Generating A State-Wide Baseline Market Characterization For Commercial And Industrial Customers

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ABSTRACT

This paper will discuss the research methodology used to create a commercial and industrial (C&I) market characterization and baseline assessment of energy consuming equipment in customer facilities in Massachusetts. Under the guidance of the local Energy Efficiency Program Administrators (PA's) and state-level Energy Efficiency Advisory Council (EEAC) EM&V oversight consultants, in 2016 the study team completed the largest evaluation study ever undertaken for Massachusetts[1]. The goal was to conduct comprehensive on-site assessments of 800 C&I facilities across 189 strata including the most complex facility types such as hospitals, college campus buildings, manufacturing facilities, and professional sports venues. Data was collected for a full range of end-uses, from standard end uses such as lighting, HVAC and water heating, to less often collected end-uses such as industrial process and industrial sized refrigeration. To achieve the research goals, the study team needed to employ innovative recruitment and sampling strategies as well as develop sophisticated weighting methods to conduct the analysis. The inventory of individual customer facilities resulted in a wealth of data that was used to provide a more complete picture of electric and natural gas customers and equipment in their facilities. In this paper we discuss the careful planning and methodologies used in this study as well as lessons learned from developing a robust sample while dealing with inconsistent or incomplete data; recruiting 800 different customers across 189 strata while maintaining customer segment quotas; crafting an on-site data collection instrument with more than 800 possible data points that is both user-friendly and intuitive to field staff; and developing sampling weights that accurately reflect the statewide C&I population while limiting bias.

Introduction

Background

In 2014, the study team, led by DNV GL, undertook the Massachusetts Commercial and Industrial (C&I) On-site Assessments and Market Share and Sales Trends (MSST) Study. This study was designed to help the Massachusetts Program Administrators (PA's) and the Energy Efficiency Advisory Council (EEAC) better understand the Commonwealth's existing C&I building and equipment stock, and to identify the greatest opportunities for expanding the statewide energy efficiency program portfolio and encouraging Massachusetts businesses to make further energy efficiency improvements. The study team included DNV GL, Itron, Inc., APPRISE, Inc., ERS, Inc., and NMR.

To complete this effort, the study team conducted comprehensive on-site assessments of C&I buildings associated with 800 electric accounts. The buildings represented 13 business types, including the most complex facility types in the market—hospitals, college campus buildings, manufacturing facilities, and professional sports venues. The sample was also divided into three electric consumption categories[2] for each business type: < 500,000

[1] The final report can be found at: http://ma-eeac.org/studies/commercial-and-industrial-studies/

[2] Consumption is based on electric billing data and does not include net metering or on-site electricity production from on-site photovoltaics.

kWh, 500,000-4,500,000 kWh, and > 4,500,000 kWh. Information was gathered on 9 distinct equipment types at each of the 800 sites. A total of 43,420 records of end-use equipment were gathered and 1,592 industry-specific pieces of equipment were inventoried, each with their own set of variables.[3] From the outset, the study was intended to collect information on the highest priority electric and non-electric-fueled end uses for the PA's, including lighting, heating, ventilation, air conditioning (HVAC), refrigeration, and domestic water heating systems,[4] as well as kitchen equipment, office equipment, energy management system (EMS) equipment, and on-site generation systems. For process-related equipment the study team collected information on compressed air systems, process heating, process refrigeration/cooling, injection molding machines, wastewater treatment systems, motors/drives, and others. The study team collected vital business and equipment information to the extent possible, including equipment make and model data. As part of the MSST Study, the study team analyzed recent purchase information (2009-2015) for lighting, HVAC, water heating, and EMS, and assessed sales trends and market shares for recently purchased standard and high-efficiency equipment for these equipment types.

To conduct the analysis, the study team needed to create a sophisticated set of 96 distinct weights to expand the 800-site sample to the total Massachusetts electric customer population. In summing up building equipment categories (such as internal lighting and external lighting) by size, business type, and kWh usage, these weights achieved a level of precision and bias-elimination superior to traditional weighting approaches, which merely compute a single weight to relate the sample data back up to the population.

To assess the distribution of equipment efficiencies across the state, the study team researched the federal efficiency standards and lighting information from the Consortium of Energy Efficiency and gathered information about the PA Energy Efficiency Program incentive standards and customer participation from 2011 to 2014. The study team collected the information necessary to evaluate and classify each of the different measures (lighting, cooling, heating, and water heating) per federal standards (at, below, or above), by fuel, unit size, and technology type, and by program eligibility. The study team then compiled the information on federal standards, purchase date, fuel type, technical specifications, customer size, and program participation so program planners could identify trends and act on them.

