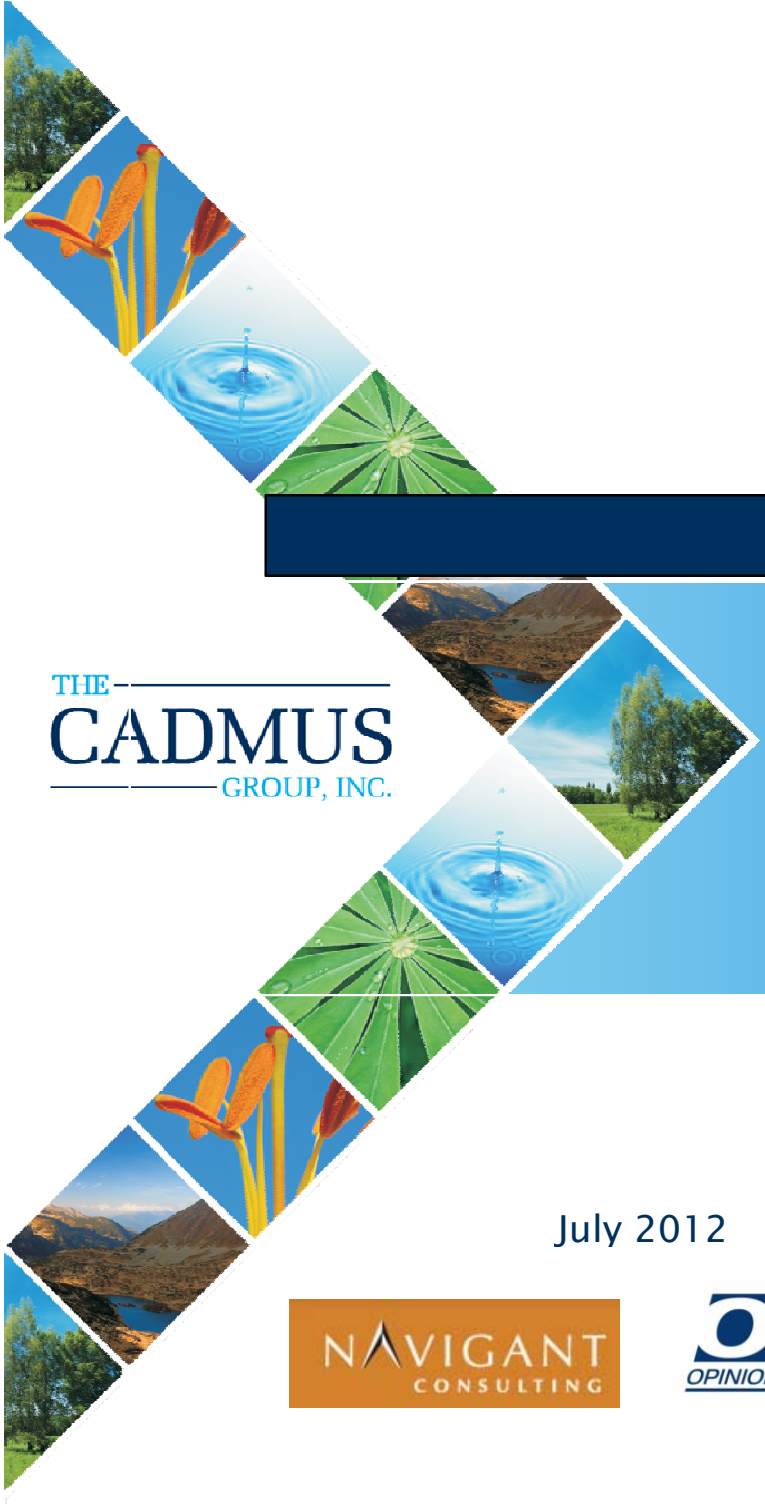

THE CADMUS GROUP, INC.

Massachusetts Multifamily Program Impact Analysis

July 2012

NAVIGANT CONSULTING

ODC OPINION DYNAMICS CORPORATION

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Table of Contents

Acronym Glossary 2

Executive Summary 3

Evaluation Activities and Objectives 3

Findings 3

Conclusions and Recommendations 4

1. Introduction and Objectives 6

Overview of the Massachusetts Multifamily Program 6

Evaluation Activities and Objectives 7

2. Statewide Savings Estimates 9

2.1 Overview 9

2.2 Engineering Review 9

2.3 Steps in the Review Process 10

2.4 Results 12

3. Program Attribution and Related Adjustments 16

3.1 Participating Property Manager/Owner and Tenant/Condo Owner Surveys 16

Property Manager Survey 16

Tenant and Condo Owner Survey 17

3.2 Adjustment Factors 19

3.3 Results 21

4. Conclusions and Recommendations 24

Appendix A. 29

Acronym Glossary

Acronym	Full Name
BCR	Benefit-Cost Ratio
C&I	Commercial and Industrial
CET	Center for Ecological Technology
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CSG	Conservation Services Group
DHW	Domestic Hot Water
EMS	Energy Management System
ERV	Energy Recovery Ventilator
HRV	Heat Recovery Ventilator
MF	Multifamily
MMI	Multifamily Market Integrator
HVAC	Heating, Ventilation, and Air Conditioning
LED	Light-Emitting Diode lamp
MWh	Megawatt hour
PA	Program Administrator
PM	Property Manager
TRM	Technical Reference Manual
WMECO	Western Massachusetts Electric Company

Executive Summary

The Multifamily Program Impact Analysis was conducted by The Cadmus Group Inc. (Cadmus), Opinion Dynamics Corporation, and Itron, Inc. collectively referred to as the Evaluation Team. The analysis addresses the multifamily program activities of the following Program Administrators (PAs) operating in Massachusetts: National Grid, NSTAR, Columbia Gas, Cape Light Compact, and WMECo. We drew the findings, conclusions, and recommendations primarily from a review of each Program Administrator's (PA's) multifamily program tracking data, the measure-specific savings estimates used by the PAs, as well as a related review of program audit data not contained in the program tracking databases. Data collected from the PAs for this analysis covered the period between January 2010 and July 2011.

Evaluation Activities and Objectives

This impact analysis has two primary objectives. First, the goal of the impact work is to provide a set of savings approaches (i.e., algorithms and deemed values) that can be used by all PAs (statewide) in future program years. Second, the analysis collected information to inform program attribution, including the measurement of installation rates, persistence, freeridership, and spillover.

These evaluation efforts began with a thorough review of each PA's Multifamily Program tracking data as well as a related review of program audit data not contained in the program tracking databases (e.g., electronically stored or paper copies). This review was necessary to determine what data are being collected, what data are available, and which data can be used in algorithms to calculate per unit electric and gas savings. For example, if a program audit recommended attic insulation, we attempted to identify the methods the program used to estimate the associated savings and determine if the needed pre- and post-installation data (i.e., R-values, square feet) are available in the tracking database, in a supplemental program database, or in hardcopy audit records.

As part of this effort, we also reviewed the measure-specific engineering savings estimates contained in each PA's program tracking database, and their relationships to the per unit values in PA Benefit-Cost Ratio (BCR) models and to the methods described in the Technical Reference Manual (TRM). We used this information to develop a list of measures in each measure category, the characteristics of those measures (e.g., R-value, watts, size, and flow rates), the quantities of measures installed, and their units-of-measure.

Findings

The major deliverable of this work can be found in Appendix A. For each program measure, this appendix provides information similar to that provided in the TRM, detailing the recommended algorithm, required inputs to be collected during implementation, and underlying assumptions (to calculate algorithm-based assumptions) or deemed values. For each measure, the appendix also provides the justification for the savings approach, such as current application of the algorithm or values within or outside Massachusetts, or data and implementation-related reasons for selecting the approach. Finally, again by measure, the appendix details the data each PA would need to collect and track to calculate savings using the recommended approach.

Conclusions and Recommendations

Below we summarize the Evaluation Team's conclusions and recommendations. For more detail on each of these conclusions and recommendations, refer to Sections 3 and 4 of this report.

- **Savings Estimates.** Appendix A provides a set of revised savings approaches (i.e., algorithms and deemed values) that can be used statewide in future program years. It includes, by measure, detailed algorithms and deemed values, along with the associated assumptions. This appendix is the primary deliverable from the engineering review effort.

- **Attribution Factors and Related Adjustments.** In general, the multifamily program is experiencing excellent installation and persistence rates. Perhaps the biggest challenge in this regard is ensuring that programmable thermostats are used to their full capabilities after installation (i.e., that they remained "programmed"). Freeridership also appears to be well under control, as indicated by an across measure category freeridership rate (i.e., at the program level) of just 18%. Finally, the program appears to be having a very limited impact (at least at this point in time) on the propensity of property managers to go on to take "like-program" efficiency actions in the absence of the program. We found that, expressed as percent of program savings realized by participating property managers, that less than 1% of additional savings (due to spillover) can be attributed to the influence of the Multifamily Program.

- **Participant data is tracked differently by each PA and there are significant gaps in the types of program information being collected and tracked.** The implementer is primarily the one responsible for collecting, tracking, and entering data into the PA's system/database, while data verification and quality control is primarily done by the PA by either verifying the data entered into their system or by entering data from implementer invoices to verify data. Most PAs receive a monthly update of what has been completed by their implementer and what is in the pipeline.

- **Significant gaps exist in program tracking and/or audit data.** A key input to impact analysis is complete program tracking and/or audit data, which includes site characteristics, baseline measure characteristics, installed measure characteristics, and diagnostic test results. In addition, most PAs do not collect or track telephone numbers of customers in the dwelling units that participate in the program. Most PAs also had difficulty providing complete contact information for participating property managers. Evaluation efforts would be aided by comprehensive contact information, including telephone numbers. In addition, baseline conditions are not consistently recorded and tracked by PAs. Existing conditions and existing equipment at the facility and dwelling-unit level are needed to evaluate savings assumptions for many measures and participants.

  Recommendation: Reduce differences in tracking data across PAs. While it is impractical to ask all PAs to use the same database for program tracking purposes, it would be beneficial to bring about more consistencies in how multifamily programs are tracked. Consider forming a working group to establish a common database nomenclature and structure.

  Recommendation: Work to provide more accurate/complete inputs. Important inputs to estimate savings are often incomplete. The systematic collection and recording of the

following information would greatly enhance the ability to verify claimed savings and assess program impacts.

- Universal Facility ID linking accounts to multifamily properties (only National Grid currently has this functionality). Program identifiers are needed at the facility and dwelling-unit levels. Tracking information at a facility level and dwelling-unit level are important for participant surveys and may facilitate keeping track of building characteristics required for impact evaluations.
- Property manager and tenant/condo owner contact information.
- Fully described measure characteristics, such as insulation R-values, equipment size, degrees setback/turndown, and diagnostic test results.
- Baseline/existing equipment conditions and key operational parameters (e.g., pre-retrofit insulation levels, building characteristics, equipment efficiency levels).
- Clearly defined units of measurement (e.g., per square foot, per job, per hour of air sealing).

Recommendation: Update and catalog savings algorithms and sources. Many PAs and implementers were unable to provide documentation to support measure-level claimed savings. To expedite future evaluations, this information (for each PA and implementer) should be centralized and documented. PAs should update their current algorithms and deemed savings values with the primary and alternative savings approaches provided in this report.,

Recommendation: Conduct field research to support multifamily program savings estimates. In some cases, to more accurately estimate measure-level program savings, it may be necessary to obtain up-to-date Massachusetts- and multifamily-specific information via on-site data collection. Table 8 below describes some potential areas for additional research.

1. Introduction and Objectives

This report provides the results of the 2011 Massachusetts Multifamily Program Impact Analysis. The analysis addresses the 2010-2011 Multifamily Program activities of the following utilities operating in Massachusetts: National Grid, NSTAR, Columbia Gas, Cape Light Compact, and WMECo. Other Massachusetts Program Administrators (PAs) either had no formal multifamily program in 2010 and 2011 or were unable to provide the data needed for this analysis.

