Business Sector Market Assessment and Baseline Study: Existing Industrial Facilities

Vol. 1

Final Report

Prepared for the Vermont Department of Public Service

Madison, Wisconsin, September 25, 2009

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Objectives

This is the Final Report of the Vermont Business Sector Market Assessment and Baseline Study: Existing Industrial Facilities. It is the third 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 existing commercial buildings and commercial new construction.

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. NEMA Premium Efficiency electric motors versus motors that meet minimum federal efficiency standards).
- 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, horsepower of electric motors.
- Estimate the level of adoption of energy efficiency measures that are commonly applicable in key industrial energy systems.

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

To address these objectives, KEMA developed and deployed an on-site survey of a stratified random sample of 43 industrial facilities. In developing this on-site sample, KEMA conducted screening interviews with a random sample of 547 commercial and industrial 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.

Key Findings

General

- ***Most of Vermont's industrial facilities are very small.*** Overall, 44 percent of manufacturing facilities employ fewer than 5 persons. An additional 31 percent employ from 5 to 19 persons.
- ***Five industries, out of the 21 NAICS categories, account for over 53 percent of manufacturing facilities.*** These are fabricated metals, non-metallic mineral products, wood products, food processing, and printing and related activities.
- ***Vermont industrial facilities are of relatively recent construction.*** According to the results of the survey, only 8 percent of manufacturing facilities were built before 1970. Only 27 percent were built before 1980. By contrast, 62 percent of commercial facilities in Vermont were built before 1970.
- ***A high proportion of Vermont industrial establishments lease their facilities.*** According to the results of the survey, 31 percent of Vermont's industrial establishments lease their facilities, versus 14 percent for commercial establishments. These establishments may experience split incentives in regard to investing in the energy efficiency of their facilities.
- ***Many Vermont industrial are currently running one shift.*** The median annual operating hours for the facilities in the sample was 2,400, means that roughly half of

Vermont's industrial establishments were running one full shift or less at the time of the survey. However, the average operating hours for the entire sample was 4,195, which suggests that the remaining one-half of the facilities were operating an average of 5,980 hours per year, which corresponds to three shifts.

Characteristics and Installed Capacity of Major Energy Systems

Electric Motors

- On average, 42.3 + 17.1 integral horsepower electric motors are installed in Vermont industrial facilities.
- The average installed capacity of motors in industrial facilities is 421 horsepower (HP), + 151 HP.
- Motor equipment is more highly concentrated in generic centrifugal applications such as pumps, fans, and compressors in Vermont than in the country as a whole: 50 percent of units versus 37 percent.
- The saturation of NEMA Premium Efficiency motors 10.3 percent of total installed units, 21.6 percent of total installed HP.
- The prevalence of variable loads in the population of motorized systems is 40.6 percent of installed HP. Variable loads are spread fairly evenly among motor size catetgories.
- The saturation of variable frequency drives (VFDs) is 34 percent of the total HP driving variable loads. The saturation of VFDs increases with motor size.

Compressed Air Systems

- Industrial facilities representing 94.5 percent (+ 5.9 percent) of industrial electricity usage in Vermont have an electric-powered compressed air system in place.
- The average number of compressors installed was 2.5, with an 80 percent confidence interval of + 0.5 units.
- The weighted average horsepower of the systems observed was 51, with an 80 percent confidence interval of + 22 hp.
- Compressed air systems with air storage capacity are present in facilities that represent 75 of industrial electric consumption or in roughly 79 percent of all compressed air systems, weighted by facility electric use.

- Most of the compressed air systems observed have simple start/stop controls. Coupled with the observed level of air storage available, these are adequate to provide efficient load control.

Process Heating and Cooling

- Approximately 46 percent of industrial facilities in Vermont have equipment dedicated to process heating installed. A significant portion of the output of other central heating systems is also used for process heating.
- Process heat is delivered by a wide range of equipment. Furnaces, steam boilers, hot water boilers, direct-fired devices, and electric resistance heaters are all present in more than 20 percent of facilities with process heating equipment installed.
- Dedicated process heating equipment was observed in only two facilities, which does not provide a sufficient basis for generalization as to characteristics or installed capacity.

Space Cooling

- Sixty-two percent of industrial facilities have space cooling systems installed.
- A number of facilities contain more than one kind of system. Room air conditioners were the most frequently observed type of system; they were found in 29 percent of the sample facilities. Packaged HVAC systems were the next most prevalent cooling equipment type, observed in 26 percent of facilities. Heat pumps were observed in 17 percent of utilities. Large, built-up central cooling plants (Other Central Cooling Plant) are found in relatively few facilities.
- Average tons of capacity installed per facility: 36.9 tons
- Average tons of capacity used for space cooling: 19.9 tons ± 9.6 tons

Space Heating

- Eighty-one percent of industrial facilities have central space heating systems. Those that do not have primarily outdoor operations – for example gravel pits and quarries.
- The most prevalent space heating equipment type is direct, which, taking together radiant and other types of direct heaters (direct fired space heaters) are present in 36 percent of facilities. This is consistent with the heavy representation of small facilities in the population. More mechanically complex systems such as hot water and steam boilers serve a combined 22 percent of facilities.

- Natural gas is the most common primary heating fuel, accounting for 46% of facilities. Propane and fuel oil each account for 26 percent of the remaining facilities, with wood providing fuel for primary heat in one percent of facilities. Only 18 percent of facilities have secondary heating systems or fuel capability. Most of these are natural gas.

Interior Lighting

- Linear fluorescent fixtures are by far the most common lighting technology in Vermont's industrial facilities, accounting for 61 percent of all weighted occurrences. Compact fluorescent and other fluorescent fixtures account for an additional 7 percent of total occurrences. High Intensity Discharge (HID) fixtures are the next most common type, with 14 percent of total weighted occurrences.

- T8 fixtures have the highest level of saturation among the basic fluorescent technologies. T8 fixtures of various kinds account for 58 percent of the total ratio-weighted occurrences of fluorescent fixtures; T12 for 33 percent; and T5 for 4 percent. Unidentified fluorescent tubes account for an additional 9 percent of total weighted occurrences.
- Overall, we estimated the lighting power density of the sample facilities at 0.76 Watts per square foot, with an 80 percent confidence interval of ±0.12 Watts per square foot. This figure is likely to be low due to the difficulty of recording all light sources in the sample spaces. The maximum standard LPD for industrial facilities per the *Vermont Guidelines* is 1.30 Watts per square foot.

- More than 95 percent of indoor lighting is controlled by manual on/off switches and more than 95 percent is used for area lighting. This suggests that lighting controls represent an untapped resource of energy savings.

Recent Facility and Equipment Upgrades

- Thirty-seven percent of the sample respondents, ± 21 percent, reported that they had made major renovations or additions to their facilities in the past five years, for an average rate of 6.2 percent per year.

- Overall, 62 percent of facilities report that they made upgrades over the past five years to at least one of the following equipment systems: heating and ventilation, cooling and air conditioning, lighting, and refrigeration. Thirty percent of facilities reported that they had made upgrades to their lighting equipment, 15 percent had made upgrades to refrigeration and heating/ventilation systems.

- Eighteen percent of the sample facilities (± 10 percent) reported that they had used rebates from their local electric utility or Efficiency Vermont to defray the cost of energy efficiency improvements. This finding is consistent with Efficiency Vermont participation records, which suggest that roughly 6 percent of industrial customers participate each year.

Recent Implementation of Energy Efficiency Measures

Energy efficiency efforts among the sample firms focused on a small number of measures:

- Replacement of standard efficiency motors with NEMA Premium Efficiency Models: 26 percent (energy weighted);
- Installation of variable speed drives (30 percent);
- Leak reduction in compressed air systems (40 percent);
- Installation of part load controllers in compressed air systems (18 percent);
- Installation of new rotary screw compressors (33 percent);
- Replacement of indoor lighting with more efficient fixtures (25 percent); and,
- Installation of improved lighting controls (17 percent).

On a premise-weighted basis, the frequency of implementation for these measures is much lower.

These findings suggest the presence of two large areas of opportunity for promotion of energy efficiency in Vermont's industrial sector. The first is to target smaller facilities more effectively, given their large presence in the population. The second is to provide engineering and financial support for system versus component oriented measures. For example, facilities representing only 4 percent of total industrial electric use implemented measures to reduce compressed air system pressures, and only 5 percent increased air storage. Both of these measures require a significant amount of diagnostic engineering to characterize and specify. However, they have the potential produce the large percentage decreases in system energy use through highly cost-effective projects. We found that similarly low portions of customers undertook system-oriented measures for pump and fan systems.

Our analysis of energy efficiency opportunities focuses on those found in generic systems such as lighting and centrifugal motor applications. Systems such as process heating, process cooling, and refrigeration proved to be too complex to characterize on the basis of a short visit and too heterogeneous to characterize in the aggregate based on a small number of observations.

Interior Lighting

- Cost-effective opportunities to upgrade to High Performance T-8s were identified in facilities that represent 54 percent of industrial electric consumption.
- Opportunities to upgrade to Standard T-8s were identified in facilities representing 14 percent of consumption.
- Opportunities to improve controls, primarily through the installation of occupancy sensors, were identified in facilities representing well over half of total industrial electric consumption.
- High bay lighting was present in facilities representing roughly one-half of total industrial electric consumption. Opportunities to upgrade the efficiency of HID lighting were identified in facilities representing roughly 30 percent of industrial consumption. The presence of cost-effective opportunities to improve high bay lighting efficiency is likely higher given recent trends in cost and technology.

Motor Systems

- The motor system efficiency opportunity identified most frequently was replacement of installed motors with NEMA Premium Efficiency models, which the engineers judged to be applicable for 28 percent of all motors observed.
- The field engineers concluded that VFDs could be applied cost-effectively to 20 percent of the motor systems observed.
- The engineers identified supplemental tank insulation and pipe insulation for most domestic hot water heating systems, regardless of heating fuel.

Compressed Air Systems

- The field engineers identified the following potential energy efficiency measures in 20 percent or more of the compressed air systems observed: install engineered nozzles (43 percent), reduce leaks (31 percent), increase air storage (26 percent), reduce operating pressures (22 percent), and install rotary screw air compressors (22 percent).

Space Heating and Cooling

Space cooling equipment with significant capacity was found in fewer than half of the sample facilities. The field engineers identified only limited opportunities for efficiency improvements in this end use. Significant opportunities were found for improving the efficiency of central heating equipment including the following:

- Install set-back controls (46 percent of facilities, premise weighted);
- Replace the furnace or boiler with a more efficient model (42 percent);
- Tune boilers (28 percent);
- Install demand control ventilation (21 percent); and,
- Install economizers.

Recommendations

Customer-oriented efforts to increase measure adoption

Program delivery. This survey identified a large volume of potential energy efficiency improvements in generic lighting, motor, and compressed air systems among both small and larger customers. Market research and the experience of energy efficiency program administrators in other jurisdictions suggest that different program vehicles may be needed to reach small versus large customers. Smaller customers in particular are constrained by lack of personnel resources for identifying and managing energy efficiency improvements. Approaches that have proven to be effective in promoting adoption of common prescriptive measures by small businesses include:

- Direct installation programs, in which the sponsor assumes responsibility or contracts for identification of opportunities for a small menu of measures, specification of installations, engagement of contractors, and management of contractor payment.
- Vendor-driven programs, in which contractors take responsibility for the marketing the direct-installation services described above.

These approaches have been applied successfully in a number of jurisdictions and markets to accelerating adoption of efficient lighting, HVAC, and, in a few cases, motors.

