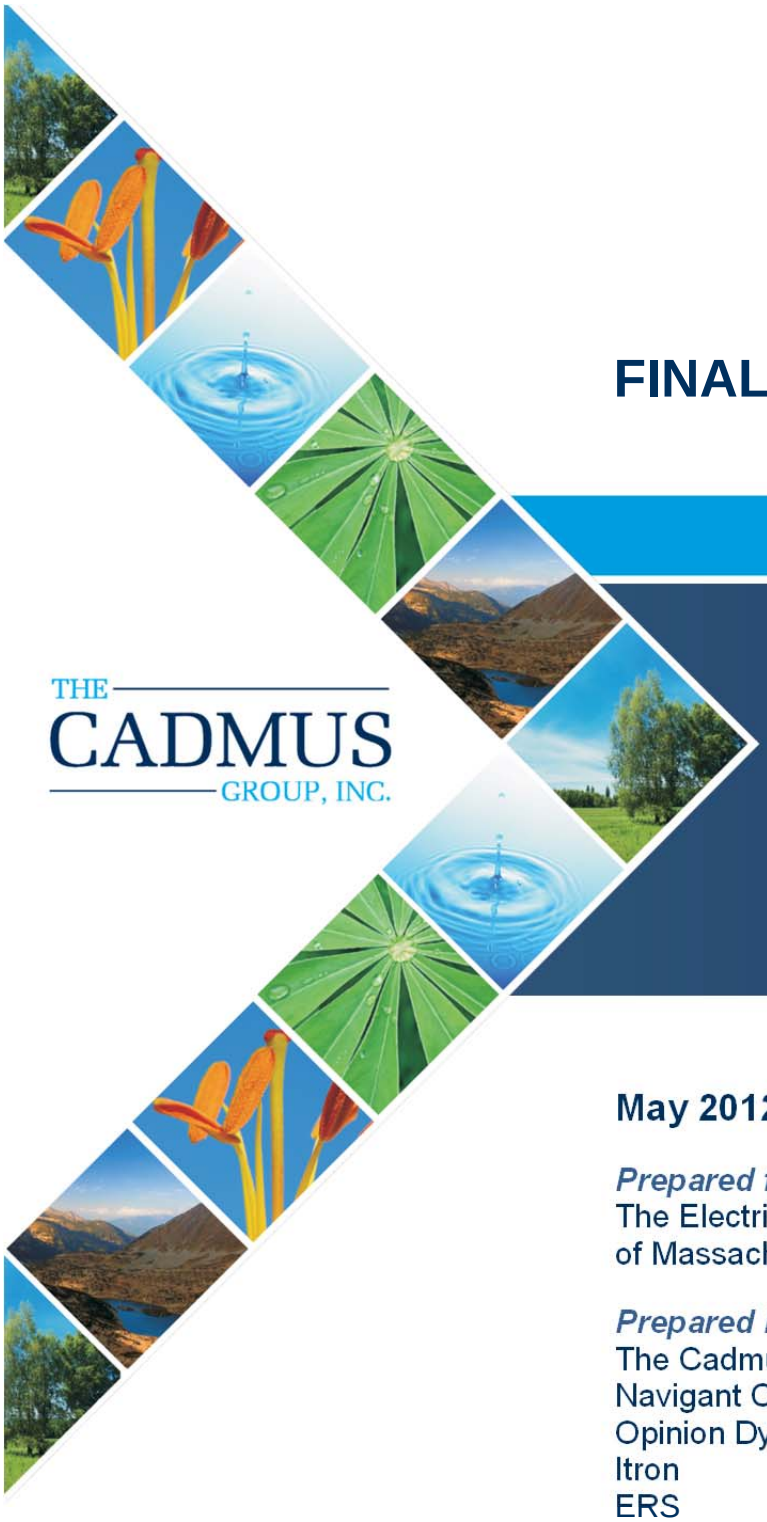

FINAL REPORT

Massachusetts Multifamily Market Characterization and Potential Study Volume 1

May 2012

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EXECUTIVE SUMMARY

This study assesses the potential energy-efficiency savings available in Massachusetts' multifamily buildings. The research was conducted as part of the evaluation of the 2010-2012 Residential Retrofit and Low Income program areas conducted for the following program administrators (PAs): NSTAR, National Grid, Columbia Gas, Unitil, Cape Light Compact, Berkshire Gas, New England Gas, and Western Massachusetts Electric Company (WMECO).

The following companies, collectively referred to as the Evaluation Team, conducted this research: The Cadmus Group, Inc. (Cadmus), Opinion Dynamics, Navigant Consulting (Navigant), Itron, and Energy and Resource Solutions (ERS).

Research Areas of This Study

The 2010-2012 energy-efficiency programs mandated by the Massachusetts Green Communities Act represent one of the most ambitious and comprehensive demand-side management (DSM) portfolios ever offered. The results of this study inform ongoing energy-efficiency planning and program design by identifying the quantity of available potential and determining how it is distributed across end uses (lighting, central air conditioners, furnaces, etc.) in multifamily buildings.

The Evaluation Team addressed two key research areas in this effort:

1. Characteristics of multifamily—residential buildings with five or more tenant units—dwellings in the Commonwealth of Massachusetts; and

2. Electric and natural gas energy-efficiency potentials for multifamily dwellings in Massachusetts from 2010 to 2030.

We began the study with a market characterization that collected data to inform these key aspects of the potential study:

- The size of the multifamily market in Massachusetts;
- Tenant, building shell, and in-unit characteristics of multifamily buildings; and
- Multifamily property manager and owner decision-making processes.

Data Collection Activities

Our market characterization, presented in Section 2 of this report, focuses on the outcomes of two primary data-collection activities.

- ***Workshops on achievable potential*** collected information on barriers and motivations to participate in energy-efficiency programs from multifamily property managers (PMs) and PA program implementers from Massachusetts.

- ***On-site visits*** collected building shell and detailed equipment—HVAC, water heating, appliances, and consumer electronics—saturation information from 193 multifamily buildings in Massachusetts.

These data—supplemented with information from PA data tracking systems and secondary sources where necessary—provided the foundational elements for estimating the technical, economic, and achievable potentials. Other key research activities performed by the Evaluation Team were these:

- Forecasting the quantity of multifamily units and buildings from 2010 to 2030 using data from the Census Bureau.
- Preparing building simulation models and energy calculations, using saturations of equipment from the on-site data to derive a bottom-up estimate of energy consumption in multifamily buildings from 2010 to 2030.
- Identifying energy-efficiency measures and associated characteristics—many of which are currently offered by the Massachusetts PAs—to estimate technical and economic potentials net of federal efficiency standards.
- Developing two achievable potential scenarios:
  - ***Maximum achievable*** estimates how much of the economic potential can be captured with 100% incremental cost incentives, and with program designs targeting hard-to-reach customers and measures.
  - ***Business-as-usual (BAU) achievable*** estimates how much of the economic potential can be captured under current Massachusetts multifamily program designs.

Electricity Consumption and Potentials

Massachusetts' statewide baseline electric sales forecast for multifamily dwellings is shown in Table 1. This table also shows what the estimated technical and economic potentials are expected to be by the end of the 20-year planning horizon (2030).

The results indicate that 2.8 million MMBTU of technically feasible, electric energy-efficiency potential will be available by 2030. Once screened for cost-effectiveness, this technical potential translates into an economic potential of 1.8 million MMBTU. Should all of this cost-effective potential be deployed, the result would be a 14% reduction in 2030 forecast energy consumption. Our percentage estimates of electric technical and economic potentials are comparable to those for multifamily buildings in a 2010 Consolidated Edison potential study[1].

Table 1. Multifamily Technical and Economic Electric Energy-Efficiency Potential in 2030 (MMBTU)

Location	Baseline 2030 Sales (MMBTU)	Technical Potential (MMBTU)	Technical Potential as % of Baseline	Economic Potential (MMBTU)	Economic Potential as % of Baseline
Within Unit	8,570,664	2,211,710	26%	1,353,079	16%
Common Area	3,022,490	548,898	18%	422,310	14%
Total	11,593,154	2,760,608	24%	1,775,389	15%

Table 2. Multifamily Technical and Economic

[1] Energy Efficiency Potential Study for Consolidated Edison Company of New York, Inc. Volume 2: Electric Potential Report, Global Energy Partners, LLC, Walnut Creek, March 2010

Electric Energy-Efficiency Potential in 2030 (GWh)

Location	Baseline 2030 Sales (GWh)	Technical Potential (GWh)	Technical Potential as % of Baseline	Economic Potential (GWh)	Economic Potential as % of Baseline
Within Unit	2,512	648	26%	397	16%
Common Area	886	161	18%	124	14%
Total	3,398	809	24%	520	15%

The identified economic potential consists of all measures with a benefit-to-cost ratio greater than or equal to 1.0. We estimate that electric maximum achievable potential is 12% of baseline sales (1.3 million MMBTU) and that business-as-usual achievable potential would capture 9% of baseline sales (1.0 million MMBTU, Table 3).

Table 3. Multifamily Electric Achievable Potential (MMBTU, Cumulative in 2030)

	Baseline 2030 Sales	Economic Potential	Maximum Achievable Potential		BAU Achievable Potential	
Location	MMBTU	MMBTU	MMBTU	% of Baseline	MMBTU	% of Baseline
Within Unit	8,570,664	1,353,079	978,111	11%	798,808	9%
Common Area	3,022,490	422,310	357,365	12%	292,420	10%
Total	11,593,154	1,775,389	1,335,476	12%	1,091,228	9%

Table 4. Multifamily Electric Achievable Potential (GWh, Cumulative in 2030)

Location	Baseline 2030 Sales	Economic Potential	Maximum Achievable Potential		BAU Achievable Potential	
	GWh	GWh	GWh	% of Baseline	GWh	% of Baseline
Within Unit	2,512	397	287	11%	234	9%
Common Area	886	124	105	12%	86	10%
Total	3,398	520	391	12%	320	9%

Natural Gas Consumption and Potentials

Table 5 shows forecasted baseline gas sales and the technical and economic potential for multifamily buildings in 2030, the end of the 20-year planning horizon. The study results indicate that 7.0 million MMBTU of technically feasible, natural gas energy-efficiency potential will be available by 2030. This technical potential translates to an economic potential of 5.2 million MMBTU.

Table 5. Multifamily Technical and Economic Gas Energy-Efficiency Potential in 2030 (MMBTU)

Location	Baseline 2030 Sales (MMBTU)	Technical Potential (MMBTU)	Technical Potential as % of Baseline	Economic Potential (MMBTU)	Economic Potential as % of Baseline
Within Unit	18,326,216	6,171,106	34%	4,450,358	24%
Common Area	3,818,503	838,347	22%	787,682	21%
Total	22,144,719	7,009,453	32%	5,238,040	24%

Table 6. Multifamily Technical and Economic Gas Energy-Efficiency Potential in 2030 (Therms)

Location	Baseline 2030 Sales (Million Therms)	Technical Potential (Million Therms)	Technical Potential as % of Baseline	Economic Potential (Million Therms)	Economic Potential as % of Baseline
Within Unit	183	62	34%	45	24%
Common Area	38	8	22%	8	21%
Total	221	70	32%	52	24%

We estimate that gas maximum achievable potential is 19% of baseline sales (4.2 million MMBTU) and that business-as-usual achievable potential would capture 16% of baseline sales (3.5 million MMBTU, Table 7).

Table 7. Multifamily Gas Achievable Potential (MMBTU, Cumulative in 2030)

	Baseline 2030 Sales	Economic Potential	Maximum Achievable Potential		BAU Achievable Potential	
Location	MMBTU	MMBTU	MMBTU	% of Baseline	MMBTU	% of Baseline
Within Unit	18,326,216	4,450,358	3,547,995	19%	2,984,905	16%
Common Area	3,818,503	787,682	661,696	17%	535,711	14%
Total	22,144,719	5,238,040	4,209,691	19%	3,520,616	16%

Table 8. Multifamily Gas Achievable Potential (Therms, Cumulative in 2030)

Location	Baseline 2030 Sales	Economic Potential	Maximum Achievable Potential		BAU Achievable Potential	
	Million Therms	Million Therms	Million Therms	% of Baseline	Million Therms	% of Baseline
Within Unit	183	45	35	19%	30	16%
Common Area	38	8	7	17%	5	14%
Total	221	52	42	19%	35	16%

Combined Consumption and Potentials

Summing the totals across fuels, we estimate 34 million MMBTU of multifamily electric and gas energy consumption in 2030. Our study indicates nearly 10 million MMBTU (29% of baseline sales) of technically feasible energy-efficiency potential and 7.0 million MMBTU (21% of baseline sales) of total economic potential (Table 9) will be available by 2030. Both sales and potentials are more heavily weighted toward the gas fuel type.

Table 9. Multifamily Technical and Economic Energy-Efficiency Potential in 2030 (MMBTU)

Fuel Type	Baseline 2030 Sales (MMBTU)	Technical Potential (MMBTU)	Technical Potential as % of Baseline	Economic Potential (MMBTU)	Economic Potential as % of Baseline
Electric	11,593,154	2,760,608	24%	1,775,389	15%
Gas	22,144,719	7,009,453	32%	5,238,040	24%
Total	33,737,873	9,770,061	29%	7,013,429	21%

Of the potentials shown in Table 9, we estimate a maximum of 5.5 million MMBTU (16% of baseline sales) of achievable energy-efficiency potential and 4.6 million MMBTU (14% of baseline sales) under a business-as-usual achievable scenario (Table 10).

Table 10. Multifamily Achievable Potential (MMBTU, Cumulative in 2030)

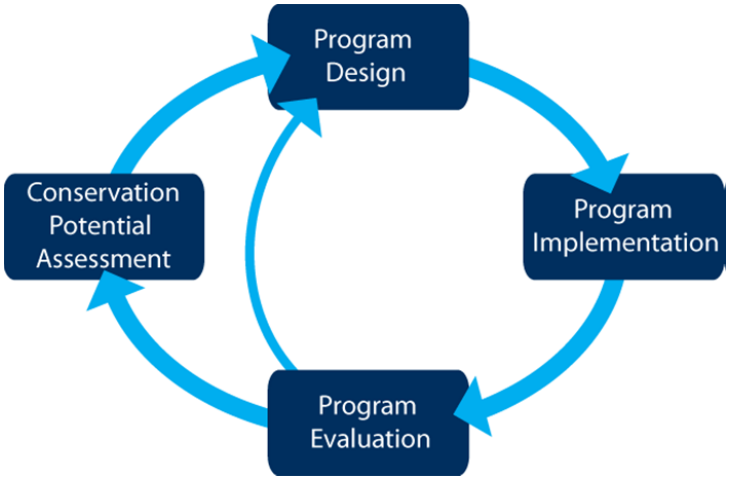
Fuel Type	Baseline 2030 Sales	Economic Potential	Maximum Achievable Potential		BAU Achievable Potential	
	MMBTU	MMBTU	MMBTU	% of Baseline	MMBTU	% of Baseline
Electric	11,593,154	1,775,389	1,335,476	12%	1,091,228	9%
Gas	22,144,719	5,238,040	4,209,691	19%	3,520,616	16%
Total	33,737,873	7,013,429	5,545,167	16%	4,611,844	14%

Using the Study Results

An assessment of potential provides information on the size and source of the energy efficiency opportunities in the region studied. In this case it is focused on potential in multifamily buildings in Massachusetts. This information is valuable as a starting point for program design (see figure 1).and should be used to inform the design of programs targeting multifamily buildings in Massachusetts. The evaluation team's assessment was based on a comprehensive set of energy-efficiency measures., and, in effect, provides a catalog of energy-efficiency measures that energy-efficiency programs can draw from. The study results identify end uses and energy-efficiency measures that present the greatest opportunities for realizing savings through program activities.

The objective of the program design process is to determine how best to capitalize on these opportunities. The next step in the process is to compare current program measures and the savings being realized from those measures to the list cost-effective measures in this report's Appendix C (Volume 2). This will allow you to identify any cost effective measures that are not currently being offered through the program. It will also allow you to identify measures performing strongly relative to their potential and measures that are performing poorly relative to their potential. Analysis to understand drivers of strong performance can provide insights into the program efforts that have been successful and can potentially be leveraged for other measures. Analysis to understand potential causes of poor performance will help identify adjustments to program design to improve performance of those measures.

Figure 1. Potentials Assessment in Context of Energy Efficiency Programs



Organization of This Report

The Massachusetts multifamily potential study report consists of two volumes. This document, Volume 1, presents methodologies and findings, and it contains these sections:

- ***Section 1, Data Collection Activities***, provides an overview of data collection activities.
- ***Section 2, Market Characterization***, presents an assessment of the multifamily market, building characteristics, and attitudes toward energy efficiency.
- ***Section 3, Potentials Estimates***, presents the methodology for and results from the following in this study:
  - baseline energy consumption
  - technical potential
  - economic potential
  - achievable potential.

Volume 2 provides the supplemental technical information, assumptions, data, and other relevant details:

- Appendix A: Measure Descriptions
- Appendix B: Detailed Baseline and Technical Potential
- Appendix C: Measure Details
- Appendix D: Details from Achievable Potential Workshops

SECTION 1. DATA COLLECTION ACTIVITIES

The Multifamily Market Characterization and Potential Study conducted by the Evaluation Team encompassed a number of interrelated data collection activities, most of which were designed to inform key aspects of the potential study in Section 3. Each of these activities is listed and briefly described in this section.

Workshops on Achievable Potential

The Evaluation Team based the estimates of achievable potential on primary data from three achievable potential workshops, from PA program tracking data, and from recent estimates of achievable potential developed in other jurisdictions. We held the first two workshops with Massachusetts PMs on consecutive evenings on May 10 and May 11, 2011. These workshops—each two hours long—were attended by 17 PMs who own or manage 356 buildings, totaling over 11,000 units in Massachusetts. Represented within the 356 buildings were three key multifamily segments:

- Owned and rented tenant units;
- Low income (public housing, non-profit affordable housing, and for-profit Section 8 housing) and non-low income units; and
- Geographic locations across Massachusetts.

On May 12, we met with the Massachusetts PAs in the third workshop, which lasted three hours. The PA workshop was attended by Multifamily and Low Income Program Managers (from NSTAR, National Grid, and Columbia Gas) and implementation contractors (ICs) from RISE and CSG. Although more than 10 representatives from the PAs attended, only eight individuals provided data contributing toward the adoption curves.[2]

About the Delphi Method Approach

The Evaluation Team modeled its approach to the workshops on the Delphi method, which combines various perspectives of subject-matter experts (SMEs) into a single answer to a research question. The Delphi method begins with having a panel of experts make anonymous projections on a specific topic. The aggregated results are then presented and discussed among the experts. After discussing their rationales for their initial projections, the respondents are asked to anonymously complete a questionnaire. (Additional rounds of discussion and completion of the questionnaire can be part of this process.) Ultimately, the SMEs achieve near consensus (or consensus), and their final projections typically tend to predict more accurately the actual conditions or projections.

About the Workshop Surveys

At our workshops, we distributed questionnaires that contained the tables shown in Figure 2, Figure 3, and Figure 4 on the following pages. Independently and anonymously, the attendants noted the percentage of PMs they thought would likely adopt the measure at the respective

[2] Some of the representatives who attended the PA workshop provided useful information relevant to the markets in which they work, yet chose not to provide responses to the questionnaires because they are members of the PA evaluation teams.

incentive level. We also asked respondents to note by what amount, if any, these percentages would increase with the inclusion of aggressive program marketing. We also left a space for respondents to note barriers and motivators that can drive—at least in part—the adoption of energy-efficient equipment. Additionally, we asked respondents to answer similar questions regarding weatherization measures and the replacement of heating systems and lighting.

We specified these measures because they:

- Represent a large share of program savings and DSM potentials;
- Include a mix of replacement (i.e., replace on failure, as for heating systems) and retrofit/discretionary (i.e., install at the customer's discretion, not driven by equipment failure, as for weatherization and new lighting fixtures) measures; and
- Represent a wide range of incremental cost considerations, and thus customer decision-making criteria.

Figure 2. Achievable Potential Workshop Questionnaire: Heating

Additional Cost of Energy Efficient Boiler/Furnace	Annual Savings	Lifetime Savings (20 years)	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Install EE Boiler/Furnace
$5,000	**$500**	**$10,000**	$0	$5,000	10 years	%
			$1,250	$3,750	7.5 years	%
			$2,500	$2,500	5 years	%
			$3,750	$1,250	2.5 years	%
			$5,000	$0	Immediate	%

Figure 3. Achievable Potential Workshop Questionnaire: Weatherization

Cost of Insulation, Sealing, Caulking Improvements	Annual Savings	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Make Insulation, Sealing, Caulking Improvements
$10,000	**$1,500**	$0	$10,000	6.7 years	%
		$2,500	$7,500	5 years	%
		$5,000	$5,000	3.3 years	%
		$7,500	$2,500	1.7 years	%
		$10,000	$0	Immediate	%

Figure 4. Achievable Potential Workshop Questionnaire: Lighting

Additional Cost of Energy Efficient Lighting	Annual Savings	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Install EE Lighting
$50/Fixture	$25/ Fixture	$0	$50	2 years	%
		$15	$35	1.4 years	%
		$25	$25	1 year	%
		$40	$10	5 months	%
		$50	$0	Immediate	%

Survey Methodology

During the workshops, we aggregated attendees' responses and presented the results in the form of graphs showing the relationship between measure adoption and monetary incentive (the achievable potential curves). Upon presentation of the graphs, we moderated a discussion among the attendees and then asked attendees to explain their responses.

After the attendees completed the same questionnaires a second time, we presented these results of their aggregated responses with the chart of results from the first round. Again, we asked attendees for further explanations of why they adjusted (or did not adjust) their responses. Ultimately, the attendees' projections about the market became more homogenous, providing a more realistic model of measure adoption.

In Section 3 of this report, we discuss the results of the achievable potential workshops and apply them in our calculations of present energy-efficiency potentials for Massachusetts.

On-Site Data Collection

The primary purpose of the Evaluation Team's overall building and in-unit data collection activities was to inform the potential study modeling efforts. We visited a total of 193 sites between November 2010 and August 2011, and we used this on-site data to further our understanding of the Massachusetts multifamily building stock—with individual buildings representing the unit of analysis.

Our quantitative data collection form was designed to gather information on both common areas and on at least one tenant-unit per building.

- The building information we collected during these on-site visits included the following: equipment saturations and fuel shares; shell characteristics; and heating, cooling, and water heating end-use data.
- Our in-unit data collection activities focused on lighting, windows, and appliances.

Recruiting Approach and Site Visits

Identifying multifamily buildings and potentials is one of the most challenging activities in the energy-efficiency industry. As discussed further in Section 2, these challenges are the result of situations such as these:

- ***There are multiple meters and accounts per building***. Unlike other residences, multifamily buildings are generally characterized by two types of spaces (common areas and individual units), for which separate bills go to different decision-makers (landlords, property managers, and tenants). Consequently, it is not a simple matter to count the number of multifamily customers in a utility billing or CIS system and then derive the number of customers.

- ***Utility rate schedules are not synchronized with dwelling definitions.*** These schedules are established to handle different rates for commercial and residential customers. However, single-family customers are not distinguished from multifamily customers after an individual obtains a residential account. Similarly, billing systems generally do not distinguish between multifamily buildings and other types of buildings after an entity obtains a commercial account.

- ***Owners and property managers sometimes aggregate common- area account.*** Many large property managers handle scores of buildings, and they often have the common-area meters across buildings aggregated into a single bill. Also, even when this isn't an issue, the address to which the common-area bill is sent may not the same as the physical address of the building.

These issues—which are well known in the industry—were the driving factors for conducting this potential study of energy efficiency in multifamily buildings in Massachusetts. The two recruiting approaches used by the Evaluation Team (tenant-based and property manager-based) are summarized below.

Tenant-Based Recruiting

Our site-visit recruitment efforts began in November 2010 and continued through August 2011. Initially, we used a tenant-based recruiting approach. The three primary tenant-based recruiting efforts were these:

- ODC outbound calling using a PA provided CIS dataset (response rate[3] 0.4%)
- ODC mailers and inbound calling (response rate 1.0%)
- OAC outbound calling using list purchased from Survey Sampling, Inc. (response rate 0.9%)

From our tenant-based approach (in which recruiting was done through tenant survey calls), we conducted on-site visits at 82 multifamily buildings between November 2010 and March 2011. We recruited 42 additional tenants with whom we were unable to complete a visit for these

[3] Response rate is the number of contacts recruited for a site visit divided by the total number of contacts called. Not all recruits netted on-site visits; there was some attrition after recruiting, as we could not follow up with some recruits (both tenant and PM) to finalize a schedule for a visit.

reasons: (1) the tenant cancelled; (2) the building had too few units to qualify for a site visit; or (3) we were ultimately unable to reach the tenant. After we encountered scheduling difficulties, we switched to a PM-based approach for recruiting.

To obtain data on the building as a whole, our recruiters attempted to collect contact information— during either the recruitment call or a follow-up call—for the tenant's property manager. The property manager was then contacted to schedule a visit. To maximize efficiency, we attempted to schedule the property manager and tenant visit for the same day. However, coordinating a visit between the tenant and property manager proved difficult, so in early 2011, we made a decision to conduct these site visits independent of each other.

Collecting data for building-level HVAC and water heating systems was difficult through the tenant-based approach. These spaces are typically locked and require coordination with an on-site property manager for access. For example, we were not able to assess the primary water heating system type for 30% of the sites recruited through the tenant-based approach, versus 4% of the sites recruited through the PM-based approach. After scheduling a visit with the tenant, the Evaluation Team often had difficulty obtaining contact information for and scheduling an appointment with the building's PM to allow our technicians to collect data in the locked spaces. Also, when a PM did consent to a visit, our team typically was not able to coordinating the PM's schedule with the schedule of the tenant so that our technicians could visit the building only once.

Recruitment of Property Managers (PMs)

After a three-month suspension in on-site data collection (March through May 2011), the Evaluation Team focused on recruiting PMs. For this undertaking, we purchased calling lists from these entities: Survey Sampling, Inc.; InfoUSA; and Dun & Bradstreet. We also contracted with Discovery Research Group to make the telephone calls.

This approach proved more effective in terms of response rates. However, while we were able to collect more complete data on building-level HVAC and water heating systems, we found there was a trade-off in terms of in-unit data quality. PMs were often unable to access occupied units, and 29% of the units visited from this recruiting approach were vacant. We did not consider vacancies to be a significant problem, as the amount of in-unit data already collected was sufficient to inform the saturations of appliances and consumer electronics needed for our potentials estimate in Section 3.

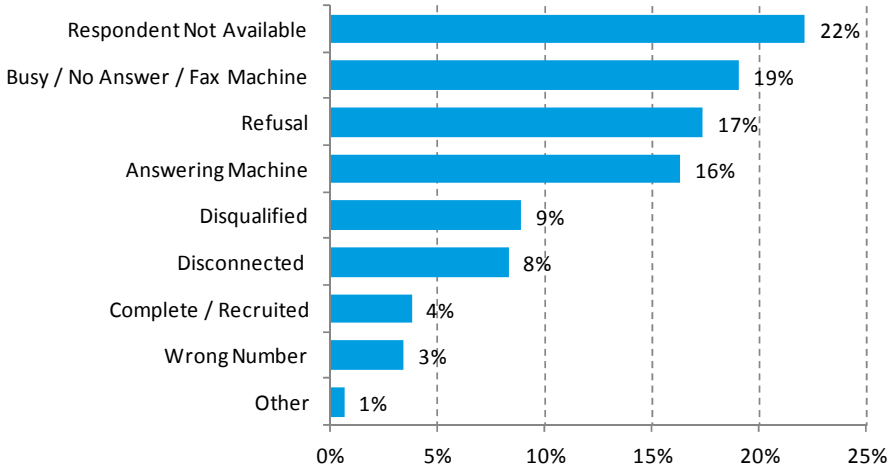
Our tactics for recruiting PMs were these:

- Outbound calling by ODC which was done in conjunction with achievable potential workshop recruitment calls.
- A property manager recruitment pilot by Cadmus, using contact information that was purchased.
- Outbound calling by Discovery Research Group which achieved a response rate of 3.52% by using contact lists from Survey Sampling, Inc.; InfoUSA; and Dun & Bradstreet. We also used sources identified through Internet research (irem.com, craigslist.com, yellowpages.com, manta.com, and allpropertymanagement.com.)

The majority of PM recruitment occurred through DRG's outbound calling. The calling sample contained a total of 3,754 unique contacts, and DRG made multiple attempts to reach each individual.

The final dispositions from the PM recruitment effort are shown in Figure 5.The most common reason for not reaching contacts (21% of all final dispositions) was because they were unavailable. (Typically, a receptionist or screener told us the contact person was unavailable.)

Figure 5. DRG Property Manager Recruitment Final Dispositions (n=3,754)

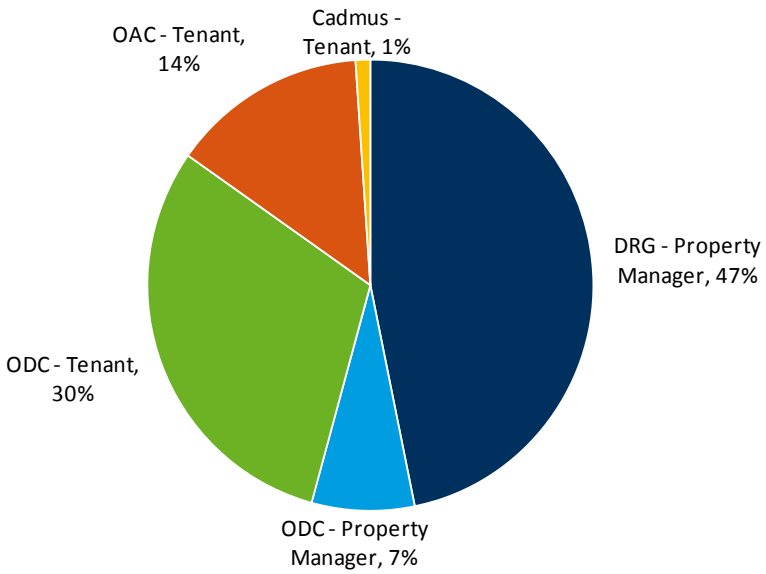


The Evaluation Team encountered a several challenges in the approach that focused on property managers, which entailed business-to-business outbound calling to a difficult-to-reach population.

- Both the InfoUSA and Dun & Bradstreet lists were selected based on SIC (Standard Industrial Classification) codes, which do not distinguish between property management firms and property management offices for individual buildings.
- Calling the corporate office of property management firms was often unsuccessful, since reaching the corporate decision maker was rarely possible.
- Corporate offices were rarely willing to release the contact information for their on-site managers, which made it impossible to reach many of the on-site decision-makers (who, historically, were more likely to agree to a visit). On occasion, however, when a corporate decision maker was reached and agreed to participate, we were able to recruit several properties at once.

Due to the various methods used, several firms were involved in the site visit recruitment efforts: Opinion Dynamics Corporation (ODC), Opinion Access Corporation (OAC), Discovery Research Group (DRG), and Cadmus. Both ODC and OAC are responsible for the tenant recruitment effort, while DRG and Cadmus conducted property management recruitment calls. The proportion of total recruits attributable to each firm is shown in Figure 6.

Figure 6. Percent of Total Recruits from Each Firm



Key Lessons from Recruiting

The Evaluation Team learned these efficiencies and subtleties from the site visit recruitment effort that can be applied to future studies:

- Defining a population and obtaining a sample for both tenants and property managers is challenging (as discussed in Section 2 of this report).
- Low response rates must be anticipated and planned for, especially if tenant-based recruiting is used.
- If a tenant-based approach is used to recruit for site visits, technicians will likely encounter difficulty when trying to access to building-level HVAC and water heating systems.
- Property manager-based recruiting is more efficient than tenant-based recruiting, as PMs tend to be more professional than tenants and are able to offer higher quality information about the buildings.
- PMs may lack access to occupied units, which makes obtaining accurate and detailed inventories at the unit level more difficult.
- Accurately characterizing low-income tenants is difficult because PMs tend to lack sufficient knowledge about the requirements for low-income qualifications, which vary by jurisdiction.
- Distinctions between sites and buildings are often not made by property managers. Many PMs think in terms of the number of units or the amount of floor area on a per-property basis rather than on a per-building basis. Thus, PMs typically have a better understanding of the high-level characteristics of the property.

- Standard Industrial Classification lists do not distinguish between property management firms and individual building management offices; however, successful recruitment requires a distinct approach for each.
  - When contacting large corporate property management firms, focus on reaching a lower-level decision maker and asking for access to multiple properties is most efficient.
  - When contacting individual building managers, focus on the building they manage. Then, after recruitment, asking the manager to put you in contact with other building managers is typically most productive.

Other Data Collection Activities

The Evaluation Team performed several other data collection activities listed in this section. .

Tenant Survey

The Evaluation Team completed 192 tenant surveys. This survey instrument was designed to collect basic unit and demographic information, assess tenants' general attitudes about energy efficiency, and determine tenants' awareness of energy-efficiency programs. The survey was also designed to generate leads and contact information for the on-site visits.

Property Manager (PM) Survey

The Evaluation Team completed 143 PM surveys in December 2010. Similar to the tenant survey, the property manager/owner survey assessed the following:

- General attitudes about energy efficiency;
- Barriers to program participation;
- Awareness of energy-efficient equipment options and program offerings, and other information needed to develop measure adoption curves required for the potential study; and
- Recruitment for on-site audit visits.

Interviews With Program Administrators and Implementation Contractors

The Evaluation Team conducted interviews, completed in November 2010, with three of the eight program administrators (PAs) of the Multifamily Retrofit Program (National Grid, NSTAR, Columbia Gas) and two implementation contractors (RISE and CSG).

These interviews with program staff were designed to understand the roles of the individuals and groups involved and the program's approaches and processes. The interviews informed the evaluation team's understanding of program delivery and provided insight into program strengths, areas for improvement, and ways to proceed with the evaluation. Specifically, the in-depth interviews with program staff addressed these elements:

- Program design, delivery, and status;

- Program participation, marketing, and implementation; and
- Program data tracking, reporting, and verification.

HVAC and Plumbing Contractor Survey

The Evaluation Team completed 33 interviews with plumbing contractors who had installed hot water heaters and boilers (n=16) and with HVAC contractors who had installed electric and/or gas equipment (n=17) in multifamily properties over the last two years.

Designed to inform the multifamily potential study, the survey explored the market share of efficient water heating and HVAC equipment. It also explored these additional research areas: program participation among contractors; benefit of and barriers to participation; general market trends; and the volume and type of installations completed within multifamily buildings over the past two years.

SECTION 2. MARKET CHARACTERIZATION

This section presents the details of the Evaluation Team's findings in the multifamily market characterization:

- The size of the multifamily market,
- Characteristics of multifamily buildings, and
- A discussion of multifamily property manager and owner decision-making processes.

For the market characterization portion of this report, it is important to understand the primary objectives of each data collection activity. When we collected information pertinent to the characteristics of the Massachusetts market of multifamily buildings containing five or more-units, our activities were centered on supporting the potential study. Thus, we focused on:

- ***Informing the achievable aspect of the potential study***. Toward this goal, the property manager/administrator workshops (focus groups) were designed to facilitate an understanding of the willingness to pay for various types of energy-efficient upgrades at varying incentive levels. This potential study used this information to estimate the amount of economic potential that could actually be achieved (realized) through various program efforts.
- ***Collecting data for potential study modeling.*** This aspect of our work focused on recruiting multifamily buildings for on-site data collection. The primary purpose of this activity was to collect baseline efficiency-related information for use in the potential study modeling efforts.

The remainder of this section describes the information—collected through the building on-site visits, surveys, and workshops—used to assist in characterizing the Massachusetts multifamily market. We supplement this information with information from these sources:

- 2005 Census projections
- Residential Energy Consumption Survey (RECS)
- Energy Information Administration (EIA) Electricity and Natural Gas data
- Utility billing data
- 2010 American Community Survey (ACS),
- 2009 Residential Appliance Saturation Survey (RASS) for the State of Massachusetts. (This consisted of 357 completed surveys with residents in multifamily structures.)

While these sources provide relevant market characteristics (number of buildings, number of units, etc.) they do not enable us to characterize the multifamily market at the same depth as a study devoted to market characterization only.

Sources for Sampling

As discussed briefly in the previous section of this report, the multifamily market is difficult to research for a number of reasons. The challenges tend to fall in one of two main categories: (1) securing a representative sampling frame, and (2) identifying decision-makers and securing their cooperation. These are detailed below.

About Sampling Challenges

Securing a Representative Sampling Frame

The basic nature of multifamily buildings and tenants makes it difficult to secure a representative sample of either the buildings or the occupants. One of the best sources of information is utility billing/CIS systems; however, most billing/CIS systems have limitations.

- ***Multifamily buildings may not be designated as "multifamily" within a utility CIS or billing system.*** Identifying multifamily buildings through the use of a commercial rate code can be difficult. Often, a building has a commercial rate code, but there is little information regarding building use. This also applies both to buildings for which the landlord pays the utilities only for the common areas and to buildings for which the landlord pays for one or both utilities (gas and electricity).
- ***Using a tenant-based approach to identifying multifamily buildings does not always work.*** Many times, tenants have a residential rate code that does not distinguish them from other residential customers. Still, the Evaluation Team made elaborate attempts to identify qualified tenants by:
  - Searching for lower-than-average energy consumption,
  - Identifying multiple accounts with the same street address, and
  - Searching for apartment numbers in the service/billing address, etc.

  However, we are unable to confirm the relative success of such efforts.
- ***A tenant-based approach can introduce bias.*** Using a tenant-based approach to building identification naturally leads to a higher probability of identifying buildings with a higher-than-average number of units. (As there is a greater probability of calling someone in a building that has a large number of units, there is a risk of introducing an element of large-building bias to the study.)

Identifying Decision-Makers and Securing Their Cooperation

Regardless of the approach (the top-down with PMs, or bottom-up with tenants), a multi-step process is usually involved in securing the name and contact information for the energy decision-maker. Also, we encountered a considerable amount of attrition in the process (due to non-cooperation), as the researcher had to rely on everyone in the communication chain to share both the name and the contact information of the individual believed to be the correct contact person. In any such chain, a certain percentage of respondents will be apprehensive and unwilling to provide name and contact information. The more people who are involved in the search for the key decision-maker, the more likely it is that the communication chain will be broken (that is, someone will decide not to cooperate further).

Given these limitations, we used several approaches to secure our sample (and the associated contact information) for each of the efforts in this study. For the following sources of sample for the major data collection efforts, keep in mind that the primary purposes of the tenant surveys and PM surveys were to identify multifamily buildings and to recruit for the on-site visits. While we did complete survey questions with both the tenants and the PMs, most of that effort focused on questions about willingness to pay and willingness to participate. Ultimately, we decided that the program manager/PA workshops were the most reliable source of information on willingness-to-pay/participate issues.

On-Site Visits

While on-site visits were secured through several approaches, the main sources of Cadmus' sample were these:

- ***PMs identified through the tenant survey.*** As previously mentioned, a primary objective of the tenant survey was to obtain contact information for the firm or individual who owns or manages the apartment building. The source of the tenant sample (as noted in Section 1) was primarily the NGrid and NSTAR CIS systems.
- ***PMs who participated in the PM Survey.*** In addition to completing the survey, these individuals were recruited for on-site visits. The source of this sample (as noted in Section 1) was Survey Sampling, Inc.
- ***Purchased lists from InfoUSA*** (n = 1,033) ***and Dun & Bradstreet*** (n = 4,245), each of which also covered the Commonwealth of Massachusetts.[4] The outbound calling based on this list was directed by Cadmus and completed by Discovery Research Group.
- ***PM Workshop Recruits:***
  - Individuals who were recruited for a May 2010 project manager workshop and who subsequently attended the workshop were also recruited for on-site visits. A portion of the PM sample used in this recruitment was purchased from Survey Sampling, Inc.
  - Individuals who were recruited for a May 2010 PM workshop but who did not attend were recruited for on-sites. A portion of the PM sample purchased from Survey Sampling, Inc., was used in this recruitment.

Tenant Survey

- All PAs provided standard customer contact data from their respective Customer Information Systems (CIS): name, address, telephone number, and annual energy usage information. Through various methods that ranged from using algorithms to scan for an apartment number within a service/billing address, to identifying multiple records with the same address, to identifying residential customers with lower than annual usage—ODC staff worked on each CIS dataset to identify customers who were likely to live in a multifamily building. A variable was added to each dataset to flag a multifamily-likely resident and then the datasets were joined together.

[4] The Standard Industrial Classification (SIC) code included in the InfoUSA sample was 651303-Apartments and 653118-Real Estate. The SIC codes included in the Dun & Bradstreet sample were: 651310200-Real Estate; 65529902-Residential Real Estate Development; 65310105-Residential Real Estate Brokerage & Management; 65139903-Residential Property Management; and 65120000-Commercial Property Management.

- Using the aggregated dataset described above, ODC started outbound calling. This approach ultimately proved to be unproductive, as only eight tenant surveys were completed.
- Based on the challenges encountered in attempting to identify tenants, we chose to focus on NGrid and NSTAR territories only. After drawing 12,000 names of multifamily-likely individuals from the CIS dataset, with proportionate (to the population) representation from each of the utilities (NGRID at 42% and NSTAR at 58%), ODC and Cadmus split the names. ODC retained 7,307 names, all of which were in Region 4 (Northeast Massachusetts), while Cadmus retained 4,693 names (from the other four regions: west, north central, south central, and southeast).
- From this new dataset, ODC contacted the 7,307 customers by mail, asking them to call in and complete a survey. ODC completed a total of 82 tenant surveys through this approach.
- From its dataset of 4,693 names, Cadmus continued using the outbound calling approach, which resulted in a total of 102 completed tenant surveys.

Property Manager Survey

From Survey Sampling, Inc., ODC purchased a list covering the entire Commonwealth of Massachusetts (n=1,773). The SIC codes for this sample were these: 6513-Apartment Building Operators, 6519-Real Property Lessors NE, and 6531-Real Estate Agents and Managers. The outbound calling was done by ODC's call center.

Estimate of Number of Buildings (5 or More Units)

For the reasons discussed above, the Evaluation Team was unable to aggregate billing data from each PA to estimate the number of multifamily buildings in Massachusetts. Thus, we relied on a secondary source—the 2010 American Community Survey (ACS)[5]—which specifies the total number of units at 584,896, and the number of occupied units (either by renter or owner) at 524,230. For the potentials estimate, our interest is in the number of occupied units.

Using ACS data about the quantity of multifamily residences in Massachusetts, we developed an estimate of both the number of multifamily units and the number of multifamily buildings in the commonwealth. (See Table 11)

Table 11. Massachusetts Multifamily Units

Units in Structure	Total Units	Total Occupied Units
5 to 9	173,652	150,275
10 to 19	119,593	109,050
20 to 49	119,746	108,604
50 or more	171,905	156,301
Total	*584,896*	*524,230*

Using the information in Table 11, we obtained the average building size of approximately 16 units by:

- Using the midpoints of the first three intervals shown in (for from 5 to 9 units in a structure we use 7; for from 10 to 19 units in a structure we use 15, etc.);
- Using 100 for the fourth interval (50 or more); and
- Weighting each by the number of occupied units in that interval.

The results of these calculations are shown in Table 12.

Table 12. Estimated Number of Multifamily Buildings

Units in Structure	Total Occupied Units		Assumed Units Per Building	Estimated Buildings	
	N	Percent		N	Percent
5 to 9	150,275	29%	7	21,468	64%
10 to 19	109,050	21%	15	7,270	22%
20 to 49	108,604	21%	35	3,103	9%
50 or more	156,301	30%	100	1,563	5%
Total	*524,230*	*100%*	*16*	*33,404*	*100%*

For the purposes of the potentials estimate in Section 3, we also developed a forecast of the number of occupied units. Our projection, which is based upon a 2000 to 2030 population projection for Massachusetts by the U.S. Census Bureau,[6] forecasts the population at five-year intervals. Using an average growth rate of 0.26% from 2010 to 2030, we applied the projected

[5] 2010 American Community Survey, 1-Year Estimates. http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

[6] Interim Projections of the Total Population for the United States and States: April 1, 2000 to July 1, 2030 http://www.census.gov/population/projections/SummaryTabA1.pdf

growth rates to the number of multifamily units and multifamily buildings to obtain the forecasted numbers shown in Table 13.

Table 13. Projected Massachusetts Multifamily Units and Buildings, Electric

Year	Number of Multifamily Units	Number of Multifamily Buildings
2010	524,230	33,404
2015	532,873	33,955
2020	540,552	34,444
2025	547,132	34,863
2030	552,943	35,233

We assume that all multifamily units have electric service, but we cannot make the same assumption about natural gas service. To project the number of units and buildings with natural gas service, we used our on-site data, which show approximately 60% of multifamily units with natural gas service. Our estimate of multifamily units with natural gas is higher than the statewide average reported by the EIA[7]; however, we note that multifamily buildings are more common in densely populated areas that are more likely to have natural gas service.

This ratio is the basis of our estimation of the number of units and buildings having natural gas service, shown in Table 14.

Table 14. Projected Massachusetts Multifamily Units and Buildings, Natural Gas

Year	Number of Multifamily Units	Number of Multifamily Buildings
2010	311,849	19,871
2015	316,990	20,199
2020	321,558	20,490
2025	325,472	20,739
2030	328,929	20,959

[7] Natural Gas customers: http://www.eia.gov/dnav/ng/ng_cons_num_dcu_SMA_a.htm and Electric Customers: http://www.eia.gov/cneaf/electricity/epa/customers_state.xls

Building Characteristics

This section contains details—obtained from primary data collection activities and from secondary data sources—regarding the characteristics of multifamily buildings.

Occupancy Characteristics

Cadmus' analysis of the 2010 American Community Survey (ACS)[8] indicates that approximately 17% of multifamily buildings in Massachusetts are owner-occupied, with the remaining 83% of buildings occupied by tenant renters (Table 15).

Table 15. Summary of Occupancy Characteristics

Occupancy Characteristic		% of Buildings	Data Source
Rent/Own	% Owned	17%	2010 American Community Survey
	% Rented	83%	
Income Level	Low income	31%	Discovery Research Group recruiting data
	Not low income	69%	
Management Structure	Manage	43%	Property manager survey
	Own	8%	
	Both	49%	

Note: Percentages sum to 100% under the Characteristic designations (e.g., Rent/Own)

We estimate the proportion of low-income buildings in Massachusetts to be 31% of all multifamily buildings. Our estimate is derived from our PM-based on-site visit recruiting sample from Discovery Research Group (n=770 buildings managed by 97 PMs). After following up with each PM, we were able to designate specific buildings as low-income because 50% or more of the tenants received rent assistance.

This estimate is consistent with that found in the 2009 RECS survey, which reported that 25% of the Massachusetts multifamily residents live in public housing projects or receive rental assistance. Although the unit of analysis in the RECS survey is different, we believe it is plausible that approximately 30% of all multifamily buildings and individual units in RECS in our recruiting sample meet could be classified as low income.

From the information provided by the PMs we surveyed, we estimate that about 49% of the PMs in the Commonwealth of Massachusetts own the properties they manage; another 43% of PMs manage properties for others, while approximately 8% own properties that are managed by another entity.

Physical Characteristics

Our assessment of the physical characteristics of buildings was based primarily on our on-site data collection efforts. While the distribution of the units we visited is similar to the statewide distribution in terms of units per structure, the distribution of buildings visited is not.

The distribution of individual units by building size in our on-site data is similar to that found in ACS. However, as shown in Table 16, we observed that large buildings (20 or more units) were

[8] 2010 American Community Survey, 1-Year Estimates. http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

over-represented in our on-site data collection, while smaller buildings were under-represented. This is an artifact of our building-centered focus in on-site recruiting. By visiting one tenant in each building, we implicitly give both the building and the tenant unit the same weight in our on-site data.

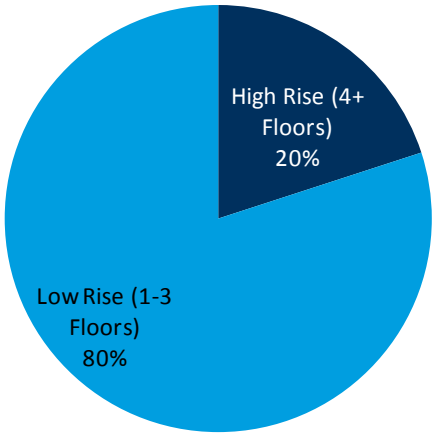
To correct for this bias in our analysis of building physical characteristics, we assigned each building in the on-site data a weight such that the sum of building weights is equal to the sample size of 193.

Table 16. Weighting for Buildings in On-Site Data

Units in Structure	ACS % of Buildings	On-Site % of Buildings	On-Site Building Weight
5 to 9	64%	21%	3.1
10 to 19	22%	21%	1.0
20 to 49	9%	29%	0.3
50 or more	5%	29%	0.2
Total	100%	100%	--

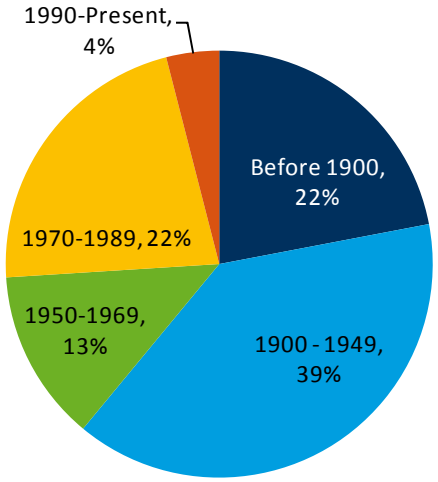
From the on-site data, we estimated that 80% of multifamily buildings in Massachusetts are low-rise buildings (three or fewer floors), while the remaining 20% are high-rise (Figure 7).

Figure 7. Multifamily Building Characteristics: High-Rise vs. Low-Rise



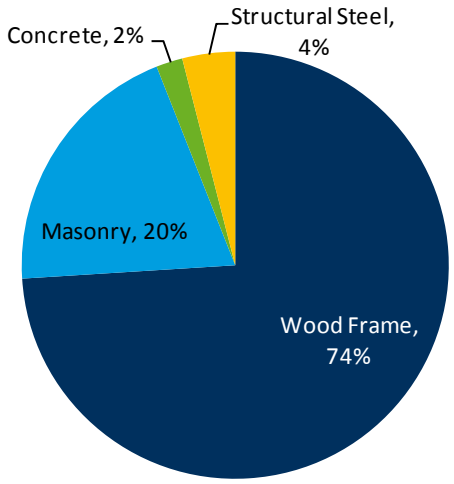
More than half of the multifamily buildings we visited were constructed before 1950 (Figure 8).

Figure 8. Multifamily Building Characteristics: Year Built



As shown in Figure 9, wood framing is most common construction material for multifamily residences, which tend to be smaller buildings.