The final report included information on installed equipment efficiencies relative to PA-sponsored program eligibility requirements to highlight where opportunities for savings possibly remain, and where PA's may need to adjust programs to propel the market further forward. The study team were also able to identify where PA's may need to introduce programs or improve education to help motivate Massachusetts businesses to purchase more high-efficiency technologies. The analysis and report allow for a deep, nuanced understanding of C&I customer equipment stock efficiency, behaviors, and areas for potential energy efficiency improvements throughout Massachusetts. The findings may also be used for other ongoing and future study efforts to better understand C&I customers and the share of incentivized high efficiency equipment.

Scope

The ultimate goal of the C&I On-site Assessments Study and the MSST was to provide confirmed customer-level information that can be used to help focus the Massachusetts C&I energy efficiency programs' efforts as they continue to grow and expand offerings in the coming years. This study effort was built upon a previous study of C&I customer characteristics and practices that was conducted using a telephone survey to gather customer information. Using both the telephone survey results, and the results from the C&I Customer On-site Assessments study, the Massachusetts PAs were able to gain a better understanding of the existing C&I building market in Massachusetts.

3 Variables included systems' age, condition, and efficiency levels as well as information on building operating practices.
4 High-priority end uses were identified through stakeholder feedback and annual energy efficiency program savings.

Further, through the MSST portion of the study, market share and sales trends for recently purchased equipment was obtained.

The on-site data collection efforts focused primarily on collecting information on electric and non-electric energy end-uses that are the dominant sources of both existing and potential savings for the energy efficiency programs. This includes lighting, HVAC and motor/drives for the electric programs, and HVAC and hot water production for gas programs. Information on refrigeration systems, compressed air systems, other process-type equipment, and on-site generation was also collected from businesses where these systems were found. The raw data collected during the site visits included system information such as equipment age, condition, and level of efficiency, as well as premise-level information such as general business type, operational schedules, and maintenance practices.

To develop a comprehensive cross-section of data from a range of facility types and sizes, the study team conducted 800 site visits. Data collection required careful management of the sample to ensure that an adequate representation of small, medium and large customers was achieved, as well as an adequate representation of customers within each PA's service territory. Large customers are often the most difficult to recruit and for this study many of the large business-type strata had a limited sample. The study team devised a number of strategies to overcome these challenges and recruit the desired number of businesses which are described in the methods section of the paper.

The final study report summarized the analysis of those highest- priority electric and non-electric end uses at C&I facilities. For process-type equipment information was provided on compressed air systems, process heating, process refrigeration/cooling, injection molding machines, wastewater treatment systems, motors, and others. The study team also presented recent (2009-2015) purchase information for lighting, HVAC, water heating, and EMS, and assess sales trends and market shares for recently purchased standard and high-efficiency equipment. While these analyses provided an understanding of what equipment exists in C&I facilities, the data from this study can also be useful for supporting updates to energy conservation measure baselines, or assessing prospective additional energy efficiency opportunities at program participant sites, which may be extrapolated to the statewide population.

Further, the study team compared the C&I Customer On-site Assessment results against the results from the original C&I customer telephone survey. This comparison helped to characterize the reliability of self-reported data for consideration when developing future studies. There were 943 responses to the telephone survey with more than half of the respondents being smaller customers (customers with an average demand below 200 kW). The telephone survey was focused on understanding customer operations and maintenance practices as they pertain to energy-using equipment and less so on detailed equipment characterization and saturation. Lighting, HVAC cooling and heating systems, EMS, and hot water systems are the areas where direct comparisons of data could be made between the two studies. While there were similarities in reported data, the comparisons indicated that when seeking technology-specific data, self-reported data is generally unreliable, with vast differences in linear lighting technologies, the number of LEDs at customer facilities, and types of water heating systems.

Methodology

The study team designed the original sample based on two separate frames: the 2013 C&I billing data and the 2011 C&I billing data[5]. A third sampling frame was added to accommodate the needs of a technical potential study in the Cape Light Compact territory. The sample represented customers geographically distributed across the state of

[5] During the C&I customer telephone survey conducted in 2013, 443 customers indicated that they were willing to participate in the future on-site assessments. The sample that was used for the telephone survey was based on 2011 billing data and therefore that was used as one of the sample frames for the on-site assessments.

Massachusetts. It was not based on PA customer territories; however, recruitment was tracked so that a sample of customers proportional to the customers served by each PA was visited in each electric PA territory. The key information required to develop the sample for the on-site assessments included business type and annual electric consumption.