Based on previous evaluations, we are aware that Efficiency Vermont has done a good job of recruiting larger industrial customers into its programs through direct personal representation and custom rebate offers. The results of this survey suggest that additional savings could be developed through these customer relationships and program efforts by making sure that all lighting and motors opportunities are addressed over time as large customers carry out upgrades to their facilities.

Knowledge barriers. As discussed earlier, a number of factors may help explain the finding that very few industrial facilities had undertaken common efficiency upgrades to key energy systems. However, even if those mitigating factors are taken into account, this finding suggests that there may be some knowledge barriers at work in inhibiting adoption of both capital and operating measures. Potential program approaches to address these barriers include:

- Provision of training in optimization of common systems such as pumps, fans, and air compressors. These services are most likely to be effective in achieving actual energy savings when marketed to larger firms with dedicated facility management staffs. We are aware that Efficiency Vermont has sponsored such trainings.
- Support of vendor provision of system optimization and maintenance services, such as HVAC and compressed air system diagnostics.

Vendor-oriented approaches

Analysis of the results of the supply channel surveys identified the following opportunities to support vendors in their promotion of energy-efficient equipment and services.

- 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.

- 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 promoting the replacement of internal HID lighting with fluorescent tube lighting.
- 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.

1. Introduction

1.1 Project Objectives

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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. DPS and the stakeholders also requested that KEMA engineers characterize energy efficiency opportunities associated with early replacement of inefficient equipment. Given the constraints on the field engineers' time on-site and the difficulty of assessing the condition of components that were often hidden from view, this proved to be infeasible.

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 industrial 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.

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 discussed in Section 7.

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 and industrial 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 and industrial 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.
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 – electric motors, indoor lighting, process heating – 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	**44 industrial sites completed**[3]

[3] The screening activity also identified a sample of 117 existing commercial facilities. The results of the survey of existing commercial facilities are reported in KEMA Inc., *Business Sector Market Assessment and Baseline Study: Existing Commercial Buidlings.* Vermont Department of Public Service. July 10, 2009.

Activity/ Key Objectives	Sample Frame	Sample Size and Other Details
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 Industrial Facilities* –** provides an overview of the segmentation of Vermont's industrial facilities by size (number of employees), industrial classification, energy consumption, and other basic characteristics such as facility size and tenure. This section makes use of data from federal sources such as the U. S. Census Bureau's *County Business Patterns* and the *Manufacturing Energy Consumption Survey,* as well as results from the screening and on-site surveys.
- ***Section 4: 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, motor systems, process heating, and space heating and cooling.

- ***Section 5: Recent Facility and Energy System Upgrades –*** presents the results of questions concerning sample customers' recent renovations and additions to their facilities, energy efficiency improvements made to major systems over the past few years, and participation in programs offered by the Energy Efficiency Utility.
- ***Section 6: 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 7: 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 8: 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 primarily based on premise weights (used to represent the percent of premises in Vermont). This proved to be the most appropriate method of weighting and presenting the results given the heterogeneity of Vermont's population of industrial facilities.

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 industrial facilities, and to provide information to support the development of programs to capture those opportunities. To 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 industrial 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. The U. S. Energy Information Administration's *Manufacturing Energy Consumption Survey* (MECS) provides good information on energy consumption, end-use and fuel saturations, but reports these results at a very 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.

2.2 Sampling

2.2.1 Objectives

The key objectives of the sample design were to:

- Provide unbiased representation of the full population of industrial 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.

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
Total		

*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.[4] 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.

[4] 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 Commercial on-site survey, please see: "Final Report of the Vermont Business Sector Market Assessment and Baseline Study: Existing Commercial Buildings.

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

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

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[5].

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 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.

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

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 (See Table 2-4.) 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 industrial facilities as well as by geo vs. non-geo-targeted areas. Given the small sample available for the industrial analysis, any apparent differences in results between the geo and non-geo areas are unlikely to be statistically meaningful. We have therefore decided the sake of clarity and concision to present only statewide results in the text. The tables in the appendix are disaggregated by geographic 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 and practices that appear to be closely related to facility energy consumption, we used ratio estimation to calculate the percentage of the industrial market, as measured by total energy consumption, that had the specific characteristics in question.

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	=	Energy 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.

With a few exceptions noted in the text, we chose to use the population weighting scheme for representing the results of the industrial on-site survey. The basic reason for doing this is that we observed no close association between the installed capacity of various types of equipment and the overall consumption of the sample facilities. For example, a relatively large facility (in terms of energy consumption) may have no compressed air system or only a small system to run pneumatic controls depending on the nature of the operation. Thus, we believe that results calculated with the population weights described in Section 2.2.5 provide the most useful view equipment saturations.

Treatment of missing data. For the majority of the analysis cases with missing data were excluded from the analysis and not included in the denominator. For example, if five percent of the respondents for which the 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 Industrial 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 Industrial Establishments

3.1.1 Distribution by Industry and Energy Consumption

The most recent U. S. Census Bureau analysis of Vermont businesses (*County Business Patterns – 2006)*[6] identifies 1,094 manufacturing establishments in Vermont and roughly 150 additional non-manufacturing industrial facilities consisting principally of mining operations (57), public utilities (56), and ski facilities (17). Public utility plants are likely undercounted. For example, the Vermont Department of Environmental Conservation lists 50 surface water systems in the state, versus 8 in *County Business Patterns.*

[6] *County Business Patterns* is an annual data product prepared by the U. S. Bureau of the Census using payroll data reports that should be submitted by all business establishments. http://censtats.census.gov/cgi-bin/cbpnaic/cbpsel.pl accessed June 20, 2009.

Table 3-1
Population and Sample of Industrial Facilities by NAICS and Size Categories

	# in Sample	# of Estab.	% in Employment Size Category			
			1-4	5-19	20-99	> 100
Food	5	138	41%	33%	21%	6%
Beverage and Tobacco Products	1	17	41%	29%	29%	0%
Textile Mills	1	9	44%	22%	33%	0%
Textile Product Mills		25	64%	36%	0%	0%
Apparel		26	38%	42%	19%	0%
Leather and Allied Products		5	60%	20%	20%	0%
Wood Products	5	114	40%	37%	18%	4%
Paper		11	18%	0%	27%	55%
Printing and Related Activities	5	99	52%	33%	12%	3%
Petroleum and Coal Products		11	73%	18%	9%	0%
Chemicals		23	22%	48%	17%	13%
Plastics and Rubber Products	4	29	28%	31%	21%	21%
Nonmetallic Mineral Products	4	115	45%	35%	18%	2%
Primary Metals	1	2	50%	0%	50%	0%
Fabricated Metals	2	119	47%	32%	14%	7%
Machinery	5	75	31%	27%	28%	15%
Computer and Electronic Products		45	38%	24%	22%	16%
Electrical Equipment	2	19	21%	16%	32%	32%
Transportation Equipment		13	46%	23%	8%	23%
Furniture and Related Products	2	90	48%	34%	10%	8%
Miscellaneous Manufacturing	3	109	60%	21%	17%	3%
Total Manufacturing	***40***	***1,094***	***44%***	***31%***	***18%***	***7%***
Non-Manufacturing	4[7]	~150				

[7] Non-manufacturing facilities in the sample include one waste management facility, 2 wastewater treatment plants, and a ski area.

Key conclusions about Vermont's population of industrial facilities to be gleaned from Table 3-1 are as follows.

- ***Most of Vermont's industrial facilities are very small.*** Overall, 44 percent of manufacturing facilities employ fewer than 5 persons. An additional 31 percent employ from 5 to 19 persons.
- ***Five industries, out of the 21 NAICS categories, account for over 53 percent of manufacturing facilities.*** These are fabricated metals, non-metallic mineral products, wood products, food processing, and printing and related activities.

Table 3-2 shows the percentage distribution of Vermont manufacturing NAICS categories by percentage of total establishments, employees, annual energy use, and annual electric use in the state's manufacturing sector. We estimated energy and electric use at the NAICS category level by applying factors derived from the Department of Energy's 2002 *Manufacturing Energy Consumption Survey* to employment figures provided by *County Business Patterns*.

Table 3-2
Distribution of Vermont Manufacturing NAICS Categories by Percent of Total Establishments, Employees, Annual Energy Use and Annual Electric Use

NAICS Code	Industry	% of Estab.	% of Employees	% of Annual Energy	% of Annual Electricity
334	Computer and Electronic Product Manufacturing	4.1%	22.9%	11.0%	16.4%
325	Chemical Manufacturing	2.1%	2.7%	5.1%	12.1%
311	Food Manufacturing	12.6%	9.6%	10.8%	11.0%
322	Paper Manufacturing	1.0%	3.2%	21.5%	10.2%
327	Nonmetallic Mineral Product Manufacturing	10.5%	4.5%	19.7%	9.5%
321	Wood Product Manufacturing	10.4%	6.4%	5.1%	6.1%
326	Plastics and Rubber Products Manufacturing	2.7%	4.1%	2.6%	5.7%
332	Fabricated Metal Product Manufacturing	10.9%	7.6%	3.1%	5.5%
333	Machinery Manufacturing	6.9%	10.1%	3.3%	5.2%
336	Transportation Equipment Manufacturing	1.2%	4.9%	3.3%	3.8%
335	Electrical Equipment Manufacturing	1.7%	5.1%	2.6%	3.4%
339	Miscellaneous Manufacturing	10.0%	6.6%	1.6%	2.5%
323	Printing and Related Support Activities	9.0%	3.8%	1.3%	1.9%
337	Furniture and Related Product Manufacturing	8.2%	5.8%	1.4%	1.7%
313	Textile Mills	0.8%	0.5%	0.6%	1.2%
324	Petroleum and Coal Products Manufacturing	1.0%	0.1%	4.8%	1.2%
312	Beverage and Tobacco Product Manufacturing	1.6%	0.8%	1.0%	1.0%
331	Primary Metal Manufacturing	0.2%	0.1%	0.8%	1.0%
314	Textile Product Mills	2.3%	0.3%	0.1%	0.2%
315	Apparel Manufacturing	2.4%	0.8%	0.1%	0.2%
316	Leather and Allied Product Manufacturing	0.5%	0.1%	0.1%	0.0%
	Total	**1,094**	**36,964**		

The results shown in Table 3-2 further emphasize the concentration in industrial electric and total energy use in a relatively small segment of the population. The top five NAICS categories, ranked by annual electrical consumption, account for 30 percent of all establishments, but for 59 percent of total annual electric use and 68 percent of total annual energy use.

Readers will notice that the sample does not contain sites from some NAICS categories that rank highest in electric use, for example Computer and Electronic Products and Paper Manufacturing. The distribution of sample sites by industrial classification was an artifact of the sampling approach. Recall that information on industrial classification was not available in the sample frame. Rather, the sample frame was segmented only by the electric usage amount and region, and the sample selected to fill those quotas. The distribution by primary economic use was left to chance.

In selecting the sampling approach for the industrial survey, we needed to make a trade-off between using the sample frame provided by utility billing records on the one hand and a broad-based directory of business establishments such as Dunn & Bradstreet's data products on the other. The key advantages of using the billing record database were:

- It provided the most directly relevant measure of size for purposes of stratification;
- It included only direct utility customers as opposed to a mix of direct customers and tenants who did not pay their energy bills;
- It was consistent with the method used to select commercial facilities; and,
- It supported the ratio estimation approach we initially planned to apply for characterizing market share of technologies and practices.

The key disadvantage was that facilities could not be characterized by industry in advance of sample selection. Given the relatively small sample size, it was therefore possible that some important industries would be left out of the sample.