Figure 9. Multifamily Building Characteristics: Structural Material



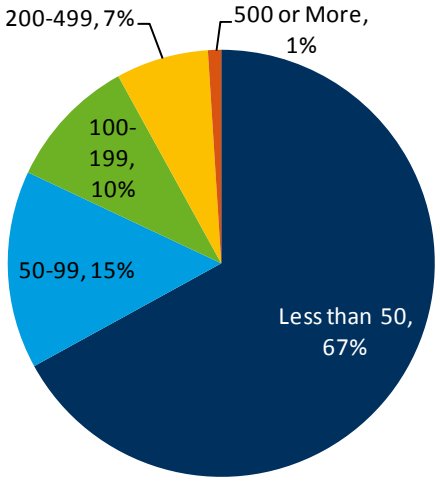
As shown in Table 17, more than 80% percent of multifamily buildings have within-building common areas—specifically, 55% of buildings have a common laundry facility. Although pools, kitchens, and elevators tend to be common in larger structures, these amenities are provided in less than 20% of the multifamily buildings statewide, since the stock is skewed towards smaller buildings.

Table 17. Multifamily Building Characteristics: Common Areas

Common Area Characteristic		Percent of Buildings
Common Area Location	Inside and Outside Building	51%
	Inside Building Only	36%
	Outside Building Only	5%
Common Laundry Facility		55%
Common Kitchen Facility		6%
Elevator Present in Building		14%
Common Pool Area	On Complex	14%
	In Building	1%

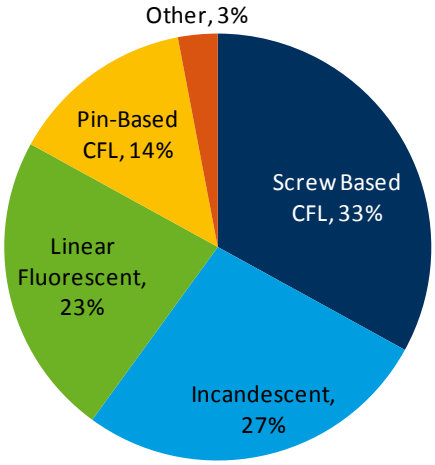
Figure 10 provides details of the quantity of light bulbs in the common areas of the building we visited. We experienced difficulty collecting comprehensive common-area lighting data for each building. However, assuming that bulb quantity is correlated with the size of a structure, we noted that the distribution of observed quantities appeared to be unbiased.

Figure 10. Common Area Lighting Quantity



Nearly 50% of buildings visited in our on-site sample (Figure 11) were reported to have either standard CFLs or pin-based CFLs as the primary common-area lighting type. There may be other common-area bulb types on site, but those are installed in smaller quantities.

Figure 11. Common Area Primary Light Bulb Type



In terms of utility bills, our site visits revealed the following:

- The utility bills that are most commonly paid by tenants are for heating (in 60% of buildings) and cooling (in 86% of buildings having some form of cooling system).
- Payments for water heating are split between the landlord and the tenant.
- In a small portion of buildings, condominium fees cover the cost of HVAC and water heating.

Table 18. Utility Payment for HVAC and Water Heating

Utility Payment	Heating (Pct. of Buildings)	Cooling (Pct. of Buildings)	Water Heat (Pct. of Buildings)
Condo Fees	7%	3%	8%
Paid by Landlord	33%	11%	47%
Paid by Tenant Directly	60%	86%	45%
Total	100%	100%	100%

We provide HVAC and water heating system information in the In-Unit Characteristics subsection, as energy consumption from these end uses was included in our within-unit potentials model.

In-Unit Characteristics

This section contains a discussion of in-unit characteristics for multifamily buildings in Cadmus' evaluation. We first present information about equipment saturations and fuel, calculated specifically as inputs for our potentials estimate in Section 3 of this report. We then focus in detail on in-unit lighting and windows. The data presented in this section are taken primarily from our on-site visits, for which the average size of a unit was slightly less than 800 square feet.

Equipment Saturations and Fuel Shares

In this report section, the majority of the data in the tables was collected during our on-site visits; however, these data are supplemented by the 2009 RASS, which was conducted by Opinion Dynamics Corporation.

Definitions and Details

- ***About Saturation.*** For the purpose of our baseline energy consumption estimate, we define "saturation" as the average number of units of end-use equipment per home; thus, the saturation rate may exceed 100%. (For example, Table 19, on the following page, shows that oven saturation is 97%, indicating that there are, on average, 0.97 ovens per multifamily unit.)
- ***About Fuel Share.*** This is a percentage of end-use equipment that uses a given fuel as the primary fuel type. (For example, Table 19 shows an electric fuel share of 60% for ovens.) Multiplying the number of multifamily units by the oven saturation and electric fuel share provides an estimate of the number of electric ovens in Massachusetts multifamily buildings.
- ***About Elective HVAC and Water Heating.*** Our on-site visit data suggest that multifamily heating and water heating systems typically serve multiple units: 63% of units have building-level heating and 63% of units have building-level water heating. The most common cooling system is room air conditioning, although only 70% of the multifamily units we visited had cooling.
- ***About Appliances.*** In multifamily settings, appliances are kitchen-centric. The average multifamily unit has just over one refrigerator, and standalone freezers are very uncommon (1% saturation). The laundry facilities, however, are typically found in common areas; we observed a dryer in only 21% of multifamily units.
- ***About Lighting and Plug Loads.*** Since we assume all multifamily units have lighting, we chose to distinguish between standard and specialty lighting for potentials estimation (saturation is 100% for both end uses). Similarly, we assume all units have some additional plug load saturation, such as phone chargers and smaller electric appliances in the kitchen.

Table 19. Electric Equipment Saturation

End Use Category	End Use	Equipment Saturation	Fuel Share	Source
Cooling	Unit-Based Room AC	35%	100%	On-Site Visits
	Unit-Based Central AC	16%	100%	On-Site Visits
	Building Central AC	10%	100%	On-Site Visits
Heating	Unit-Based Room Heat	17%	88%	On-Site Visits
	Unit-Based Furnace	13%	12%	On-Site Visits
	Building Boiler	52%	3%	On-Site Visits
	Building Furnace	11%	5%	On-Site Visits
Heat Pump	Unit-Based Heat Pump	8%	100%	On-Site Visits
Water Heating	Unit-Based Water Heat	37%	36%	On-Site Visits
	Building Water Heat	63%	8%	On-Site Visits
Ventilation	Ventilation	86%	100%	On-Site Visits
Lighting	Standard Lighting	100%	100%	Assumption
	Specialty Lighting	100%	100%	Assumption
Appliances	Refrigerator	101%	100%	On-Site Visits
	Freezer	1%	100%	On-Site Visits
	Microwave	61%	100%	On-Site Visits
	Oven	97%	60%	On-Site Visits
	Range	99%	60%	On-Site Visits
	Dryer	21%	88%	On-Site Visits
Plug Load	Dehumidifier	8%	100%	2009 RASS
	TV Set Top Box	64%	100%	On-Site Visits
	DVD Player	52%	100%	On-Site Visits
	Television	91%	100%	On-Site Visits
	Television, Big Screen	18%	100%	On-Site Visits
	Computer - Desktop	31%	100%	On-Site Visits
	Monitor	32%	100%	On-Site Visits
	Home Audio System	61%	100%	2009 RASS
	Other Plug Load	100%	100%	Assumption

For buildings that have gas service, gas is typically used to fuel the heating and water heating systems. These systems tend to be building-wide, serving multiple units: 73% of heating systems and 68% of water heating systems for gas customers (Table 20). The population considered in Table 20 is a subset of that shown Table 19, as we condition on presence of gas service in order to capture the proper number of units of end-use equipment in our potentials estimates. For this reason, there may be variation in the equipment saturations of similar end uses across the two fuel types. As noted in our estimate of the number of homes, gas customers represent approximately 60% of the total multifamily residence stock.

Table 20. Gas Equipment Saturation

End Use Category	End Use	Equipment Saturation	Fuel Share	Source
Heating	Unit-Based Room Heat	6%	38%	On-Site Visits
	Unit-Based Furnace	16%	100%	On-Site Visits
	Building Boiler	61%	87%	On-Site Visits
	Building Furnace	12%	82%	On-Site Visits
Water Heating	Unit-Based Water Heat	32%	82%	On-Site Visits
	Building Water Heat	68%	88%	On-Site Visits
Appliances	Oven	96%	35%	On-Site Visits
	Range	98%	35%	On-Site Visits
	Dryer	21%	7%	On-Site Visits

In-Unit Characteristics: Lighting

The data for in-unit lighting penetration and saturation for multifamily buildings in Massachusetts were collected and recorded by primary and secondary lighting types on a room-by-room basis (bedrooms, bathrooms, kitchens, living spaces, and hallways).

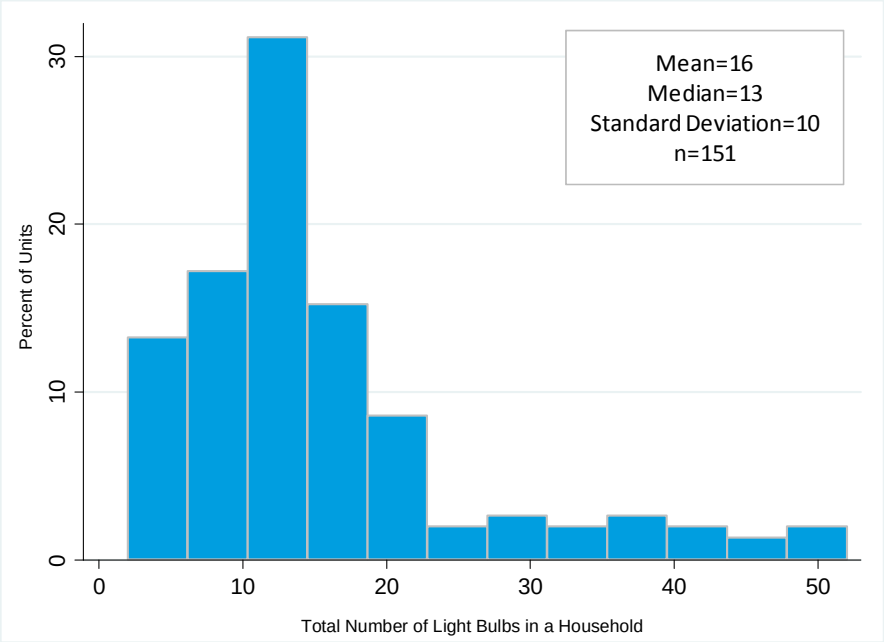
The Evaluation Team cleaned and aggregated the data to present the results on a unit level. As shown in Figure 12, the pertinent details of our efforts are these:

- When information on the in-unit lighting was missing because the evaluators could not gain access to units, those units were removed from the analysis.
- In instances when evaluators were given access to the unit but not to all of the rooms, those units were retained in analysis; however, with data for rooms with no access marked as missing.
- A few multifamily buildings in the sample were boarding houses having shared kitchens and/or bathrooms. In those cases, kitchens and bathrooms were considered part of the common-area space and, as such, were excluded from the in-unit lighting analysis.

All of our data are for light bulbs currently in use, unless explicitly stated otherwise. (Inspectors did not collect the data on the light bulbs in storage.) An average multifamily unit has 16 light bulbs in use. The median number of light bulbs in use is 13.

It is important to note that 29% of units visited during the on-site data collection were vacant units. This may result in an understatement of the total number of light bulbs in multifamily units, as residents often bring lighting with them when they move in (such as table lamps and floor lamps).

Figure 12. Total Number of Light Bulbs in Multifamily Units



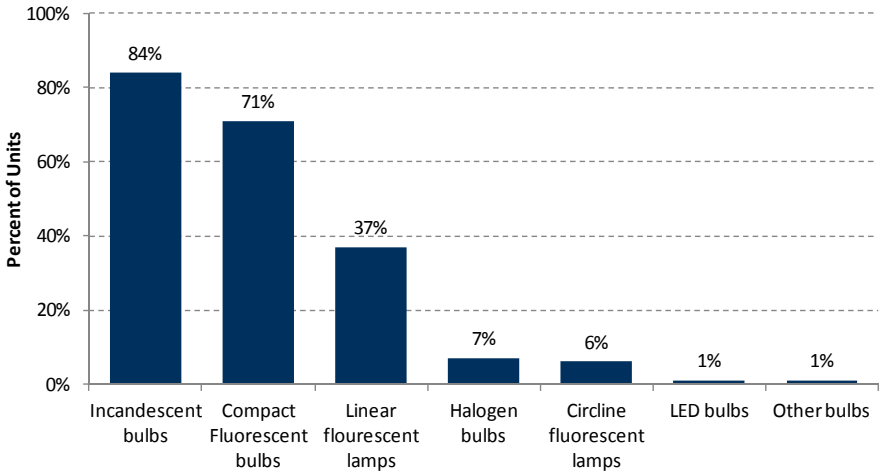
As shown in Table 21, one-third of multifamily units (36%) have between 11 and 15 light bulbs, and another third have more than 15 light bulbs.

Table 21. Lighting Penetration in Multifamily Units

Number of Light Bulbs	Percent of Units
1-5	9%
6-10	21%
11-15	36%
16-20	14%
21-25	7%
26 or More	13%
Mean number of bulbs in use	16

In terms of the various lighting technologies present in multifamily units, incandescent lighting has the highest penetration rate (84%). However, 71% of multifamily units have at least one CFL. Linear fluorescent lighting is present in 37% of multifamily units, and the penetration rates for the other lighting technologies are low (Figure 13).

Figure 13. Penetration Rate of Various Lighting Technologies

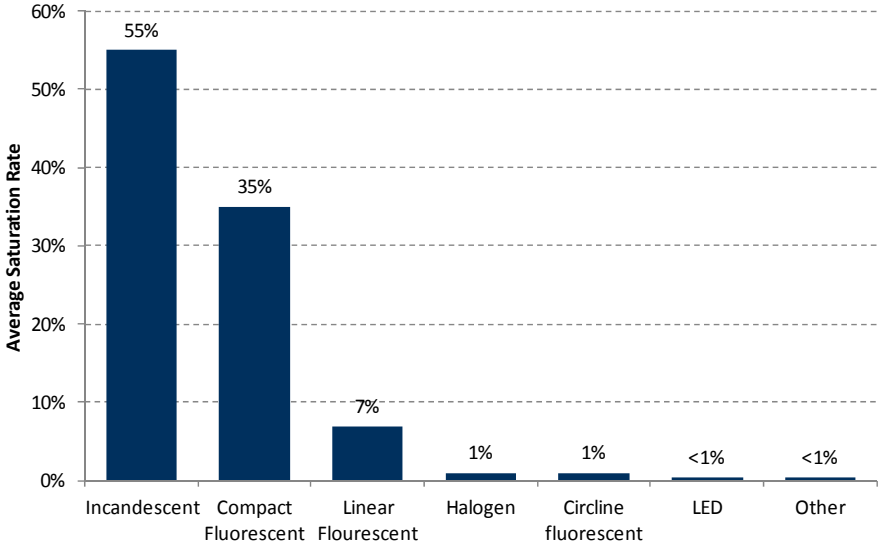


Saturation Rates of Bulb Types

As shown in Figure 14:

- Incandescent lighting continues to be the dominant lighting technology, accounting for 55% of bulbs that are currently in use in multifamily units.
- 35% of the bulbs in use are CFLs.
- 7% are linear fluorescent lamps.
- Other lighting technologies constitute 1% or less of the total unit lighting.

Figure 14. Saturation Rate of Various Lighting Technologies

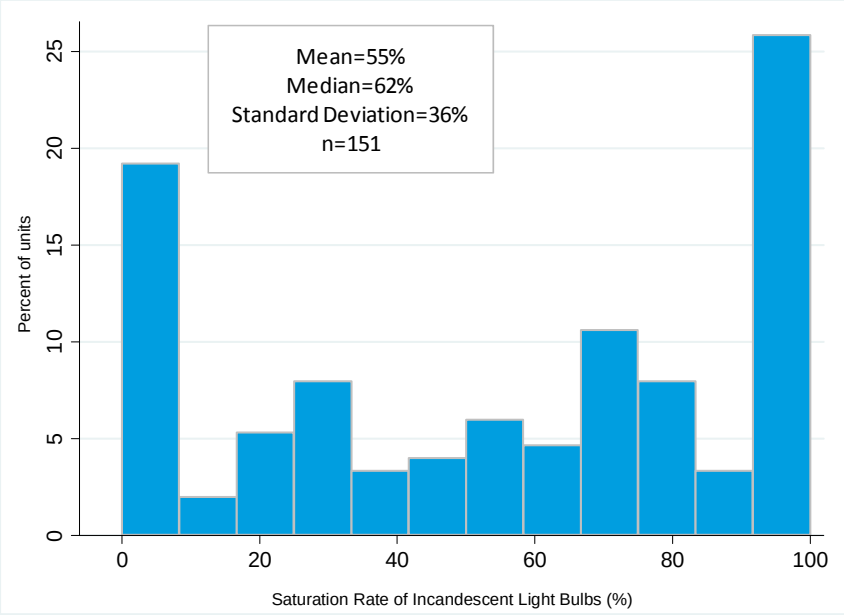


Note: Saturation is defined as the percentage of total household bulbs that are a particular bulb type. The numbers reported here are the average household saturation rates.

Saturation Rates of Bulbs Types

The histograms in Figure 15 show the saturation rates of incandescent and compact fluorescent lighting. Clearly, the market for CFLs in multifamily buildings in Massachusetts is far from being saturated, as 21% of multifamily units use incandescent lighting exclusively.

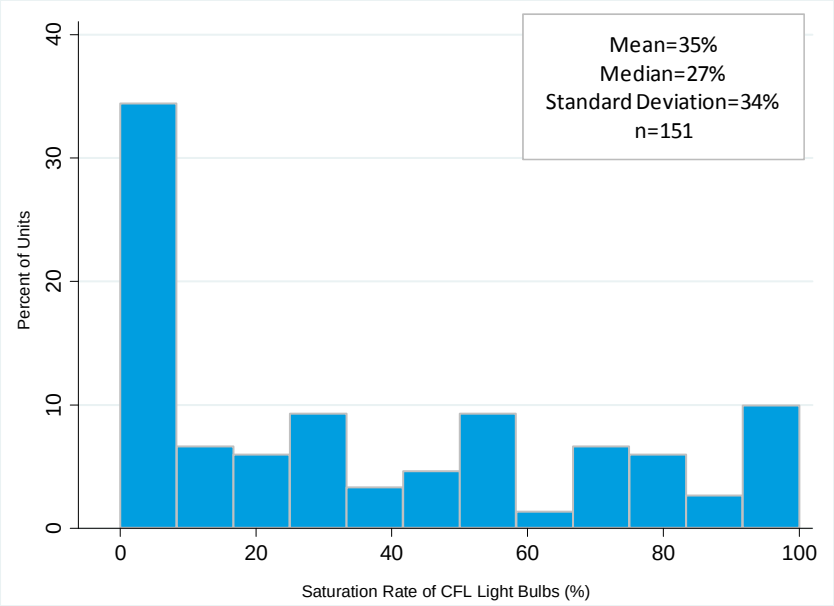
Figure 15. Saturation Rate of Incandescent Lighting



Note: Saturation is defined as the percentage of total household bulbs of a particular bulb type. Numbers reported here are average household saturation rates.

In contrast, only 7% of units use CFLs exclusively (Figure 16). Also, less than a third of tenants (31%) use CFLs for the majority of their lighting, whereas 57% use incandescent light bulbs for the majority of their lights.

Figure 16. Saturation Rate of CFL Lighting



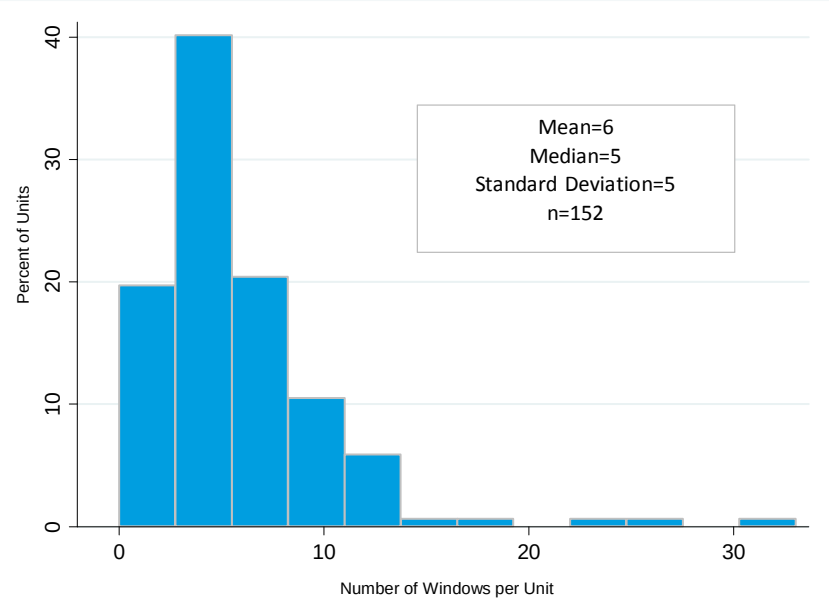
Note: Saturation is defined as the percentage of total household bulbs of a particular bulb type. Numbers reported here are average household saturation rates.

In-Unit Characteristics: Windows

This section presents Cadmus' in-unit window penetration and saturation data by frame and pane type for multifamily in Massachusetts. We collected and recorded the data on a room-by-room basis. We then cleaned and aggregated the data to present results on a unit level. An average multifamily unit has six windows, and the median number of windows is 5. (See Figure 17.)

- When information on the in-unit windows was missing because the evaluators could not gain access to units, those units were removed from the analysis.
- In instances when evaluators were given access to the unit but not to all of the rooms, those units were retained in analysis; however, with data for rooms with no access marked as missing.
- In instances when either the pane or frame type was not recorded, those windows were retained in analysis, with either incomplete pane or frame data marked as missing.
- For the few multifamily buildings in the sample that were boarding houses having shared kitchens and/or bathrooms, those shared rooms were considered a part of the common-area space and, thus, were excluded from the analysis.

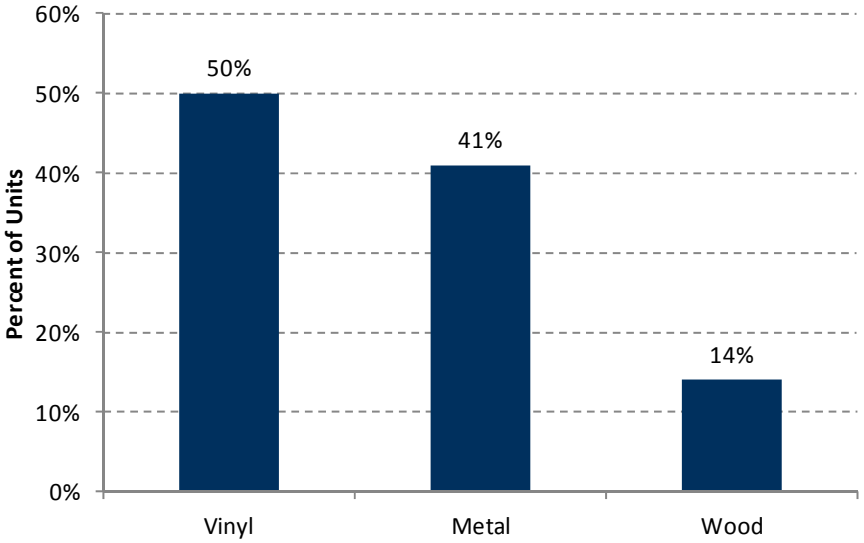
Figure 17. Total Number of Windows in Multifamily Units



Penetration Rates of Window Frame Types

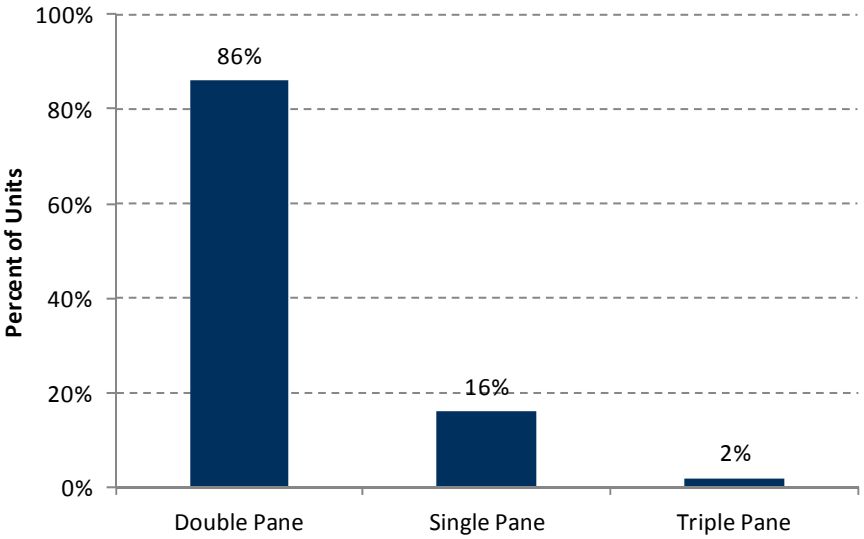
Regarding the window frames in multifamily units, vinyl frames have the highest penetration rate (50%). However, 41% of multifamily units with at least one metal frame window.

Figure 18. Penetration Rate of Window Frame Types



Regarding window panes in multifamily units, double-pane windows have the highest penetration rate, with 86% of multifamily units having at least one double-pane window. While there is a limited penetration of single-pane windows (16%), there are even fewer instances of units with triple panes (2%).

Figure 19. Penetration Rate of Window Pane Types

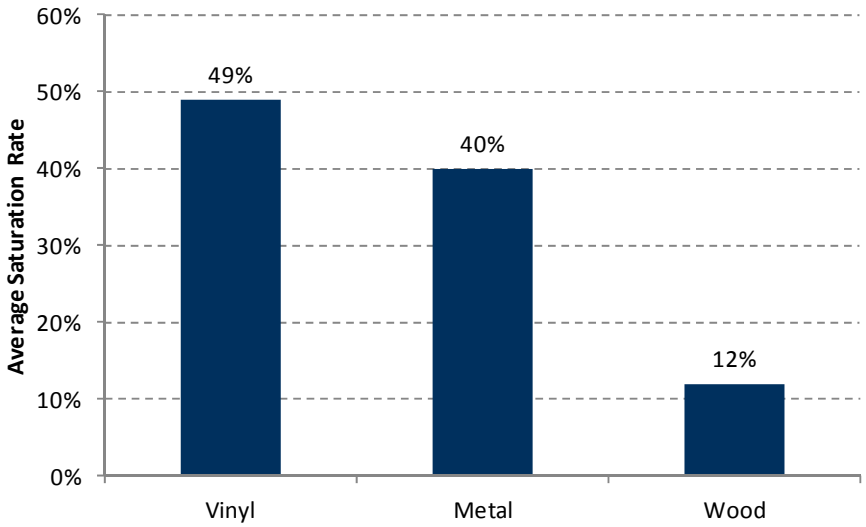


Saturation Rates of Window Frame Types

Cadmus' data about saturation rates (by pane and frame) are nearly identical to the associated penetration rates, because frame and pane type are consistent throughout the unit. (That is, 95% of units have windows with the same pane type throughout the unit, and 93% of units have windows with the same frame type throughout the unit).

As illustrated in Figure 20, nearly half of all windows in multifamily units (49%) have vinyl frames, while metal frames comprise 40% of all windows.

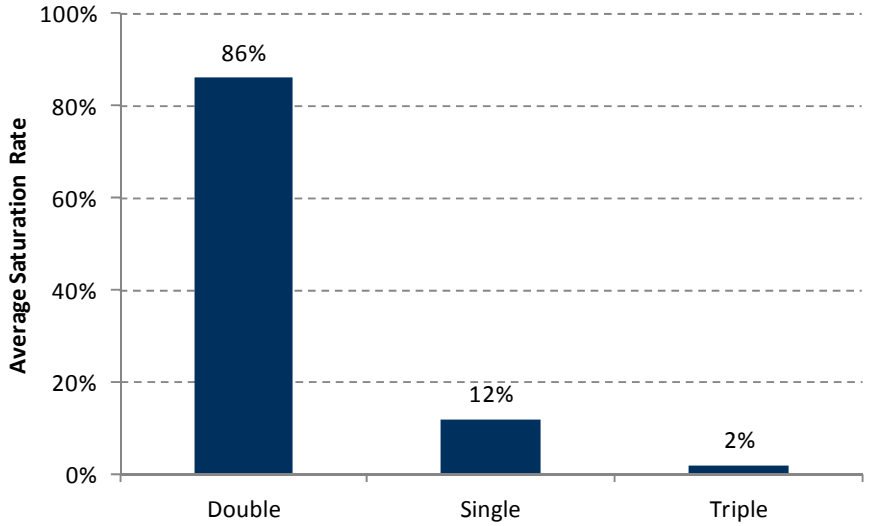
Figure 20. Saturation Rate of Window Frame Types



Saturation is defined as the percentage of total household window frames that are a particular frame type. The numbers reported are the average household saturation rates.

Consistent with the high penetration rates, 86% of multifamily unit window panes are double-pane windows.

Figure 21. Saturation Rate of Window Pane Types



Saturation is defined as the percentage of total household window panes that are a particular pane type. The numbers reported here are the average household saturation rates.

Multifamily Property Owner/Manager Decision-Making

The qualitative information in this subsection is primarily based on the results of the achievable potential workshops, which were attended by a total of 17 PMs. These PMs own or manage 356 buildings, which contain more than 11,000 units in Massachusetts. (The material here was supplemented with information from PAs, when warranted.)

The PA workshops were attended by representatives from implementation contractors (RISE and CSG) and PMs for Multifamily and/or Low Income programs sponsored by NSTAR, National Grid, and Columbia Gas. The information presented in this subsection is primarily based on the information provided by PMs—supplemented with information from PAs when warranted.

Barriers to Adoption of Energy-Efficient Technologies

Within the multifamily sector, there are numerous barriers to the adoption of energy-efficient technologies —both with and without PA-provided incentives. The key barriers are these:

- Initial costs before an upgrade is installed and the risk of code violations
- Installation inconveniences
- Lack of PM knowledge
- Tenant resistance
- Split incentives
- Return on investment
- First cost of investment
- Concerns about energy-efficient measure performance.

Details regarding these barriers and participant responses from the workshops are provided in Appendix D.

Motivators to Adoption of Energy-Efficient Technologies

Despite the barriers, there are specific reasons PMs want to take energy-efficiency actions, even in absence of PA program incentives. The key motivators to adoption are these, and they are detailed in Appendix D:

- Reducing Operating Expenses
- Attracting and Retaining Tenants
- Experiencing Non-Energy Benefits
- Supporting Green Marketing Initiatives
- Having access to trusted contractors.

SECTION 3. POTENTIALS ESTIMATES

This section contains a description of the methodology used by the Evaluation Team to estimate baseline energy consumption and energy-efficiency potentials for multifamily buildings in Massachusetts. It concludes with the results of our calculations of baseline energy consumption and energy-efficiency potentials.

Approach to Estimating Energy Efficiency Potentials

Overview

Cadmus' end-use forecasting model, End Use Forecaster (EUF), served as the underlying engine for generating the baseline, technical potential, economic potential, and achievable potential scenarios. Our methodology and the key data and assumptions we used to develop the electric and natural gas baselines and potential estimates for the Massachusetts multifamily sector are detailed here.

The demand-side resources analyzed in this study differ with respect to several salient attributes, such as the load shape of the energy impact and the availability, reliability, and applicability of the resources to various building vintages. The demand-side resources also require fundamentally different approaches to program design, incentive structures, and delivery mechanisms for their deployment. Therefore, analysis of the potential for these resources requires methods tailored to address the unique technical and market characteristics of each resource.

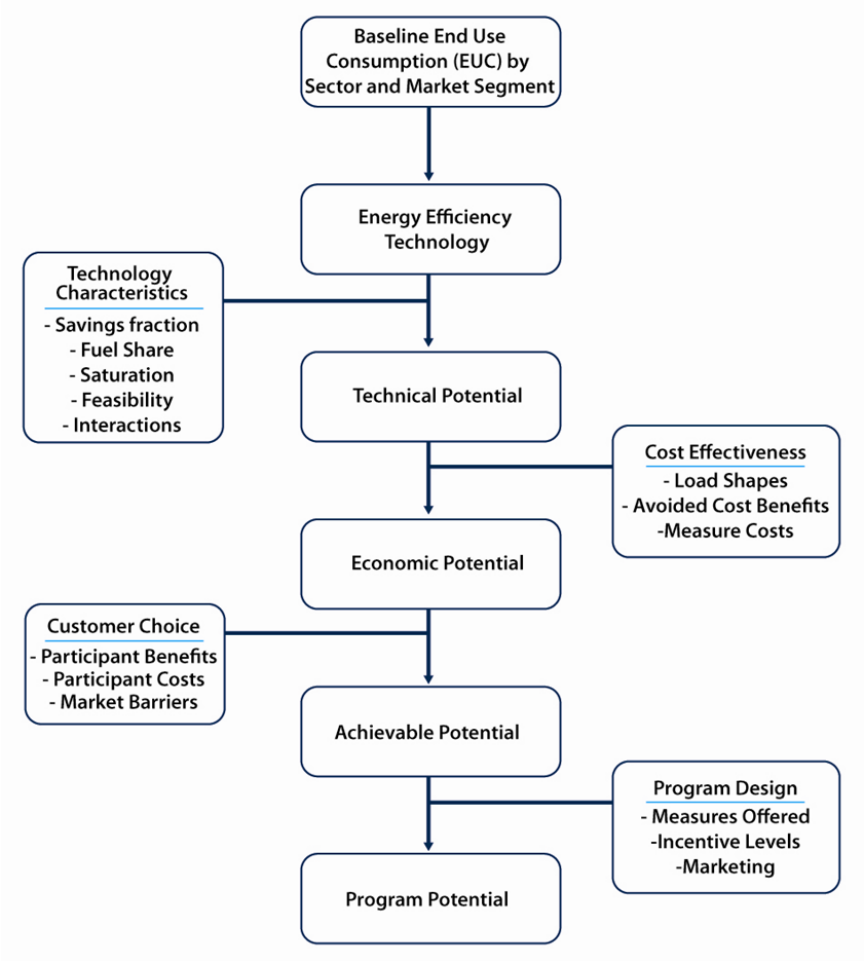
These tailored methods, however, generally spring from a common conceptual framework, and their applications to various resources rely on similar analytic methodologies. This general methodology is best described as a hybrid "top-down/bottom-up" approach.

- **Top-Down Approach**. As shown in Figure 22 (on the following page), the top-down methodology component begins by developing both a natural gas load forecast and an electricity load forecast for all multifamily buildings within Massachusetts. These forecasts, which are based on customer characteristics and end-use energy consumption estimates, include the buildings' common areas.
- **Bottom-Up Approach**. The bottom-up component considers the potential technical impacts of various demand-side and supplemental resource technologies, measures, and practices on each end use. These are then estimated based on engineering calculations that take into account fuel shares, current market saturations, technical feasibility, and costs. These individual impacts are aggregated to produce estimates of resource potential at the segment and end-use levels. In many ways, the approach is analogous to generating two alternative load forecasts at the end-use level (one with and one without DSM and supplemental resources) and calculating the resource potential as the difference between the two forecasts.

Definition of Resource Potentials

In this study, the estimates of technical and economic potential are based on best-practice research methods and analytic techniques standard in the utility industry. Consistent with accepted industry standards, the Evaluation Team's approach distinguishes among four definitions of resource potential widely used in utility resource planning.

Figure 22. Methodology for the Assessment of Energy Efficiency Potentials



- ***Naturally occurring conservation*** refers to reductions in energy that occur due to normal market forces, such as: technological changes, energy prices, market transformation efforts, equipment turnover, and improved energy codes and standards. In this analysis, naturally occurring conservation is accounted for in several ways.
  - First, the potential associated with certain energy-efficiency measures assumes a natural rate of adoption. (For example, the savings associated with ENERGY STAR® appliances account for current customer adoption trends or market share.)
  - Second, current codes and standards are applied to the consumption characteristics of new construction.

  - Finally, the assessment accounts for the gradual increase in efficiency as older equipment in existing buildings is replaced by units meeting current standards. (However, this assessment does not forecast changes to codes and standards; rather, it treats them as "frozen" at a given efficiency level.)

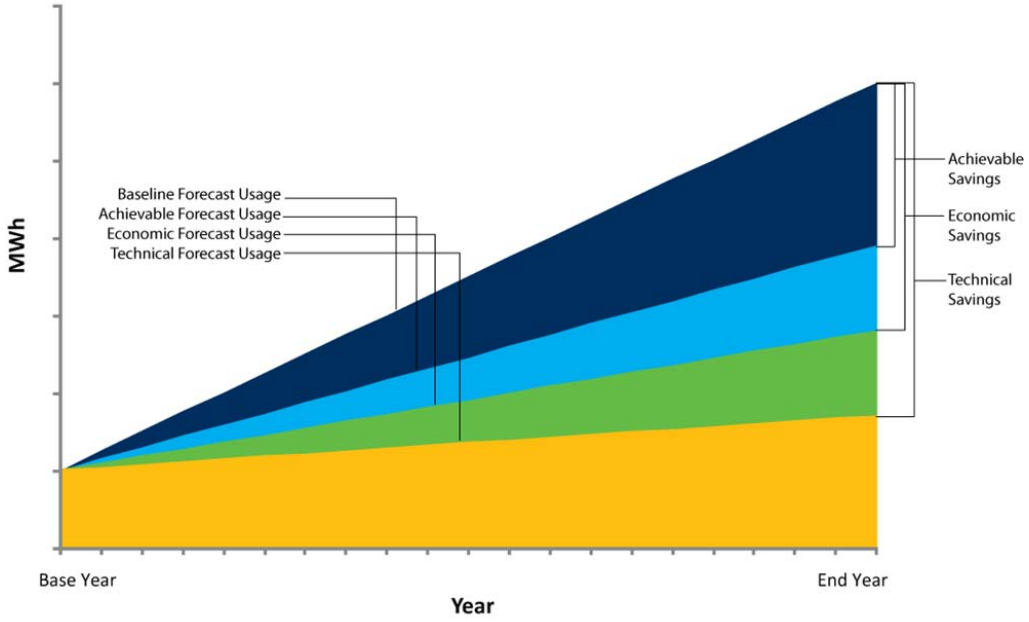
- ***Technical potential*** assumes all technically feasible energy-efficiency measures may be implemented, regardless of their costs or market barriers. For energy-efficiency resources, technical potential can be organized in three distinct classes: (1) retrofit opportunities in existing buildings, (2) equipment replacement in existing buildings, and (3) new construction. Theoretically, the first class—retrofitting current building stock—can be acquired at any point in the planning horizon. However, the timing of the other two classes is dictated by end-use equipment turnover and new construction rates.
- ***Economic potential*** represents a subset of technical potential, consisting only of measures meeting the cost-effectiveness criterion and based on Massachusetts' avoided energy and capacity costs. For each energy-efficiency measure, the benefit-cost test is structured as the ratio of the net present values of the measure's benefits and costs. Only measures with a benefit-to-cost ratio of 1.0 or greater are deemed cost-effective and included in economic potential estimates. However, since program administrative costs are not considered in this measure screening, the economic potential screen is slightly less restrictive than a typical program-level cost-effectiveness analysis.
- ***Achievable potential*** as the portion of economic potential that might be assumed reasonably achievable in the course of the planning horizon (20 years in this study), given market barriers that may impede customer participation in PA programs. Program achievable potential can vary sharply, based on program incentive structures, marketing efforts, energy costs, customer socioeconomic characteristics, and other factors.

  This study analyzed achievable potential in two scenarios: (1) a business-as-usual (BAU) case estimating how much of the economic potential can be captured under current Massachusetts multifamily program designs and annual budgets; and (2) a maximum achievable potential (Max) scenario consistent with both 100% incremental cost incentives and program designs targeting hard-to-reach customers and measures.[9]

[9] For Massachusetts, the BAU case is roughly consistent with ***Program Potential*** as shown in Figure 22.

In the general alternate definitions of potentials (Figure 23), achievable potential is shown as a subset of economic potential, and economic potential is a subset of technical potential. The differences between the baseline and each alternative forecast represent the different types of potential.

Figure 23. Example of Alternative Forecast Approach to the Estimation of Energy-Efficiency Potential



Note: Baseline and alternative forecasts shown in Figure 23 are purely for illustrative purposes, and do not represent actual data underlying this assessment.

Data Assimilation

Many data inputs were required to create a baseline forecast that accurately reflected the consumption characteristics of Massachusetts multifamily customers. The key inputs were these:

- Sales and customer forecasts;
- Customer counts by major customer segments (e.g., multifamily unit versus common area);
- End-use and equipment saturation;
- Fuel shares;
- Efficiency shares (the percent of equipment below, at, and above code); and
- Annual end-use consumption estimates by efficiency level.

Table 22 summarizes the data sources that the Evaluation Team used for this study.

Table 22. Key Potential Study Data Inputs and Sources

Data Type	Data Source
Base Year Sales and Customers	American Community Survey, 2010 (1 Year Estimate) Number of Occupied Multifamily Units
Forecasted Sales and Customers	Census Bureau 2005-2030 Population Projection
End-Use Energy Consumption	Building simulations, EIA, Energy Star, etc.
Saturations and Fuel Shares	**On-Site data collection**
Efficiency Shares	**On-Site data collection**, secondary sources
Energy Efficiency Measures	Itron measure list, Massachusetts TRM
Cost-Effectiveness Assumptions	Massachusetts BCR Model inputs
Maximum Achievable Potential	**Achievable Potential Workshops**, secondary sources

Note: Items highlighted in **bold** are from primary data collection efforts.

Estimating Baseline Energy Consumption

Upon completing the data collection and compilation phase, the Evaluation Team combined the model inputs to produce base year estimates of electricity and natural gas usage. For each fuel, estimates of base year (2010) annual usage were produced by combining the following inputs:

- Number of customers.
- Estimates of Unit Energy Consumption (UECs)/Energy Use Intensity (EUIs) by building and end use.
- End-use saturations: percentages of customers having particular end uses.
- End-use fuel shares: percentages of end-uses powered by the different fuel types.
- End-use efficiency shares: percentages of end-uses at the different efficiency levels.

To estimate total annual energy usage, we used this formula to combine the inputs:

(1) $$EUSE_{ij} = \Sigma_e \, ACCTS_i * SAT_{ij} * FSH_{ij} * ESH_{ije} * EUI_{ije}$$

where:

$EUSE_{ij}$ = total energy consumption for end use j in customer segment i

$ACCTS_i$ = the number of dwellings for the in-unit model and the number of buildings in the common area model for customer segment i

SAT_{ij} = the share of customers in customer segment i with end use j

FSH_{ij} = the share associated with electricity in end use j in customer segment i

ESH_{ije} = the market share of efficiency level e in the equipment for customer segment ij

EUI_{ije} = energy consumption per unit for the equipment configuration ije

Total annual consumption in each sector was then determined as the sum of $EUSE_{ij}$ across the end uses and customer segments. The key to ensuring the accuracy of the baseline forecasts is the calibration of the end-use model estimates of total consumption to the U.S. Census estimates of actual electricity and natural gas sales to Massachusetts multifamily customers in 2010. This calibration to base year sales entails making appropriate adjustments, as needed, so that the data conform to known information from a variety of sources about customer counts, appliance and equipment saturations, and fuel shares.

Derivation of End-Use Consumption Estimates

Estimates of end-use energy consumption (EUI_{ije}) are one of the most important components in developing the baseline forecast. In the residential sector, these estimates are based on the unit energy consumption (UEC), which represents the annual energy consumption associated with the end use at the building level. (In some cases, the end use represents the specific type of equipment, such as a furnace or water heater.). The accuracy of these estimates is critical, so the estimates account for weather and other factors described below that drive differences among the various segments.

For this study, the UECs for the primary equipment types were generated using SitePro building simulation software. SitePro is a user interface built on top of a DOE-2 simulation engine, which creates estimates of energy consumption by end use given building characteristics, equipment configurations, and weather data.

Multifamily building prototypes were created to represent the most typical combinations of equipment and fuel types found in multifamily housing in Massachusetts. The primary HVAC equipment types modeled in SitePro for the two fuel types are shown in Table 23. Up to five levels of equipment efficiency were modeled for each when applicable. Separate prototypes were created to represent existing and new construction. Additionally, separate models were run for multifamily units in buildings with individual HVAC equipment versus those with shared HVAC systems. In total, 90 separate prototypes were created to generate the different estimates of baseline consumption for the within-unit models.

Table 23. Equipment Types Modeled in Site Pro

SitePro Equipment Type	Fuel		Study Equipment Type / End Use
	Electric	Gas	
Boiler		✓	Building Boiler, Heating (Common Area)
Furnace	✓	✓	Unit-Based Furnace, Building Furnace, Heating (Common Area)
Heat Pump	✓		Unit-Based Heat Pump
Resistance	✓		Unit-Based Room Heat
Room Heater		✓	Unit-Based Room Heat
Central AC	✓	✓	Unit-Based Central AC, Building Central AC
Room AC	✓	✓	Unit-Based Room AC
Chiller	✓		Cooling (Common Area)

While SitePro has a set of default inputs in its extensively researched prototype library, this study leveraged data from a number of sources to customize the prototypes to be as specific as possible to the multifamily population in Massachusetts. The site visit data was used to populate the

typical apartment configurations (average floors, foundation and roof characteristics) and per-unit floor space estimates. We used public use data from the Energy Information Administration's Residential Energy Consumption Survey (RECS) for the New England Census Region to estimate the average occupancy distributions and refrigerator configurations. The 2009 MA RASS was used to model baseline operation schedules and thermostat setback settings. We incorporated weather data from Worchester, MA to capture the prevailing weather conditions for the majority of customers in Massachusetts.

The UECs for heating and cooling equipment were the most important product of the building simulations because of their weather sensitivity. Three considerations dictated the types of HVAC equipment that were modeled to generate estimates of end-use consumption:

- ***Source of consumption:*** Within-unit and common-area consumption were assessed separately, and each required a different methodological approach.

- ***Equipment types prevalent in multifamily housing:*** This study relied on the site visit data to identify the most common equipment types.

- ***Equipment types available in SitePro prototypes:*** The within-unit simulation relied on a multifamily prototype to estimate energy consumption. The common area model relied on a lodging prototype. Within SitePro, these two different prototypes have their own sets of available equipment types; these sets only partially overlap.

SitePro also produced estimates of consumption for a number of other end uses that either were used directly or served to validate other sources. For example, the refrigerator UEC was used directly from SitePro results for stock average consumption, with secondary sources used to estimate the UECs for higher efficiencies

The common area energy consumption estimates for HVAC and lighting were based on a SitePro lodging prototype. Given the general homogeneity in the types of equipment associated with common areas, only four permutations of the lodging prototypes were created to estimates, the EUIs for heating and cooling in existing and new construction. For common area heating, the gas EUIs were based on a gas boiler and the electric EUIs were based on an electric furnace. For common area cooling, all EUIs were modeled as chillers due to the limitations in cooling equipment available in the SitePro prototypes. To the extent possible, we set up the prototypes based on the simulation guidelines for the Energy Star multifamily high rise program.[10]

For the other end uses, we based the EUIs on secondary sources that were converted to EUIs based on information on common area square footage from the site visit data. The water heating EUIs represent the usage associated with common-area laundry facilities.

We assessed the quality of the estimated baselines is to compare the model estimated baseline with the overall average multifamily apartment consumption. This comparison value is referred to as a control total. For the electric model, the control total was based on an analysis of billing

[10] http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/mfhr/ENERGY_STAR_MFHR_Simulation_Guidelines_V1.0.pdf

records for multifamily customers identified in our tenant surveys, which showed an average annual consumption of 4,728 kWh. Because this figure was based on the billing records for individual units, we assume that this control total excludes the consumption associated with shared HVAC and water heating systems. The billing data associated with the gas customers in the tenant survey did not have a sufficient sample size to develop a reliable estimate of average consumption, so we used a control total of 600 Therms, which was based on an analysis for multifamily buildings in the New England Census Region for RECS. Note that the RECS average consumption is for only apartments that have gas.

Table 24: Comparison of Estimated Baselines with Control Totals

	Electric (kWh)	Gas (Therms)
Baseline Usage	5,024	558
Control Total	4,728	600
Baseline as Percent of Control	106%	93%

As shown in Table 24, the estimated baseline for electricity consumption is 6% higher than the control total of 4,728 kWh and within a reasonable range such that the difference can be eliminated by making minor adjustments to the simulation inputs or by adjusting the simulation-estimated UECs downward. The overall average multifamily unit's consumption including the shared equipment consumption is 5,324 kWh. For the gas model, the overall baseline consumption is 7% lower than the control total of 600 Therms. Rather than adjust the UECs upward, this discrepancy can be eliminated by allocating the remaining consumption to the "other" gas end use. We convert these quantities to MMBTU for presentation purposes in this report.

Estimating Technical Potential

After the development of the baseline forecasts, the next step is estimation of technical potential. Because technical potential is based on creating an alternative forecast[11] that reflects the installation of all possible measures, appropriate energy-efficiency measures must reflect the mix of measures applicable to the service area. The measure list came from combining existing multifamily program measures with measures not currently included in the program and emerging technologies such as LEDs.

Technical potential is calculated by subtracting the alternative forecast from the baseline, which yields savings by all dimensions included in the segmentation design (vintage, segment, etc.). The procedure involves three analytic steps, as follows.

Determine Measure Impacts

The starting point in assessment of technical potential is the estimation of measure-level impacts. It begins by compiling and analyzing data on the following measure characteristics:

- ***Measure savings:*** The energy savings associated with a measure as a percentage of total end-use consumption.
- ***Measure costs:*** The per-unit cost (either full or incremental, depending on the application) associated with installation of the measure.
- ***Measure life:*** The expected lifetime of the measure.
- ***Measure applicability***: A general term encompassing a number of factors, including the technical feasibility of installation and the current or naturally occurring saturation of the measure as well as factors to allocate savings associated with competing. The various factors are described below.

[11] The alternative forecast actually consists of separate forecasts to allow delineation between existing and new construction and equipment and non-equipment measures. These distinctions are explained later in this section.

Table 25 contains a list of those measures used in estimating energy efficiency potentials.

