected chiller items in the on-site survey: compressor type, installed capacity, presence of chilled water loop, control type, and control strategy. There are few "central tendencies" to be seen on any of these dimensions.

Table 5-13
Summary of Chiller Inventory

		Chiller Units
Number of Sites with Chillers		10
Number of Chillers Observed		13
Compressor Type	Reciprocating	2
	Screw	2
	Scroll	1
	Centrifugal	2
	Unknown	6
Chilled Water Loop Present	Yes	8
	No	2
	Unknown	3
Installed Capacity(tons)	0 – 50	2
	100 – 200	3
	500	1
	Unknown	7
Control Type	Lead/Lag	2
	Base Load	1
	On Demand	4
	Unknown	6
Energy Management System Control Strategy	Constant	1
	Reset-Temp.	3
	Scheduled	1
	None	2
	Unknown	6

5.5 Space Heating

Saturation and technology shares by floor space served. Table 5-14 shows the distribution of commercial floor space served by the different varieties of heating equipment. When viewed in this manner, there appears to be considerable overlap of heating supply. Individual buildings that represent roughly 80 percent of total Vermont commercial floor space are served by at least two different equipment types. From a space standpoint, boilers are the most prevalent, serving

77 percent of total space (versus 46 percent of facilities). Hot air furnaces are the next most prevalent, serving facilities representing 54 percent of total floor space. Furnaces are most common in low electric use facilities with 67 percent, as opposed to only 27 percent of high use facilities.

Table 5-14
Heating Equipment by Building Type
Square Footage Weighted n = 110

Type of Heating Equipment	Building Type			Consumption Category		All Com.
	Office	Retail	Balance of Com.	Low	High	
Boiler	83%	52%	83%	74%	83%	77%
Furnace	45%	63%	56%	67%	27%	54%
Electric Resistance	16%	1%	5%	3%	16%	8%
Unit Heater	1%	2%	4%	0%	7%	3%
Cabinet Unit Heater	0%	0%	7%	0%	11%	4%
Heat Pump	4%	0%	1%	0%	6%	2%
Other	5%	2%	20%	12%	11%	12%

Heating fuel types by floor space served. Fuel oil heating systems are the most common type of system in Vermont commercial facilities with 45 percent of premises using fuel oil for the primary heat source; however, natural gas heats the majority of conditioned floor space in Vermont. Around 20 percent of facilities have LPG or electric primary heating systems as well, with LPG most commonly employed in balance of commercial space.

Table 5-15
Fuel Type by Building Type and Consumption Category
Square Footage Weighted n = 110

Fuel Type	Building Type			Consumption Category		All Com.
	Office	Retail	Balance of Com.	Low	High	
Electric	18%	13%	14%	12%	23%	16%
Natural Gas	54%	13%	65%	54%	47%	52%
Fuel Oil	41%	70%	35%	38%	55%	44%
LPG	5%	13%	40%	31%	9%	24%
Neither Electric Nor Natural Gas	0%	1%	7%	0%	11%	4%
Other	12%	28%	8%	7%	26%	13%
Unknown	0%	0%	13%	7%	5%	6%

Heating Controls. Manual thermostats are the most common control method for heating in Vermont commercial facilities, controlling 38 percent of heating units. Twenty-five percent of heating units are controlled by programmable thermostats, with an additional 6 percent controlled by Energy Management Systems (EMS). EMS systems are more likely to be found in high consumption facilities where they comprise 16 percent of heating controls.

Table 5-16
Thermostat Controls by Building Type and Consumption Category
Premise Weighted n = 110

Temperature Control	Building Type			Consumption Category		All Com.
	Office	Retail	Balance of Com.	Low	High	
Programmable Thermostat	28%	15%	30%	26%	25%	25%
Manual Thermostat	48%	21%	44%	34%	52%	38%
EMS	15%	1%	5%	3%	16%	6%
Other	1%	0%	6%	4%	2%	3%
Unknown	7%	64%	15%	34%	6%	27%

Age and Capacity. Age and capacity information for heating systems proved difficult to collect. Missing information exceeded 50 percent of units. No estimates could be made based on the data collected for capacity. Age was not estimated on nearly 50 percent of units. The average age of the units with known values is six years, but given the amount of missing information this estimate is likely to be skewed toward newer units and is inaccurate.

5.6 Domestic Hot Water

5.6.1 Saturation, Fuel and Technology Shares

Table 5-17 shows the population weighted percentage of commercial facilities that have domestic hot water (DHW) equipment and, below that, the DHW fuel shares for those facilities. Based on the results of the on-site survey, we estimate that 90 percent of all commercial facilities have DHW equipment. Nearly all office facilities have DHW equipment; the saturation in the other two sectors is 85 percent for retail and 91 percent in the balance of commercial. While it may seem surprising that a sizable portion of commercial facilities do not have hot water equipment, these findings are consistent with CBECS. The 2003 survey found that only 83 percent of commercial facilities in the Northeast Census region had DHW equipment, with warehouses, retail stores, and miscellaneous service facilities showing the lowest saturations.

Table 5-17
Saturation and Fuel Shares of Domestic Hot Water Equipment
Premise weighted n = 117

	Building Type			
	Office	**Retail**	**Balance of Com.**	**All Com.**
Premises with Water Heater	98%	85%	91%	90%
Percent of Units By Fuel Type, n = 104				
Electric	48%	61%	61%	58%
Natural Gas	20	18	7	14
Fuel Oil	17	18	7	13
LPG	14	3	21	14
Other	1	0	1	1
Total	**100%**	**100%**	**100%**	**100%**

The survey results show that electricity is by far the most common hot water heating fuel in commercial facilities, with a market share of 58 percent. The market share of natural gas, fuel oil, and LPG are roughly equal, in the range of 13 to 14 percent.

Table 5-18 shows the saturation of DHW equipment types by fuel. Self-contained hot water tanks are the most common type of equipment overall (75 percent) and for all fuels except fuel oil. For facilities with fuel oil DHW, the most frequently installed type of DHW equipment is a separate tank fed by the boiler. Side-arm heaters account for a large portion of DWH installations powered by LPG.

Table 5-18
Saturation and Fuel Shares of Domestic Hot Water Equipment
Premise weighted n = 104

	Electric n=54	Natural Gas n=22	Fuel Oil n=20	LPG n=13	Total
Self contained	93%	51%	34%	77%	76%
Boiler with separate tank	0	25	65	1	12
Instantaneous	8	0	0	2	5
HW Generator with separate tank	0	3	0	0	1
Side arm	0	0	1	20	3
Unknown	0	21	0	0	3
Total	**100%**	**100%**	**100%**	**100%**	**100%**

5.7 Refrigeration

KEMA field engineers collected inventory information on the following types of refrigeration equipment:

- **Self-contained.** In-store display cases with refrigeration equipment built-in.
- **Display cases.** Display cases cooled by remote equipment, typical of larger food stores.
- **Walk-in cool rooms and freezers.** Walk-in cold storage, generally cooled by remote equipment.
- **Non-commercial refrigerators.** Consumer units found in commercial premises.

Saturation and technology shares. Table 5-19 shows the facility-level saturation of these types of refrigeration equipment. Self-contained display units are the most common type of commercial refrigeration equipment. They are present in sample facilities that represent 27 percent of all commercial facilities. Their saturation in the balance of commercial segment is particularly high (49 percent), which may reflect their presence in institutional kitchens and lunchrooms. Remotely refrigerated commercial displays are found in only 3 percent of commercial facilities, which likely reflects their presence in grocery stores. Walk-in units are found in 17 percent of all facilities; 35 percent of retail facilities. Finally, non-commercial units are found in 38 percent of all commercial facilities, with fairly even distribution across building types.

Table 5-19
Refrigeration Equipment by Building Type
Premise Weighted n = 117

	Building Type			
Type of Refrigeration Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Self-contained display	2%	24%	49%	27%
Commercial display	0	7	1	3
Walk-in	1	35	9	17
Non-commercial	40	28	47	38

Table 5-20 shows the distribution of facilities by type of self-contained refrigeration equipment present. The columns do not add to the figure in the 'All Types' row because a single premise may contain more than one kind of self-contained equipment. Overall, glass door beverages are the most common kind of self contained unit (present in 14 percent of facilities), followed by ice making machines and ice storage boxes (10 percent of facilities each).

Table 5-20
Self-Contained Refrigeration by Building Type
Premise Weighted n = 41

	Building Type			
Type of Self-Contained Refrigeration Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Glass Door Beverage Cases	0%	20%	18%	14%
Open Upright Display Cases	0	3	0	1
Island Cases	0	3	0	1
Service Cases	0	4	4	3
Closed Door Storage Cases	1	2	14	6
Upright Glass Freezer Cases	0	4	2	2
Coffin Glass Freezer Cases	0	18	1	7
Ice Storage Boxes	0	15	13	10
Ice Making Machines	1	4	22	10
Other	0	0	0	0
All Types	**2%**	**24%**	**49%**	**27%**

Table 5-21 shows the distribution of facilities by type of commercial display equipment present. Once again, the columns do not add to the figure in the 'All Types' row because a single premise may contain more than one kind of equipment. Overall, roughly equal percentages of facilities contain fresh and frozen remotely cooled displays.

Table 5-21
Commercial Display Refrigeration Equipment by Building Type
Premise Weighted n = 8

	Building Type			
Type of Commercial Display Refrigeration Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Ice Cream / Frozen Juice	0%	0%	0%	0%
Frozen Food / Meat/ Bakery	0	3	0	1
Fresh Meat / Deli Meat	0	2	1	1
Dairy / Produce / Beverage	0	6	0	2
Other Display Types	0	0	0	0
Don't Know	0	0	0	0
Missing	0	0	0	0
Total	**0%**	**7%**	**1%**	**3%**

Table 5-22 shows the distribution of facilities by type of walk-in refrigeration equipment present. Overall, we estimate on the basis of the on-site survey results that 17 percent of all commercial facilities have some type of walk-in refrigeration equipment. Most of these are walk-in storage coolers installed in commercial facilities. An estimated nine percent of facilities in the balance of commercial segment also have walk-in equipment installed. The average volume of walk-in capacity installed is 1,311 cubic feet, with an 80 percent confidence interval of ± 236 cubic feet. Thirty-one percent of the walk-in units are equipped with economizers.

Table 5-22
Walk-in Refrigeration Equipment by Building Type
Population Weighted n =36

	Building Type			
Type of Commercial Display Refrigeration Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Freezer	0%	3%	4%	3%
Cooler	1	33	8	16
Prep Area	1	2	4	2
Other Walk-in Type	0	1	0	0
Don't Know	0	0	0	0
Missing	0	1	0	0
Total	**1%**	**35%**	**9%**	**17%**

Table 5-23 summarizes information on the inventory of non-commercial refrigerators and freezers observed in the sample facilities. Field engineers identified non-commercial units in buildings representing 38 percent of all commercial facilities, with a slightly higher percentage in the balance of commercial segment. The balance of commercial segment also had a much higher saturation of refrigerators and freezers, 6.7 per facility v. 3.1 and 1.3 in the office and retail segments respectively. ENERGY STAR® models account for 25 percent of the units installed, which is consistent with the ENERGY STAR market share of refrigerator sales in recent years.

Table 5-23
Details of Installed Non-commercial Refrigerators
n = 54

	Building Type			
Type of Commercial Display Refrigeration Equipment	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Percent of Facilities with Refrigerators/Freezers	40%	28%	47%	38%
Mean number of refrigerators/freezers per facility	3.1	1.3	6.7	4.1
Mean number of ENERGY STAR refrigerators/freezers per facility	0.7	0.1	1.94	1.1

5.8 Cooking Equipment

Facilities representing 32 percent of commercial square footage in Vermont have at least some cooking equipment, as shown in Table 5-24 below. The incidence of cooking equipment is greatest in high consumption facilities, of which 58 percent have some cooking equipment. Ranges are found in 82 percent of facilities with cooking equipment and general ovens are found in 70 percent. Most facilities with cooking equipment also have dishwasher booster heaters (65 percent) and griddles or grills (54 percent). The offices with cooking equipment in the sample all showed a high incidence of all cooking technologies, but the sample size is quite small at nine premises. These are most likely buildings comprised of mostly offices, with a cafeteria or restaurant.