Because PA electricity sales cover the entire state of Massachusetts (minus those areas served by municipal electric utilities) and natural gas customer accounts cannot be readily matched to electric customer accounts, the sample was selected based on electric accounts only. The total population of electric accounts in the 2013 billing and tracking database was 313,340. To avoid contacting accounts with little to no energy consumption, the study team removed accounts with annual consumption of less than 2,000 kWh. This resulted in a decrease of 84,017 accounts in the population. The average annual energy usage in each of these accounts was less than 800 kWh representing less than 0.25% of the total annual kWh consumption. The resulting population was 229,323 accounts.[6] While all of these accounts were used in the sample design, according to the 2013 data set, only approximately 78% of customer records were assigned a business type. An additional business type category was created for the unknowns. A statewide sample design of 800 accounts was developed to represent the C&I market including the customers in Cape Light Compact's territory. The sample was allocated to the business type and usage (kWh) strata in a manner that maximizes precision of resulting estimates. The stratification included 14 business types and 3 usage strata including other and unknown, and split education and healthcare between campus and non-campus accounts and hospital and non-hospital accounts respectively. The building type classifications follow closely the definitions used for CBECS. The 3 usage strata allocated electricity consumption so that each group contained approximately one the C&I population's electricity usage.

The study team used Model Based Statistical Sampling (MBSS)[7] to estimate the optimal sample size for each stratum based on the variability of the kWh between customer accounts within the stratum and the total stratum kWh. Once the sample sizes were established, members of each stratum were then randomly assigned a contact order for the on-site data collection. The study team also used this system to estimate expected relative precisions for the sample design. DNV GL used an error ratio of 0.5 to estimate expected precisions, and an error ratio of 0.7 to estimate "worst case" expected precisions. These bounds follow typical sampling design practices for evaluation studies.

Following the development of the sample design the data collection instrument was developed. The instrument was based on a similar instrument used in California so that data from the studies could be compared, if desired. The instrument was designed to collect general premise-level information, including building ownership type, operating hours, business specific characteristics, and maintenance practices for HVAC equipment, as well as extensive information on the major energy-using equipment within a building. The instrument was programmed into an iPad database application. The iPad application helped to streamline data transfer from the field to the master database, facilitate equipment photo labeling, and improve the overall quality and consistency of the data gathered. The study team initiated the data collection activities in August 2014.

Initial data collection focused on the customers in the low (below 500,000 kWh) consumption range and mid-level kWh consumption range (500,000 – 4,500,000 kWh). The intent of focusing our efforts on these customers first was to ensure that the data collection tool functioned properly before visiting the more difficult, larger customer sites. Larger customers tend to be more difficult to recruit for these types of study efforts and can also be some of

6 The counts here reflect the sample frame at the time the original sample was selected. Some additional supplementation of the sample did occur during data collection using more current billing records. Section 1.4 and Appendix A of the report presents the final counts of the survey eligible population by kWh size and industry.

7 Model-based stratification is a method for producing an efficiently stratified sampling plan based on a value known for members of the population. For this study, it was annual consumption.

the most complex buildings to gather adequate data on. It is often a challenge to find the right contact and often once the right contact is reached, they need to seek authorization from upper level management for our staff to visit the facility. As the study team worked through the sample and various strata, an enhanced strategy to assist with recruitment of larger customers needed to be developed. The team engaged PA account managers from Eversource and National Grid who work closely with larger customers. It was useful to leverage their relationships and have them assist in encouraging customer participation in the study. As part of our outreach to account managers the study team:

- Provided an introductory letter to the account managers summarizing the study and its objectives
- Provided a list of large customers that the study team would be attempting to recruit in the upcoming months in respective PA territories
- Followed up with both Eversource and National Grid account managers to further review the study intent and methods, and answer any questions they may have about the study

As data collection progressed, the study team continued to refine recruitment strategies while being careful not introduce selection bias. This was done by identifying customers in the randomized sample who were likely to be contacted by recruiters and engaged account managers who had relationships with property management firms who manage multiple properties within the sample. They also had National Grid and/or Eversource account managers identify and reach out to multi-site national accounts in the sample. As the recruitment of customers proceeded it became clear that relying on account managers would not be enough and new recruiting strategies were explored. The study team undertook several additional actions to improve recruitment results, including:

- Adjusting recruitment procedures to maximize the likelihood of reaching customer contacts (e.g., USPS Priority mailing introductory letters to customer contacts and allow recruiters more flexibility on the timing of calls)
- Offering site summary reports as an additional incentive
- Allowing for some flexibility in the quotas for various strata when recruiting
- Engaging the recruiting staff to assist with hard scheduling the on-site visits

The additional strategies that the study team members implemented proved effective. The study team recruited 955 customers to complete 800 site visits; oversampling was required due to sample attrition (e.g., some customers recruited were non-responsive to requests to schedule a visit after initial recruitment, and others cancelled after being recruited).