Table 25. Equipment and Retrofit Energy Efficiency Measures

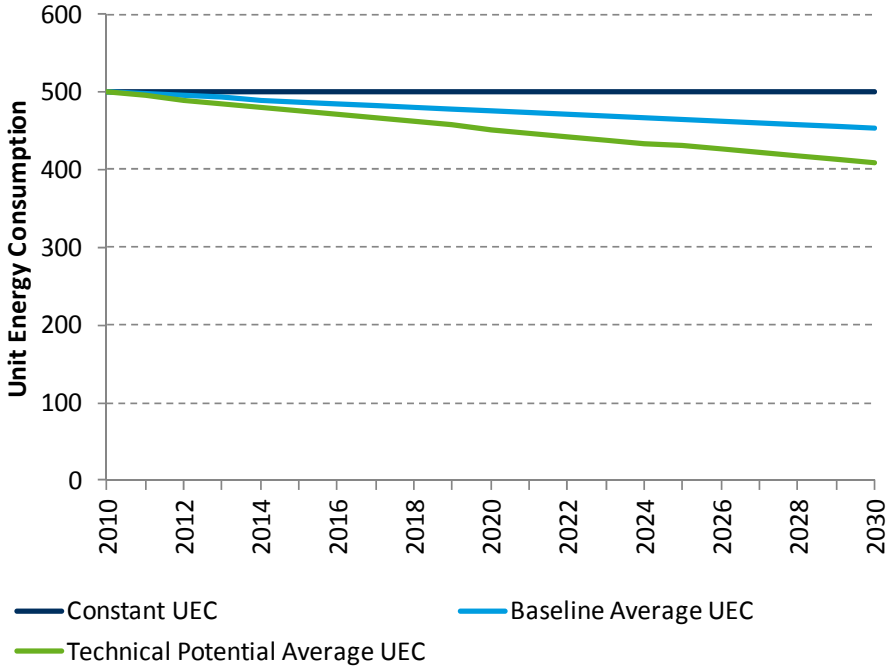
Measure Description	Measure Description
AFUEB 0.8 Building Boiler	HSPF 7.7-SEER 13-Heat Pump
AFUEB 0.85 Boiler	SEER 14.5 Air Source Heat Pump
AFUEB 0.9 Boiler	SEER 19 Heat Pump
AFUEF 0.78 Building Furnace	SEER 23 Heat Pump
AFUEF 0.78 Unit Central Heat	Infiltration ACH 1 - ACH 0.65
AFUEF 0.92 Furnace	Insulation - Duct R-Value (State Code)
AFUEF 0.92 Central Heating Unit	Specialty CFL
AFUEF 0.94 Furnace	2012 EISA Compliant Bulb
AFUEF 0.94 Central Heating Unit	EISA Backstop Provision Bulb
Boiler Economizer	Standard CFL
Ceiling Insulation R 13.14 - R 38	LED Lighting
Ceiling Insulation R 13.14 - R 49	Code Required LPD And Control Strategies
Ceiling Insulation R 13.14 - R 60	Lighting Package, High Efficiency 15% Reduction in W/sqft
Ceiling Insulation R 49 - R 60	Lighting Package, Premium Efficiency 20% Reduction in W/sqft
Ceiling Fan (no lighting kit)	Lighting Package, Super Premium Efficiency 25% Reduction in W/sqft
Chilled Water / Condenser Water Settings- Additional Control Features	Low-Flow Faucet Aerators 1.5 GPM
VSD for secondary chilled water loop	Outdoor LED Lighting with Automatic Controls
Install Economizer	Low-Flow Faucet Aerators 2.2 GPM (Federal Code)
Clothes Dryer w/ Moisture Sensor	Low-Flow Showerheads 2.0 GPM
Energy Star Clothes Washer - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	Low-Flow Showerheads 2.5 GPM (Federal Code)
Energy Star Clothes Washer - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	Energy Star Computer Monitor
Energy Star Commercial Clothes Washer MEF=1.73	CEE PE+ Motor for HVAC Applications
Energy Star Computer	Pump And Fan System Optimization w/ VSD
Variable Volume Air System	Motor - Vav Box High Efficiency (Ecm) ECM Motor
Convection cooking oven	Motor Rewind >15, <500 HP
Cooking Oven	O&m Tune-Up Tune-up/Maintenance

Measure Description	Measure Description
Lighter Colored Shingles (White)	Energy Star Office Copier
Cooling Tower-Two-Speed Fan Motor	Energy Star Office Printer
Variable-Speed Tower Fans replace Two-Speed	Proper Sizing - HVAC Unit
Energy Star Humidifier	Solar Pool/Spa Heating Systems
Demand Controlled Circulating Systems (VFD control by demand)	Passive solar water heating
Evaporative Cooler	Re-Commissioning
Energy Star Dishwasher, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	Energy Star Refrigerator
R-5 (Composite Doors with foam core) - ENERGY STAR	Proper Disposal of Refrigerator/Freezer
Weatherstripping And Adding Door Sweeps	SEER 13-Building Air Conditioner
Install (Power-Pipe or GFX) - Heat Recovery Water Heater	SEER 13-Unit Central Air Conditioner
Duct Insulation Upgrade R-8 (code)	SEER 14.5 Air Conditioner
Reduction In Duct Losses to 5 %	SEER 14.5 Central Air Conditioner
Energy Star DVD Player	SEER 19 Air Conditioner
Air-Side Economizer	SEER 19 Central Air Conditioner
DX Tune-Up / Diagnostics	SEER 23 Air Conditioner
EER 9.8-Unit Room Air Conditioner	SEER 23 Unit Air Conditioner
EER 10.8 Room Air Conditioner	Energy Star Qualified Set Top Box
EER 11.14 Room Air Conditioner	Smart Strip
EF 0.575-Building Water Heat	Solar thermal collector
EF 0.575-Unit Water Heat	Proper Disposal of Freezer
EF 0.620 Building Water Heater	Plastic Or Foam Pool Covers (50-65% Energy Savings)
EF 0.620 Unit Water Heater	Thermostat HAS= 0 - HAS= 1
EF 0.670 Building Water Heater	Multi-Zone Individual Room Temperature Control for Major Occupied Rooms
EF 0.670 Unit Water Heater	Energy Star TV
EF 0.70 Building Water Heater	Energy Star Big Screen TV
EF 0.70 Unit Water Heater	0.937 High Efficiency Unit Water Heater
Energy Star Battery Chargers	Wall Insulation R 8.68 - R 19
Exhaust Air to Ventilation Air Heat Recovery	Wall Insulation R 8.68 - R 21
Energy Star Freezer	Wall Insulation R 21 - R 22

Measure Description	Measure Description
Vegetation on Roof	Wall Insulation R 8.68 - R 22
Energy Star Qualified Home Audio System	Wall Insulation R 8.68 - R 32
Hot Water Pipe Insulation R-4 Wrap	Slab – 2" Foam / R-20
	Basement Insulation R-19
	Water Heater Tank Blanket/Insulation Install Insulation (R-5)
	Water Heater Thermostat Setback 120 degrees
	Window Film
	Windows U 0.3 - U 0.2
	Windows U 0.35 - U 0.2
	Windows U 0.35 - U 0.3

In estimating potential savings of equipment measures, it is assumed the baseline efficiency for the measure would shift from its current level to prevailing codes upon burnout. Thus, it is assumed the average baseline efficiencies for this class of measures would improve over time as existing, sub-code equipment are replaced at the end of their normal, useful lives. An example of this methodology is provided in Figure 24,[12] which shows the average UEC (annual energy consumption per unit) associated with a piece of end-use equipment in the baseline forecast, the technical potential scenario, and a constant UEC scenario, in which the effects of natural decay and current codes and standards are eliminated. The difference between the baseline UEC and the technical potential UEC represents the savings.

Figure 24. Example of Equipment Potential: Average UEC Over Planning Horizon



The demonstration highlights two important aspects of the approach. First, the figure shows how average baseline usage gradually declines as more equipment decays and is replaced by units that comply with current code. In this case, based on an assumed 20-year life for this measure, its expected baseline efficiency would improve by almost 10% over 20 years. That is, by the end of this forecast period example, all the existing sub-code equipment would be replaced by code.

Second, by contrasting the average usage in the baseline with the constant efficiency scenario, the figure shows how estimates account for the effects of naturally occurring conservation. The technical potential savings are represented by the difference between the technical potential and the baseline, which would not be the case with a constant UEC. This demonstrates how this approach accurately estimates total potential and accurately accounts for naturally occurring potential. It is important to note, however, that the approach does not include any increased efficiency requirements embodied in future changes to codes and standards (that is, the baseline assumes a frozen efficiency).

[12] This is a purely illustrative example and does not contain Massachusetts-specific data.

The approach for non-equipment (retrofit) measures is more complicated, because it requires assessing the collective impacts of a variety of measures with interactive effects. For each segment and end-use combination, the objective of the analysis is to estimate the cumulative effect of the bundle of eligible measures and incorporate those impacts into the end-use model as a percentage adjustment to the baseline end-use consumption. In other words, the objective of the approach is to estimate the percentage reduction in end-use consumption that could be saved in a typical multifamily structure by installing all available measures.

The starting point for this approach entails characterizing individual measure savings in terms of the percentage of end-use consumption rather than the measure's absolute energy savings. For each individual non-equipment measure, savings are estimated using the following basic relationship:

$$SAVE_{ijm} = UEC_{ije} * PCTSAV_{ijem} * APP_{ijem}$$

where:

$SAVE_{ijm}$ = annual energy savings for measure m for end use j in customer segment i

UEC_{ije} = calibrated annual end-use energy consumption for the equipment e for end use j and customer segment i

$PCTSAV_{ijem}$ = the percentage savings of measure m relative to the base usage for the equipment configuration ije, taking into account interactions among measures such as lighting and HVAC calibrated to annual end-use energy consumption

APP_{ijem} = measure applicability, a fraction that represents a combination of the technical feasibility, existing measure saturation, end-use interaction, and any adjustments to account for competing measures

As described later in this section, it is appropriate to view a measure's savings in terms of what it saves as a percentage of baseline end-use consumption, given its overall applicability. In the case of wall insulation that saved 10% of space heating consumption, if the overall applicability is only 50%, the final percentage of the end use saved would be 5%. This value represents the percentage of baseline consumption the measure saves in an average home. Note that the percentage energy savings for a single building may far exceed that of the overall estimates of potential that we present in Section 3 of this report, because the applicability of each measure is limited to only a subset of the overall population based upon technical constraints.

Measure Stacking Effects

This study deals almost exclusively with cases in which multiple measures affect a single end use. To avoid overestimation of total savings, the assessment of cumulative impact accounts for the interaction among the various measures—a treatment called "measure stacking." The primary means of accounting for stacking effects is to establish a rolling, reduced baseline applied

iteratively as measures in the stack are assessed. This is shown in these equations, where measures 1, 2, and 3 are applied to the same end use:[13]

(1) $SAVE_{ij1} = UEC_{ij\,e} * PCTSAV_{ije1} * APP_{ije1}$

(2) $SAVE_{ij2} = (UEC_{ije} - SAVE_{ij1}) * PCTSAV_{ije2} * APP_{ije2}$

(3) $SAVE_{ij3} = (UEC_{ije} - SAVE_{ij1} - SAVE_{ij2}) * PCTSAV_{ije3} * APP_{ije3}$

After iterating through all of the measures in a bundle, the final percentage of end-use consumption reduced is the sum of the individual measures' stacked savings that is then divided by the original baseline consumption.

The nature of this approach requires clarification, in that there are actually two types of savings associated with a measure:

- ***Stand-alone savings*** are the savings the measure would provide when installed entirely on its own This savings type is used for economic screening.
- ***Stacked savings*** are the savings attributable to a measure when it assessed in conjunction with other measures and accounting for the various factors that affect applicability. These are intended to represent the average savings a measure would achieve when installed across all homes.

A summary of the factors that affect the overall potential associated with a measure are presented in Table 26.

Table 26. Measure Applicability Factors

Measure Impact	Explanation
Fuel Saturation	The percentage of customers who use electricity vs. gas for the specific end use (water heat, space heat, etc.).
End-Use Saturation	The percentage of customers who have the specific end use. (If not all residential customers have a gas furnace, for example, the end-use saturation would be less than 100%.)
Measure Share	Used to distribute the percentage of market shares for competing measures (e.g., tankless versus condensing water heaters).
Measure Incomplete Factor	The percentage of buildings that do not have the specific measure currently installed.
Technical Feasibility	The percentage of buildings that can have the measure physically installed. Several factors may affect this percentage, including whether the building already has the baseline measure (e.g., dishwasher) as well as limitations on installation (e.g., size of unit and space available to install the unit).
Measure Interaction	Considers the net effects of cross end-use interactions. For example, reducing lighting loads and associated heat output affects HVAC loads.

[13] In some cases, there may not be complete interaction between measures (e.g., wall and ceiling interaction). However, based on building simulation and engineering experience, it is believed the interaction is substantial. This method provides a somewhat conservative approach to potential estimates in some cases, but to assume no interaction could greatly inflate the actual available potential.

Estimate Phased-In Technical Potential

The savings from the technical energy-efficiency potential are estimated by incorporating measure impacts (equipment and non-equipment) into the baseline forecast in four steps to develop alternative forecasts. In these steps, each case builds on the previous scenario:

1. Replace the burned out equipment in existing buildings with equipment measures upgraded to the highest level of efficiency.
2. Install equipment measures in new construction in which all construction elements of the building are upgraded to the highest level of equipment efficiency.
3. Install non-equipment measures in existing construction, in which the collective measure energy savings impacts are applied to end-use consumption estimates.
4. Install non-equipment in new construction, in which the collective measure energy savings are applied to end-use consumption estimates.

The sequence of this approach is necessary to account for the interaction between the equipment and the non-equipment measures. Over time, as equipment is replaced with the highest-efficiency option, the average consumption associated with the end use declines, resulting in a reduction in the absolute impact associated with non-equipment measures. Accounting for this interaction results in a more accurate estimate of the potential associated with non-equipment measures.

Estimating Economic Potential

The approach applied in estimating economic potential is identical to the technical approach, except that the impacts for both equipment and non-equipment measures are based only on measures calculated to be cost-effective using the total resource cost (TRC) test criterion. For each measure, the test is structured as the ratio of the net present values of the measure's stand-alone savings (benefits) and costs. Only measures with a benefit-to-cost ratio equal or greater than 1.0 are cost-effective and retained. In general, for each measure we have:

(1) $$\frac{Benefits}{Costs} \geq 1$$

where

(2) $$Benefits = NPV\left(\sum_{year=1}^{measurelife}\left(\sum_{i}^{i=8760}(impact_i \times avoidedcost_i)\right)\right)$$

and

(3) $$Costs = MeasureCost$$

The Evaluation Team performed a full cost-benefit analysis for every fuel, customer segment, vintage, end use, and measure combination. We used the PA's 2011 avoided costs, line losses, and discount rate estimates in conjunction with the measure costs, savings, and expected lifetimes to perform the benefit-to-cost ratio screening.

The electric avoided costs distinguish the value of saved energy on a seasonal basis. The peak demand (capacity) is based on coincidence with the summer peak, as determined by the NE ISO. To approximate long run electric capacity values we did the following:

1. Examined the multifamily central air conditioning load shape developed by SITEPRO under extreme weather conditions
2. Selected the highest summer (June-August) weekday kW value occurring between 1 and 5 pm to define a peak hour
3. Used estimated kW from SITEPRO load shapes for the associated end-uses at the peak hour to get the capacity value for all electric measures.

To distinguish the different energy values, natural gas avoided costs are divided into space heat and other end-use categories.

Interpreting the Economic Screen

There are three important considerations in interpreting the results of economic screening as it relates to assessment of energy-efficiency potential.

- The analysis is based on a TRC perspective and, as such, no assumptions are made as to how measure costs are split between PA and participants in energy-efficiency programs. Additionally, this is a pure economic screen at the measure level, with no program administration costs assumed.
- The outcomes of the screening procedure depend on assumptions that will likely change over time. (Measure costs, for example, may decline over time, as the demand for energy-efficient technologies increases.) At the same time, the cost of reaching each successive participant often increases. Also, the forecasted avoided costs are likely to change over time, and, as these values change, so do the value of savings resulting from the installation of energy-efficient technologies. (For example, a measure failing the economic screen in the early years of the planning period may become cost-effective later if decrement values increase over the course of the planning horizon.)
- The economic analysis is based on assumptions intended to reflect the average or typical customer. Thus, while a measure might not pass the economic screen within the context of this study, there could be instances where the measure would be cost-effective. (For example, a premium central air conditioner may not be cost-effective in an average single-family home; however, in a large home with more occupants, it could pass the economic screen due to increased savings.) In instances where a measure—such as ceiling insulation—passes under most but not all building type/equipment/vintage combinations, the measure is deemed to pass in all configurations, consistent with actual program delivery.

Despite these caveats, the underlying inputs for this study have undergone a thorough review, and they represent the best information available about specific conditions (regarding both technical measure details and customer attributes) in the Massachusetts at the time. As with any study of this nature, when more current information becomes available, it can be used to update key drivers. Still, the current study results are sufficient to inform both the resource planning and program delivery process.

Estimating Achievable Potential

As defined above, achievable potential is the portion of economic potential that could reasonably be assumed achievable in the course of the planning horizon (20 years in this study), given market barriers that may impede customer participation in PA programs. The amount of potential realistically achievable is very difficult to quantify, as it depends on program incentive structures, marketing efforts, energy costs, customer socioeconomic characteristics, and other factors.

This study analyzed achievable potential using two separate scenarios:

1. A business-as-usual (BAU) case, estimating how much economic potential can be captured under current Massachusetts multifamily program designs and annual budgets. In this scenario, penetration rates by measure used are based upon PA 2010-2011 program tracking data.
2. A maximum achievable potential (Max) scenario, consistent with 100% incremental cost incentives and use of program designs targeting hard-to-reach customers and measures. Maximum achievable potential scenario penetration rates are based on combining results from achievable potential workshops (discussed in Section 1) and a review of recent potential studies conducted in the Northeast.

Similar studies of achievable potential typically rely on an experience-based approach (analysis of other potentials assessments or actual program accomplishments), or on complex diffusion models that attempt to predict measure adoption using assumptions about customer behaviors.[14] This study used an experience-based approach to estimate achievable penetration rates, expressed a percentage of economic potential, and relying on several sources.

- ***Hood River Conservation Project.***[15] This residential retrofit program in Hood River, OR, established a theoretical maximum for achievable potential (85%) in the early 1980s.
- ***Workshops on Achievable Potential***. As described in Section 1 of this report, the evaluation team conducted a series of workshops with PMs and PAs, which sought to estimate achievable penetration rates using a Delphi approach. We used information obtained in these workshops to benchmark the measure-level penetration rates shown in Table 27. Appendix E contains a memorandum describing the workshops and subsequent analysis.
- ***Similar studies***. We used similar studies to benchmark our achievable potential estimates, including:

[14] Haeri, M. Hossein. "Frontiers of Efficiency." Public Utilities Fortnightly. April 2011.
[15] Hood River Conservation Project, An Experiment in Going Deep Community-wide. http://drivingdemand.lbl.gov/reports/lbnl-3960e-hrcp.pdf

- Vermont Department of Public Service (2007)[16]
- Consolidated Edison (2010)[17]
- Midwest Residential Market Assessment (2006)[18]

We combined these sources to obtain measure-level, achievable penetration rates for both BAU and Max scenarios, as shown in Table 27.

We use an 85% penetration rate for all low-income measures in both scenarios to be consistent with the PAs' program designs and the efforts of industry experts across the country. Direct-install programs—in which measures are free—can obtain these high penetration rates. The Low-Income Multifamily Program overcomes a significant barrier for equipment replacement in that the costs of standard equipment are covered, in addition to the incremental costs of high-efficiency equipment. This occurs when customers receive new refrigerators, HVAC, and water heating equipment.

We assume lower penetration rates for equipment replacement (20%) and shell measures (33% to 50%), where market barriers are most pronounced. In the case of equipment replacement, frequent tenant turnover and split incentives (property management not paying for electric consumption) present significant barriers to energy efficiency.

Table 27. Achievable Penetration Rates by Measure Category and Income Level

Measure Category	Low Income	Standard Income		Blended	
		BAU	Max	BAU	Max
Aerators/Showerheads	85% for all measure categories	50%	85%	60%	85%
Other Low Cost		50%	85%	60%	85%
Attic Insulation		50%	70%	60%	75%
Basement Insulation/Other Shell		50%	70%	60%	75%
Wall Insulation		33%	70%	50%	75%
Appliance/Small Equipment		20%	50%	40%	60%
Air Sealing		80%	85%	80%	85%
CFL		85%	85%	85%	85%
Thermostat		85%	85%	85%	85%
DHW Setback		85%	85%	85%	85%
Unit HVAC and DHW		20%	50%	40%	60%
Building Equipment		50%	75%	60%	80%
Common Area Lighting		65%	85%	70%	85%
Other Common Area		65%	85%	70%	85%

[16] Vermont Electric Energy Efficiency Potential Study. http://publicservice.vermont.gov/energy-efficiency/vteefinalreportjan07v3andappendices.pdf

[17] Energy-Efficiency Potential Study for Consolidated Edison Company of New York, Inc. Volume 2: Electric Potential Report, Global Energy Partners, LLC, Walnut Creek, March 2010.

[18] Midwest Residential Market Assessment and DSM Potential Study. http://www.mwalliance.org/meea-publications/midwest-residential-market-assessment-and-dsm-potential-study.

- ***The BAU scenario for standard-income customers*** ranges from 20% to 85%. At the high end, the Multifamily Program installs free items such as CFLs and air sealing, achieving essentially the same penetration rates as the Low-Income Multifamily Program. However, customer contributions and other market barriers exist for other recommended measures, and PA tracking data reveal that the penetration rates are lower than 85%.
- ***The Max scenario for standard-income customers*** is derived from the achievable potential workshops and the application of measure-specific adjustments to account for the apparent market barriers in the PA tracking data. For example, the 50% penetration rate for unit-level equipment and appliances assumes that incentives rise to 100% of incremental costs. However, these incentives but do not go as far as the Low-Income Multifamily program and implicitly pay for all equipment and appliance costs. Finally, the standard and low-income categories are combined to provide the final BAU and Max penetration rates.[19]

[19] See Section 2 for discussion on low-income share.

The achievable penetration rates shown in Table 27 are properly characterized as long-run penetration rates. That is:

- For retrofit measures in existing building, these rates represent the share of the building stock and dwelling units that can be eventually obtained.
- For equipment measures and new construction, these rates represent the share of customers and dwellings "in the market" in each year of the planning horizon.

Given the fact that the PAs have been operating multifamily programs for years—and are aggressively addressing the market with current program offerings—a key question posed by the PAs to the Evaluation Team was this, "How long can we keep running programs at the present rate?"

As the answer to this question is effectively part of the BAU scenario, we looked at the PA tracking and Massachusetts Census data to develop our estimate of 16 years. Thus, although the planning horizon is 20 years in the study, the BAU scenario captures all of its retrofit achievable potential over 16 years. The Max achievable potential scenario assumes an even more aggressive annual rate of capture, with all existing building retrofits conducted over a 10-year period.

Baseline Consumption Estimate

To develop reasonable estimates of available energy-efficiency potentials, the Evaluation Team must first produce forecasts of energy consumption using the data and methodology described in the previous sections.

Figure 25 shows the 20-year annual electric forecasts for within-unit and common area sales.

Figure 25. Projected Massachusetts Multifamily Electric Sales

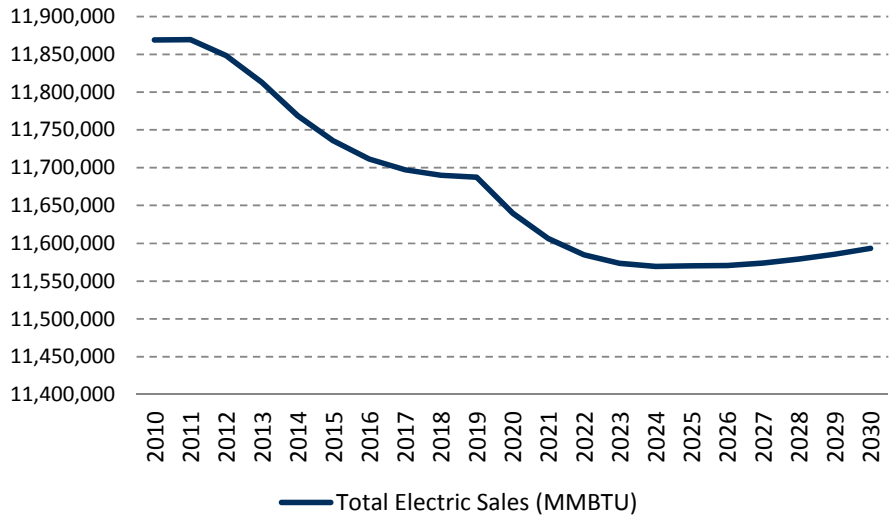
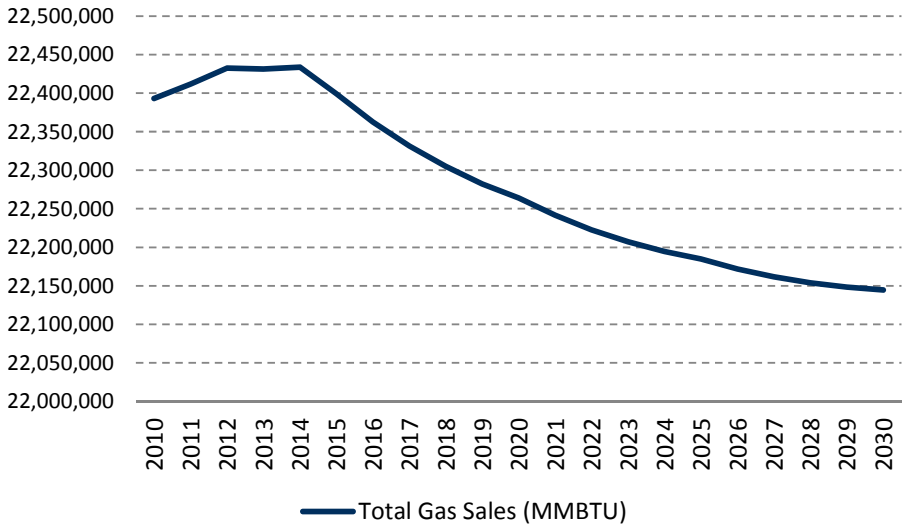


Figure 26 show the 20-year annual natural gas forecasts for within-unit and common area sales.

Figure 26. Projected Massachusetts Multifamily Gas Sales

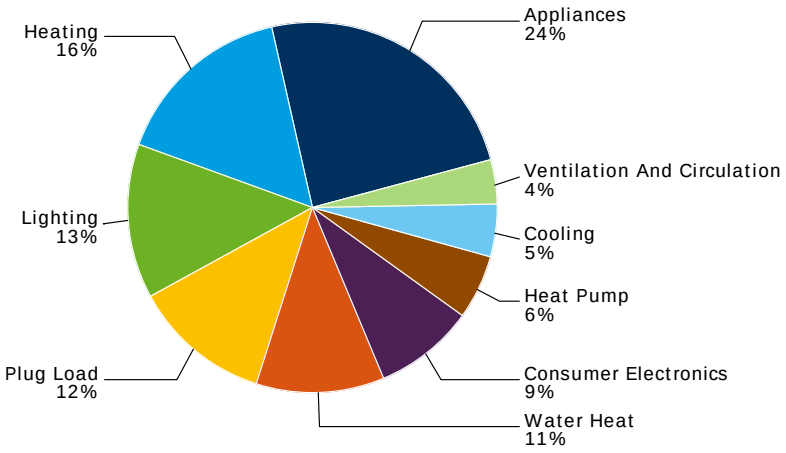


The within-unit sales of electricity comprised approximately 75% and natural gas comprised approximately 84% of total multifamily electric and natural gas sales. The remainder of consumption occurs in the common areas.

As seen in the previous figures, slight declines in electric and natural gas consumption occurring over the first half of the forecast horizon are due predominantly to changes in federal equipment standards. These standards, described in more detail in the next subsection, were accounted for in the Evaluation Team's baseline projections of energy consumption, so as not to overstate the impacts associated with the estimates of energy-efficiency potential.

Figure 27 shows residential baseline electric sales by end use for the within-unit area segment. Appliances, heating, and lighting comprised a majority of the energy usage for the within-unit segment. The data collected from site visits indicated that there was a fairly sizable share of electric heat, which accounts for approximately 16% of total energy usage for the within-unit segment.

Figure 27. Within-Unit Electric Sales by End Use (2010)



We note in Section 2 of this report how utility bills for the heating, cooling, and water heating end uses are paid, either by landlord or by tenant. We use these results to inform Figure 28, which shows that approximately 67% of the heating, cooling, and water heating energy consumption is paid for by individual tenants, while the remaining 33% is paid for by the landlord.

Figure 28. Within-Unit Electric HVAC Sales by Payment Category

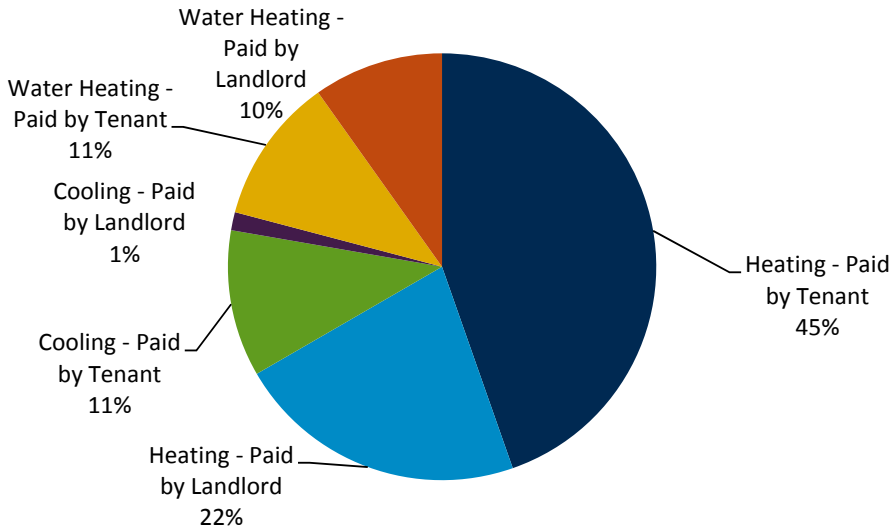


Figure 29 shows residential baseline electric sales by end use for the common area segment. Lighting, cooling, and auxiliary HVAC end uses were responsible for most of the energy usage in the common area segment.

Figure 29. Common Area Electric Sales by End Use (2010)

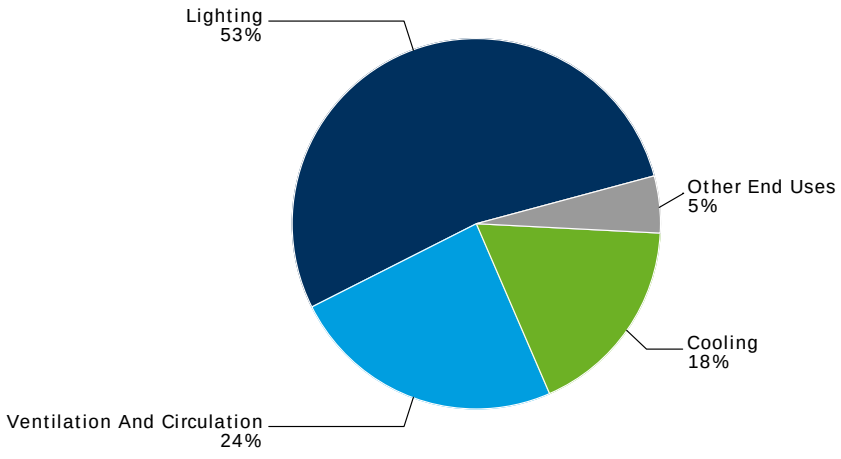


Figure 30 shows residential baseline gas sales by end use for the within-unit area segments.

Figure 30. Within-Unit Gas Sales by End Use (2010)

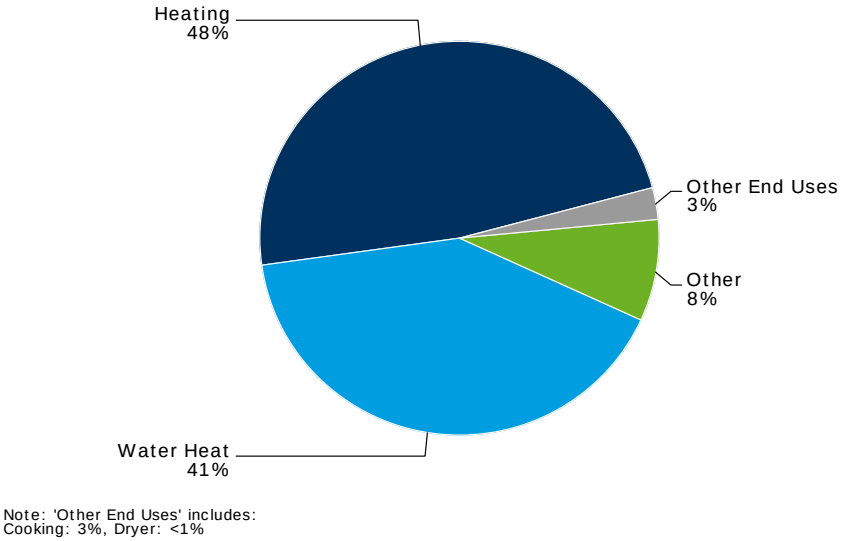


Figure 31 allocates within-unit gas heating and water heating energy consumption into tenant (62% of total end-use consumption) and landlord (38% of total end-use consumption) payment categories.

Figure 31. Within-Unit Gas HVAC Sales by Payment Category

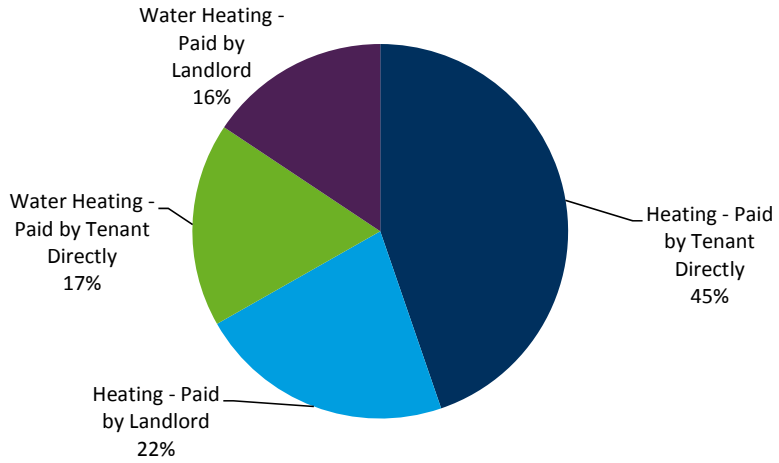
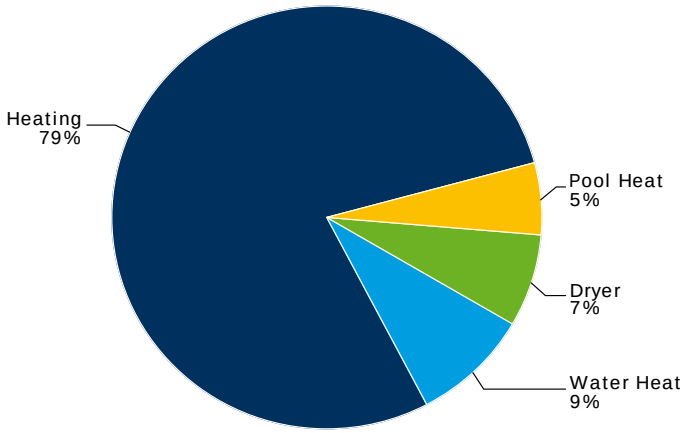


Figure 32 shows residential baseline gas sales by end use for the common area segments.

Figure 32. Common Area Gas Sales by End Use (2010)



In the natural gas sector, space heating and water heating comprised a majority of the energy usage for the within-unit segment, while space heating was responsible for almost 80% of common area gas usage.

Energy Savings from Federal Standards

The Evaluation Team estimated savings from a number of federal equipment-efficiency standards in the baseline consumption projection. As mentioned, we simulate equipment being replaced at or above the federal standard upon turnover, which effectively phases in the standard over the expected equipment lifetime. For example, the 2015 Water Heating standard mandates that residential water heating equipment have a minimum efficiency factor (EF) of 0.62. Our model phases in the standard in existing construction in roughly equal increments over the expected useful lifetime of water heating equipment. We model new water heating equipment installations to be at least as efficient as the federal standard of 0.62 EF.

Our energy savings estimates include savings from efficiency standards currently in place and from future efficiency standards.

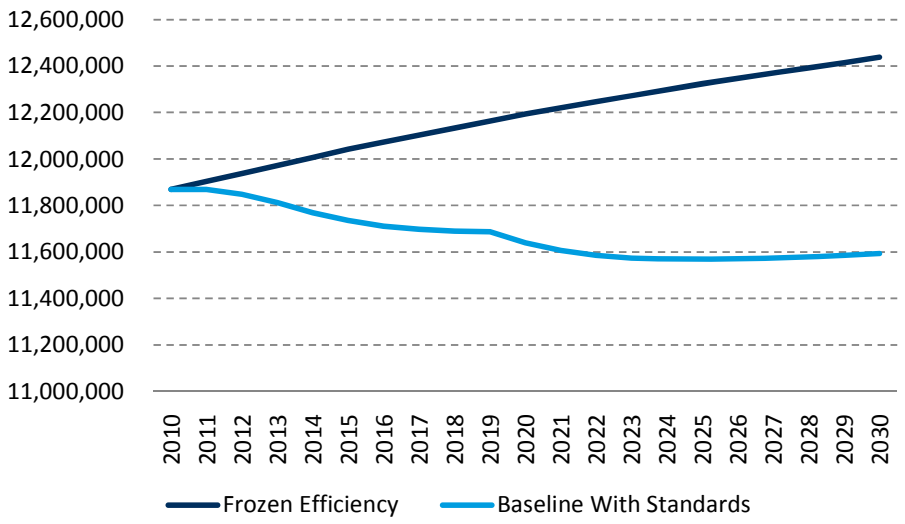
- Refrigerator and Freezers (2001)
- Water Heating (2001)
- Central Air Conditioning and Heat Pumps (2006)
- EISA Lighting (2012)
- Refrigerators and Freezers (2014)
- Water Heating (2015)
- EISA Backstop Lighting (2020)

Impacts of Federal Standards on Electricity Usage

We compared energy savings from the standards listed above to a frozen-efficiency case that assumes that a snapshot of equipment efficiency from 2010 is carried forward until 2030, (thus,

below-standard equipment remains in the equipment stock over the forecast horizon). Figure 33 shows the forecasts of electricity usage under the frozen-efficiency scenario and the forecast that takes into account the above standards. Our estimate of multifamily electric consumption after federal efficiency standards is approximately 11.6 million MMBTU, which represents 7% energy savings (845 thousand MMBTU) from the frozen-efficiency forecast.

Figure 33. Estimated Multifamily Electric Consumption (MMBTU): Frozen Efficiency vs. Standards



Lighting standards from the Energy Independence and Security Act of 2007 (EISA) account for nearly half of the projected savings. As shown in Table 28, EISA standards occur in two phases: the first, which begins in 2012, mandates a 30% reduction in energy consumption from incandescent lighting; and the second, beginning in 2020, mandates an additional 50% reduction in energy consumption from incandescent lighting in 2020.

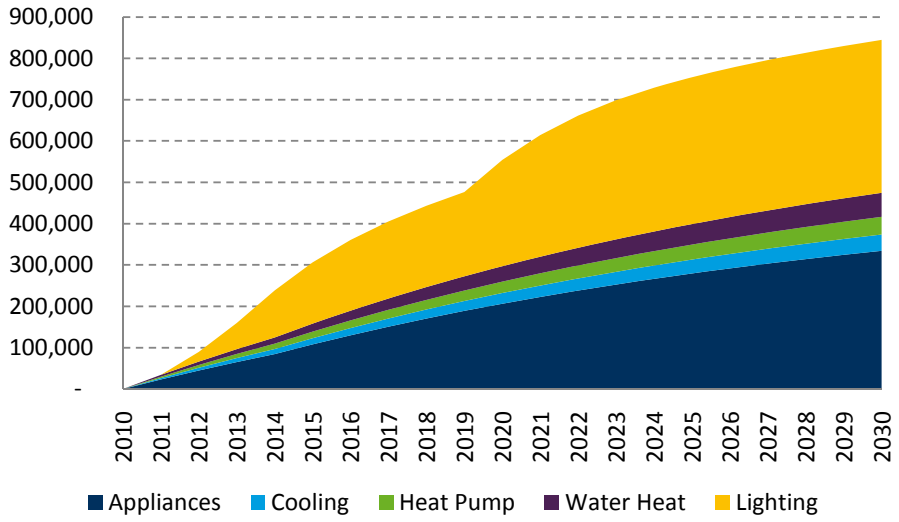
Table 28. Electric Energy Savings from Efficiency Standards by End Use

End Use	Year Standard in Effect	Estimated Savings (MMBTU, 2010-2030)	Estimated Savings (GWh, 2010-2030)
Refrigerator and Freezer	2001, 2014	334,410	98
Water Heating	2001, 2015	58,130	17
Central AC/Heat Pump	2006	39,424	12
Lighting	2012, 2020	370,015	108
Total	--	844,683	235

Refrigerators and freezers also have sizable energy savings due to efficiency standards. In a multifamily setting, these appliances account for a large portion of household energy consumption.

Figure 34 illustrates the annual impacts of federal efficiency standards by end use.

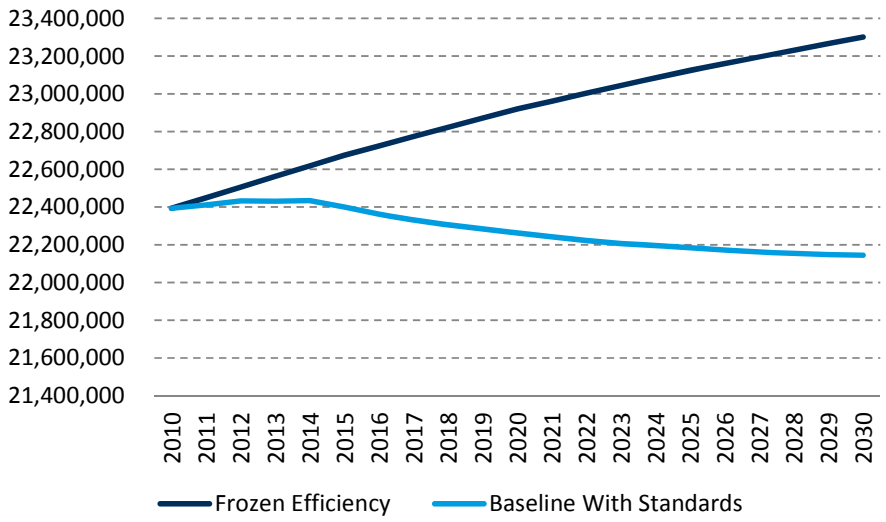
Figure 34. Estimated Federal Efficiency Standards Electric Impacts (MMBTU) by End Use and Year



Impacts of Federal Standards on Natural Gas Usage

Federal equipment standards only affect two of the end uses—space heating and water heating—considered in our modeling of natural gas energy efficiency potentials. Figure 35 shows the forecasts of gas usage under the frozen-efficiency scenario and the forecast that accounts for the equipment standards. Our estimate of multifamily gas consumption after federal efficiency standards is approximately 190 million MMBTU, which represents 5% energy savings (1.15 million MMBTU) from the frozen-efficiency forecast.

Figure 35. Estimated Multifamily Gas Consumption (MMBTU): Frozen Efficiency vs. Standards



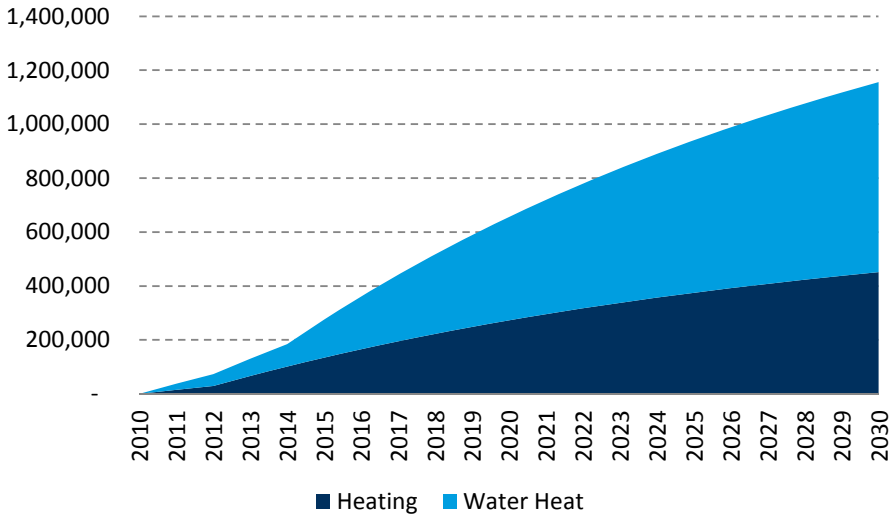
As shown in Table 29, water heating standards account for nearly 60% of projected savings, while standards affecting space heating are responsible for the remaining 40% of projected savings.

Table 29. Gas Energy Savings from Efficiency Standards by End Use

End Use	Year Standard in Effect	Estimated Savings (MMBTU, 2010-2030)	Estimated Savings (Million Therms, 2010-2030)
Heating	2014	451,490	4.5
Water Heating	2001, 2015	704,655	7.0
Total	--	1,156,145	11.5

Figure 36 shows the annual impacts of federal efficiency standards on natural gas usage, by end use.

Figure 36. Estimated Federal Efficiency Standards Gas Impacts (MMBTU) by End Use and Year



Technical, Economic, and Achievable Potential Estimates

This section contains a summary of the Evaluation Team's potentials estimates for Massachusetts multifamily buildings. We use the methodology described above to estimate technical, economic, and achievable potentials from 2011 to 2030, after accounting for energy savings from efficiency standards.

Summary of Electric Potentials Estimates

Figure 37 presents electric energy efficiency potentials for multifamily buildings.

- Technical potential is 24% of the baseline energy forecast in year 2030.
- Economic potential is 15% of the baseline energy forecast in year 2030.
- Maximum achievable potential is 12% of the baseline energy forecast in year 2030.
- Business-as-usual achievable potential is 9% of the baseline energy forecast in year 2030.

Figure 37. Electric Energy Efficiency Potentials (Percent of Year 2030 Consumption)

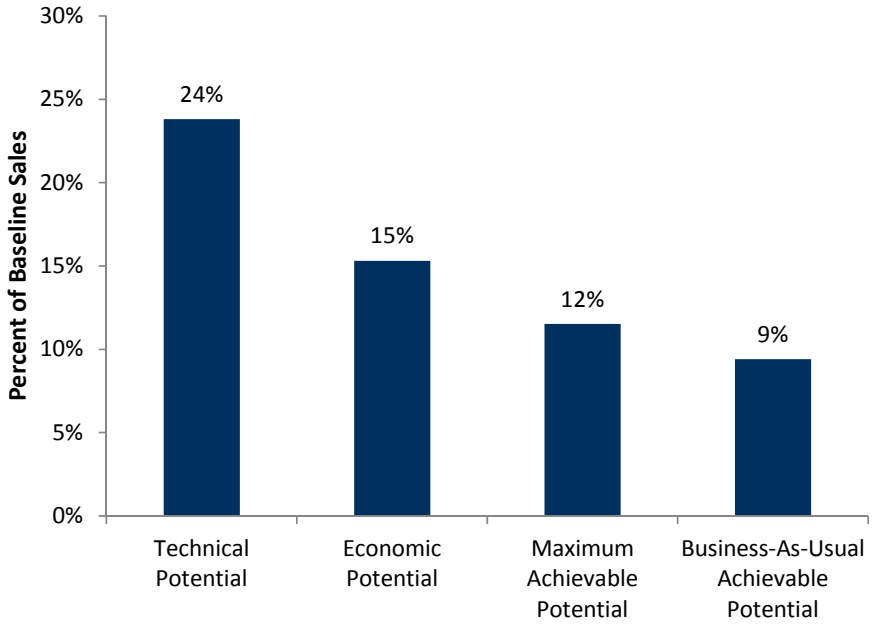
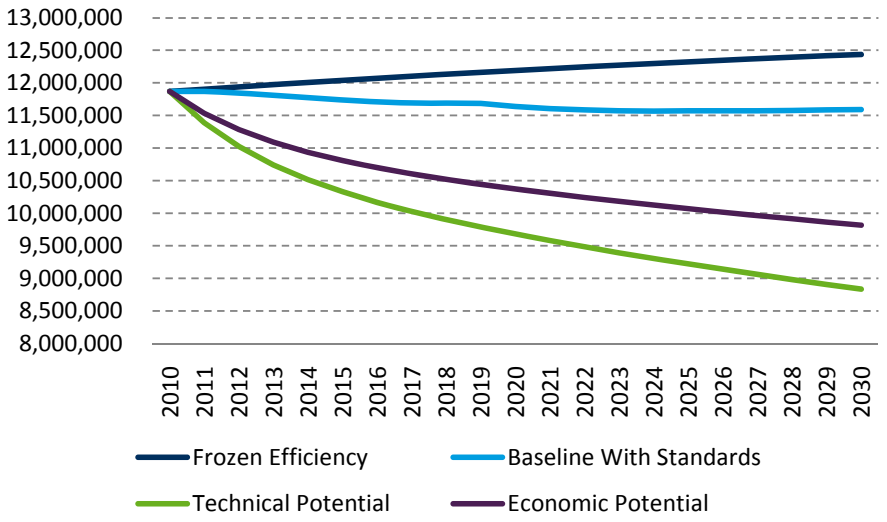


Figure 38 shows the forecasts of electricity usage under four scenarios:

- The frozen-efficiency scenario
- The baseline forecast scenario including impacts from equipment standards
- The technical potential scenario
- The economic potential scenario

Figure 38. Estimated Multifamily Electric Consumption (MMBTU): Frozen Efficiency, Equipment Standards, Technical and Economic Potentials



Within-unit end-uses account for 76% (1.4 million MMBTU) of total economic potential and common-area end uses account for the remaining 24% (0.4 million MMBTU, Table 30).

Table 30. Electric Baseline Consumption and Potentials: Within-Unit and Common Area (MMBTU in 2030)

Source	Baseline Sales (MMBTU)	Technical Potential (MMBTU)	Economic Potential (MMBTU)	Maximum Achievable (MMBTU)	BAU Achievable (MMBTU)
Within Unit	8,570,664	2,211,710	1,353,079	978,111	798,808
Common Area	3,022,490	548,898	422,310	357,365	292,420
Total	11,593,153	2,760,608	1,775,389	1,335,476	1,091,228

Table 31 shows the contents of Table 30 in GWh.