Table 5-24
Installed Cooking Equipment
Square Footage Weighted n = 117

Equipment Type	Building Type			Consumption Category		All Com.
	Office	Retail	Balance of Com.	Low	High	
Premises with cooking equipment	34%	39%	29%	21%	58%	32%
Percent of Facilities with cooking equipment *n=52*						
Fryers	90%	15%	32%	35%	57%	46%
Griddle/grill	90%	22%	45%	35%	70%	54%
Range	100%	92%	68%	89%	77%	82%
Oven-Baking	98%	24%	38%	40%	65%	53%
Oven-General	84%	85%	56%	73%	68%	70%
Steam Kettle	90%	16%	32%	34%	58%	47%
Dishwasher Booster Heater	93%	83%	42%	74%	58%	65%

The incidence of electric cooking equipment is considerably lower than that of cooking equipment overall, limiting the effect of cooking equipment of electric demand. Only 8 percent of fryers, 10 percent of baking ovens and 14 percent of steam kettles are electric. The equipment type that is most likely to be electric is general ovens at 63 percent, followed by dishwasher booster heaters at 56 percent.

Table 5-25
Percent of Installed Cooking Equipment that is Electric
Square Footage Weighted n = 52

Equipment Type	Building Type			Consumption Category		All Com.
	Office	Retail	Balance of Com.	Low	High	
Fryers	4%	24%	10%	4%	9%	8%
Griddle/grill	49%	32%	11%	1%	46%	32%
Range	7%	78%	44%	63%	13%	38%
Oven-Baking	7%	21%	12%	13%	9%	10%
Oven-General	35%	83%	77%	59%	67%	63%
Steam Kettle	12%	43%	12%	2%	20%	14%
Dishwasher Booster Heater	24%	100%	64%	55%	56%	56%

Data collected on the energy efficient options in place, such as infrared fryers, infrared stovetops and convection ovens was inconsistently completed on the survey forms, with 75 percent unknown. For the purposes of this analysis, unknowns were treated as “not present,” with the assumption that the on site engineer would more likely record those sites that have the energy efficient option in place than those that lacked it. This makes the estimates reported in Table 5-26 minimum estimates of energy efficient equipment saturation, with a possibility of the incidence being substantially higher.

Convection ovens are the only energy efficient option being employed with regularity in Vermont commercial kitchens. Over a quarter of commercial kitchens in large consumption facilities have convection ovens. This is likely due to their cooking properties, and not the efficiency aspects. None of the other energy efficiency options specified were found in more then 3 percent of space.

Table 5-26
Minimum Incidence of Energy Efficient Electric Cooking Equipment
Square Footage Weighted n = 52

Equipment Type	Building Type: Office	Building Type: Retail	Building Type: Balance of Com.	Consumption Category: Low	Consumption Category: High	All Com.
Infrared Fryers	0%	4%	2%	1%	2%	2%
Infrared Stovetops	0%	4%	2%	1%	2%	2%
Convection Ovens	13%	7%	21%	3%	27%	16%
Smart Range Hoods (Melink sensor controlled)	0%	6%	4%	1%	5%	3%
Engineered Pre-rinse Nozzles	0%	6%	2%	1%	2%	2%

5.9 Miscellaneous Systems

The field engineers collected inventory information on miscellaneous electric equipment which are known to contribute significant portions of commercial load: office equipment, elevators, vending machines, and laundry equipment. Table 5-18 displays some key results from observations of miscellaneous energy systems. On-site engineers could indicate that energy efficient equipment or features were present, were not present, or they these data are missing. The results in Table 5-27 show the percent of facilities in which engineers indicated that specific energy saving equipment was *not* present.[13] In other words, these show the indicated minimum opportunity for energy savings, since some of the missing data represent additional opportunity. They can be summarized as follows.

- **Vending Machines.** Vending machines were found in sample facilities that represent 30 percent of the population. Vending machines in 20 percent of facilities with such equipment (population weighted) were identified as ENERGY STAR compliant. Machines in less than 7 percent of the facilities were outfitted with vending misers, a plug device that controls vending machine lighting and refrigeration in response to ambient activity and temperature.

[13] Missing data was treated as possibly present

- **Office equipment.** Office equipment is found in sample facilities that represent 82 percent of all commercial facilities. In 63 percent of those facilities, the field engineers found that none of the equipment was ENERGY STAR compliant. This figure is consistent with recent market penetration data published by the national ENERGY STAR program. Operating practices strongly affect energy consumption by office equipment. The field engineers queried the occupants of sample facilities regarding three operating approaches that are known to reduce energy consumption in office equipment. At least 26 percent of the facilities with office equipment report that they do not enable the 'sleep mode' of operation on computers and copiers. This practice reduces energy consumption during periods of low use. Forty-four percent report not using a hard shut off at night, which totally disconnects equipment and eliminates power demand during low-use periods.
- **Elevators.** Elevators are found in sample facilities that represent 20 percent of all commercial facilities. Sixty-two percent of these facilities report not shutting down some elevators during periods of low use to save energy. At least 70 percent do not program their elevator controls to optimize positioning of cars when they are not in use.
- **Laundry Equipment.** The field engineers identified laundry equipment (washers, dryers) in facilities representing 14 percent of the total commercial population. Of these facilities, at least 69 percent did not have laundry equipment with an ENERGY STAR label.

Table 5-27
Details of Miscellaneous Equipment Installed
n = 117

	Building Type			
	Office	**Retail**	**Balance of Com.**	**All Com.**
Vending Machines*				
Vending Machines present	42%	3%	51%	30%
No Energy Star Vending Machines, n=44	77%	82%	81%	80%
No Vending Miser, n = 44	96%	100%	91%	93%
Office Equipment*				
Office equipment present	83%	94%	68%	82%
No ENERGY STAR Office Equipment, n=99	41%	84%	50%	63%
No Computer Sleep Function Enabled, n=99	30%	36%	8%	26%
No Copier Sleep Function Enabled, n=99	25%	37%	11%	26%
No Hard shut-off at night, n=99	60%	40%	37%	44%
Elevators*				
Elevators present	27%	13%	23%	20%
No Shut down equipment during low-use periods, n=39	30%	100%	65%	62%
Do not use system to optimally position cabs, n=39	84%	5%	96%	70%
Laundry Equipment*				
Laundry Equipment present	5%	3%	34%	14%
ENERGY STAR Laundry Equipment, n=33	13%	100%	72%	69%

*Indicates percent of equipment for which energy efficient equipment or practice is not present or unknown.

6. Recent Facility Upgrades and Current Maintenance Practices

In this section we present results from the on-site survey pertaining to current customer behavior in regard to capital upgrades and maintenance of major energy systems in their facilities.

6.1 Recent Upgrades to Major Energy Systems

As part of the on-site data collection effort, the field engineers requested information from the participating facility occupants regarding upgrades that they had made to energy-related systems in their facilities. As Table 6-1 shows, 40 percent of facilities updated major energy-related systems in their facilities. Retail facilities report making major upgrades more frequently than the other building types: 56 percent versus 23 percent for office facilities and 33 percent for the balance of commercial segment. Sixty-five percent of those customers report updating system only; another 25 percent report that they updated two systems. The remainder updated three or four systems.

Table 6-1
Upgrades to Energy Systems in Past 2 Years
Premise Weighted n = 112

	Building Type			
Updated systems in 2 years prior to survey	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Yes	23%	56%	33%	40%
No	77	38	61	56
Unknown	0	5	6	4
Total	100%	100%	100%	100%

Table 6-2 shows the frequency with which sample facilities report updating specific systems. The columns do not add to 100 percent because respondents could name more than one system. Among the customer who report making updates in the two years prior to the survey, 57 percent changed lighting systems and an additional 13 percent changed lighting controls. HVAC system updates were the next most frequently reported changes: 35 percent reported updating HVAC equipment; 8 percent reported updating HVAC controls. Twenty-eight percent report updating refrigeration equipment. Among sample facilities in the office segments, updates were highly concentrated in lighting equipment and controls. For facilities in the retail and balance of commercial segments, updates were spread more evenly among lighting, HVAC, and refrigeration systems.

Table 6-2
Energy Systems Updated in the Past 2 Years
Premise Weighted n = 39

	Building Type			
Systems Updated in 2 Years Prior to Survey	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Lighting	80%	50%	59%	57%
Lighting Controls	20%	0%	34%	13%
HVAC	23%	49%	15%	35%
HVAC Controls	18%	0%	17%	8%
Water Heating	1%	1%	1%	1%
Refrigeration	1%	30%	37%	28%
Roof	1%	0%	5%	2%
Windows	1%	0%	13%	4%
Other	1%	0%	1%	1%

6.2 Maintenance Practices

In this section, we summarize information from a series of questions that the field engineers posed to occupants of the sample facilities concerning whether and how often they carried out specified maintenance procedures on key energy-using systems. Some of these questions were contained in a battery of items to be asked at the beginning of the on-site visit. Others were posed as the field engineer toured the facility accompanied by a representative of the occupant's organization. The responses are organized below by major system.

Packaged HVAC Systems. Sample respondents representing more than half of all commercial facilities with packaged HVAC units report servicing or checking operations of the system one or more times per year. Fifty-six percent report cleaning the coils, 48 percent check refrigerant levels and 63 percent check the damper operation. These maintenance practices are less prevalent in the retail sector where one-quarter to one-third of respondents report that they never conduct these maintenance activities.

Table 6-3
Maintenance Practices for Packaged HVAC Units
Premise Weighted n = 49

	Building Type[1]			
MAINTENANCE PROCEDURE/ Frequency	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Clean Coils				
Not at all	5%	33%	3%	9%
< 1 Time per Year	0	0	5	2
Once per Year	22	47	23	27
Twice per Year	50	5	6	19
3+ Times per Year	18	8	7	10
Check Refrigerant Level				
Not at all	11%	28%	20%	18%
< 1 Time per Year	0	1	5	3
Once per Year	2	47	14	15
Twice per Year	65	8	2	23
3+ Times per Year	18	1	5	9
Check Damper Operation				
Not at all	11%	27%	13%	15%
< 1 Time per Year	0	1	5	3
Once per Year	2	47	51	35
Twice per Year	62	8	3	22
3+ Times per Year	16	1	1	6

1 Frequencies of maintenance practices do not add to 100 percent because information on maintenance practices was not provided for some facilities

Chillers. Sample respondents representing 65 percent of all commercial facilities with chillers report that they have their chiller systems serviced once annually. Sixteen percent report semiannual service calls, and 13 percent report having their units serviced three times per year. Only three percent report having the unit serviced less than once per year.

Boilers. Sample respondents representing 42 percent of all commercial facilities with oil and natural gas boilers report that they have their boilers serviced once annually. Sixteen percent report semiannual service calls, and two percent report having their units serviced three times per year. Eleven percent report that they have the efficiency of their boiler checked less frequently than once per year, and nine percent report that they do not have it done at all.

7. Opportunities for Increased Energy Efficiency

In this section we present information on the opportunities for increased energy efficiency among the major energy users in commercial facilities. These include;

- indoor and outdoor lighting,
- cooling,
- space heating,
- domestic hot water,
- refrigeration, and
- air handlers.

The energy efficiency opportunities were identified by the on-site engineers based on what could be observed in a walk-through audit. Most of the tables presented in this section report the minimum percentage of space that includes the particular opportunity. For example, in Table 7-1 there is the opportunity to switch to CFLs in at least 24 percent of the commercial floor space. Neither of the tables indicates the amount of wattage that could be replaced with CFLs. The energy efficiency opportunities were not collected at that level of detail.

Some opportunities are premise weighted, such as Table 7-6, where the outdoor lighting percentages represent the minimum percentage of buildings that have that opportunity. The appendices, in Volume 2 of this report, include both premise and square foot weighted results for most energy efficiency opportunities[14]. The on-site engineers did not identify opportunities for early replacement of equipment.