3.2 Size and Configuration of Industrial 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.

Single v. multiple building facilities. Thirty-six percent of the sample industrial facilities (facility or population weighted) consisted of two or more buildings.

Distribution by total enclosed floor space. As Table 3-3 shows, the population of industrial establishments in Vermont appears to be concentrated in the 10 – 20,000 square foot size category. The weighted average enclosed floor space among the sample facilities was 23,760 ± 7,091 square feet. This finding is somewhat at odds with the *County Business Pattern* data, which show that 44 percent of manufacturing establishments have fewer than 5 employees. One possible explanation of this finding is that such small manufacturers lease their facilities and do not appear as customers in utility billing records.

Table 3-3
Facility Size and Type – All Space
Facility-Weighted n = 38

Facility Size (SF)	% of Facilities
2000 and Under	2%
2001 – 5000	19%
5001 – 10000	5%
10001 – 20000	60%
20001 – 50000	6%
Over 50000	9%
Total	100%*
Average square feet	23,760

*Does not add to 100% due to rounding.

3.3 Other Key Facility Characteristics

Distribution by tenure arrangement. Table 3-4 displays the distribution of the on-site industrial sample by tenure arrangement. Projected to the population the sample findings indicate that 68 percent of commercial utility customers own and occupy their facilities: 55 percent of facilities are occupied in their entirety by owners; 13 percent are occupied in part by their owners. Thus, the utility customers of record in roughly two-thirds of Vermont's industrial facilities are owners and in position to appropriate both the energy savings and capital appreciation benefits associated with energy efficiency improvements.

Thirty-one percent of the sample are tenants, with 17 percent leasing a whole building and 14 percent leasing a portion of a building. By virtue of being included in the sample, we know these customers are responsible for their own electricity costs. These establishments are likely to be directly responsible for their energy bills and thus motivated to make some energy efficiency improvements.

Table 3-4
On-Site Sample by Tenure Arrangement
Premise-Weighted n = 117

Tenure Arrangement	% of Facilities
Own and Occupy the Entire Facility	55%
Own the Entire Facility and Occupy a Part of It	13%
Lease the Entire Facility from another Organization	17%
Lease part of the Facility from another Organization	14%
Other Ownership Arrangement	1%
Total	100%

Distribution by year built. Table 3-5 shows the population weighted distribution of facilities in the on-site sample by year built. Occupants of 31 percent of the facilities were unable to provide information on their age. Among the remaining facilities, 52 percent (36%/69% with reported ages) were built between 1990 and 2000, with an additional 27 percent clustered in the 1970s. A relatively small number of industrial facilities were built prior to 1970.

The distribution of industrial facilities by age differs significantly from that for commercial facilities. According to the results of the survey of existing commercial buildings undertaken for this project, over 62 percent of commercial buildings were built prior to 1970.

Table 3-5
Industrial Facilities by Year Built
Premise Weighted n = 44

Year Built	% of Facilities
Before 1900	2%
1900 – 1959	3%
1960 – 1969	2%
1970 – 1979	19%
1980 – 1989	7%
1990 – 2000	36%
After 2000	2%
Unknown	31%
Total	100%

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. Table 3-6 presents mean and median annual hours of operation in the sample industrial facilities. The mean annual hours of operation is 4,195 with an 80 percent confidence interval of ± 1,119 hours or 27 percent. These results show that industrial facility operating hours vary widely within the population.

Table 3-6
Annual Hours of Operation
Premise Weighted n = 44

	All Com.
Mean	4,195
80% Confidence Interval	*±1,119*
Median	2,400

The median number of annual operating hours is 2,400, which means that one-half of Vermont industrial establishments were operating one shift or less at the time of the survey. To arrive at a mean of 4,195, the remaining establishments would need to operate an average of 5,980 hours per year, which corresponds to nearly three shifts. This sharp split in the distribution of operating hours between low and high is typical of many of the characteristics of Vermont's population of industrial establishments.

4. Characteristics and Installed Capacity of Major Energy Systems

This section presents survey results on the type, installed capacity, and efficiency characteristics of the following equipment systems:

- Electric motors;
- Compressed air systems;
- Process heat and refrigeration systems;
- Space heating and cooling systems; and,
- Indoor Lighting.

As discussed in Section 2, KEMA applied used two different weighting procedures in analyzing the survey data on the saturation of various kinds of energy equipment.

- **Premise Weighting** is a conventional population weighting approach that associates the portion of the total population represented by the stratum from which a sample site was drawn with the data collected from that site. The sample proportions thus estimate the portion of all Vermont industrial facilities in which a particular type of equipment or characteristic is found. Sample means represent the mean value of a particular indicator, such as installed electric motor horsepower averaged across all manufacturing establishments.
- **Energy Weighting** refers to the ratio estimation approach discussed in Section 2. In this case, responses from sample sites are weighted by stratum weight and the facility's annual electric consumption. The sample proportions developed through this method can be characterized as "facilities representing xx percent of total industrial electric consumption in Vermont". We developed and used this approach to provide a reasonable representation of saturation in a population where 44 percent of the establishments employ fewer than 5 people and consumption is highly concentrated in a small number of large facilities.

In the paragraphs below, we have elected to represent saturation using premise weighting approach in some cases, the energy weighting approach in others, and both approaches in still other instances. Our selection of weighting approach took into account the following considerations.

- **Nature of the data collected on site.** In most cases, our selection of weighting approach was driven primarily by technical considerations of how best to translate the data collected on site into an indicator that usefully represented saturation of an end-use or equipment type. In the case of lighting, we processed the data on fixture and technology types collected on site into a series of saturation estimates for each site. That is, for each site, we developed a percentage distribution of lighting technologies (incandescent, fluorescent, etc.) and efficiency-related (T-12, T-8, etc) categories installed. Given the space sampling approach, there was no way to scale the on-site observations directly to the population. Therefore, we scale the site-level percentage distributions. In this case, the use of the energy weighting provides the most appropriate representation of market share because the site level observations, expressed as they are in terms of proportions, do not carry any size information with them. Moreover, because the indoor lighting is present in every facility, it is reasonable to expect that there is some regular relationship between total electric use and electricity use in lighting for the sample facilities.

  The inventory of motors was developed in an entirely different way. Basically, for each site we developed an actual or in some cases estimated count of individual motors characterized by size, type, efficiency category, control system, and application. Applying the premise weights to these counts directly produces a representation of the entire industrial motor inventory in Vermont. Further weighting by electric consumption is unnecessary for representing saturation in this case. In fact, it would account twice for facility size factors and thus distort the depiction of the population.

  The selection of weighting approaches for the remaining technologies was not as clear-cut as it was for lighting and motors. Compressed air systems were present in a large percentage of sample facilities, and had capacity roughly related to facility energy consumption. We therefore used the energy weighting scheme for representing saturation of that technology. For thermal technologies such as process heat and cooling, which were not found in many facilities and which, in many cases, were powered by fuels other than electricity, we found premise weighting to be the more appropriate and reasonable approach.

- **Application of the findings.** In the sections presenting saturation results, we have selected either the premise or the energy weighting approach based on a technical judgment concerning which provides the most appropriate representation of saturation. When we present information on energy efficiency actions taken or opportunities available, we generally show the results of using both approaches, because program planners and managers are likely to be interested in both sets of results. The premise weighting provides a sense of the percentage of facilities whose owners have completed measures or in which such opportunities are available. This is useful for planning marketing and delivery activities. The energy weighted results are more appropriate for use in program planning and costs effectiveness assessment since they provide a better sense of the remaining potential for specific energy efficiency measures in the current market.

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4.1 Electric Motors

Electric motors consume roughly two-thirds of all electricity used by manufacturing establishments in the United States. Table 4-1, developed from the results of the U. S. Energy Information Administration's 2004 Manufacturing Energy Consumption Survey (MECS) shows

Table 4-1
Distribution of Electricity Consumption by End-Use
2004 Manufacturing Energy Consumption Survey

	US	Northeast
Indirect Uses-Boiler Fuel	**0.7%**	**0.5%**
Conventional Boiler Use	0.3%	0.2%
CHP and/or Cogeneration Process	0.4%	0.3%
Direct Uses-Total Process	**79.6%**	**73.0%**
Process Heating	10.8%	11.5%
Process Cooling and Refrigeration	6.5%	6.8%
Machine Drive	53.0%	48.3%
Electro-Chemical Processes	8.9%	5.7%
Other Process Use	0.4%	0.0%
Direct Uses-Total Nonprocess	**16.7%**	**22.1%**
Facility HVAC (e)	8.5%	11.0%
Facility Lighting	6.4%	8.7%
Other Facility Support	1.5%	2.0%
Onsite Transportation	0.1%	0.1%
Conventional Electricity Generation	0.0%	0.0%
Other Nonprocess Use	0.1%	0.3%
End Use Not Reported	**3.0%**	**4.4%**
Total Motor-Driven End-Uses	**67.9%**	**66.1%**
TOTAL CONSUMPTION (GWH/Year)	**966,231**	**110,652**

the distribution of electricity consumption among all manufacturing end uses, with those constituted entirely of electric motors shaded. Motors also account for some of the consumption included in the "Process Heating" and "Other Facility Support" categories. Our efforts to characterize the inventory of motors in place in Vermont industrial facilities focused on motors found in Machine Drive and Process Cooling and Refrigeration, which account for 88 percent of total motor electricity use at the national level; 83 percent for the Northeast Census Region.

4.1.1 Overview of the Motor Inventory

The field engineers identified 1,818 motors in the 43 sample industrial facilities in which motors were present, or 42.3 motors per facility. The total capacity of installed motors averaged 421 horsepower per site. Table 4-2 shows the distribution of integral horsepower motors observed and of installed horsepower by motor horsepower categories. The pattern shown is similar to that found in the 1998 *United States Industrial Electric Motor System Market Opportunities Assessment,*[8] which was based on detailed surveys of a national sample of 252 manufacturing facilities. Sixty-three percent of the motors observed in Vermont are 5 HP or smaller, compared to 59 percent in the national sample. Fifty-two percent of installed capacity is concentrated in the size ranges from 6 to 50 HP. Moreover, based on the *Motor System Market Opportunities Assessment,* motor system energy use is further concentrated in the higher horsepower ranges because larger motors tend to run more hours per year than small motors.

Table 4-2
Distribution of Motors and Installed Horsepower by Horsepower Category, n = 43

	Vermont 2008		U. S. 1998
Horsepower Category	**% of Motors**	**% of Installed HP**	**% of Motors**
1-5 hp	62.8%	19.5%	58.8%
6-20 hp	23.5%	33.3%	26.4%
21-50 hp	5.0%	18.9%	9.1%
51-100 hp	1.7%	14.5%	2.9%
101-200 hp	0.5%	8.4%	1.8%
201-500 hp	0.1%	3.1%	0.7%
501-1000 hp	0.0%	0.9%	0.2%
Greater than 1000 hp	0.0%	1.3%	0.1%

[8] XENERGY, Inc. 1998. *United States Industrial Electric Motor System Market Opportunities Assessment.* Washington, D. C.: U. S. Department of Energy, Office of Industrial Technologies.

Table 4-3 shows the distribution of motors and installed horsepower by basic application. We also show the distribution of motors by application from the US DOE study referenced above. The split of motors between the generic fluid applications (pumps, fans, compressors) and materials processing and handling applications is similar for the two studies. Fifty percent of the motors identified in the Vermont sample drive fluid applications versus 37 percent in the national sample. The percentage of motors that drive fan and air compressor systems in Vermont is slightly higher than in the national sample; and the saturation of pumps slightly lower.