Table 31. Electric Baseline Consumption and Potentials: Within-Unit and Common Area (GWh in 2030)

Source	Baseline Sales (GWh)	Technical Potential (GWh)	Economic Potential (GWh)	Maximum Achievable (GWh)	BAU Achievable (GWh)
Within Unit	2,512	648	397	287	234
Common Area	886	161	124	105	86
Total	3,398	809	520	391	320

The assumed achievable penetration rates are higher for common-area end uses, so achievable potential is more heavily weighted toward common-area end uses—29% of both maximum achievable potential and business-as-usual (BAU) achievable potential.

Figure 39 shows the distribution of economic potential by end use of the within-unit segments. Lighting (21% of total within-unit EP) and consumer electronics are the two largest sources of within-unit economic potential. Even after the impact of EISA lighting standards, there is still cost-effective potential that can be acquired by replacing incandescent specialty bulbs with more efficient technologies.

Figure 39. Within-Unit Electric Economic Potential (Percent of Total)

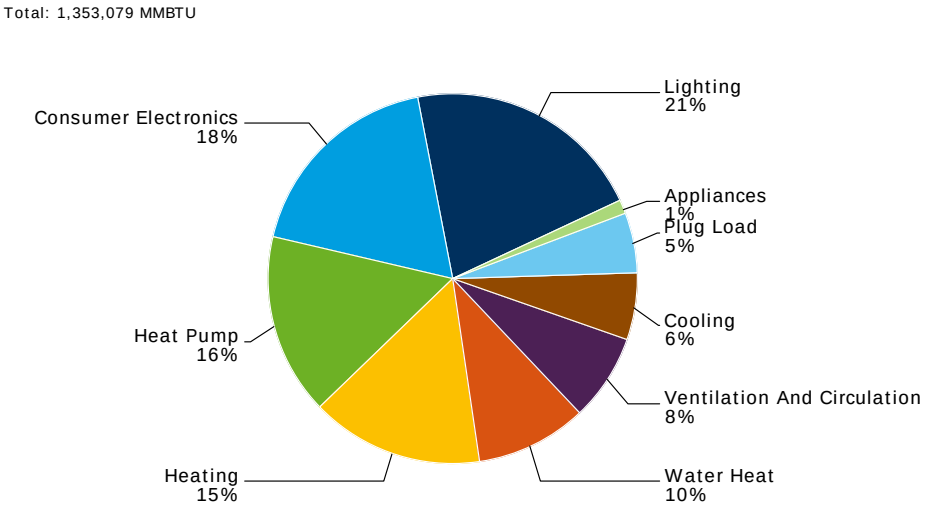
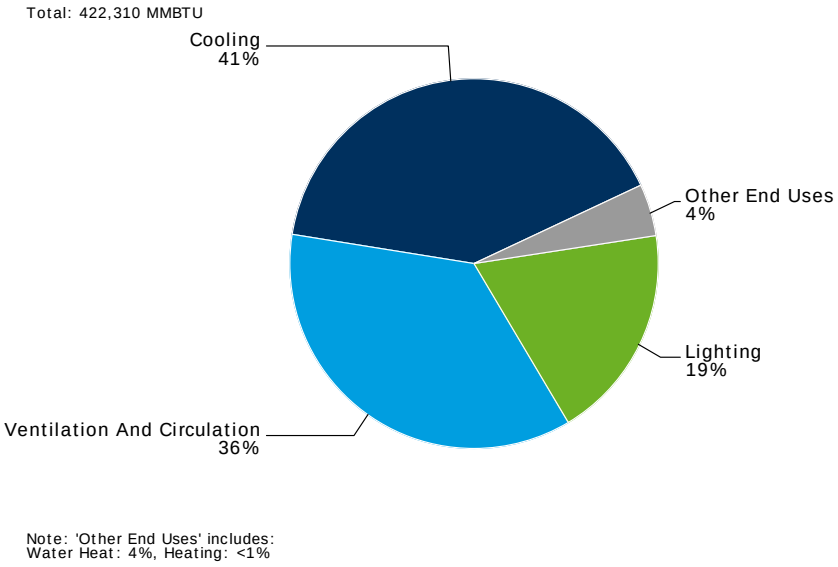


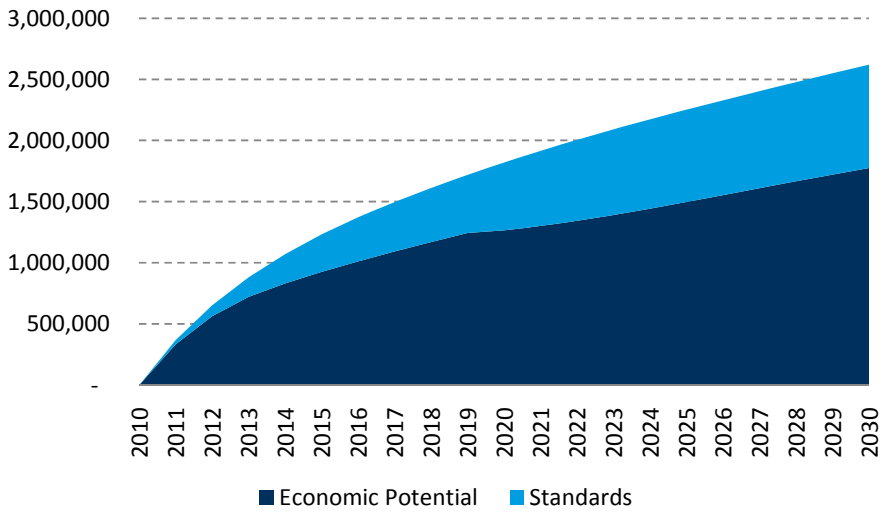
Figure 40 shows the distribution of economic potential by end use of the common-area segments. Cooling (41% of total common-area economic potential) and ventilation are the largest sources of economic potential in common areas.

Figure 40. Common Area Electric Economic Potential (Percent of Total)



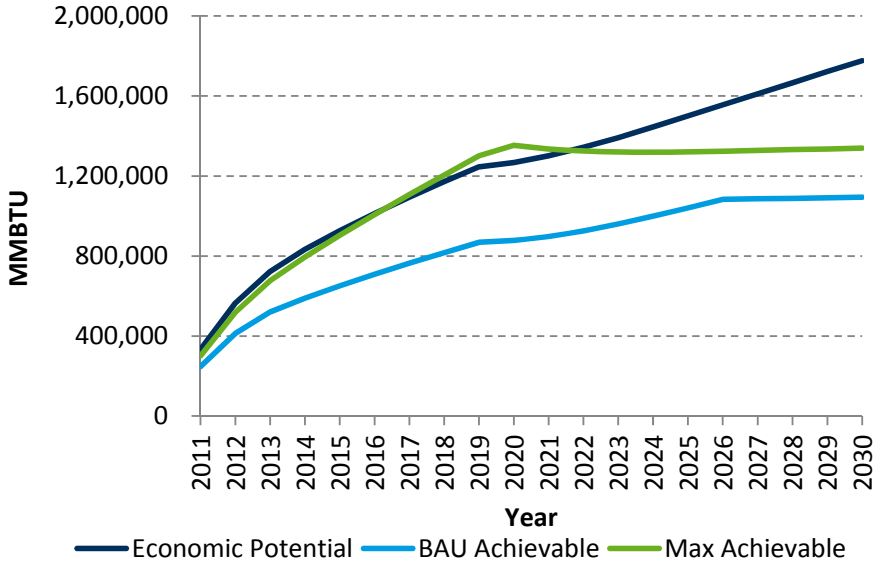
The total annual impact of electric energy savings from efficiency standards and from economic potential is shown in Figure 41. Although the annual growth rate of economic potential is stunted by the 2012 and 2020 lighting standards, the total savings impact continues to grow steadily through 2030.

Figure 41. Annual Electric Economic Potential and Savings (MMBTU) from Equipment Standards



The net annual economic and achievable potentials of federal efficiency standards are shown in Figure 42. The BAU achievable potentials are acquired over a 16-year period, while the maximum achievable potentials are acquired over a 10-year period. Both achievable scenarios accelerate the acquisition rate of discretionary retrofit potential when compared to the economic potential scenario, which takes place over 20 years. Thus, the green Max achievable scenario actually rises above the economic potential scenario in the middle of the planning horizon.

Figure 42. Annual Electric Economic and Achievable Potential (2011-2030)



Baseline consumption and potentials for within-unit electric end uses are shown in Table 32.

Table 32. Within-Unit Electric Technical and Economic Potential by End Use (MMBTU in 2030)

End Use	Baseline Sales (MMBTU)	Technical Potential (MMBTU)	Economic Potential (MMBTU)	Maximum Achievable (MMBTU)	BAU Achievable (MMBTU)
Appliances	1,977,326	45,459	16,083	9,650	6,433
Consumer Electronics	830,774	285,825	247,939	148,763	99,176
Cooling	386,746	230,209	78,615	60,633	51,016
Heat Pump	476,561	216,095	214,992	153,438	123,842
Heating	1,473,367	336,173	204,566	153,693	122,741
Lighting	907,130	585,647	285,125	242,357	242,357
Plug Load	1,149,725	77,906	71,430	42,858	28,572
Ventilation And Circulation	358,830	102,829	102,829	61,698	41,132
Water Heat	1,010,204	331,566	131,499	105,022	83,540
Total	8,570,664	2,211,710	1,353,079	978,111	798,808

Table 33 shows the contents of Table 32 in GWh.

Table 33. Within-Unit Electric Technical and Economic Potential by End Use (GWh in 2030)

End Use	Baseline Sales (GWh)	Technical Potential (GWh)	Economic Potential (GWh)	Maximum Achievable (GWh)	BAU Achievable (GWh)
Appliances	580	13	5	3	2
Consumer Electronics	243	84	73	44	29
Cooling	113	67	23	18	15
Heat Pump	140	63	63	45	36
Heating	432	99	60	45	36
Lighting	266	172	84	71	71
Plug Load	337	23	21	13	8
Ventilation And Circulation	105	30	30	18	12
Water Heat	296	97	39	31	24
Total	2,512	648	397	287	234

Baseline consumption and potentials for common area electric end uses are shown in Table 34.

Table 34. Common Area Electric Technical and Economic Potential by End Use (MMBTU in 2030)

End Use	Baseline Sales (MMBTU)	Technical Potential (MMBTU)	Economic Potential (MMBTU)	Maximum Achievable (MMBTU)	BAU Achievable (MMBTU)
Cooling	532,375	227,469	171,169	143,895	116,621
Elevators	30,347	0	0	0	0
Heating	15,492	4,624	2,934	2,494	2,054
Lighting	1,604,228	124,566	79,650	67,702	55,755
Pool Pump	26,094	0	0	0	0
Ventilation And Circulation	733,917	161,940	152,492	129,618	106,744
Water Heat	80,037	30,299	16,066	13,656	11,246
Total	3,022,490	548,898	422,310	357,365	292,420

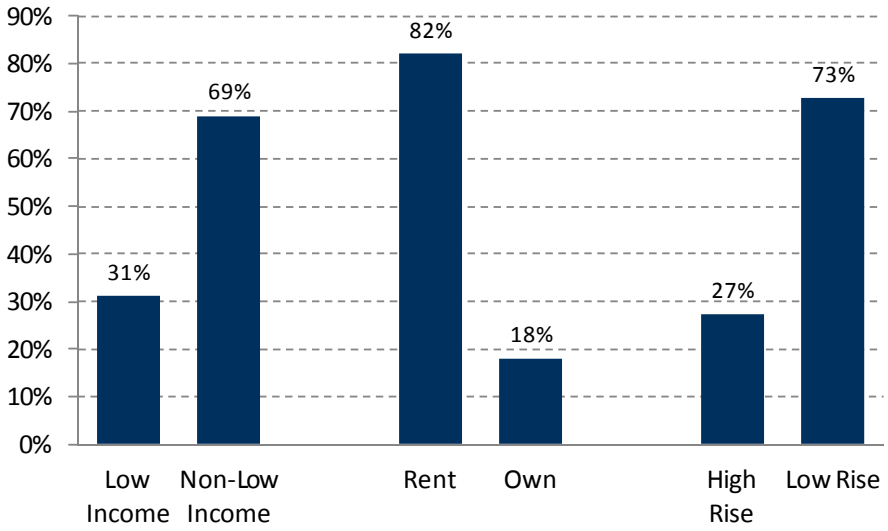
.

Table 35. Common Area Electric Technical and Economic Potential by End Use (GWh in 2030)

End Use	Baseline Sales (GWh)	Technical Potential (GWh)	Economic Potential (GWh)	Maximum Achievable (GWh)	BAU Achievable (GWh)
Cooling	156	67	50	42	34
Elevators	9	0	0	0	0
Heating	5	1	1	1	1
Lighting	470	37	23	20	16
Pool Pump	8	0	0	0	0
Ventilation And Circulation	215	47	45	38	31
Water Heat	23	9	5	4	3
Total	886	161	124	105	86

The estimated proportions of total electric economic potential for various building classifications are shown in Figure 43. The Evaluation Team accounted for differences in equipment saturations, particularly for HVAC end uses—for within unit and shared—when allocating potential to high rise buildings.

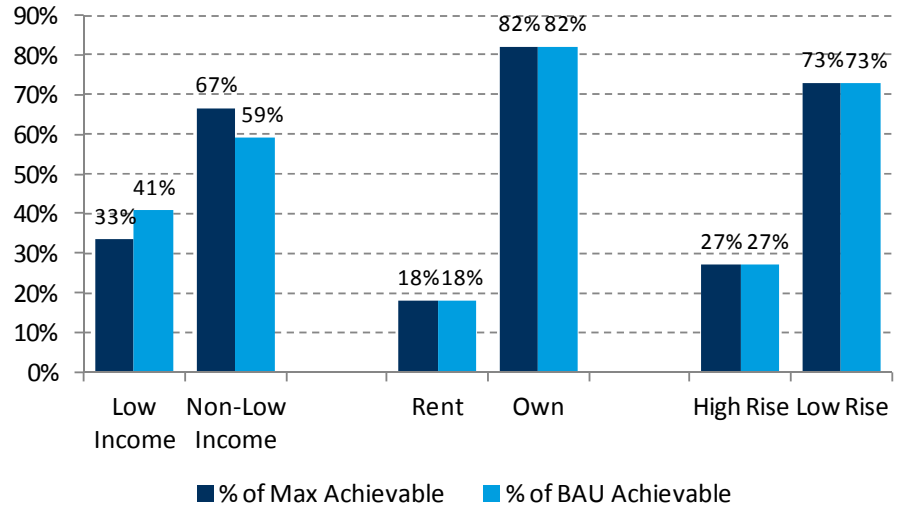
Figure 43. Electric Economic Potential by Building Classification (Percent of Total)



Note: Percentages sum to 100% within income, rent/own, and high/low-rise classifications

Figure 44 shows the proportion of achievable potentials allocated across various building classifications. The achievable potentials are more heavily weighted toward low-income buildings, especially in the BAU scenario, because Massachusetts low-income programs offer more aggressive incentives than the non-low income programs.

Figure 44. Electric Achievable Potential by Building Classification (Percent of Total)



Note: Percentages sum to 100% within income, rent/own, and high/low-rise classifications

Table 36 shows electric achievable potential, allocated by PA. We overlaid multifamily residence counts from the American Community Survey (ACS) with service territory boundaries to develop the proportions used in these estimates. Our methodology yields only rough results, as service territory boundaries are defined on a much more granular level than data from ACS can be obtained. Ngrid and NSTAR have the largest share of Massachusetts multifamily residences (total more than 80%), and thus the largest share of potential.

Table 36. Electric Achievable Potential by Program Administrator (Cumulative in 2030)

Program Administrator	Share of Mass. Multifamily	Max Achievable (MMBTU)	Max Achievable (GWh)	BAU Achievable (MMBTU)	BAU Achievable (Gwh)
Ngrid	42%	560,120	164	457,678	134
NSTAR	39%	526,380	154	430,110	126
Municipals	11%	141,022	41	115,230	34
WMECO	6%	82,769	24	67,631	20
Other	2%	25,185	7	20,579	6
Total	100%	1,335,476	391	1,091,228	320

Note: Other includes Cape Light Compact and Unitil. Share of Massachusetts multifamily buildings is for electric customers

Summary of Gas Potentials Estimates

Figure 45 presents energy electric energy-efficiency potentials for multifamily buildings.

- Technical potential is 32% of the baseline energy forecast in year 2030.
- Economic potential is 24% of the baseline energy forecast in year 2030.
- Maximum achievable potential is 19% of the baseline energy forecast in year 2030.
- BAU achievable potential is 16% of the baseline energy forecast in year 2030.

Figure 45. Gas Energy-Efficiency Potentials
Percent of Year 2030 Consumption)

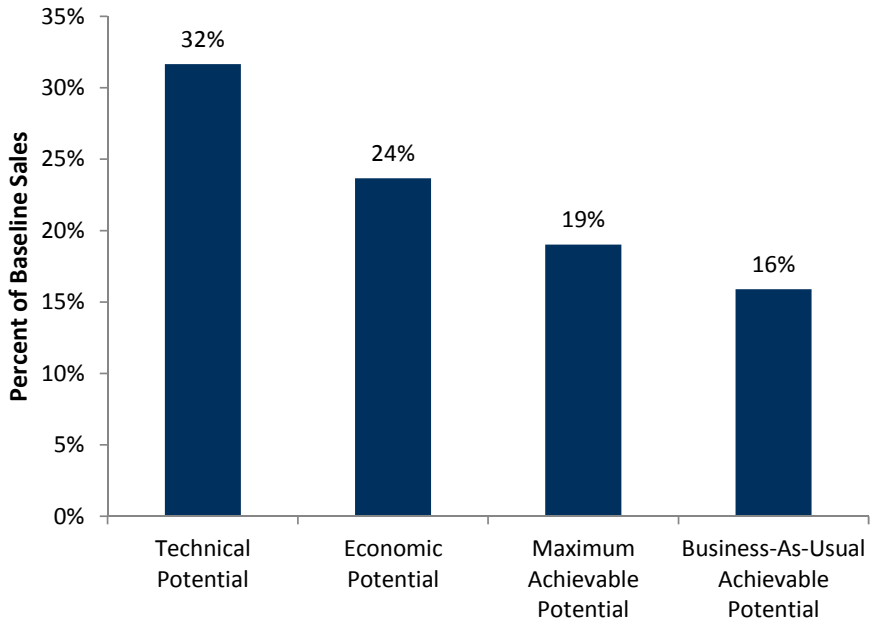
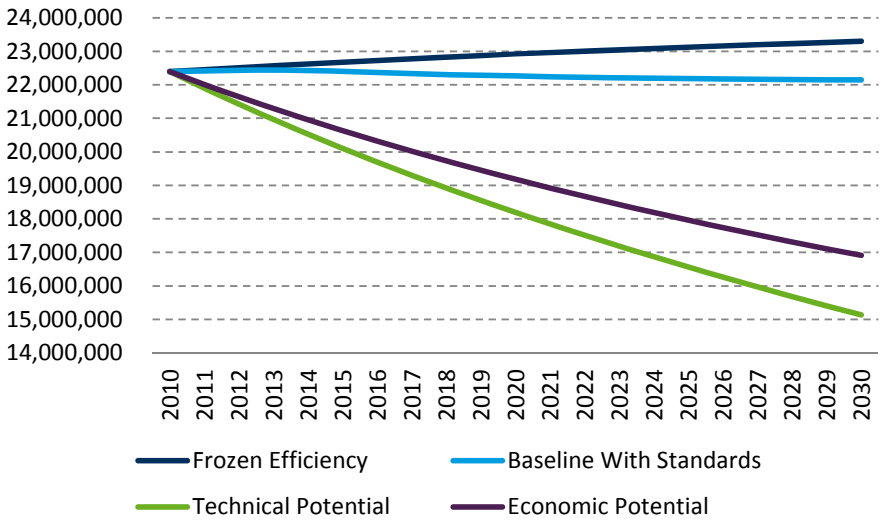


Figure 46 shows the forecasts of gas usage under four scenarios:

- The frozen-efficiency scenario
- The baseline forecast scenario including impacts from equipment standards
- The technical potential scenario
- The economic potential scenario.

Figure 46. Estimated Multifamily Gas Consumption (MMBTU): Frozen Efficiency, Equipment Standards, Technical and Economic Potentials



We determined that 85% (4.5 million MMBTU) of total economic potential comes from within-unit end-uses and 15% (0.8 million MMBTU) comes from common-area end uses. Maximum achievable potential (4.2 million MMBTU) is 80% of economic potential, and BAU achievable potential (3.5 million MMBTU) is 67% of economic potential.

Table 37. Gas Baseline Consumption and Potentials: Within-Unit and Common Area (MMBTU in 2030)

Source	Baseline Sales (MMBTU)	Technical Potential (MMBTU)	Economic Potential (MMBTU)	Achievable Potential – Max (MMBTU)	Achievable Potential - BAU (MMBTU)
Within Unit	18,326,216	6,171,106	4,450,358	3,547,995	2,984,905
Common Area	3,818,503	838,347	787,682	661,696	535,711
Total	22,144,719	7,009,453	5,238,040	4,209,691	3,520,616

Table 38 shows the contents of Table 37 in Therms.

Table 38. Gas Baseline Consumption and Potentials: Within-Unit and Common Area (Million Therms in 2030)

Source	Baseline Sales (Million Therms)	Technical Potential (Million Therms)	Economic Potential (Million Therms)	Maximum Achievable (Million Therms)	BAU Achievable (Million Therms)
Within Unit	183	62	45	35	30
Common Area	38	8	8	7	5
Total	221	70	52	42	35

As shown in the following figures, and, heating measures account the largest portion of gas economic potential. Figure 47 shows the within-unit potential—67% of total. Water heating measures account for the remaining within-unit economic potential.

Figure 47. Within-Unit Gas Economic Potential (Percent of Total)

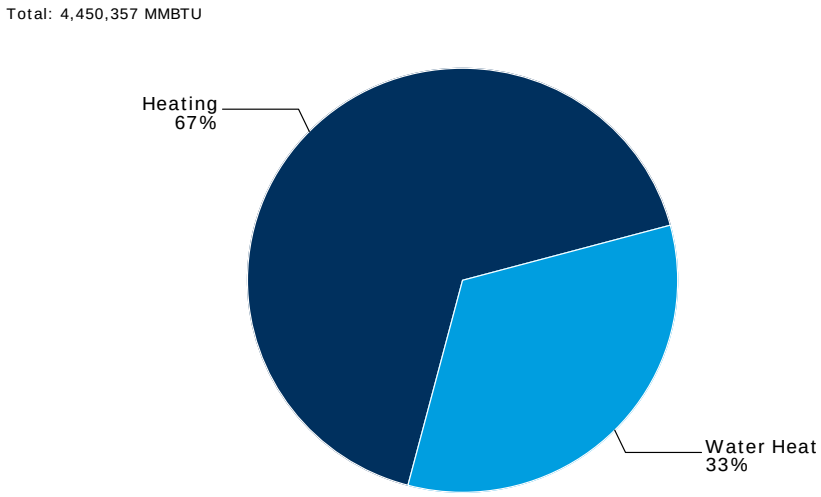


Figure 48 shows the common-area potential for heating measures: 63% of total.

Figure 48. Common-Area Gas Economic Potential (Percent of Total)

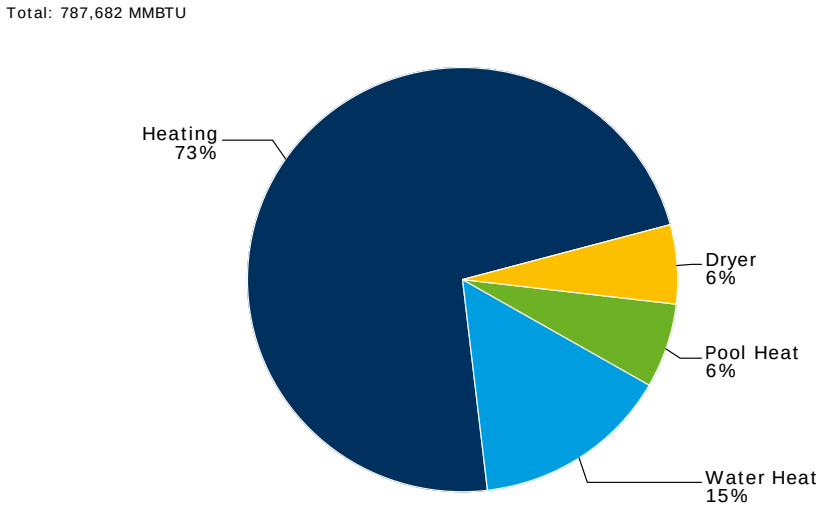
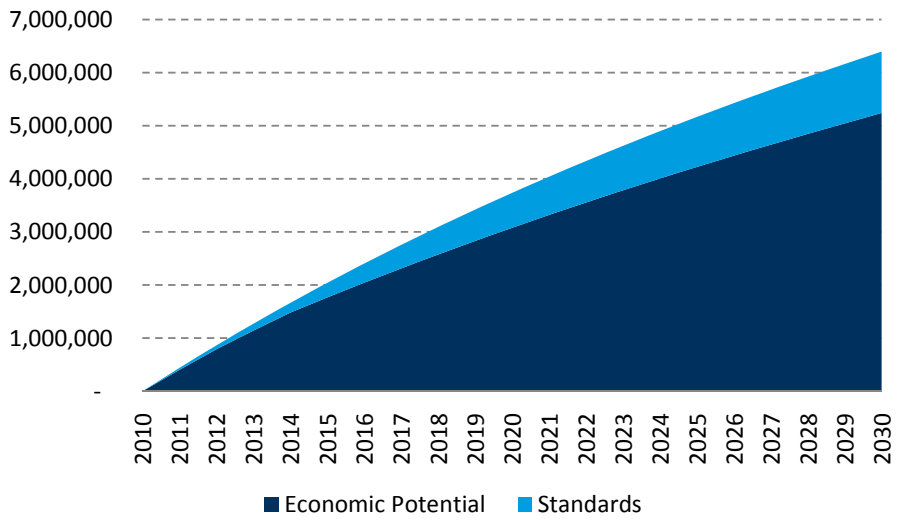


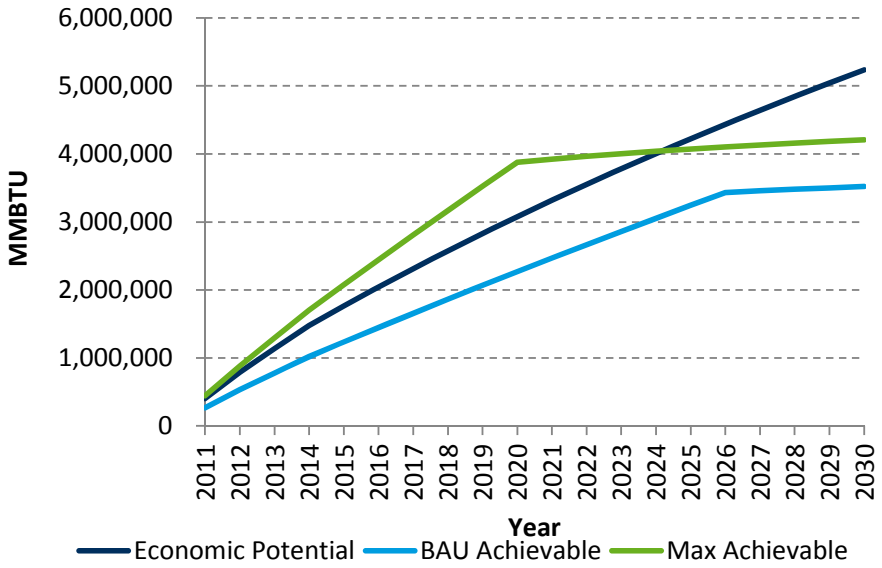
Figure 49 shows the total annual impact of gas energy savings from efficiency standards and from economic potential.

Figure 49. Annual Gas Economic Potential and Savings (MMBTU) From Equipment Standards



The BAU achievable potentials are acquired over a 16-year period at approximately 200 thousand MMBTU (2 million therms) per year (Figure 50). The maximum achievable potentials are acquired over a 10-year period at a rate of 300 thousand (3 million therms) per year. Both achievable scenarios accelerate the acquisition rate of potential when compared to the economic potential scenario, which takes place over 20 years.

Figure 50. Annual Gas Economic and Achievable Potential (2011-2030)



Baseline consumption and potentials for within-unit gas end uses are shown in Table 39.

Table 39. Within-Unit Gas Technical and Economic Potential by End Use (MMBTU in 2030)

End Use	Baseline Sales (MMBTU)	Technical Potential (MMBTU)	Economic Potential (MMBTU)	Maximum Achievable (MMBTU)	BAU Achievable (MMBTU)
Cooking	511,218	0	0	0	0
Dryer	13,190	0	0	0	0
Heating	8,763,157	3,387,919	2,971,537	2,367,131	2,001,063
Other	1,644,249	0	0	0	0
Water Heat	7,394,402	2,783,187	1,478,820	1,180,864	983,842
Total	18,326,216	6,171,106	4,450,357	3,547,995	2,984,905

Table 40. Within-Unit Gas Technical and Economic Potential by End Use (Million Therms in 2030)

End Use	Baseline Sales (Million Therms)	Technical Potential (Million Therms)	Economic Potential Million Therms)	Maximum Achievable (Million Therms)	BAU Achievable (Million Therms)
Cooking	5	0	0	0	0
Dryer	0	0	0	0	0
Heating	88	34	30	24	20
Other	16	0	0	0	0
Water Heat	74	28	15	12	10
Total	183	62	45	35	30

Baseline consumption and potentials for common area gas end-uses are shown in Table 41.

Table 41. Common Area Gas Technical and Economic Potential by End Use (MMBTU in 2030)

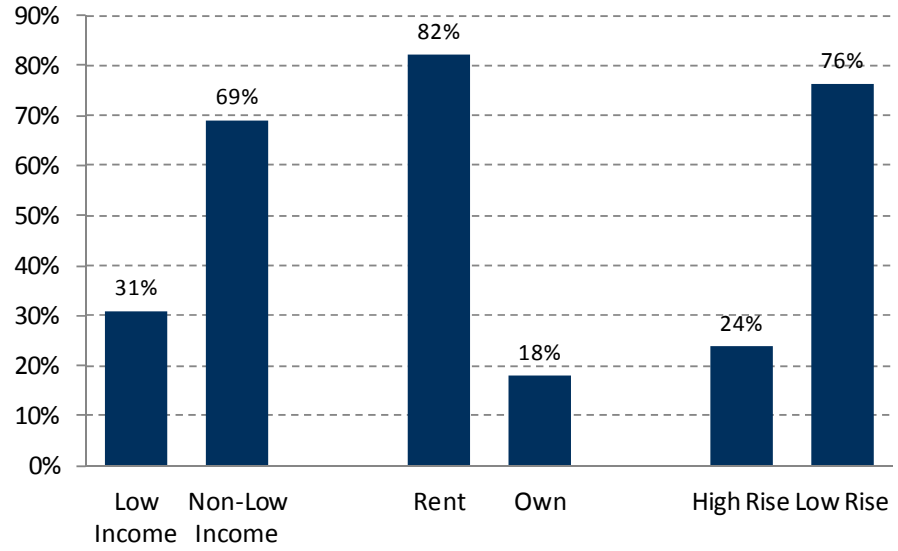
End Use	Baseline Sales (MMBTU)	Technical Potential (MMBTU)	Economic Potential MMBTU)	Maximum Achievable (MMBTU)	BAU Achievable (MMBTU)
Dryer	274,722	47,108	47,108	37,687	28,265
Heating	2,985,957	581,567	572,443	485,756	399,070
Pool Heat	213,025	50,576	50,576	40,461	30,346
Water Heat	344,800	159,095	117,555	97,793	78,030
Total	3,818,503	838,347	787,682	661,696	535,711

Table 42. Common Area Gas Technical and Economic Potential by End Use (Million Therms in 2030)

End Use	Baseline Sales (Million Therms)	Technical Potential (Million Therms)	Economic Potential Million Therms)	Maximum Achievable (Million Therms)	BAU Achievable (Million Therms)
Dryer	2.7	0.5	0.5	0.4	0.3
Heating	29.9	5.8	5.7	4.9	4.0
Pool Heat	2.1	0.5	0.5	0.4	0.3
Water Heat	3.4	1.6	1.2	1.0	0.8
Total	38.2	8.4	7.9	6.6	5.4

The estimated proportions of total electric economic potential for various building classifications are shown in Figure 51. The Evaluation Team accounted for differences in equipment saturations (particularly for HVAC end uses—within-unit and shared) when allocating potential to high-rise buildings.

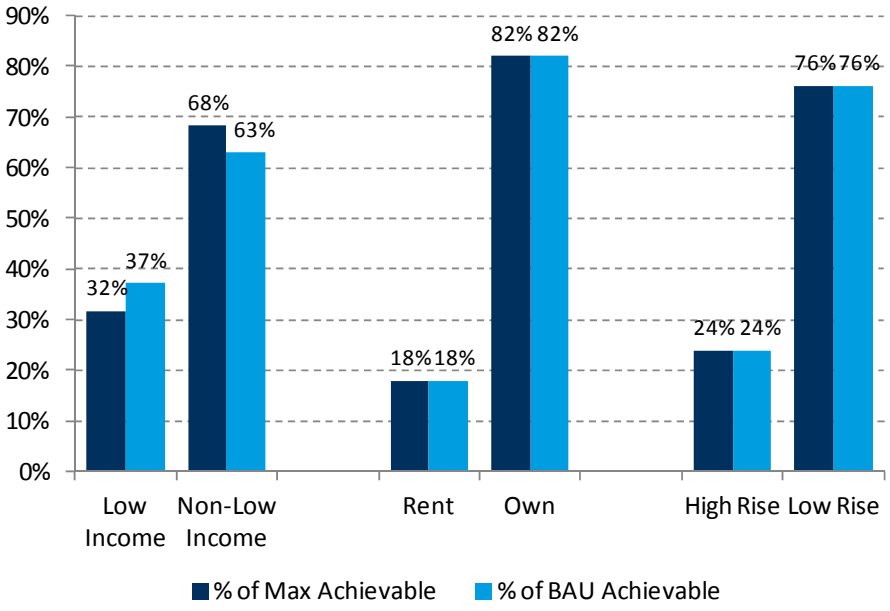
Figure 51. Gas Economic Potential by Building Classification (Percent of Total)



Note: Percentages sum to 100% within income, rent/own, and high/low-rise classifications

Figure 52 shows the proportion of achievable potentials allocated across various building classifications. Similar to the electric fuel type, gas achievable potentials are more heavily weighted towards low-income buildings, especially in the BAU scenario. This is because Massachusetts' low-income programs offer more aggressive incentives than the non-low income programs.

Figure 52. Gas Achievable Potential by Building Classification (Percent of Total)



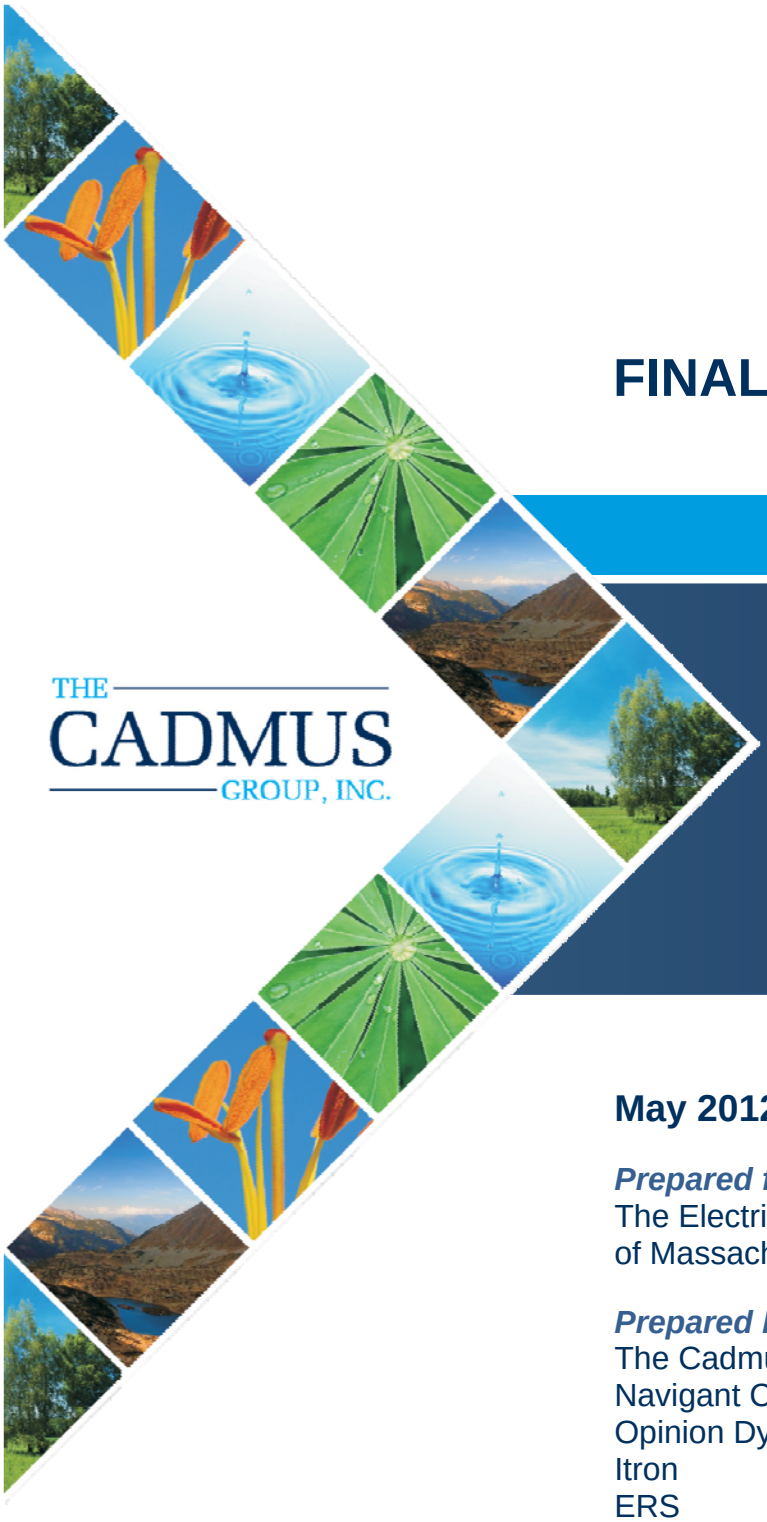
Note: Percentages sum to 100% within income, rent/own, and high/low-rise classifications

Table 43 shows gas achievable potential allocated by program administrator. We overlaid multifamily residence counts from the American Community Survey (ACS) with service territory boundaries to develop the proportions used in these estimates. Our methodology yields only rough results, as service territory boundaries are defined on a much more granular level than data from ACS can be obtained. Ngrid and NSTAR have the largest share of Massachusetts multifamily residences with gas service (total over 70%), and thus the largest share of potential.

Table 43. Gas Achievable Potential by Program Administrator (Cumulative in 2030)

Program Administrator	Share of Mass. Multifamily	Max Achievable (MMBTU)	Max Achievable (Million Therms)	BAU Achievable (MMBTU)	BAU Achievable (Million Therms)
Ngrid	48%	2,026,025	20	1,694,390	17
NSTAR	25%	1,064,668	11	890,395	9
Columbia Gas	17%	706,526	7	590,876	6
Other	10%	412,472	4	344,955	3
Total	100%	4,209,691	42	3,520,616	35

Note: Other includes New England Gas, Berkshire Gas, Unitil, and Municipals. Share of Massachusetts multifamily buildings is for gas customers only



FINAL REPORT

Massachusetts Multifamily Market Characterization and Potential Study, Volume 2

May 2012

Prepared for:
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Volume 2 provides the supplemental technical information, assumptions, data, and other relevant details:

- Appendix A: Measure Descriptions
- Appendix B: Detailed Baseline and Technical Potential
- Appendix C: Measure Details
- Appendix D: Barriers and Motivators to Measure Adoption
- Appendix E: Achievable Potential Workshop Memo

APPENDIX A: MEASURE DESCRIPTIONS

Basement/Foundation Insulation. Adding insulation to the basement or crawlspace walls of existing homes increases the thermal performance (R-value) of the concrete foundation.

Boiler Economizer. Boiler economizers improve boilers' efficiency by recovering useful enthalpy from fluid streams that are not hot enough for use in a boiler. They use exhaust gases from the boiler to preheat the feed water.

Ceiling Fan. ENERGY STAR®-qualified ceiling fans have improved motors and blade designs that allow the user to decrease their thermostat by a couple of degrees yet still feel at least 5° cooler. The fans do not create cooler temperatures; all savings are associated with the improved fan design. The ceiling fan in the kit does not include light fixtures.

Ceiling Insulation. Adding insulation to the ceiling in existing buildings increases the thermal performance (R-value) of the building, with the amount of increase depending on vintage.

Chilled Water / Condenser Water Settings Optimization. As part of the direct digital controls system, this measure optimizes control of the chilled water temperature and/or flow settings.

Chilled Water Piping Loop with Variable Speed Drive (VSD) Control. VSD control allows the user to adjust cooling flow and draft according to load, providing greater energy efficiency.

Chiller-Water Side Economizer. During optimal environmental conditions, warm return water is routed to the economizer. There, condenser water accepts this heats and ejects it into the atmosphere via a dry cooler or evaporative tower.

Clothes Dryer. High-efficiency dryers have special features, such as moisture sensors, that minimize the amount of energy used while retaining the same performance.

Clothes Washer. Clothes washers with the ENERGY STAR label have a greater tub capacity, allowing for fewer loads to clean the same amount of laundry. Many have sensors that monitor incoming water levels and temperature. They also save water by rinsing the clothes with repeated high-pressure spraying instead of soaking them in a full tub of water.

Convert Constant Volume Air System to Variable Air Volume (VAV). The fan capacity control of the VAV reduces the energy consumed by fans, lowering the total cooling energy requirements of a building.

Cool Roof. ENERGY STAR-qualified cool roofs can lower the roof surface temperature by up to 100º F, thereby decreasing the amount of heat transferred into a building and reducing the amount of air conditioning needed. This measure can reduce peak cooling demand by 20%.

Cooling Tower-Two-Speed Fan Motor. This measure allows the cooling tower system to meet set point through two-speed control instead of cycling at full speed.

Cooling Tower-Variable Speed Drive Fan Control. This measure allows the cooling tower system to meet set point by continuously adjusting fan motor speed.

Demand Controlled Circulating Systems. This system delivers hot water to fixtures based on user demand, rather than relying on a timer activated system.

Direct Expansion Package Air-Side Economizer. Air-side economizers save energy in buildings by using cooler outside air to cool the space inside. This is energy-efficient when the enthalpy of the outside air is less than the enthalpy of the recirculated air.

Direct Expansion (DX) Tune-Up / Diagnostics. A DX tune-up can improve the operating efficiency of cooling equipment and be used to identify potential repairs before the equipment breaks down. Savings vary depending on the type and condition of equipment, potentially reducing cooling costs by more than 20%.

Direct / Indirect Evaporative Cooling, Pre-Cooling. The power consumption with evaporative cooling is limited to the fan and water pump. Because the water vapor is not recycled, it is not necessary to have a compressor, an item that consumes most of the power in closed-cycle refrigeration.

Dishwasher. ENERGY STAR-qualified dishwashers are, on average, 10% more energy efficient than non-qualified models. The efficient model uses less than 307 kWh/year (including standby consumption) for running 215 cycles, and use less than 5 gallons of water per cycle. The federal standard allows for a maximum consumption of 355 kWh/year and 6.5 gallons per cycle.

Door. Composite doors with a foam core increase a building's overall insulation, which slows heat loss. This measure includes adding a thermal door with a resistance value of R-5 to houses that have neither thermal nor storm doors.

Door Weatherization. This measure minimizes infiltration door sweep via weather stripping that is mounted to the bottom of the door. It consists of an extruded aluminum strip that holds a flexible vinyl strip, which blocks the air space between the door frame and the door.

Drain Water Heat Recovery Water Heater. These devices recover heat energy from domestic drain water, and are used to pre-heat cold water entering the hot water tank to minimize the temperature difference between the heating set point and the water entering the system.

Duct Insulation Upgrade. Adding insulation around the ducts in the heating system reduces heat loss to unconditioned spaces and increases the thermal performance (R-value) of the building.

Duct Repair and Sealing. Duct sealing cost-effectively saves energy, improves air and thermal distribution (comfort and ventilation), and reduces cross contamination between different areas of the building (e.g., smoking vs. non-smoking, bio-aerosols, localized indoor air pollutants).

ENERGY STAR Battery Charger. This measure recharges a wide variety of cordless products, including power tools, small household appliances, and electric shavers. ENERGY STAR-qualified battery chargers use an average of 35% less energy than conventional models.

Exhaust Air-to-Ventilation Air Heat Recovery. These systems use heat recovery to minimize the amount of energy lost due to ventilation. During the winter, the heat exchanger transfers heat energy from the warmer exhaust air into the cooler supply air, reducing the energy needed to heat that supply air to room temperature. During the summer, the heat exchanger works in reverse, cooling the incoming warm air with the cooler exhaust air.

Green Roof. The added mass and thermal resistance of green roofs reduces the heating and cooling loads of the building. These systems reduce the ambient temperature around the roof, decreasing the building's urban heat island effect; they also reduce the ambient temperature of the roof surface and slow the transfer of heat into the building, which reduces cooling costs. Green roofs add insulation to the structure, reducing the winter heating requirements.

High-Efficiency Central Air Conditioner (CAC). CACs are rated according to their seasonal energy-efficiency ratio (SEER), which indicates the relative amount of energy needed to provide a specific cooling output. Many older systems have SEER ratings of 6 or less. The minimum SEER allowed in 2012 is 13.

High-Efficiency Electric Water Heater. High-efficiency water heaters reduce standby losses and have an energy factor (EF) of 0.95, compared to a standard water heater which has an EF of 0.91.

High-Efficiency Gas Boiler. Boilers are either condensing or non-condensing. Condensing boilers condense the flue gas and water vapor, extracting useful heat and improving the boiler efficiency. There are several boiler options with various thermal efficiencies, with the overall efficiency defined as the gross output energy divided by the input energy. The efficiency is affected by combustion efficiency, standby losses, cycling losses, and heat transfer. This measure is applicable to both new and existing construction.

High-Efficiency Gas Furnace. Improvements in furnace technology, such as a new ignition and heat exchange design, have led to increased furnace efficiency.

High-Efficiency Gas Storage Water Heater. This measure employs the same technology as a standard gas storage water heaters: a burner located at the bottom of the glass-lined steel tank heats water. High-efficiency models have better insulation and heat traps, and more efficient burners. These improvements have a modest impact on price but increase efficiency by approximately 7.5%.

High-Efficiency Heat Pump. Electric heat pumps move heat, either to or from the air or ground, to cool and heat the home. High-efficiency models dehumidify better than standard models, resulting in less energy usage and more cooling comfort during the summer. Higher efficiencies are achieved with geothermal heat pumps, which transfer heat between the house and either the ground or a nearby water source.

High-Efficiency Room Air Conditioning. ENERGY STAR-qualified room air conditioners use less energy than conventional models through improved energy performance and timers that allow for better temperature control. This measure has an energy-efficient rating (EER) of 10.8 or 12, compared to a standard model of 9.8 EER.

Hot Water Pipe Insulation. Adding R-4 insulation around hot water pipes will decrease heat loss and increase the thermal performance of the building.

Infiltration Reduction. This measure detects any defects in the sanitary sewer collection system, improving the system capacity and reducing overflow and backup.

Insulation – Duct. Adding insulation around the ducts in the heating system reduces heat loss to unconditioned spaces and increases the thermal performance (R-value) of the building..

Low-Flow Faucet Aerator. By mixing water and air, faucet aerators reduce the amount of water that flows out of the faucet. They create a fine water spray with a screen that is inserted in the faucet head.

Low-Flow Showerhead. Low-flow showerheads mix water and air to reduce the amount of water that flows through the showerhead. They create a fine water spray through a screen that is inserted in the showerhead.

Motor - Consortium for Energy Efficiency (CEE) Premium-Efficiency Plus. Motors that meet CEE Premium-Efficiency Plus standards must have a nominal efficiency of at least one full National Electrical Manufacturers Association band higher than the 2007 EISA nominal efficiency.

Motor - Pump and Fan System with Variable Speed Control. Air conditioning motor-driven applications that do not require full speed can save energy by controlling the motor with a variable speed drive. The torque required is roughly the square of the speed, and the horsepower required is roughly the cube of the speed. This results in a large reduction in horsepower for a small reduction in speed.

Motor - Variable Air Volume Box High-Efficiency Electronically Commutated Motor (ECM). ECMs consume less power than standard motors, and cost between 30% less (during high flow rate conditions) and 70% less (during turndown) to operate. For existing construction, ECMs have a technical feasibility of 65% for cooling and varying amounts for HVAC auxiliary (with gas or electric heating as the primary fuel). This 65% feasibility for cooling may underestimate the total potential of this specific application. In equipment fuel shares and saturations, the feasibility for HVAC auxiliary measures accounts for the percentage of homes that currently use this type of equipment,, but because of the HVAC auxiliary end use, these factors had to accounted for in the technical feasibility.

Motor Rewind. A rewound motor that failed with an undamaged magnetic core will retain its original efficiency if appropriate procedures are followed. Properly repaired, a standard efficiency motor will retain its original standard efficiency, and an energy-efficient motor will retain its original high efficiency.

Office Copier. Energy-efficient office copiers have a special design that eliminates wasted energy by using less energy to perform regular tasks and automatically entering a low-power mode when not in use.

Office Printer. Energy-efficient office printers have a special design that eliminates wasted energy by using less energy to perform regular tasks and automatically enter a low-power mode when not in use.

Operation and Maintenance Tune-up. Proper system tune-up/maintenance ensures that both the refrigerant charge and airflow through the evaporator coil are properly tested and correctly adjusted; two factors that affect system efficiency. Maintenance includes changing filters and cleaning coils to maintain the overall performance and efficiency of the unit.

Outdoor LED Lighting with Automatic Controls. This measure is used to control the usage of multiple lights and saves energy by automatically turning on at dusk and allowing the user to create schedules of illumination.

Programmable Thermostat. A programmable thermostat controls set-point temperatures automatically, ensuring the HVAC system does not run during low-occupancy hours.

Programmable Thermostat, Multizone. A multizone programmable thermostat controls set-point temperatures automatically and differently for multiple areas (rooms or zones), ensuring the HVAC system is does not run during low-occupancy hours, and allowing the user to program areas depending on room use.

Proper Sizing of HVAC Unit. Properly sized central air conditioners operate for longer periods of time rather than frequently cycling on and off, resulting in optimum equipment operating efficiency and better control.