7.1 Indoor and Outdoor Lighting

In this subsection we present information on the opportunities for increased energy efficiency for indoor lighting. In the case of indoor lighting, some of the opportunities overlap. For example, a

[14] For some opportunities square footage weighted results were not included because it is not a meaningful number.

specific lamp (for example, standard T-8s) may have had multiple opportunities identified (such as switch to HP T-8s and switch to T-5s).

The tables of energy efficiency opportunities are presented in this section based on ratio estimation. This means that percentages are based on the percentage of space that contains that lighting type (not the percentage of buildings). This provides a better measure of the opportunity to increase efficiency. Premise weighted results are provided in the appendices.

7.1.1 Indoor Lighting

The greatest opportunities for lighting overall exist for upgrading fluorescent tube lighting (to T-8s or HPT-8s) and for lighting controls to all lighting types, especially occupancy sensors.

Table 7-1
All Indoor Lighting EE Ops
Square Footage Weighted n=115

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Switch to CFLs	36%	14%	20%	24%
Switch to Standard T-8s	68%	47%	16%	37%
Switch to High Performance T-8s	96%	66%	85%	85%
Switch to T-5s	58%	20%	16%	29%
Switch to Pulse-Start Metal Halide	18%	1%	49%	32%
Replace Ballasts with Auto Daylighting	87%	8%	16%	36%
Install Occupancy Sensors	89%	45%	85%	79%
Install Dimmers	37%	10%	10%	18%

Fluorescent Tube Lighting Opportunities. Fluorescent linear tube lighting represents a large portion of the lighting in the commercial sector and substantial opportunity to increase the efficiency. At least half of the represented space with T-12 lighting can be made more energy efficient by installing standard T-8 lighting. This lighting represents an opportunity to “leap frog” past T-8 lighting directly to HPT-8s or, in some applications, T-5 lighting. The substantial energy savings from this type of upgrade may provide impetus for lighting upgrades separate from other space changes.

The opportunity to upgrade installed T-8 lighting to HPT-8s may be more difficult to realize. The average age of standard T-8 lighting is only six years, and the energy cost savings unlikely to offset the capital expense and hassle factor associated with lighting upgrades. This is an opportunity, however, when other changes and renovations are being made to a facility.

All linear fluorescent lighting technologies have opportunities for savings through the use of better controls. Occupancy sensors were identified as an opportunity in more than half of the space for each fluorescent lighting technology. Of the three building types, offices could benefit the most from replacing ballasts for auto daylighting.

Table 7-2 shows minimum percent of space (with T-12s and standard T-8s respectively) that have a given opportunity. For example, 50 percent of the space with T-12 lighting (in the 58 premises with T-12s) could save energy by replacing the T-12s with HP T-8s.

Table 7-2
Fluorescent Linear Tube EE Ops
Square Footage Weighted

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
T-12 n=58				
Switch to Standard T-8s	97%	95%	16%	50%
Switch to High Performance T-8s	97%	88%	93%	93%
Switch to T-5s	71%	37%	11%	31%
Switch to Pulse-Start Metal Halide	22%	0%	0%	6%
Replace ballasts with Auto Daylighting	28%	8%	12%	16%
Install Occupancy Sensors	84%	44%	93%	84%
Standard T-8 n=64				
Switch to High Performance T-8s	87%	83%	95%	91%
Switch to T-5s	50%	1%	1%	16%
Replace Ballasts with Auto Daylighting	38%	5%	10%	18%
Install Occupancy Sensors	86%	60%	86%	84%

Incandescent and Compact Fluorescent Lighting. There is still substantial opportunity to switch incandescent lighting to CFLs, as shown in Table 7-3. As noted earlier, the installed capacity of incandescent lighting is relatively high overall. Much of this lighting is in locations that could benefit from occupancy sensors. Premise weighted results included in the appendix (Table 209) show that almost 80 percent of premises with incandescent lamps could switch to CFLs and 45 percent of premises have incandescent lamps in places where occupancy sensors would effectively provide energy savings.

Table 7-3
Incandescent Lighting EE Ops
Square Footage Weighted n=56

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Switch to CFLs	51%	35%	73%	55%
Install Occupancy Sensors	37%	9%	33%	31%

The engineers identified occupancy sensors (Table 7-4), as an opportunity for some compact fluorescent lighting. The premise weighted results in the appendix (table 215) show that 73 percent of offices have this opportunity. This indicates that the CFLs are likely to be in locations that are not occupied all the time, such as bathrooms, meeting rooms or supply closets. Engineers identified LEDs several times as an opportunity for improving upon CFLs in certain applications. The engineers also identified some opportunity for dimmers. This opportunity is likely to increase as the prevalence of compact fluorescent lamps and dimmable models increases. Promotions of compact fluorescent lamps should address the newer, dimmable products available, as well as control options for lamps in specific applications.

Table 7-4
Compact Fluorescent EE Ops
Square Footage Weighted n=60

Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Install Occupancy Sensors	44%	32%	36%	39%
Install Dimmers	5%	0%	13%	7%
Other Opportunities	23%	6%	12%	15%

Indoor HID lighting. While HID lighting has low saturation in the commercial sector, much of it is less efficient than Pulse Start Metal Halide lighting and can be upgraded to either this technology, or linear tube lighting, such as T-5s. The switch to linear tube lighting in high and medium bay settings represents a large energy and cost savings to the end-user and can often be justified by the quick payback.

Table 7-5
HID EE Ops
Square Footage Weighted n=15

Energy Efficiency Opportunity	Office	Retail	Balance of Com.	All Com.
Switch to High Performance T-8s	0%	0%	80%	76%
Switch to T-5s	20%	66%	12%	13%
Switch to Pulse-Start Metal Halide	100%	100%	83%	84%
Install Occupancy Sensors	20%	0%	11%	12%

7.1.2 Outdoor Lighting

Much of the outdoor lighting has opportunity for increased efficiency (see Table 7-6) through upgrades to the lighting itself and with better controls to minimize hours of operation. The two greatest opportunities are to switch to pulse start metal halide lighting and to install controls to minimize outdoor lighting hours. Table 333 in the appendix has the premise weighted results for overall outdoor lighting. The premise weighted opportunities for improved controls are similar to the wattage weighted opportunities

Table 7-6
Outdoor Lighting EE Ops Based on Installed Wattage
Wattage Weighted* n=89

	Building Type			
Overall Energy Efficiency Opportunities	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Switch to CFL	41%	23%	17%	26%
Switch to Pulse Start Metal Halide	42%	58%	48%	49%
Install Astronomical Time clock	37%	65%	28%	42%
Install Light Sensing Controls	21%	65%	27%	37%
Other Opportunities	13%	4%	2%	6%
HID EE Ops *n=53*				
Switch to Pulse Start Metal Halide	82%	100%	78%	86%
Install Astronomical Time clock	3%	85%	9%	33%
Install Light Sensing Controls	6%	85%	5%	31%

*Ratio estimation done based on installed wattage. The percentages are the percentage of installed wattage that have the EE Opportunity.

7.2 Cooling

The on-site engineers identified, from a list, energy efficiency opportunities for cooling equipment (Table 7-7). The most common measures identified were associated with cooling system motors - NEMA Premium Efficiency Motors for 20 percent or Electric Commutating motors for 18 percent of space cooled. This opportunity would be difficult to realize, however, unless a motor fails or a system is being replaced.

Approximately one-quarter of space and over 30 percent of facilities could benefit from an automatic setback thermostat to reduce cooling loads. The opportunity is far greater in the retail sector, where the engineers identified the opportunity in 59 percent of cooled space.

Table 7-7
Overall Cooling EE Ops
Conditioned Square Footage Weighted n=92

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Economizer	25%	61%	15%	25%
NEMA Premium Efficiency Motors	29%	14%	18%	20%
Electric Commutating Motors	37%	8%	10%	18%
Automatic Setback Thermostat	17%	59%	11%	20%
Other HVAC Controls	0%	12%	4%	4%
Refrigerant Charge	0%	10%	2%	2%
Other Operations and Maintenance	2%	7%	2%	2%
Other Cooling Opportunities	18%	14%	12%	15%

7.3 Space Heating

Overall, space heating opportunities were dominated by the opportunity for more efficiency motors and by better controls. More efficient motors for heating systems (which will also reduce cooling costs for businesses with combined distribution systems) are likely to be realized only as part of a system replacement or other major renovations. Retrofitting existing systems can be technically challenging and have longer payback times than in replacement situations. It is more likely to be cost effective for larger facilities and applications, and unlikely to occur in small facilities. Other opportunities suggested by the on-site engineers were primarily annual maintenance.

Percentages in the tables below indicate the minimum opportunity available. For example, though only 12 percent of commercial space with electric heat has the opportunity for automatic setback thermostats, this does not mean that the opportunity does not exist for some of the remaining 88 percent of electrically heated space. The onsite engineer may have indicated the opportunity did not apply, or was unable to determine if it existed

Table 7-8
Electric Heating EE Ops
Square Footage Weighted n=18

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
NEMA Premium Efficiency Motors	2%	0%	0%	1%
Automatic Setback Thermostat	5%	4%	43%	12%
Electric Commutating Motors	65%	1%	0%	37%
Other HVAC Controls	0%	1%	0%	0%
Refrigerant Charge	0%	1%	0%	0%
Economizer	11%	0%	3%	7%
Energy Management System	0%	0%	0%	0%
VFD on Motors	0%	0%	0%	0%
Other Opportunities	0%	6%	35%	8%

Table 7-9
Natural Gas Heating EE Ops
Square Footage Weighted n=39

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
NEMA Premium Efficiency Motors	11%	65%	19%	18%
Automatic Setback Thermostat	17%	43%	1%	12%
Electric Commutating Motors	0%	36%	1%	3%

Table 7-10
Fuel Oil Heating EE Ops
Square Footage Weighted n=48

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
NEMA Premium Efficiency Motors	40%	42%	24%	34%
Other Opportunities	3%	1%	0%	1%

Energy efficiency opportunities for boilers include motor upgrades: VFDs in at least 38 percent of space, NEMA Premium efficiency motors in at least 41 percent of space and electric commutated motors in at least 31 percent of space. Improved controls also present significant opportunities for savings: outdoor resets in 29% of space and outdoor cut offs in 24 percent of space. Premise weighted tables indicate that improved controls are an opportunity in close to half of all commercial facilities, as seen in table 686 in the appendix.

Table 7-11
Boiler EE Ops
Square Footage Weighted n=60

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
VFD on Motors	9%	56%	53%	38%
NEMA Premium Efficiency Motors	21%	56%	51%	41%
Electric Commutating Motors	10%	53%	40%	31%
Outdoor Reset	29%	76%	18%	29%
Outdoor Cut off	27%	76%	11%	24%
Modulating Boiler	20%	54%	10%	19%
Duct Sealing / Insulation	0%	1%	5%	3%
Pipe Insulation	0%	1%	2%	1%
Replace Steam Traps	1%	0%	0%	0%
Replace Steam Vents	1%	0%	0%	0%
Balance System	3%	53%	8%	12%
Other O & M	3%	0%	3%	2%
Other Opportunities	3%	0%	1%	1%

7.4 Domestic Hot Water

Electric Water Heating. Table 7-12 shows the opportunities identified by the on-site engineers. Roughly two-thirds of electric water heaters could benefit from timers to keep systems from maintaining high water temperatures during non-occupied periods.

Table 7-12
Electric DHW EE Ops
Premise Weighted n=52

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Install Timers	79%	60%	68%	67%
Pipe Insulation	64%	42%	85%	63%
Supplemental Tank Insulation	75%	60%	67%	66%

Other Water Heating. The engineers identified supplemental tank insulation and pipe insulation for most domestic hot water heating systems, regardless of heating fuel. The supplemental tank insulation may be overstated since a quick look at a system may not identify how well insulated the existing tank is. The need for pipe insulation, however, is easily observed.