Table 4-3
Distribution of Motors and Installed Horsepower by Application, n = 43

	Vermont 2008		U. S. 1998
Horsepower Category	**% of Motors**	**% of Installed HP**	**% of Motors**
Pumps	6.6%	15.2%	19.7%
Fans and Blowers	20.1%	13.0%	11.2%
Air compressors	15.1%	8.0%	5.1%
Refrigerant Compressor	4.8%	1.8%	0.8%
Materials Processing	45.4%	50.2%	42.2%
Materials Handling	5.7%	8.8%	16.8%
Other	2.3%	3.1%	4.2%

4.1.2 Saturation of NEMA Premium Efficiency Motors

NEMA Premium Efficiency electric motors are standard design integral horsepower AC motors that comply with efficiency standards established by the National Electrical Manufacturers Association (NEMA). The NEMA Premium Efficiency specifications cover motors in the range from 1 to 200 horsepower. NEMA Premium Efficiency motors are 1.2 to 3.5 percent more efficient than motors that comply with current federal minimum efficiency standards; the difference between the two decreases as motor size increases. Since their introduction in 2002, the market share of NEMA Premium Motors, in terms of annual sales, has increased rapidly and their price premium in relation to standard efficiency motors has decreased.

Table 4-4 displays saturation of NEMA Premium Efficiency motors in terms of motors and capacity installed.[9] Overall, NEMA Premium Efficiency motors account for 10.3 percent of all units and 21.6 percent of total capacity installed. The highest saturation in terms of both motors and installed capacity occurs in the 21 – 50 HP range, where over 60 percent of installed capacity is NEMA premium.

Table 4-4
Saturation of NEMA Premium Efficiency Motors by Horsepower Category, n = 43

Horsepower Category	% of Motors	% of Installed HP
All Motors	***10.3%***	***21.6%***
1-5 hp	3.7%	5.9%
6-20 hp	12.5%	23.6%
21-50 hp	27.4%	60.4%
51-100 hp	2.9%	5.3%
101-200 hp	4.9%	4.8%

4.1.3 Prevalence of Variable Loads and Saturation of Variable Frequency Drives

Industrial facility owners can achieve significant energy savings through the use of variable frequency drives (VFDs) on centrifugal machines such as pumps, fans and some compressors, as well as on other types of production equipment. For centrifugal equipment energy use varies roughly in proportion to the cube of the speed of the machines leading edge. Matching motor speed to load requirements in these devices offers an attractive energy saving opportunity. For materials processing and handling applications in particular, VFDs offer important non-energy benefits in terms of increased control over production processes, leading to reduced waste and downtime.

[9] As used here, the term saturation denotes the percentage of NEMA premium motors among all motors or all motor horsepower installed.

Table 4-5 shows the prevalence of motors with variable load and the saturation of VFDs in terms of installed capacity. Forty-one percent of all installed motor capacity drives variable loads – that is loads that vary significantly while the motor is on. The prevalence of variable loads varies by motor size, ranging from 14.9 percent of installed horsepower for motors in the 21 – 50 hp category to 100 percent for the largest motors in the inventory.

Overall, the saturation of VFDs is 13.8 percent of total installed capacity and 34.0 of installed capacity with variable loads. Saturation of VFDs in terms of percentage of capacity with variable load generally increases with motor size, reflecting the higher level of savings available with larger motors and longer hours of use.

Table 4-5
Prevalence of Variable Loads & Saturation of VFDs by Motor HP

	Prevalence of Variable Load	Saturation of VFDs	
Horsepower Category	**as % of Installed HP**	**% of Total Installed HP**	**% of Installed HP with Variable Load**
All Motors	***40.6%***	***13.8%***	***34.0%***
1-5 hp	50.7%	4.6%	9.3%
6-20 hp	69.0%	21.6%	31.9%
21-50 hp	14.9%	9.4%	66.2%
51-100 hp	27.8%	15.7%	56.5%
101-200 hp	35.9%	0.0%	0.0%
201-500 hp	63.2%	40.4%	64.0%
501-1000 hp	100.0%	100.0%	100.0%
Greater than 1000 hp	100.0%	100.0%	100.0%
n =	*43*	*41*	*41*

4.2 Compressed Air Systems

4.2.1 Overview of Installed Systems

Based on the results of the on-site inspections, we developed the following characterization of the fleet of compressed air systems installed in Vermont's industrial facilities.

- **Fraction of facilities with compressed air systems.** Using the energy weighting system, industrial facilities representing 94.5 percent (± 5.9 percent) of industrial electricity usage in Vermont have an electric-powered compressed air system in place.[10]
- **Average number of compressors installed.** The average number of compressors installed was 2.5, with an 80 percent confidence interval of ± 0.5 units.
- **Average horsepower of installed systems.** The weighted average horsepower of the systems observed was 51, with an 80 percent confidence interval of ± 22 hp.
- **Compressed Air Applications.**

[10] Eighty-six percent of Vermont industrial facilities have a compressed air system installed, with an 80 percent confidence interval of ± 16 percent.

Table 4-6 shows the distribution of systems by application of compressed air. The most common application is air supply to pneumatic controls, which is found in facilities representing 49.2 percent of industrial electric use. The second most common application is air tool drive, which is found in facilities representing 25.4 percent industrial electricity use. The high saturation of these end-uses, neither of which requires significant compressed air capacity, is consistent with the relatively modest size of the systems installed. Over 18 percent of the facilities used compressed air for open blowing which is, in most cases, an inefficient use of compressed air for purposes better served by mechanical systems.

Table 4-6
Compressed Air Applications, n =42

Compressed Air Application	% of Industrial Electric Use Represented
Pneumatic Controls	49.2%
Air Tool Drive	25.4%
Open Blowing	18.1%
Vacuum Generation	2.1%
Aeration, Agitation, Oxygenation of Liquids	1.6%
Transport of liquids or light solids (padding)	0.0%
Transport of Solids	0.0%
Diaphragm Pumps	0.0%
Other	3.6%
Total	**100.0%**

- **Compressor fuel.** Facilities representing 99 percent of industrial electric usage have electric-powered compressors installed. Facilities representing 3 percent of industrial energy use of diesel-powered compressors installed.
- **Saturation of Compressor Types.** As Table 4-7 shows, lubricant-injected rotary screw compressors, both lubricant injected and lubricant free, is by far the most common types, with each being present in facilities representing 77 percent of industrial electric consumption. Single-acting rotary screw models are the next most common, being found in facilities representing 29 percent of total industrial electric consumption.

Table 4-7
Air Compressors Installed by Type, n = 42

Compressor Type	% of Industrial Electric Use Represented
Lubricant Injected Rotary Screw	44%
Lubricant-Free Rotary Screw	33%
Single Acting Reciprocating	29%
Double Acting Reciprocating	12%
Centrifugal	3%
Other (Scroll)	3%

* Adds to > 100% due to presence of compressors of different types in single facilities.

4.2.2 Compressed Air System Controls and Auxiliaries

System controls. Best practices in design and operation of compressed air systems, particularly larger ones, call for the use of a combination of automatic controls and compressed air storage to enable compressors to operate in the efficient range of part loads and to shut off entirely when compressed air is not needed. Our findings in regard to storage and controls were as follows.

- **Fraction of systems with compressed air storage.** Compressed air systems with air storage capacity are present in facilities that represent 75 of industrial electric consumption or in roughly 79 percent of all compressed air systems, weighted by facility electric use.

- **Average capacity of storage systems.** The weighted average capacity of the compressed air storage systems observed was 348 gallons, with an 80 percent confidence interval of ± 134 gallons. Given the average size of the system installed, this average air storage capacity is generally sufficient to provide load management capability.

- **Types of controls.** Table 4-8 shows the distribution of compressed air systems by control type. In interpreting these results it is important to keep in mind that compressed air systems are complex and that their efficiency is determined to a much greater extent by the interaction of their components than by the inherent efficiency of the individual components.

Table 4-8
Control Systems Installed, n = 37

Control Type	% of Industrial Electric Use Represented
Start-Stop	43%
Load/Unload	34%
Modulating	35%
Variable Displacement	2%
Variable Speed Drive	2%
Other	6%

Simple start-stop controls based on pressure sensors can provide energy-efficient load following when matched to with appropriate air storage capacity and properly-sized compressors. In fact, this is the preferred technical approach for small and mid-size systems running in part load ranges below 60 percent, which is typical of systems that drive pneumatic controls and air tools.[11] Modulating controls are appropriate for systems that run at the higher load levels associated with materials processing applications. Thus, the distribution by control type is consistent with information collected on compressed air system size and applications.

Auxiliary equipment (air dryers). Most compressed air systems require air dryers to remove moisture entrained in the compressed air prior to circulation through the end-use system. Otherwise, as the air cools, water condenses within the system causing corrosion and erratic performance. All types of air dryers use mechanical processes such as refrigeration, desiccant circulation, and desiccant regeneration to extract moisture from the air as it exits the compressor. Proper control and integration of dryer and system operation is needed so that air is properly conditioned without wasting energy in overdrying air. The type of dryer used depends to on many factors, including system capacity, ambient temperatures, and compressor type. No one dryer type will be most energy-efficient in all cases. Table 4-9 shows the percentage of facilities with air dryers of different type and the average number of dryers installed in facilities that have them.

Table 4-9
Air Dryer Systems Installed, n = 41

Dryer Type	% of Industrial Electric Use Represented	Average # of Dryers
All Air Dryers	79%	1.2
Refrigerant Dryers	62%	1.1
Desiccant Dryers	12%	2.0
Deliquescent Dryers	1%	2.0

[11] XENERGY, Inc. 2001. *Compressed Air System Assessment Manual.* Albany, NY: New York State Energy Research and Development Authority.

4.3 Process Heating and Cooling

4.3.1 Process Heating

Types of equipment installed. Approximately 46 percent of the industrial facilities in Vermont have process heating equipment installed. As discussed in Section 4.5, a significant portion of the installed central heating capacity is also used for process heat. Table 4-10 provides a breakdown by type of the dedicated process heating equipment identified in the sample facilities. The most prevalent heating equipment types were furnaces, steam boilers, hot water boilers, and direct fired process heating equipment.

Table 4-10
Types of Process Heating Equipment Installed, n = 30

Unit Type	% of Facilities
Furnace	38%
Steam Boiler	37%
Hot Water Boiler	36%
Direct-fired	34%
Electric resistance	20%
Other	9%

Process heating fuels. Unfortunately, the field engineers were unable to obtain information on process heating fuels in a number of the sample facilities. However, of those buildings that did have process heating and equipment information was available, electricity and “other fuels” were the most common fuel source. The category, “Delivered Fuels” includes woodchips and fuel oil.

Table 4-11 indicates the percentage breakdown of fuel types across buildings with process heating, including the percentage of buildings with no information. The percentage totals to over one-hundred percent because some buildings used multiple fuel types for their process heating.

Table 4-11
Process Heating Fuel Types, n = 30

Primary Process Heating Fuel	% of Facilities
Delivered Fuels	37%
Electricity	15%
Natural Gas	3%
Propane	1%
Missing	47%

* "Delivered Fuels includes wood chips and fuel oil

Installed capacity. In many of the sample facilities, the process heating equipment was not accessible for inspection. Therefore, information on installed capacity is missing for roughly half of the sample (population weighted).

Table 4-12
Process Heat System Rated Input in MBtu/Hour, n=30

Rated Input in MBtu/Hour	% of Facilities
Less than 50	7%
50 to 100	0%
100 to 500	5%
500 to 1000	0%
1000 to 3000	36%
3000 to 6000	4%
Don't Know	7%
Missing	50%

As Table 4-12 shows, in those facilities where process heat installed capacity could be determined, the size of the installations clustered in the range from 1,000 to 3,000 MBtu/Hour.