Re-Commissioning. Re-commissioning restores the original intended operating performance of an existing building through systematically evaluating electrically powered systems and implementing no/low-cost measures.

Refrigerator/Freezer - Removal of Secondary. This refers to the environmentally friendly disposal of unneeded appliances, such as secondary refrigerators or stand-alone freezers.

Slab – 2-inch Foam / R-20. Adding insulation to the building slab increases the thermal performance (R-value) of the building and increases comfort over cold floors. Even if the foundation wall is insulated vertically under the slab, significant heat can still be lost from an uninsulated slab edge that is closest to the cold outside air.

Smart Strip. Energy-saving products, such as a workstation power strip with an occupancy sensor, will turn the power on and off to all devices plugged into the power strip, such as computers, desk lights, and audio equipment, based on occupancy within the work area.

Solar Hot Water. This measure uses solar energy to heat water through a collector, which is often fastened to a roof or a wall facing the sun and is either pumped (active system) or driven by natural convection (passive system) through it.

Solar Pool/Spa Heating System. This heating system pumps pool water through the filter and then the solar collector(s), where it is heated before being returned to the pool. In hot climates, the system can cool the pool by circulating water through the collector(s) at night.

Solar Water Heating. These systems include storage tanks and solar collectors, and can be active, with circulating pumps and controls, or passive. The system increases the temperature of water entering the storage tank, reducing the amount of energy required by the hot water heater to achieve the set-point temperature.

Stand-Alone Freezer – Removal. Stand-alone freezers use energy inefficiently and require proper disposal due to hazardous materials, such as Freon and chlorofluorocarbons.

Swimming Pool/Spa Covers. Pool covers minimize evaporation, both outdoor and indoor, and is the single most effective means of reducing pool heating costs, creating savings of 50% to 70%.

Wall Insulation. Adding insulation to the walls of existing homes increases the thermal performance (R-value) by slowing the transfer of heat and reducing the heating and cooling loads of the building.

Water Heater Tank Blanket/Insulation. Adding R-5 insulation to older water heaters with no insulation reduces the equipment stand-by losses.

Water Heater Thermostat Setback. This measure generates savings by reducing the set-point temperature of a water heater from 135° F to 120° F, which is often set higher than necessary.

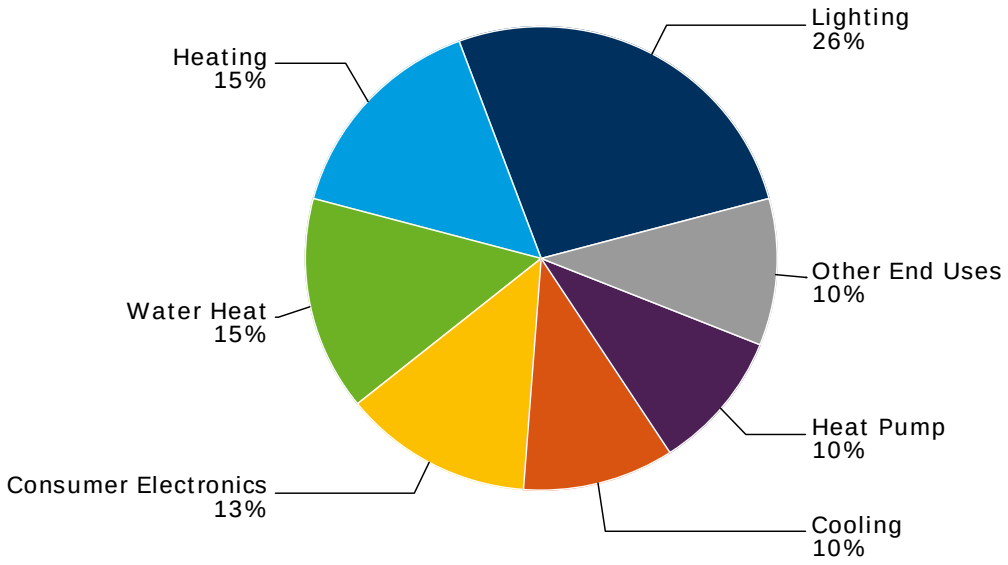
Window Film. Applying solar control window film reduces the peak demand during hot months by conserving energy from the air conditioner. These films also reduce exposure to ultraviolet radiation and glare.

Windows. Building thermal performance is increased by installing windows with a reduced U-value in existing buildings and new construction.

Appendix B: Potential Details

Figure 1. Within-Unit Electric Technical Potential

Total: 2,211,710 MMBTU



Note: 'Other End Uses' includes:
Ventilation And Circulation: 5%, Plug Load: 4%, Appliances: 2%

Figure 2. Within-Unit Electric Economic Potential

Total: 1,353,079 MMBTU

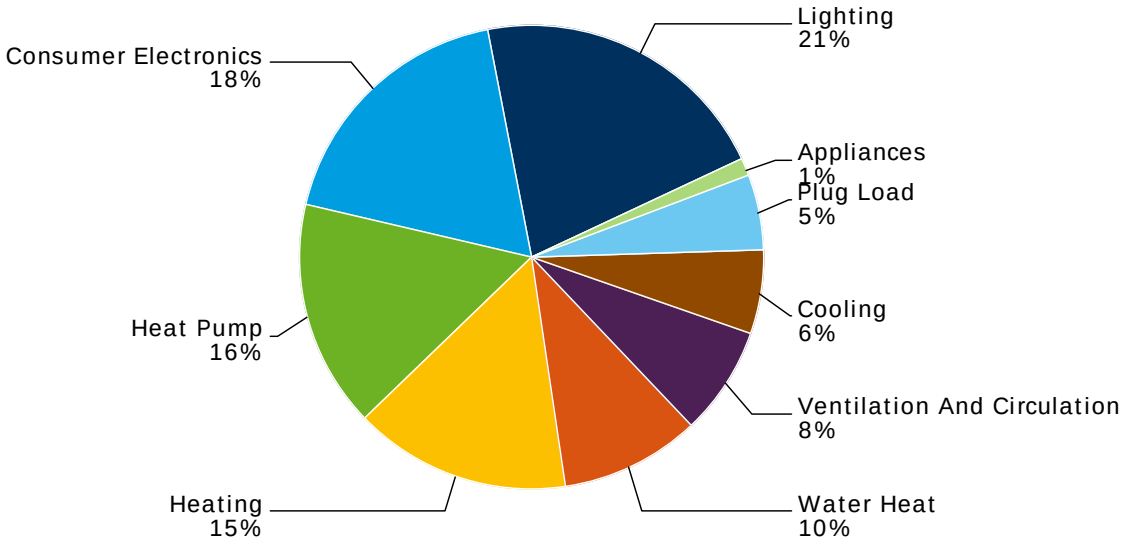


Figure 3. Common Area Electric Technical Potential

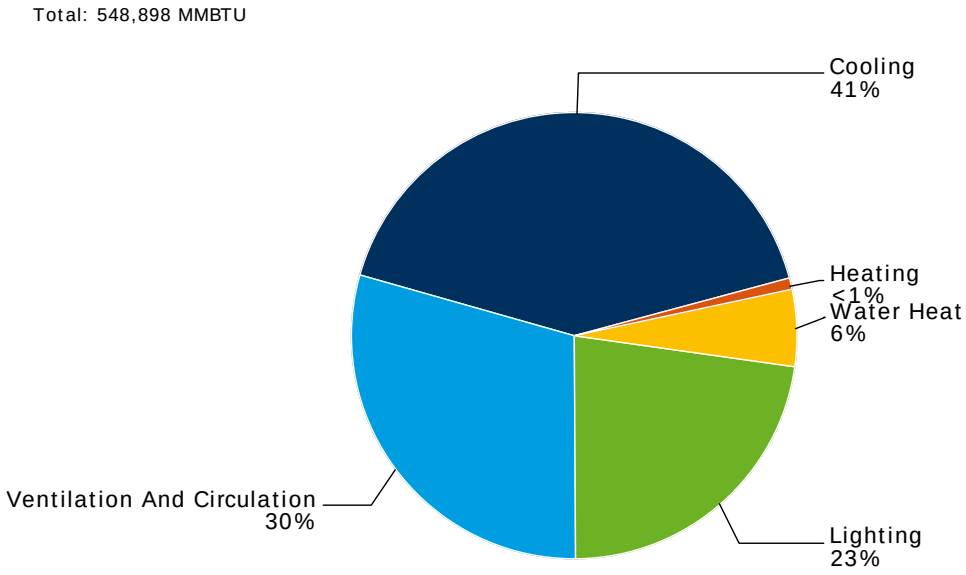
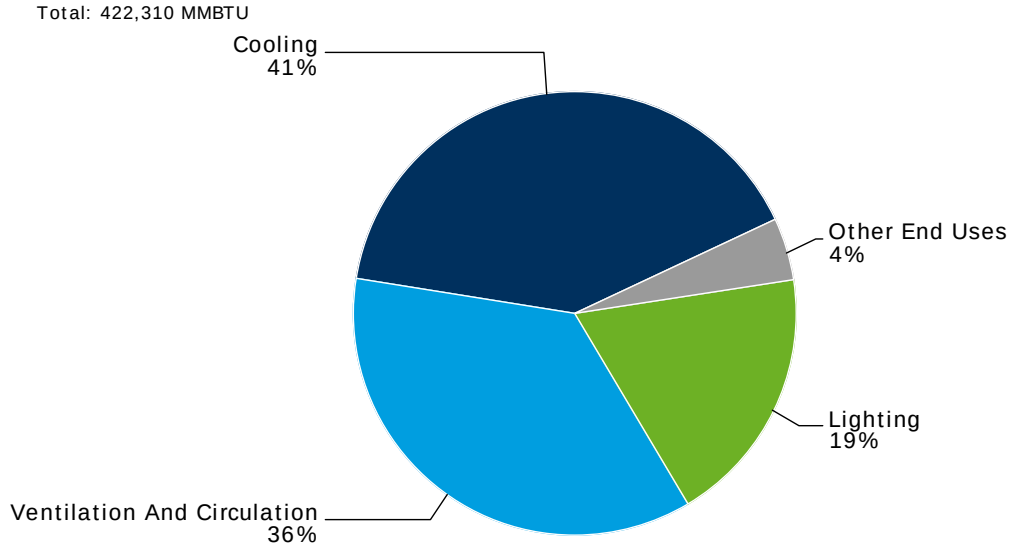


Figure 4. Common Area Electric Economic Potential



Note: 'Other End Uses' includes:
Water Heat: 4%, Heating: <1%

Figure 5. Within-Unit Gas Technical Potential

Total: 6,171,106 MMBTU

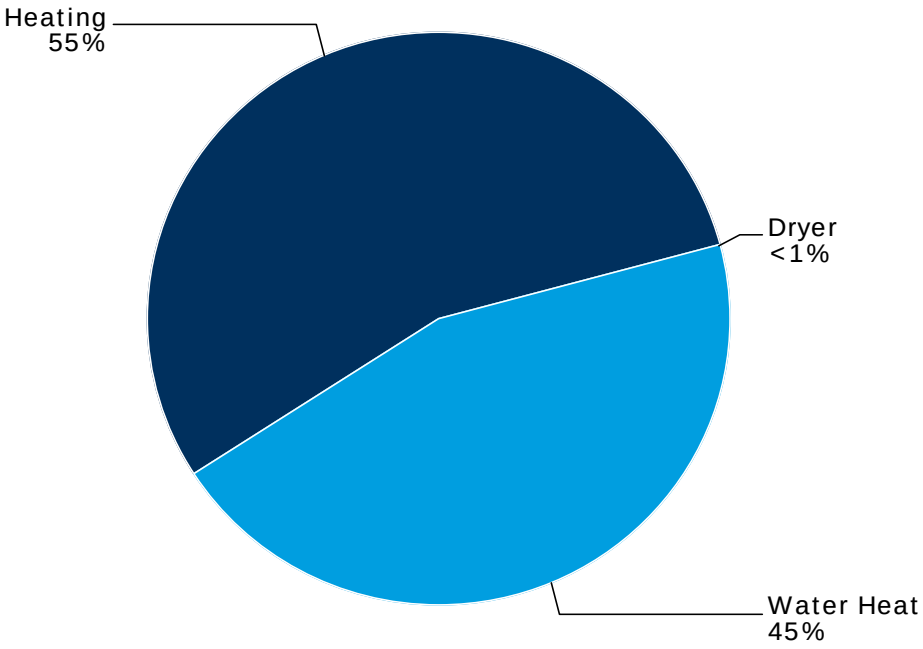


Figure 6. Within-Unit Gas Economic Potential

Total: 4,450,357 MMBTU

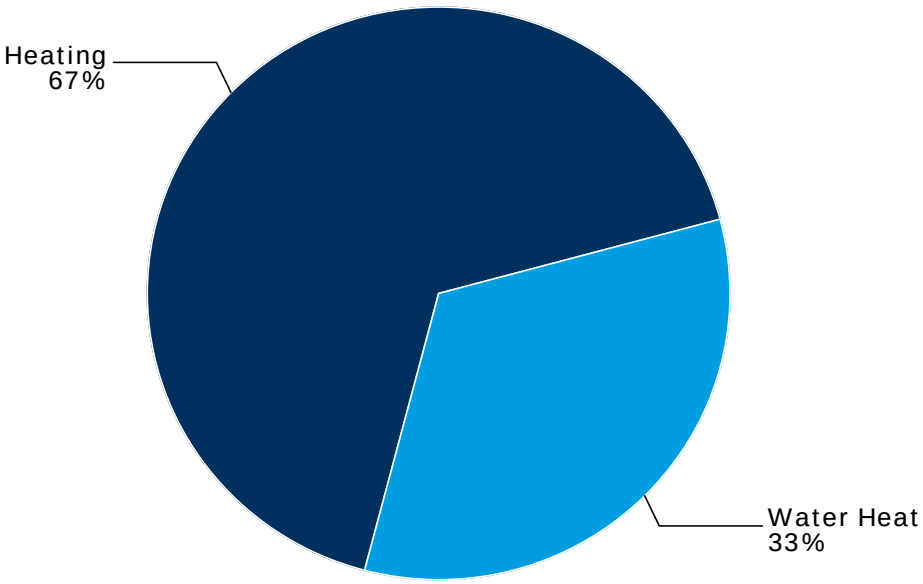


Figure 7. Common Area Gas Technical Potential

Total: 838,347 MMBTU

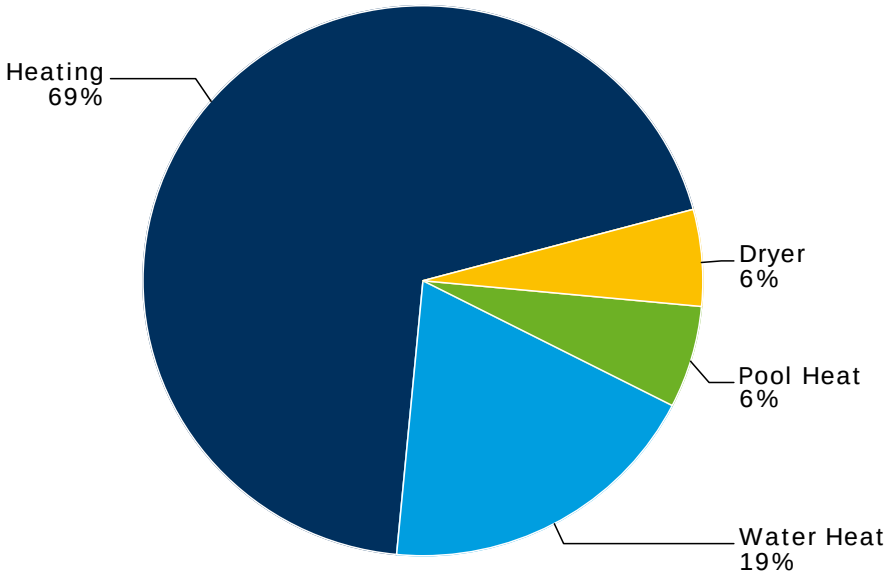


Figure 8. Common Area Gas Economic Potential

Total: 787,682 MMBTU

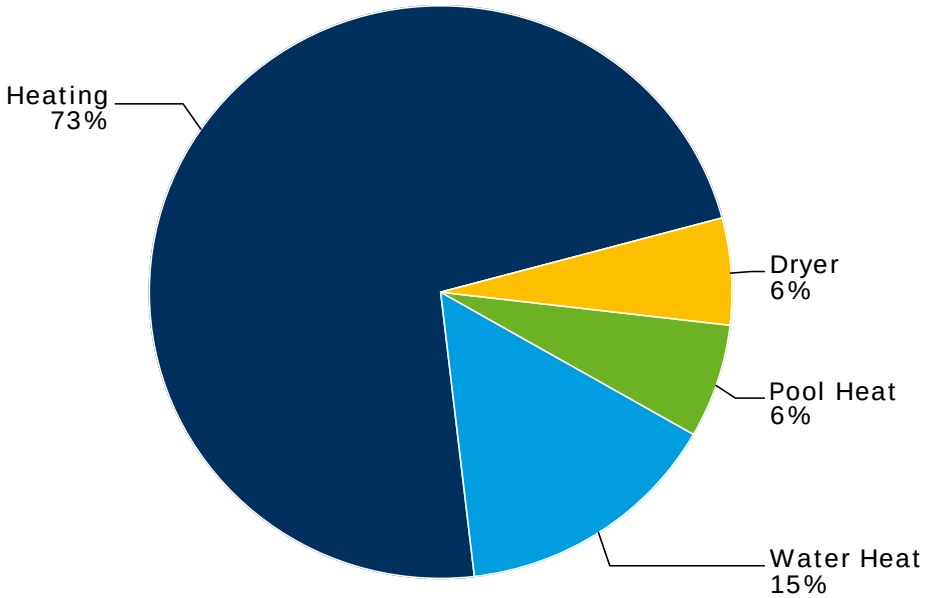


Figure 9. Electric Technical Potential by Income, Rent/Own, and High/Low-Rise Categories

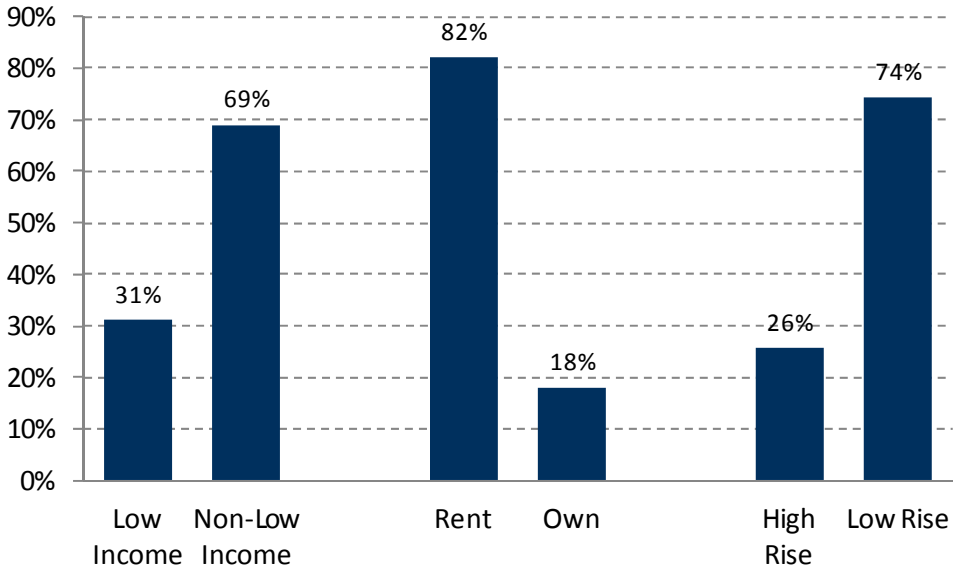


Figure 10. Electric Economic Potential by Income, Rent/Own, and High/Low-Rise Categories

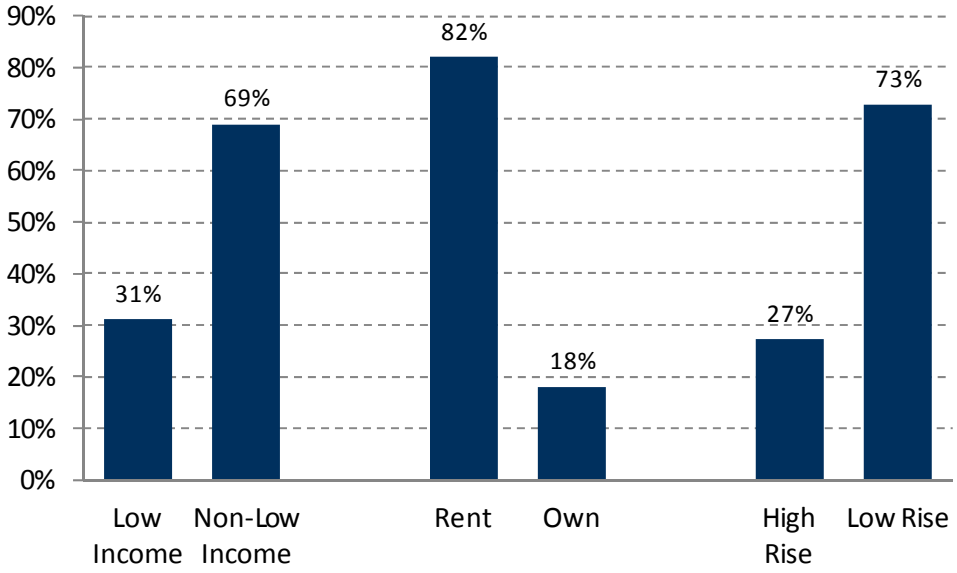


Figure 11. Gas Technical Potential by Income, Rent/Own, and High/Low-Rise Categories

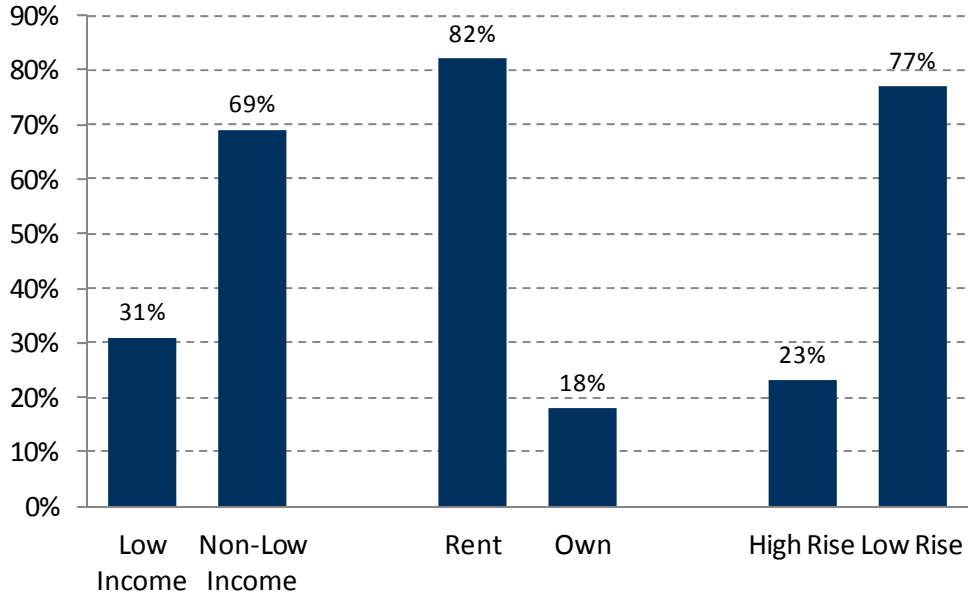
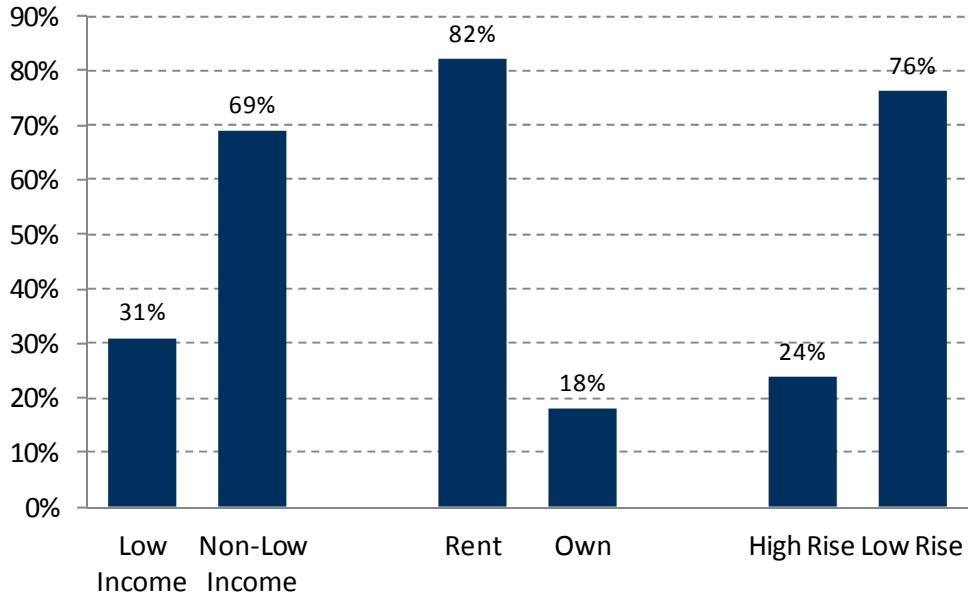


Figure 12. Gas Economic Potential by Income, Rent/Own, and High/Low-Rise Categories



Appendix C.1 – Within-Unit Electric Measure Details

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Ac	Basement Insulation - R-19	Basement Insulation - R-19	Existing	614	11%	20	$75	90%	90%	2.9	1,630	5,558
Within Unit	Building Ac	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	614	8%	20	$59	65%	75%	2.6	261	891
Within Unit	Building Ac	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	614	9%	20	$72	80%	20%	2.3	96	327
Within Unit	Building Ac	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	614	10%	20	$86	95%	10%	2.2	61	208
Within Unit	Building Ac	Ceiling - R 60	Ceiling R 49 - R 60	New	434	1%	20	$28	95%	10%	0.6	3	9
Within Unit	Building Ac	Ceiling Fan	Ceiling Fan (no lighting kit)	Existing	614	12%	10	$276	70%	50%	0.4	613	2,090
Within Unit	Building Ac	Ceiling Fan	Ceiling Fan (no lighting kit)	New	434	10%	10	$276	70%	50%	0.3	75	255
Within Unit	Building Ac	Chilled Water / Condenser Water Settings-Optimization	Additional Control Features	Existing	614	5%	5	$26	95%	81%	1.1	779	2,656
Within Unit	Building Ac	Chilled Water / Condenser Water Settings-Optimization	Additional Control Features	New	434	5%	5	$26	95%	81%	0.8	106	360
Within Unit	Building Ac	Chilled Water Piping Loop W/ Vsd Control	VSD for secondary chilled water loop	Existing	614	12%	10	$119	25%	70%	1.1	409	1,394
Within Unit	Building Ac	Chilled Water Piping Loop W/ Vsd Control	VSD for secondary chilled water loop	New	434	12%	10	$119	25%	70%	0.8	55	186
Within Unit	Building Ac	Chiller-Water Side Economizer	Install Economizer	Existing	614	10%	15	$957	30%	45%	0.2	183	626
Within Unit	Building Ac	Chiller-Water Side Economizer	Install Economizer	New	434	10%	15	$957	30%	45%	0.1	27	91
Within Unit	Building Ac	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	614	12%	15	$1,509	80%	80%	0.1	995	3,391
Within Unit	Building Ac	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	434	12%	15	$1,509	80%	80%	0.1	145	494
Within Unit	Building Ac	Cool Roofs	Lighter Colored Shingles (White)	Existing	614	10%	15	$1,595	98%	45%	0.1	264	899
Within Unit	Building Ac	Cool Roofs	Lighter Colored Shingles (White)	New	434	10%	15	$1,595	98%	45%	0.1	38	131
Within Unit	Building Ac	Cooling Tower-Two-Speed Fan Motor	Cooling Tower-Two-Speed Fan Motor	Existing	614	14%	15	$33	35%	95%	6.4	623	2,124
Within Unit	Building Ac	Cooling Tower-Two-Speed Fan Motor	Cooling Tower-Two-Speed Fan Motor	New	434	14%	15	$33	35%	95%	4.5	81	277
Within Unit	Building Ac	Cooling Tower-Vsd Fan Control	Variable-Speed Tower Fans replace Two-Speed	Existing	614	4%	13	$55	75%	95%	1.0	272	926
Within Unit	Building Ac	Cooling Tower-Vsd Fan Control	Variable-Speed Tower Fans replace Two-Speed	New	434	4%	15	$55	75%	95%	0.8	38	128
Within Unit	Building Ac	Dx Package-Air Side Economizer	Air-Side Economizer	Existing	614	15%	10	$257	30%	10%	0.6	78	265
Within Unit	Building Ac	Dx Package-Air Side Economizer	Air-Side Economizer	New	434	15%	10	$257	30%	10%	0.4	11	39
Within Unit	Building Ac	Dx Tune-Up / Diagnostics	DX Tune-Up / Diagnostics	Existing	614	5%	5	$192	72%	95%	0.1	459	1,564
Within Unit	Building Ac	Dx Tune-Up / Diagnostics	DX Tune-Up / Diagnostics	New	434	5%	5	$192	72%	95%	0.1	67	228
Within Unit	Building Ac	Direct / Indirect Evaporative Cooling, Pre-Cooling	Evaporative Cooler	Existing	614	10%	15	$2,533	94%	50%	0.1	550	1,874
Within Unit	Building Ac	Direct / Indirect Evaporative Cooling, Pre-Cooling	Evaporative Cooler	New	434	10%	15	$2,533	94%	50%	0.0	80	273
Within Unit	Building Ac	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	614	5%	25	$50	80%	75%	2.4	309	1,055
Within Unit	Building Ac	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	434	5%	25	$50	80%	75%	1.7	45	154
Within Unit	Building Ac	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	614	10%	5	$19	80%	75%	3.0	707	2,411
Within Unit	Building Ac	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	434	10%	5	$19	80%	75%	2.1	93	317
Within Unit	Building Ac	Duct Insulation Upgrade	R-8 (code)	Existing	614	3%	20	$124	90%	90%	0.5	174	592
Within Unit	Building Ac	Duct Insulation Upgrade	R-8 (code)	New	434	3%	20	$124	90%	90%	0.3	26	88
Within Unit	Building Ac	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	614	2%	18	$75	80%	90%	0.4	153	521
Within Unit	Building Ac	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	434	2%	18	$75	80%	90%	0.4	41	138
Within Unit	Building Ac	Green Roof	Vegetation on Roof	Existing	614	10%	25	$16,249	98%	4%	0.0	22	74
Within Unit	Building Ac	Green Roof	Vegetation on Roof	New	434	10%	25	$16,249	98%	4%	0.0	3	11
Within Unit	Building Ac	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	614	7%	5	$54	39%	10%	0.8	50	171
Within Unit	Building Ac	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	434	15%	5	$54	39%	10%	1.1	18	60
Within Unit	Building Ac	Insulation - Duct	R-Value (State Code)	Existing	614	6%	20	$166	80%	50%	0.7	210	716
Within Unit	Building Ac	Insulation - Duct	R-Value (State Code)	New	434	6%	20	$166	80%	50%	0.5	31	104
Within Unit	Building Ac	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	614	5%	10	$15	76%	95%	3.4	853	2,907
Within Unit	Building Ac	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	434	5%	10	$15	76%	95%	2.4	112	382
Within Unit	Building Ac	O&m Tune-Up	Tune-up/Maintenance	Existing	614	5%	5	$115	57%	95%	0.2	376	1,283
Within Unit	Building Ac	O&m Tune-Up	Tune-up/Maintenance	New	434	5%	5	$115	57%	95%	0.2	55	187

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Ac	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	614	4%	18	$-166	50%	50%	-0.4	270	922
Within Unit	Building Ac	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	434	4%	18	$-166	50%	50%	-0.3	35	120
Within Unit	Building Ac	Seer 13-Building Ac	Seer 13-Building Ac	Existing	673	0%	23	$0	NA	100%	0.0	0	0
Within Unit	Building Ac	Seer 13-Building Ac	Seer 13-Building Ac	New	0.00	.	23	$0	NA	100%	0.0	0	0
Within Unit	Building Ac	Seer 14.5-Building Ac	SEER 14.5 Air Conditioner	Existing	521	10%	23	$174	NA	100%	1.1	0	0
Within Unit	Building Ac	Seer 14.5-Building Ac	SEER 14.5 Air Conditioner	New	446	10%	23	$174	NA	100%	0.9	0	0
Within Unit	Building Ac	Seer 19-Building Ac	SEER 19 Air Conditioner	Existing	521	30%	23	$1,047	NA	100%	0.5	0	0
Within Unit	Building Ac	Seer 19-Building Ac	SEER 19 Air Conditioner	New	446	30%	23	$1,047	NA	100%	0.5	0	0
Within Unit	Building Ac	Seer 23-Building Ac	SEER 23 Air Conditioner	Existing	521	41%	23	$1,548	NA	100%	0.5	2,421	8,255
Within Unit	Building Ac	Seer 23-Building Ac	SEER 23 Air Conditioner	New	446	41%	23	$1,548	NA	100%	0.4	586	1,998
Within Unit	Building Ac	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	614	11%	20	$83	90%	50%	2.6	210	715
Within Unit	Building Ac	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	614	16%	11	$30	74%	90%	6.2	1,393	4,750
Within Unit	Building Ac	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	434	16%	11	$30	74%	90%	4.4	181	619
Within Unit	Building Ac	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	614	20%	11	$250	74%	90%	0.9	1,251	4,267
Within Unit	Building Ac	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	434	20%	11	$187	74%	90%	0.9	196	668
Within Unit	Building Ac	Wall - R 19	Wall R 8.68 - R 19	Existing	614	7%	20	$31	65%	75%	4.3	207	704
Within Unit	Building Ac	Wall - R 21	Wall R 8.68 - R 21	Existing	614	7%	20	$35	80%	20%	4.2	73	250
Within Unit	Building Ac	Wall - R 22	Wall R 21 - R 22	New	434	0%	20	$6	95%	10%	0.8	0	1
Within Unit	Building Ac	Wall - R 22	Wall R 8.68 - R 22	Existing	614	8%	20	$37	95%	10%	4.1	45	154
Within Unit	Building Ac	Wall - R 32	Wall R 8.68 - R 32	Existing	614	10%	20	$72	95%	10%	2.7	51	173
Within Unit	Building Ac	Wall - R 32	Wall R 8.68 - R 32	New	434	10%	20	$41	95%	10%	3.4	15	52
Within Unit	Building Ac	Window Film	Window Film	Existing	614	20%	10	$449	90%	75%	0.5	2,293	7,818
Within Unit	Building Ac	Window Film	Window Film	New	434	20%	10	$449	90%	75%	0.3	328	1,119
Within Unit	Building Boiler	Building Boiler	Building Boiler	Existing	3,452	0%	20	$0	NA	100%	0.0	0	0
Within Unit	Building Boiler	Building Boiler	Building Boiler	New	3,452	0%	20	$0	NA	100%	0.0	0	0
Within Unit	Building Boiler	Building Boiler	Forced hot water boiler	Existing	3,001	5%	20	$900	NA	100%	0.2	1,421	4,845
Within Unit	Building Boiler	Building Boiler	Forced hot water boiler	New	3,001	5%	20	$900	NA	100%	0.2	315	1,074
Within Unit	Building Boiler	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	3,302	12%	15	$1,509	80%	80%	0.3	1,316	4,487
Within Unit	Building Boiler	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	3,302	12%	15	$1,509	80%	80%	0.3	218	744
Within Unit	Building Boiler	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	3,302	5%	25	$150	80%	75%	2.0	337	1,150
Within Unit	Building Boiler	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	3,302	5%	25	$150	80%	75%	2.0	56	191
Within Unit	Building Boiler	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	3,302	10%	5	$56	80%	75%	2.5	696	2,372
Within Unit	Building Boiler	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	3,302	10%	5	$56	80%	75%	2.5	115	394
Within Unit	Building Boiler	Duct Insulation Upgrade	R-8 (code)	Existing	3,302	3%	20	$372	90%	90%	0.4	216	736
Within Unit	Building Boiler	Duct Insulation Upgrade	R-8 (code)	New	3,302	3%	20	$372	90%	90%	0.4	35	120
Within Unit	Building Boiler	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	3,302	2%	18	$225	80%	90%	0.4	244	832
Within Unit	Building Boiler	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	3,302	2%	18	$225	80%	90%	0.4	45	154
Within Unit	Building Boiler	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	Existing	3,302	20%	14	$2,017	94%	5%	0.4	163	554
Within Unit	Building Boiler	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	New	3,302	20%	14	$2,017	94%	5%	0.4	27	92
Within Unit	Building Boiler	Insulation - Duct	R-Value (State Code)	Existing	3,302	6%	20	$497	80%	50%	0.6	216	735
Within Unit	Building Boiler	Insulation - Duct	R-Value (State Code)	New	3,302	6%	20	$497	80%	50%	0.6	36	122
Within Unit	Building Boiler	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	3,302	5%	10	$15	76%	95%	8.7	839	2,860
Within Unit	Building Boiler	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	3,302	5%	10	$15	76%	95%	8.7	139	475
Within Unit	Building Boiler	O&m Tune-Up	Tune-up/Maintenance	Existing	3,302	5%	5	$115	57%	95%	0.6	497	1,696
Within Unit	Building Boiler	O&m Tune-Up	Tune-up/Maintenance	New	3,302	5%	5	$115	57%	95%	0.6	83	282
Within Unit	Building Boiler	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	3,302	5%	18	$-166	50%	50%	-1.4	304	1,037
Within Unit	Building Boiler	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	3,302	5%	18	$-166	50%	50%	-1.4	50	172
Within Unit	Building Boiler	Re-Commissioning	Re-Commissioning	Existing	3,302	5%	10	$99	85%	90%	1.4	847	2,889
Within Unit	Building Boiler	Re-Commissioning	Re-Commissioning	New	3,302	5%	10	$90	85%	90%	1.5	141	480

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Boiler	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	3,302	20%	11	$750	74%	90%	0.8	2,838	9,677
Within Unit	Building Boiler	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	3,302	20%	11	$687	74%	90%	0.9	471	1,606
Within Unit	Building Furnace	Basement Insulation - R-19	Basement Insulation - R-19	Existing	3,823	11%	20	$224	90%	90%	2.8	572	1,951
Within Unit	Building Furnace	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	3,823	6%	20	$176	65%	75%	1.8	65	222
Within Unit	Building Furnace	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	3,823	6%	20	$217	80%	20%	1.6	24	82
Within Unit	Building Furnace	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	3,823	7%	20	$259	95%	10%	1.5	15	52
Within Unit	Building Furnace	Ceiling - R 60	Ceiling R 49 - R 60	New	3,068	1%	20	$83	95%	10%	0.3	1	2
Within Unit	Building Furnace	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	3,823	12%	15	$1,509	80%	80%	0.4	459	1,566
Within Unit	Building Furnace	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	3,068	12%	15	$1,509	80%	80%	0.3	68	232
Within Unit	Building Furnace	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	3,823	5%	25	$150	80%	75%	2.3	111	378
Within Unit	Building Furnace	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	3,068	5%	25	$150	80%	75%	1.8	16	55
Within Unit	Building Furnace	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	3,823	10%	5	$56	80%	75%	2.9	251	855
Within Unit	Building Furnace	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	3,068	10%	5	$56	80%	75%	2.3	33	114
Within Unit	Building Furnace	Duct Insulation Upgrade	R-8 (code)	Existing	3,823	3%	20	$372	90%	90%	0.5	75	256
Within Unit	Building Furnace	Duct Insulation Upgrade	R-8 (code)	New	3,068	3%	20	$372	90%	90%	0.4	11	37
Within Unit	Building Furnace	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	3,823	2%	18	$225	80%	90%	0.4	73	248
Within Unit	Building Furnace	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	3,068	2%	18	$225	80%	90%	0.4	15	52
Within Unit	Building Furnace	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	Existing	3,823	20%	14	$2,017	94%	5%	0.4	57	196
Within Unit	Building Furnace	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	New	3,068	20%	14	$2,017	94%	5%	0.3	8	29
Within Unit	Building Furnace	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	3,823	26%	5	$162	39%	10%	2.6	81	277
Within Unit	Building Furnace	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	3,068	31%	5	$162	39%	10%	2.5	14	47
Within Unit	Building Furnace	Insulation - Duct	R-Value (State Code)	Existing	3,823	6%	20	$497	80%	50%	0.7	75	256
Within Unit	Building Furnace	Insulation - Duct	R-Value (State Code)	New	3,068	6%	20	$497	80%	50%	0.6	11	38
Within Unit	Building Furnace	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	3,823	5%	10	$15	76%	95%	10.1	324	1,105
Within Unit	Building Furnace	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	3,068	5%	10	$15	76%	95%	8.1	43	147
Within Unit	Building Furnace	O&m Tune-Up	Tune-up/Maintenance	Existing	3,823	5%	5	$115	57%	95%	0.7	173	591
Within Unit	Building Furnace	O&m Tune-Up	Tune-up/Maintenance	New	3,068	5%	5	$115	57%	95%	0.6	26	88
Within Unit	Building Furnace	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	3,823	5%	18	$-166	50%	50%	-1.6	117	401
Within Unit	Building Furnace	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	3,068	5%	18	$-166	50%	50%	-1.3	16	53
Within Unit	Building Furnace	Re-Commissioning	Re-Commissioning	Existing	3,823	5%	10	$115	85%	90%	1.4	274	935
Within Unit	Building Furnace	Re-Commissioning	Re-Commissioning	New	3,068	5%	10	$83	85%	90%	1.5	41	139
Within Unit	Building Furnace	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	3,823	11%	20	$250	90%	50%	2.5	74	252
Within Unit	Building Furnace	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	3,823	14%	11	$89	74%	90%	5.3	418	1,424
Within Unit	Building Furnace	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	3,068	14%	11	$89	74%	90%	4.3	55	188
Within Unit	Building Furnace	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	3,823	20%	11	$750	74%	90%	0.9	459	1,565
Within Unit	Building Furnace	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	3,068	20%	11	$687	74%	90%	0.8	68	233
Within Unit	Building Furnace	Wall - R 19	Wall R 8.68 - R 19	Existing	3,823	9%	20	$94	65%	75%	5.7	97	330
Within Unit	Building Furnace	Wall - R 21	Wall R 8.68 - R 21	Existing	3,823	10%	20	$105	80%	20%	5.5	34	117
Within Unit	Building Furnace	Wall - R 22	Wall R 21 - R 22	New	3,068	0%	20	$18	95%	10%	1.3	0	1
Within Unit	Building Furnace	Wall - R 22	Wall R 8.68 - R 22	Existing	3,823	11%	20	$111	95%	10%	5.4	21	72
Within Unit	Building Furnace	Wall - R 32	Wall R 8.68 - R 32	Existing	3,823	13%	20	$216	95%	10%	3.5	26	90
Within Unit	Building Furnace	Wall - R 32	Wall R 8.68 - R 32	New	3,068	13%	20	$122	95%	10%	5.0	7	26
Within Unit	Building Furnace	Windows - U 0.2	Windows U 0.3 - U 0.2	New	3,068	5%	10	$1,805	66%	75%	0.1	21	73
Within Unit	Building Furnace	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	3,823	6%	10	$1,805	66%	75%	0.1	88	298
Within Unit	Building Furnace	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	3,823	2%	10	$1,643	66%	75%	0.0	28	94
Within Unit	Building Water Heat	Building Water Heat	Building Water Heat	Existing	3,266	0%	15	$0	NA	100%	0.0	0	0
Within Unit	Building Water Heat	Building Water Heat	Building Water Heat	New	0.00	.	15	$0	NA	100%	0.0	0	0

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Water Heat	Building Water Heat	Building Water Heater	Existing	3,124	5%	15	$50	NA	100%	4.4	742	2,528
Within Unit	Building Water Heat	Building Water Heat	Building Water Heater	New	3,124	5%	15	$50	NA	100%	4.4	112	382
Within Unit	Building Water Heat	Building Water Heat	Building water heater	Existing	3,124	3%	15	$25	NA	100%	5.2	0	0
Within Unit	Building Water Heat	Building Water Heat	Building water heater	New	3,124	3%	15	$25	NA	100%	5.2	0	0
Within Unit	Building Water Heat	Clothes Washer	Energy Star - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	Existing	3,215	3%	11	$798	70%	41%	0.1	126	429
Within Unit	Building Water Heat	Clothes Washer	Energy Star - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	New	3,065	3%	11	$475	70%	41%	0.2	20	69
Within Unit	Building Water Heat	Clothes Washer	Energy Star - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	Existing	3,215	4%	11	$927	70%	41%	0.1	178	606
Within Unit	Building Water Heat	Clothes Washer	Energy Star - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	New	3,065	4%	11	$604	70%	41%	0.2	29	98
Within Unit	Building Water Heat	Clothes Washer	Energy Star - Tier 3 (MEF 2.46 or higher) Top 10% of Energy Star Model - Electric DHW & Dryer	Existing	3,215	5%	11	$1,055	70%	41%	0.1	230	786
Within Unit	Building Water Heat	Clothes Washer	Energy Star - Tier 3 (MEF 2.46 or higher) Top 10% of Energy Star Model - Electric DHW & Dryer	New	3,065	5%	11	$732	70%	41%	0.2	37	127
Within Unit	Building Water Heat	Demand Controlled Circulating Systems	Demand Controlled Circulating Systems (VFD control by demand)	Existing	3,215	5%	10	$119	80%	55%	1.2	1,490	5,081
Within Unit	Building Water Heat	Demand Controlled Circulating Systems	Demand Controlled Circulating Systems (VFD control by demand)	New	3,065	5%	10	$119	80%	55%	1.2	236	805
Within Unit	Building Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	Existing	3,215	1%	10	$12	90%	65%	2.3	384	1,310
Within Unit	Building Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	New	3,065	1%	10	$12	90%	65%	2.2	62	211
Within Unit	Building Water Heat	Hot Water Pipe Insulation	R-4 Wrap	Existing	3,215	5%	13	$40	86%	75%	4.6	2,306	7,862
Within Unit	Building Water Heat	Hot Water Pipe Insulation	R-4 Wrap	New	3,065	5%	13	$40	86%	75%	4.4	372	1,267
Within Unit	Building Water Heat	Low-Flow Faucet Aerators	1.5 GPM	Existing	3,215	9%	5	$5	45%	90%	30.3	2,803	9,556
Within Unit	Building Water Heat	Low-Flow Faucet Aerators	2.2 GPM (Federal Code)	New	3,065	12%	5	$5	45%	90%	37.0	585	1,993
Within Unit	Building Water Heat	Low-Flow Showerheads	2.0 GPM	Existing	3,215	1%	10	$15	57%	80%	2.3	367	1,252
Within Unit	Building Water Heat	Low-Flow Showerheads	2.5 GPM (Federal Code)	New	3,065	0%	10	$15	57%	80%	0.8	20	67
Within Unit	Building Water Heat	Solar Hot Water (Shw)	Solar thermal collector	Existing	3,215	53%	20	$9,506	82%	50%	0.3	14,197	48,405
Within Unit	Building Water Heat	Solar Hot Water (Shw)	Solar thermal collector	New	3,065	53%	20	$9,506	82%	50%	0.3	2,296	7,830
Within Unit	Building Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	Existing	3,215	2%	7	$25	75%	60%	1.9	700	2,387
Within Unit	Building Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	New	3,065	2%	7	$25	75%	60%	1.8	113	387
Within Unit	Building Water Heat	Water Heater Thermostat Setback	120 degrees	Existing	3,215	6%	11	$179	60%	60%	1.1	1,497	5,103
Within Unit	Building Water Heat	Water Heater Thermostat Setback	120 degrees	New	3,065	6%	13	$179	60%	60%	1.2	245	835
Within Unit	Computer	Computer	Computer	Existing	223	0%	4	$0	NA	100%	0.0	0	0
Within Unit	Computer	Computer	Computer	New	223	0%	4	$0	NA	100%	0.0	0	0
Within Unit	Computer	Computer	Energy Star Computer	Existing	223	34%	4	$37	NA	100%	0.8	10,787	36,780
Within Unit	Computer	Computer	Energy Star Computer	New	223	34%	4	$37	NA	100%	0.8	324	1,106
Within Unit	Cooking Oven	Cooking Oven	Convection cooking oven	Existing	125	0%	19	$74	NA	100%	0.0	4,115	14,029
Within Unit	Cooking Oven	Cooking Oven	Convection cooking oven	New	125	0%	19	$74	NA	100%	0.0	863	2,942
Within Unit	Cooking Oven	Cooking Oven	Cooking Oven	Existing	156	0%	19	$0	NA	100%	0.0	0	0
Within Unit	Cooking Oven	Cooking Oven	Cooking Oven	New	156	0%	19	$0	NA	100%	0.0	0	0
Within Unit	Dehumidifier	Dehumidifier	Dehumidifier	Existing	917	0%	12	$0	NA	100%	0.0	0	0