7.5 Refrigeration

The on-site sample did not include many facilities with commercial refrigeration equipment. In the retail sector 41 sites included self-contained refrigeration. Energy efficiency opportunities varied, as show in Table 7-13.

Table 7-13
Self-Contained Refrigerator EE Ops
n=41

	Building Type			
Energy Efficiency Opportunity	**Office**	**Retail**	**Balance of Com.**	**All Com.**
Smart Anti-sweat Controls	0%	14%	0%	5%
Super-high Insulation Windows	0%	46%	4%	18%
Economizer Coolers	0%	62%	3%	23%
Electric Commutating Motors	0%	3%	28%	19%
Other Efficiency Features	0%	2%	25%	17%
Don't know	0%	4%	26%	18%

Display refrigeration was found in only eight sites visited. The engineers identified anti-sweat controls in approximately half of the equipment, and the opportunity for their installation in an additional 25 percent. Other opportunities included cleaning seals and coils, high efficiency lights and improved light controls.

Table 7-14
Display Refrigerator EE Ops
Premise Weighted n=8

	Building Type			
	Office	**Retail**	**Balance of Com.**	**All Com.**
Premises With Smart Anti-sweat Controls Present	0%	55%	0%	47%
Energy Efficiency Opportunity				
Install Smart Anti-sweat Controls	0%	13%	100%	25%
Other Operations and Maintenance	0%	50%	0%	43%
Other Opportunities	0%	42%	0%	36%

7.6 Air Handlers

Approximately one-quarter of the heated space has built up, external air handlers, with air handlers most prevalent in office buildings, and balance of commercial. One-half of the space with air handlers could benefit from a VFD on the air handler motor. Other opportunities found were primarily improved CO_2 controls, and the installation of duct fans and economizers.

Table 7-15
Air Handlers EE Ops
n=28

	Building Type			
	Office	**Retail**	**Balance of Com.**	**All Com.**
Percent of Heated Conditioned Space That Uses Air Handlers	31%	0%	33%	26%
Energy Efficiency Opportunity				
VFD on Air Handler System Motors	46%	0%	46%	46%
Other Operations and Maintenance	4%	0%	10%	7%
Other Opportunities	9%	0%	41%	23%

8. Market Share of Energy-Efficient Equipment

8.1 Objectives and Approach

The on-site surveys of existing and newly constructed buildings provide a snapshot of the penetration of energy efficiency equipment, but do not provide information on the market share of high efficiency equipment. Nor do they provide insight into sales trends for high efficiency versus lower efficiency equipment. To assess market share and trends, KEMA conducted in-depth interviews with contractors or suppliers of motors, lighting, and HVAC equipment for commercial and industrial installation in Vermont. These interviews focused on the percent of equipment sold in the past twelve months that was high efficiency (using specific definitions of high efficiency), the extent to which the market share of high efficiency equipment is increasing, and the factors driving purchase decisions.

We conducted the in-depth interviews by telephone in July of 2008. Although the supplier interviews were primarily qualitative, we did capture quantitative data on the percentage of sales associated with different efficiency levels. These data were analyzed using ratio estimation. This approach takes into account the relative sales of each respondent (of the specific equipment sold for installation in Vermont). For the motors study the findings should be considered qualitative and directional rather than statistically rigorous, as the study included only five respondents, some of whom sold motors but not variable frequency drives and vice versa.

We defined the relevant populations of suppliers for each technology category (lighting, HVAC, and motors) using Standard Industrial Classification (SIC) codes. We used SIC rather than NAICS codes to obtain a sample from Dun and Bradstreet (D&B). D&B has not assigned NAICS codes to most of their records. The choice of which SIC codes to include for each technology category was driven both by our goal – identifying businesses close to the final customer in equipment purchase decisions – and availability

With the three populations of interest defined, we assigned targets for the number of completed surveys within each population by size. Ideally, we would have been able to use annual sales as our measure of size, as this is the most direct measure of each supplier’s impact on the market. Sales data, however, were available for only a fraction of the D&B records. Instead, we used the number of employees at the supplier’s location as the measure of size for stratification. For those D&B records that had both employee and sales data, the two were very highly correlated (r = .96), indicating that number of employees is a good proxy for annual sales.

A more complete discussion of the supplier interview samples and weighting is included in each of the supply chain subsections below. The survey instruments can be found in the appendix.

8.2 Motor Supply Chain Interviews

8.3 Population, Sample and Weighting

The specific SIC codes chosen for the motor supply chain sample frame were:

50630000 -- Electrical apparatus and equipment wholesalers
50639905 -- Electric motor wholesalers
50840000 – Industrial machinery and equipment wholesalers
50850000 -- Industrial supplies wholesalers

The column labeled "Initial Population Estimate" in Table 8-1 shows the number of business establishments in Vermont that have one of these as their primary SIC code according to the D&B database.

The other columns in Table 8-1 show the number of completed interviews that we targeted (i.e., the sample plan), the actual number of surveys completed, and our revised estimate of the population size based on screening data obtained while recruiting respondents to complete the survey.

Table 8-1
Motor Dealers Population and Sample

	Initial Population Estimate (# of premises)	Targeted Completes	Revised Population Estimate (# of premises)	Completed Interviews*
Motor Distributors	54	5	10	5

*Five motor distributors were interviewed (based on SIC code) but only 3 sold motors. The other two sold VFDs.

In the process of screening to identify qualified respondents for the survey, we completed telephone calls (though not full interviews) with 34 business establishments. Based on their self-report, only a small fraction of those establishments actually sold electric motors or drives. Applying this fraction to the original population counts gave us a revised estimate of how many establishments fell into the population of interest.

In evaluating the small number of establishments remaining in the revised population estimate – and in interpreting the results that follow – it is important to remember that they only represent sales by motor distributors that are located in Vermont. The sample did not include businesses outside of Vermont who may sell motors for installation in Vermont.

8.3.1.1 Survey weighting and ratio estimation

Because of the very small number of motor distributor interviews, we did not attempt to divide them into size-based strata for purposes of weighting. We did, however, use ratio estimation to adjust a given distributor's responses for amount of commercial/industrial electric motor sales in Vermont that they accounted for.

The survey asked respondents how many full-time equivalent employees they had working at their location, what percent of their revenues in the past 12 months came from the sale of new electric motors, and what percent of their revenue from the sale of new electric motors came from sales to Vermont businesses. We multiplied these three numbers to obtain a ratio estimator for each respondent. This number represents the sales revenue that a particular respondent obtained from sales of new electric motors to business customers in Vermont in the past 12 months. We used this ratio estimator to weight all responses to quantitative questions (i.e., where averages were reported) about motors.

We followed a similar ratio estimation approach for VFDs. Here, however, we multiplied the number of employees by the percent of their Vermont sales in the past 12 months that were from sales of VFDs. The resulting ratio estimator represents the sales revenue that a given respondent obtained from selling VFDs to business customers in Vermont in the past 12 months. We weighted all responses to quantitative questions about drives by this number.

8.3.2 Overview of the Motor Market in Vermont

Ninety percent of the electric motor sales[15] represented by the distributors we spoke with are AC induction motors, with three-quarters of the total being general purpose AC motors. The largest share of their motor sales in the past twelve months were direct sales to commercial or

[15] We did not include very small (< 1 horsepower) motors in this analysis.

industrial customers, with sales to electrical or mechanical contractors accounting for the next largest share.

8.3.2.1 Sales of NEMA Premium Efficiency Motors

The vast majority (83 percent) of these distributors' non-OEM AC motor sales in the past 12 months were NEMA premium efficiency motors. NEMA premium efficiency motors accounted for a higher percentage of the sales of larger motors than they did of small motors. Table 8-2 shows the percent of respondents' motor sales in the past twelve months that were NEMA premium efficiency motors by horsepower.

Table 8-2
NEMA Premium Efficiency by Horsepower

Motor Size	NEMA Premium Efficiency motors
1-5 HP	50%
6-20 HP	73%
21-50 HP	97%
51-200 HP	97%
200+ HP	97%
Overall	**83%**

As already noted, these results are based on very small sample sizes and thus should be viewed as directional only. But for these suppliers at least, 20 hp seemed to be a threshold beyond which high efficiency motors had virtually saturated their market.

When asked if sales of NEMA premium efficiency motors have increased, decreased, or stayed the same over the past two years, two out of three respondents said sales have stayed the same. The other believed that sales of NEMA motors had increased over the past two years.

8.3.2.2 Drivers of Motor Sales

In addition to collecting data on their relative sales of high efficiency versus standard efficiency motors, we probed for respondents' views on what drives these sales. The major themes that emerged were equipment prices, electricity prices, availability of equipment, sales channel (contractor versus direct-to-customer), and the question of whether an existing motor should be repaired or replaced.

Equipment Prices – The distributors we spoke with said that NEMA premium efficiency motors cost 11 percent more on average than standard efficiency electric motors. One noted that the impact of price varies by sector. In his experience, the commercial sector is more price sensitive than industrial customers, who are more concerned with reliability and downtime and thus willing to pay more up front. This could partially explain the observation that larger motors (which are more likely to be installed for industrial applications) are more likely to be NEMA premium efficiency motors.

Of course saying that industrial customers are less price sensitive for motors does not mean that they do not care about price. Another distributor we spoke with asserted that even industrial customers will often balk at a payback of more than three years.

Unfortunately, as respondents noted, many industrial customers have left Vermont in recent years. On the plus side, some of those that remain (e.g., Ben & Jerry's) have instituted policies to only purchase NEMA premium efficiency motors.

Electricity Prices – Respondents noted that the relationship between the price of electricity and customers' willingness to pay the necessary premium for high efficiency motors is straightforward – the more electricity costs the faster NEMA premium efficiency motors pay for themselves and the more likely customers are to buy them.

Equipment Availability – The availability of NEMA premium motors, both from distributors and from manufacturers, emerged as an issue in our conversations with motor suppliers. One respondent noted that not all local distributors carry NEMA motors, an observation supported by another respondent, who does not keep motors in stock and has not sold a single NEMA motor in the past twelve months. This respondent's firm focuses on the MRO (maintenance, repair, and operation) market; their customers call them when they need to replace a motor, read them the model number for the unit they are replacing, and order the exact same thing.

More problematic, at least from the perspective of one respondent, are manufacturers that have difficulty keeping up with demand for NEMA premium efficiency motors. This results in missed opportunities as a customer who needs a motor now buys a lower efficiency model.

Sales Channel – One respondent claimed that customers are more likely to end up with high efficiency motors when they purchase them directly from a distributor rather than through a contractor. His reasoning is that contractors shop for the lowest price motors so that they can maximize the markup they can charge.

Repair vs. Replacement – Another issue that affects how rapidly NEMA premium efficiency motors saturate the market is an individual customer's decision to either repair (rewind) or replace an existing motor. The distributors we spoke with varied in how they help customers with this decision (all three of the distributors that sold new motors also had a repair/rewind business). One almost always recommends replacement. The exception would be if the motor in question was custom-designed, such that replacing it would necessitate changing out other pieces of equipment.

The other two respondents said they base their recommendation on the condition of the motor; if the core is damaged or the overall condition of the motor is poor, they recommend replacement. One of these distributors has a rule of thumb that they usually suggest replacing motor under 100 hp and rewinding those over 100 hp due to the price of purchasing larger motors. They will not rewind a motor, however, if they cannot achieve an efficiency that at least matches that of the original motor.

On balance, these distributors recommend replacement over repair just under half the time (45 percent). Respondents generally agreed that customers go with their recommendation in most cases.

8.3.3 Opportunities to Increase NEMA Premium Efficiency Motors

Our interviews with motor suppliers suggest that NEMA premium efficiency motors are well on their way to saturating the market in Vermont, particularly the market for larger horsepower motors. To the extent that additional efforts to increase penetration are in order, these data point to several possibilities.