Operating Hours. Among the facilities whose managers were able to report process heating system hours of operation, run time averaged 62 hours per week. . Of the buildings with process heating, the average equipment operating hours is 62 hours per week. The majority used their equipment less than forty hours per week on average. Table 4-13 illustrates the distribution.

Table 4-13
Process Heat System Average Operating Hours per Week, n = 30

Average Weekly Hours of Operation	% of Facilities
Less than 40	39%
40 to 56	1%
56 to 84	5%
84 to 120	3%
120 to 168	7%
"Don't Know"	1%
"Not Applicable"	0%
“Missing	50%

4.3.2 Process Cooling and Refrigeration

The industrial building sample provided limited information on industrial refrigeration. Process cooling and refrigeration systems were observed in only two facilities, which does not provide a sufficient basis for generalization. Both Energy Star and non-Energy Star non-commercial, self-contained refrigerators were observed in industrial buildings. Equipment ranged from one- and two-door to under counter refrigerators. With regard to other types of refrigeration (e.g., commercial, self-contained and remote), few to no energy efficiency measures, such as variables speed drives or economizers, were observed.

4.4 Space Cooling

4.4.1 Saturation and Technology Shares

Saturation and technology shares by floor space served. Sixty-two percent of industrial facilities have space cooling systems installed. A number of facilities contain more than one kind of system. As Table 4-14 shows, room air conditioners were the most frequently observed type of system; they were found in 29 percent of the sample facilities. Packaged HVAC systems were the next most prevalent cooling equipment type, observed in 26 percent of facilities. Heat pumps were observed in 17 percent of utilities. Large, built-up central cooling plants (Other Central Cooling Plant) are found in relatively few facilities.

Room air conditioners and packaged HVAC each accounted for 24 percent of the equipment units observed, and split-system HVAC accounted for another 20 percent of total units.

Table 4-14
Distribution of Cooling Equipment Type for Facilities with Cooling Systems
Premise Weighted

Type of Equipment Installed	% of Facilities*	% of Total Units
	n = 44	n = 25
None	38%	
Room A/C	29%	24%
Packaged HVAC	26%	24%
Heat Pump	17%	9%
Split System HVAC	11%	20%
Other Central Cooling Plant	3%	1%
Miscellaneous Cooling	16%	21%

* Does not add to 100% because one facility may house multiple systems.

Installed capacity. The field engineers were able to estimate the installed capacity (in tons of cooling output) for 18 of the 25 sites with central cooling plants. The key results from this set of observations are as follows.

- Average tons of capacity installed per facility: 36.9 tons $\pm$ 12.4 tons
- Average tons of capacity used for space cooling: 19.9 tons $\pm$ 9.6 tons

- Average tons of capacity installed per unit: 9.5 tons ± 7.9 tons.

The average the installed capacity of the central cooling plants is relatively small which suggests that most of the cooling installations are used to condition relatively small spaces. However, the large relative confidence interval as well as the relatively high percentage of capacity used for applications other than space cooling reflects presence of some larger installations in the sample. Indeed, there were several plants in the sample with 500 to 1,000 tons of installed central cooling capacity.

Operating schedule. According to facility occupants, 68 percent of facilities with central cooling plants operate them on a highly seasonal basis: 13 to 26 weeks per year. In the sample, systems representing 23 percent of facilities operated more for the full year: the majority of these systems provided primarily process cooling. See Table 4-15.

During periods of operation, most of the cooling systems (61 percent) are on for 40 – 84 hours, which suggests that plants with central cooling plants operate longer-than-average schedules. Thirty-one percent of central cooling systems operate 120 or more hours per week.

Table 4-15
Operating Schedule of Central Cooling Plants
Premise Weighted, n = 18

Weeks per Year	% of Facilities
Less than 13	0%
13 to 26	68%
26 to 39	4%
39 to 52	0%
Not Seasonal	23%
Unknown	5%
Hours per Week	
Less than 40	0%
40 to 56	24%
56 to 84	37%
84 to 120	0%
120 to 168	31%
Unknown	8%

4.5 Space Heating

Saturation and technology shares by floor space served. Eighty-one percent of industrial facilities have central space heating systems. Those that do not have primarily outdoor operations – for example gravel pits and quarries. Table 4-16 shows the distribution of industrial facilities with central heating that are served by the different varieties of heating equipment. The most prevalent space heating equipment type is direct, which, taking together radiant and other types of direct heaters (direct fired space heaters) are present in 36 percent of facilities. This is consistent with the relatively high share of propane heating fuel (see below) and the heavy representation of small facilities in the population. More mechanically complex systems such as hot water and steam boilers serve a combined 22 percent of facilities.

Table 4-16
Heating Equipment Installed
Premise Weighted n = 33

Heating Equipment Type	% of Facilities
Direct-fired radiant	28%
Furnace	27%
Hot Water Boiler	17%
Packaged HVAC	8%
Other direct heating	8%
Steam Boiler	5%
Unknown	7%

Heating fuel types. On a premise-weighted basis, natural gas is the most common primary heating fuel, accounting for 46% of facilities. Propane and fuel oil each account for 26 percent of the remaining facilities, with wood providing fuel for primary heat in one percent of facilities. Only 18 percent of facilities have secondary heating systems or fuel capability. Most of these are natural gas.

Table 4-17
Primary and Secondary Space Heating Fuel Type
Premise Weighted n = 33

	Primary Fuel	**Secondary Fuel**
Heating Fuel	**% of Facilities**	**% of Facilities**
Natural Gas	46%	17%
Propane	26%	0%
Fuel Oil	26%	1%
Electric	0%	1%
Wood	1%	0%
Not Applicable	0%	82%

Columns do not add to 100% due to rounding.

Installed capacity. As Table 4-18 shows, the installed capacity of space heating equipment installed in industrial facilities is fairly modest. The average installed capacity per facility is 1,754 MBtu per hour. The average capacity of individual units is 854 MBtu per hour. Three percent of facilities have space heating systems with rated output less than 100 MBtu per hour. An additional 22 percent have rated output less than 500 MBtu per hour.

Table 4-18
Rated Output of Space Heating Equipment
Premise Weighted n = 33

Space Heating Equipment Output Capacity (MBtu/Hour	**% of Facilities**
Less than 100	3%
100 to 500	22%
500 to 1,000	21%
1,000 to 5,000	8%
5,000 to 10,000	1%
Greater than 10,000	1%
Unknown	44%

Age of installed heating systems. Most of the central space heating equipment installed is of relatively recent vintage. The average age of installed systems is 14.7 ± 2.9 years. In most gas energy efficiency potential studies with which we are familiar the effective useful life of central heating equipment is assumed to be 25 years.[12] More than 90 percent of units were reported to be 10 years old or older.

Table 4-19
Age of Installed Space Heating Equipment
Premise Weighted n = 33

Age of Installed Equipment	% of Facilities
Less than 5	1%
5 to 10	9%
10 to 20	45%
20 to 30	38%
30 to 40	1%
40 to 50	0%
50 to 60	1%
Don't Know	4%

Operating schedule. The average heating system operating hours reported by occupants of the sample facilities was 1,917 per year, ± 514. These findings are consistent with the relatively low hours of facility operation discussed in Section 3. According to facility occupants, 50 percent of facilities use their central heating systems seasonally, with an average heating season of 29 weeks. When the systems are on, 40 percent of facilities with central heating units operate them on a 40 or fewer hours per week, corresponding to one shift. Twenty percent operate on a two shift basis, and 31 percent operate on a three shift or continuous basis.

[12] See, for example, Optimal Energy, Inc. *Natural Gas Energy Efficiency Resource Development Potential in New York.* 2006. *Energy Efficiency and Renewable Energy Resource Development Potential in New York State.* Albany: New York State Energy Research and Development Authority. Appendix B.

Table 4-20
Operating Schedule of Space Heating Equipment
Premise Weighted, n = 10

Hours per Week	% of Facilities
Less than 40	40%
40 to 56	8%
56 to 84	20%
84 to 120	1%
120 to 168	31%
Don't Know	3%

Use of heating system capacity. According to occupants, capacity utilization of central heating equipment is concentrated in the high and low parts of the range. Fifty-one percent of respondents reported that they use 75 to 100 percent of their system's capacity when the systems are running. Nineteen percent report that their systems run at lower than 25 percent capacity. One quarter of facilities were not able to provide an estimate of their heating system capacity utilization.

Application of central heating plant capacity. The sample facilities show a wide range of variation in the application of output from the central heating plant for space versus process heat. On average, occupants reported that 59 percent of central heating plant output was used for space heating. However, the 80 percent confidence interval around that mean was 27 percent (n = 33).

4.6 Indoor Lighting

All space surveyed has indoor lighting equipment. Table 4-21 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.

4.6.1 Saturation and technology shares by floor space served

All space surveyed has indoor lighting equipment. Table 4-21 shows the saturation of the principal indoor lighting technologies using the energy weighting system. The middle column shows the percentage of total industrial electricity use accounted for by spaces lit with the various technologies shown in the left-hand column. Percentages in this column will add to more than 100 percent because individual spaces are often served by more than one type of lighting. In fact, most observed spaces were served by 2 – 3 types of lighting technologies. The right hand column provides a more conventional depiction of saturation. The figures there can be interpreted as the percentage of total installed lighting equipment.

Table 4-21
Lighting Equipment Saturation
kWh Ratio Weighted n = 43

Indoor Lighting Technology	% of Industrial Electric Use Represented	% of All Lighting Installed
Incandescent Technologies		
Incandescent Lighting	10%	6%
Quartz	2%	1%
Linear Fluorescent		
T5	7%	4%
Standard T-8	41%	23%
High Performance T-8	6%	3%
Unknown T-8	15%	8%
T-12	36%	20%
Unknown Fluorescent Tube	3%	2%
Compact & Other Fluorescent		
Compact Fluorescent Lamps	10%	6%
Other Fluorescent	15%	8%
High Intensity Discharge		
HID	25%	14%
Other		
Other	7%	4%
TOTAL		**100%**

Key observations to be drawn from Table 4-21 include the following.

- Linear fluorescent fixtures are by far the most common lighting technology in Vermont's industrial facilities, accounting for 61 percent of all weighted occurrences. Compact fluorescent and other fluorescent fixtures account for an additional 7 percent of total occurrences. High Intensity Discharge (HID) fixtures are the next most common type, with 14 percent of total weighted occurrences.

- T8 fixtures have the highest level of saturation among the basic fluorescent technologies. T8 fixtures of various kinds account for 58 percent of the total ratio-weighted occurrences of fluorescent fixtures; T12 for 33 percent; and T5 for 4 percent. Unidentified fluorescent tubes account for an additional 9 percent of total weighted occurrences. The saturation of High Performance T8s is still low, at 6 percent of all observed fluorescent installations.

4.6.2 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 manufacturing facilities is 1.3 watts/square feet. 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 often impossible to collect complete information for each lighting type present in a sampled space. In cases where partial information about the lamps was known, average values were used to fill in missing data. Given constraints on time in the facility, the field engineers were unable to inventory literally all lighting fixtures in the sampled spaces.

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 technology specific LPDs and it was used in less than 13 percent of cases. One quarter 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 was used to estimate the wattage for the lighting group with missing information. Using the observed average technology specific LPDs in this way keeps the overall distribution of light types in the LPD analysis consistent with the technology shares of the lit spaces and provides more accurate results than dropping the spaces with insufficient data from the analysis entirely. This correction was employed in 35 percent of cases.