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Dehumidifier	Dehumidifier	Dehumidifier	New	917	0%	12	$0	NA	100%	0.0	0	0
Within Unit	Dehumidifier	Dehumidifier	Energy Star Humidifier	Existing	846	8%	12	$11	NA	100%	6.6	3,377	11,513
Within Unit	Dehumidifier	Dehumidifier	Energy Star Humidifier	New	846	8%	12	$11	NA	100%	6.6	377	1,284
Within Unit	Dryer	Dryer	Dryer	Existing	670	0%	18	$0	NA	100%	0.0	3,040	10,365
Within Unit	Dryer	Dryer	Dryer	New	670	0%	18	$0	NA	100%	0.0	598	2,040
Within Unit	Dvd	Dvd	Dvd	Existing	31	0%	7	$0	NA	100%	0.0	0	0
Within Unit	Dvd	Dvd	Dvd	New	31	0%	7	$0	NA	100%	0.0	0	0
Within Unit	Dvd	Dvd	Energy Star DVD Player	Existing	31	59%	7	$8	NA	100%	1.6	4,100	13,980
Within Unit	Dvd	Dvd	Energy Star DVD Player	New	31	59%	7	$8	NA	100%	1.6	223	760
Within Unit	Freezer	Freezer	Energy Star Freezer	Existing	445	12%	11	$33	NA	100%	1.7	5	17
Within Unit	Freezer	Freezer	Energy Star Freezer	New	445	12%	11	$33	NA	100%	1.7	0	0
Within Unit	Freezer	Freezer	Freezer	Existing	518	0%	11	$0	NA	100%	0.0	0	0
Within Unit	Freezer	Freezer	Freezer	New	0.00	.	11	$0	NA	100%	0.0	0	0
Within Unit	Freezer	Stand-Alone Freezer - Removal	Proper Disposal of Freezer	Existing	485	100%	8	$165	50%	100%	2.3	832	2,836
Within Unit	Freezer	Stand-Alone Freezer - Removal	Proper Disposal of Freezer	New	427	100%	8	$165	50%	100%	2.0	125	427
Within Unit	Heat Pump	Basement Insulation - R-19	Basement Insulation - R-19	Existing	3,611	11%	20	$451	90%	90%	3.0	7,556	25,763
Within Unit	Heat Pump	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	3,611	2%	20	$354	65%	75%	0.7	270	919
Within Unit	Heat Pump	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	3,611	2%	20	$438	80%	20%	0.7	101	343
Within Unit	Heat Pump	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	3,611	3%	20	$521	95%	10%	0.6	65	221
Within Unit	Heat Pump	Ceiling - R 60	Ceiling R 49 - R 60	New	2,865	0%	20	$167	95%	10%	0.2	3	10
Within Unit	Heat Pump	Ceiling Fan	Ceiling Fan (no lighting kit)	Existing	3,611	2%	10	$276	70%	50%	0.5	532	1,815
Within Unit	Heat Pump	Ceiling Fan	Ceiling Fan (no lighting kit)	New	2,865	1%	10	$276	70%	50%	0.3	56	192
Within Unit	Heat Pump	Cool Roofs	Lighter Colored Shingles (White)	Existing	3,611	2%	15	$1,965	98%	45%	0.1	353	1,204
Within Unit	Heat Pump	Cool Roofs	Lighter Colored Shingles (White)	New	2,865	2%	15	$1,965	98%	45%	0.1	53	182
Within Unit	Heat Pump	Direct / Indirect Evaporative Cooling, Pre-Cooling	Evaporative Cooler	Existing	3,611	2%	15	$1,162	94%	50%	0.1	616	2,100
Within Unit	Heat Pump	Direct / Indirect Evaporative Cooling, Pre-Cooling	Evaporative Cooler	New	2,865	1%	10	$1,162	94%	50%	0.1	77	261
Within Unit	Heat Pump	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	3,611	5%	25	$200	80%	75%	3.8	1,618	5,516
Within Unit	Heat Pump	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	2,865	5%	25	$200	80%	75%	3.0	233	796
Within Unit	Heat Pump	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	3,611	5%	5	$75	80%	75%	2.4	1,477	5,035
Within Unit	Heat Pump	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	2,865	5%	5	$75	80%	75%	1.9	207	706
Within Unit	Heat Pump	Duct Insulation Upgrade	R-8 (code)	Existing	3,611	3%	20	$496	90%	90%	0.8	1,018	3,472
Within Unit	Heat Pump	Duct Insulation Upgrade	R-8 (code)	New	2,865	3%	20	$496	90%	90%	0.6	150	510
Within Unit	Heat Pump	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	3,611	2%	18	$300	80%	90%	0.7	1,121	3,823
Within Unit	Heat Pump	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	2,865	2%	18	$300	80%	90%	0.7	208	709
Within Unit	Heat Pump	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	Existing	3,611	20%	14	$2,438	94%	5%	0.7	795	2,712
Within Unit	Heat Pump	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	New	2,865	20%	14	$2,438	94%	5%	.	0	0
Within Unit	Heat Pump	Green Roof	Vegetation on Roof	Existing	3,611	2%	25	$20,019	98%	4%	0.0	23	79
Within Unit	Heat Pump	Green Roof	Vegetation on Roof	New	2,865	2%	25	$20,019	98%	4%	0.0	4	12
Within Unit	Heat Pump	Hspf 10.1-Seer 19-Heat Pump	SEER 19 Heat Pump	Existing	3,271	19%	18	$1,366	NA	100%	1.4	0	0
Within Unit	Heat Pump	Hspf 10.1-Seer 19-Heat Pump	SEER 19 Heat Pump	New	2,910	20%	18	$1,366	NA	100%	1.3	0	0
Within Unit	Heat Pump	Hspf 10.6-Seer 23-Heat Pump	SEER 23 Heat Pump	Existing	3,271	26%	18	$2,277	NA	100%	1.2	12,447	42,439
Within Unit	Heat Pump	Hspf 10.6-Seer 23-Heat Pump	SEER 23 Heat Pump	New	2,910	26%	18	$2,277	NA	100%	1.0	2,313	7,887
Within Unit	Heat Pump	Hspf 7.7-Seer 13-Heat Pump	Hspf 7.7-Seer 13-Heat Pump	Existing	3,832	0%	18	$0	NA	100%	0.0	0	0
Within Unit	Heat Pump	Hspf 7.7-Seer 13-Heat Pump	Hspf 7.7-Seer 13-Heat Pump	New	0.00	.	18	$0	NA	100%	0.0	0	0
Within Unit	Heat Pump	Hspf 8.2-Seer 14.5-Heat Pump	SEER 14.5 Air Source Heat Pump	Existing	3,271	6%	18	$228	NA	100%	2.7	0	0
Within Unit	Heat Pump	Hspf 8.2-Seer 14.5-Heat Pump	SEER 14.5 Air Source Heat Pump	New	2,910	6%	18	$228	NA	100%	2.4	0	0
Within Unit	Heat Pump	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	3,611	14%	5	$261	39%	10%	2.0	534	1,819
Within Unit	Heat Pump	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	2,865	19%	5	$261	39%	10%	2.1	113	387
Within Unit	Heat Pump	Insulation - Duct	R-Value (State Code)	Existing	3,611	6%	20	$662	80%	50%	1.1	1,028	3,504
Within Unit	Heat Pump	Insulation - Duct	R-Value (State Code)	New	2,865	6%	20	$662	80%	50%	0.9	152	519
Within Unit	Heat Pump	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	3,611	5%	10	$15	76%	95%	21.6	4,177	14,242
Within Unit	Heat Pump	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	2,865	5%	10	$15	76%	95%	17.2	592	2,020

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Heat Pump	O&m Tune-Up	Tune-up/Maintenance	Existing	3,611	5%	5	$115	57%	95%	1.6	2,597	8,856
Within Unit	Heat Pump	O&m Tune-Up	Tune-up/Maintenance	New	2,865	5%	10	$115	57%	95%	2.3	413	1,408
Within Unit	Heat Pump	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	3,611	9%	18	$-266	50%	50%	-3.8	2,754	9,391
Within Unit	Heat Pump	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	2,865	9%	18	$-266	50%	50%	-3.0	391	1,332
Within Unit	Heat Pump	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	3,611	11%	20	$361	90%	50%	3.8	1,078	3,677
Within Unit	Heat Pump	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	3,611	14%	11	$119	74%	90%	8.4	5,249	17,896
Within Unit	Heat Pump	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	2,865	14%	11	$119	74%	90%	6.7	750	2,558
Within Unit	Heat Pump	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	3,611	20%	11	$1,000	74%	90%	1.5	6,250	21,310
Within Unit	Heat Pump	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	2,865	20%	11	$937	74%	90%	1.2	905	3,085
Within Unit	Heat Pump	Wall - R 19	Wall R 8.68 - R 19	Existing	3,611	6%	20	$135	65%	75%	5.6	823	2,806
Within Unit	Heat Pump	Wall - R 21	Wall R 8.68 - R 21	Existing	3,611	7%	20	$152	80%	20%	5.5	295	1,006
Within Unit	Heat Pump	Wall - R 22	Wall R 21 - R 22	New	2,865	0%	20	$25	95%	10%	1.3	2	7
Within Unit	Heat Pump	Wall - R 22	Wall R 8.68 - R 22	Existing	3,611	7%	20	$161	95%	10%	5.4	182	620
Within Unit	Heat Pump	Wall - R 32	Wall R 8.68 - R 32	Existing	3,611	9%	20	$312	95%	10%	3.6	225	768
Within Unit	Heat Pump	Wall - R 32	Wall R 8.68 - R 32	New	2,865	9%	20	$177	95%	10%	5.0	66	226
Within Unit	Heat Pump	Window Film	Window Film	Existing	3,611	10%	10	$543	90%	75%	1.2	1,955	6,667
Within Unit	Heat Pump	Window Film	Window Film	New	2,865	20%	10	$543	90%	75%	2.0	1,009	3,440
Within Unit	Heat Pump	Windows - U 0.2	Windows U 0.3 - U 0.2	New	2,865	2%	10	$2,181	66%	75%	0.1	74	251
Within Unit	Heat Pump	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	3,611	3%	10	$2,181	66%	75%	0.1	356	1,213
Within Unit	Heat Pump	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	3,611	1%	10	$1,985	66%	75%	0.0	112	382
Within Unit	Home Audio System	Home Audio System	Energy Star Qualified Home Audio System	Existing	83	61%	7	$15	NA	100%	2.2	12,918	44,044
Within Unit	Home Audio System	Home Audio System	Energy Star Qualified Home Audio System	New	83	61%	7	$15	NA	100%	2.2	703	2,395
Within Unit	Home Audio System	Home Audio System	Home Audio System	Existing	83	0%	7	$0	NA	100%	0.0	0	0
Within Unit	Home Audio System	Home Audio System	Home Audio System	New	83	0%	7	$0	NA	100%	0.0	0	0
Within Unit	Lighting Interior Specialty	Lighting Interior Specialty	Lighting Interior Specialty	Existing	226	0%	3	$0	NA	100%	0.0	0	0
Within Unit	Lighting Interior Specialty	Lighting Interior Specialty	Lighting Interior Specialty	New	226	0%	3	$0	NA	100%	0.0	0	0
Within Unit	Lighting Interior Specialty	Lighting Interior Specialty	Specialty CFL	Existing	103	59%	3	$8	NA	100%	2.1	74,349	253,495
Within Unit	Lighting Interior Specialty	Lighting Interior Specialty	Specialty CFL	New	103	59%	3	$8	NA	100%	2.1	1,716	5,850
Within Unit	Lighting Interior Standard	Lighting Interior Standard	EISA Backstop Provision Bulb	Existing	425	76%	3	$32	NA	100%	2.8	0	0
Within Unit	Lighting Interior Standard	Lighting Interior Standard	EISA Backstop Provision Bulb	New	425	76%	3	$32	NA	100%	2.8	0	0
Within Unit	Lighting Interior Standard	Lighting Interior Standard	LED Lighting	Existing	425	121%	3	$288	NA	100%	0.5	93,555	318,976
Within Unit	Lighting Interior Standard	Lighting Interior Standard	LED Lighting	New	425	121%	3	$288	NA	100%	0.5	2,149	7,326
Within Unit	Lighting Interior Standard	Lighting Interior Standard	Lighting Interior Standard	Existing	607	32%	3	$10	NA	100%	5.2	0	0
Within Unit	Lighting Interior Standard	Lighting Interior Standard	Lighting Interior Standard	New	607	32%	3	$10	NA	100%	5.2	0	0
Within Unit	Lighting Interior Standard	Lighting Interior Standard	Standard CFL	Existing	425	81%	3	$36	NA	100%	2.6	0	0
Within Unit	Lighting Interior Standard	Lighting Interior Standard	Standard CFL	New	425	81%	3	$36	NA	100%	2.6	0	0
Within Unit	Microwave	Microwave	Microwave	Existing	36	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Microwave	Microwave	Microwave	New	36	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Microwave	Microwave	Microwave Oven	Existing	36	0%	9	$0	NA	100%	0.0	-0	-0
Within Unit	Microwave	Microwave	Microwave Oven	New	36	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Monitor	Monitor	Energy Star Computer Monitor	Existing	62	23%	9	$11	NA	100%	1.1	1,805	6,153

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Monitor	Monitor	Energy Star Computer Monitor	New	62	23%	9	$11	NA	100%	1.1	134	458
Within Unit	Monitor	Monitor	Monitor	Existing	62	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Monitor	Monitor	Monitor	New	62	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Plug Load Other	Energy Star Battery Chargers	Energy Star Battery Chargers	Existing	541	0%	7	$25	90%	20%	0.0	76	258
Within Unit	Plug Load Other	Energy Star Battery Chargers	Energy Star Battery Chargers	New	541	0%	7	$25	90%	20%	0.0	13	43
Within Unit	Plug Load Other	Office Copier	Office Copier	Existing	541	1%	6	$100	61%	100%	0.0	1,553	5,296
Within Unit	Plug Load Other	Office Copier	Office Copier	New	541	1%	6	$100	61%	100%	0.0	258	879
Within Unit	Plug Load Other	Office Printer	Office Printer	Existing	541	1%	5	$0	90%	100%	184.0	1,626	5,545
Within Unit	Plug Load Other	Office Printer	Office Printer	New	541	1%	5	$0	90%	100%	184.0	270	920
Within Unit	Plug Load Other	Smart Strip	Smart Strip	Existing	541	10%	4	$16	90%	60%	1.3	13,122	44,741
Within Unit	Plug Load Other	Smart Strip	Smart Strip	New	541	10%	4	$16	90%	60%	1.3	2,178	7,427
Within Unit	Refrigerator	Refrigerator	Energy Star Refrigerator	Existing	628	27%	18	$30	NA	100%	8.9	1,615	5,505
Within Unit	Refrigerator	Refrigerator	Energy Star Refrigerator	New	628	27%	18	$30	NA	100%	8.9	388	1,323
Within Unit	Refrigerator	Refrigerator	Refrigerator	Existing	892	0%	18	$0	NA	100%	0.0	0	0
Within Unit	Refrigerator	Refrigerator	Refrigerator	New	0.00	.	18	$0	NA	100%	0.0	0	0
Within Unit	Refrigerator	Refrigerator/Freezer - Removal Of Secondary	Proper Disposal of Refrigerator/Freezer	Existing	795	100%	8	$165	50%	1%	3.7	1,529	5,213
Within Unit	Refrigerator	Refrigerator/Freezer - Removal Of Secondary	Proper Disposal of Refrigerator/Freezer	New	605	100%	8	$165	50%	1%	2.8	223	762
Within Unit	Set Top Box	Set Top Box	Enegy Star Qualified Set Top Box	Existing	128	13%	4	$2	NA	100%	3.4	14,114	48,123
Within Unit	Set Top Box	Set Top Box	Enegy Star Qualified Set Top Box	New	128	13%	4	$2	NA	100%	3.4	424	1,447
Within Unit	Set Top Box	Set Top Box	Set Top Box	Existing	167	0%	4	$0	NA	100%	0.0	0	0
Within Unit	Set Top Box	Set Top Box	Set Top Box	New	167	0%	4	$0	NA	100%	0.0	0	0
Within Unit	Tv	Tv	Energy Star TV	Existing	152	39%	6	$15	NA	100%	2.3	23,228	79,197
Within Unit	Tv	Tv	Energy Star TV	New	152	39%	6	$15	NA	100%	2.3	1,060	3,613
Within Unit	Tv	Tv	Tv	Existing	152	0%	6	$0	NA	100%	0.0	0	0
Within Unit	Tv	Tv	Tv	New	152	0%	6	$0	NA	100%	0.0	0	0
Within Unit	Tv Bigscreen	Tv Bigscreen	Energy Star Big Screen TV	Existing	353	50%	6	$86	NA	100%	1.2	13,399	45,684
Within Unit	Tv Bigscreen	Tv Bigscreen	Energy Star Big Screen TV	New	353	50%	6	$86	NA	100%	1.2	611	2,084
Within Unit	Tv Bigscreen	Tv Bigscreen	Tv Bigscreen	Existing	353	0%	6	$0	NA	100%	0.0	0	0
Within Unit	Tv Bigscreen	Tv Bigscreen	Tv Bigscreen	New	353	0%	6	$0	NA	100%	0.0	0	0
Within Unit	Unit Central Ac	Basement Insulation - R-19	Basement Insulation - R-19	Existing	582	11%	20	$113	90%	90%	1.9	2,346	7,999
Within Unit	Unit Central Ac	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	582	5%	20	$89	65%	75%	1.1	253	861
Within Unit	Unit Central Ac	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	582	6%	20	$109	80%	20%	1.0	94	321
Within Unit	Unit Central Ac	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	582	6%	20	$130	95%	10%	0.9	57	193
Within Unit	Unit Central Ac	Ceiling - R 60	Ceiling R 49 - R 60	New	408	1%	20	$42	95%	10%	0.2	2	7
Within Unit	Unit Central Ac	Ceiling Fan	Ceiling Fan (no lighting kit)	Existing	582	12%	10	$276	70%	50%	0.4	1,124	3,831
Within Unit	Unit Central Ac	Ceiling Fan	Ceiling Fan (no lighting kit)	New	408	10%	10	$276	70%	50%	0.3	139	473
Within Unit	Unit Central Ac	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	582	12%	15	$1,824	80%	80%	0.1	1,519	5,178
Within Unit	Unit Central Ac	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	408	12%	15	$1,824	80%	80%	0.1	238	812
Within Unit	Unit Central Ac	Cool Roofs	Lighter Colored Shingles (White)	Existing	582	10%	15	$1,965	98%	45%	0.1	403	1,373
Within Unit	Unit Central Ac	Cool Roofs	Lighter Colored Shingles (White)	New	408	10%	15	$1,965	98%	45%	0.1	60	205
Within Unit	Unit Central Ac	Dx Package-Air Side Economizer	Air-Side Economizer	Existing	582	15%	10	$257	30%	10%	0.6	123	419
Within Unit	Unit Central Ac	Dx Package-Air Side Economizer	Air-Side Economizer	New	408	15%	10	$257	30%	10%	0.4	18	63
Within Unit	Unit Central Ac	Dx Tune-Up / Diagnostics	DX Tune-Up / Diagnostics	Existing	582	5%	5	$192	72%	95%	0.1	735	2,505
Within Unit	Unit Central Ac	Dx Tune-Up / Diagnostics	DX Tune-Up / Diagnostics	New	408	5%	5	$192	72%	95%	0.1	110	375
Within Unit	Unit Central Ac	Direct / Indirect Evaporative Cooling, Pre-Cooling	Evaporative Cooler	Existing	582	10%	15	$1,162	94%	50%	0.1	975	3,325
Within Unit	Unit Central Ac	Direct / Indirect Evaporative Cooling, Pre-Cooling	Evaporative Cooler	New	408	10%	10	$1,162	94%	50%	0.1	135	459
Within Unit	Unit Central Ac	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	582	5%	25	$50	80%	75%	2.4	501	1,709
Within Unit	Unit Central Ac	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	408	5%	25	$50	80%	75%	1.6	69	235
Within Unit	Unit Central Ac	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	582	5%	5	$19	80%	75%	1.5	459	1,563
Within Unit	Unit Central Ac	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	408	5%	5	$19	80%	75%	1.0	68	231

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Unit Central Ac	Duct Insulation Upgrade	R-8 (code)	Existing	582	3%	20	$124	90%	90%	0.5	317	1,080
Within Unit	Unit Central Ac	Duct Insulation Upgrade	R-8 (code)	New	408	3%	20	$124	90%	90%	0.3	47	161
Within Unit	Unit Central Ac	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	582	1%	18	$75	80%	90%	0.3	237	808
Within Unit	Unit Central Ac	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	408	2%	18	$75	80%	90%	0.4	64	217
Within Unit	Unit Central Ac	Green Roof	Vegetation on Roof	Existing	582	10%	25	$20,019	98%	4%	0.0	35	119
Within Unit	Unit Central Ac	Green Roof	Vegetation on Roof	New	408	10%	25	$20,019	98%	4%	0.0	5	18
Within Unit	Unit Central Ac	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	582	7%	5	$65	39%	10%	0.6	78	266
Within Unit	Unit Central Ac	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	408	14%	5	$65	39%	10%	0.8	24	83
Within Unit	Unit Central Ac	Insulation - Duct	R-Value (State Code)	Existing	582	6%	20	$166	80%	50%	0.7	333	1,134
Within Unit	Unit Central Ac	Insulation - Duct	R-Value (State Code)	New	408	6%	20	$166	80%	50%	0.5	50	169
Within Unit	Unit Central Ac	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	582	5%	10	$15	76%	95%	3.3	1,225	4,175
Within Unit	Unit Central Ac	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	408	5%	10	$15	76%	95%	2.3	166	566
Within Unit	Unit Central Ac	O&m Tune-Up	Tune-up/Maintenance	Existing	582	5%	5	$115	57%	95%	0.2	595	2,028
Within Unit	Unit Central Ac	O&m Tune-Up	Tune-up/Maintenance	New	408	5%	10	$115	57%	95%	0.3	108	368
Within Unit	Unit Central Ac	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	582	4%	18	$-266	50%	50%	-0.3	381	1,299
Within Unit	Unit Central Ac	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	408	4%	18	$-266	50%	50%	-0.2	51	174
Within Unit	Unit Central Ac	Seer 13-Unit Central Ac	Seer 13-Unit Central Ac	Existing	644	0%	15	$0	NA	100%	0.0	0	0
Within Unit	Unit Central Ac	Seer 13-Unit Central Ac	Seer 13-Unit Central Ac	New	0.00	.	15	$0	NA	100%	0.0	0	0
Within Unit	Unit Central Ac	Seer 14.5-Unit Central Ac	SEER 14.5 Central Air Conditioner	Existing	490	11%	15	$198	NA	100%	0.7	0	0
Within Unit	Unit Central Ac	Seer 14.5-Unit Central Ac	SEER 14.5 Central Air Conditioner	New	420	11%	15	$198	NA	100%	0.6	0	0
Within Unit	Unit Central Ac	Seer 19-Unit Central Ac	SEER 19 Central Air Conditioner	Existing	490	34%	15	$1,188	NA	100%	0.3	0	0
Within Unit	Unit Central Ac	Seer 19-Unit Central Ac	SEER 19 Central Air Conditioner	New	420	34%	15	$1,188	NA	100%	0.3	0	0
Within Unit	Unit Central Ac	Seer 23-Unit Central Ac	SEER 23 Unit Air Conditioner	Existing	490	46%	15	$1,756	NA	100%	0.3	5,559	18,953
Within Unit	Unit Central Ac	Seer 23-Unit Central Ac	SEER 23 Unit Air Conditioner	New	420	46%	15	$1,756	NA	100%	0.3	823	2,804
Within Unit	Unit Central Ac	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	582	11%	20	$90	90%	50%	2.3	334	1,139
Within Unit	Unit Central Ac	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	582	16%	11	$30	74%	90%	6.1	2,009	6,850
Within Unit	Unit Central Ac	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	408	16%	11	$30	74%	90%	4.2	269	919
Within Unit	Unit Central Ac	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	582	20%	11	$250	74%	90%	0.9	1,982	6,758
Within Unit	Unit Central Ac	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	408	20%	11	$187	74%	90%	0.8	295	1,006
Within Unit	Unit Central Ac	Wall - R 19	Wall R 8.68 - R 19	Existing	582	9%	20	$34	65%	75%	5.1	392	1,337
Within Unit	Unit Central Ac	Wall - R 21	Wall R 8.68 - R 21	Existing	582	10%	20	$38	80%	20%	5.0	140	476
Within Unit	Unit Central Ac	Wall - R 22	Wall R 21 - R 22	New	408	1%	20	$6	95%	10%	1.1	1	4
Within Unit	Unit Central Ac	Wall - R 22	Wall R 8.68 - R 22	Existing	582	10%	20	$40	95%	10%	4.9	86	294
Within Unit	Unit Central Ac	Wall - R 32	Wall R 8.68 - R 32	Existing	582	13%	20	$78	95%	10%	3.3	107	364
Within Unit	Unit Central Ac	Wall - R 32	Wall R 8.68 - R 32	New	408	13%	20	$44	95%	10%	4.0	30	103
Within Unit	Unit Central Ac	Window Film	Window Film	Existing	582	20%	10	$543	90%	75%	0.4	3,433	11,704
Within Unit	Unit Central Ac	Window Film	Window Film	New	408	20%	10	$543	90%	75%	0.3	495	1,686
Within Unit	Unit Central Heat	Basement Insulation - R-19	Basement Insulation - R-19	Existing	3,984	11%	20	$338	90%	90%	1.9	1,775	6,051
Within Unit	Unit Central Heat	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	3,984	3%	20	$266	65%	75%	0.7	97	332
Within Unit	Unit Central Heat	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	3,984	3%	20	$328	80%	20%	0.6	36	123
Within Unit	Unit Central Heat	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	3,984	4%	20	$391	95%	10%	0.5	23	79
Within Unit	Unit Central Heat	Ceiling - R 60	Ceiling R 49 - R 60	New	3,297	0%	20	$125	95%	10%	0.1	1	3
Within Unit	Unit Central Heat	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	3,984	12%	15	$1,824	80%	80%	0.3	1,524	5,197
Within Unit	Unit Central Heat	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	3,297	12%	15	$1,824	80%	80%	0.3	230	784
Within Unit	Unit Central Heat	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	3,984	5%	25	$150	80%	75%	2.4	379	1,293
Within Unit	Unit Central Heat	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	3,297	5%	25	$150	80%	75%	2.0	53	182
Within Unit	Unit Central Heat	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	3,984	5%	5	$56	80%	75%	1.5	347	1,183
Within Unit	Unit Central Heat	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	3,297	5%	5	$56	80%	75%	1.2	53	179
Within Unit	Unit Central Heat	Duct Insulation Upgrade	R-8 (code)	Existing	3,984	3%	20	$372	90%	90%	0.5	246	840
Within Unit	Unit Central Heat	Duct Insulation Upgrade	R-8 (code)	New	3,297	3%	20	$372	90%	90%	0.4	38	128
Within Unit	Unit Central Heat	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	3,984	1%	18	$225	80%	90%	0.3	158	539
Within Unit	Unit Central Heat	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	3,297	2%	18	$225	80%	90%	0.3	35	118

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Unit Central Heat	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	Existing	3,984	20%	14	$2,438	94%	5%	0.4	188	642
Within Unit	Unit Central Heat	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	New	3,297	20%	14	$2,438	94%	5%	0.3	28	97
Within Unit	Unit Central Heat	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	3,984	25%	5	$195	39%	10%	2.1	251	857
Within Unit	Unit Central Heat	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	3,297	30%	5	$195	39%	10%	2.1	42	143
Within Unit	Unit Central Heat	Insulation - Duct	R-Value (State Code)	Existing	3,984	6%	20	$497	80%	50%	0.7	248	846
Within Unit	Unit Central Heat	Insulation - Duct	R-Value (State Code)	New	3,297	6%	20	$497	80%	50%	0.6	38	128
Within Unit	Unit Central Heat	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	3,984	5%	10	$15	76%	95%	10.5	1,000	3,411
Within Unit	Unit Central Heat	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	3,297	5%	10	$15	76%	95%	8.7	137	469
Within Unit	Unit Central Heat	O&m Tune-Up	Tune-up/Maintenance	Existing	3,984	5%	5	$115	57%	95%	0.7	573	1,952
Within Unit	Unit Central Heat	O&m Tune-Up	Tune-up/Maintenance	New	3,297	5%	5	$115	57%	95%	0.6	87	296
Within Unit	Unit Central Heat	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	3,984	5%	18	$-266	50%	50%	-1.0	363	1,237
Within Unit	Unit Central Heat	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	3,297	5%	18	$-266	50%	50%	-0.8	50	170
Within Unit	Unit Central Heat	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	3,984	11%	20	$271	90%	50%	2.4	253	862
Within Unit	Unit Central Heat	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	3,984	14%	11	$89	74%	90%	5.6	1,289	4,396
Within Unit	Unit Central Heat	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	3,297	14%	11	$89	74%	90%	4.6	176	600
Within Unit	Unit Central Heat	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	3,984	20%	11	$750	74%	90%	0.9	1,517	5,172
Within Unit	Unit Central Heat	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	3,297	20%	11	$687	74%	90%	0.9	230	783
Within Unit	Unit Central Heat	Wall - R 19	Wall R 8.68 - R 19	Existing	3,984	10%	20	$101	65%	75%	5.8	319	1,088
Within Unit	Unit Central Heat	Wall - R 21	Wall R 8.68 - R 21	Existing	3,984	11%	20	$114	80%	20%	5.7	113	386
Within Unit	Unit Central Heat	Wall - R 22	Wall R 21 - R 22	New	3,297	1%	20	$19	95%	10%	1.3	1	3
Within Unit	Unit Central Heat	Wall - R 22	Wall R 8.68 - R 22	Existing	3,984	11%	20	$120	95%	10%	5.6	69	237
Within Unit	Unit Central Heat	Wall - R 32	Wall R 8.68 - R 32	Existing	3,984	14%	20	$234	95%	10%	3.6	87	296
Within Unit	Unit Central Heat	Wall - R 32	Wall R 8.68 - R 32	New	3,297	14%	20	$133	95%	10%	5.2	25	87
Within Unit	Unit Central Heat	Windows - U 0.2	Windows U 0.3 - U 0.2	New	3,297	5%	10	$2,181	66%	75%	0.1	62	211
Within Unit	Unit Central Heat	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	3,984	6%	10	$2,181	66%	75%	0.1	251	855
Within Unit	Unit Central Heat	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	3,984	2%	10	$1,985	66%	75%	0.0	79	270
Within Unit	Unit Room Ac	Basement Insulation - R-19	Basement Insulation - R-19	Existing	211	11%	20	$113	90%	90%	0.8	2,369	8,076
Within Unit	Unit Room Ac	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	211	6%	20	$89	65%	75%	0.6	307	1,048
Within Unit	Unit Room Ac	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	211	7%	20	$109	80%	20%	0.5	116	395
Within Unit	Unit Room Ac	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	211	8%	20	$130	95%	10%	0.5	75	257
Within Unit	Unit Room Ac	Ceiling - R 60	Ceiling R 49 - R 60	New	175	1%	20	$42	95%	10%	0.1	3	10
Within Unit	Unit Room Ac	Ceiling Fan	Ceiling Fan (no lighting kit)	Existing	211	6%	10	$276	70%	50%	0.1	515	1,757
Within Unit	Unit Room Ac	Ceiling Fan	Ceiling Fan (no lighting kit)	New	175	4%	10	$276	70%	50%	0.0	47	159
Within Unit	Unit Room Ac	Cool Roofs	Lighter Colored Shingles (White)	Existing	211	10%	15	$1,965	98%	45%	0.0	524	1,788
Within Unit	Unit Room Ac	Cool Roofs	Lighter Colored Shingles (White)	New	175	10%	15	$1,965	98%	45%	0.0	82	278
Within Unit	Unit Room Ac	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	211	5%	25	$50	80%	75%	1.0	506	1,725
Within Unit	Unit Room Ac	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	175	5%	25	$50	80%	75%	0.8	72	244
Within Unit	Unit Room Ac	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	211	5%	5	$19	80%	75%	0.6	463	1,578
Within Unit	Unit Room Ac	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	175	5%	5	$19	80%	75%	0.5	71	240
Within Unit	Unit Room Ac	Duct Insulation Upgrade	R-8 (code)	Existing	211	3%	20	$124	90%	90%	0.2	359	1,224
Within Unit	Unit Room Ac	Duct Insulation Upgrade	R-8 (code)	New	175	3%	20	$124	90%	90%	0.2	53	181
Within Unit	Unit Room Ac	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	211	2%	18	$75	80%	90%	0.2	370	1,262
Within Unit	Unit Room Ac	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	175	2%	18	$75	80%	90%	0.2	74	253
Within Unit	Unit Room Ac	Eer 10.8-Unit Room Ac	EER 10.8 Room Air Conditioner	Existing	193	10%	9	$50	NA	100%	0.7	0	0
Within Unit	Unit Room Ac	Eer 10.8-Unit Room Ac	EER 10.8 Room Air Conditioner	New	160	10%	9	$50	NA	100%	0.6	0	0
Within Unit	Unit Room Ac	Eer 11.14-Unit Room Ac	EER 11.14 Room Air Conditioner	Existing	193	13%	9	$546	NA	100%	0.1	4,428	15,098
Within Unit	Unit Room Ac	Eer 11.14-Unit Room Ac	EER 11.14 Room Air Conditioner	New	160	13%	9	$546	NA	100%	0.1	317	1,081
Within Unit	Unit Room Ac	Eer 9.8-Unit Room Ac	Eer 9.8-Unit Room Ac	Existing	217	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Unit Room Ac	Eer 9.8-Unit Room Ac	Eer 9.8-Unit Room Ac	New	181	0%	9	$0	NA	100%	0.0	0	0
Within Unit	Unit Room Ac	Green Roof	Vegetation on Roof	Existing	211	10%	25	$20,019	98%	4%	0.0	46	155
Within Unit	Unit Room Ac	Green Roof	Vegetation on Roof	New	175	10%	25	$20,019	98%	4%	0.0	7	24
Within Unit	Unit Room Ac	Insulation - Duct	R-Value (State Code)	Existing	211	6%	20	$166	80%	50%	0.3	359	1,223

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Unit Room Ac	Insulation - Duct	R-Value (State Code)	New	175	6%	20	$166	80%	50%	0.2	56	189
Within Unit	Unit Room Ac	O&m Tune-Up	Tune-up/Maintenance	Existing	211	5%	5	$115	57%	95%	0.1	673	2,293
Within Unit	Unit Room Ac	O&m Tune-Up	Tune-up/Maintenance	New	175	5%	10	$115	57%	95%	0.2	121	413
Within Unit	Unit Room Ac	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	211	11%	20	$90	90%	50%	1.0	337	1,150
Within Unit	Unit Room Ac	Wall - R 19	Wall R 8.68 - R 19	Existing	211	10%	20	$34	65%	75%	2.4	429	1,462
Within Unit	Unit Room Ac	Wall - R 21	Wall R 8.68 - R 21	Existing	211	11%	20	$38	80%	20%	2.3	153	521
Within Unit	Unit Room Ac	Wall - R 22	Wall R 21 - R 22	New	175	0%	20	$6	95%	10%	0.5	1	4
Within Unit	Unit Room Ac	Wall - R 22	Wall R 8.68 - R 22	Existing	211	12%	20	$40	95%	10%	2.3	94	320
Within Unit	Unit Room Ac	Wall - R 32	Wall R 8.68 - R 32	Existing	211	15%	20	$78	95%	10%	1.5	119	405
Within Unit	Unit Room Ac	Wall - R 32	Wall R 8.68 - R 32	New	175	15%	20	$44	95%	10%	2.2	33	114
Within Unit	Unit Room Ac	Window Film	Window Film	Existing	211	20%	10	$543	90%	75%	0.2	3,841	13,096
Within Unit	Unit Room Ac	Window Film	Window Film	New	175	20%	10	$543	90%	75%	0.1	577	1,966
Within Unit	Unit Room Heat	Basement Insulation - R-19	Basement Insulation - R-19	Existing	3,951	11%	20	$338	90%	90%	1.9	21,307	72,645
Within Unit	Unit Room Heat	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	3,951	3%	20	$266	65%	75%	0.7	1,257	4,287
Within Unit	Unit Room Heat	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	3,951	3%	20	$328	80%	20%	0.6	465	1,587
Within Unit	Unit Room Heat	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	3,951	4%	20	$391	95%	10%	0.5	297	1,013
Within Unit	Unit Room Heat	Ceiling - R 60	Ceiling R 49 - R 60	New	3,266	0%	20	$125	95%	10%	0.1	12	40
Within Unit	Unit Room Heat	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	3,951	5%	25	$150	80%	75%	2.4	4,552	15,520
Within Unit	Unit Room Heat	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	3,266	5%	25	$150	80%	75%	2.0	640	2,181
Within Unit	Unit Room Heat	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	3,951	5%	5	$56	80%	75%	1.5	4,164	14,198
Within Unit	Unit Room Heat	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	3,266	5%	5	$56	80%	75%	1.2	630	2,149
Within Unit	Unit Room Heat	Duct Insulation Upgrade	R-8 (code)	Existing	3,951	3%	20	$372	90%	90%	0.5	3,170	10,807
Within Unit	Unit Room Heat	Duct Insulation Upgrade	R-8 (code)	New	3,266	3%	20	$372	90%	90%	0.4	483	1,648
Within Unit	Unit Room Heat	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	3,951	1%	18	$225	80%	90%	0.1	1,096	3,736
Within Unit	Unit Room Heat	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	3,266	1%	18	$225	80%	90%	0.2	220	751
Within Unit	Unit Room Heat	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	3,951	25%	5	$195	39%	10%	2.1	3,040	10,366
Within Unit	Unit Room Heat	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	3,266	30%	5	$195	39%	10%	2.1	507	1,728
Within Unit	Unit Room Heat	Insulation - Duct	R-Value (State Code)	Existing	3,951	6%	20	$497	80%	50%	0.7	3,193	10,886
Within Unit	Unit Room Heat	Insulation - Duct	R-Value (State Code)	New	3,266	6%	20	$497	80%	50%	0.6	483	1,647
Within Unit	Unit Room Heat	O&m Tune-Up	Tune-up/Maintenance	Existing	3,951	5%	5	$115	57%	95%	0.7	7,365	25,109
Within Unit	Unit Room Heat	O&m Tune-Up	Tune-up/Maintenance	New	3,266	5%	5	$115	57%	95%	0.6	1,114	3,799
Within Unit	Unit Room Heat	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	3,951	11%	20	$271	90%	50%	2.4	3,034	10,346
Within Unit	Unit Room Heat	Wall - R 19	Wall R 8.68 - R 19	Existing	3,951	10%	20	$101	65%	75%	5.8	3,856	13,148
Within Unit	Unit Room Heat	Wall - R 21	Wall R 8.68 - R 21	Existing	3,951	11%	20	$114	80%	20%	5.7	1,368	4,665
Within Unit	Unit Room Heat	Wall - R 22	Wall R 21 - R 22	New	3,266	1%	20	$19	95%	10%	1.3	10	34
Within Unit	Unit Room Heat	Wall - R 22	Wall R 8.68 - R 22	Existing	3,951	11%	20	$120	95%	10%	5.6	840	2,862
Within Unit	Unit Room Heat	Wall - R 32	Wall R 8.68 - R 32	Existing	3,951	14%	20	$234	95%	10%	3.6	1,048	3,573
Within Unit	Unit Room Heat	Wall - R 32	Wall R 8.68 - R 32	New	3,266	14%	20	$133	95%	10%	5.2	293	1,000
Within Unit	Unit Room Heat	Windows - U 0.2	Windows U 0.3 - U 0.2	New	3,266	5%	10	$2,181	66%	75%	0.1	881	3,003
Within Unit	Unit Room Heat	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	3,951	6%	10	$2,181	66%	75%	0.1	3,563	12,150
Within Unit	Unit Room Heat	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	3,951	2%	10	$1,985	66%	75%	0.0	1,125	3,835
Within Unit	Unit Water Heat	Clothes Washer	Energy Star - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	Existing	3,005	3%	11	$798	70%	41%	0.1	312	1,063
Within Unit	Unit Water Heat	Clothes Washer	Energy Star - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	New	2,865	3%	11	$475	70%	41%	0.2	51	172
Within Unit	Unit Water Heat	Clothes Washer	Energy Star - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	Existing	3,005	4%	11	$927	70%	41%	0.1	440	1,502
Within Unit	Unit Water Heat	Clothes Washer	Energy Star - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	New	2,865	4%	11	$604	70%	41%	0.2	71	244
Within Unit	Unit Water Heat	Clothes Washer	Energy Star - Tier 3 (MEF 2.46 or higher) Top 10% of Energy Star Model - Electric DHW & Dryer	Existing	3,005	5%	11	$1,055	70%	41%	0.1	571	1,946
Within Unit	Unit Water Heat	Clothes Washer	Energy Star - Tier 3 (MEF 2.46 or higher) Top 10% of Energy Star Model - Electric DHW & Dryer	New	2,865	5%	11	$732	70%	41%	0.2	93	316
Within Unit	Unit Water Heat	Demand Controlled Circulating Systems	Demand Controlled Circulating Systems (VFD control by demand)	Existing	3,005	5%	10	$119	80%	55%	1.1	3,607	12,299
Within Unit	Unit Water Heat	Demand Controlled Circulating Systems	Demand Controlled Circulating Systems (VFD control by demand)	New	2,865	5%	10	$119	80%	55%	1.1	586	1,999

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Unit Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	Existing	3,005	1%	10	$12	90%	65%	2.2	952	3,245
Within Unit	Unit Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	New	2,865	1%	10	$12	90%	65%	2.1	154	525
Within Unit	Unit Water Heat	Hot Water Pipe Insulation	R-4 Wrap	Existing	3,005	2%	13	$16	86%	75%	4.3	2,239	7,635
Within Unit	Unit Water Heat	Hot Water Pipe Insulation	R-4 Wrap	New	2,865	2%	13	$16	86%	75%	4.1	362	1,234
Within Unit	Unit Water Heat	Low-Flow Faucet Aerators	1.5 GPM	Existing	3,005	9%	5	$5	45%	90%	28.4	6,805	23,201
Within Unit	Unit Water Heat	Low-Flow Faucet Aerators	2.2 GPM (Federal Code)	New	2,865	12%	5	$5	45%	90%	34.6	1,423	4,853
Within Unit	Unit Water Heat	Low-Flow Showerheads	2.0 GPM	Existing	3,005	1%	10	$15	57%	80%	2.2	909	3,100
Within Unit	Unit Water Heat	Low-Flow Showerheads	2.5 GPM (Federal Code)	New	2,865	0%	10	$15	57%	80%	0.7	49	166
Within Unit	Unit Water Heat	Solar Hot Water (Shw)	Solar thermal collector	Existing	3,005	53%	20	$9,506	82%	50%	0.3	35,157	119,868
Within Unit	Unit Water Heat	Solar Hot Water (Shw)	Solar thermal collector	New	2,865	53%	20	$9,506	82%	50%	0.3	5,704	19,447
Within Unit	Unit Water Heat	Unit Water Heat	0.937 High Efficiency Unit Water Heater	Existing	2,921	3%	13	$25	NA	100%	4.6	0	0
Within Unit	Unit Water Heat	Unit Water Heat	0.937 High Efficiency Unit Water Heater	New	2,921	3%	13	$25	NA	100%	4.6	0	0
Within Unit	Unit Water Heat	Unit Water Heat	Efficient Water Heater	Existing	2,921	6%	13	$50	NA	100%	3.9	1,969	6,713
Within Unit	Unit Water Heat	Unit Water Heat	Efficient Water Heater	New	2,921	6%	13	$50	NA	100%	3.9	234	798
Within Unit	Unit Water Heat	Unit Water Heat	Unit Water Heat	Existing	3,054	0%	13	$0	NA	100%	0.0	0	0
Within Unit	Unit Water Heat	Unit Water Heat	Unit Water Heat	New	0.00	.	13	$0	NA	100%	0.0	0	0
Within Unit	Unit Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	Existing	3,005	2%	7	$25	75%	60%	1.8	1,733	5,910
Within Unit	Unit Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	New	2,865	2%	7	$25	75%	60%	1.7	282	960
Within Unit	Unit Water Heat	Water Heater Thermostat Setback	120 degrees	Existing	3,005	6%	13	$179	60%	60%	1.2	3,790	12,920
Within Unit	Unit Water Heat	Water Heater Thermostat Setback	120 degrees	New	2,865	6%	13	$179	60%	60%	1.1	608	2,073
Within Unit	Ventilation And Circulation	Motor - Pump & Fan System - Variable Speed Control	Pump And Fan System Optimization w/ VSD	Existing	227	50%	15	$119	70%	65%	2.4	8,511	29,017
Within Unit	Ventilation And Circulation	Motor - Pump & Fan System - Variable Speed Control	Pump And Fan System Optimization w/ VSD	New	181	50%	15	$119	70%	65%	1.9	1,126	3,841
Within Unit	Ventilation And Circulation	Motor - Vav Box High Efficiency (Ecm)	ECM Motor	Existing	227	80%	18	$90	75%	65%	6.0	18,124	61,793
Within Unit	Ventilation And Circulation	Motor - Vav Box High Efficiency (Ecm)	ECM Motor	New	181	80%	18	$90	75%	65%	4.8	2,399	8,179

Appendix C.2 – Within-Unit Gas Measure Details

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (Therms)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 Therms Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Boiler	Afueb 0.8-Building Boiler	Afueb 0.8-Building Boiler	Existing	343	0%	20	$0	NA	100%	0.0	0	0
Within Unit	Building Boiler	Afueb 0.8-Building Boiler	Afueb 0.8-Building Boiler	New	275	0%	20	$0	NA	100%	0.0	0	0
Within Unit	Building Boiler	Afueb 0.85-Building Boiler	AFUEB 0.85 Boiler	Existing	300	6%	20	$38	NA	100%	9.8	0	0
Within Unit	Building Boiler	Afueb 0.85-Building Boiler	AFUEB 0.85 Boiler	New	241	6%	20	$38	NA	100%	7.8	0	0
Within Unit	Building Boiler	Afueb 0.9-Building Boiler	AFUEB 0.9 Boiler	Existing	300	11%	20	$79	NA	100%	8.9	4,584,227	458,423
Within Unit	Building Boiler	Afueb 0.9-Building Boiler	AFUEB 0.9 Boiler	New	241	11%	20	$79	NA	100%	7.1	912,271	91,227
Within Unit	Building Boiler	Basement Insulation - R-19	Basement Insulation - R-19	Existing	336	11%	20	$224	90%	90%	3.5	3,073,134	307,313
Within Unit	Building Boiler	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	336	6%	20	$176	65%	75%	2.2	358,474	35,847
Within Unit	Building Boiler	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	336	6%	20	$217	80%	20%	2.0	131,790	13,179
Within Unit	Building Boiler	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	336	7%	20	$259	95%	10%	1.9	84,085	8,409
Within Unit	Building Boiler	Ceiling - R 60	Ceiling R 49 - R 60	New	270	1%	20	$83	95%	10%	0.4	2,996	300
Within Unit	Building Boiler	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	336	5%	25	$113	80%	75%	3.7	656,552	65,655
Within Unit	Building Boiler	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	270	5%	25	$113	80%	75%	3.0	89,048	8,905
Within Unit	Building Boiler	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	336	4%	5	$56	80%	75%	1.5	462,976	46,298
Within Unit	Building Boiler	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	270	4%	5	$56	80%	75%	1.2	68,429	6,843
Within Unit	Building Boiler	Duct Insulation Upgrade	R-8 (code)	Existing	336	4%	20	$372	90%	90%	0.8	601,493	60,149
Within Unit	Building Boiler	Duct Insulation Upgrade	R-8 (code)	New	270	4%	20	$372	90%	90%	0.6	86,375	8,638
Within Unit	Building Boiler	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	336	14%	18	$225	80%	90%	4.1	4,957,682	495,768
Within Unit	Building Boiler	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	270	14%	18	$225	80%	90%	3.3	665,487	66,549
Within Unit	Building Boiler	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	336	26%	5	$162	39%	10%	3.5	455,570	45,557
Within Unit	Building Boiler	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	270	32%	5	$162	39%	10%	3.5	84,553	8,455
Within Unit	Building Boiler	Insulation - Duct	R-Value (State Code)	Existing	336	8%	20	$497	80%	50%	1.1	603,726	60,373
Within Unit	Building Boiler	Insulation - Duct	R-Value (State Code)	New	270	8%	20	$497	80%	50%	0.9	90,144	9,014
Within Unit	Building Boiler	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	336	5%	18	$200	50%	50%	1.6	488,371	48,837
Within Unit	Building Boiler	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	270	5%	18	$200	50%	50%	1.3	72,183	7,218
Within Unit	Building Boiler	Re-Commissioning	Re-Commissioning	Existing	336	5%	10	$296	85%	90%	0.7	1,397,184	139,718
Within Unit	Building Boiler	Re-Commissioning	Re-Commissioning	New	270	5%	10	$212	85%	90%	0.8	212,053	21,205
Within Unit	Building Boiler	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	336	11%	20	$250	90%	50%	3.1	396,400	39,640
Within Unit	Building Boiler	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	336	3%	11	$89	74%	90%	1.5	385,422	38,542
Within Unit	Building Boiler	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	270	4%	11	$89	74%	90%	1.4	70,151	7,015
Within Unit	Building Boiler	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	336	7%	11	$750	74%	90%	0.4	818,892	81,889
Within Unit	Building Boiler	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	270	7%	11	$687	74%	90%	0.4	122,201	12,220
Within Unit	Building Boiler	Wall - R 19	Wall R 8.68 - R 19	Existing	336	9%	20	$94	65%	75%	7.0	566,181	56,618
Within Unit	Building Boiler	Wall - R 21	Wall R 8.68 - R 21	Existing	336	10%	20	$105	80%	20%	6.8	201,077	20,108
Within Unit	Building Boiler	Wall - R 22	Wall R 21 - R 22	New	270	0%	20	$18	95%	10%	1.6	2,735	273
Within Unit	Building Boiler	Wall - R 22	Wall R 8.68 - R 22	Existing	336	11%	20	$111	95%	10%	6.7	123,390	12,339
Within Unit	Building Boiler	Wall - R 32	Wall R 8.68 - R 32	Existing	336	13%	20	$216	95%	10%	4.3	154,001	15,400
Within Unit	Building Boiler	Windows - U 0.2	Windows U 0.3 - U 0.2	New	270	5%	10	$1,805	66%	75%	0.1	135,004	13,500
Within Unit	Building Boiler	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	336	6%	10	$1,805	66%	75%	0.1	541,729	54,173
Within Unit	Building Boiler	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	336	2%	10	$1,643	66%	75%	0.1	170,872	17,087
Within Unit	Building Furnace	Afuef 0.78-Building Furnace	Afuef 0.78-Building Furnace	Existing	346	0%	18	$0	NA	100%	0.0	0	0
Within Unit	Building Furnace	Afuef 0.78-Building Furnace	Afuef 0.78-Building Furnace	New	0.00	.	18	$0	NA	100%	0.0	0	0
Within Unit	Building Furnace	Afuef 0.92-Building Furnace	AFUEF 0.92 Furnace	Existing	328	15%	18	$300	NA	100%	3.2	0	0
Within Unit	Building Furnace	Afuef 0.92-Building Furnace	AFUEF 0.92 Furnace	New	266	15%	18	$300	NA	100%	2.6	0	0
Within Unit	Building Furnace	Afuef 0.94-Building Furnace	AFUEF 0.94 Furnace	Existing	328	17%	18	$343	NA	100%	3.2	92,912	9,291
Within Unit	Building Furnace	Afuef 0.94-Building Furnace	AFUEF 0.94 Furnace	New	266	17%	18	$343	NA	100%	2.6	17,152	1,715
Within Unit	Building Furnace	Basement Insulation - R-19	Basement Insulation - R-19	Existing	339	11%	20	$224	90%	90%	3.5	528,423	52,842
Within Unit	Building Furnace	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	339	5%	20	$176	65%	75%	2.1	56,979	5,698