Whatever efforts Efficiency Vermont takes[16], they should be focused toward the markets for motors < 20 Hp. One option is to encourage customers to purchase motors directly from the distributor rather than through a contractor, or encourage/educate contractors to sell NEMA

[16] EVT's 2009 program includes rebates for NEMA premium efficiency motors of all sizes. Custom rebates are available for motors greater than 200 hp.

premium efficiency motors. This would address an issue identified by least one distributor who believes contractors are less likely to sell high efficiency motors than distributors are. It is unlikely that Efficiency Vermont could change customer purchase behavior, but it is possible that they could influence what and how contractors sell motors. This approach recognizes customers' relationships with specific vendors (contractors) they trust and their preference for outsourcing the entire purchase and installation process.

A more effective way of increasing the sale of NEMA premium efficiency motors would be to provide distributors (and contractors, for that matter) with additional tools to help them make the economic case for a) replacing a motor versus rewinding it and b) paying a bit more up front for a higher efficiency motor. It is clear that many distributors already use "back of the envelope" economic analyses to sell higher efficiency motors; whether Efficiency Vermont could provide them with better or more credible tools is an open question.

Other ideas that the distributors we interviewed suggested include setting up a motors program similar to Efficiency Vermont's lighting program, where motor specialists would visit motor users to assess the efficiency opportunities; continuing to educate motor users on the value of investing in high efficiency motors; and continuing financial incentives that draw attention to premium efficiency motors and help customers overcome the hurdle of higher first costs. Interestingly, none of the respondents suggested that incentive levels be increased. Indeed, they believed that the current incentives have done a very good job of encouraging NEMA premium efficiency motor sales.

One barrier appears to be availability of NEMA premium efficiency motors. If this is the case there may be some opportunities to work with manufacturers to ramp up production of NEMA premium efficiency motors, speeding up deliveries to distributors and customers. One of the distributors we spoke with felt very strongly that providing incentives to manufacturers was the most fruitful approach for Efficiency Vermont to take. Whether this is true, particularly given the size of the incentives that might be required to change manufacturers' behavior, and how small Vermont is relative to the motors market, is less clear. It would probably be more effective to offer additional incentives for distributors to stock and/or sell NEMA motors, particularly if the program could identify and target those distributors who are not already selling these motors. Any efforts targeted to manufacturers would need to be done on a regional or national basis.

8.3.4 Variable Frequency Drives (VFDs)

8.3.4.1 Sales of Variable Frequency Drives

Four of the distributors we spoke with sold variable frequency drives (VFDs); one sold only VFDs while the others sold both motors and drives. On average these distributors had sold one VFD in Vermont for every two motors sold in Vermont in the past twelve months. Roughly three-quarters of these VFDs were sold to be used with pumps; the remainder was evenly split between motors and general applications. Two-thirds of the VFDs sold by these distributors were sold as part of an integrated motor-VFD or pump-VFD piece of equipment. The other third were sold as stand-alone VFD units.

The distributors we spoke with were evenly split between those who had seen their VFD sales increase over the past two years and those who said they had remained flat. Those whose sales had increased cited a variety of drivers including rebates, a greater awareness of the value of using less energy for the environment, and efforts to control costs. One respondent noted that industrial customers in particular are focused on reducing their repetitive costs (such as energy) to remain competitive. They said that one clear example of this has been facilities that use a lot of air compression (such as ski resorts) where VFDs have achieved considerable savings.

The distributors whose sales had remained flat cited that fact that they had not been emphasizing VFD sales, as well as the number of manufacturing firms leaving Vermont as reasons.

8.3.4.2 Drivers VFD Sales

In addition to the number of industrial customers departing the state, distributors mentioned several factors that are influencing sales of VFDs:

Economics – Distributors were split on the impact of current economics on VFD sales. One claimed that the economic slowdown is reducing sales of VFDs, while two others asserted that the heightened need to cut costs has focused attention on energy savings and increased the sale of VFDs.

Rebates – Two respondents cited the positive impact of Efficiency Vermont's rebates and credited them with contributing to recent sales.

Going Green – One respondent thought that a greater appreciation of the environmental costs of using energy has helped sell VFDs, at least in some cases.

8.3.5 Opportunities to Increase VFD Sales

One of the challenges in increasing penetration of VFDs is that it is not possible to retrofit a VFD in most cases; adding a VFD means replacing a motor or pump. This means that the opportunity to sell a VFD usually arises only when a motor or pump is already being replaced. As a result, the approaches discussed in the prior section to encourage customers to replace rather than rewind motors are also likely to increase the sale of VFDs. One distributor we spoke with felt that Efficiency Vermont needs to increase the rebate level on VFDs, primarily to help customers justify the replacement decision. This is particularly true for large air compressors where they see a large portion of VFD applications.

Another VFD dealer talked about the need for more assistance with marketing and customer education. He specifically cited more advertisements and the development of case studies showing Vermont companies that have saved money with VFDs as helpful steps.

8.4 Lighting Supply Chain Interviews

8.4.1 Population, Sample and Weighting

The specific SIC codes chosen for the lighting supply chain sample frame were:

17319903 -- General electrical contractor
17319904 -- Lighting contractor
50630000 -- Electrical apparatus and equipment wholesalers
50630206 -- Electrical supplies, not elsewhere classified (wholesalers)

Note that one of these codes, 5063000, also appeared in the SIC code list for motors suppliers. Because the motor and lighting supply chain data were not combined for analysis, this does not pose an analytic or weighting problem.

The column labeled “Initial Population Estimate” in Table 8-3 shows the number of business establishments in Vermont that have one of these as their primary SIC code according to the D&B database. It also shows how we grouped these establishments into size categories.

The other columns in Table 8-3 show the number of completed interviews that we targeted within each size category (i.e., the sample plan), the actual number of surveys completed, and our revised estimate of the population size based on screening data obtained while recruiting respondents to complete the survey.

Table 8-3: Lighting Suppliers Sample and Completions

Size Group	Initial Population Estimate (# of premises)	Targeted Completes	Final Population Estimate (# of premises)	Completes
1 to 5 employees	88	5	29	5
6 to 19 employees	40	5	22	5
20 + employees	14	5	12	5
Total Electrical (lighting) suppliers	142	15	63	15

In the process of screening to identify qualified respondents for the survey, we completed telephone calls (though not full interviews) with 32 business establishments. Based on their self-report, only a fraction of those establishments actually sold or installed lighting products to end-users. Applying this fraction to the original population counts gave us a revised estimate of how many establishments truly fell into the population of interest.

In evaluating the small number of establishments remaining in the revised population estimate – and in interpreting the results that follow – it is important to remember that they only represent sales by contractors that are located in Vermont. We did not include sales of lighting products into Vermont by out of state suppliers in our analysis.

8.4.1.1 Survey Weighting and Ratio Estimation

The first step in weighting the data from the lighting supplier interviews was to create strata weights that would adjust for the fact that we sampled disproportionably across size strata. Disproportional sampling by size is common whenever dealing with a population characterized by a few large entities and many very small entities. Given the distribution of lighting contractors by size (number of employees) it was clear that a simple random sample would consist almost entirely of very small contractors. That would be fine if we wanted to represent the population of sellers. But to accurately represent the population of lighting *sales*, we needed to focus a substantial fraction of the sample on larger contractors that account for more sales.

Strata weights allow us to account for this disproportional sampling when analyzing the survey data. To calculate strata weights we simply divided the revised population estimate for each stratum by the number of completed surveys in the stratum. The resulting number is the number of contractors of similar size that a given respondent represents. We multiplied all quantitative responses by the appropriate strata weight for each respondent.

The survey asked respondents how many full-time equivalent employees they had working at their location, what percent of their revenues in the past 12 months came from the sale of lighting products to Vermont businesses, and what percent of their commercial/industrial lighting revenues came from sales of various categories of lighting products (e.g., HID or high bay fluorescents, CFLs or incandescents). We multiplied these numbers to obtain four ratio estimators for each respondent. Each of these four numbers represents the sales revenue that a particular respondent obtained from selling a particular category of lighting products to business customers in Vermont in the past 12 months. For each product category we multiplied all quantitative responses by the appropriate ratio estimator, as well as multiplying them by the strata weights as described above.

8.4.2 Overall Lighting Market in Vermont

To gain insight into trends in commercial and industrial lighting sales, we spoke with 15 contractors that sold or installed lighting for business applications in Vermont. We began by determining which respondent’s sold/installed specific categories of lighting (HID or high-bay fluorescents, non-high bay fluorescents, CFLs or incandescents, and LEDs) and then explored the market in each of these categories with the appropriate contractors.

A slight majority of these contractors’ revenue from the installation of commercial/industrial lighting (57 percent) came from new construction projects. This is significant because the respondents generally agreed (there were two dissenters) that it is easier to sell and install high efficiency lighting in new construction projects than it is in retrofits.

A retrofit customer always has the choice to do nothing, whereas a new construction project has to install some kind of lighting. Furthermore, according to our respondents, customers are willing to spend more money up front when constructing a building than they are when retrofitting an old building. The selection of a lighting system for a new building tends to be made by architects or engineers who understand what the available options are. Decisions on lighting retrofits are usually made by the building's owners who often need to be educated on their options. Retrofitting may also require ceilings to be torn down or other disruptions to ongoing business activities that are not an issue in new construction. One respondent noted that even pulling a permit for a lighting retrofit can be a barrier to some customers.

In general the contractors agreed that higher efficiency lighting (efficiency beyond code) is becoming the standard in new construction. One commented, however, that this depends on the age of the architect or engineer doing the specifying; older A&E professionals will sometimes stick with the technologies they know and are comfortable with.

8.4.3 HID and High Bay Fluorescents

8.4.3.1 Sales of HID and High Bay Fluorescents

According to the contractors we interviewed, high bay fluorescents were installed in 78 percent of the applications where they were options in the past year. Although customers occasionally requested high bay fluorescent lighting, it was usually the contractor who brought it to the customer's attention and made the recommendation.

Approximately two-thirds (65 percent) of the contractors we surveyed said that sales of high bay fluorescents have increased over the past two years. The remainder said that sales of high bay fluorescents have remained flat during this period.

High performance[17] T8s (HP T8s) do not appear to be the lamp of choice for high bay fluorescent installations. Contractors reported installing HP T8s in less than 20 percent of their

[17] At the beginning of the interview we asked respondents if they were familiar with the term 'High performance T8 systems.' Only those who said yes, and who – when probed – said that such systems include both high lumen lamps and ballasts with low ballast factors were asked subsequent questions about HP T8s. Respondents who understood what HP T8s are accounted for 70 percent of the lighting sales represented by our sample.

high bay fluorescent projects in the past twelve months.[18] The majority of installations were either standard efficiency T8s (25 percent) or T5s (roughly 40 percent).

8.4.3.2 Drivers of HID and High Bay Fluorescents

Although sales of high bay fluorescent lighting are clearly displacing HID sales, there are still cases where customers choose traditional HID lighting. The contractors said that the biggest driver of such choices is price. Half of our respondents mentioned higher first costs or longer payback periods as reasons why customers choose not to install high bay fluorescents. One noted that in the current economy many business customers are not confident that they will be around long enough to achieve payback.

Another issue is that when customers are only retrofitting part of a premise, they often want to remain consistent with their legacy lighting systems. In addition, replacing HID lighting is expensive; it requires a lift and may require wiring changes. One contractor also mentioned customers declining to install high bay fluorescents due to concerns that the low ambient temperature of the space would impede their functioning.

The agricultural sector appears to present some unique barriers to high bay fluorescents. A contractor who does 70 percent of his business this sector noted that many farmers have a negative perception of the lighting quality of high bay fluorescents. In his opinion they also distrust the technology because it is unfamiliar and they have to “see it to believe it.” Perception is not the only barrier in the agriculture sector, however. Barn applications present special challenges for high bay fluorescents because they are not as durable as HID lighting in the face of humidity, temperature fluctuations, and bird nests, reducing lamp life.