Overview of the Massachusetts Multifamily Program

The Mass Save® Multi-Family Retrofit Program (Multifamily Program) offers comprehensive energy efficiency services for owners and property managers of multifamily buildings with five or more residential units. The Multi-Family Energy Assessment is performed by a qualified Energy Specialist to identify opportunities throughout the whole facility to maximize energy savings. The measures available to each property vary slightly by each PA, but can include:

- Energy efficient lighting upgrades and controls (e.g., occupancy sensors)
- Domestic Hot Water (DHW) measures (e.g., low flow showerheads, aerators, and pipe wrap)
- Programmable thermostats
- Insulation (e.g., attic, wall, pipe, and rim joist)
- Air sealing
- ENERGY STAR®-rated refrigerators

A number of measures are offered via the Multifamily (MF) Program, but are typically supplied and rebated through other Massachusetts programs, such as the Commercial and Industrial (C&I) Program. These measures include:

- HVAC high-efficiency equipment upgrades and controls
- Variable Speed Drives
- Chillers
- Energy Management Systems (EMS)
- Air compressors
- Water heating equipment, including solar hot water heating systems
- Combined Heat and Power (CHP) Heat Recovery Ventilators (HRV) / Energy Recovery Ventilators (ERV)
- Custom Technologies

Efforts in the last year have aimed to make these measures consistent across all PAs, as well as to standardize measure offerings between master- and individually-metered buildings.

There are four categories of measure incentives depending upon the particular measure and where it is installed, including a) 100% incentive with $0 customer co-pay; b) fixed incentive and customer co-pay per measure; c) incentive expressed as a percentage of the total installed cost; and d) custom incentives based on expected savings.

Overall program goals. The overall goals of the Multifamily Program are to create and increase energy savings among multifamily customers as well as to increase customer awareness of and education in energy saving measures, while providing a seamless and thorough process for customers to participate in the program.

Participation and savings goals. According to the three-year plan, statewide participation and savings goals for both electric and gas have increased steadily since 2010 as shown in Table 1.

Table 1. Multifamily Program Savings Goals (2010-2012)

	2010	2011	2012
Electric Savings Goals (MWh)	14,349	18,992	23,489
Gas Savings Goals (Therms)	355,271	490,127	683,524

As of August 2011 when we interviewed PA representatives, PAs were either on target with their goals for 2011, or were behind their YTD goal. However, those who were behind their goal projected that they would meet their year-end goals due to a substantial amount of projects currently in their pipeline.

Participation in multifamily gas programs has shown increases over last year as awareness of the program has increased since implementing the gas program in mid-2010. PAs indicated that gas participants in 2010 and 2011 were a mix of entirely new buildings to the program and buildings that have previously participated that are coming back for additional measures (i.e., had done electric measure retrofit previously, and are now doing gas measures).

Evaluation Activities and Objectives

This impact analysis has two primary objectives. First, to provide a set of savings approaches (i.e., algorithms and deemed values, including installation rates and persistence) that can be used by all PAs (statewide) in future program years. Second, the evaluation collected information to inform program attribution, including freeridership, and spillover.

The remainder of this document is divided into three sections. In Section 2, we outline the research approach and associated results related to the provision of statewide savings estimates (i.e., algorithms or deemed values). In Section 3, we outline the methodology and present the results pertinent to program attribution and other adjustment factors. Finally, in Section 4, we provide an overall report summary including recommendations that will serve to enhance PAs' ability to track, report, and evaluate future program outcomes. In addition to these sections, we provide an extensive appendix (Appendix A) that provides all of the important details, by measure, for each of the recommended statewide savings algorithms.

2. Statewide Savings Estimates

As a prerequisite to establishing savings estimates, the Evaluation Team conducted a thorough review of each PA's multifamily program tracking data as well as a related review of program audit data not contained in the program tracking databases (e.g., electronically stored or paper copies). This review was necessary to determine what data are being collected, what data are available, and which data can be used in algorithms to calculate per unit electric and gas savings. For example, if a program audit recommended attic insulation, we attempted to identify the methods the program used to estimate the associated savings and determine if the needed pre- and post-installation data (i.e., R-values, square feet) are available in the tracking database, in a supplemental program database, or in hardcopy audit records.

As part of this effort, we also reviewed the measure-specific engineering savings estimates contained in each PA's program tracking database, and their relationships to the per unit values in PA BCR models and to the methods described in the TRM. We used this information to develop a list of measures in each measure category, the characteristics of those measures (e.g., R-value, watts, size, and flow rates), the quantities of measures installed, and their units-of-measure. In general, we found that while many of the important measures' characteristics are present in program participant tracking data, not all PAs were able to provide multifamily program participant tracking data and audit data files, and data provided often did not fully describe characteristics of either baseline or installed, retrofit measures.

2.1 Overview

A key objective of this impact analysis is to provide PAs with a single set of revised savings estimates (i.e., algorithms, deemed values), by measure, that can be used statewide in future program years. While the methodology and approach used to address this research objective is outlined in this section, the major deliverable can be found in Appendix A. This appendix provides, by measure, information similar to that provided in the TRM, detailing the recommended algorithm, required inputs to be collected during implementation, and underlying assumptions (to calculate algorithm-based assumptions) or deemed values. For each measure, the appendix also provides the justification for the savings approach, such as current application of the algorithm or values within or outside Massachusetts, or data and implementation-related reasons for selecting the approach. Finally, again by measure, the appendix details the data each PA would need to collect and track to calculate savings using the recommended approach.

2.2 Engineering Review

For all PAs, the Evaluation Team conducted an engineering review of the algorithms[1] and deemed savings estimates currently used to derive measure-level savings. The primary purpose of the review was to ensure that the most accurate assumptions and local sources are being used and that per measure (or measure category), savings are not being over or under estimated.

[1] Existing algorithms used by PAs may be formula-based algorithms, or per-unit deemed values. We use the general term "algorithm" to refer to many types of savings estimation approaches, which may be as simple as multiplying a deemed per-unit value by quantity, or entail a complex formula with multiple site-specific inputs.

A key input to this review was the provision of program tracking and/or audit data, which includes site characteristics, baseline measure characteristics, installed measure characteristics, and diagnostic test results. This information was specifically requested in data requests to all PAs. Documentation of savings algorithms and deemed value inputs were also critical to the analysis as many PAs use savings algorithms that are not explained in the Massachusetts TRM.

For every measure or measure category listed in the PA's BCR tool (that generated savings during the analysis period), the engineering analysis began with a review of the measure-specific engineering savings estimates contained in each PA's program tracking database, and their relationships to methods described in the TRM. The analysis assessed relative strengths of the deemed values and assumptions informing savings algorithms.

The engineering analysis examined electric and gas savings associated with the following program measures:

- Lighting (Fixtures, Compact Fluorescent Lamps [CFLs] and Occupancy Sensors)
- Refrigerators
- Insulation
- Air Sealing
- Programmable Thermostats
- Heat Pump Tune-Up
- DHW (Showerheads and Aerators)
- DHW (Tank and Pipe Wrap)

2.3 Steps in the Review Process

Below, we outline and describe the specific steps in the engineering review process:

Step 1: Grouping Measures into Categories

This step involved identifying the unique list of measures that are offered by each utility and grouping them into measure categories. We grouped measures into categories for two main reasons: 1) so we could evaluate them together, as most of the measures in the group are likely to have similar algorithms and assumptions; and 2) to standardize the measure categories so that all five utilities can use them.

Step 2: Verify Current Algorithms

We looked at each measure category individually and evaluated it based on the available data. This process included reviewing the existing savings algorithms, deemed values (if used), and sources of the deemed input variables that go into each algorithm. In addition to assessing whether current approaches can be validated, the verification process compared the different approaches taken by the PAs[2] to strengthen our understanding of how approaches are used statewide.

[2] In many cases, deemed input variables had no verifiable source. In other cases, for some utilities, it was not clear where their savings algorithms came from, so we had to examine several different sources,

Step 3: Review Third Party Reports and Documents

We reviewed third party algorithms from other Technical Resource Manuals or from recent studies to get another perspective of how various jurisdictions calculate savings for similar measures. These reviews included both local sources (within Massachusetts or New England utilities), as well as outside sources like the Database for Energy Efficient Resources (DEER), the Ohio TRM, and the New York TRMs.

Step 4: Analyze Program and Outside Data

Along with the review of third party reports and documents, we reviewed program data and the sources of program assumptions. If the program tracking data or secondary sources did not support the use of existing assumptions, the team identified alternative sources for deemed values or inputs. In many cases, at least some of the PAs collect comprehensive baseline and retrofit measure information to calculate savings. In these cases, we were able to develop values to use as direct inputs to algorithms. In addition, the team considered "other" sources of data such as weather data to create heating degree day and cooling degree hour information specific to the region.

When reviewing the various sources, the team considered the following questions/issues:

- History of assumptions – Are the referenced sources recent?
- Robustness – How rigorous is the study that provided the supporting data?
- Regional appropriateness – Is the option/value appropriate for Massachusetts?
- Transparent and traceable – Are the calculations all present, and are the reference sources for key parameters or factors all publicly available?
- Ability to evaluate – Can the key assumptions be updated by evaluation?

Step 5: Formulate Primary Savings Recommendations

Based on the review of current algorithms and deemed input variables used by the Massachusetts PAs, and those used by other utilities and in outside reports, we developed a primary savings algorithm along with deemed input variable recommendations. We recommend that these algorithms and assumptions be used by the utilities going forward, to provide clear and traceable sources, and to standardize the savings assumptions throughout the state.

Step 6: Formulate Alternative Savings Algorithms

Our review of available program data suggested that some of the recommended primary algorithms require inputs that are not currently being collected or documented by all PAs and implementation contractors (e.g., existing insulation levels or pre-audit air infiltration rates). Therefore, we developed an alternative approach with a greater reliance upon deemed input values and default assumptions. The alternative approach can be applied in cases where the requisite level of detailed data – needed to apply the primary algorithm – is not available in the PAs' underlying databases.

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including algorithm documents provided by implementation contractors and the TRM. Identifying the actual approach used by some PAs took a considerable amount of time because the team had to test different algorithms and input values in an attempt to replicate various PAs' savings estimates. The approach was successful for some, but certainly not all, measures.

These alternative approaches generally apply deemed value assumptions in place of site-specific baseline data inputs. Where baseline data were available for one or more PAs, but not all, we leveraged the available baseline data to develop deemed input values for use in calculating savings in place of site-specific baseline data. These values can be used in future program years by those utilities that do not have the ability to collect the recommended inputs during their audits.

Step 7: Traceable Sources

This last step in the process was a final check of the first six steps. The step involved ensuring – by essentially double checking past steps – that clear and traceable sources are provided for all recommended algorithms and deemed savings values. Most importantly, this step ensured that these traceable sources are relevant to the Commonwealth of Massachusetts and multifamily properties.

2.4 Results

Significant variations exist between the types of data collected and maintained by each of the Massachusetts PAs implementing multifamily programs. In addition, the methods used to estimate program savings vary between PAs and are not always documented – neither in the Massachusetts TRM nor elsewhere. Despite these challenges, the project team was able to provide a set of revised savings approaches (i.e., algorithms and deemed values) that can be used statewide in future program years. The detailed recommended savings algorithms, deemed input values (for alternative savings approach), associated assumptions, citations of all sources and discussion of future research for all the measures can be found in Appendix A. This appendix is the primary deliverable from the engineering review effort.

The results cannot be summarized in a manner that compares savings across the different PAs for different measure categories. The variation in savings calculations, units of measure, and methods of tracking being used by the PAs make this comparison impossible to summarize in a table for each PA. This detailed information is provided in Appendix A. Table 2, below, provides a summary of the proposed primary and alternative savings approaches for each measure category and each fuel type.