The study team proceeded to visit each of the 800 sites and inventory the major energy consuming equipment. Field staff were onsite to collect the desired information for no more than one day. When necessary, multiple surveyors were deployed to the same site to ensure that the information was captured within that timeframe. Certain businesses posed significant challenges to field staff, including individual buildings, universities that had sites with multiple tenant sub-meters; large buildings with limited access; and facilities that required special clearances. For these situations, field staff used sampling protocols. For multi-metered buildings, where the energy consumption of individual tenants was monitored by a private (not utility-owned) sub-meter, field staff were to:

- Survey all common and other accessible areas
- Survey unique tenant spaces representing a significant percentage of building floor area
- Identify tenants with similar space requirements and floor areas, business hours, and equipment needs, and collect information from a sample of these tenants that was a best representation of the site

For large facilities and/or facilities with limited access, field staff attempted to collect as much information as possible on the central HVAC equipment and then collected all other end use equipment information on approximately one third of the facility. Field staff noted in the data collection instrument that the information is a sample of the equipment onsite and indicated the percentage sampled. During the data compilation phase, equipment counts were scaled up based on the area surveyed and the total area represented by the sample. For campus situations (e.g., colleges and universities, and large hospitals), the team developed a sampling protocol similar to that for large facilities, finding a building or buildings (3 maximum) that best represent that campus. The information collected from these facilities was then scaled up to represent the entire premise.

Following the field data collection effort, the study team compiled and analyzed the data. In preparation for the analysis, an extensive quality control (QC) process was used. After being uploaded to the DNV GL On-Site Assessment Master Database, all sites were assigned to a senior engineer who was responsible for the QC review. The QC reviewer:

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

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

During the analysis, the data were reviewed again to ensure quality and consistency. This involved checking the number of records for each data point once the master dataset was exported for analysis, running a proc-univariate function to look at minimum, maximum and median results for key variables, checking for outliers, and assessing whether or not the means were sensible. Further, the study team checked for missing values, negative values, and that percentages were correct. Finally, the study team checked to make sure that the number of sites or records matched what was expected, ensured there were no duplicate entries, and confirmed that the equipment found in the buildings made sense for that business type.

To create unbiased population estimates, three sample weights were created for all businesses considered respondents to this data collection effort. Data from the sample were used to generate business-level, site-level, and kWh-level weights for this analysis. In most instances, a responding business reflected data for a single site in the original sample frame but there were some cases that included data for more than one site. The 800 responding businesses in this study accounted for 897 sites and 1,790,106 MWh of annual consumption in the original target population. As noted previously, the sample for this study was selected from three sources:

- Massachusetts C&I Customer Telephone Survey (based on 2011 C&I billing data)
- Cape Light Compact 2014 Penetration, Potential and Program Opportunity Study
- Massachusetts 2013 C&I billing data

The samples from the Massachusetts C&I Customer Telephone Survey and the Massachusetts 2013 C&I billing data were randomly selected from a stratified sample frame that covered the same target population (i.e., those geographical areas served by National Grid, Eversource, and Unitil). The sample from the Cape Light Compact

Technical Potential Study was selected from a frame that covered businesses in the Cape Light Compact region. Important aspects of the sample to note are:

- The samples from the three sources covered the entire target population of interest (i.e., businesses across the Commonwealth of Massachusetts with annual energy consumption greater than 2,000 kWh).[8]
- Since every business in the target population had some non-zero chance of being selected for this study, estimates generated from the respondent data were not necessarily biased due to some trait inherent in the study's sample design.

The final target population for this study included 250,796 businesses and 250,893 sites. Billing data revealed that the businesses in the target population had an annual energy consumption of 28,332,050 MWh.[9] This covered 99.7% of electricity sold by the PA's in 2013. The final calibration of the sample weights adjusted the weights so that the weighted sample correctly summed to the total number of businesses, the total number of sites, and the total kWh use of the target population. The study team did this for each stratum, including building type (campuses, education, food sales, etc.), PA, and kWh usage category. The study team also ensured that the weights correctly summed the program participants to the total number of participants that year. The weights included an item non-response factor as part of the weighting adjustments to account for information that was not obtained during the on-site assessments (e.g. make/model numbers, efficiency rating, etc.). This adjustment was developed independently for each of the sample populations using a model-based calibration technique.[10]

For the on-site assessment/market characterization aspects in general, the study team summarized major energy end-use equipment found in the existing buildings market, distinguishing between program participants and non-participants where possible. The study team also noted potential opportunities and challenges in the market based on significant variations in the results across business and customer size segments. The C&I Customer On-site Assessments results did not assess the differences between customers in the various PA territories or geographic locations, or other firmographics. Much of this information was collected, however, and may be used for future analyses.

Results

While conducting the site visits, field staff were asked to confirm the business type and activities being conducted at the site. Approximately 38% of the sites visited needed to be reclassified from the original classification to the field-confirmed classification, excluding the unknown category.[11] The office business type category saw the greatest increase from field confirmations, gaining 36 sites. The average was +/- 10 sites reclassified across the various business type categories. Disaggregating the businesses by square footage also showed that about 86% of the businesses have small- and medium-sized square footage. Table 1 shows the distribution of the square footage of buildings visited for the study.

8 Not including customers served by municipal utilities. Further, since the sample was based solely on electric PA accounts, municipal utility customers provided natural gas by Gas PA's would also not be included.