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (Therms)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 Therms Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Furnace	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	339	6%	20	$217	80%	20%	1.9	21,058	2,106
Within Unit	Building Furnace	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	339	6%	20	$259	95%	10%	1.7	13,439	1,344
Within Unit	Building Furnace	Ceiling - R 60	Ceiling R 49 - R 60	New	256	1%	20	$83	95%	10%	0.4	462	46
Within Unit	Building Furnace	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	339	5%	25	$113	80%	75%	3.7	112,893	11,289
Within Unit	Building Furnace	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	256	5%	25	$113	80%	75%	2.8	14,327	1,433
Within Unit	Building Furnace	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	339	4%	5	$56	80%	75%	1.5	78,925	7,892
Within Unit	Building Furnace	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	256	4%	5	$56	80%	75%	1.2	11,021	1,102
Within Unit	Building Furnace	Duct Insulation Upgrade	R-8 (code)	Existing	339	4%	20	$372	90%	90%	0.8	102,584	10,258
Within Unit	Building Furnace	Duct Insulation Upgrade	R-8 (code)	New	256	4%	20	$372	90%	90%	0.6	13,911	1,391
Within Unit	Building Furnace	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	339	14%	18	$225	80%	90%	4.1	843,688	84,369
Within Unit	Building Furnace	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	256	14%	18	$225	80%	90%	3.1	107,074	10,707
Within Unit	Building Furnace	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	339	24%	5	$162	39%	10%	3.3	65,630	6,563
Within Unit	Building Furnace	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	256	30%	5	$162	39%	10%	3.0	12,603	1,260
Within Unit	Building Furnace	Insulation - Duct	R-Value (State Code)	Existing	339	8%	20	$497	80%	50%	1.1	102,965	10,296
Within Unit	Building Furnace	Insulation - Duct	R-Value (State Code)	New	256	8%	20	$497	80%	50%	0.9	14,518	1,452
Within Unit	Building Furnace	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	339	5%	18	$200	50%	50%	1.6	83,254	8,325
Within Unit	Building Furnace	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	256	5%	18	$200	50%	50%	1.2	11,625	1,163
Within Unit	Building Furnace	Re-Commissioning	Re-Commissioning	Existing	339	5%	10	$299	85%	90%	0.7	238,288	23,829
Within Unit	Building Furnace	Re-Commissioning	Re-Commissioning	New	256	5%	10	$234	85%	90%	0.7	34,152	3,415
Within Unit	Building Furnace	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	339	11%	20	$250	90%	50%	3.1	67,511	6,751
Within Unit	Building Furnace	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	339	3%	11	$89	74%	90%	1.4	62,826	6,283
Within Unit	Building Furnace	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	256	3%	11	$89	74%	90%	1.2	10,390	1,039
Within Unit	Building Furnace	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	339	7%	11	$750	74%	90%	0.4	139,661	13,966
Within Unit	Building Furnace	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	256	7%	11	$687	74%	90%	0.3	19,682	1,968
Within Unit	Building Furnace	Wall - R 19	Wall R 8.68 - R 19	Existing	339	9%	20	$94	65%	75%	6.7	92,335	9,234
Within Unit	Building Furnace	Wall - R 21	Wall R 8.68 - R 21	Existing	339	10%	20	$105	80%	20%	6.6	32,811	3,281
Within Unit	Building Furnace	Wall - R 22	Wall R 21 - R 22	New	256	0%	20	$18	95%	10%	1.4	417	42
Within Unit	Building Furnace	Wall - R 22	Wall R 8.68 - R 22	Existing	339	10%	20	$111	95%	10%	6.4	20,143	2,014
Within Unit	Building Furnace	Wall - R 32	Wall R 8.68 - R 32	Existing	339	13%	20	$216	95%	10%	4.2	25,160	2,516
Within Unit	Building Furnace	Windows - U 0.2	Windows U 0.3 - U 0.2	New	256	5%	10	$1,805	66%	75%	0.1	20,832	2,083
Within Unit	Building Furnace	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	339	6%	10	$1,805	66%	75%	0.1	88,896	8,890
Within Unit	Building Furnace	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	339	2%	10	$1,643	66%	75%	0.0	28,090	2,809
Within Unit	Building Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	Existing	285	2%	10	$12	90%	65%	5.0	513,781	51,378
Within Unit	Building Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	New	272	2%	10	$12	90%	65%	4.8	80,178	8,018
Within Unit	Building Water Heat	Ef 0.575-Building Water Heat	Ef 0.575-Building Water Heat	Existing	300	0%	20	$0	NA	100%	0.0	0	0
Within Unit	Building Water Heat	Ef 0.575-Building Water Heat	Ef 0.575-Building Water Heat	New	0.00	.	20	$0	NA	100%	0.0	0	0
Within Unit	Building Water Heat	Ef 0.620-Building Water Heat	EF 0.620 Building Water Heater	Existing	275	7%	20	$38	NA	100%	8.9	0	0
Within Unit	Building Water Heat	Ef 0.620-Building Water Heat	EF 0.620 Building Water Heater	New	275	7%	20	$38	NA	100%	8.9	0	0
Within Unit	Building Water Heat	Ef 0.670-Building Water Heat	EF 0.670 Building Water Heater	Existing	275	14%	20	$79	NA	100%	8.4	0	0
Within Unit	Building Water Heat	Ef 0.670-Building Water Heat	EF 0.670 Building Water Heater	New	275	14%	20	$79	NA	100%	8.4	0	0
Within Unit	Building Water Heat	Ef 0.70-Building Water Heat	EF 0.70 Building Water Heater	Existing	275	18%	20	$120	NA	100%	6.9	1,899,400	189,940
Within Unit	Building Water Heat	Ef 0.70-Building Water Heat	EF 0.70 Building Water Heater	New	275	18%	20	$120	NA	100%	6.9	433,218	43,322
Within Unit	Building Water Heat	Hot Water Pipe Insulation	R-4 Wrap	Existing	285	5%	13	$40	86%	75%	4.3	1,286,300	128,630
Within Unit	Building Water Heat	Hot Water Pipe Insulation	R-4 Wrap	New	272	5%	13	$40	86%	75%	4.1	200,733	20,073

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (Therms)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 Therms Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Building Water Heat	Low-Flow Faucet Aerators	1.5 GPM	Existing	285	9%	5	$5	45%	90%	29.1	1,583,611	158,361
Within Unit	Building Water Heat	Low-Flow Faucet Aerators	2.2 GPM (Federal Code)	New	272	13%	5	$5	45%	90%	39.0	351,492	35,149
Within Unit	Building Water Heat	Low-Flow Showerheads	2.0 GPM	Existing	285	1%	10	$15	57%	80%	2.2	205,982	20,598
Within Unit	Building Water Heat	Low-Flow Showerheads	2.5 GPM (Federal Code)	New	272	0%	10	$15	57%	80%	0.7	11,116	1,112
Within Unit	Building Water Heat	Solar Hot Water (Shw)	Solar thermal collector	Existing	285	52%	20	$9,506	82%	50%	0.3	8,087,162	808,716
Within Unit	Building Water Heat	Solar Hot Water (Shw)	Solar thermal collector	New	272	52%	20	$9,506	82%	50%	0.3	1,266,437	126,644
Within Unit	Building Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	Existing	285	3%	7	$25	75%	60%	2.1	460,716	46,072
Within Unit	Building Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	New	272	3%	7	$25	75%	60%	2.0	72,282	7,228
Within Unit	Building Water Heat	Water Heater Thermostat Setback	120 degrees	Existing	285	17%	13	$10	60%	60%	57.7	2,721,099	272,110
Within Unit	Building Water Heat	Water Heater Thermostat Setback	120 degrees	New	272	17%	13	$10	60%	60%	55.1	431,403	43,140
Within Unit	Dryer	Dryer	Dryer	Existing	28	0%	18	$0	NA	100%	0.0	0	0
Within Unit	Dryer	Dryer	Dryer	New	28	0%	18	$0	NA	100%	0.0	0	0
Within Unit	Dryer	Dryer	Efficient Clothes Dryer	Existing	28	0%	18	$46	NA	100%	0.0	0	0
Within Unit	Dryer	Dryer	Efficient Clothes Dryer	New	28	0%	18	$46	NA	100%	0.0	0	0
Within Unit	Unit Central Heat	Afuef 0.78-Unit Central Heat	Afuef 0.78-Unit Central Heat	Existing	483	0%	18	$0	NA	100%	0.0	0	0
Within Unit	Unit Central Heat	Afuef 0.78-Unit Central Heat	Afuef 0.78-Unit Central Heat	New	0.00	.	18	$0	NA	100%	0.0	0	0
Within Unit	Unit Central Heat	Afuef 0.92-Unit Central Heat	AFUEF 0.92 Central Heating Unit	Existing	458	15%	18	$300	NA	100%	4.5	0	0
Within Unit	Unit Central Heat	Afuef 0.92-Unit Central Heat	AFUEF 0.92 Central Heating Unit	New	383	15%	18	$300	NA	100%	3.8	0	0
Within Unit	Unit Central Heat	Afuef 0.94-Unit Central Heat	AFUEF 0.94 Central Heating Unit	Existing	458	17%	18	$343	NA	100%	4.4	205,190	20,519
Within Unit	Unit Central Heat	Afuef 0.94-Unit Central Heat	AFUEF 0.94 Central Heating Unit	New	383	17%	18	$343	NA	100%	3.7	38,911	3,891
Within Unit	Unit Central Heat	Basement Insulation - R-19	Basement Insulation - R-19	Existing	472	11%	20	$338	90%	90%	3.2	1,132,298	113,230
Within Unit	Unit Central Heat	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	472	3%	20	$266	65%	75%	1.0	61,813	6,181
Within Unit	Unit Central Heat	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	472	3%	20	$328	80%	20%	0.9	22,922	2,292
Within Unit	Unit Central Heat	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	472	3%	20	$391	95%	10%	0.9	14,635	1,463
Within Unit	Unit Central Heat	Ceiling - R 60	Ceiling R 49 - R 60	New	368	0%	20	$125	95%	10%	0.2	533	53
Within Unit	Unit Central Heat	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	Existing	472	5%	25	$113	80%	75%	5.2	246,601	24,660
Within Unit	Unit Central Heat	Doors	R-5 (Composite Doors with foam core) - ENERGY STAR	New	368	5%	25	$113	80%	75%	4.0	32,685	3,269
Within Unit	Unit Central Heat	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	Existing	472	4%	5	$56	80%	75%	2.1	174,822	17,482
Within Unit	Unit Central Heat	Doors - Weatherization	Weatherstripping And Adding Door Sweeps	New	368	4%	5	$56	80%	75%	1.7	25,140	2,514
Within Unit	Unit Central Heat	Duct Insulation Upgrade	R-8 (code)	Existing	472	4%	20	$372	90%	90%	1.1	227,419	22,742
Within Unit	Unit Central Heat	Duct Insulation Upgrade	R-8 (code)	New	368	4%	20	$372	90%	90%	0.8	32,675	3,267
Within Unit	Unit Central Heat	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	472	14%	18	$225	80%	90%	5.7	1,848,815	184,882
Within Unit	Unit Central Heat	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	368	14%	18	$225	80%	90%	4.4	244,266	24,427
Within Unit	Unit Central Heat	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	472	24%	5	$195	39%	10%	3.6	147,947	14,795
Within Unit	Unit Central Heat	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	368	28%	5	$195	39%	10%	3.4	23,789	2,379
Within Unit	Unit Central Heat	Insulation - Duct	R-Value (State Code)	Existing	472	8%	20	$497	80%	50%	1.6	228,263	22,826
Within Unit	Unit Central Heat	Insulation - Duct	R-Value (State Code)	New	368	8%	20	$497	80%	50%	1.2	32,796	3,280
Within Unit	Unit Central Heat	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	472	5%	18	$200	50%	50%	2.3	184,411	18,441
Within Unit	Unit Central Heat	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	368	5%	18	$200	50%	50%	1.8	26,519	2,652
Within Unit	Unit Central Heat	Re-Commissioning	Re-Commissioning	Existing	472	5%	10	$417	85%	90%	0.7	524,461	52,446
Within Unit	Unit Central Heat	Re-Commissioning	Re-Commissioning	New	368	5%	10	$336	85%	90%	0.7	75,899	7,590
Within Unit	Unit Central Heat	Slab - 2" Foam / R-20	Slab - 2" foam / R-20	Existing	472	11%	20	$271	90%	50%	4.0	160,315	16,032
Within Unit	Unit Central Heat	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	472	3%	11	$89	74%	90%	1.8	127,228	12,723
Within Unit	Unit Central Heat	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	368	3%	11	$89	74%	90%	1.6	20,143	2,014
Within Unit	Unit Central Heat	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	472	7%	11	$750	74%	90%	0.6	307,387	30,739
Within Unit	Unit Central Heat	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	368	7%	11	$687	74%	90%	0.5	44,484	4,448

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (Therms)	Savings as Percent of End Use	Measure Life	Measure Cost	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 Therms Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Within Unit	Unit Central Heat	Wall - R 19	Wall R 8.68 - R 19	Existing	472	9%	20	$101	65%	75%	9.2	214,218	21,422
Within Unit	Unit Central Heat	Wall - R 21	Wall R 8.68 - R 21	Existing	472	10%	20	$114	80%	20%	8.9	76,114	7,611
Within Unit	Unit Central Heat	Wall - R 22	Wall R 21 - R 22	New	368	0%	20	$19	95%	10%	2.0	972	97
Within Unit	Unit Central Heat	Wall - R 22	Wall R 8.68 - R 22	Existing	472	11%	20	$120	95%	10%	8.8	46,732	4,673
Within Unit	Unit Central Heat	Wall - R 32	Wall R 8.68 - R 32	Existing	472	13%	20	$234	95%	10%	5.7	52,536	5,254
Within Unit	Unit Central Heat	Windows - U 0.2	Windows U 0.3 - U 0.2	New	368	4%	10	$2,181	66%	75%	0.1	39,890	3,989
Within Unit	Unit Central Heat	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	472	5%	10	$2,181	66%	75%	0.1	169,429	16,943
Within Unit	Unit Central Heat	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	472	2%	10	$1,985	66%	75%	0.0	53,437	5,344
Within Unit	Unit Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	Existing	285	2%	10	$12	90%	65%	5.0	219,538	21,954
Within Unit	Unit Water Heat	Dishwasher	Energy Star, July 1st 2011, <= 307 kWh/year , <= 5.0 gallons/cycle	New	272	2%	10	$12	90%	65%	4.8	34,516	3,452
Within Unit	Unit Water Heat	Ef 0.575-Unit Water Heat	Ef 0.575-Unit Water Heat	Existing	300	0%	13	$0	NA	100%	0.0	0	0
Within Unit	Unit Water Heat	Ef 0.575-Unit Water Heat	Ef 0.575-Unit Water Heat	New	0.00	.	13	$0	NA	100%	0.0	0	0
Within Unit	Unit Water Heat	Ef 0.620-Unit Water Heat	EF 0.620 Unit Water Heater	Existing	275	7%	13	$70	NA	100%	3.4	0	0
Within Unit	Unit Water Heat	Ef 0.620-Unit Water Heat	EF 0.620 Unit Water Heater	New	275	7%	13	$70	NA	100%	3.4	0	0
Within Unit	Unit Water Heat	Ef 0.670-Unit Water Heat	EF 0.670 Unit Water Heater	Existing	275	14%	13	$400	NA	100%	1.2	0	0
Within Unit	Unit Water Heat	Ef 0.670-Unit Water Heat	EF 0.670 Unit Water Heater	New	275	14%	13	$400	NA	100%	1.2	0	0
Within Unit	Unit Water Heat	Ef 0.70-Unit Water Heat	EF 0.70 Unit Water Heater	Existing	275	18%	15	$685	NA	100%	1.0	985,622	98,562
Within Unit	Unit Water Heat	Ef 0.70-Unit Water Heat	EF 0.70 Unit Water Heater	New	275	18%	15	$685	NA	100%	1.0	148,420	14,842
Within Unit	Unit Water Heat	Hot Water Pipe Insulation	R-4 Wrap	Existing	285	2%	13	$16	86%	75%	4.3	219,854	21,985
Within Unit	Unit Water Heat	Hot Water Pipe Insulation	R-4 Wrap	New	272	2%	13	$16	86%	75%	4.1	34,565	3,457
Within Unit	Unit Water Heat	Low-Flow Faucet Aerators	1.5 GPM	Existing	285	9%	5	$5	45%	90%	29.1	676,675	67,668
Within Unit	Unit Water Heat	Low-Flow Faucet Aerators	2.2 GPM (Federal Code)	New	272	13%	5	$5	45%	90%	39.0	151,314	15,131
Within Unit	Unit Water Heat	Low-Flow Showerheads	2.0 GPM	Existing	285	1%	10	$15	57%	80%	2.2	89,776	8,978
Within Unit	Unit Water Heat	Low-Flow Showerheads	2.5 GPM (Federal Code)	New	272	0%	10	$15	57%	80%	0.7	4,881	488
Within Unit	Unit Water Heat	Solar Hot Water (Shw)	Solar thermal collector	Existing	285	52%	20	$9,506	82%	50%	0.3	3,524,730	352,473
Within Unit	Unit Water Heat	Solar Hot Water (Shw)	Solar thermal collector	New	272	52%	20	$9,506	82%	50%	0.3	556,091	55,609
Within Unit	Unit Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	Existing	285	3%	7	$25	75%	60%	2.1	200,800	20,080
Within Unit	Unit Water Heat	Water Heater Tank Blanket/Insulation	Install Insulation (R-5)	New	272	3%	7	$25	75%	60%	2.0	31,739	3,174
Within Unit	Unit Water Heat	Water Heater Thermostat Setback	120 degrees	Existing	285	17%	13	$10	60%	60%	57.7	1,162,723	116,272
Within Unit	Unit Water Heat	Water Heater Thermostat Setback	120 degrees	New	272	17%	13	$10	60%	60%	55.1	185,715	18,572

Appendix C.3 – Common Area Electric Measure Details

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost (SqFt)	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Common Area	Cooling	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	4,462	8%	20	$0.34	65%	75%	1.2	1,291	4,403
Common Area	Cooling	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	4,462	9%	20	$0.42	80%	20%	1.1	474	1,617
Common Area	Cooling	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	4,462	10%	20	$0.50	95%	10%	1.0	307	1,045
Common Area	Cooling	Ceiling - R 60	Ceiling R 49 - R 60	New	3,879	1%	20	$0.16	95%	10%	0.3	5	16
Common Area	Cooling	Ceiling Fan	Ceiling Fan (no lighting kit)	Existing	4,462	2%	10	$0.10	70%	50%	0.6	817	2,785
Common Area	Cooling	Ceiling Fan	Ceiling Fan (no lighting kit)	New	3,879	3%	10	$0.10	70%	50%	0.6	46	155
Common Area	Cooling	Chilled Water / Condenser Water Settings-Optimization	Additional Control Features	Existing	4,462	5%	5	$0.03	95%	81%	2.5	4,526	15,431
Common Area	Cooling	Chilled Water / Condenser Water Settings-Optimization	Additional Control Features	New	3,879	5%	5	$0.01	95%	81%	6.9	233	795
Common Area	Cooling	Chilled Water Piping Loop W/ Vsd Control	VSD for secondary chilled water loop	Existing	4,462	12%	10	$0.77	25%	70%	0.4	2,110	7,193
Common Area	Cooling	Chilled Water Piping Loop W/ Vsd Control	VSD for secondary chilled water loop	New	3,879	12%	10	$0.77	25%	70%	0.4	102	349
Common Area	Cooling	Chiller-Water Side Economizer	Install Economizer	Existing	4,462	10%	15	$1.16	30%	45%	0.3	1,296	4,418
Common Area	Cooling	Chiller-Water Side Economizer	Install Economizer	New	3,879	10%	15	$1.16	30%	45%	0.3	63	214
Common Area	Cooling	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	4,462	12%	15	$1.75	80%	80%	0.3	7,272	24,795
Common Area	Cooling	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	3,879	12%	15	$1.75	80%	80%	0.2	352	1,201
Common Area	Cooling	Cool Roofs	Lighter Colored Shingles (White)	Existing	4,462	10%	15	$1.85	98%	45%	0.2	1,928	6,572
Common Area	Cooling	Cool Roofs	Lighter Colored Shingles (White)	New	3,879	10%	15	$1.85	98%	45%	0.2	93	318
Common Area	Cooling	Cooling Tower-Two-Speed Fan Motor	Cooling Tower-Two-Speed Fan Motor	Existing	4,462	14%	15	$0.21	35%	95%	2.6	2,803	9,557
Common Area	Cooling	Cooling Tower-Two-Speed Fan Motor	Cooling Tower-Two-Speed Fan Motor	New	3,879	14%	15	$0.21	35%	95%	2.2	126	431
Common Area	Cooling	Cooling Tower-Vsd Fan Control	Variable-Speed Tower Fans replace Two-Speed	Existing	4,462	4%	13	$0.06	75%	95%	2.4	1,612	5,495
Common Area	Cooling	Cooling Tower-Vsd Fan Control	Variable-Speed Tower Fans replace Two-Speed	New	3,879	4%	15	$0.06	75%	95%	2.3	79	268
Common Area	Cooling	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	4,462	0%	18	$0.11	45%	45%	0.1	30	104
Common Area	Cooling	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	3,879	0%	18	$0.11	45%	45%	0.1	2	6
Common Area	Cooling	Green Roof	Vegetation on Roof	Existing	4,462	10%	25	$18.85	98%	4%	0.0	168	571
Common Area	Cooling	Green Roof	Vegetation on Roof	New	3,879	10%	25	$18.85	98%	4%	0.0	8	28
Common Area	Cooling	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	4,462	7%	5	$0.25	39%	10%	0.4	288	984
Common Area	Cooling	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	3,879	15%	5	$0.25	39%	10%	0.8	29	100
Common Area	Cooling	Insulation - Duct	R-Value (State Code)	Existing	4,462	6%	20	$0.77	80%	50%	0.4	2,360	8,048
Common Area	Cooling	Insulation - Duct	R-Value (State Code)	New	3,879	6%	20	$0.77	80%	50%	0.3	114	390

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost (SqFt)	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Common Area	Cooling	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	4,462	5%	10	$0.01	76%	90%	24.7	4,351	14,835
Common Area	Cooling	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	3,879	5%	10	$0.01	76%	90%	21.5	207	706
Common Area	Cooling	O&m Tune-Up	Tune-up/Maintenance	Existing	4,462	5%	5	$0.04	57%	5%	1.8	158	539
Common Area	Cooling	O&m Tune-Up	Tune-up/Maintenance	New	3,879	5%	5	$0.04	57%	5%	1.6	8	26
Common Area	Cooling	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	4,462	16%	11	$0.14	74%	90%	3.4	6,778	23,109
Common Area	Cooling	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	3,879	16%	11	$0.14	74%	90%	2.9	310	1,058
Common Area	Cooling	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	4,462	20%	11	$0.36	74%	90%	1.7	7,415	25,281
Common Area	Cooling	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	3,879	20%	11	$0.34	74%	90%	1.5	353	1,204
Common Area	Cooling	Wall - R 19	Wall R 8.68 - R 19	Existing	4,462	7%	20	$0.26	65%	10%	1.3	154	525
Common Area	Cooling	Wall - R 21	Wall R 8.68 - R 21	Existing	4,462	7%	20	$0.29	80%	5%	1.3	103	353
Common Area	Cooling	Wall - R 22	Wall R 21 - R 22	New	3,879	0%	20	$0.05	95%	1%	0.3	0	1
Common Area	Cooling	Wall - R 22	Wall R 8.68 - R 22	Existing	4,462	8%	20	$0.31	95%	1%	1.3	25	87
Common Area	Cooling	Window Film	Window Film	Existing	4,462	20%	10	$0.00	66%	90%	908.9	17,486	59,617
Common Area	Cooling	Window Film	Window Film	New	3,879	20%	10	$0.00	66%	90%	790.1	833	2,839
Common Area	Heating	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	5,645	8%	20	$1.02	65%	75%	0.2	42	144
Common Area	Heating	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	5,645	9%	20	$1.26	80%	20%	0.2	16	53
Common Area	Heating	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	5,645	10%	20	$1.50	95%	10%	0.2	10	34
Common Area	Heating	Ceiling - R 60	Ceiling R 49 - R 60	New	4,915	1%	20	$0.48	95%	10%	0.1	0	1
Common Area	Heating	Convert Constant Volume Air System To Vav	Variable Volume Air System	Existing	5,645	12%	15	$1.75	80%	80%	0.2	253	862
Common Area	Heating	Convert Constant Volume Air System To Vav	Variable Volume Air System	New	4,915	12%	15	$1.75	80%	80%	0.1	12	42
Common Area	Heating	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	5,645	1%	18	$0.11	45%	45%	0.2	7	23
Common Area	Heating	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	4,915	1%	18	$0.11	45%	45%	0.2	0	1
Common Area	Heating	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	Existing	5,645	20%	14	$2.34	94%	5%	0.2	31	107
Common Area	Heating	Exhaust Air To Ventilation Air Heat Recovery	Exhaust Air to Ventilation Air Heat Recovery	New	4,915	20%	14	$2.34	94%	5%	0.2	2	5
Common Area	Heating	Insulation - Duct	R-Value (State Code)	Existing	5,645	6%	20	$0.77	80%	50%	0.2	83	284
Common Area	Heating	Insulation - Duct	R-Value (State Code)	New	4,915	6%	20	$0.77	80%	50%	0.2	4	14
Common Area	Heating	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	Existing	5,645	5%	10	$0.01	76%	90%	14.8	143	489
Common Area	Heating	Motor - Cee Premium-Efficiency Plus	CEE PE+ Motor for HVAC Applications	New	4,915	5%	10	$0.01	76%	90%	12.9	7	23
Common Area	Heating	O&m Tune-Up	Tune-up/Maintenance	Existing	5,645	5%	5	$0.04	57%	5%	1.0	6	19
Common Area	Heating	O&m Tune-Up	Tune-up/Maintenance	New	4,915	5%	5	$0.04	57%	5%	0.9	0	1
Common Area	Heating	Re-Commissioning	Re-Commissioning	Existing	5,645	5%	10	$0.06	85%	90%	1.4	160	547

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost (SqFt)	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Common Area	Heating	Re-Commissioning	Re-Commissioning	New	4,915	5%	10	$0.05	85%	90%	1.4	8	26
Common Area	Heating	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	5,645	20%	11	$0.36	74%	90%	1.0	536	1,829
Common Area	Heating	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	4,915	20%	11	$0.34	74%	90%	0.9	26	87
Common Area	Heating	Wall - R 19	Wall R 8.68 - R 19	Existing	5,645	7%	20	$0.78	65%	10%	0.3	5	18
Common Area	Heating	Wall - R 21	Wall R 8.68 - R 21	Existing	5,645	7%	20	$0.88	80%	5%	0.3	3	12
Common Area	Heating	Wall - R 22	Wall R 21 - R 22	New	4,915	0%	20	$0.15	95%	1%	0.1	0	0
Common Area	Heating	Wall - R 22	Wall R 8.68 - R 22	Existing	5,645	8%	20	$0.93	95%	1%	0.3	1	3
Common Area	Lighting Exterior	Outdoor Lighting, Area Lighting	Outdoor LED lighting with Automatic Controls	Existing	3,014	41%	12	$0.75	35%	90%	0.6	5,201	17,732
Common Area	Lighting Exterior	Outdoor Lighting, Area Lighting	Outdoor LED lighting with Automatic Controls	New	2,511	41%	12	$0.57	35%	90%	0.7	219	747
Common Area	Lighting Exterior	Outdoor Lighting, Parking Lot	Outdoor LED lighting with Automatic Controls	Existing	3,014	41%	12	$0.75	35%	90%	0.6	7,398	25,224
Common Area	Lighting Exterior	Outdoor Lighting, Parking Lot	Outdoor LED lighting with Automatic Controls	New	2,511	41%	12	$0.57	35%	90%	0.7	356	1,214
Common Area	Lighting Interior	Lighting Package, Below Code	Code Required LPD And Control Strategies	Existing	10,457	10%	13	$0.00	25%	90%	254.1	1,893	6,456
Common Area	Lighting Interior	Lighting Package, Below Code	Code Required LPD And Control Strategies	New	8,714	10%	13	$0.00	25%	90%	199.3	86	295
Common Area	Lighting Interior	Lighting Package, High Efficiency	15% Reduction in W/sqft	Existing	10,457	15%	13	$0.01	28%	90%	59.8	3,119	10,635
Common Area	Lighting Interior	Lighting Package, High Efficiency	15% Reduction in W/sqft	New	8,714	15%	13	$0.01	28%	90%	49.8	142	485
Common Area	Lighting Interior	Lighting Package, Premium Efficiency	20% Reduction in W/sqft	Existing	10,457	20%	13	$0.01	37%	75%	84.7	4,644	15,835
Common Area	Lighting Interior	Lighting Package, Premium Efficiency	20% Reduction in W/sqft	New	8,714	20%	13	$0.01	37%	75%	70.6	212	723
Common Area	Lighting Interior	Lighting Package, Super Premium Efficiency	25% Reduction in W/sqft	Existing	10,457	25%	13	$0.00	83%	70%	274.7	12,684	43,247
Common Area	Lighting Interior	Lighting Package, Super Premium Efficiency	25% Reduction in W/sqft	New	8,714	25%	13	$0.00	83%	70%	228.9	579	1,974
Common Area	Ventilation And Circulation	Motor - Pump & Fan System - Variable Speed Control	Pump And Fan System Optimization w/ VSD	Existing	6,109	72%	15	$0.12	75%	65%	33.0	34,240	116,741
Common Area	Ventilation And Circulation	Motor - Pump & Fan System - Variable Speed Control	Pump And Fan System Optimization w/ VSD	New	6,109	72%	15	$0.12	75%	65%	33.0	1,875	6,394
Common Area	Ventilation And Circulation	Motor - Vav Box High Efficiency (Ecm)	ECM Motor	Existing	6,109	80%	18	$0.03	50%	20%	156.2	8,163	27,832
Common Area	Ventilation And Circulation	Motor - Vav Box High Efficiency (Ecm)	ECM Motor	New	6,109	80%	18	$0.03	50%	20%	156.2	447	1,524
Common Area	Ventilation And Circulation	Motor Rewind	>15, <500 HP	Existing	6,109	10%	10	$0.58	25%	65%	0.7	2,627	8,958
Common Area	Ventilation And Circulation	Motor Rewind	>15, <500 HP	New	6,109	10%	10	$0.58	25%	65%	0.7	144	491
Common Area	Water Heat Building	Clothes Washer	Energy Star - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	Existing	6,036	17%	11	$0.27	80%	95%	1.4	814	2,775
Common Area	Water Heat Building	Clothes Washer	Energy Star - Tier 1 (MEF 2.0 - 2.19) - Electric DHW & Dryer	New	6,036	17%	11	$0.16	80%	95%	2.3	45	152
Common Area	Water Heat Building	Clothes Washer	Energy Star - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	Existing	6,036	24%	11	$0.31	80%	95%	1.7	1,220	4,160
Common Area	Water Heat Building	Clothes Washer	Energy Star - Tier 2 (MEF 2.2 - 2.45) - Electric DHW & Dryer	New	6,036	24%	11	$0.20	80%	95%	2.6	67	229
Common Area	Water Heat Building	Clothes Washer	Energy Star - Tier 3 (MEF 2.46 or higher) Top 10% of Energy Star Model - Electric DHW & Dryer	Existing	6,036	31%	11	$0.35	80%	95%	1.9	1,709	5,825
Common Area	Water Heat Building	Clothes Washer	Energy Star - Tier 3 (MEF 2.46 or higher) Top 10% of Energy Star Model - Electric DHW & Dryer	New	6,036	31%	11	$0.24	80%	95%	2.7	94	320

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (kWh)	Savings as Percent of End Use	Measure Life	Measure Cost (SqFt)	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 mWh Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Common Area	Water Heat Building	Demand Controlled Circulating Systems	Demand Controlled Circulating Systems (VFD control by demand)	Existing	6,036	5%	10	$0.11	80%	55%	0.9	391	1,334
Common Area	Water Heat Building	Demand Controlled Circulating Systems	Demand Controlled Circulating Systems (VFD control by demand)	New	6,036	5%	10	$0.11	80%	55%	0.9	21	73
Common Area	Water Heat Building	Hot Water Pipe Insulation	R-4 Wrap	Existing	6,036	2%	13	$0.01	86%	75%	4.1	315	1,074
Common Area	Water Heat Building	Hot Water Pipe Insulation	R-4 Wrap	New	6,036	2%	13	$0.01	86%	75%	4.1	17	59
Common Area	Water Heat Building	Low-Flow Faucet Aerators	1.5 GPM	Existing	6,036	1%	5	$0.00	45%	90%	2.7	111	377
Common Area	Water Heat Building	Low-Flow Faucet Aerators	2.2 GPM (Federal Code)	New	6,036	2%	5	$0.00	45%	90%	3.5	8	27
Common Area	Water Heat Building	Low-Flow Showerheads	2.0 GPM	Existing	6,036	1%	10	$0.01	57%	80%	3.9	100	339
Common Area	Water Heat Building	Low-Flow Showerheads	2.5 GPM (Federal Code)	New	6,036	0%	10	$0.01	57%	80%	1.4	2	5
Common Area	Water Heat Building	Solar Hot Water (Shw)	Solar thermal collector	Existing	6,036	50%	20	$7.69	82%	50%	0.2	3,566	12,158
Common Area	Water Heat Building	Solar Hot Water (Shw)	Solar thermal collector	New	6,036	50%	20	$7.69	82%	50%	0.2	196	667
Common Area	Water Heat Building	Water Heater Thermostat Setback	120 degrees	Existing	6,036	3%	11	$0.06	60%	60%	1.1	202	688
Common Area	Water Heat Building	Water Heater Thermostat Setback	120 degrees	New	6,036	3%	13	$0.06	60%	60%	1.2	11	36

Appendix C.4 – Common Area Gas Measure Details

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (Therms)	Savings as Percent of End Use	Measure Life	Measure Cost (SqFt)	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 Therms Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Common Area	Dryer	Clothes Dryer	Clothes Dryer w/ Moisture Sensor	Existing	275	15%	15	$0.02	80%	90%	9.2	254,461	25,446
Common Area	Dryer	Clothes Dryer	Clothes Dryer w/ Moisture Sensor	New	275	15%	15	$0.02	80%	90%	9.2	42,239	4,224
Common Area	Dryer	Clothes Washer Commercial	Energy Star Commercial Clothes Washer MEF=1.73	Existing	275	27%	15	$0.04	75%	35%	8.4	149,559	14,956
Common Area	Dryer	Clothes Washer Commercial	Energy Star Commercial Clothes Washer MEF=1.73	New	275	27%	15	$0.04	75%	35%	8.4	24,826	2,483
Common Area	Heating	Boiler Economizer	Economizer	Existing	1,743	5%	15	$0.40	30%	45%	1.3	146,125	14,613
Common Area	Heating	Boiler Economizer	Economizer	New	1,482	5%	15	$0.40	30%	45%	1.1	20,605	2,061
Common Area	Heating	Ceiling - R 38	Ceiling R 13.14 - R 38	Existing	1,743	6%	20	$1.02	65%	75%	0.7	193,641	19,364
Common Area	Heating	Ceiling - R 49	Ceiling R 13.14 - R 49	Existing	1,743	6%	20	$1.26	80%	20%	0.7	71,190	7,119
Common Area	Heating	Ceiling - R 60	Ceiling R 13.14 - R 60	Existing	1,743	7%	20	$1.50	95%	10%	0.6	45,421	4,542
Common Area	Heating	Ceiling - R 60	Ceiling R 49 - R 60	New	1,482	1%	20	$0.24	95%	10%	0.3	1,718	172
Common Area	Heating	Duct Insulation Upgrade	R-8 (code)	Existing	1,743	4%	20	$0.58	45%	45%	0.9	87,083	8,708
Common Area	Heating	Duct Insulation Upgrade	R-8 (code)	New	1,482	4%	20	$0.58	45%	45%	0.8	12,280	1,228
Common Area	Heating	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	Existing	1,743	14%	18	$0.11	45%	45%	15.7	704,553	70,455
Common Area	Heating	Duct Repair And Sealing	Reduction In Duct Losses to 5 %	New	1,482	14%	18	$0.11	45%	45%	13.4	99,409	9,941
Common Area	Heating	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	Existing	1,743	26%	5	$0.25	39%	10%	4.2	232,177	23,218
Common Area	Heating	Infiltration - Ach 0.65	Infiltration ACH 1 - ACH 0.65	New	1,482	32%	5	$0.25	39%	10%	4.4	43,083	4,308
Common Area	Heating	Insulation - Duct	R-Value (State Code)	Existing	1,743	8%	20	$0.77	80%	50%	1.4	352,003	35,200
Common Area	Heating	Insulation - Duct	R-Value (State Code)	New	1,482	8%	20	$0.77	80%	50%	1.2	49,636	4,964
Common Area	Heating	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	Existing	1,743	5%	18	$-0.10	50%	50%	-6.4	327,093	32,709
Common Area	Heating	Proper Sizing - Hvac Unit	Proper Sizing - HVAC Unit	New	1,482	5%	18	$-0.10	50%	50%	-5.4	46,151	4,615
Common Area	Heating	Re-Commissioning	Re-Commissioning	Existing	1,743	5%	10	$0.02	85%	90%	20.0	988,394	98,839
Common Area	Heating	Re-Commissioning	Re-Commissioning	New	1,482	5%	10	$0.02	85%	90%	20.6	139,458	13,946
Common Area	Heating	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	Existing	1,743	3%	11	$0.14	74%	90%	1.7	225,551	22,555
Common Area	Heating	Thermostat - Has= 1	Thermostat HAS= 0 - HAS= 1	New	1,482	4%	11	$0.14	74%	90%	1.8	37,687	3,769
Common Area	Heating	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	Existing	1,743	20%	11	$0.36	74%	90%	4.5	1,608,218	160,822
Common Area	Heating	Thermostat - Multi-Zone	Individual Room Temperature Control for Major Occupied Rooms	New	1,482	20%	11	$0.36	74%	90%	3.8	224,043	22,404
Common Area	Heating	Wall - R 19	Wall R 8.68 - R 19	Existing	1,743	9%	20	$0.78	65%	10%	1.6	44,250	4,425
Common Area	Heating	Wall - R 21	Wall R 8.68 - R 21	Existing	1,743	10%	20	$0.88	80%	5%	1.5	29,742	2,974

Customer Type	End Use	Measure Name	Measure Description	Construction Vintage	Baseline Usage (Therms)	Savings as Percent of End Use	Measure Life	Measure Cost (SqFt)	Percent of Installations Incomplete	Percent of Installations Technically Feasible	TRC Benefit-Cost Ratio	2030 Therms Savings (Technical Potential)	2030 MMBTU Savings (Technical Potential)
Common Area	Heating	Wall - R 22	Wall R 21 - R 22	New	1,482	0%	20	$0.09	95%	1%	0.6	141	14
Common Area	Heating	Wall - R 22	Wall R 8.68 - R 22	Existing	1,743	11%	20	$0.93	95%	1%	1.5	7,320	732
Common Area	Heating	Windows - U 0.2	Windows U 0.3 - U 0.2	New	1,482	5%	10	$1.00	50%	15%	0.3	12,063	1,206
Common Area	Heating	Windows - U 0.2	Windows U 0.35 - U 0.2	Existing	1,743	6%	10	$1.00	50%	15%	0.5	50,487	5,049
Common Area	Heating	Windows - U 0.3	Windows U 0.35 - U 0.3	Existing	1,743	2%	10	$1.00	50%	15%	0.2	16,141	1,614
Common Area	Pool Heat	Re - Installation Of Solar Pool/Spa Heating Systems	Solar Pool/Spa Heating Systems	Existing	932	90%	15	$0.92	20%	90%	4.4	269,333	26,933
Common Area	Pool Heat	Re - Installation Of Solar Pool/Spa Heating Systems	Solar Pool/Spa Heating Systems	New	932	90%	15	$0.92	20%	90%	4.4	44,708	4,471
Common Area	Pool Heat	Swimming Pool/Spa Covers	Plastic Or Foam Pool Covers (50-65% Energy Savings)	Existing	932	50%	15	$0.02	20%	90%	147.9	164,428	16,443
Common Area	Pool Heat	Swimming Pool/Spa Covers	Plastic Or Foam Pool Covers (50-65% Energy Savings)	New	932	50%	15	$0.02	20%	90%	147.9	27,294	2,729
Common Area	Water Heat	Clothes Washer Commercial	Energy Star Commercial Clothes Washer MEF=1.73	Existing	284	27%	15	$0.04	75%	35%	8.7	166,357	16,636
Common Area	Water Heat	Clothes Washer Commercial	Energy Star Commercial Clothes Washer MEF=1.73	New	284	27%	15	$0.04	75%	35%	8.7	27,614	2,761
Common Area	Water Heat	Drainwater Heat Recovery Water Heater	Install (Power-Pipe or GFX) - Heat Recovery Water Heater	Existing	284	51%	15	$0.20	90%	20%	3.5	198,830	19,883
Common Area	Water Heat	Drainwater Heat Recovery Water Heater	Install (Power-Pipe or GFX) - Heat Recovery Water Heater	New	284	51%	15	$0.20	90%	20%	3.5	33,005	3,300
Common Area	Water Heat	Hot Water Pipe Insulation	R-4 Wrap	Existing	284	0%	13	$0.01	86%	75%	0.1	1,250	125
Common Area	Water Heat	Hot Water Pipe Insulation	R-4 Wrap	New	284	0%	13	$0.01	86%	75%	0.1	208	21
Common Area	Water Heat	Low-Flow Faucet Aerators	1.5 GPM	Existing	284	1%	5	$0.00	45%	90%	1.5	9,913	991
Common Area	Water Heat	Low-Flow Faucet Aerators	2.2 GPM (Federal Code)	New	284	2%	5	$0.00	45%	90%	2.2	2,314	231
Common Area	Water Heat	Low-Flow Showerheads	2.0 GPM	Existing	284	1%	10	$0.01	57%	80%	1.9	8,923	892
Common Area	Water Heat	Low-Flow Showerheads	2.5 GPM (Federal Code)	New	284	0%	10	$0.01	57%	80%	0.6	515	51
Common Area	Water Heat	Re - Solar Water Heater	Passive solar water heating	Existing	284	50%	15	$7.69	90%	50%	0.1	219,036	21,904
Common Area	Water Heat	Re - Solar Water Heater	Passive solar water heating	Existing	284	50%	15	$7.69	90%	50%	0.1	194,395	19,439
Common Area	Water Heat	Water Heater Thermostat Setback	120 degrees	Existing	284	59%	13	$0.06	60%	60%	11.2	624,868	62,487
Common Area	Water Heat	Water Heater Thermostat Setback	120 degrees	New	284	59%	13	$0.06	60%	60%	11.2	103,725	10,372

APPENDIX D: BARRIERS AND MOTIVATORS TO MEASURE ADOPTION

Appendix D summarizes both barriers and motivators to measure adoption in multifamily buildings. The responses below are from the achievable potential workshops conducted in May 2011. A full write-up of the workshops can be found in Appendix E.

Barriers to Adoption of Energy-Efficient Technologies

Initial Costs Before an Upgrade Is Installed and the Risk of Code Violations

The multifamily buildings that currently exist in Massachusetts often require an up-front investment to prepare for the installation of energy-efficient upgrades. The cost of this initial investment varies and appears to be driven primarily by the age and location of the building. The higher the investment cost, the more likely it is to deter PMs from adopting energy-efficient equipment.

Many PAs, for example, mention the knob-and-tube wiring common to older buildings as an impediment to making insulation installation affordable. [1] Also, one PM stated is unwilling to undergo an energy audit of his buildings because of existing building code violations that would be costly to fix or upgrade.[2] Other PMs agree that this risk also presents a barrier for them.

> *"A lot of older buildings in Massachusetts you have knob and tube wiring, and it's harder to insulate over knob and tube wiring. It can be dangerous, and rewiring it is very expensive."*

Installation Inconveniences

The inconveniences—such as time, schedule coordination, construction-related disorder—entailed in installing energy-efficient measures are also significant deterrents for PMs. Specifically, the PMs made these comments (primarily about insulation projects). The issues of inconvenience remain barrier remains, even with possibility of higher incentives.

> *"You have to call [tenants]. You have to make arrangements. They have to rearrange their schedule. Sometimes they don't show up. Sometimes they don't want it. I mean, there are so many things you have to do."*

> *"Because if you haven't planned to do a rehab on your property and you're just doing the rehab for insulation, it's not worth it, because you may have to move your tenants. They have relocation costs. It's just too much."*

Lack of Property Manager Knowledge

Many PMs report their frustrations with the limited resources they have regarding to contractors and measure information. They express skepticism about the quality and reliability of contractors and wonder how to find professionals. PMs—in particular, those who manage a small number of

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1 Homes built before or during the early 1900s often have knob-and-tube wiring, which does not allow for easy installation of insulation and often requires an electrical wiring upgrade.

2 It is unclear whether the building code violations referenced by this PM reference would need to be remedied before energy-efficient measures could be installed. It is possible that PMs erroneously believe an energy audit involves inspections for state codes.

buildings and/or units—also complain that they are not informed about available energy-efficient technologies. This barrier also remains present with higher incentives.

"A lot of [PMs], especially smaller owners, are not familiar with the technology that's available."

"I think the main problem is, see, we estimate that 70% of the housing in Massachusetts is small buildings, three, four, six, eight, 10 units, and a lot of the owners don't understand the technology…. A lot of the [market actors] don't know what to do."

"I can insulate a building, seal it and not change the heating system and reduce the heating cost in half—just that alone. But it's got to be done by a professional; you can't have Joe Schmoe down the street say, yeah, I can insulate your building for you, because he just doesn't have the experience or the knowledge of how a building is put together, and where to look, and where it's sealed."

"What is the best approach? Everyone [says] we should insulate, we should do this, but there are a lot of different options that are available… I've had NSTAR come in and they look, and install fluorescent light fixtures and do this and do that. But I'm still kind of foggy as to really what is the best approach? How do you really evaluate what you want to do with your buildings? And everyone has unique situations. They're all unique, and who's the expert? There's no expert."

"There's a lot of fly-by-night insulation contractors for the small guys, and they don't know what they're doing, especially with the wiring."

Tenant Resistance

PMs often face a great deal of resistance from their tenants; however, having tenant buy-in is crucial to the implementation of energy-efficient measures. If tenants are willing, then implementation can be a challenge. This is another barrier that exists even with higher incentives.

"I manage an elder building.... For people to come into their home, it's difficult to get that resident to kind of do what the contractor wants them to do. So it kind of depends on what it is for my specific complex—what we choose to do—if we can get the resident to do it. Like we did the lighting; it was really hard to get the ladies to let the guy in to change the light. 'I like the light this way. I don't need a new light.' It was difficult."

"Getting into a tenant's property, crawling around the windows and around furniture and—it's like pulling teeth."

Split Incentives

Due to the nature of multifamily buildings, PMs emphasize the influence of the metering characteristics of the building. A PM is far less likely to invest in the cost of energy-efficient measures in a sub-metered building (where the PM does not pay the utility bills). Likewise, tenants are less willing to deal with the inconveniences of measure installation if they will not reap the reward, such as reduced energy costs in a master-metered building.

"We're not going to put a nickel into a tenant's space if [the tenants are] paying the electric bill or the heating bill, unfortunately… the owner just will not put a nickel into a tenant's space if they're paying the utility bill."

Return on Investment

The adoption of energy-efficient technology is highly driven by the return on investment (ROI or payback). This is particularly true for market actors who manage small properties. PMs point out that shorter payback periods become are essential for smaller properties or smaller management agencies, mainly due to the larger financial pressure to which they are subject. However, when incentives are sufficiently high, this type of impediment becomes less of an issue.

"If you've got a small portfolio, you don't have a lot of money to play with. So if you're going to save $5,000 or $10,000 now, today, you don't know what's going to happen five years from now, 10 years from now. So they're really looking more to [the] short term. The larger property owners, they're looking long term."

PMs indicate that they or the homeowner associations (HOAs) with which they work typically seek payback periods of approximately two to three years or less. PMs have observed that HOAs tend to seek shorter ROIs than PMs because of the short length of time in which they are typically invested in the living space. However, in the case of heating systems, HOAs tend to view these as long-lasting investments, so they are more inclined to accept a longer payback period.

"The condo boards that I manage are looking for the quickest payback possible."

"[HOAs] won't even consider anything unless it's under two [years]. The [longest ROI] I saw was 3.3 years. That's a stretch to think three years out."

"Ten years, it's a capital improvement of your building as far as the boiler is concerned. That's why the high numbers, in my opinion."

"The problem on the condo side is you don't know if it's a long-term condo owner or a short-term. They're not going to throw extra money into a unit that they've got to maybe sell in a couple or three years. They don't care. Throw the cheap one in; I'm out of here."

First Cost of Investment

Not unlike other markets, many PMs mention the troubled economy and the first costs of energy-efficient equipment as barriers to adoption. However, this is another barrier that tends to be less of an issue when incentives are sufficiently high.

"You're dealing with a market right now on the small end where—I don't know whether there's 40 or 50% of the owners [who] are upside down. They owe more than the property's worth. I guess I'm a little bit west of where most of you are, but I'm out into Marlboro and Worcester a lot, where you just see whole neighborhoods that are just either something that's going to be foreclosed on or has been foreclosed on. So yeah, you get a lot of these people that are just 'bandaid-ing' their problems and trying to survive."

Concerns with Energy-Efficient Measure Performance

PMs are less inclined to invest in certain measures due to their skepticism that the measure will last the full length of a projected payback period. Also, PMs expressed concerns with some of the environmental, health, and physical issues with measures, like Compact Fluorescent Lamps (CFLs).

> *"Caulking doesn't last. Sealing doesn't last."*

> *"I can't tell you how many buildings I've fixed over the past 15 years from everybody stuffing insulation in the walls. You open them up and it's just mold. The whole thing is mold, and then you're into another problem, serious problem."*

> *"Some people don't like the light [a CFL bulb] gives off."*

> *"We were doing all these transitions, and now we've got to deal with disposal of [CFLs], so it's kind of an issue."*

Motivators to Adoption of Energy-Efficient Technologies

Reducing Operating Expenses

One of the key motivational factors for installing energy-efficient equipment is to reduce a building's operating expenses. The PMs indicated that reducing their monthly utility bills in master-metered buildings was an attractive option.

> *"A lot of the buildings in Boston are very old. There's all this—you have high bills because of the sort of insulation you have in the old buildings."*

> *"Well we had good luck insulating the attic of a 47-unit building by just adding probably twice the insulation that originally had been provided, and it wasn't difficult to do or terribly expensive. We've also been insulating heating lines and hot and cold water lines, which is a really slow process that requires someone very meticulous, but if you can take the time and do it right, both of those are things that have great savings forever. When I look at these, I think of the payback—the time it takes to recover the cost of the improvement—but I hope beyond that, that we're reducing our largest operating expense forever. That many [of the] things the building manager can spend money on will have that result and [are] going to reduce your operating expense forever."*

Attracting and Retaining Tenants

PMs noted that reducing tenant turnover and attracting new tenants are motivators for making energy-efficient improvements. By reducing monthly utility bills for tenants in sub-metered buildings, PMs believe they more easily retain tenants. At least one PM said energy efficiency was a draw for potential tenants of luxury units as well.