Table 2. Summary of Proposed Savings Approaches

Measure Category	Primary Algorithm	Alternative Approach
Lighting – CFLs	$\Delta kWh = \frac{N \times (Watts_{pre} - Watts_{post}) \times Hrs}{1{,}000} XISR$	$\Delta kWh = \frac{N * (Watts_{post}) \times \Delta WattsMult \times Hrs}{1{,}000} XISR$
Lighting – Linear Fluorescents	$\Delta kWh = \frac{((N_{pre} * Watts_{pre}) - (N_{post} * Watts_{post})) \times Hrs}{1{,}000}$	Same algorithm, but deemed values are provided for baseline wattage and operational hours.
Lighting – LED Exit Signs	$\Delta kWh = \frac{n \times (Watts_{pre} - Watts_{post}) \times Hrs}{1{,}000}$	Same algorithm but, some deemed input values are provided.
Lighting – Metal Halides	$\Delta kWh = \frac{((N_{pre} * Watts_{pre}) - (N_{post} * Watts_{post})) \times Hrs}{1{,}000}$	Same algorithm, but deemed values are provided for baseline wattage and operational hours.
Lighting – Occupancy Sensors	$\Delta kWh = \frac{(Watts_{controlled}) \times Hrs \times svg}{1{,}000}$	Same algorithm, but some deemed input values are provided.
Refrigerators	*Refrigerator Recycling* $\Delta kWh = \left[\left((kWh_{pre} - kWh_{std})\right) \times \frac{(12-8)}{12} + \left((kWh_{std} - kWh_{ES})\right) \times \frac{8}{12}\right] \times F_{occ}$ *No Recycling* $\Delta kWh = (kWh_{std} - kWh_{ES}) \times F_{occ}$	Same algorithm, but some deemed input values are provided.
Attic, Basement, Wall Insulation (gas)	$MMBtu_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}}$	Same algorithm, but some deemed input values are provided.
Attic, Basement, Wall Insulation (electric)	*Air Conditioning Savings:* $kWh_{annual} \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times CDH \times DUA \times Area}{1{,}000\ Btu/kBtu \times \eta_{cool}}$ *Electric Heating Savings:* $kWh_{annual} \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}} \times 293.1$	Same algorithm, but some deemed input values are provided.
Other Insulation (electric)	Deemed annual savings for No-AC with ER heat = 124 kWh Deemed annual savings for AC and ER heat = 136 kWh. Deemed annual savings for HP = 117 kWh Deemed annual savings for AC-Only= 12 kWh	
Other Insulation (gas)	Deemed annual MMBtu savings = 1.1 MMBtu.	
Air sealing (electric)	$\Delta kWh = \frac{Vol \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{3413}$	Same algorithm producing a deemed savings approach per 1000 ft^2 based on zip code and heating type
Air Sealing (gas)	$\Delta MMBtu = \frac{Vol \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{1{,}000{,}000}$	Same algorithm producing a deemed savings approach per 1000 ft^2 based on zip code and heating type
Thermostats (electric)	Deemed annual savings for No-AC with ER heat = 257 kWh Deemed annual savings for AC and ER heat = 281 kWh. Deemed annual savings for HP = 241 kWh Deemed annual savings for AC-Only= 25 kWh	
Thermostats (gas)	Deemed annual MMBtu savings = 2.3 MMBtu.	
Heat pump tune-up	$kWh = tons \times 12 \frac{kBtuh}{ton} \times \left(\frac{1}{SEER} \times Hours_{cooling} + \frac{1}{HSPF} \times Hours_{heating}\right) \times \%savings$ $kWh = kBtuh \times \left(\frac{1}{SEER} \times Hours_{cooling} + \frac{1}{HSPF} \times Hours_{heating}\right) \times \%savings$	ΔkWhdwelling = 180 kWh ΔkWhCommonArea = 325 kWh
Aerators (electric)	Deemed annual kWh savings = 41.7 kWh.	
Aerators (gas)	Deemed annual MMBtu savings = 0.36 MMBtu.	
Showerheads (electric)	Deemed annual kWh savings = 55.6 kWh.	
Showerheads (gas)	Deemed annual MMBtu savings = 0.48 MMBtu.	
Pipe Wrap (electric)	Deemed annual kWh savings = 55.6 kWh	
Pipe Wrap (gas)	Deemed annual MMBtu savings = 0.48 MMBtu.	
Tank Wrap (electric)	$\Delta kWh = kWh_{base} \times \left(\frac{EF_{new} - EF_{base}}{EF_{new}}\right)$	Deemed savings per wrap = 31.5 kWh

As shown in Table 2, for most of the measures, an algorithm is proposed as the primary savings method. For many of the measures, the alternative savings method uses the primary algorithm with some deemed input variables provided in the event that the PAs are unable to collect the required information to utilize the primary savings algorithm.[3] For several of the measures with lower savings levels, a deemed approach has been recommended. Using the deemed savings approach for measures with lower savings levels will result in a simplified methodology for all PAs to both standardize their savings claims and ensure appropriate measure level savings.

[3] For the majority of the secondary proposed methods, the input deemed values are derived from Massachusetts data. For example, the deemed input values for baseline wattage and lighting hours of use are derived from National Grid data.

3. Program Attribution and Related Adjustments

In addition to revised savings estimates, a key objective of the impact analysis of the Multifamily Program is to provide attribution and related adjustment factors that PAs can use to inform future program design. It is important to note that this deliverable is not intended to be the definitive source of information regarding savings adjustments going forward. Rather, it is designed to provide insight into program attribution issues, toward the goal of contributing to future program planning. Subsection 3.1 and 3.2 describe the surveys that were implemented to inform the various adjustment factors as well as the process (or algorithms) used to determine the actual values. Results of the analysis can be found in subsection 3.3 (Results).

3.1 Participating Property Manager/Owner and Tenant/Condo Owner Surveys

To inform both the process evaluation and impact analysis, we conducted telephone surveys of property managers and building owners, as well as tenants and condo owners in buildings participating in the Multifamily Program. The primary purpose of these surveys was to inform the process evaluation, the results of which are provided in a separate report; however, the surveys also took advantage of the contact with these program stakeholders to collect information on program attribution and related adjustments. The survey instruments and summary of responses are presented in Appendix B and C of the MA RRLI Multifamily Process Evaluation report.

Property Manager Survey

We interviewed property managers and building owners who had participated in the Multifamily Program in 2010 or through July of 2011 for both the process evaluation and impact analysis. After requesting multifamily participant information and property manager contact information from each PA, we were able to draw the survey sample from data received from NSTAR, National Grid, and Cape Light Compact. We identified phone numbers for 360 of 419 participating facilities. As shown in Table 3 below, following the removal of 73 duplicates that existed in the lists, our total sample frame consisted of 287 unique property managers or owners, all of which we attempted to interview.

Table 3. Survey Sample Frame

PA	Total Sample Frame
NSTAR	156
National Grid	195
Cape Light Compact	9
Multiple (Duplicates)	(73)
Total	287

We implemented the survey by telephone between January 9 and 18, 2012. As shown in Table 4, we completed 63 interviews covering 63 different properties.

Table 4. Call Disposition by Sample Frame

Disposition	Total Contacts	Percent Sample Frame
Refusal (R)	90	31%
Interviewed (I)	63	22%
Answering machine (U)	56	20%
Call back (NC)	27	9%
Customer said it was wrong number (e)	22	8%
Bad number/busy/disconnected/computer tone (e)	17	6%
No answer (U)	6	2%
Residential phone (e)	5	2%
Language problem (NC)	1	0%
Total	287	100%

We calculated the response rate using the standards and formulas set forth by the American Association for Public Opinion Research (AAPOR),[4] specifically, AAPOR Response Rate 3 (RR3). RR3 includes an estimate of eligibility for these unknown sample units. The formulas used to calculate RR3 are presented below. Table 3 above, displays the definitions of the letters used in the formulas.

$$E = (I + R + NC) / (I + R + NC + e)$$

$$RR3 = I / ((I + R + NC) + (E*U))$$

The overall response rate for the property manager survey was 27%.

Tenant and Condo Owner Survey

Using phone numbers in the PA customer account databases, we drew a sample of customers living in participating multifamily properties. For NSTAR, Cape Light Compact, Columbia Gas, and WMECo, account numbers of participating units are tracked in participant data, so we were able to match phone numbers from account databases to participant account numbers. For National Grid, the program does not track individual accounts that receive program treatment, so we used a list of all account numbers associated with the facilities that participate in the program. For each PA, we matched account numbers with 2010 and 2011 customer account databases, and found phone numbers for 52% of accounts. We also used customer account databases to combine electric and gas records across unique households. As shown in

Table 5, following the removal of 16,620 accounts without phone numbers, the consolidation of accounts across electric and gas (resulting in 17,276 unique accounts) and the removal of 2,025 duplicates, our total sample frame consisted of 15,246 unique customers in participating multifamily properties, from which we drew a random sample of 2,824 customers.[5]

Table 5. Survey Sample Frame

[4] *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys*, AAPOR, 2009. http://www.aapor.org/Standard_Definitions/1818.htm

[5] 2,415 pieces of sample were actually used.

PA		Account Numbers	Unique Customers with Phone Number	Sample Frame (Non-Duplicate Unique Customers with Valid Phone Numbers)
NSTAR	Electric	8,701	5,633	5,147
	Gas	825		
National Grid[6]	Electric	20,218	11,446	10,159
	Gas	4,575		
Cape Light Compact		97	89	89
Columbia Gas		140	67	64
WMECo		50	41	41
Total		34,606	17,276	15,246

We implemented the survey by telephone between January 17 and 22, 2012. As shown in Table 6, we completed 73 interviews. Using the AAPOR RR3, we calculated the overall response rate for the tenant/condo owner survey as 5%.

Table 6. Call Disposition by Sample Frame

Disposition	Total Contacts	Percent Sample Frame
Refusal (R)	503	21%
Interviewed (I)	73	3%
Answering machine (U)	338	14%
Call back (NC)	121	5%
Customer said it was wrong number (e)	159	7%
Bad number/busy/disconnected/computer tone (e)	443	18%
No answer (U)	741	31%
Business phone (e)	11	0%
Language problem (NC)	26	1%
Total	2,415	100%

3.2 Adjustment Factors

In this subsection, we outline the approach used to address program attribution and determine related adjustment factors. As previously stated, these estimates are not intended to be the definitive source of information with respect to program attribution and spillover. Rather, they are provided to gain insight into, and contribute toward, future program design considerations.

Measure Installation and Persistence. The property manager and tenant surveys included a set of questions (self-reports) to measure installation rates and persistence. Installation rates

[6] National Grid participant counts may overstate the number of program participants, because program tracking is at a facility level rather than individual account level; therefore, counts represent the total number of accounts – including common area accounts and units that may not have been treated -- in all multifamily facilities that participated in the program. Other PAs did not appear to track participation at this level.

were exclusively determined through the property manager survey since property managers are the primary program participant (i.e., in most cases, they authorize and oversee both the common-area and in-unit installations). With respect to persistence, property manager survey results were used to assess common-area measures and CFLs while tenant survey results were generally used to assess in-unit measures (e.g., lighting fixtures in tenant spaces, faucet aerators, showerheads, programmable thermostats). We asked tenants about in-unit measures because they are in the best position to report whether or not a given measure is still installed. For programmable thermostats, we also asked tenants if the thermostat was programmed (as installation alone does not guarantee savings). Finally, while we asked property managers if insulation and air sealing was completed (to determine installation rates), we did not explore measure persistence for this measure because it is assumed that insulation and air sealing – once installed – is highly unlikely to be removed.

Attribution. Another element of the analysis was to estimate net-to-gross savings factors that the PAs can use as an input to future program planning. The property manager and tenant surveys, where applicable, were used to develop self reported freeridership at the measure-category and program level for the more common program measures (i.e., CFLs in common areas, CFLs in tenant spaces, lighting fixtures in common areas, lighting fixtures in tenant spaces, insulation and air sealing, aerators and showerheads, and programmable thermostats). Freeriders are program participants who would have implemented the incented energy efficient measure(s) even without the program. Estimates of freeridership are based on a series of questions in both the property manager and tenant surveys that explore the influence of the program on the decision to take action through the program as well as likely actions had the incentive not been available.

Because it is primarily property managers who drive participation and the installation of energy efficiency measures in both common areas and tenant spaces, the property manager surveys are the source of input to freerider estimation. The only exception to this is for CFLs installed in dwelling units, where tenants and condo owners were asked to comment on the likelihood that they would have installed CFLs in their unit in absence of the program. Each freeridership rate consists of three scores that, as described below, are ultimately averaged together to arrive at measure-level freeridership. These scores include:

(PI) Program Influence Score. The PI score is based on two survey questions. The first question asks respondents to rate the likelihood that they would have installed the measure at all in the absence of the program. Greater importance of the program means lower level of freeridership. The second question asks respondents to compare the number or amount of each measure that they would have installed on their own to what was installed through the program. The fewer the measures that they would have installed on their own, the lower the freeridership.