9 These numbers represent the final counts of the survey eligible population by kWh size and industry based on additional supplementation of the sample using more current billing records than what was available at the time of the original sample design.

10 See Folsom and Singh, The Generalized Exponential Model for Sampling Weight Calibration for Extreme Values, and Poststratification, 2000

11 The original business type classification was based upon data from PA's billing system provided to DNV GL for the 2013 C&I Customer Profile Study. The building type field in customer billing databases is often based on the SIC or NAIC code for the business and it may not properly reflect the specific use of the building. For example, the offices of a manufacturer may be classified as manufacturing however, for purposes of this study the site would be re-classified from manufacturing to office.

Table 1: Number of on-site visits completed by business square footage

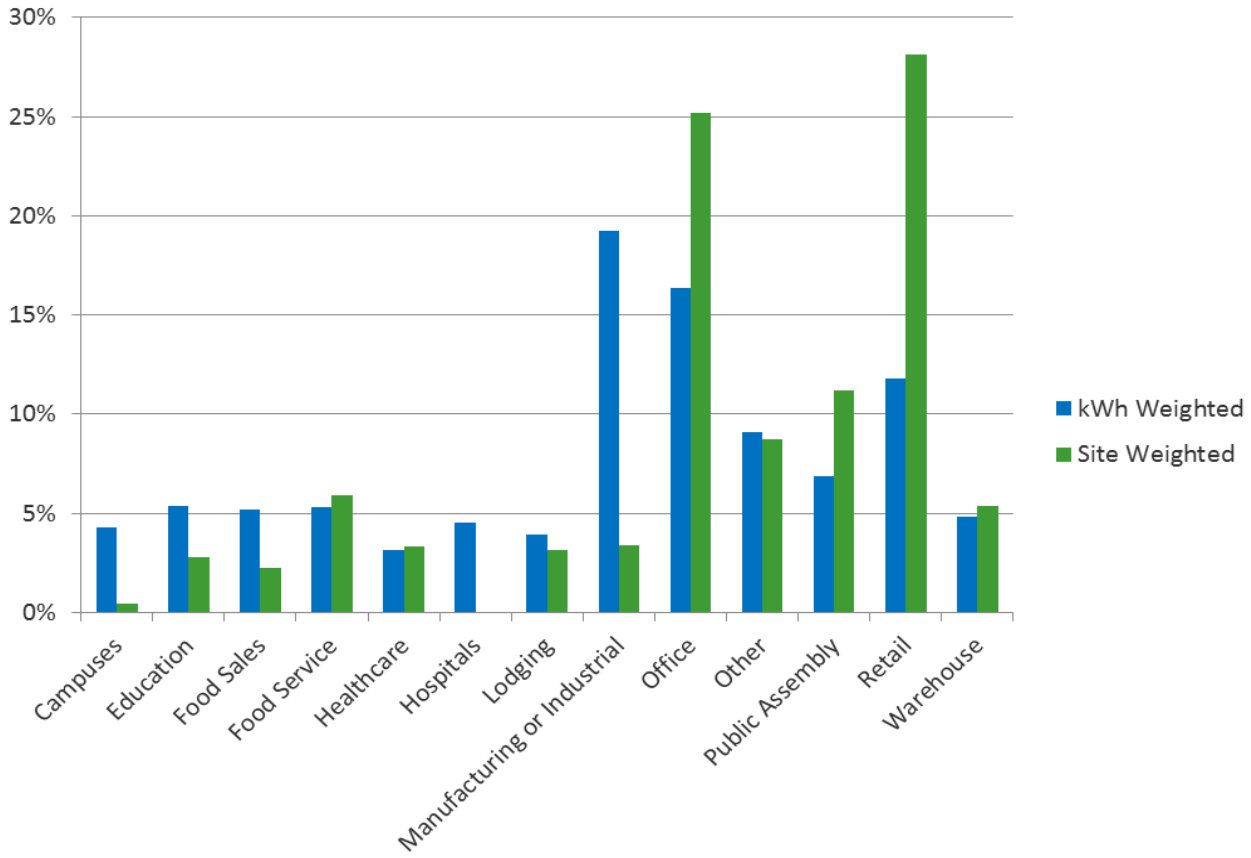
Size in square feet	On-sites completed	Share of completed on-sites
Less than 5,001	175	22%
5,001 to 10,000	73	9%
10,001 to 25,000	88	11%
25,001 to 50,000	121	15%
50,001 to 100,000	128	16%
100,001 to 200,000	101	13%
200,001 to 500,000	72	9%
Greater than 500,000	41	5%
Unknown	1	-
Total	800	100%

The study team made a considerable effort to maximize the recruitment and completion of on-site visits. For low- and mid-range consumption categories (those with annual energy consumption of less than 500,000 kWh and 500,000 to 4,500,000, respectively), the target number of completes was 0.1% and 4% of the total available population of customers in these size-related classifications. For the higher energy usage businesses, the 221 target completes were nearly 30% of the total 770 available high energy usage businesses in the sample frame. When looking at the number of customer sites visited by energy efficiency program participation using 2011 to 2014 data, a total of 338 businesses (42%) were found to have participated in the programs. Because of the limited information available on upstream program participation at the time of the study, program participation in this case refers only to customer-level participation. Follow on studies have considered upstream program participation more fully.