Lighting Power Density Results. Overall, we estimated the lighting power density of the sample facilities at 0.76 Watts per square foot, with an 80 percent confidence interval of ±0.12 Watts per square foot. The maximum standard LPD for industrial facilities per the *Vermont Guidelines* is 1.30 Watts per square foot.

4.6.3 Additional Indoor Lighting Details

Usage and Controls. More than 95 percent of indoor lighting is controlled by manual on/off switches and more than 95 percent is used for area lighting. This suggests that lighting controls represent an untapped resource of energy savings.

Age. On average, lighting fixtures in Vermont industrial facilities are between seven and eight years old. T12 fixtures average almost 13 years old, while Standard T8s average closer to nine years, HP T8s around five years and T5s a little more than 2 years old.

Ballast Types. Most of the ballasted lamps in Vermont Industrial facilities have electronic ballasts; however most T12s, and almost half of HIDs have standard magnetic ballasts

5. Recent Facility and Equipment Upgrades

5.1 Recent Renovation and Equipment Replacement Activity

In an attempt to develop information on the pace and extent of additions and major renovations, KEMA staff that conducted the screening interviews asked survey participants a series of questions concerning the scope of renovations and replacements of major energy-using equipment that they might have undertaken in the past few years. The following paragraphs summarize key findings on these topics.

- **Percent of facilities making major additions and renovations.** Thirty-seven percent of the sample respondents, ± 21 percent, reported that they had made major renovations or additions to their facilities in the past five years, for an average rate of 6.2 percent per year. An analysis of fire safety (occupancy) permits conducted for the Phase 2 Evaluation of Efficiency Vermont Business Programs found an average rate of roughly 7 percent per year.[13] Thus, these survey results are consistent with those developed from population-based data.

- **Systems upgraded in past five years.** Overall, 62 percent of facilities report that they made upgrades over the past five years to at least one of the following equipment systems: heating and ventilation, cooling and air conditioning, lighting, and refrigeration. Thirty percent of facilities reported that they had made upgrades to their lighting equipment, 15 percent had made upgrades to refrigeration and heating/ventilation systems. Only 1 percent reported making upgrades to refrigeration equipment. This pace of improvement to key energy systems corresponds closely with findings on the same topic from the survey of industrial customers undertaken for the Phase 2 evaluation. That survey also found that large customers undertook improvements at a much higher rate than smaller customers.

[13] RLW Analytics, Inc. and KEMA, Inc. 2005. *Final Report: Phase 2 Evaluation of Efficiency Vermont Business Programs.* Montpelier, VT: Vermont Department of Public Service.

Table 5-1
Percentage of Facilities Upgrading Major Systems in Past 5 Years
Premise Weighted, n = 23

Equipment System	% of Facilities
Heating and Ventilation	15%
Cooling/Air Conditioning	1%
Lighting	30%
Refrigeration	15%
None of the above	38%

- **Participation in energy efficiency programs.** Eighteen percent of the sample facilities (+ 10 percent) reported that they had used rebates from their local electric utility or Efficiency Vermont to defray the cost of energy efficiency improvements. This finding is consistent with Efficiency Vermont participation records, which suggest that roughly 6 percent of industrial customers participate each year.

5.2 Efficiency Upgrades to Major Energy Using Systems

The field engineers asked operating staff in the sample facilities regarding whether they had implemented specific energy efficiency measures in their major energy-using systems over the past two years. Table 5-2 summarizes facility staff responses to these questions. The column labeled "n" contains the number of facilities in which the respective systems were present and at which, therefore, the questions were posed. The column labeled "% of Facilities" contains the premise-weighted percentage of facilities whose representatives reported that they had implemented the measure in question within the two years prior to the survey. The right-hand column shows the results weighted by facility electric consumption.

Table 5-2
Energy Efficiency Actions taken in Past Two Years

Equipment System/Measure	**N**	**% of Facilities (Premise Weighted)**	**% of Industrial Electric Use Represented**
Motor Systems			
Replaced standard efficiency motors with NEMA Premium	40	6%	26%
Installed electronic variable speed drives	40	3%	30%
Replaced motor generator set for DC drives with silicon-controlled rectifier	34	1%	1%
Other motor measure	32	3%	5%
Compressed Air Systems			
Reduced leaks from compressed air system	40	16%	40%
Increased air storage	39	3%	5%
Reduced operating pressures	39	3%	4%
Installed part load controllers	39	4%	18%
Equipped air compressors with unloading kits	39	1%	6%
Installed new, rotary screw air compressors	40	6%	33%
Installed engineered nozzles	39	5%	12%
Other compressed air measure	37	1%	5%
Process Heating and Cooling			
Applied pinch technology to rework systems	17	0%	0%
Installed VSD to control fan speed	17	0%	0%
O2 trim controls	17	3%	12%
Adjusted burners and installed excess air controls	17	0%	0%
High-temperature humidity controls on ovens & dryers	17	3%	12%
Used recovered exhaust heat to warm incoming air/water	17	3%	12%
Other	14	0%	0%
Lighting			
Replaced existing fixtures with higher efficiency equipment	41	3%	25%
Installed improved controls: e. g. time clocks, motion sensor	40	2%	17%
Reduced the number of fixtures installed in existing spaces	41	1%	6%
Other lighting measure	35	2%	3%

As would be expected, the energy-weighted fractions of facilities managers reporting that they had taken the various energy savings measures are generally much higher than the premise weighted results. This finding reflects that larger facilities implement energy efficiency measures much more frequently than smaller ones. This is consistent with findings from the survey of commercial and industrial customers undertaken as part of the Phase 2 evaluation of Efficiency Vermont.[14] The finding also reflects the high portion of industrial facilities in the smallest size categories. Finally, the survey question addressed only two years of activity. Most of the measures involve some level of capital investment and are accomplished most cost-effectively when replacing failed or outmoded equipment. The survey may not have captured the cycle of replacements.

Energy efficiency efforts among the sample firms focused on a small number of measures:

- Replacement of standard efficiency motors with NEMA Premium Efficiency Models: 26 percent (energy weighted);
- Installation of variable speed drives (30 percent);
- Leak reduction in compressed air systems (40 percent);
- Installation of part load controllers in compressed air systems (18 percent);
- Installation of new rotary screw compressors (33 percent);
- Replacement of indoor lighting with more efficient fixtures (25 percent); and,
- Installation of improved lighting controls (17 percent).

These findings are consistent with the results of the supply-side market actor surveys and other information available to us on levels of industrial customer participation in EVT programs**.**

The results summarized in Table 5-2 suggest that there is a great deal of opportunity for improving the efficiency of key energy systems in Vermont's industrial facilities. The kinds of

[14] RLW Analytics and KEMA, Inc. 2006. *Final Report: Phase 2 Evaluation of the Efficiency Vermont Business Programs.* Montpelier, VT: Vermont Department of Public Service.

measures undertaken in significant portions of the industrial facility population represent for the most part “low hanging fruit”. Surveys of supply side actors suggest that the market for many of these measures, particularly NEMA Premium Motors, variable frequency drives, and efficient high bay lighting are already well-developed and in the process of transformation.

The findings displayed in Table 5-2 suggest the presence of two large areas of opportunity for promotion of energy efficiency in Vermont’s industrial sector. The first is to target smaller facilities more effectively, given their large presence in the population. The second is to provide engineering and financial support for system versus component oriented measures. For example, facilities representing only 4 percent of total industrial electric use implemented measures to reduce compressed air system pressures, and only 5 percent increased air storage. Both of these measures require a significant amount of diagnostic engineering to characterize and specify. However, they have the potential produce the large percentage decreases in system energy use through highly cost-effective projects. We found that similarly low portions of customers undertook system-oriented measures for pump and fan systems.

6. Opportunities for Increased Energy Efficiency

In this section we present information on the opportunities for increased energy efficiency among the major energy using systems described in Section 4. The energy efficiency opportunities were identified by the on-site engineers based on what could be observed in a walk-through audit. The tables in this section show the percentage of facilities in which the field engineers were able to determine whether the energy efficiency opportunity was appropriate – that is, technically feasible and likely to be cost effective. The field engineers were also instructed to indicate whether the various measures included in the survey forms were inapplicable or applicable but not likely to be cost effective. The field engineers were not able to make those judgments in a consistent manner given the time available on the site. Therefore, the opportunities quantified in the various tables in this section should be interpreted as a minimum estimate of the potential for the respective energy efficiency measures.

6.1 Indoor 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 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 is consistent with the approach to representing lighting equipment saturation used in Section 4.6. 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.

Table 6-1 presents the ratio-weighted frequencies with which various major lighting energy efficiency measures were identified in the sample facilities. The greatest opportunities for lighting overall exist for upgrading fluorescent tube lighting to HPT-8s and for lighting controls to all lighting types, especially occupancy sensors. Cost-effective opportunities to upgrade to High Performance T-8s were identified in facilities that represent 54 percent of industrial electric consumption; opportunities to upgrade to Standard T-8s were identified in facilities representing 14 percent of consumption. Opportunities to improve controls, primarily through the installation of occupancy sensors, were identified in facilities representing well over half of total industrial electric consumption.

Table 6-1
Indoor Lighting Energy Efficiency Opportunities
kWh Ratio Weighted n=43

Lighting Efficiency Opportunities	% of Industrial Electric Use Represented
Switch to CFLs	17%
Switch to Standard T-8s	14%
Switch to High Performance T-8s	54%
Switch to T-5s	21%
Switch to Pulse-Start Metal Halide	6%
Replace Ballasts with Auto Daylighting	19%
Install Occupancy Sensors	49%
Install Dimmers	10%

Fluorescent Tube Lighting Opportunities. Fluorescent linear tube lighting represents a large portion of the lighting in the industrial sector and substantial opportunity to increase the efficiency. As shown in Table 6-2, the field engineers found that over one half of T-12 lighting can be made more efficient by installing HPT-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 (available in facilities representing almost 80 percent of electric use) may be more difficult to realize. The average age of standard T-8 lighting is nine 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.

Linear fluorescent lighting generally has additional opportunities for savings through the use of better controls. Occupancy sensors were identified as an opportunity for each fluorescent lighting technology.

Table 6-2
Fluorescent Linear Tube Energy Efficiency Opportunities
kWh Ratio Weighted

Energy Efficiency Opportunity	% of Industrial Electric Use Represented
T-12 n=22	
Switch to Standard T-8s	14%
Switch to High Performance T-8s	57%
Switch to T-5s	20%
Switch to Pulse-Start Metal Halide	4%
Replace ballasts with Auto Daylighting	12%
Install Occupancy Sensors	45%
Standard T-8 n=27	
Switch to High Performance T-8s	79%
Switch to T-5s	17%
Replace Ballasts with Auto Daylighting	22%
Install Occupancy Sensors	63%

Indoor HID lighting. While HID lighting was found in almost half of surveyed industrial facilities, opportunities identified by the engineers were limited. This may be due to unique facility characteristics that make linear fluorescent lighting unfeasible, but because 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, we expect that more opportunities exist than were identified in Table 6-3. Occupancy sensors were identified as an opportunity in facilities representing at least one-quarter of industrial energy use.

Table 6-3
Indoor HID Energy Efficiency Opportunities
kWh Ratio Weighted, n=18

Energy Efficiency Opportunities	% of Industrial Electric Use Represented
Switch to High Performance T-8s	20%
Switch to T-5s	11%
Switch to Pulse-Start Metal Halide	5%
Install Occupancy Sensors	27%

6.2 Motor Systems

Table 6-4 displays the prevalence of cost-effective opportunities for implementation of selected energy efficiency measures in the sampled motor systems. The applicability of the measures in individual instances was determined by the field engineers based on information about operations in the sample facility and the engineers' own energy auditing and facilities management experience. The motor system efficiency opportunity identified most frequently was replacement of installed motors with NEMA Premium Efficiency models, which the engineers judged to be applicable for 28 percent of all motors observed. A number of circumstances may render this measure inapplicable, including low annual hours of use or need for special motor configurations not covered by the NEMA Premium Efficiency specifications. The field engineers concluded that VFDs could be applied cost-effectively to 20 percent of the motor systems observed.