PI (Likelihood) = (likelihood of installing without program on 0-10 scale) / 10

PI (Adjustment) = (% installation without program)/100

PI = PI (Likelihood) * PI (Adjustment)

(PC) Program Components Score. The PC score is based on a series of three questions. These questions ask respondents to rate the importance of three program components, on a scale of 0 to 10 (where 0 is not at all important and 10 is extremely important): the financial incentives (i.e., free, discounted, or rebated measures); recommendations from the auditor, contractor, or Mass Save representative; and information from the multifamily program marketing materials. This score is equal to the inverse of the highest rating given to any one of these components. Greater importance of the program components means lower level of freeridership.

PC = [(max [Importance of factors influencing decision to install: a. financial incentives, b. auditor/contractor recommendations, c. program information and marketing materials]) – 10/10] * (-1)

(PT) Program Timing Score. The PT score is developed based on three questions: 1) if the respondent was thinking about installing any of the measures when they learned about the multifamily program; 2) if the measure would have been installed at the same time without the program; and 3) if the measure would have been installed later, respondents are asked when it would have been installed. Later installation without the program means lower level of freeridership.

If you had not participated in program, when would you have installed the measure?

Same time:	PT = 1.0
within 6 months:	PT = 0.75
6 months to 1 year:	PT = 0.50
1-2 years later:	PT = 0.25
2+ years later:	PT = 0

Overall Freeridership Score

Each score (PI, PC, PT) can take on a value of 0 to 1, where a higher score means a higher level of freeridership. The overall F.R. factor for each measure is the average of the three scores (program influence, components, and timing).

F.R. = Mean (PI, PC, PT)

In cases where the tenants pay for their electricity use (the majority of survey responses), the freeridership rate for in-unit CFLs was based upon the tenant survey. And, this freeridership rate was based on the Program Influence (PI) and Program Timing (PT) scores only. This is because the program is aimed at property managers and, therefore, the tenants are unlikely to be aware of the program components (i.e., financial incentives, auditor/contractor recommendations, program information, and marketing materials) that are typically directed only at property managers and owners. It should also be noted that property manager responses to the in-unit CFL questions

were only used in those cases where the property manager indicated electricity bills are included in the tenant's rent or association fees.

Spillover. Both the property manager and tenant surveys included a battery of qualitative questions to develop a program-level spillover factor. These questions include whether the property manager or tenant took any other actions on their own to improve the energy efficiency of the facilities they manage (or unit they occupy) and, if so, what specifically they did and how much influence the Multifamily Program had on their decision to take these actions (on a 0-10 scale). Savings values (kWh, therms) were assigned to each respondent who indicated a program influence rating greater than 5.

3.3 Results

Table 7 provides the results of the analysis of survey data to determine installation rates, persistence, and freeridership. While we attempted to interview every participating multifamily property manager for which we were able to get contact information, as shown below, the number of completed interviews are sufficient to definitively estimate program attribution overall, but are not sufficient to provide high levels of precision at the individual measure level. Key findings from the table include:

- **High Installation Rates.** With the exception of common area CFLs, installation rates are generally close to 100%. Lighting measures had an installation rate of 96%, with a precision level of ±17% at the 90% confidence level. All measures had a rate of 97%, with a precision of ±13% at the 90% confidence level.
- **High Persistence Rates.** Similar to installation rates, we found that most installed measures continue to be installed. Programmable thermostats had, by far, the lowest overall persistence rate (at 69%). This is because the measure was only considered to still be installed (and thus "persist" in its use and savings) if the unit occupant indicated that the thermostat was, indeed, programmed. However, overall persistence for lighting measures and all measures, were 100% ±1% and 100% ±5%, respectively, at the 90% confidence level.
- **Modest Freeridership.** As illustrated in Table 7, freeridership rates range from a low of 12% (for dwelling unit CFLs where the landlord pays the electricity bill) to a high of 31% (for common area CFLs). The sole exception to freeridership falling within this range is for dwelling unit CFLs where the occupant pays the electricity bill. For this measure, which happens to be the only measure where freeridership is based on the tenant survey, freeridership is 51% – meaning that tenants reported that they were highly likely to install CFLs in their unit in the absence of the program.

Table 7. Measure Installation, Persistence, and Freeridership

Measure	PA Data Source	Installation Rate	Persistence Rate	FR (Weighted)	FR (n)
Common Area CFLs	All (except NSTAR)	91%	100%	31%	9
Dwelling CFLs	All (except NSTAR)	98%	99%	12%	3[1]
Dwelling CFLs	All (except NSTAR)	98%	99%	51%	49
Other CFLs	NSTAR	89%	100%	27%	6
Common Area Lighting Fixtures	All PAs	100%[2]	99%	20%	27
Dwelling Lighting Fixtures	All PAs	99%	100%	16%	31
Total Lighting (except CFLs in units where the occupant pays the electric bill)		96%	100%[3]	18%	63
Insulation/Air Sealing	All PAs	100%	100%	19%	22
Showerheads	Showerheads and aerators combined	100%	93%	15%	15
Aerators	Showerheads and aerators combined	100%	96%	15%	15
Programmable Thermostats	All PAs	100%	69%[4]	24%	20
Total (All)		97%	100%[3]	18%	63

1. For property managers that pay for dwelling electricity; 2. One respondent reported installing more measures than PA participant tracking data, 100% assumes respondent recall was inaccurate; 3. PM and Tenant combination 4. Installed and programmed;

Based on PM Survey Responses

Based on Tenant/Condo Owner Survey Responses

In addition to computing freeridership at a measure level, we also computed it across all measure categories (i.e., at the program level). We found freeridership across all measure categories to be 18%, with a precision level of ±18% at the 90% confidence level. We also had adequate case counts to compute freeridership and precision for dwelling CFLs (as reported by occupants) and the entire "lighting" category. As indicated in Table 7, freeridership for dwelling unit CFLs (as reported by occupants who pay their own electric bill) was 51%. This estimate has a precision of ±13% at the 90% confidence level. Freeridership across the entire lighting category (weighted by savings and including all lighting measures except CFLs in units where the occupant pays the electric bill) is 18%, with a precision of ±18% at the 90% confidence level.

In addition to the parameters illustrated in Table 7, the Evaluation Team also explored program-related spillover. Of the 63 property managers that were interviewed, just five indicated that they had taken relatively modest actions to save energy outside the program (involving measures that are similar to those promoted through the program) due to their program experience.[7] For four of the five, this involved sealing windows and/or doors while the other involved adding insulation.

[7] Only measures that were similar to those incented through the program were considered in this spillover calculation. Those respondents who indicated they took a "like-program" action and gave a 6 or higher rating to the influence that the program had on their decision to take the additional action are included in the spillover estimate. The rating was on a scale of 0 to 10, with 0 meaning the program was "not at all influential" in their decision to take the additional action(s) and 10 meaning the program was "extremely influential" in their decision to take the additional action(s).

Expressed as a percentage of the total program savings realized across property manager respondents, the spillover is 0.28% for kWh and 0.45% for therms. This means that for every kWh or therm saved by property manager participants through the program, they went on to realize a negligible amount of additional savings on their own (by taking actions similar to those incented through the program who were influenced by their program participation).

4. Conclusions and Recommendations

Significant variations exist between the types of data collected and maintained by each of the Massachusetts PAs implementing multifamily programs. In addition, the methods used to estimate program savings vary between PAs and are not always documented – neither in the Massachusetts TRM nor elsewhere. Despite these challenges, this impact analysis provides several deliverables of value to the Massachusetts PAs in administering their multifamily programs. First, as a central objective of the analysis, it provides a set of revised savings approaches (i.e., algorithms and deemed values) that can be used statewide in future program years. This resulted in a single per-unit value or algorithm and associated assumptions and deemed input values for every measure category used in the program BCR for use by all PAs. An "alternative" method/value was also provided in those situations where the requisite level of detailed data – needed to apply a particular algorithm or value – is not available in the PA's underlying database. Second, the analysis provides a set of program attribution and related adjustment factors using property manager and tenant surveys – to estimate measure level in-service (install) rates, persistence, freeridership, and spillover – that can be used by PAs to inform future program design.

- **Savings Estimates.** Appendix A provides a set of revised savings approaches (i.e., algorithms and deemed values) that can be used statewide in future program years. It includes, by measure, detailed algorithms and deemed values, along with the associated assumptions. This appendix is the primary deliverable from the engineering review effort.
- **Attribution Factors and Related Adjustments.** In general, the multifamily program is experiencing excellent installation and persistence rates. Perhaps the biggest challenge in this regard is ensuring that programmable thermostats are used to their full capabilities after installation (i.e., that they remained "programmed"). Freeridership also appears to be well under control, as indicated by an across measure category freeridership rate (i.e., at the program level) of just 18%. Finally, the program appears to be having a very limited impact (at least at this point in time) on the propensity of property managers to go on to take "like-program" efficiency actions in the absence of the program. We found that, expressed as percent of program savings realized by participating property managers, that less than 1% of additional savings (due to spillover) can be attributed to the influence of the Multifamily Program.

This impact analysis effort presented a number of challenges that the Massachusetts PAs should consider addressing in the future. Recommended adjustments or improvement to current processes or information sources include:

- **Participant data is tracked differently by each PA and there are significant gaps in the types of program information being collected and tracked.** The implementer is primarily the one responsible for collecting, tracking, and entering data into the PA's system/database, while data verification and quality control is primarily done by the PA by either verifying the data entered into their system or by entering data from implementer invoices to verify data. Most PAs receive a monthly update of what has been completed by their implementer and what is in the pipeline.

- **Significant gaps exist in program tracking and/or audit data.** A key input to impact analysis is complete program tracking and/or audit data, which includes site characteristics, baseline measure characteristics, installed measure characteristics, and diagnostic test results. In addition, most PAs do not collect or track telephone numbers of customers in the dwelling units that participate in the program. Most PAs also had difficulty providing complete contact information for participating property managers. Evaluation efforts would be aided by comprehensive contact information, including telephone numbers. In addition, baseline conditions are not consistently recorded and tracked by PAs. Existing conditions and existing equipment at the facility and dwelling-unit level are needed to evaluate savings assumptions for many measures and participants.

(1) Recommendation: Reduce differences in tracking data across PAs. While it is impractical to ask all PAs to use the same database for program tracking purposes, it would be beneficial to bring about more consistencies in how multifamily programs are tracked. Consider forming a working group to establish a common database nomenclature and structure.

(2) Recommendation: Work to provide more accurate/complete inputs. Important inputs to estimate savings are often incomplete. The systematic collection and recording of the following information would greatly enhance the ability to verify claimed savings and assess program impacts.

- Universal Facility ID linking accounts to multifamily properties (only National Grid currently has this functionality). Program identifiers are needed at the facility and dwelling-unit levels. Tracking information at a facility level and dwelling-unit level are important for participant surveys and may facilitate keeping track of building characteristics required for impact evaluations.
- Property manager and tenant/condo owner contact information.
- Fully described measure characteristics, such as insulation R-values, equipment size, degrees setback/turndown, and diagnostic test results.
- Baseline/existing equipment conditions and key operational parameters (e.g., pre-retrofit insulation levels, building characteristics, equipment efficiency levels).
- Clearly defined units of measurement (e.g., per square foot, per job, per hour of air sealing).

(3) Recommendation: Update and catalog savings algorithms and sources. Many PAs and implementers were unable to provide documentation to support measure-level claimed savings. To expedite future evaluations, this information (for each PA and implementer) should be centralized and documented. PAs should update their current algorithms and deemed savings values with the primary and alternative savings approaches provided in this report.

(4) Recommendation: Conduct field research to support multifamily program savings estimates. In some cases, to more accurately estimate measure-level program savings, it may be necessary to obtain up-to-date Massachusetts- and multifamily-specific information via on-site data collection. Table 8 below describes some potential areas for additional research.