Population-based estimates of the distribution of types of businesses in Massachusetts were developed by applying both a kWh weight and site or business-level weight to the C&I customer on-site sample. Figure 1 shows the distribution of the kWh weighted sample versus the site weighted sample by business type. These data indicated that manufacturing or industrial businesses were the most common when weighted by kWh, with 19% of business electricity consumption, followed by office (16%) and retail (12%). The site-weighted distribution shows that retail accounts for 28% of Massachusetts businesses followed by offices at 25% of businesses. Manufacturing or industrial businesses make up only 3% of the businesses but 19% of the C&I kWh.[12]

12 For the analysis by business type, a customer's weight was dependent upon the business type in the utility customer information system. If the customer's building type found on-site differed from the building type in the customer information system, the building type was updated for the analysis but maintained the original weight.

Figure 1: Distribution of businesses



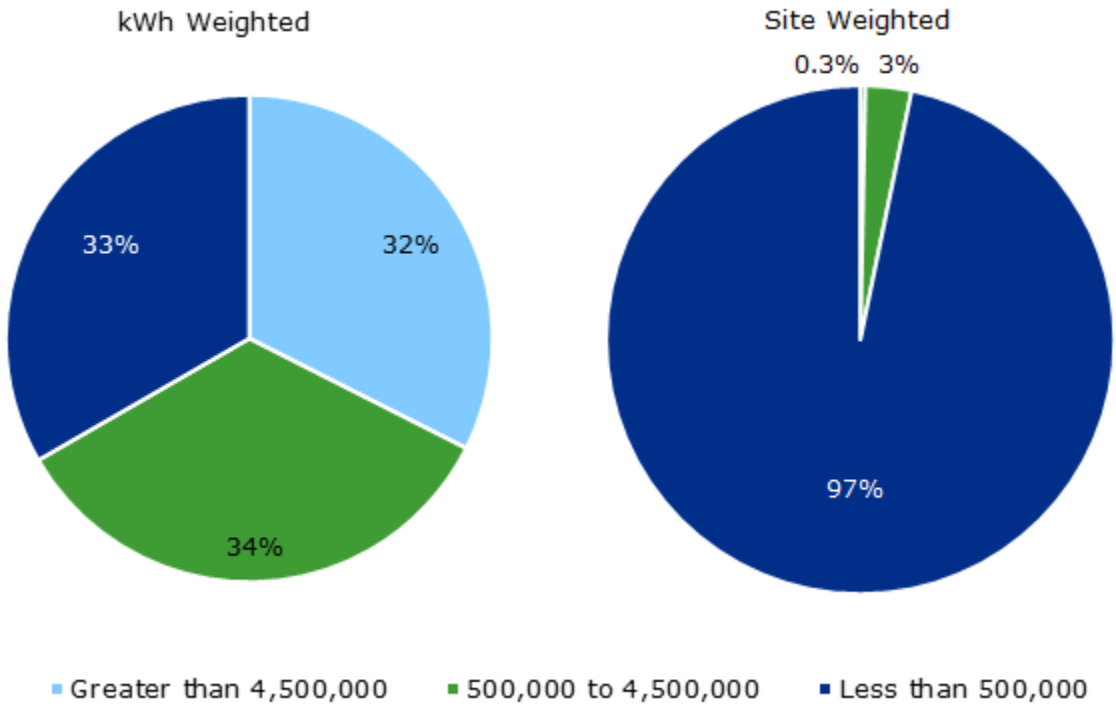
*Results are weighted using the kWh-level and the site-level sample weight.

**These data represent 800 total sites.

Figure 2 illustrates the weighted distribution of C&I electricity consumption by the customer consumption categories. The sample design for the study developed these three categories such that each size represents approximately one-third of the C&I kWh consumption. The sample design incorporated more data collection points with customers with annual usage below 500,000 kWh (293) and customers with annual usage of 500,000 kWh to 4,500,000 kWh (286) relative to large customers (221) to account for the significantly greater number of customers in these categories.[13]

13 The definitions of small, medium, and large were developed to allocate one-third of the annual electricity consumption to each group. This approach was chosen for sampling purposes. These definitions may differ from other analyses (e.g., customer profiling) in Massachusetts.

Figure 2: Distribution of C&I customer electricity (Annual kWh) consumption



*Results are weighted using the kWh-level and site-level sample weight.