Contractors cited many reasons why sales of high bay fluorescents have increased in the past two years. Economics was the most commonly mentioned factor, with rebates[19], higher energy prices, and long-term savings all playing a role. Technology improvements have also played a role. Contractors said that current high bay fluorescent technologies produce more light and

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[18] In calculating sales we assumed that those respondents who did not know what the term HP T8 meant had not sold any in the past 12 months.

[19] EVT’s 2009 program offers rebates for HP T8 high bay lighting and new or retrofit of T5 lighting, in addition to HID lighting rebates.

start up faster. The latter is particularly an issue for customers who want to pair them with occupancy sensors. Finally, respondents credited increased familiarity with the technology on the part of customers and greater awareness and promotion on the part of contractors with increasing market penetration for high bay fluorescents.

Those who see growth expect this trend to continue and put the impact of rebates high on the list of reasons. One said that rebates currently cover 25 percent to 30 percent of the incremental cost of high bay fluorescents. Others said that continued high energy prices and more high bay fluorescent products coming onto the market will keep the momentum going. One noted that the market is moving toward T5s, causing the cost of this technology to drop from $7.00 per lamp a few years ago to $2.50 per lamp now.

Those contractors who have seen high bay fluorescent installations remain flat typically cited the high first costs and a slowing economy as the reasons. Others mentioned a lack of energy consciousness among customers, architects who continue to specify HID, and the fact that high bay fluorescents are still not suitable for some applications. Most of these contractors, however, expect that sales of high bay fluorescents will eventually increase. One reason is that it represents a "better" technology – in terms of efficiency and lamp life (i.e., HIDs lose output over time faster than T8s or T5s). One contractor said that customers will ultimately be "forced" into high bay fluorescents because that is where the market is moving.

8.4.4 Non-High Bay Fluorescents

8.4.4.1 Sales of Non-High Bay Fluorescent Lighting[20]

We looked at the market for fluorescent lighting in non-high bay applications separately because these markets have very different sets of competing technologies. In non-high bay applications where HP T8s were viable, our respondents said they were installed 68 percent of the time. The subject of HP T8s is raised a bit more often by contractors (43 percent of the time) than by customers (30 percent of the time). According to these contractors, customers purchase HP T8s roughly three out of every four times that a contractor recommends them. Several contractors mentioned that schools are installing HP T8s at a higher rate than other segments, and a handful said that the manufacturing and retail sectors are also leading the way.

[20] EVT's 2009 program offers rebates for new HP T8 lighting and HP T8 retrofits for existing T8 lighting.

Respondents were divided on whether there has been an upward trend in sales of HP T8s. Seventy-eight percent had seen sales increase over the past two years, while the remainder said that sales had remained flat.

8.4.4.2 Drivers of Non-High Bay Fluorescent Lighting

Contractors who said that sales of HP T8s have been increasing most commonly cited rebates and tax incentives as the reasons. Other common explanations were increased customer education and awareness, rising energy costs, and a downward trend in equipment costs. Individual contractors mentioned other factors including technology advances in ballasts, improved availability of HP T8s in the supply chain, customer interest in being “green,” and an economic slowdown that is driving customers to cut costs.

Those respondents who said that sales of HP T8s have remained flat had fewer explanations. One said it was the high cost of the equipment, while another said that it was his own choice not to push the technology. He was skeptical about the reliability of ballasts made by “no name” companies and was therefore not recommending HP T8s to his customers.

When asked about the primary barriers to increasing sales of HP T8s, most contractors cited high costs (both first costs and costs for replacement lamps) and customer confusion about the product and the payback. One contractor noted that although HP T8 ballasts are roughly the same price as regular ballasts, HP T8 lamps cost twice as much as standard T8s. Multiple contractors noted that a $10 rebate lowers the price premium for HP T8s (versus standard T8s) to between $1 and $1.50 per lamp, but many customers are still unwilling to pay this premium[21].

Their reluctance may have to do with the cost of replacement lamps, which are just as expensive as the originals but not rebated. A contractor described one of their banking clients who has HP T8 ballasts installed but is using standard T8 bulbs, significantly reducing the energy savings. “He’s not willing to invest that extra $1.50 a lamp.”

Another contractor explained that it is much easier to get customers to switch from T12s to HP T8s than it is to get a customer with standard T8s to upgrade. He also pointed out that the

[21] EVT’s Smart Lighting program provides discounted lamps through electrical distributors that should address this market.

ballast/lamp combination can be confusing to some customers: “Getting it right is not very straightforward.”

Barriers to additional HP T8 sales that were each cited by only one respondent included concerns about light quality, customers that want to avoid “mixing” lighting systems but are not ready to replace all of their lighting, and short-term thinking (i.e., will we still be in business when the system achieves payback?).

8.4.5 Incandescent Lamps and Compact Fluorescent Lamps

8.4.5.1 Sales of Incandescent and CFLs

Survey respondents said that compact fluorescent lighting (CFL) was installed in 80 percent of the commercial/industrial applications in the past 12 months where it would have been appropriate. Roughly half of the CFLs sold or installed by contractors in Vermont over the past two years were pin based (as opposed to screw-in). Virtually everyone we spoke with agreed that CFL sales have increased in the past two years. The one exception was a contractor who rarely sells CFLs to the commercial and industrial sectors and believes that there are few applications in business settings that call for CFLs.

According to the contractors, customers were about as likely to come in requesting CFLs as contractors were to bring them up (38 percent of the time versus 36 percent of the time). About 20 percent of the time, however, a contractor recommended CFLs and the customer chose incandescent lighting instead.

8.4.5.2 Drivers of Incandescent and CFLs

Where CFLs are not selling, contractors cite several factors. Higher costs and customers’ perceptions of light quality were the most commonly mentioned. There are still a number of customers who dislike the color rendering of CFLs and who think the light they produce is harsher than incandescent bulbs. Then there are technical limitations that affect which applications can take CFLs. The fact that they are somewhat slower to come on and cannot readily be dimmed, for example, rules them out in situations where customers want lights on a dimmer or occupancy sensor. Finally, some customers are put off by the hazardous waste issue (i.e., not being able to dispose of used CFL lamps as easily as they can dispose of burned out incandescent bulbs).

As already noted, however, these barriers have not stopped CFLs' market share from increasing in the commercial and industrial sectors. In explaining this increase respondents frequently mentioned energy savings, greater awareness through education and marketing, and the role of rebates. A few contractors cited improvements in the technology that have lowered the price, as well as the advantages of longer lamp life and lower starting temperatures.

8.4.6 LED Lighting

8.4.6.1 Sales of LED Lighting

LED lighting still accounts for a very small percentage of commercial/industrial lighting sales and it is not clear that penetration is growing. The contractors we interviewed said that about two percent of commercial and industrial lighting sales in the past 12 months involved LED lighting. Contractors were evenly split between those who think LEDs penetration is increasing and those who think it has held steady for the past two years.

Only one contractor reported installing LED lighting for general commercial lighting applications. Those who sold or installed LED lights reported exit lighting, emergency lighting, recessed lighting retrofits, access lighting, and retail down lighting as the predominant applications.

8.4.6.2 Drivers of LED Lighting[22]

One contractor claimed that Efficiency Vermont's CRI standards are so hard to meet that they cannot obtain rebates on LED lighting. Others cited high prices and the fact that LEDs produce light in a narrow beam as significant barriers to adoption.

Those contractors who believed that LED sales had been increasing attributed this increase to technological developments that have lowered the price and opened up more potential applications. Regardless of whether they believed that LED lighting had increased its penetration in the recent past, virtually all of the contractors we spoke with believed that LED sales will increase in the future. This belief was driven by the expectation of continuing technology improvements and price reductions, the potential impact of rebates, and simply how cheap they are to operate.

[22] EVT's lighting rebate form indicates that in 2009 it is offering rebates for a variety of LED lighting products.

8.4.7 Opportunities to Increase Sales of High Efficiency Lighting

The contractors we interviewed had several suggestions for how to increase the sale of high efficiency lighting in Vermont's commercial and industrial sectors:

Education and promotion – This was by far the most common response. Contractors believe that Efficiency Vermont's efforts to educate the public about high efficiency lighting have been effective but that there is still more to be done. Some noted a continuing need for education of salespeople and other levels of the supply chain, not just customers.

Continue or increase incentives – Our respondents believe that Efficiency Vermont's rebate programs have had a considerable impact on the market. Some feel that the current incentive levels are adequate, while a few argue for increasing rebate amounts.

Interestingly, two of the contractors we spoke with specifically argued *against* raising incentive levels. One said that the current programs are "realistic and working." He was concerned that putting more financial incentives in the market would lead to improper lighting designs and applications, as "lighting companies will just chase the dollar." This, in turn, could result in bad projects that hurt these technologies in the long run. Another contractor asserted that EVT should never be in the position of giving the customer a totally free installation, "That's ridiculous." Instead, he argued for reducing the payback to one year and letting the market take care of the rest.

Work with manufacturers and standards – A few contractors mentioned the importance of increasing lighting standards and working with manufacturers to bring down equipment costs and increase availability. One expressed this as a need for quality assurance at the manufacturing level. He experienced a large number of ballast failures when he was first installing T8 electronic ballasts.

8.5 HVAC Supply Chain Interviews

8.5.1 Population, Sample and Weighting

The specific SIC codes chosen for the HVAC supply chain sample frame were:

17110000 -- Plumbing, heating, air-conditioning
17110400 -- Heating and air conditioning contractors

17110401 -- Mechanical contractor
17110405 -- Warm air heating and air conditioning contractor

The column labeled "Initial Population Estimate" in Table 8-4 shows the number of business establishments in Vermont that have one of these as their primary SIC code according to the D&B database. It also shows how we grouped these establishments into size categories.

The other columns in Table 8-4 show the number of completed interviews that we targeted within each size category (i.e., the sample plan), the actual number of surveys completed, and our revised estimate of the population size based on screening data obtained while recruiting respondents to complete the survey.

Table 8-4
HVAC – Sample and Completes

	Initial Population Estimate (# of premises)	Targeted Completes	Final Population Estimate (# of premises)	Completes
1 to 5 employees	215	5	12	1
6 to 19 employees	19	5	5	4
20 + employees	14	5	11	7
Install chillers*		5		5
Total HVAC Contractors	248	15	28	12

*The five interviews with HVAC contractors that install chillers were **not** in addition to 12 total HVAC interviews.

In the process of screening to identify qualified respondents for the survey, we completed telephone calls (though not full interviews) with 43 business establishments. Based on their self-report, only a fraction of those establishments actually sold or installed central cooling equipment to commercial/industrial end-users. Applying this fraction to the original population counts gave us a revised estimate of how many establishments truly fell into the population of interest.

In evaluating the small number of establishments remaining in the revised population estimate – and in interpreting the results that follow – it is important to remember that they only represent sales by contractors that are located in Vermont. We did not include sales of HVAC products into Vermont by out of state suppliers in our analysis.

8.5.1.1 Survey Weighting and Ratio Estimation

The first step in weighting the data from the HVAC supplier interviews was to create strata weights that would adjust for the fact that we sampled disproportionably across size strata. Disproportional sampling by size is common when dealing with a population characterized by a few large entities and many very small entities. Given the distribution of HVAC contractors by size (number of employees), it was clear that a simple random sample would consist almost entirely of very small contractors. That would be fine if we wanted to represent the population of sellers, but to accurately represent the population of HVAC *sales*, we needed to focus a substantial fraction of the sample on larger contractors that account for more sales.

Strata weights allow us to account for this disproportional sampling when analyzing the survey data. To calculate strata weights, we simply divided the revised population estimate for each stratum by the number of completed surveys in the stratum. The resulting number is the number of contractors of similar size that a given respondent represents. We multiplied all quantitative responses by the appropriate strata weight for each respondent.

The survey asked respondents how many full-time equivalent employees they had working at their location, what percent of their revenues in the past 12 months came from the sale or installation of HVAC products to end-users, what percent of their HVAC revenues were from Vermont, and what percent of their Vermont HVAC revenues came from the commercial and industrial sectors. We multiplied these numbers to obtain a ratio estimator for each respondent. This number represents the sales revenue that a particular respondent obtained from the sale of HVAC products to business customers in Vermont over the past 12 months. We multiplied all quantitative responses that dealt with general HVAC equipment by this ratio estimator, as well as multiplying them by the strata weights as described above.