Table 8. Recommended Future Research on Measure Impacts

Measure	Electric	Gas	Future Research
All Measures	X	X	1. A consistent set of baseline, unit energy consumption (UEC) values (similar to RASS or RECS) should be created to sanity check all savings numbers. This is especially true for heating and cooling.
Air Sealing	X	X	1. Through a more detailed multifamily analysis of some participant facilities, the savings produced by these algorithms (and for other measures as well) should be compared to actual electric and gas consumption values for multifamily buildings, to make sure that they are reasonable. Any savings determined by an algorithm that is developed independently of actual use and with such uncertainty, should be checked in this manner. 2. Consider the comprehensive use of a building simulation approach to estimate savings, as was done for the New York TRM. Itron's *SitePro* system was used for the multifamily potential study, and ACH is a parameter that can be changed in that model. Multifamily implementation vendors may be performing some simulation modeling, but it was not clarified to the Evaluation Team how this is performed, what measures it is used for, and it does not appear to be used across all implementers and PAs. 3. Consider performing blower door tests on a sample of dwelling units, as described by ENERGY STAR®. Another option is to perform whole building blower door tests as described by Don Hynek in *Home Energy Magazine*.[8] 4. Collect contextual data on building characteristics, which could help improve

[8] Hynek, D. (2011). Blower Door Testing in Multifamily Buildings. *Home Energy Magazine,* September/October 2011, http://www.homeenergy.org/show/article/magazine/120/id/1711.

			the alternative approach values. For example, it makes sense that older buildings with larger and more holes to seal should receive more savings, but the current methods for estimating savings are not substantiated. If all utilities track more contextual values, and the same values, along with some limited blower door testing, it may be possible to develop a more robust savings estimate. 5. Consider developing air sealing kWh savings impacts for HVAC fan energy savings. Fan energy kWh savings could be claimed for cooling, gas heating as well as some types of electric heating (i.e., electric wall heaters, heat pumps, electric furnaces). However, the savings impacts from fans have been shown to be relatively small compared to the cooling and heating savings impacts.
Heat Pump Tune-Up	X		1. Collect information on-site of the average size of heating and cooling units for both common areas and dwelling units. 2. Conduct M&V to determine the current equivalent full load hours (EFLH) of heating and cooling in multifamily buildings. The MF potential study onsite data showed a heat pump saturation of 8%, but EFLH was not estimated. The values used in the Massachusetts-TRM are not adequately documented, and secondary sources for multifamily buildings in regions similar to Massachusetts are not available. 3. Conduct M&V on the savings associated with heat pump tune-ups. The percent savings value currently being used by the Massachusetts-TRM is a reasonable engineering estimate based on the pre- and post-tune up field measurements taken in the recent study in Wisconsin study of before and after field EER on residential air conditioner tune-ups. However, there is some uncertainty surrounding the Wisconsin study values (savings values in Wisconsin ranged from negative 8% to positive 32%) and, if the MA PAs anticipate expanding the heat pump tune measure, they should consider conducting field research to update this value and this large variation creates uncertainty of the savings value.
Set Back Thermostat	X	X	1. Use a combination of on-site Measurement and Verification (M&V) and surveys to better estimate percent savings from programmable thermostats. Determine set points, including the percent of households that were manually setting back thermostats before installing programmable thermostats. Consider a gas billing analysis to further analyze the actual savings resulting in the multifamily sector. 2. Estimate the electric and gas consumption of the heating and cooling units in Massachusetts multifamily buildings. Such estimates were developed for the MF Potential Study using Itron's *SitePro,* considering local weather data and taking into account saturation and efficiency of different heating systems. These results are currently the best available currently, but future research is recommended to gather more up-to-date information on efficiency levels for the multifamily sector in Massachusetts.
Insulation	X	X	1. Conduct M&V to estimate annual electric and gas consumption used in heating and cooling at the building level. This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the discretionary use adjustments. 2. Conduct on-site research on the R-value of the entire assembly (minus insulation) of floors, walls, and attics in Massachusetts multifamily buildings. This information will allow the estimation of deemed R-values to use for the

			floor, wall, and attic assemblies.
Lighting - CFL	X		1. Conduct on-site M&V in the form of post installation logger studies to determine the hours of use for the installation of new lighting measures and occupancy sensors in multifamily common areas and dwelling units. Consider both pre- and post- logger studies for lighting retrofits involving lighting controls. Such logger studies would show energy savings at the activity area level.
Showerheads and Aerators	X	X	1. Consider conducting hot water and total water consumption audits for multifamily DHW units to verify or update current kWh and therm consumption provided in the measure templates with Massachusetts-specific consumption data.

Appendix A – Multifamily Measure Savings

Table of Contents

_1_ Introduction 1-1

1.1 Engineering Review Process 1-2
1.2 Measure Templates 1-4
1.3 Conclusion and Recommendations 1-5

_2_ Lighting Measures: CFL Lamp/Fixtures 2-1

_3_ Lighting Measures: Linear Fluorescent Fixtures 3-1

_4_ Lighting Measures: LED Exit Signs 4-1

_5_ Lighting Measures: Metal Halides and Sodium High Pressure Lamps 5-1

_6_ Electric: Occupancy Sensor Measures 6-1

_7_ Electric: Refrigerators 7-1

_8_ Electric: Attic Insulation 8-1

_9_ Gas: Attic Insulation 9-1

_10_ Electric: Basement Insulation 10-1

_11_ Gas: Basement Insulation 11-9

_12_ Electric: Wall Insulation 12-1

_13_ Gas: Wall Insulation 13-1

_14_ Electric: Insulation – Other 14-1

_15_ Gas: Insulation – Other 15-1

_16_ Air Sealing: Gas & Electric 16-1

_17_ Electric: Setback Thermostats 17-1

_18_ Gas: Programmable Setback Thermostats 18-1

_19_ Electric: Heat Pump Tune-Up 19-1

_20_ Electric: Aerators 20-1

_21_ Gas: Aerators 21-1

_22_ Electric: Showerheads 22-1

_23_ Gas: Showerheads 23-1

_24_ Electric: DHW Pipe Wrap 24-1

_25_ Gas: DHW Pipe Wrap 25-1

_26_ Electric: DHW Tank Wrap 26-1

1

Introduction

As part of the Massachusetts Multifamily Impact Evaluation, Itron, as part of the Evaluation Team, conducted an engineering review of the electric and natural gas savings estimates being used by the Massachusetts Program Administrators (PAs). The primary purpose of the evaluation is to ensure that the most accurate assumptions and local sources are being used to develop savings values, and that per-measure (or measure category) savings are not being over or under-estimated. The engineering review included an assessment of different approaches to estimating per unit gross impacts, and involved conducting a thorough analysis of existing program data, vendor algorithms, Massachusetts TRM, and other sources, both local and national.

The Evaluation Team has proposed a primary or preferred savings method for each measure category. As part of this primary savings approach, either an algorithm or a deemed per unit value is provided. In some cases, PAs may already be collecting the data needed to calculate savings using this primary savings method, where as in other cases, the PAs may need to begin collecting data that are not currently being tracked. Where appropriate, we also provide a "secondary" or "alternative" method. This method can be used as an alternative for those PAs that are unable to collect all the necessary information required for the primary savings method. Because each PA collects or records different data points, we present this alternative method at the utility level and it may vary between utilities.

The Evaluation Team also reviewed the Massachusetts PAs' 2010 and 2011 tracking data and creating measure categories for each measure that generated savings during this analysis period. We reviewed engineering savings estimates in each of the PA's tracking databases when available. The analysis assessed the relative strengths of the deemed values and assumptions imbedded in the savings algorithms. Specifically, the engineering analysis examined electric and gas savings associated with the following program measures[1]:

- Lighting (Linear Fluorescents, CFLs, LED Exit Signs, and Occupancy Sensors)
- Refrigerators

[1] This list includes all program measures, with the possible exception of gas hot water heaters installed by Columbia Gas.

- Insulation
- Air Sealing
- Thermostats
- Heat Pump Tune-Up
- DHW (Showerheads and Aerators)
- DHW (Tank and Pipe Wrap)

We also assessed the methods described in the Massachusetts TRM for each of these measures with respect to:

- History of assumptions – How recent are the referenced sources;
- Robustness – Quality and rigor of supporting data and studies;
- Regional appropriateness – How well they represent Massachusetts;
- Transparent and traceable – (Are the calculations all present, and are the reference sources for key parameters or factors all publicly available?); and
- Ability to evaluate – (Can the key assumptions be updated by evaluation? Ideally, verifications/evaluations are designed to feedback and update savings estimates.).

For those values or algorithms in need of revision, we recommend alternative values or algorithms based on existing secondary data. For all PAs, this engineering review resulted in a set of algorithms, underlying assumptions and deemed values that can be used statewide, going forward. Justification for the recommended savings approaches is also provided, such as current application of the algorithm or values within or outside Massachusetts, or data and implementation-related reasons for selecting the approach. Finally, it details what additional data each PA needs to collect and track to calculate savings using the primary and alternative recommended approach.

We present these recommendations and underlying data by measure category in individual measure templates. Measure categories that have both electric and natural gas savings are typically presented in two different documents.

1.1 Engineering Review Process

This section provides the major steps that were taken as part of the engineering review process.

Step 1: Grouping Measures into Categories. We identified the unique list of measures that are offered by each PA and grouped them into measure categories. We grouped measures for two main reasons: 1) so they can be evaluated together, as the measures in each group are

likely to have similar algorithms and assumptions; and 2) to standardize the measure categories so that they can be used by all PAs implementing the Multifamily Program.

Step 2: Verify Current Algorithms. We reviewed and evaluated available information for each measure category individually. This process included reviewing the savings algorithms, deemed values (if used), and sources of the deemed input variables that went into each algorithm. As part of the verification process we assessed whether current approaches could be validated. In some cases, deemed input variables had no verifiable source. The verification process also allowed for the comparison of the different approaches taken by the utilities, which strengthened our understanding of how approaches are used statewide. Note that for some utilities, the source of their savings algorithms was not completely clear, so several different sources had to be examined, including different algorithm documents provided by the contractors and the TRM. Identifying the actual approach used by the PAs took considerable effort, and it was not always possible to determine the approach. We tested many different algorithms and input values in attempts to replicate the savings estimates that were unclear. During the review of several measure categories for some PAs, the evaluation was unable to determine the PA's savings calculation approach.

Step 3: Review Third Party Reports and Documents. We reviewed third party algorithms, from other Technical Resource Manuals, or from outside studies, to get a perspective of how other jurisdictions calculate their savings. These reviews included both local sources (within MA or New England), as well as outside sources like DEER[2], the Ohio TRM[3], and the NY-TRM[4].

Step 4: Analyze Program and Outside Data. Along with the review of the third party reports and documents, we reviewed the program data and the sources for the assumptions were reviewed. If the program tracking data or secondary sources did not support the use of existing assumptions, we identified alternative sources for deemed values or inputs. Some of the PAs already collect comprehensive baseline and retrofit measure information to calculate savings. In some cases, we used this information to develop assumptions as direct inputs to algorithms. We developed these assumptions by analyzing tracking data for certain measure categories to create weights used in the savings algorithms as multiple measures may be grouped together (e.g., CFL measures combine multiple measures consisting of multiple wattages). Other sources of data we

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2 Itron Inc. Database for Energy Efficient Resources (DEER) Update Study. Final Report. Prepared for Southern California Edison. December 2005.

3 Vermont Energy Investment Corporation. *State of Ohio Energy Efficiency Technical Reference Manual.* Prepared for the Public Utilities Commission of Ohio. August 6th, 2010.

4 TecMarket Works. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Prgorams. Residential, Multifamily, and Commercial/Industrial Measures. Prepared for New York Department of Public Service. October 15th, 2010.

analyzed included weather data to create Heating Degree Day and Cooling Degree Hour information specific to the region.

Step 5: Formulate Primary Savings Recommendations. Based on the review of current algorithms and deemed input variables used by the Massachusetts utilities, and those used by third party utilities and in outside reports, we provide a primary savings algorithm along with deemed input variable recommendations. These recommendations can be used by the utilities going forward, to provide clear and traceable sources, and to standardize the savings assumptions throughout the state.