**These data represent 800 total sites.

***The results are rounded.

In Massachusetts, over half of the businesses (67% of businesses by site weight and 56% by kWh weight) are associated with buildings that were constructed prior to 1978. In contrast, very few businesses (5% of businesses by site weight and 9% by kWh weight) are associated with buildings constructed from 2006 to 2015. Pre-1978 construction represented the largest share of square footage in all square footage size categories.

The analysis showed that most sites purchased new equipment. For small sites, 88% purchased some new equipment from 2009-2015, while 92% of medium sites and 91% of large sites were found to have recently purchased equipment. The distribution of the end use of recent purchase, however, differed by customer energy consumption. The lighting data collected showed that lighting equipment was purchased frequently by all customer sizes, consistent with the shorter life of non-LED lighting and its lower cost relative to the other end uses. This provided an indication of the progress achieved in replacing inefficient measures with newer, more efficient technologies. Lighting equipment data collected on-site were classified as one of eight lighting types: linear fluorescent, compact fluorescent, LED, halogen, incandescent, high intensity discharge (HID), neon, or other lighting. LED lamps used as replacement for linear fluorescents were referenced in this report as tubular LEDs (TLEDs) and classified as linear fluorescents, while non-linear LEDs were treated as a separate lighting category and reported in the ICLH (Incandescent, CFL, LED, Halogen) section. The data showed that while LEDs represent an increasing share of linear lighting purchases, many business segments were still found to have a large share of base linear lighting technologies (T12 and 700- and 800-Series T8s).

The three business types with the highest installed share of base efficiency linear lighting were offices (86%), retail (88%), and public assembly (94%). These business types represented 65% of the population on a site-weighted basis. Prior to 2012, linear LEDs were seldom purchased in the Massachusetts commercial sector. From 2012-2014,

the study team found that linear LEDs represented 18% of linear purchases. The data also indicated that Massachusetts businesses are rapidly retrofitting incandescent and CFL lamps with LEDs. CFL lamps were 44% of the existing stock of socket and pin-based lamps; however, recent purchase data (purchases between 2009 - 2015) showed a marked decline in CFL lamps (6%) and a dramatic increase in recent LED purchases (44%).

HVAC systems represent a significant portion of energy use and peak demand within the C&I sector. The C&I Customer On-site Assessments collected extensive field data on HVAC systems, from which it is possible to measure progress toward improved HVAC efficiency in the C&I sector. The MSST Study's analysis of HVAC system purchases from 2009-2015 includes information on these systems' efficiency. The majority of businesses in Massachusetts were found to be cooled by split and packaged cooling systems. Many businesses also had smaller window/wall or packaged terminal air conditioner (PTAC) units. Chillers were found to be used less often in businesses (1%) but account for the cooling of 20% of business square footage. The efficiency analysis of split and packaged systems in Massachusetts businesses found that 30% of the existing stock of units were above standards, while 53% of recent purchases were above standards. The substantial share of high-efficiency purchases applied to most sized systems, though limited evidence indicated that medium-sized commercial units (135-239 kBtuh) were less commonly purchased above standards. Nearly 40% of cooling units in Massachusetts businesses were PTAC and window/wall units. These units average 1.2 tons and are designed to cool either a room or a relatively small area. These units were largely found in campuses, lodging, and hospitals. Given the prevalence of these units, the study team suggested that the PA's explore offering incentives for high-efficiency versions of these units. The majority of Massachusetts businesses were found to heat their facilities using furnaces. Boilers and furnaces are both crucial to heating business area and were both found as heating choices in more than 50% of business square footage. These technologies often heat facilities individually and in combination with each other or other equipment. The study team's efficiency analysis of recently purchased of split and packaged heating systems found that the majority of small furnaces in Massachusetts businesses exceeded the federal standard of 78 AFUE. Many small furnaces, 25%, in Massachusetts met or exceeded the 95 AFUE requirement to receive a program incentive.

Beyond these findings, the report documents many other findings related to refrigeration, hot water heaters, maintenance practices, office equipment and process equipment. These findings make up the report for the C&I Onsite Assessments and MSST Study and provide the Massachusetts PA's evidence of what equipment exists in Ci& buildings today, but it by no means is an end to how the database may be used. The data are currently beginning to be used to assist in the development of technical potential studies for individual PA's. It will also be used for other program evaluation and study efforts.