We used a slightly different ratio estimation approach for the questions about chiller sales, given that only a fraction of the respondents sold chillers. The survey asked those respondents who said they sold chillers how many chillers they had sold in the past 12 months. For quantitative questions about chillers, we multiplied responses by the number of chillers each respondent had sold and by their strata weight. We did not use the ratio estimator described in the preceding paragraph for these questions.

8.5.2 Overall HVAC Market in Vermont

A little less than a third of the HVAC sales made in the past year by the contractors we interviewed were in the new construction market. According to these respondents, it is much easier to get high efficiency HVAC equipment installed in new construction projects than in retrofits. This is mostly because architects and engineers specify high efficiency equipment; many owners want to get LEED certification, and new construction projects can afford longer lead times to obtain high efficiency equipment. In retrofit situations, not only do contractors frequently need to get a replacement fast, ease of installation is a concern. As one contractor pointed out, the choice of what equipment to install is often limited by the surrounding infrastructure (e.g., duct work). Finally, in retrofits, contractors are typically trying to go from “high efficiency to higher efficiency,” making the economics more difficult.

Another factor that differentially affects new construction versus retrofit projects in Vermont is Act 250, the state’s land use and development act. This law, passed in 1970, creates pressure for new buildings to be environmentally friendly and energy efficient.

When asked about the most important trends in the HVAC industry in the past two years, contractors mentioned a slowdown in new construction, greater interest in energy efficiency and environmental issues, and new standards that have reduced the spectrum of allowable efficiencies, in many cases causing customers to pay a lot more for a small increment in efficiency.

In the coming years, these contractors expect to see increased use of building automation controls and VFDs, both of which will increase energy efficiency. One contractor is seeing an increase in ductless systems and inverters which he expects will continue. Several contractors also spoke of a shift toward renewable fuels that might affect HVAC systems in ways that are hard to predict.

8.5.3 Cooling Equipment (not including chillers)

8.5.3.1 Sales of Cooling Equipment

We began by asking HVAC contractors about their sales of packaged and split system cooling equipment, as well as water source heat pumps. The intention was to cover the range of commercial and industrial cooling options for which Efficiency Vermont provides rebates[23]. The first column in Table 8-5 shows the categories of cooling equipment that we asked contractors about. This list differs from the way cooling equipment is listed on Efficiency Vermont's 2008 rebate application in two ways. WE combined two size ranges for packaged or split systems (65,000 BTU/h to < 135,000 BTU/h and 135,000 BTU/h to < 240,000 BTU/h) into a single size range for purposes of the survey. We did this to reduce respondent burden (thus increasing the likelihood of survey completion). These particular size ranges were combined because they have the same minimum efficiency standard for rebates (11.5 EER).

Table 8-5
Cooling Equipment:
Sales by Type and Efficiency

Technology	Percent of Sales	Percent of Type High Efficiency
Packaged systems < 65,000 BTU/h	24%	24%
Split systems < 65,000 BTU/h	15	40%
Packaged or split systems > 65,000 BTU/hr and < 240,000 BTU/h	29	58%
Packaged or split systems > 240,000 BTU/h	11	31%
Water source heat pumps < 375,000 BTU/h	21	22%
	100%	

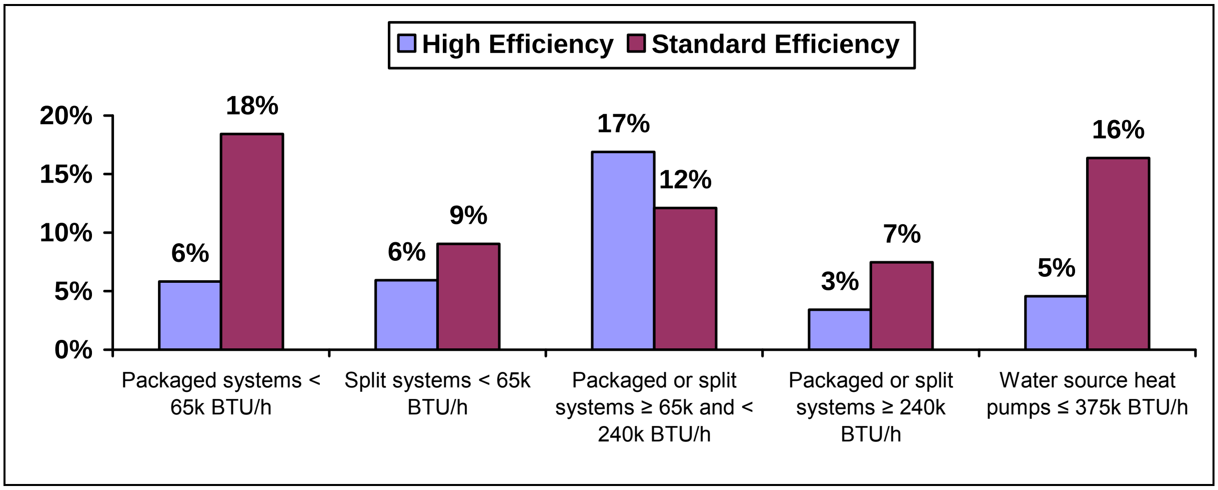
[23] EVT provides rebates for high efficiency equipment of the sizes and types listed in Table 8-5 that meets specific standards. The contractor respondents were asked to use the specific EVT cut points to indicate high efficiency.

The first column in Table 8-5 shows the percent of respondents' total sales of non-chiller cooling systems to commercial and industrial customers that each category accounted for in the past year. Packaged or split systems in the 65,000 BTU/h to 240,000 BTU/h range accounted for the largest proportion of sales, followed by smaller packaged units and water source heat pumps.

The second column shows the percent of sales in each technology category that met Efficiency Vermont's minimum SEER or EER criteria to qualify for rebates. These percentages represent the penetration of high efficiency cooling technologies within each category. For the most commonly sold type of systems – packaged or split systems from 65,000 BTU/h to 240,000 BTU/h – high efficiency systems accounted for the majority of these contractors' sales in the past 12 months (58 percent). The penetration of high efficiency technologies was lowest for small packaged systems (24 percent) and water source heat pumps (22 percent). There is substantial opportunity to increase the efficiency of new cooling equipment purchased in Vermont.

Table 8-5 provides a slightly different view of these data. Within each technology category (i.e., within each row in Table 8-4) we multiplied the percent of sales that were high efficiency systems by the percent of total sales that the category accounted for to obtain the percent of all sales of non-chiller cooling equipment to Vermont businesses that were high efficiency units of a given category.

Figure 8-6
HVAC System Sales by Type and Efficiency



For example, packaged systems less than 65,000 BTU/h accounted for 24 percent of all sales, and 24 percent of those sales were high efficiency (Figure 8-6). This means that high efficiency packaged units less than 65,000 BTU/h accounted for six percent of all sales to Vermont businesses by Vermont contractors (24 percent times 24 percent equals six percent). This is represented by the bar on the far left in Figure 8-6. Since packaged systems less than 65,000 BTU/h accounted for 24 percent of sales in aggregate, standard efficiency packaged units in this size range accounted for 18 percent of total sales (total category sales of 24 percent minus high efficiency category sales of six percent equals standard efficiency category sales of 18 percent).

Summing the high efficiency bars in Figure 8-6 reveals that high efficiency systems in aggregate accounted for just under half (47 percent) of all sales of cooling equipment to Vermont business customers. The largest portion of these high efficiency sales (17 percent) were mid-sized packaged or split systems. The largest opportunities for increasing the sales of high efficiency systems appear to be among large packaged and split systems (on capacity basis) or among small packaged units and water source heat pumps (on a unit basis).

Ninety-two percent of all the packaged units sold in the past year by these contractors came with economizers, as did 19 percent of the split systems. Only 12 percent of the systems they sold, however, came with demand control ventilation.

All but one of the contractors we spoke with agreed that sales of high efficiency cooling equipment have increased over the past two years. The lone dissenter said they have remained stable.

Two-thirds (65 percent) of the commercial and industrial HVAC equipment these contractors install report a commissioning process. Some contractors do internal commissioning on all of their installations. Most only use external commissioning when the bid requires it. Respondents said that the benefits of commissioning were “finding the little things” that could go wrong and thus avoiding callbacks. One also noted that commissioning helps weed out smaller, unqualified contractors. The barriers to commissioning, all agreed, were time and money.

8.5.3.2 Drivers of Cooling Equipment

The contractors we interviewed attribute increased sales of high efficiency systems to rebates and increasing energy costs. The latter has caused the cost of operating a standard efficiency cooling system to increase substantially relative to the incremental cost of purchasing a high efficiency versus standard efficiency system. Our respondents estimated the incremental cost of a high efficiency system at 36 percent for smaller units (fewer than 65,000 BTU/h) and 21 or 22 percent for larger units and heat pumps. Weighting these price premiums by the relative sales volume of different types of units reveals that the average incremental price for high versus standard efficiency systems purchased by Vermont businesses in the past year was 27 percent.

Other drivers of increasing efficiency cited by the contractors included ongoing efforts to raise awareness and educate customers about efficient HVAC technologies, the impact of code changes and the phase-out of CFC based refrigerants, and increased availability of high efficiency equipment from manufacturers. The one contractor who said sales were flat over the past two years cited problems obtaining high efficiency equipment from manufacturers and project economics that break down when the building’s owner and tenant try to split the incentive payment (making the economics not sufficiently favorable for either of them). Interestingly, another contractor has found a way to deal with availability issues that provides added benefits. He said that by ordering high efficiency equipment ahead of demand and stocking it, he gets a better price which he can then pass on to his customers.

According to one contractor, the increased penetration of high efficiency cooling has occurred in the face of significant increases in the price of high efficiency equipment. And code changes, while moving the market toward greater efficiency overall, have not been without their complexities. This same respondent noted that he saw an increase in sales of energy efficient equipment a year ago, but that last year there was a decrease from that base. In his view this was due to the code increase from 12 to 13 SEER. *"Twenty-four months ago customers were going from a 10 SEER to a 13 SEER, getting good rebates, product was available and the cost was coming down. Last year, due to the ramping up of the standard, customers had to move from a 13 SEER to a 14 or higher SEER where most manufacturers do not offer equipment,"* he reported. He went on to note that only one packaged unit meets the 14 SEER spec, though there is greater availability in split systems.

The contractors we spoke with generally expect the trend of increasing high efficiency sales to continue. This is because they expect high energy prices, rebates, and the tightening of codes to continue.

8.5.4 Chillers

8.5.4.1 Sales of Chillers

Only five of the contractors we spoke with had sold chillers in the past year, with a total of 31 chiller sales between them. Twenty-eight of those were air-cooled electric chillers with capacities less than 150 tons. A quarter of those chillers met the IECC criteria for high efficiency (2.80 COP and 2.80 IPLV). None of the other chillers these contractors sold in the past year (a larger air cooled unit, two water cooled positive displacement units, and one water cooled centrifugal unit) qualified as high efficiency chillers. The contractors who represented a slight majority of the chillers sold thought that the percent of chiller sales that were high efficiency had increased over the past two years; the remainder believed sales of high efficiency chillers had remained flat.

8.5.4.2 Drivers of Chillers

The contractors who believe that high efficiency chillers are increasingly penetrating the market attribute this to greater availability of units (in some cases there are no lower efficiency options) and "a new generation of younger engineers willing to try new things." Of the three contractors who believe that high efficiency chillers sales have been on the rise, two believe this trend will continue (mostly due to codes). One believes it will level off soon because "there is a limit to how far you can push energy performance."

8.5.5 Opportunities to Increase Sales of High Efficiency

When asked what could be done to increase the sale of high efficiency HVAC equipment, the most common answer was to increase or otherwise improve rebates and incentives. One contractor suggested structuring rebates to automatically increase as mandatory SEER values increase. This would help address the issue of customers suddenly having to pay a lot more for a smaller increment over standard efficiency because the standard efficiency has increased.