Step 6: Formulate Alternative Savings Algorithms. Our review of available program data suggests that some of the primary algorithms we recommend require inputs that are not currently being collected or documented by all PAs and implementation contractors (e.g. existing insulation levels or pre-audit air infiltration rates). Therefore, where necessary, we provide an "alternative" algorithm, which is generally the same algorithm with deemed input values, that can be applied in those situations where the requisite level of detailed data—needed to apply the primary algorithm—are not available in the PA's underlying databases.

These alternative approaches rely to a greater degree upon deemed-values instead of site-specific baseline data inputs. There are two possible uses for the alternative savings algorithms. First, for PAs that do not have the information needed to utilize the primary recommendations, they can be used to re-evaluate (re-estimate) 2010-2011 gross savings. Second, for those utilities that do not have the ability to collect the recommended inputs during their audits going forward, these recommended savings values should be applied in future program years.

Step 7: Traceable Sources. The last step in the process was a final check of the first six steps. This step involves ensuring—by essentially double checking past steps—that clear and traceable sources are provided for all recommended algorithms, deemed savings values, and alternative recommendations. Most importantly, this step ensured that these traceable sources are relevant to the Commonwealth of Massachusetts and multifamily properties.

1.2 Measure Templates

The measure templates are separated by both measure category and fuel type. We analyzed measures that have dual fuel savings separately for each fuel in independent measure templates[5]. This approach will provide the PAs with a consistent, documented method to determine both electric and gas savings. Previously, some PAs reported dual fuel measure savings using different methodologies by fuel type. The measure templates contain the proposed savings

[5] The exception to this is the Air Sealing Measure, which has been combined into a single document. Reasons for this are explained in the Air Sealing Measure document.

recommendations, both primary and alternative, along with a justification for the recommendations. All input variables have been clearly defined, and where necessary, deemed values have been provided. The deemed input variables, sources, look-up tables, and a discussion on future research has been included, where applicable, to support the validity of the deemed values.

1.3 Conclusion and Recommendations

The Evaluation Team's review of the Massachusetts Multi-Family Program's savings claims began with an assessment of data provided by the PAs. The majority of the data analyzed involved tracking data, implementer algorithms, benefit-cost ratio spreadsheets and facility audit spreadsheets. Other research that was performed encompassed not only Massachusetts and New England based studies to provide locally-relevant information, but also nation-wide studies to compare different savings methods throughout the nation. Overall, we praise the efforts of some of the PAs to provide complete and accurate data. Their effort to collect and compile these data is invaluable, both to the utilities and to the review process. Through this review-process, several high-level recommendations have been formulated:

Completeness of Tracking Data. The tracking data provided by the PAs should encompass all customer information, project status and applicable dates, pre- and post-retrofit information, and savings information at a customer level. This level of detail combined into a *single tracking database* would be beneficial to each PA, not only in early stages of the program planning, but also as a status indicator during the program and a tool for evaluators at the end of the program.

Collection of Baseline Information. Baseline information should be collected during pre-retrofit project audits or at the time of the retrofit or measure installation. At the time of measure installation, these data are readily available, and few additional resources are necessary to collect these data. This important information provides locally-sourced, multi-family-relevant baseline data for use in refining savings estimates and in the planning of future programs.

Availability of Savings Algorithms and Sources. Savings algorithms used by implementers or PAs should be available, along with all deemed inputs and sources. The ability to produce these algorithms and sources upon request can increase the validity of the claimed savings approaches.

2

Lighting Measures: CFL Lamp/Fixtures

Applicable Program Administrators

National Grid, NSTAR, WMECO and Cape Light Compact

Measure Description

This measure involves replacing an incandescent lamp/fixture with CFL lamp/fixture**.**

Proposed Savings Method Justification

The algorithms that we are recommending are currently being used by National Grid to calculate their savings estimates. The basis for this approach is consistent with other TRMs, including the Mid-Atlantic TRM[6] and the OH-TRM[7]. Justification for deemed input variables are described below.

Proposed Primary Savings Method

We recommend the following algorithm for the primary savings method as it provides the best estimate of actual savings:

$$Annual\ \Delta kWh = \frac{N \times \left(Watts_{pre} - Watts_{post}\right) \times Hrs \times ISR}{1{,}000}$$

N	=	Quantity of lamps/fixtures
$Watts_{pre}$	=	Baseline Wattage (Auditor Input)
$Watts_{post}$	=	Post retrofit wattage (Auditor Input)
Hrs	=	Annual Operating hours (Auditor Input)
ISR	=	In Service Rate (Listed in Table 2-1)

For this primary savings approach, we Recommend that the site specific values be collected for baseline wattage, post retrofit wattage and operational hours of the lamp/fixture.

6 Vermont Energy Investment Corporation. Mid-Atlantic Technical Reference Manual. Version 2.0. July 2011.

7 Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010.

Inputs

The following minimum inputs are required to be collected by the PAs using this approach.

- **Quantity:** The quantity of measures should be collected by the onsite auditor.
- **Watts$_{pre}$:** The pre-retrofit baseline watts should be collected by the onsite auditor. For the primary savings approach, the auditor should collect the wattage of the of baseline fixture.
- **Watts$_{post}$:** The post-retrofit watts should be collected by the onsite auditor. For the primary savings approach, the wattage of the installed lamp or fixture should be recorded.
- **Hrs:** For the primary savings approach, annual operating hours of the fixture should be collected by the on-site auditor.

In-Service Rate:

In-service rate is the percentage of the rebated lights that are actually installed. Table 2-1 provides the in-service rate for CFL lamps and fixtures by location type.

Table 2-1: In-Service Rate by location type

Measure	Location	ISR
CFL Lamp	Dwelling Unit	0.90[8]
CFL Lamp	Common Area (Interior)	1.00
CFL Lamp	Common Area (Exterior)	1.00
CFL Fixture	Dwelling Unit	1.00
CFL Fixture	Common Area (Interior)	1.00
CFL Fixture	Common Area (Exterior)	1.00

Proposed Alternative Savings Method

The alternative approach can be used for the utilities that do not collect all the input variables required for the primary savings algorithm. In this method deemed values for input variables calculated from the National Grid tracking data can be used.

Alternative Savings Approach Algorithm:

$$\Delta kWh = \frac{N * \left(Watts_{post}\right) \times DeltaWattsMult \times Hrs \times ISR}{1{,}000}$$

[8] Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, Oct 2011. For the dwelling unit, in-service rate of CFL from Home Energy Saver program.

N	=	Quantity of lamps/fixtures
$Watts_{post}$	=	Post Retrofit wattage (Auditor Input)
DeltaWattsMult	=	ratio of post retrofit wattage and baseline wattage[9] (Provided in Appendix B: CFL_Analysis in spreadsheet format.)
Hrs	=	Operational hours of CFL Lamp/Fixture (Listed in Table 2-3*)*
ISR	=	In Service Rate (Listed in Table 2-1)

For the alternative approach, the post retrofit wattage of installed CFL lamp/fixture should be collected by the auditor. The delta watts multiplier and the operational hours assumption of the fixtures can be obtained from Appendix B based on the post retrofit wattage and location of the installed lamp or fixture.

Delta Watts Multiplier:

The delta watts multiplier is the ratio applied to the post retrofit wattage to obtain the baseline wattage. This is a commonly used approach and is consistent with DEER and Mid-Atlantic TRM[10]. The data needed for the calculation of the delta watts multiplier are currently only available from the National Grid tracking data. The weighted average of the baseline wattage was calculated using the National Grid tracking data, which was in turn used to calculate the delta watts multiplier for each of the measure codes.

Appendix B[11] provides the delta watts multiplier for each of the measure codes, which varies by the wattage and zone of the rebated measure. Appendix B also provides the recommended delta watts multipliers by CFL wattage range and zone type, these values are also listed in Table 2-2.

9 The Delta Watts Multiplier varies based on the post retrofit wattage and location of the rebated measure and it is provided in Appendix B: CFL_Analysis in spreadsheet format.

10 Mid-Atlantic Technical Reference Manual Version 2.0, July 2011

11 Table 3-1 is taken from the CFL_DeltaWatts_Buckets tab in the CFL_Analysis spreadsheet (Appendix B). The complete list of CFL Delta Watts multipliers by measure code and zone type are provided in "CFL_DeltaWatts" tab.

Table 2-2: Recommended Delta Watts Multiplier by CFL Wattage Range and Zone

CFL Wattage Range	Delta Watts Multiplier Dwelling Unit	Delta Watts Multiplier Common Area (Int.)	Delta Watts Multiplier Common Area (Ext.)
< = 13	4.57	3.58	3.22[12]
14 – 18	3.82	4.22	3.7
19 – 24	3.01	3.02	2.93
> = 25	3.42	2.99	2.68

Operational Hours:

Based on the location of the post retrofit lamp/fixture, we calculated the operational hours provided in Table 2-3 per day by zone and usage category from the National Grid tracking data.

Table 2-3: Operational hours by Zone and Usage Category

Zone	Usage Category	Hours/Day (Calc.)	Annual Operational Hours
Common Area (Exterior)	Exterior	10.3	3,760
Common Area (Interior)	Extended Hours & 24/7	24.0	8,760
Common Area (Interior)	Low Usage	3.4	1,241
Common Area (Interior)	Medium Usage	12.5	4,563
Common Area (Interior)	Non-Area Specific	16.2	5,913
Dwelling Unit	Unit	2.6	949

For all the lamps or fixtures installed in exterior common areas, we recommend using 10.3 hours per day. For the lamps or fixtures installed in the interior common areas, there are two options depending upon the available information:

a) If the actual location of the lamp or fixture is recorded, use the operational hours from the appropriate usage category. All locations within the interior common areas are mapped into three usage categories as shown in Table 2-4. This is the recommended approach as it will yield the best estimate of actual savings.

b) If the first option cannot be used due to the lack of common area location information, we recommend using a default operational hours estimate of 16.2 hours per day. The non-specific common area interior hours was calculated using a weighted average of Nation Grid's interior common area hours.

[12] The National Grid Tracking data did not have any measures for this wattage range so a weighted average delta watts multiplier for the CFL's installed in common area exterior locations was used for 13 Watt and smaller CFL in exterior common area locations.

Table 2-4: Mapping table between location and usage category

Location (Tracking Data)	Usage Category
Stairways	Extended Hours & 24/7
Hallways	
Lobby	
Elevators	
Entrance	Medium Usage
Laundry Room	
Other	
Clubhouse	Low Usage
Boiler Room	
Office	
Restroom	

Recommended Approaches by PA

National Grid: For the CFL measures, the National Grid tracking system currently collects the baseline wattage, post retrofit wattage and operational hours in the tracking data. These site specific variables are used to calculate the measure-level savings. Itron recommends that National Grid continue with the existing approach and calculate savings using the primary proposed savings method.

NSTAR: NSTAR captures the baseline wattage and location of the energy efficient lamp or fixture in the implementer audit spreadsheets but these sheets are not consistently populated or maintained, and the required variables are not populated in the tracking data. We recommend that the input variables from all implementer audit spreadsheets be added in the tracking database. In cases where the data audit spreadsheets are not populated for all measures, the alternative savings approach can be used to calculate the savings used to calculate the savings.

Cape Light Compact: Cape Light Compact provided the quantify of lamps/fixtures installed, pre and post retrofit wattage the kWh savings in their tracking data but do not track the primary input variables like operational hours that are used in the primary savings algorithm. We recommend that the PAs track the input variables that are required for the primary savings algorithm and calculate measure-level savings. If the input variables cannot be tracked, the alternative savings approach can be used.

WMECO: WMECO provides the kWh savings in their tracking data but do not track the primary input variables like the pre-retrofit wattage and operational hours that are used in the primary savings algorithm. We recommend that the PAs track the input variables that are required for the

primary savings algorithm and calculate measure-level savings. If the input variables cannot be tracked, the alternative savings approach can be used.

Future Research

1. For the alternative savings method, the operation hours are recommended based on the self reported hours from the National Grid tracking data. A metering or logger study is recommended to verify the accuracy of the proposed self reported hours of usage.
2. The delta watts multiplier that is recommended for the alternative savings method should be reviewed again next year as the sample size for some of the measure codes is very small. These numbers should be reviewed every year to validate the current recommendation and make modifications when required. Over time is it possible that delta watts calculations may change due to changes in technology, personal tastes, or adjustments made due to perceived low lighting levels.
3. It is recommended that verification analysis is performed to validate the current installation rates that are being used.