Conclusions

There were many lessons to be learned from conducting such a comprehensive effort to create a comprehensive statewide characterization of C&I customers. Each step required careful planning, gathering feedback from various stakeholders, and patience as refinements were made to processes and procedures. In Massachusetts, the stakeholders consist of representatives from seven different program administrators, and representatives from the Massachusetts Energy Efficiency Advisory Council consultant team, as well as State-level regulators and policy makers. Having such a large group of stakeholders is not, and will not be, uncommon for a study like this, but it does pose particular challenges. While there were overarching needs for this type of assessment, it should be recognized and acknowledged from the start that everyone has their own interests as it relates to their work and the customers they serve. Clear and regular communications on the status of tasks, as well as any difficulties with tasks, and progress on budget and expenditures is essential to having a successful outcome. A baseline characterization to this extent is not inexpensive. In this case, the costs were over $3M. Costs are driven by the planning process itself, ensuring needs are being met, and in the execution of the project. The difficulties in recruiting customers, managing a sample across many multiple strata, maintaining consistency and quality of the data being collected and in the analysis of data should not be underestimated. In addition, these efforts take time. When conducting this type of study, there will be points during the study where decisions need to be made that affect timing of the delivery of the

analysis and reporting. In the Massachusetts On-site Assessments Study, outside of the need for an interim report to be delivered to the PA's in early 2016, the study team was fortunate to be able to maintain some flexibility in the schedule during the data collection period. It was well agreed upon amongst the stakeholders and study team that we didn't want to compromise the quality of the data and reporting to finish the study more quickly. This allowed us to continue focus on our efforts to recruit larger customers towards the end of data collection that resulted in a much richer data set for the baseline market characterization.

When crafting an on-site data collection instrument the study team and stakeholders must determine if there are specific items at customer facilities that should be focused on or if its more valuable to collect a wider range of data. There are trade-offs with both. Should a study team choose to focus on certain types of equipment, it's likely that the quality of the data will be improved over a more generalized inventory approach. However, the ability of study teams to get into a customer's building to collect information on equipment are limited and since these studies rely on customer cooperation, minimizing burden on the customer base is vital for maintaining any robust evaluation program. Taking the opportunity to collect as much information as possible on a wide range of data helps reduce this burden, but this may come at the expense of the quality and consistency of the data collected in the field. In addition, building an on-site data collection instrument with hundreds of possible data points that is both user-friendly and intuitive to field staff is a challenge. Recognizing that our ability in Massachusetts to get on-site to collect information in the future may be more difficult, the study team and stakeholders chose to gather a wider range of information from customer facilities during a 6-8 hour visit to a site.

Recruitment of customers is a difficult task. As the Massachusetts On-site Assessment Study progressed, it became clear that relying on program administrator account managers would not be enough to reach our quotas for large customers. A number of modified recruitment techniques needed to be developed, including the development of an additional incentive mechanism (in our case, this was in the form of a site summary report which many had customers expressed interest in). Incentives need to be properly assessed. Gift cards or a monetary incentive of a couple hundred dollars is of little interest to large customers. Reporting back something that is of use to facility managers, such as summary of information gathered than can be used to identify where potential opportunities for improvements lie in efficiency or performance, was found to be a good approach. In addition, the Massachusetts study team ultimately needed to recruit 955 customers to complete 800 site visits. This need to recruit additional customers is something that should be planned from the outset to anticipate sample attrition.

The challenges with matching electric and natural gas customer data is also something that should not be minimized. The natural gas PA's have needs equivalent to those of the electric PA's in meeting energy efficiency program goals and the inability to define natural gas sites and determine gas consumption in relation relate to the electric accounts greatly diminishes the natural gas PA's ability to conduct and analyze the data by consumption. The natural gas PA's in Massachusetts will be able to take advantage of the site-weighted analyses, and to some extent to kWh weighted analyses, but having an analysis weighted by therm consumption, as well as having quotas for natural gas customers will greatly increase the value of these efforts for natural gas utilities in the future.

Finally, weighting our sample up to the total Massachusetts electric customer population to adequately reflect myriad nuances across numerous variables was another deeply complex effort. Our objective in the weighting design was to produce total population estimates that were precise, unbiased, and defensible. Typically in survey studies like this one, a single weight is computed to expand the sample data back to the population. The weight incorporates adjustments to account for selecting the sample, adjustments for sample members who were selected but did not respond, and adjustments to account for frame coverage errors. Notably, however, having just one weight does not allow us to account for non-response for part of an observation, or what is called item-level non-response (for example, if information was collected on the make of a lighting unit, but not the model number). For the Massachusetts study, it was crucial to eliminate potential bias in our estimates by accounting for item-level non-response, and therefore required us to create multiple weights. To achieve this, the study team grouped data items into 32 categories (such as internal lighting, external lighting, etc.) and created three weights (size, building type, and

kWh usage) that would correctly sum this data to the correct population total for each technology. Having thirty-two groups by three types of weights means that instead of the single weight typically developed for a survey study, the study team developed a set of ninety-six weights. The weights were designed and calibrated to ensure that they were consistent, and that they summed to the population totals for size, business type and kWh usage. Our methodology succeeded in correcting for a variety of non-response without jeopardizing variance levels. Ultimately, this means that our estimates achieve a level of precision and bias-elimination far beyond what traditional weighting approaches would produce.

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