Beyond rebates, contractors had few ideas. Some suggested simply mandating high efficiency, while others talked of the need to get manufacturers to increase the availability and reduce lead times for high efficiency equipment.

9. Summary and Recommendations

9.1 Building Characteristics

9.1.1 General

- Overall, roughly three quarters of Vermont businesses in this study occupied space that they own[24], and thus are likely to be motivated to make some energy efficiency improvements.
- The population of commercial establishments in Vermont is characterized by small facilities. Nearly 54 percent are smaller than 5,000 square feet; 31 percent occupy 2,000 square feet or less.
- While large premises comprise a small percentage of Vermont businesses, they occupy 15 percent of the commercial floor space. Still, small and medium businesses (based on consumption) occupy 66 percent of floor space.
- Over one-half of the facilities were constructed before 1960. Vermont's stock of commercial buildings is slightly older than that of New England as a whole.
- Overall electric energy intensity is 15kWh/sq foot for conditioned space. Vermont electric energy intensity is comparable to the CBECs Northeast Region.
- On-site generators were found in 18 percent of the sample facilities providing generation capacity for 21 percent of the floor space. There was little variation across building type. In most cases the on-site generation is for emergency purposes only.
- Approximately one-fifth of premises heat all or part of the facility with electric heat. Fuel oil is the most prevalent heating type, present in 45 percent of buildings, with natural gas and LNG each present in about one-fifth of facilities.

[24] This estimate may be high due to self-selection bias, as discussed earlier in the report.

- Furnaces are the most common heating type, found in 41 percent of commercial facilities and 59 percent of the retail sector. Boilers, although found in approximately one-third of premises, heat two-thirds of commercial floor space.

- Manual thermostats control 38 percent of the space heating units. Twenty-five percent of heating units are controlled by programmable thermostats, with an additional 6 percent controlled by Energy Management Systems (EMS). EMS systems are more likely to be found in high consumption facilities where they comprise 16 percent of heating controls.

- Approximately one –half of total indoor floor space is served by cooling equipment, as is 55 percent of total conditioned space. (This calculation is based on the square footage served by the equipment.)

- More than 90 percent of commercial floor space is served by some fluorescent linear tube lighting. There is T12 lighting in 49 percent of commercial floor space and standard T8 lighting in 42 percent of commercial floor space. (There can be more than one lighting type within a space.) This means that there is substantial opportunity to increase the efficiency of lighting, especially by replacing T12 lighting with HP T8 fixtures.

- Some incandescent or compact fluorescent lighting is present in 23 and 41 percent (respectively) of commercial floor space.

- The observed mean Lighting Power density (LPD) for all commercial facilities is lower than the weighted average maximums contained in the Vermont *Guidelines*.
- The observed LPDs in the office segment is roughly equal to the maximum standards in the Vermont *Guidelines*.
- Eighty percent of commercial facilities have some outdoor lighting, most frequently lighting walkways or parking lots.

- More than one-half of the outdoor lighting is HID, with much of it less efficient HID technologies. An additional one-third of outdoor lighting is incandescent/quartz lighting. Outdoor lighting represents an opportunity for improved efficiency, through lighting replacement and controls.

- Forty percent of facilities report upgrading at least one major energy related system at their facility. This is more frequent in retail than other facilities.

- Lighting upgrades to equipment (57 percent) and controls (13 percent) were most common, with HVAC equipment (35 percent) and controls (8 percent) also being common.
- Ninety percent of commercial facilities contain domestic hot water and 58 percent of these are fueled by electricity. The shares of natural gas, fuel oil, and LPG water heating are roughly equal, in the range of 13 to 14 percent.
- Self-contained hot water tanks are the most common type of equipment overall (75 percent) and for all fuels except fuel oil.
- Commercial refrigeration equipment was found in a low percentage of surveyed facilities.
- Self-contained display units are the most common type of commercial refrigeration equipment. They are present in sample facilities that represent 27 percent of all commercial facilities. Their saturation in the balance of commercial segment is particularly high (49 percent), which may reflect their presence in institutional kitchens and lunchrooms.
- Office equipment is found in sample facilities that represent 82 percent of all commercial facilities. In 37 percent of those facilities, the field engineers identified ENERGY STAR compliant equipment, which is consistent with recent market penetration data published by the national ENERGY STAR program.
- Seventy-four percent of the facilities with office equipment report that they enable the ‘sleep mode’ of operation on computers and copiers. Fifty-six percent report using a hard shut off at night, which totally disconnects equipment and eliminates power demand during low-use periods.
- Elevators are found in sample facilities that represent 20 percent of all commercial facilities. Thirty-eight percent of these facilities report shutting down some elevators during periods of low use to save energy. Thirty percent report programming their elevator controls to optimize positioning of cars when they are not in use.
- The field engineers identified laundry equipment in facilities representing 14 percent of the total commercial population. Of these facilities, 31 percent had laundry equipment that was ENERGY STAR compliant.
- NEMA premium efficiency motors constitute the large majority of sales for motors 6 hp and larger.

- First cost and opportunities to rewind motors are the largest barriers to full market share for NEMA premium efficiency motors. Availability of NEMA premium efficiency motors was also cited as a barrier by some distributors.
- High bay fluorescent lighting is capturing approximately three-quarters of new installations where it is seen as an option by the lighting contractor.
- High first costs and consistency with other high bay fixtures are seen as barriers to greater market penetration of high bay fluorescent lighting in many commercial settings.
- Negative perceptions of high bay fluorescent lighting combined with durability in less climate controlled barn application present extra barriers for the agricultural sector.
- HP T-8 lighting comprising approximately three-quarters of the new market share in non-high bay applications, with contractors more likely to recommend this lighting than for customers to request it.
- Both contractor and end-user awareness and understanding of HP T-8 lighting could be increased through additional education.
- Compact fluorescent lighting was installed in approximately 80 percent of business applications where it was seen as appropriate by the contractor, with approximately one-half of these being pin based. Sales of CFLs are increasing among the business sector and awareness is relatively high among sellers and buyers.
- Initial cost and color rendering remain as barriers to the installation of CFLs. Slow turn-on and other limitations with their use with occupancy sensors or dimmers also inhibit full adoption.
- LED lighting sales are low but there is some indication that it will be increasing as prices decrease and product quality and availability increase.
- Market share of high efficiency cooling equipment is relatively low, with roughly one-half of systems sold not meeting Efficiency Vermont rebate standards. High efficiency cooling equipment is more likely to be installed in new construction than in existing facilities.

9.2 Energy Efficiency Opportunities

- The greatest opportunities for lighting overall exist for upgrading fluorescent tube lighting (to T-8s or HPT-8s) and for lighting controls to all lighting types, especially occupancy sensors.

- Fluorescent linear tube lighting represents a large portion of the lighting in the commercial sector and substantial opportunity to increase the efficiency. Approximately 1/3 of the linear tube lighting is less efficient than standard T-8 lighting.

- There is still substantial opportunity to switch incandescent lighting to CFLs.

- HID lighting has low saturation in the commercial sector, and what is present is less efficient than Pulse Start Metal Halide lighting and can be upgraded to either this technology, or linear tube lighting, such as T-5s.

- Much of the outdoor lighting has opportunity for increased efficiency, through upgrades to the lighting itself and with better controls to minimize hours of operation.

- Energy efficiency opportunities for cooling equipment are associated with cooling system motors - NEMA Premium Efficiency Motors for 24 percent or Electric Commutating motors for 17 percent of space cooled.

- Approximately one-quarter of the facilities could benefit from an automatic setback thermostat to reduce cooling loads. The opportunity is far greater in the retail sector, where the engineers identified the opportunity in 70 percent of cooled space, and thermostats dominated the opportunities for split systems. The savings, however, will be realized only if the occupants are not effectively manually controlling the space temperature.

- Overall, space heating opportunities were dominated by the opportunity for more efficient motors and by better controls. More efficient motors for heating systems will also reduce cooling costs for businesses with combined distribution systems.

- Roughly two-thirds of electric water heaters could benefit from timers to keep systems from maintaining high water temperatures during non-occupied periods.

- The engineers identified supplemental tank insulation and pipe insulation for most domestic hot water heating systems, regardless of heating fuel.

9.3 Recommendations

The distribution of Vermont businesses is highly skewed. It is populated by a large number of very small premises, with a relatively low number of large premises dominating space and energy consumption. This points to a continued need for programs that address the small and large businesses with different approaches. Small businesses have greater barriers to energy efficiency, including tighter operating budgets, fewer employees to address energy issues, a need for faster paybacks, less information and less access to capital budgets. Larger businesses may have longer lag times in project implementation, needing time to get internal approvals and financing.

Smaller business customers could benefit from programs that reduce both high initial costs and "hassle factor" barriers to installing energy efficiency measures. Quick identification and installation of energy efficiency opportunities, with minimal disruption to business activities are key to high adoption rates in this sector. Efforts to increase efficiency in small businesses should also include a focus on maintenance of cooling systems, especially in the retail sector, where one-quarter to one-third of facilities report never conducting regular maintenance on their equipment. The high level of owner occupied facilities in Vermont bodes well for high adoption rates, where split incentives are less common.

All Vermont businesses are challenged by the higher initial cost of energy efficient equipment. Current economic conditions further inhibit adoption of energy efficiency measures specifically, and upgrades in general. Contractors of all equipment types noted a tightening of belts among Vermont businesses and a reluctance to make long term investments in an uncertain economy. High and rising energy costs, coupled with some reductions in the incremental costs of efficient equipment, offer some counter balance to the overall economic situation, as they accelerate payback periods. Still, programs may be challenged to maintain participation levels as overall spending decreases. Retrofits primarily to improve energy efficiency will be a tough sell.

Efficiency Vermont's existing programs are cited as one of the reasons for the sales of energy efficient equipment in Vermont. Contractors are likely to recommend high efficiency equipment to their customers and take advantage of the rebate programs. In general, they credit the program with the increased sales of high efficiency equipment – as it reduces the first cost and has increased awareness.

There still exists opportunities to increase lighting contractor knowledge. More than one lighting contractor in our supply chain study was not familiar with HP T-8 lighting and therefore not promoting it to end-users. Greater contractor (and end-user) awareness of the types of compact fluorescent lamps (better light quality, dimmable bulbs and a large variety of sizes) might increase sales of these lamps in a variety of settings.

Lighting controls, for both indoor and outdoor lighting of all technology types, is an opportunity for decreased lighting consumption. Lighting controls are more easily installed when other retrofits are occurring, but much existing and functioning lighting can benefit from this improvement. Further exploration into this opportunity separate from major retrofits is warranted.

The adoption of (more efficient) fluorescent tube lighting in high bay settings is relatively high and could be increased. Many end-users are opting for standard T8 fixtures (approximately 25 percent) over T5 or HP T-8 lighting. In some situations, end-users are installing HID lighting in order to maintain consistency with HID lighting in other parts of the facility. This presents a potential for replacing much internal HID lighting with fluorescent tube lighting.

The adoption of high efficiency cooling equipment is somewhat low. This may be due partially to high standards and a relatively short cooling season. Very small systems – less than 65,000 BTU/h and larger systems – greater than 240,000 BTU/h, however, have relatively low adoption rates for high efficiency equipment, as do heat pumps.

The opportunity to improve motor efficiency in the commercial sector is substantial and challenging. Many small motors are inefficient and increasing the efficiency of these in aggregate, could provide substantial savings. The incremental nature of this improvement, along with technical and institutional barriers to retrofits, makes the market potential substantially lower than the technical potential. The opportunity to reduce the incidence of rewinding in favor of motor replacement for larger motors exists, and would be achieved through education with motor sellers (contractors and distributors). Efficiency Vermont should also determine if availability of NEMA premium efficiency motors is a real problem that can be addressed. In addition, at least one contractor mentioned the need for more assistance from the program in promoting VFDs – marketing materials and evidence that VFDs save money.