> *"You can reduce your turnover though. I've talked to tenants that have given that as their reason for moving."*

"I think, long-term goals [are] that the units be worth as much as possible, and [that] reducing the operating expenses controls the condo fees and makes the building seem more affordable."

"I don't think you can really sell it too much, because you can really get yourself in trouble with promising something that doesn't pan. But I think the other side—the tenants that are living in buildings where the energy costs are high—don't stay very long."

"Well, in our luxury complex in Arlington, we can sell energy efficiency as a green aspect, and tenants in the $2400-$2500 a month apartment—they enjoy that."

Non-Energy Benefits

PMs also mention in their marketing approaches to prospective tenants the non-energy benefits provided by the improvements. For example, PMs say the thermal comfort and air quality improvements associated with weatherization upgrades are attractive to their clientele.

"There's a lot of links with asthma and health benefits, and it is important, especially in areas where you have a lot of people suffering from asthma. So it's a selling point."

"What [PMs] think is, is there any benefit in terms of comfort or maybe lower utility bills that would make that building more marketable….. Less noise and things like that."

Green Marketing Initiatives

PAs perceive that, increasingly, market actors are upgrading energy-efficient technologies in an effort to be recognized as an environmentally conscientious business or entity.

Trusted Contractors

PAs noted that the level of trust PMs have in their contractors significantly influences the likelihood that the PMs will install a measure—with or without the existence of a program. So, when contractors recommend an action, the PMs are likely to take that action, irrespective of available incentives. Thus, contractor endorsement of energy-efficient technologies can be a significant motivator for customer adoption.

APPENDIX E: ACHIEVABLE POTENTIAL WORKSHOP MEMO

This appendix contains the full write-up from the workshops on achievable potential, conducted in May 2011.

Memo

Massachusetts 2010 Residential Retrofit and Low-Income Evaluation: Multifamily Potential Study Achievable Potential Scenario Workshops

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1. Introduction

In this memo, we report results of workshops contributing towards the Massachusetts (MA) Multifamily Potential Study. The multifamily potential study seeks to both provide a descriptive assessment of the multifamily market size and characteristics, plus quantify energy savings potential within the state's multifamily market. By identifying information about the state of the multifamily market, the assessment can inform program implementation and goal-setting metrics. The Multifamily Potential Study includes technical, economic, and achievable potential.

Definition of Resource Potentials

We based our estimates of technical, economic, and achievable potential on best-practice research methods and analytic techniques that are standard in the utility industry. Consistent with accepted industry standards, this study's approach distinguishes among four definitions of resource potential widely used in utility resource planning.

- ***Naturally occurring conservation*** refers to reductions in energy use due to normal market forces (such as technological change, energy prices, market transformation efforts, and improved energy codes and standards). This analysis accounts for naturally occurring conservation in several ways.
  - First, the potential associated with certain energy-efficiency measures assumes a natural rate of adoption. For example, the savings associated with ENERGY STAR® appliances account for current customer adoption trends.
  - Second, current codes and standards are applied in the consumption characteristics of new construction.
  - Finally, the assessment accounts for the gradual increase in efficiency as older equipment is replaced by units meeting current standards. However, this assessment does not forecast changes to codes and standards; rather, it treats them as "frozen" at a given efficiency level.
- ***Technical potential*** assumes all available Demand-Side Management (DSM) measures and supplemental resource options may be implemented, regardless of their costs or market barriers. For energy-efficiency resources, the technical potential falls into two classes: retrofit (discretionary) and equipment (phased-in or lost-opportunity resources). It is important to recognize the notion of technical potential is less relevant to resources such as capacity-focused programs and distributed generation since most end-use loads may be subject to interruption through load curtailment or displacement by on-site generation, from a strictly technical point of view.
- ***Economic potential*** represents a subset of technical potential consisting only of measures that meet the cost-effectiveness criteria based on statewide average avoided energy and capacity costs for electricity and gas. For each energy-efficiency measure, the benefit-cost test is structured as the ratio of the net present values of the measure's benefits and costs. Only measures with a benefit-to-cost ratio of 1.0 or greater are deemed cost-effective.
- ***Program achievable potential*** is defined as the portion of economic potential that might be assumed to be reasonably achievable in the course of the planning horizon, given market barriers that may impede customer participation in utility programs. The

definition of achievable potential varies widely across the industry. On one extreme, the estimate is based on virtually giving away all total resource cost (TRC) cost-effective measures without a customer contribution, which yields 75 percent or more of economic potential. On the other extreme, achievable potential is constrained by (1) supply, and (2) program budget constraints. This memo presents the results and findings from three workshops conducted in May 2011 aimed at estimating the achievable potential for energy efficiency savings in the Massachusetts multifamily property market.

Overview

The evaluation team conducted several research activities contributing to the Achievable Potential scenario model. In late 2010, we completed 129 telephone surveys with Massachusetts property managers and owners (PMs)[1] of multifamily buildings in which we asked a series of Willingness to Participate (WTP) questions. Early in 2011, we conducted 124 telephone surveys with Massachusetts multifamily building tenants, also including a series of WTP questions. WTP questions determine measure adoption curves or relationships of incentive levels to adoption of specified energy-efficiency measures. We discuss these questions at greater length later in this memo.

Based on our experience, these tenant and PM surveys resulted in unrealistically high adoption curves. The hypothetical nature of WTP questions and their focus exclusively on monetary incentives make them prone to higher, and perhaps unrealistic, adoption curves. Because many factors other than incentives drive the decision-making process (e.g., concerns over measure performance), we held three Achievable Potential workshops to refine these survey-based models. The workshops not only allow respondents more time to think about various scenarios, but also allow them to learn more information from their peers that broadens their perspectives. By integrating discussions to temper responses and explore reasoning behind initial responses, we permitted respondents to revise what might have been their immediate responses to the WTP questions.[2] This memo presents the results of the Achievable Potential Workshops.

We held two workshops—each two hours long—with MA PMs on subsequent evenings on May 10 and May 11, 2011. The third workshop, lasting three hours, occurred on May 12, 2011, where we met with MA Program Administrators (PAs). The PA workshop included Multifamily and Low Income Program Managers and their Implementation Contractors (ICs). While more than ten representatives from the PAs attended, only eight individuals provided data contributing towards the adoption curves.[3]

Table 1 summarizes the various research activities we have conducted that contribute to the Achievable Potential model.

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[1] Throughout this memo, we refer to both property managers and owners as PMs. However, if the distinction between ownership as opposed to management is relevant to a specified topic, it is noted.

[2] The workshops employed a Modified Delphi Method that allows participants to revise their initial responses and work towards a consensus. We discuss this approach in more detail later in this memo.

[3] Many of the representatives who attended the PA workshop provided useful information relevant to the markets in which they work, yet chose not to provide responses to the questionnaires because they are members of the PA evaluation teams.

Table 1. Summary of Achievable Potential Activities

Activity	Details	Sample*	Date
Property manager and owner telephone surveys	Telephone survey with property managers and owners of multifamily properties including WTP modules	n=129	November and December 2010
Tenant telephone surveys	Telephone survey with tenants of multifamily properties including WTP modules	n=124	January and February 2011
Property manager and owner workshops	Workshops with property managers and owners of multifamily properties	n=17 (9 and 8)	May 10 and May 11, 2011
Program Administrator workshops	Workshops with Multifamily and Low Income Program Managers and Implementation Contractors	n=8	May 12, 2011

* These sample sizes indicate the number of respondents who completed the WTP questions.

2. Achievable Potential Workshop Methodology

Recruitment and Attendance

Using a purchased list, we recruited 26 PMs to attend the two workshops. To save resources, we used the same contact list that was used for the PM telephone survey conducted in November and December of 2010. We removed contacts that had refused to be interviewed, were determined ineligible, or had nonworking numbers during the telephone survey.

For both PM workshops, we sought to recruit approximately 12 PMs who owned and/or managed residential buildings with five or more units within Massachusetts. Of the roughly 1,200 unique phone numbers we dialed, we were able to recruit 12 PMs for Tuesday, May 10, and 14 PMs for Wednesday, May 11. As shown in Table 2 our greatest challenges were finding contacts that were willing to hear about the workshops or were unable to be reached. Nearly a fifth of our sample frame was determined ineligible. Of those we determined were eligible, however, nearly a quarter (23%) signed up to attend the workshops. More than two-thirds of those who were eligible were not interested in attending the workshops.

Table 2. Recruitment Calling Dispositions

Disposition		Total Contacts	Percent of Sample Frame
Ineligible or Eligibility Unknown	Unwilling to Speak with Us	349	29%
	Unable to Reach	329	27%
	Not a Property Manager of MF Buildings	231	19%
	Call back	117	10%
	Phone number issue	79	6%
Eligible	Not Interested in Workshop or Site Visit	71	6%
	Recruited for Workshops	26	2%
	Interest in a Site Visit, not Workshop	9	1%
	Schedule Does not Fit	8	1%
	Recruitment Rate*	*23%*	

*The recruitment rate is calculated as the number of contacts recruited for workshops over the number of individuals determined as eligible.

For each workshop, we intended to recruit at least five PMs whom we considered to manage or own a "large" number of properties. This would give us a greater sense of the decision-making processes for a larger share of properties in the state. Our criteria for "large" were that the PM own or manage at least five buildings or at least 100 units cumulatively. Ultimately, of the 17 PMs who attended the workshops, 13 met this criterion. Table 3 presents PM size distribution by workshop date.

Table 3. Workshop Attendance by PM Size and Date

Workshop	Very Large (more than 500 units)	Large (100-499 units and/or 5 buildings or more)	Medium (20-99 units and/or 2-4 buildings)	Small (Less than 20 units or 2 buildings)	Total
Tuesday, May 10	2	3	2	1	8
Wednesday, May 11	3	5	0	1	9

The number of properties managed and/or owned by workshop attendees varied significantly. On average, the PMs who attended manage and/or own about 20 buildings. In sum, attendees manage and/or own 356 buildings, totaling over 11,000 units in Massachusetts. However, two attendees managed and/or owned about 8,000 of these 11,000 buildings.

Most of attendees' firms both manage and own the buildings. Several only own the buildings and several only manage the buildings. The attendees included a good mixture of those PMs whose tenants own (i.e., condos) versus rent their units, tenant income levels, and geographic representation around the state.

The PA workshop included representatives from ICs, RISE and CSG along with Multifamily and/or Low Income program managers from NSTAR, National Grid, and Columbia Gas.

Willingness to Participate Questions

WTP questions present respondents with the incremental cost of an energy efficient measure, the annual savings in energy costs the measure would provide, and the cumulative savings in energy costs over the average lifetime of the measure. We then asked respondents about the likelihood of adoption of the measure at different incentive levels (0%, 25%, 50%, 75%, and 100% of measure costs). However, in the case of the workshops, instead of asking the workshop attendees if they personally would respond in a specific manner, we asked them what percent of PMs they think would adopt the measure at each incremental level of incentive. This approach, coupled with discussion, allowed respondents to consider the state of the market, incorporating variables controlling for specific building characteristics.

Workshop Design

We modeled our approach to the workshops after the Delphi Method, which successfully combines the varied perspectives of subject-matter experts into a single answer to a research question. The Delphi Method begins by asking a panel of experts to make anonymous projections on a specific topic. The aggregated results are presented and discussed among the experts. After discussing their rationales for their initial projections, the respondents are again asked to anonymously complete the questionnaire. Additional rounds of discussion and re-completion of the questionnaire can be added. Ultimately, the expectation is that the experts will come closer to a consensus and the final projections they make will more accurately predict actual conditions or projections.

Similarly, our workshops included questionnaires including the tables shown in Figure 1 (see full questionnaire in **Error! Reference source not found.**). Respondents independently and anonymously wrote down the percent of PMs they felt would likely adopt the measure at the respective incentive level. We also asked respondents to write by what percent, if any, these percentages would increase with the inclusion of aggressive program marketing. We also left a space for respondents to write down barriers and motivators that can drive, at least in part, the adoption of energy efficient equipment. In addition to weatherization, we asked respondents to complete similar questions regarding replacement of heating systems and lighting. We selected these measures because they:

- Are believed to represent a large share of program savings;
- Will likely represent a large share of technical and economic potential;
- Include a mix of replacement (i.e., replace on failure, as for heating systems) and retrofit/discretionary (i.e., install at the customer's discretion, not driven by equipment failure, as for weatherization and new lighting fixtures) measures;
- Represent a wide range of incremental cost considerations, and thus customer decision-making criteria.

Figure 1. Achievable Potential Workshop Questionnaire Excerpts

Additional Cost of Energy Efficient Boiler/Furnace	Annual Savings	Lifetime Savings (20 years)	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Install EE Boiler/Furnace
$5,000	$500	$10,000	$0	$5,000	10 years	%
			$1,250	$3,750	7.5 years	%
			$2,500	$2,500	5 years	%
			$3,750	$1,250	2.5 years	%
			$5,000	$0	Immediate	%

Cost of Insulation, Sealing, Caulking Improvements	Annual Savings	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Make Insulation, Sealing, Caulking Improvements
$10,000	**$1,500**	$0	$10,000	6.7 years	%
		$2,500	$7,500	5 years	%
		$5,000	$5,000	3.3 years	%
		$7,500	$2,500	1.7 years	%
		$10,000	$0	Immediate	%

Additional Cost of Energy Efficient Lighting	Annual Savings	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Install EE Lighting
$50/Fixture	**$25/ Fixture**	$0	$50	2 years	%
		$15	$35	1.4 years	%
		$25	$25	1 year	%
		$40	$10	5 months	%
		$50	$0	Immediate	%

During the workshops, we then aggregated attendees' responses and presented the results in the form of graphs showing the relationship between measure adoption and monetary incentive—or achievable potential curves. Upon presentation of the graphs, we moderated a discussion among the attendees. We asked attendees to explain why they gave the responses they had given. Attendees then filled in the same questionnaires a second time. After the second showing of their aggregated responses (alongside the chart from the first round), we asked attendees again to provide any further explanations of why they may or may not have adjusted their responses. Our experts' projections about the market became more homogenous and presented us with a more realistic model of measure adoption.

Achievable Potential Curves

Generally, we see five characteristics, not necessarily mutually exclusive, in measure adoption curves.

Linear curves: A curve with a low intercept and a coefficient close to one displays a clear correlation between an increased incentive and program participation. It indicates that the

incentive is important in increasing the adoption of the measure. It also indicates that there are minimal market barriers other than price and minimal free ridership.

Flat curves: Fairly flat curves indicate that multifamily market actors' willingness to adopt or install a measure is not highly correlated with an incremental increase in incentive. This indicates that factors other than incremental cost are more important in market actors' decision making with regard to purchase/participation.

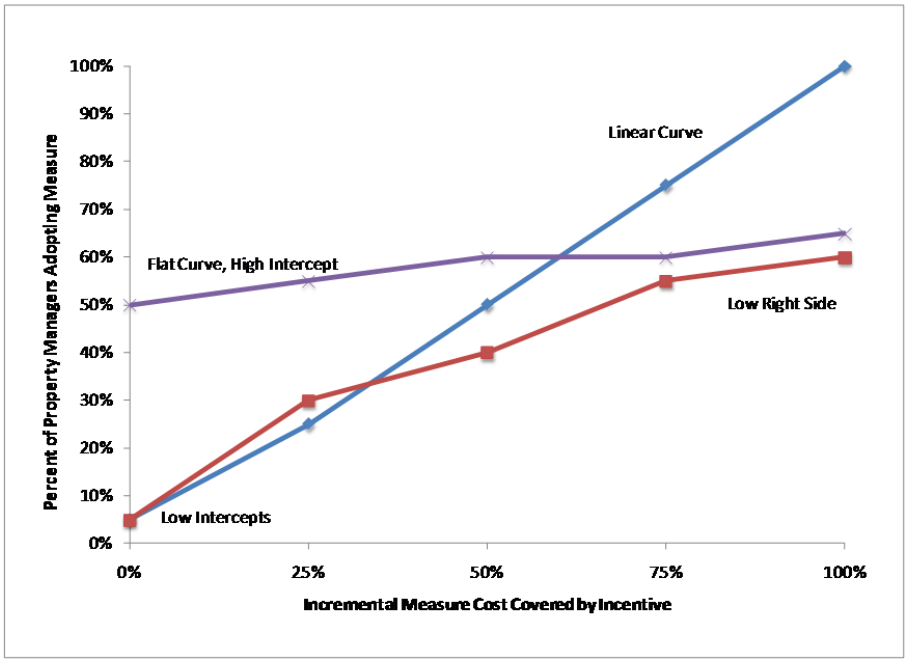
Limited maximum adoption: If the far right of the curve has not climbed with the incentive increase, it means that beyond a certain incentive level, even if an incentive covers the entire cost of the measure, market actors are still not willing to adopt it. This indicates that market barriers exist that are implicit in the technology and not related to the program.

High intercepts: A curve with a high intercept is an indicator of free ridership—meaning that a large number of multifamily customers are likely to purchase/install the measure in the absence of any program incentive.

Low intercepts: Curves that begin with low intercepts show that without an incentive, relatively few market actors are likely to adopt the measure. This is an indication that minimal free ridership is likely to occur.

Figure 2 illustrates these characteristics through a few examples.

Figure 2. Examples of Achievable Potential Model Characteristics



3. Findings

Program Manager Workshops

Measure Adoption Curves

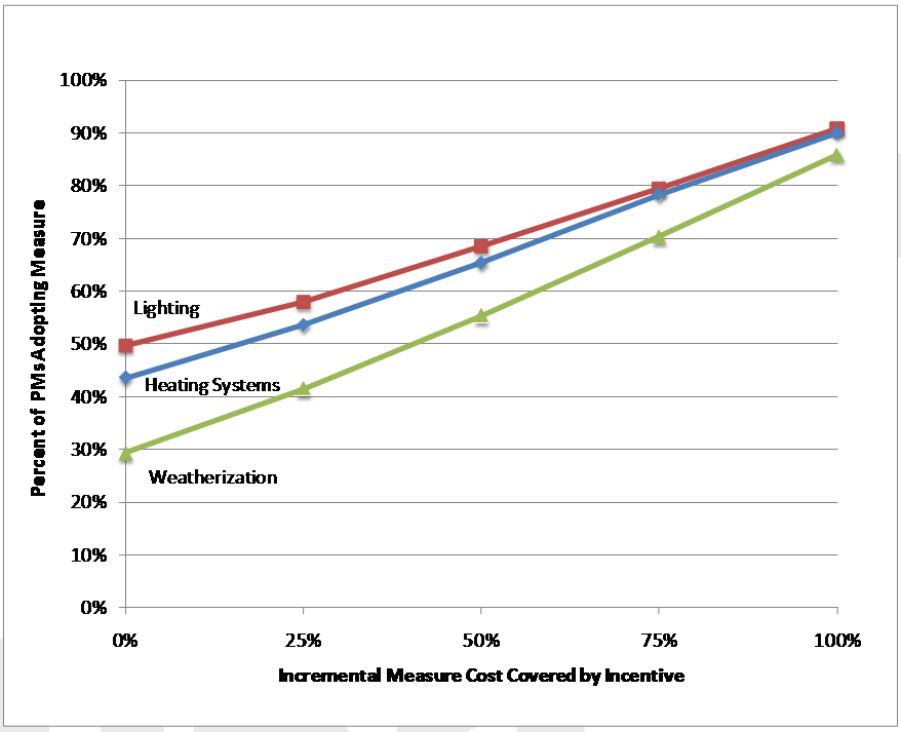
We asked workshop attendees about common area lighting, weatherization, and heating system measures. Figure 3 presents the average results from the PMs' second round of questionnaire responses.

We found that, on average, respondents provide fairly high intercepts, ranging from 30% (weatherization) to 50% (lighting). For example, PMs believe that roughly half of market actors would install energy efficient lighting measures in common areas in the absence of any program incentive. The responses also demonstrate that PMs believe that some customers—even with 100% of the incremental cost covered by an incentive—would not adopt the efficient alternative. For example, PMs believe that even with an incentive covering 100% of the cost, 15% of property managers would not have weatherization measures performed.[4] Nonetheless, weatherization measures had the lowest adoption curves regardless of incentive level, signaling the presence of barriers that extend beyond financial.

DRAFT

[4] Note that because weatherization is a discretionary measure (i.e., installation is not tied to equipment failure and does not need to be conducted at all), the incremental cost and full cost of the installation are identical.

Figure 3. Property Manager Achievable Potential Curves by Measure



On average, across the measures, PMs say that with aggressive program marketing, these curves would shift upward by 12%.

Barriers to Adoption of Energy Efficient Technologies

On average, PMs believe that even with an incentive covering 100% of the incremental cost, 10 to 15% of multifamily PMs would not install the measures. With a 75% incentive, 20 to 30% of PMs would not do so. We asked participants to explain why some market actors still would not opt to install the measures with these higher incentives. They provided us with some of the barriers they perceive to the adoption of energy efficient technologies both with and without incentives. Wherever possible, we have provided verbatim responses.

Preparatory Investments: The current nature of the building stock that exists in Massachusetts often requires an up-front investment to prepare for energy efficiency upgrades. The cost involved in these investments often deters PMs from adopting energy efficient equipment. For example, many PAs reference the knob and tube wiring common in older buildings in Massachusetts as an impediment to making insulation installation affordable. [5] One PM points out that he is unwilling to receive an energy audit in his buildings because of existing building code violations that would be

[5] The wiring of homes built before or during the early 1900s often have "knob and tube" wiring. Because of the physical nature of this type of wiring, it does not easily permit insulation and often requires an electrical wiring upgrade in the home.

costly to fix or upgrade (verbatim not recorded due to poor recording quality).[6] Other PMs agree that this also presents a barrier for them.

"A lot of older buildings in Massachusetts you have knob and tube wiring, and it's harder to insulate over knob and tube wiring. It can be dangerous, and rewiring it is very expensive."

Installation Inconveniences: The hassles involved in installing energy efficient measures also act as a major deterrent for PMs**.** The time, effort, coordination, and messiness of the installation often are a hindrance for PMs and their tenants. Specifically, PMs make these comments mostly about insulation projects. This type of barrier remains present even with higher incentives.

"You have to call [tenants]. You have to make arrangements. They have to rearrange their schedule. Sometimes they don't show up. Sometimes they don't want it. I mean there are so many things you have to do."

"Insulation, believe it or not, it's great to do when you're doing a renovation, but if you're going to try to retrofit insulation, it's a mess."

"The best way to [install insulation] is a gut. You pull the horsehair plaster off the walls, insulate, wire, plumb, total renovation, because if you're not doing the total thing, you're doing it piecemeal and nothing works right."

"Because if you haven't planned to do a rehab on your property, and you're just doing the rehab for insulation, it's not worth it, because you may have to move your tenants. They have relocation costs. It's just too much."

"You get a Victorian in Dorchester… [Tenants] look at the fit and finish a lot more... You're going to go through the outside, and a lot of these older buildings have, for instance, asbestos siding. I can go through the outside, take the vinyl off and put it back. So a lot of the insulation, the second step is the cosmetics, and that can [often be] a problem in a smaller wood frame building."

"For us, anyway, we did a common area lighting and they did pay for everything and it did go very well but they put a different size fixture in so we did a lot of backtracking and painting and patching and it kind of looked bad after the fact because there were patches that you could clearly see around the new light so I feel like that kind of fell on our end and we should have [done] a little more research on fixture they were going to put and how big it was because it then made us backtrack and spend some money… patching it up."

Lack of Knowledge: Many PMs report their frustrations with the limited resources they have with regard to contractors and measure information. They express skepticism with contractors and wonder about how to find more reliable contractors. PMs, especially those who manage a small number of buildings and/or units explain that they are not informed about available energy efficient technologies. This barrier also remains present with higher incentives.

[6] It is unclear if the building code violations that this PM references would need to be remedied to install energy efficient measures. However, it may also be the case that PMs erroneously believe that an energy audit involves inspections for state codes.

"A lot of [PMs], especially smaller owners, are not familiar with the technology that's available."

"I think the main problem is, see, we estimate that 70% of the housing in Massachusetts is small buildings, three, four, six, eight, ten units, and a lot of the owners don't understand the technology… A lot of the [market actors] don't know what to do."

"I can insulate a building, seal it and not change the heating system and reduce the heating cost in half - just that alone. But it's got to be done by a professional; you can't have 'Joe Schmo' down the street say, yeah, I can insulate your building for you because he just doesn't have the experience or the knowledge of how a building is put together and where to look and where it's sealed."

"What is the best approach? Everyone [says] we should insulate, we should do this, but there are a lot of different options that are available… I've had NSTAR come in and they look, and install fluorescent light fixtures and do this and do that, but I'm still kind of foggy as to really what is the best approach? How do you really evaluate what you want to do with your buildings? And everyone has unique situations. They're all unique, and who's the expert? There's no expert."

"There's a lot of fly by night insulation contractors for the small guys, and they don't know what they're doing, especially with the wiring."

Tenant Resistance: As mentioned above, tenant buy-in is crucial to the implementation of energy efficient measures. PMs often face a great deal of resistance from their tenants. If tenants are not on board, then implementation can be a challenge. This is another barrier that exists even with higher incentives.

"I manage an elder building... for people to come into their home it's difficult to get that resident to kind of do what the contractor wants them to do so it kind of depends on what it is for my specific complex, what we choose to do, if we can get the resident to do it. Like we did the lighting; it was really hard to get the ladies to let the guy in to change the light. 'I like the light this way. I don't need a new light.' It was difficult."

"Getting into a tenant's property, crawling around the windows and around furniture and – It's like pulling teeth."

Split Incentives: Due to the nature of multifamily buildings, PMs emphasize the influence of the metering characteristics of the building. A PM is far less likely to invest in the cost of energy efficient measures in a sub-metered building where the PM does not pay the utility bills for tenants. Likewise, tenants are less willing to deal with the inconveniences of measure installation if they are not reaping the reward in the form of reduced energy costs in a master metered building.

"We're not going to put a nickel into a tenant's space if [the tenants are] paying the electric bill or the heating bill, unfortunately… the owner just will not put a nickel into a tenant's space if they're paying the utility bill."

Return on Investment: Adoption of energy efficient technology is highly driven by the return on investment (ROI) or payback. This is particularly the case among market actors managing small properties. PMs point out that shorter payback periods become more essential for smaller properties

or smaller management agencies, mainly due to the larger financial pressure that they are under. If incentives are high enough, this type of impediment becomes less of an issue.

> *"If you've got a small portfolio, you don't have a lot of money to play with. So if you're going to save $5000 or $10,000 now, today, you don't know what's going to happen five years from now, ten years from now. So they're really looking more to short term. The larger property owners, they're looking long term."*

PMs indicate that they or the Homeowner Associations (HOAs) with whom they work typically seek payback periods of roughly two to three years or less. PMs explain that HOAs, in particular, tend to seek shorter ROIs than PMs because of the shorter length of time in which they remain invested in the living space. However, in the case of heating systems, they view these as longer-lasting investments and tend to accept longer payback periods:

> *"The condo boards that I manage are looking for the quickest payback possible."*
>
> *"We typically won't do it if it's not three years or [less]."*
>
> *"[HOAs] won't even consider anything unless it's under two [years]. The [longest ROI] I saw was 3.3 years. That's a stretch to think three years out."*
>
> *"Ten years, it's a capital improvement of your building as far as the boiler is concerned. That's why the high numbers, in my opinion."*
>
> *"The problem on the condo side is you don't know if it's a long-term condo owner or a short-term. They're not going to throw extra money into a unit that they've got to maybe sell in a couple or three years. They don't care. Throw the cheap one in; I'm out of here."*

As shown in Figure 1, the questionnaire tables presented attendees with the estimated payback schedules resulting from incremental incentive levels. The table below shows the achievable potential projected by PMs alongside the respective payback periods. In the case of lighting and weatherization measures, the two to three year payback period PMs discussed during the workshops is reflected in their responses in the questionnaires. In the case of heating systems, a somewhat longer payback period appears to be acceptable, perhaps because this is expected with larger investments. The statements made during the workshop align with the questionnaire responses as they project that over half of PMs would install these measures with five (65%) or seven (54%) year payback periods.

Table 4. Incentive-Derived Payback Periods and PM Projected Achievable Potential

Heating Systems		Weatherization		Lighting	
Payback (Years)	% of PMs Adopting*	Payback (Years)	% of PMs Adopting*	Payback (Years)	% of PMs Adopting*
0	90%	0	86%	0	91%
2.5	78%	1.7	70%	0.4	79%
5	65%	3.3	55%	1	69%
7.5	54%	5	41%	1.4	58%
10	44%	6.7	29%	2	50%

*Average percentages provided by PM Workshop respondents

First Cost of Investment: Not unlike other markets, many PMs point out the troubled economy and the first costs of energy efficient equipment as barriers to adoption. This is another barrier that becomes less of an issue if incentives are high enough:

> *"You're dealing with a market right now on the small end where - I don't know whether there's 40 or 50% of the owners are upside down. They owe more than the property's worth. I guess I'm a little bit west of where most of you are, but I'm out into Marlboro and Worcester a lot where you just see whole neighborhoods that are just either something that's going to be foreclosed on or has been foreclosed on. So yeah, you get a lot of these people that are just bandaiding their problems and trying to survive."*

Concerns with Energy Efficient Measure: PMs are less inclined to invest in certain measures due to their skepticism that they will last the full length of a projected payback period. Also, PMs express concerns with some of the environmental, health, and physical issues with measures, like Compact Fluorescent Lamps (CFLs).

> *"Caulking doesn't last. Sealing doesn't last."*
>
> *"I can't tell you how many buildings I've fixed over the past fifteen years from everybody stuffing insulation in the walls. You open them up and it's just mold. The whole thing is mold, and then you're into another problem, serious problem."*
>
> *"Basically one of the problems in buildings I deal with is they're trying to steal [CFLs]. They're trying to steal the bulbs. When they need a bulb for their apartment, they steal the bulb."*
>
> *"You do have a paranoia about the mercury in some of the communities."*
>
> *"Some people don't like the light [a CFL bulb] gives off."*
>
> *"We were doing all these transitions and now we've got to deal with disposal of [CFLs] so it's kind of an issue."*
>
> *"Some people like what they know. They use the same boiler type or the same plumber twenty, thirty years. They'll never change."*

Motivators to Adoption of Energy Efficient Technologies

As mentioned, PMs believe that about 30% to 50% of market actors opt to install energy efficient measures without program incentives. We asked PMs to explain why they or their peers might invest in energy efficiency even in the absence of program incentives. These motivators help us to understand the higher intercepts.

Reduction in Operating Expenses: One of the top motivators for installing energy efficient equipment is to reduce a building's operating expenses. On the part of PMs, reducing their monthly utility bills in master-metered buildings is quite attractive.

> *"A lot of the buildings in Boston are very old. There's all this - you have high bills because of the sort of insulation you have in the old buildings."*
>
> *"Well we had good luck insulating the attic of a forty-seven unit building by just adding probably twice the insulation that originally had been provided, and it wasn't difficult to do or terribly expensive. We've also been insulating heating lines and hot and cold water lines, which*

is a really slow process that requires someone very meticulous, but if you can take the time and do it right, both of those are things that have great savings forever. When I look at these I think of the payback, the time it takes to recover the cost of the improvement, but I hope beyond that that we're reducing our largest operating expense forever. That many things the building manager can spend money on will have that result and is going to reduce your operating expense forever."

Attracting and Retaining Tenants: PMs noted that reduction in tenant turnover and attraction of new tenants are motivators to making energy efficient improvements. By reducing monthly utility bills for tenants in sub-metered buildings, PMs believe they more easily retain tenants. At least one PM also explains that it is a draw for potential tenants of luxury units as well.

"You can reduce your turnover though. I've talked to tenants that have given that as their reason for moving."

"I think, long term goals [are] that the units be worth as much as possible, and reducing the operating expenses controls the condo fees and makes the building seem more affordable."

"I don't think you can really sell it too much, because you can really get yourself in trouble with promising something that doesn't pan. But I think the other side, the tenants that are living in buildings where the energy costs are high don't stay very long."

"Well in our luxury complex in Arlington we can sell energy efficiency as a green aspect, and tenants in the $2400-$2500 a month apartment, they enjoy that."

Non-Energy Benefits: PMs also explain that they use the non-energy benefits that the improvements provide in their marketing approaches to prospective tenants. For example, they point out that the thermal comfort and air quality improvements associated with weatherization upgrades are attractive to their clientele.

"There's a lot of links with asthma and health benefits, and it is important, especially in areas where you have a lot of people suffering from asthma. So it's a selling point."

"What [PMs] think is, is there any benefit in terms of comfort or maybe lower utility bills that would make that building more marketable….. Less noise and things like that."

Program Influence and Program Feedback

Many PM attendees have participated in statewide energy efficiency programs. During the workshops, attendees presented their own thoughts about the PA programs, including feedback on their own experiences in the programs. The feedback related to the programs also should be considered in tandem with other barriers and motivators presented above.

Program Satisfaction: Many PMs, repeatedly, point out the benefits they have seen from participating in the programs. Some also express high levels of satisfaction with the program's implementation teams.

"I really have no problems with the rebates for the utility programs. I think that they work well for us… The electric programs are fantastic. I mean, obviously, no money out of pocket is a no-brainer. And it seems like the gas companies are starting to get into some more water saving devices on the gas side which is, I think, a great move but I think CSG will actually install them on some of your properties at no cost or give them to you."

"And as far as working with the utility, I know RISE and CSG have been fantastic and they'll do all the leg work, paperwork as far as audits..."

"We've seen anywhere from 10-50% savings on insulation projects and gas usage ever since they've been installed."

"I think on the lighting side I think the programs are fantastic as I said earlier."

Issues with Programs: Upon their own volition, some PMs reported issues they have had with the delivery of the statewide utility-sponsored programs. The issues they mention caused them to forego making upgrades and resulted in lost program opportunities.

- **Late or Non-Payment.** Nearly half of the PMs attending both workshops specifically express their frustrations with receiving incentive payments from the PAs. These market actors may have been unaware that the incentive payment may have gone to their contractor rather than to them.

"Most of the time my contractors knew a contact at NSTAR or National Grid, and that's how I got [an incentive payment]. When you call National Grid or NSTAR [for information], you get to contact this number. Please leave a message. Three months later they might get back to you."

"The utility actually [has] not been very reliable with their money, and that would be a disincentive to be part of this program if the utility companies were actually funding you, because they take too much time before they deliver on their promise, and most of the time they reduce the original funding amount that they had promised. So people end up looking for money elsewhere, because they recognize that."

"I'm here today to talk about how difficult it is to get those rebates. It's not an easy task."

"They tell you that they'll give you a rebate but you can't ever get your hands on it."

"My experience with [Implementation Contractor] is they do a great job upfront but there's no post-audit and they don't help you with the rebate… I think, because we don't always have the time to, oh, they need another receipt or the serial number is missing. There [are] stupid reasons why the rebates aren't being awarded."

- **Poor Follow-through and Information Delivery.** PMs have had experiences where the implementation of programs has been difficult to navigate, and have had challenges obtaining program information. *"I think the most difficult problem with these programs is you can't get information. You go around and around and around and around."*

"I requested an energy audit and walk-through, and after I think about two months I finally had someone come out, but I still never got any results from the report, you know, nothing back."

- **Lack of Streamlining:** PMs mention issues with contacting PAs or frustrations coordinating various providers who only provide selected incentives related to the fuel source of the measure.[7]

"I have used Rise Engineering. They're great, however they only do specific. This is what we do. So we had other lighting fixtures that we wanted them to look at. Oh no, we can't do that. We only do this. How about boilers? No, we don't do that. How about solar? No, we don't do that. So you have to sift through all this and figure out who does what and who to call when."

"We had to find someone to install [a measure recommended by a gas company audit], and by the time we were done we spent two, three months on this, and it ended up going nowhere. Only one of the contractors that they [recommended to] us out of the three actually showed up. It took him two months to get us the estimate. I mean it was a nightmare. So we scrapped the project. I don't have all this time to continue running into dead ends. So that actually hurt it for other buildings that I have that wanted it, because I can't go through that process."

Suggestions for Program Improvement: In response to the barriers and frustrations related to the programs, we asked PMs how the programs would need to change to increase their participation.

- **Smooth Follow-through and Provide Information:** PMs ask that the programs be easier to navigate to permit faster and easier implementation, like through turnkey style programs. One PM suggests that case studies would also be helpful to better explain what options are available for a diverse housing stock.

"We need to get [a project] done and move on to the next project and go from there and not [be] spending months researching rebates or having somebody come and this and that when we want to do it [urgently] - I want to do it now while it's on my mind or I've got the money..."

"There [are] too many hoops to jump through especially for smaller owners and smaller properties, it's just not really worth the time and the effort sometimes so I think that to simplify that would be helpful.

"I'd find it interesting maybe if there [were] case studies on particular situations. Like this fellow has many, many buildings at the medium size versus larger buildings, larger size, and I bet there [are] probably some situations that are very consistent where the savings could be made."

- **Increase Gas Incentives:** Many PMs suggest that gas incentives should increase.

"The one area that I would recommend is just better funding of the gas programs and the incentives associated with it. I'd even like to see more incentives for changeover to gas."

"On the gas side I don't think the 50% incremental cost coverage is going to cut it. I don't think it's an incentive that would even make us blink an eye, to be honest with you. I think it needs to be 75% or 100% for it to work. Same thing with outside resets and other gas incentives, they just aren't funded well enough to make us make a decision to move toward efficiency."

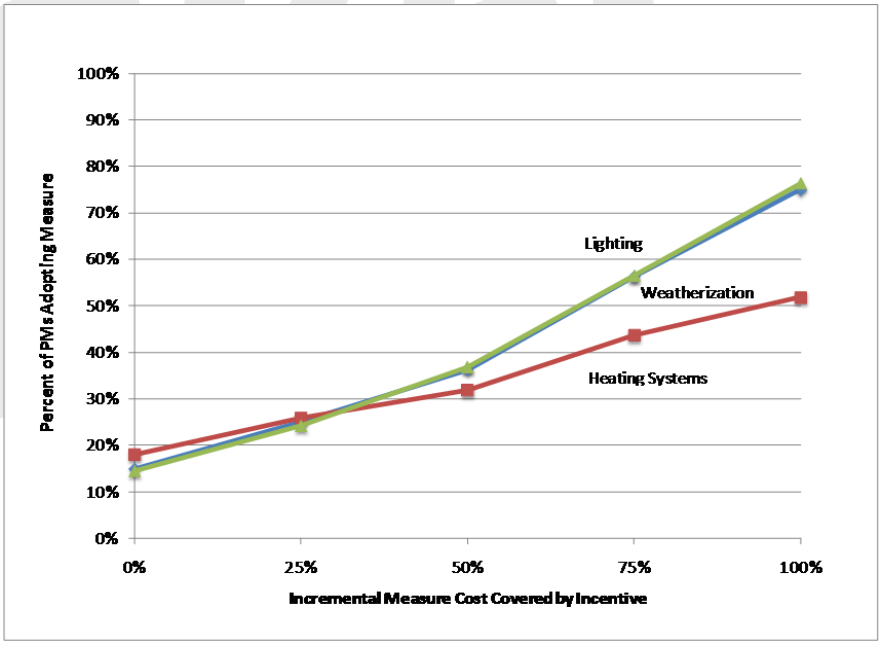
[7] The latter concern regarding coordination of various providers was intended to be remedied with the MA Multifamily Market Integrator implemented in 2010. It is perhaps the case that PMs' experiences occurred prior to this change and that they are not aware of this latest program implementation modification.

Program Administrator Workshop

Measure Adoption Curves

PAs' questionnaire responses lead to curves that are less steep than those of PMs. This indicates that PAs perceive a somewhat more tempered response to incentives in the market. PAs' responses also provide intercepts that are lower than those of the PMs. On average, PAs assume that only about 15% of market actors would implement measures in the absence of program incentives (this is in comparison to the 30 to 50% that PMs assume). However, PAs also provide lower maximum adoption, indicating they perceive greater barriers in the market that are not related to the incentives. For example, at a 100% incentive for lighting and weatherization measures, PAs assume that 25% of market actors would not implement the measures, whereas PMs believe only 10% and 15% of market actors would not do so for lighting and weatherization, respectively. However, the disparity becomes even larger between PAs and PMs with regard to heating systems. While PAs provide nearly identical curves for lighting and weatherization measures, they perceive more barriers with heating systems. PAs believe that nearly half of market actors would not install energy efficient heating systems even with a 100% incentive, while PMs believe only 10% would not do so.

Figure 4. Program Administrator Achievable Potential Curves by Measure



Like PMs, PAs say in the presence of high levels of program marketing, these curves would see an upward shift by 12%, on average, across the measures.

Through our conversations with PAs, they pointed out variables that could heavily impact the shape of the curve. For example, certain segments in the multifamily market might be saturated with a specific measure; as such, one market segment may present a much lower line than another. More so, PAs emphasized the importance of whether or not a building is master-metered. They note that a master-metered building would have a higher curve compared to a sub-metered building, where the

tenants (not the PMs) reap the benefits from measures that reduce the amount of energy used for heating. However, in the case of common area lighting, this variable would not impact the curves.

Barriers to Adoption of Energy Efficient Technologies

We asked PA workshop attendees to provide rationales, measure by measure, for the low perceived maximum adoption. Across all three measures, some barriers mentioned could apply to any of the measures, and are reflective of the challenges implicit in the multifamily market:

Sub-metering: Measures that reduce energy consumption in sub-metered buildings are less attractive for property managers and owners to invest in because they do not reap the benefits or the payback of their investment.

Homeowner Associations: In cases where occupants own the building units (condominiums), the Homeowner Association must approve upgrades. These hurdles often delay and reduce the chances of implementing measures.

Code violations: Property managers and owners are hesitant to invite contractors or auditors into their buildings as it could unveil existing housing code violations that would be costly or time-consuming to remedy.

Measure-specific Challenges: Some of the barriers the PAs discussed were relevant only to specific measures:

- **Furnaces and Boilers:** PAs explain that in the case of furnaces and boilers, the market is less inclined to respond to changes in incentives because of market actors' limited understanding of the available technologies. This insight aligns with the remarks of PMs who express their limited understanding of the available technologies. As a result, PAs believe PMs are more inclined to follow their contractors' perceptions about the value of an energy efficient heating system. If that is the case, we can deduce that contractor buy-in is an important factor in increasing program participation.
- **Weatherization:** Implementers explain that with weatherization work, especially insulation installation, capital investment is often needed to prepare for the installation. They, like PMs, also reference knob and tube wiring as presenting considerable challenges for insulation installation. Additionally, because weatherization work does not just occur in common areas, its installation often disrupts tenants. Tenants often express irritation with these disruptions. Both tenants and owners also have reservations about the potential impact the work may have on indoor air quality.[8]
- **Lighting:** PAs cite various market barriers with lighting upgrade. They, like PMs, believe that market actors have negative perceptions about energy efficient lighting related to its light quality, its potential health implications, and the concern and hassles involved in the disposal of lighting with mercury in it. Technically, energy efficient lighting can also present the challenge of being incompatible with the wiring present in older buildings. PAs

[8] If insulation or sealing work causes the home to be too tightly sealed with little air circulation and fresh air entering, tenants can suffer from poor air quality.

also believe that the lighting market in certain segments, such as public housing, has already been saturated with efficient lighting.

Motivators to Adoption of Energy Efficient Technologies

We asked PAs their perceptions about the drivers of the curves that began with higher intercepts:

Independently High ROI: With regard to furnaces and boilers, PAs explain that these technologies provide high levels of return on investment, and accordingly are likely to attract many adopters. While some PAs point out a high ROI associated with heating systems, the adoption curves they provide for these measures are still lower than those of the other two measures—this most likely reflects other barriers they mention, like lack of awareness of technologies. Of course, in master-metered buildings, property managers are going to also be more inclined to desire to save energy and therefore are less influenced to implement measures offered by the programs.

Going Green: Additionally, PAs perceive that, increasingly, market actors are making upgrades in energy efficient technologies in efforts to gain an accolade as an environmentally conscientious business or entity.

Trust in Contractors: PAs point out that PMs' trust in their contractors heavily dictates the likelihood they will install a measure—with or without the existence of a program. That is, if the contractor says they should do something, they will likely do it, again, irrespective of available incentives. Contractor endorsement of energy efficient technologies, therefore, can be a useful channel towards eliciting adoption of the technologies.

Broken Equipment: As is the case with any market, motivations to upgrade or replace a measure will be influenced by an urgent need (e.g., broken furnace or air conditioning unit, insulation needed to prevent ice dams). In such cases, the participants may be only partially or not at all influenced to adopt the measure because of the existence of the program.

Conclusions

The information and data collected through these workshops will provide valuable input into the Massachusetts Multifamily Potential Study. We will further analyze and integrate this information, together with data collected through the tenant and PM telephone surveys, into the overall potential study results. In addition to feeding into the potential study, the workshops also help to inform our overall understanding of the multifamily market and, specifically, the key barriers and motivations to the adoption of energy efficiency measures in this market. Below, we summarize the workshop findings.

- There are significant market barriers, other than cost, that limit maximum measure adoption in the multifamily market. The largest barriers are initial investment costs, ROI rates, tenant resistance, complications associated with specific measures, sub-metered buildings, and lack of awareness of technologies among PMs. Both groups believe that environmental awareness is a growing motivator, specifically in attracting new tenants.

- PA achievable potential curves are less steep than those of PMs, demonstrating that PAs perceive a somewhat more tempered response to incentives in the market. Moreover, PAs believe less free ridership occurs than do PMs. On average, PAs assume that only about 15% of market actors would implement measures in the absence of program incentives; whereas PMs believe 30 to 50% of market actors would do so. However, PAs also provide lower maximum adoption than do PMs, indicating PAs perceive greater barriers in the market that are not related to the incentives.
- PAs and PMs point out that adoption curves vary based on the metering status of buildings, and market segments related to income and ownership. Adoption curves would be higher in master-metered building than in sub-metered buildings because the PM would reap most of the benefits in a master-metered building. Moreover, PMs explain that condominium associations tend to look for faster ROI than PMs because they have shorter terms of investment in their properties. Also, in situations where the tenants are also the owners, they make the decisions about the equipment as opposed to the PMs.
- While the achievable potential workshops did not set out to evaluate the statewide multifamily program, they inevitably elicited concerns PMs have about the programs. In general, PMs say they have been satisfied with the implementation of the programs; however, many express dissatisfaction with the programs because of issues with payment and difficulties with participation. PMs specifically ask for higher gas incentives, increased program streamlining, and greater program information.

DRAFT

Appendix A: Workshop Questionnaire

Multifamily Program Workshops

May 10-12, Waltham, MA

Respondent Name (Optional):

Date:

DRAFT

BOILERS / FURNACES

Suppose an energy efficient boiler or furnace would cost $5,000 more than a similar standard efficiency unit, but would save about $500 per year on the building's energy bill over the course of the year, or $10,000 over the 20-year lifetime of the unit. Based on your own knowledge and best judgment, what percent of property managers or owners in Massachusetts would install an energy efficient boiler or furnace (when it's already time to replace the existing unit) in the following scenarios?

Additional Cost of Energy Efficient Boiler/Furnace	Annual Savings	Lifetime Savings (20 years)	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Install EE Boiler/Furnace	Comments (Optional)
$5,000	**$500**	**$10,000**	$0	$5,000	10 years	%	
			$1,250	$3,750	7.5 years	%	
			$2,500	$2,500	5 years	%	
			$3,750	$1,250	2.5 years	%	
			$5,000	$0	Immediate	%	

If, in addition to offering monetary incentives, the utilities also aggressively marketed their programs and provided a great deal of technical assistance and outreach to property managers and building owners, do you think the percent installing an energy efficient boiler or furnace would increase? YES _____ NO _____

If YES, by about how much would the numbers you entered above increase on average? +____%

Briefly, other than up-front costs, what do you see as the most important **barriers** to installing energy efficient boilers/furnaces? Why?

_____

_____

Briefly, other than potential financial incentives offered by utilities, what do you see as the most important **incentives** for installing energy efficient boilers and furnaces? Why?

_____

_____

INSULATION, CAULKING, AND SEALING

Suppose energy efficient improvements to a building, including insulation, caulking, and sealing would cost about $10,000 to make, but making these improvements would save about $1,500 per year on the building's energy bill. Based on your own knowledge and best judgment, what percent of property managers or owners in Massachusetts would improve the energy efficiency of a building including adding insulation, caulking, and sealing—over the next five to ten years—in these scenarios?

Cost of Insulation, Sealing, Caulking Improvements	Annual Savings	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Make Insulation, Sealing, Caulking Improvements	Comments (Optional)
$10,000	**$1,500**	$0	$10,000	6.7 years	%	
		$2,500	$7,500	5 years	%	
		$5,000	$5,000	3.3 years	%	
		$7,500	$2,500	1.7 years	%	
		$10,000	$0	Immediate	%	

If, in addition to offering monetary incentives, the utilities also aggressively marketed their programs and provided a great deal of technical assistance and outreach to property managers and building owners, do you think the percent making these improvements would increase?
YES _____ NO _____

If YES, by about how much would the numbers you entered above increase on average? +____%

Briefly, other than up-front costs, what do you see as the most important **barriers** to adding insulation, caulking and sealing? Why?

_____

_____

Briefly, other than potential financial incentives offered by utilities, what do you see as the most important **incentives** for adding insulation, caulking and sealing? Why?

_____

_____

COMMON AREA LIGHTING

Suppose replacing lighting in the common areas of a building would cost $50 to replace one standard efficiency lighting fixture with an energy efficient lighting fixture, but doing so would save about $25 annually on the building's energy bill, or $500 over the 20-year lifetime of the light fixtures. Based on your own knowledge and best judgment, what percent of property managers or owners in Massachusetts would install energy efficient lighting—over the next five to ten years—in these scenarios?

Additional Cost of Energy Efficient Lighting	Annual Savings	Amount Paid for by Utility	Amount Paid for by PM/Owner	Estimated Payback Period	Percent of PM/Owners Likely to Install EE Lighting	Comments (Optional)
$50/Fixture	$25/ Fixture	$0	$50	2 years	%	
		$15	$35	1.4 years	%	
		$25	$25	1 year	%	
		$40	$10	5 months	%	
		$50	$0	Immediate	%	

If, in addition to offering monetary incentives, the utilities also aggressively marketed their programs and provided a great deal of technical assistance and outreach to property managers and building owners, do you think the percent installing energy efficient lighting would increase? YES _____ NO _____

If YES, by about how much would the numbers you entered above increase on average? +____%

Briefly, other than up-front costs, what do you see as the most important **barriers** to installing energy efficient lighting? Why?

_____

_____

Briefly, other than potential financial incentives offered by utilities, what do you see as the most important **incentives** for installing energy efficient lighting? Why?

_____

_____