3

Lighting Measures: Linear Fluorescent Fixtures

Applicable Program Administrators

National Grid and NSTAR

Measure Description

This measure involves installing energy efficient Linear Fluorescent Fixtures.

Proposed Savings Justification

The algorithms that we are recommending are currently being used by National Grid to calculate their savings estimates. The basis for this approach is consistent with other TRMs, including the Mid-Atlantic TRM[13] and the OH-TRM[14]. Justification for deemed input variables are listed below in the document.

Proposed Primary Savings Method

The following algorithm is recommended for the primary proposed savings method and it provides the best estimate of actual savings:

$$Annual\ \Delta kWh = \frac{\left((N_{pre} * Watts_{pre}) - (N_{post} * Watts_{post})\right) \times Hrs}{1{,}000}$$

N_{pre}	=	Quantity of baseline fixtures
N_{post}	=	Quantity of installed fixtures (Post-retrofit)
$Watts_{pre}$	=	Baseline Wattage of the fixture including ballast watts (Auditor Input)
$Watts_{post}$	=	Post retrofit wattage of the fixture including ballast watts (Auditor Input)
Hrs	=	Annual Operating hours (Auditor Input)

In the primary savings approach, it is recommended that the site specific values be collected for baseline wattage, post retrofit wattage and operational hours of the fixture.

[13] Vermont Energy Investment Corporation. Mid-Atlantic Technical Reference Manual. Version 2.0. July 2011.

[14] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010.

Inputs

The following minimum inputs should be collected by the PAs.

- **Quantity:** The quantity of baseline fixtures and post retrofit fixtures should be collected by the onsite auditor.
- **Fixture Wattage:** The pre-retrofit and post retrofit wattage of the fixture should be collected by the onsite auditor.
- **Operational Hours:** The operational hours of the fixture should be collected by the on-site auditor.

Proposed Alternative Savings Method

Alternative savings approach can be used by the PAs that do not collect all the input variables required for the primary savings algorithm. The algorithm recommended for the alternative savings approach is similar to the primary savings approach but some of the input values for the alternative approach will be deemed and not site-specific.

$$\Delta kWh = \frac{\left((N_{pre} * Watts_{pre}) - (N_{post} * Watts_{post})\right) \times Hrs}{1{,}000}$$

In the alternative savings approach, deemed values of baseline wattage, post retrofit wattage and operational hours that were developed from the National Grid tracking data will be used.

Fixture Wattage:

For the alternative savings approach, post retrofit wattage and the baseline wattage of the fixture can be obtained from Table 3-1 based on the number of lamps and length of the proposed post retrofit fixture. The post retrofit and the baseline wattage for the fixtures were developed from the National Grid tracking data.

Table 3-1: Deemed Post Retrofit and Baseline Wattage

Measure Code	Lamp Length	Lamps per Fixture	Post Retrofit Wattage	Baseline Wattage
F21L	2 Foot	1	17	52
F22L	2 Foot	2	34	58
F24L	2 Foot	4	68	138
F31L	3 Foot	1	28	46
F32L	3 Foot	2	47	92
F41L	4 Foot	1	29	54
F42L	4 Foot	2	56	86
F43L	4 Foot	3	88	186
F44L	4 Foot	4	112	168
F81L	8 Foot	1	60	100
F82L	8 Foot	2	105	197

Operational Hours:

Based on the location of the post retrofit fixture, the following operational hours per day were calculated from the National Grid tracking data and provided in Table 2-3. The table provides the weighted average of the operational hours for the rebated fixture by zone type.

Table 3-2: Operational hours by Zone and Usage Category

Zone	Hours/Day (Calc.)	Annual Operational Hours
Common Area (Exterior)	9.60	3,504
Common Area (Interior)	14.85	5,420
Dwelling Unit	6.73	2,456

Recommended Approach

National GRID: For the Linear Fluorescent measures, National Grid tracking currently collects the baseline wattage, post retrofit wattage and operational hours in the tracking data. These site specific variables are used to calculate the measure level savings. We recommend that the National Grid continues with the existing approach and calculate savings using the primary proposed savings method.

NSTAR: NSTAR captures the baseline wattage and location of the energy efficient lamp or fixture in the data audit spreadsheets but these variables are not populated in the tracking data. It is recommended that the input variables from the data audit spreadsheets be added in the tracking database. In cases where the data audit spreadsheets are not populated for all measures, the

alternative savings approach should be used to calculate the savings used to calculate the savings.

4

Lighting Measures: LED Exit Signs

Applicable Program Administrators

National Grid

Measure Description

This measure involves replacing an incandescent or compact fluorescent exit sign with a LED exit sign.

Proposed Savings Justification

The algorithms that we are recommending are currently being used by National Grid to calculate their savings estimates. The basis behind this approach is consistent with other TRMs, including the Mid-Atlantic TRM[15] and the OH-TRM[16]. Justification for deemed input variables are listed below in the document.

Proposed Primary Savings Method

The following is the recommended algorithm for the primary proposed savings method:

$$Annual\ \Delta kWh = \frac{n \times \left(Watts_{pre} - Watts_{post}\right) \times Hrs}{1{,}000}$$

n	=	Quantity of lamps/fixtures
$Watts_{pre}$	=	Actual baseline Wattage (Auditor Input)
$Watts_{post}$	=	Actual post retrofit wattage (Auditor Input)
Hrs	=	Annual Operating hours
	=	8760

In the primary savings approach, it is recommended that the site specific values be collected for baseline wattage, post retrofit wattage and operational hours of the lamp/fixture.

15 Vermont Energy Investment Corporation. Mid-Atlantic Technical Reference Manual. Version 2.0. July 2011.

16 Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010.

Inputs

The following minimum inputs should be collected by the PAs.

- **Quantity:** The quantity of measures should be collected by the onsite auditor.
- **$Watts_{pre}$:** The pre-retrofit baseline watts should be collected by the onsite auditor. For the primary savings approach, the auditor should collect baseline technology of the exit sign. Depending on whether it is a CFL or an Incandescent, the watts can be looked up below in Table 4-1.
- **$Watts_{post}$:** The post-retrofit watts should be collected by the onsite auditor. If this is not collected, the deemed value used should be 5 watts.

Table 4-1: Baseline Wattage for Primary Savings Method

Technology	Wattage
Incandescent	32 Watts
CFL	12 Watts

Alternative Proposed Savings Method

Alternative savings approach can be used by the PAs that do not collect all the input variables required for the primary savings algorithm. We recommend the same algorithm for the alternative proposed savings method but, deemed values are provided assuming that auditors do not collected all the required information onsite to make use of the primary proposed savings method.

n	=	Quantity of lamps/fixtures
$Watts_{pre}$	=	Baseline Wattage (See Table 3-1)
$Watts_{post}$	=	Post retrofit wattage (Auditor Input)
	=	3 Watts[17]
Hrs	=	Annual Operating hours
	=	8760

Baseline Wattage:

Table 3-1 provides the deemed value of the baseline wattage for CFL baseline, an incandescent baseline, and a case where baseline technology type is not recorded. The deemed values were calculated using the baseline wattage information provided in the National Grid Tracking Data.

[17] LED Exit Signs are often either 4 watts or 2 watts. A review of the spec sheets from www.theexitstore.com reported that red LED signs are 4 watts, and green LED signs are 2 watts. It is recommended that the auditors record actual wattage of the signs, but in the case that they do not, a deemed value of 3 watts should be used.

Table 4-2: Deemed Baseline Wattage for Alternative Savings Method

Technology	Wattage
Incandescent	32 Watts
CFL	12 Watts
Unknown	22 Watts

National GRID: National Grid currently collects the baseline wattage, post retrofit wattage, and operational hours in the tracking data. These site-specific variables are used to calculate the measure-level savings. We recommend that National Grid continues with the existing approach and calculate savings using the primary proposed savings method; however, the operational hours should always be recorded as 168 hours per week.

Notes

- The proposed wattage for every record was 2 or 3 watts. It is unclear whether this was the actual wattage, or if it was just a default number. If it is a default number, then the savings should be re-evaluated using the alternative savings deemed value of 3 watts.
- There are three records in the National Grid tracking data that do not have 168 hours as the weekly hours of operation. It is recommended that for these three measures, the weekly hours should be changed to 168.
- The current electricity savings is calculated in the National Grid tracking data based on weekly hours of use multiplied by 52 weeks. The actual savings should be based on daily hours of use multiplied by 365 days, which will provide a more accurate savings (or just on an annual number of hours; 8760).

5

Lighting Measures: Metal Halides and Sodium High Pressure Lamps

Applicable Program Administrators

National Grid

Measure Description

This measure involves installing Metal Halides or Sodium High Pressure Lamps

Proposed Savings Justification

The algorithms that we are recommending are currently being used by National Grid to calculate their savings estimates. The basis for this approach is consistent with other TRMs, including the Mid-Atlantic TRM[18] and the OH-TRM[19]. Justification for deemed input variables are listed below in the document.

Proposed Primary Savings Method

The following algorithm is recommended for the primary proposed savings method and it provides the best estimate of actual savings:

$$Annual\ \Delta kWh = \frac{\left((N_{pre} * Watts_{pre}) - (N_{post} * Watts_{post})\right) \times Hrs}{1{,}000}$$

N_{pres}	=	Quantity of baseline lamps
N_{post}	=	Quantity of installed lamps (Post-retrofit)
$Watts_{pre}$	=	Baseline Wattage of the lamp (Auditor Input)
$Watts_{post}$	=	Post retrofit wattage of the lamp (Auditor Input)
Hrs	=	Annual Operating hours (Auditor Input)

In the primary savings approach, it is recommended that the site specific values be collected for baseline wattage, post retrofit wattage and operational hours of the fixture.

[18] Vermont Energy Investment Corporation. Mid-Atlantic Technical Reference Manual. Version 2.0. July 2011.

[19] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010.

Inputs

The following minimum inputs should be collected by the PAs.

- **Quantity:** The quantity of baseline lamps and post retrofit lamps should be collected by the onsite auditor.
- **Lamp Wattage:** The pre-retrofit and post retrofit wattage of the lamp should be collected by the onsite auditor.
- **Operational Hours:** The operational hours of the lamp should be collected by the on-site auditor.

Proposed Alternative Savings Method

Alternative savings approach can be used by the PAs that do not collect all the input variables required for the primary savings algorithm. The algorithm recommended for the alternative savings approach is similar to the primary savings approach but some of the input values for the alternative approach will be deemed and not site-specific.

$$\Delta kWh = \frac{\left((N_{pre} * Watts_{pre}) - (N_{post} * Watts_{post})\right) \times Hrs}{1{,}000}$$

In the alternative savings approach, deemed values of baseline wattage, post retrofit wattage and operational hours that were developed from the National Grid tracking data will be used.

Lamp Wattage:

For the alternative savings approach, post retrofit wattage and the baseline wattage of the fixture are provided in Table 3-1 based on lamp type and post retrofit wattage of the rebated lamp. The weighted average of the baseline wattage was developed from the National Grid tracking data.

Table 5-1: Deemed Post Retrofit and Baseline Wattage

Lamp Type	Post Retrofit Wattage	Baseline Wattage
Metal Halide	65	190
Metal Halide	90	205
Metal Halide	120	250
High Pressure Sodium	65	150
High Pressure Sodium	90	150
High Pressure Sodium	130	275

Operational Hours:

Based on the data provided in the National Grid tracking data, weighted average of operational hours is calculated and provided in Table 2-3.

Table 5-2: Operational hours by Zone and Usage Category

Zone	Hours/Day (Calc.)	Annual Operational Hours
Common Area (Exterior)	10.89	3,975

Recommended Approach

National GRID: For the Linear Fluorescent measures, National Grid tracking currently collects the baseline wattage, post retrofit wattage and operational hours in the tracking data. These site specific variables are used to calculate the measure level savings. We recommend that the National Grid continues with the existing approach and calculate savings using the primary proposed savings method.

6

Electric: Occupancy Sensor Measures

Applicable Program Administrators

National Grid

Measure Description

This measure involves installing an occupancy sensor that controls lighting fixtures and limits their use when the space is unoccupied. The baseline condition for this measure is a lighting fixture that is not controlled by an occupancy sensor.