Table 6-4
Prevalence of Motor System Energy Efficiency Opportunities, n =43

Efficiency Opportunity	% of Motors
Replace with NEMA Premium Motor	28%
Install VSD	20%
Replace Gen-set for DC drive with silicon controlled rectifier	14%
Other	2%

6.3 Compressed Air Systems

Table 6-5 shows the percentage of compressed air systems in which various efficiency opportunities are available per the judgment of the field engineers. The percentage of systems in which leak reduction is a cost-effective option is likely underestimated. Most compressed air efficiency manuals indicate that 60 – 70 percent of systems are likely to have excess leaks, and leak detection and repair is recommended as a regular maintenance activity for all systems.[15]

Table 6-5
Availability of Efficiency Opportunities, n = 42

Energy Efficiency Opportunity	% of Systems*
Install Engineered Nozzles	43.1%
Reduce Leaks	31.2%
Increase Air Storage	25.8%
Reduce Operating Pressures	21.8%
Install Rotary Screw Air Compressors	21.6%
Install Part Load Controllers	5.1%
Install Unloading Kits	3.0%
Other	1.7%

* Adds to > 100% due to presence of multiple efficiency opportunities in single systems.

6.4 Cooling

Table 6-6 shows the energy efficiency opportunities for cooling equipment identified in the walk-through inspections. Implementation of demand control ventilation and replacement of damper and vane controls with speed control were each identified as potential measures in 10 percent of the facilities. Replacement of ventilation fans with more efficient models was identified as a potential measure in 7 percent of facilities.

[15] See for example: U. S. Department of Energy, Office of Energy Efficiency and Renewable Energy. 2000. *Improving Compressed Air System Performance: a sourcebook for industry.*

Table 6-6
Overall Space Cooling Energy Efficiency Opportunities
Premise Weighted n=18

Opportunity Appropriate in Facility	% of Facilities
Reduce fan size to better match load?	0%
Replace damper and vane controls with electronic speed controls?	10%
Replace fan with more efficient model?	7%
Install economizer	1%
Demand control ventilation	10%
Lower condensing pressures using existing controls	0%
Control sequence controllers to increase suction pressure	0%
Install dual load limit relay to allow screw compressor to run at full load?	0%

6.5 Space Heating

Table 6-7 shows the percentage of facilities in which the field engineers identified cost-effective opportunities for selected space heating energy efficiency measures. The most frequently identified measure was to install set-back controls on thermostats to automate temperature control. This measure is cost-effective in 46 percent of the sample facilities. Other frequently identified measures included replacement of furnaces and boilers to upgrade efficiency, more regular tuning of burners, and installation of demand control ventilation systems and economizers.

Table 6-7
Space Heating Energy Efficiency Opportunities
Premise Weighted n=33

Energy Efficiency Opportunity	% of Facilities
Install Set-back Controls	46%
Replace Furnace/Boiler	42%
Regularly Tune Burners	28%
Install Demand Control Ventilation	21%
Install Economizer	20%
Replace Steam Traps	3%
Other	2%

7. Market Share of Energy-Efficient Equipment

7.1 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.

7.2 Motor Supply Chain Interviews

7.3 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 7-1 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 7-1 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 7-1
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.

7.3.1.1 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.

7.3.2 Overview of the Motor Market in Vermont

Ninety percent of the electric motor sales[16] 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

[16] 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.

7.3.2.1 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 7-2 shows the percent of respondents' motor sales in the past twelve months that were NEMA premium efficiency motors by horsepower.

Table 7-2
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.

7.3.2.2 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.

7.3.3 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[17], 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

[17] 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.

7.3.4 Variable Frequency Drives (VFDs)

7.3.4.1 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.

7.3.4.2 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.

7.3.5 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.

7.4 Lighting Supply Chain Interviews

7.4.1 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 7-3 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 7-3 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 7-3: 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.

7.4.1.1 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.

7.4.2 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 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.

7.4.3 HID and High Bay Fluorescents

7.4.3.1 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[18] 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

[18] 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.[19] The majority of installations were either standard efficiency T8s (25 percent) or T5s (roughly 40 percent).

7.4.3.2 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[20], 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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[19] 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.

[20] 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.

7.4.4 Non-High Bay Fluorescents

7.4.4.1 Sales of Non-High Bay Fluorescent Lighting[21]

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.

[21] 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.

7.4.4.2 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[22].

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

[22] 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?).

7.4.5 Incandescent Lamps and Compact Fluorescent Lamps

7.4.5.1 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.

7.4.5.2 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.

7.4.6 LED Lighting

7.4.6.1 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.

7.4.6.2 Drivers of LED Lighting[23]

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.

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

7.4.7 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.

7.5 HVAC Supply Chain Interviews

7.5.1 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 7-4 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 7-4 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 7-4
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.

7.5.1.1 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.

7.5.2 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.

7.5.3 Cooling Equipment (not including chillers)

7.5.3.1 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[24]. The first column in Table 7-5 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 7-5
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%	

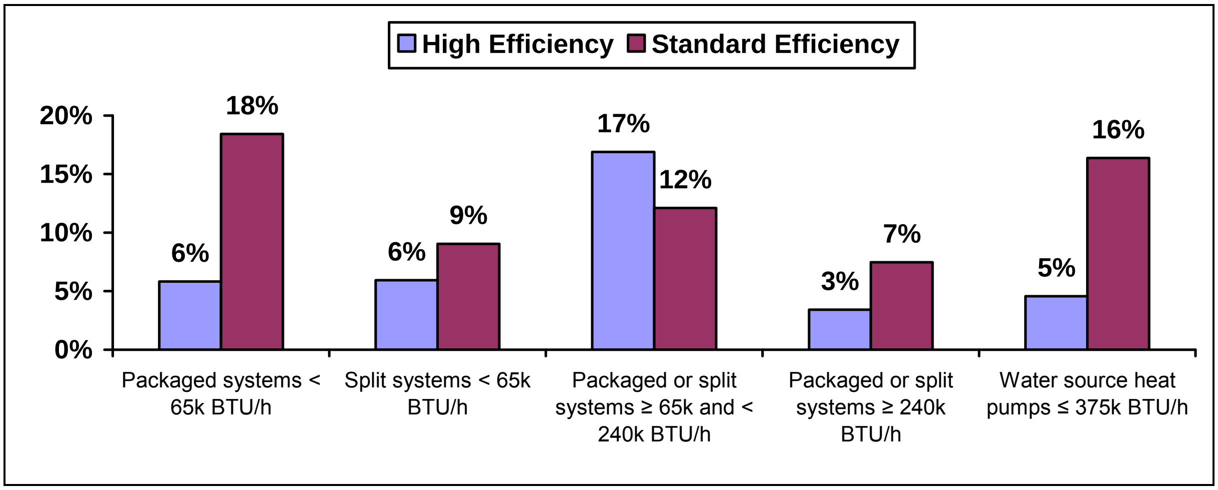
[24] EVT provides rebates for high efficiency equipment of the sizes and types listed in Table 7-5 that meets specific standards. The contractor respondents were asked to use the specific EVT cut points to indicate high efficiency.

The first column in Table 7-5 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 7-5 provides a slightly different view of these data. Within each technology category (i.e., within each row in Table 7-4) 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 7-1
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 7-1). 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 7-1. 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 7-1 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.

7.5.3.2 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.

7.5.4 Chillers

7.5.4.1 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.

7.5.4.2 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."

7.5.5 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.

8. Summary and Recommendations

8.1 Facility Characteristics

8.1.1 General

- ***Most of Vermont's industrial facilities are very small.*** Overall, 44 percent of manufacturing facilities employ fewer than 5 persons. An additional 31 percent employ from 5 to 19 persons.
- ***Five industries, out of the 21 NAICS categories, account for over 53 percent of manufacturing facilities.*** These are fabricated metals, non-metallic mineral products, wood products, food processing, and printing and related activities.
- ***Vermont industrial facilities are of relatively recent construction.*** According to the results of the survey, only 8 percent of manufacturing facilities were built before 1970. Only 27 percent were built before 1980. By contrast, 62 percent of commercial facilities in Vermont were built before 1970.
- ***A high proportion of Vermont industrial establishments lease their facilities.*** According to the results of the survey, 31 percent of Vermont's industrial establishments lease their facilities, versus 14 percent for commercial establishments. These establishments may experience split incentives in regard to investing in the energy efficiency of their facilities.
- ***Many Vermont industrial are currently running one shift.*** The median annual operating hours for the facilities in the sample was 2,400, means that roughly half of Vermont's industrial establishments were running one full shift or less at the time of the survey. However, the average operating hours for the entire sample was 4,195, which suggests that the remaining one-half of the facilities were operating an average of 5,980 hours per year, which corresponds to three shifts.

8.1.2 Characteristics and Installed Capacity of Major Energy Systems

Electric Motors

- On average, 42.3 $\pm$ 17.1 integral horsepower electric motors are installed in Vermont industrial facilities.

- The average installed capacity of motors in industrial facilities is 421 horsepower (HP), ± 151 HP.
- Motor equipment is more highly concentrated in generic centrifugal applications such as pumps, fans, and compressors in Vermont than in the country as a whole: 50 percent of units versus 37 percent.
- The saturation of NEMA Premium Efficiency motors 10.3 percent of total installed units, 21.6 percent of total installed HP.
- The prevalence of variable loads in the population of motorized systems is 40.6 percent of installed HP. Variable loads are spread fairly evenly among motor size catetgories.
- The saturation of variable frequency drives (VFDs) is 34 percent of the total HP driving variable loads. The saturation of VFDs increases with motor size.

Compressed Air Systems

- Eighty-six percent of Vermont industrial facilities have a compressed air system installed. Using the energy weighting system, industrial facilities representing 94.5 percent (± 5.9 percent) of industrial electricity usage in Vermont have an electric-powered compressed air system in place.
- The average number of compressors installed was 2.5, with an 80 percent confidence interval of ± 0.5 units.
- The weighted average horsepower of the systems observed was 51, with an 80 percent confidence interval of ± 22 hp.
- The most common application of compressed air, found in facilities representing 49.2 percent of industrial electric consumption, is to power pneumatic controls. The second most common application is air tool drive, which is found in facilities representing 25.4 percent industrial electricity use. The high saturation of these end-uses, neither of which requires significant compressed air capacity, is consistent with the relatively modest size of the systems installed.
- Over 18 percent of the facilities used compressed air for open blowing which is, in most cases, an inefficient use of compressed air for purposes better served by mechanical systems.
- Compressed air systems with air storage capacity are present in facilities that represent 75 of industrial electric consumption or in roughly 79 percent of all compressed air systems, weighted by facility electric use.

- The weighted average capacity of the compressed air storage systems observed was 348 gallons, with an 80 percent confidence interval of ± 134 gallons. Given the size of the average size of the system installed, this air storage capacity is generally sufficient to provide load management capability.

- Most of the compressed air systems observed have simple start/stop controls. Coupled with the observed level of air storage available, these are adequate to provide efficient load control.

Process Heating and Cooling

- Approximately 46 percent of industrial facilities in Vermont have equipment dedicated to process heating installed. A significant portion of the output of other central heating systems is also used for process heating.
- Process heat is delivered by a wide range of equipment. Furnaces, steam boilers, hot water boilers, direct-fired devices, and electric resistance heaters are all present in more than 20 percent of facilities with process heating equipment installed.
- Dedicated process heating equipment was observed in only two facilities, which does not provide a sufficient basis for generalization as to characteristics or installed capacity.

Space Cooling

- Sixty-two percent of industrial facilities have space cooling systems installed.
- A number of facilities contain more than one kind of system. Room air conditioners were the most frequently observed type of system; they were found in 29 percent of the sample facilities. Packaged HVAC systems were the next most prevalent cooling equipment type, observed in 26 percent of facilities. Heat pumps were observed in 17 percent of utilities. Large, built-up central cooling plants (Other Central Cooling Plant) are found in relatively few facilities.
- Room air conditioners and packaged HVAC each accounted for 24 percent of the equipment units observed, and split-system HVAC accounted for another 20 percent of total units.
- Average tons of capacity installed per facility: 36.9 tons
- Average tons of capacity used for space cooling: 19.9 tons ± 9.6 tons
- Average tons of capacity installed per unit: 9.5 tons ± 7.9 tons.

- The average the installed capacity of the central cooling plants is relatively small – 37 tons ± 12.4 tons -- which suggests that most of the cooling installations are used to condition relatively small spaces. However, the large relative confidence interval as well as the relatively high percentage of capacity used for applications other than space cooling reflects presence of some larger installations in the sample. Indeed, there were several plants in the sample with 500 to 1,000 tons of installed central cooling capacity.
- According to facility occupants, 68 percent of facilities with central cooling plants operate them on a highly seasonal basis: 13 to 26 weeks per year. In the sample, systems representing 23 percent of facilities operated more for the full year: the majority of these systems provided primarily process cooling. Thirty-one percent of central cooling systems operate 120 or more hours per week.

Space Heating

- Eighty-one percent of industrial facilities have central space heating systems. Those that do not have primarily outdoor operations – for example gravel pits and quarries.
- The most prevalent space heating equipment type is direct, which, taking together radiant and other types of direct heaters (direct fired space heaters) are present in 36 percent of facilities. This is consistent with the heavy representation of small facilities in the population. More mechanically complex systems such as hot water and steam boilers serve a combined 22 percent of facilities.
- Natural gas is the most common primary heating fuel, accounting for 46% of facilities. Propane and fuel oil each account for 26 percent of the remaining facilities, with wood providing fuel for primary heat in one percent of facilities. Only 18 percent of facilities have secondary heating systems or fuel capability. Most of these are natural gas.
- The average installed capacity per facility is 1,754 MBtu per hour. The average capacity of individual units is 854 MBtu per hour.
- The average heating system operating hours reported by occupants of the sample facilities was 1,917 per year, ± 514. These findings are consistent with relatively low hours of facility operation.
- The sample facilities show a wide range of variation in the application of output from the central heating plant for space versus process heat. On average, occupants reported that 59 percent of central heating plant output was used for space heating.

Interior Lighting

- Linear fluorescent fixtures are by far the most common lighting technology in Vermont's industrial facilities, accounting for 61 percent of all weighted occurrences. Compact fluorescent and other fluorescent fixtures account for an additional 7 percent of total occurrences. High Intensity Discharge (HID) fixtures are the next most common type, with 14 percent of total weighted occurrences.

- T8 fixtures have the highest level of saturation among the basic fluorescent technologies. T8 fixtures of various kinds account for 58 percent of the total ratio-weighted occurrences of fluorescent fixtures; T12 for 33 percent; and T5 for 4 percent. Unidentified fluorescent tubes account for an additional 9 percent of total weighted occurrences.

- Overall, we estimated the lighting power density of the sample facilities at 0.76 Watts per square foot, with an 80 percent confidence interval of ±0.12 Watts per square foot. This figure is likely to be low due to the difficulty of recording all light sources in the sample spaces. The maximum standard LPD for industrial facilities per the *Vermont Guidelines* is 1.30 Watts per square foot.

- More than 95 percent of indoor lighting is controlled by manual on/off switches and more than 95 percent is used for area lighting. This suggests that lighting controls represent an untapped resource of energy savings.

- On average, lighting fixtures in Vermont industrial facilities are between seven and eight years old. T12 fixtures average almost 13 years old, while Standard T8s average closer to nine years, HP T8s around five years and T5s a little more than 2 years old.

- Most of the ballasted lamps in Vermont Industrial facilities have electronic ballasts; however most T12s, and almost half of HIDs have standard magnetic ballasts

8.1.3 Recent Facility and Equipment Upgrades

- Thirty-seven percent of the sample respondents, ± 21 percent, reported that they had made major renovations or additions to their facilities in the past five years, for an average rate of 6.2 percent per year.

- Overall, 62 percent of facilities report that they made upgrades over the past five years to at least one of the following equipment systems: heating and ventilation, cooling and air conditioning, lighting, and refrigeration. Thirty percent of facilities reported that they had made upgrades to their lighting equipment, 15 percent had made upgrades to refrigeration and heating/ventilation systems.

- Eighteen percent of the sample facilities (± 10 percent) reported that they had used rebates from their local electric utility or Efficiency Vermont to defray the cost of energy efficiency improvements. This finding is consistent with Efficiency Vermont participation records, which suggest that roughly 6 percent of industrial customers participate each year.

8.1.4 Recent Implementation of Energy Efficiency Measures

Energy efficiency efforts among the sample firms focused on a small number of measures:

- Replacement of standard efficiency motors with NEMA Premium Efficiency Models: 26 percent (energy weighted);
- Installation of variable speed drives (30 percent);
- Leak reduction in compressed air systems (40 percent);
- Installation of part load controllers in compressed air systems (18 percent);
- Installation of new rotary screw compressors (33 percent);
- Replacement of indoor lighting with more efficient fixtures (25 percent); and,
- Installation of improved lighting controls (17 percent).

On a premise-weighted basis, the frequency of implementation for these measures is much lower.

These findings suggest the presence of two large areas of opportunity for promotion of energy efficiency in Vermont's industrial sector. The first is to target smaller facilities more effectively, given their large presence in the population. The second is to provide engineering and financial support for system versus component oriented measures. For example, facilities representing only 4 percent of total industrial electric use implemented measures to reduce compressed air system pressures, and only 5 percent increased air storage. Both of these measures require a significant amount of diagnostic engineering to characterize and specify. However, they have the potential produce the large percentage decreases in system energy use through highly cost-effective projects. We found that similarly low portions of customers undertook system-oriented measures for pump and fan systems.

8.2 Energy Efficiency Opportunities

Our analysis of energy efficiency opportunities focuses on those found in generic systems such as lighting and centrifugal motor applications. Systems such as process heating, process cooling, and refrigeration proved to be too complex to characterize on the basis of a short visit and too heterogeneous to characterize in the aggregate based on a small number of observations.

Interior Lighting

- Cost-effective opportunities to upgrade to High Performance T-8s were identified in facilities that represent 54 percent of industrial electric consumption.
- Opportunities to upgrade to Standard T-8s were identified in facilities representing 14 percent of consumption.
- Opportunities to improve controls, primarily through the installation of occupancy sensors, were identified in facilities representing well over half of total industrial electric consumption.
- High bay lighting was present in facilities representing roughly one-half of total industrial electric consumption. Opportunities to upgrade the efficiency of HID lighting were identified in facilities representing roughly 30 percent of industrial consumption. The presence of cost-effective opportunities to improve high bay lighting efficiency is likely higher given recent trends in cost and technology.

Motor Systems

- The motor system efficiency opportunity identified most frequently was replacement of installed motors with NEMA Premium Efficiency models, which the engineers judged to be applicable for 28 percent of all motors observed.
- The field engineers concluded that VFDs could be applied cost-effectively to 20 percent of the motor systems observed.
- The engineers identified supplemental tank insulation and pipe insulation for most domestic hot water heating systems, regardless of heating fuel.

Compressed Air Systems

Install Engineered Nozzles	43.1%
Reduce Leaks	31.2%
Increase Air Storage	25.8%
Reduce Operating Pressures	21.8%
Install Rotary Screw Air Compressors	21.6%

- The field engineers identified the following potential energy efficiency measures in 20 percent or more of the compressed air systems observed: install engineered nozzles (43 percent), reduce leaks (31 percent), increase air storage (26 percent), reduce operating pressures (22 percent), and install rotary screw air compressors (22 percent).

Space Heating and Cooling

Space cooling equipment with significant capacity was found in fewer than half of the sample facilities. The field engineers identified only limited opportunities for efficiency improvements in this end use. Significant opportunities were found for improving the efficiency of central heating equipment including the following:

- Install set-back controls (46 percent of facilities, premise weighted);
- Replace the furnace or boiler with a more efficient model (42 percent);
- Tune boilers (28 percent);
- Install demand control ventilation (21 percent); and,

* Install economizers.

8.3 Recommendations

As we found in the baseline survey of existing commercial facilities, the distribution of Vermont industrial facilities 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. Small businesses experience 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.

8.3.1 Customer-oriented efforts to increase measure adoption

Program delivery. This survey identified a large volume of potential energy efficiency improvements in generic lighting, motor, and compressed air systems among both small and larger customers. Market research and the experience of energy efficiency program administrators in other jurisdictions suggest that different program vehicles may be needed to reach small versus large customers. Smaller customers in particular are constrained by lack of personnel resources for identifying and managing energy efficiency improvements. Approaches that have proven to be effective in promoting adoption of common prescriptive measures by small businesses include:

* Direct installation programs, in which the sponsor assumes responsibility or contracts for identification of opportunities for a small menu of measures, specification of installations, engagement of contractors, and management of contractor payment.
* Vendor-driven programs, in which contractors take responsibility for the marketing the direct-installation services described above.

These approaches have been applied successfully in a number of jurisdictions and markets to accelerating adoption of efficient lighting, HVAC, and, in a few cases, motors.[25]

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[25] For extensive documentation of direct installation programs for small businesses, see Eco Northwest and Itron, Inc. *Final Report: Evaluation of the SCE Small Business Connection Program.* Rosemead, CA:

Based on previous evaluations, we are aware that Efficiency Vermont has done a good job of recruiting larger industrial customers into its programs through direct personal representation and custom rebate offers. The results of this survey suggest that additional savings could be developed through these customer relationships and program efforts by making sure that all lighting and motors opportunities are addressed over time as large customers carry out upgrades to their facilities.

Knowledge barriers. As discussed earlier, a number of factors may help explain the finding that very few industrial facilities had undertaken common efficiency upgrades to key energy systems. However, even if those mitigating factors are taken into account, this finding suggests that there may be some knowledge barriers at work in inhibiting adoption of both capital and operating measures. Potential program approaches to address these barriers include:

- Provision of training in optimization of common systems such as pumps, fans, and air compressors. These services are most likely to be effective in achieving actual energy savings when marketed to larger firms with dedicated facility management staffs. We are aware that Efficiency Vermont has sponsored such trainings.
- Support of vendor provision of system optimization and maintenance services, such as HVAC and compressed air system diagnostics.

8.3.2 Vendor-oriented approaches

Analysis of the results of the supply channel surveys identified the following opportunities to support vendors in their promotion of energy-efficient equipment and services.

- 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.

Southern California Edison. 2007. For analysis of a vendor-oriented replacement/retrofit program, see: Summit Blue Consulting, *Market Evaluation: MotorUp Program.* Albany, NY: New York State Energy Research and Development Authority. 2005.

- 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 promoting the replacement of internal HID lighting with fluorescent tube lighting.
- 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.