Proposed Savings Justification

The approach behind the algorithm that we are recommending is consistent with other TRMs, including the Mid-Atlantic TRM[20] and the OH-TRM[21]. Justification for deemed input variables are listed below.

Proposed Primary Savings Method

The recommended algorithm for the proposed primary savings method

$$\Delta kWh = \frac{(Watts_{controlled}) \times Hrs \times svg}{1{,}000}$$

$Watts_{controlled}$	=	Connected load wattage controlled by Occupancy Sensor
Hrs	=	Assumed run time of fixture[22] (Auditor Input)
svg	=	Percentage of annual lighting energy saved by occupancy sensor
	=	0.3[23,24]

[20] Vermont Energy Investment Corporation. Mid-Atlantic Technical Reference Manual. Version 2.0. July 2011.

[21] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010.

[22] Before the installation of occupancy sensors

[23] The value of 30% is used by multiple sources, including the Mid-Atlantic TRM Version 2 (July 2011) and Arkansas Deemed Savings Quick Start Program Commercial Measures Final Report (June 2007). These are both based off Commercial Measures however.

[24] Other sources, like Ameren Illinois Utility Multifamily Common Area Lighting Program Overview estimates 50% savings (no source). Pacific Gas and Electric program estimates between 15%-45% depending on location

Alternative Proposed Savings Method

The algorithm recommended for the alternative savings approach is same as the algorithm used in primary savings. The only difference is that for the alternative savings approach, deemed values for operational hours calculated from the National Grid Tracking data will be used instead of site specific values.

Operational Hours

Based on the location of the post retrofit lamp/fixture, the following operational hours per day were calculated from the National Grid tracking data and are provided in Table 6-1.

Table 6-1: Operational hours by Zone and Usage Category

Zone	Usage Category	Hours/Day (Calc.)
Common Area (Exterior)	Exterior	10.3
Common Area (Interior)	Extended Hours & 24/7	24.0
Common Area (Interior)	Low Usage	3.4
Common Area (Interior)	Medium Usage	12.5
Common Area (Interior)	Non-Area Specific	16.2
Dwelling Unit	Unit	2.6

For all the lamps or fixtures installed in common areas exterior location, we recommend using 10.3 hours per day. For the lamps or fixtures installed in the common areas interior location, there are two options:

a) If the location of the lamp or fixture is not recorded, we recommend using 16.2 operational hours per day.

b) If the location of the lamp or fixture is recorded then the location is sub-categorized into three usage categories. Table 6-2 provides the mapping between the location and the usage category.

(commercial only). The use of 30% is accepted for now but further research is recommended to verify the savings value.

Table 6-2: Mapping Table between Location and Usage Category

Location (Tracking Data)	Usage Category
Stairways	Extended Hours & 24/7
Hallways	
Lobby	
Elevators	
Entrance	Medium Usage
Laundry Room	
Other	
Clubhouse	Low Usage
Boiler Room	
Office	
Restroom	

Future Research

We recommend that future research be performed in the form of pre and post logger studies to determine the average savings which result from the installation of occupancy sensors in multifamily common areas. Such logger studies would show lighting reduction results at the activity area level.

7

Electric: Refrigerators

Applicable Program Administrators

National Grid and NSTAR

Measure Description

Removal of old inefficient refrigerator with the installation of a new Energy Star qualified refrigerator.

Proposed Savings Justification

The recommended approach taken takes into account both the savings from the old refrigerator (based on its RUL) and the savings of the new Energy Star refrigerator (compared to federal standards). This allows the PAs to claim savings for an early replacement.

- The MA-TRM[31] currently uses a similar approach which takes into account the savings of the existing refrigerator. However, their algorithm only works for the first year savings. It is not completely clear how they would get to lifecycle savings based on their current method. Also, their claim of 884 kWh from the existing equipment could not be confirmed from the source provided.

Proposed Primary Savings Method

Refrigerator Recycling: This primary proposed savings method is for PAs that require proof that the old refrigerator has been recycled. This method can be used for both NSTAR and National Grid.

$$\Delta kWh = \left[\left(\left(kWh_{pre} - kWh_{std}\right)\right) \times \frac{(12-8)}{12} + \left((kWh_{std} - kWh_{ES})\right) \times \frac{8}{12}\right] \times F_{occ}$$

kWh_{pre} = Annual kWh consumption of existing equipment.
kWh_{std} = Annual kWh consumption of a refrigerator meeting federal standards
kWh_{ES} = Annual kWh consumption of new Energy Star qualified refrigerator or freezer

12	=	Measure life for a new refrigerator[25]
8	=	Age of the existing refrigerator is 8 years[26]
F_{occ}	=	Occupant adjustment factor used to adjust the energy savings according to the number of occupants in the apartment.

No Recycling: This primary proposed savings method is for PAs that do not require the old refrigerator be recycled. In this case, they should not get credit for a savings over the remaining useful life of the old refrigerator.

$$\Delta kWh = (kWh_{std} - kWh_{ES}) \times F_{occ}$$

kWh_{std}	=	Annual kWh consumption of a refrigerator meeting federal standards
kWh_{ES}	=	Annual kWh consumption of new Energy Star qualified refrigerator or freezer
F_{occ}	=	Occupant adjustment factor used to adjust the energy savings according to the number of occupants in the apartment.

Inputs

The proposed algorithms provided require the PAs to collect or to lookup the following minimum information.

- **kWh_{pre}:** Value is based off of metering or AHAM database. If neither option is viable, value is deemed at 1369 kWh[27].
- **kWh_{std}:** Value calculated based on volume and configuration of existing refrigerator, based off of federal standards listed below in Table 7-2.
- **kWh_{ES}:** Nameplate rated annual energy usage collected onsite, or Value calculated based on volume and configuration of new refrigerator based off Energy Star requirements, which are 20% better than federal standards.[28] These equations can be found below in Table 7-3.

[25] Massachusetts Technical Reference Manual. October 2010. Refrigeration – Refrigerators (Retrofit). Page 54. Cited from the Energy Star Calculator: *Life Cycle Cost Estimate for ENERGY STAR Residential Refrigerator.* http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls

[26] Based on discussion with the PAs (05/09/2012), a deemed value of 8 years for the existing refrigerator is used. This is 2/3 of the effective useful life (EUL) of the refrigerator.

[27] Michael Blasnik & Associates. 2004. *Measurement & Verification of Residential Refrigerator Energy Use 2003-2004 Metering Study.* Prepared for NSTAR, MECO, NECO, and WMECO. The average annual usage for 156 existing units was 1369 kWh/year. Page 26.

[28] Some PAs are currently collecting the nameplate rated annual energy usage. If this is the case, this rated annual energy usage should be used in place of the calculated value.

- **Volume:** The actual refrigerator volume should be recorded by the onsite auditors. If not, it should default to 17 cubic feet.[29]
- **Adjusted Volume (pre and post):** The Adjusted Volume (ft^3) is used in place of the equipment volume to account for the fact that freezers require more energy than refrigerators per unit of actual volume. The calculation for the Adjusted Volume, based on actual volume, can be found below in Table 7-4. If actual volume is unknown, the Adjusted Volume is deemed at 29.75 cubic feet[30].
- **Age:** The actual age of the refrigerator is to be collected. This will help determine the savings over the remaining useful life of the refrigerator. If the age is not collected onsite, the default age that should be used is 11 years[31].
- **Number of Occupants:** This number will allow a lookup of the variable F_{occ}, based on the number of occupants in the dwelling. If this information is not collected onsite, the default occupants of 1.8 should be used, to give an F_{occ} of 1.09 as discussed in Table 7-1.

Proposed Alternative Savings Method

The primary savings approach can be used going forward by PAs, like NSTAR and National Grid, which collect make, model, and annual consumption off the existing and new units. With this information, the annual consumption of the refrigerator meeting federal standards (kWh_{std}) can be calculated. The PAs should also collect the age of the existing refrigerator. If the existing refrigerator age information is not collected, it should default to 11 years, and discussed below, and if the number of occupants are not collected, it should default 1.8, with an F_{occ} = 1.09 as discussed in Table 7-1.

It is uncertain what information other PAs currently collect on their refrigerators. At the very minimum, a refrigerator configuration must be collected off the new Energy Star refrigerator. If this is collected, the same assumptions on configuration can be made for the existing refrigerator, and the rest of the information can be looked up in Table 7-1 through Table 7-4 below.

29 Based on a weighted average of the National Grid tracking data, it was calculated that the average refrigerator size was 17 cubic feet.

30 See Footnote 29 and compare to Table 7-4.

31 Massachusetts Technical Reference Manual. October 2010. Refrigeration – Refrigerators (Retrofit). Page 54.

Table 7-1: Occupant Adjustment Factor[32]

Number of Occupants	F_{occ}
0 occupants	1.00
1 occupants	1.05
1.8 occupants[7]	1.09[33]
2 occupants	1.10
3 occupants	1.13
4 occupants	1.15
5 occupants	1.16

Table 7-2: Federal Standards for Refrigerators[34]

Configuration	Formula
Manual Defrost	= 8.82AV + 248.4
Partial Automatic Defrost	= 8.82AV + 248.4
Automatic Defrost, Top Mounted Freezer, no TTD Ice	= 9.80AV + 276
Automatic Defrost, Side Mounted Freezer, no TTD Ice	= 4.91AV + 507.5
Automatic Defrost, Bottom Mounted Freezer, no TTD Ice	= 4.60AV + 459
Automatic Defrost, Top Mounted Freezer, with TTD Ice	= 10.20AV + 356
Automatic Defrost, Side Mounted Freezer, with TTD Ice	= 10.10AV + 406

32 The occupant adjustment factor is taken from National Energy Audit Tool (NEAT). Oak Ridge National Laboratory, Oak Ridge, TN.

33 The value of 1.8 occupants is a deemed value for number of occupants in a MF unit from the MA-RASS study. The F_{occ} = 1.09 has been extrapolated based on the other information found in the table.

34 Appliances and Commercial Equipment Standards. Refrigerator, Refrigerator-Freezer and Freezers Rulemaking. Final Rule. Table II.1 – Federal Energy Efficiency Standards for Refrigerators, Refrigerator-Freezers, and Freezers. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_frnotice.pdf

Table 7-3: Energy Star Requirements for Refrigerators[35]

Configuration	Formula
Manual Defrost	= (8.82AV + 248.4)*0.80
Partial Automatic Defrost	= (8.82AV + 248.4)*0.80
Automatic Defrost, Top Mounted Freezer, no TTD Ice	= (9.80AV + 276)*0.80
Automatic Defrost, Side Mounted Freezer, no TTD Ice	= (4.91AV + 507.5)*0.80
Automatic Defrost, Bottom Mounted Freezer, no TTD Ice	= (4.60AV + 459)*0.80
Automatic Defrost, Top Mounted Freezer, with TTD Ice	= (10.20AV + 356)*0.80
Automatic Defrost, Side Mounted Freezer, with TTD Ice	= (10.10AV + 406)*0.80

Table 7-4: Adjusted Volume Calculation

Equipment	Adjusted Volume
Refrigerator-Freezer	= RefrigeratorVolume + (1.63 * 0.46 * RefrigeratorVolume)[36]

[35] Energy Star Calculator for Energy Efficient Residential Refrigerators. Energy Star Refrigerators are 20% more efficient than Federal Standards.

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Refrig_Sav_Calc.xls

[36] The actual Adjusted Volume = RefrigeratorVolume+(1.63 * FreezerVolume). However, as the freezer volume is not collected by surveyors, the variables in the Energy Star Calculator show the in the average active refrigerator models in April 2009, the freezer was 46% of the refrigerator volume. If there is no attached freezer, the adjusted volume = actual refrigerator volume.

8

Electric: Attic Insulation

Applicable Utilities

National Grid, NSTAR and Cape Light Compact

Measure Description

This measure involves adding new or upgrading the existing attic insulation. Energy savings are the result of reduced HVAC (heating, vent/fan, air conditioning/cooling) use due to reduced roof heat loss. For multifamily units, this measure is only applicable to the units on the uppermost floor.

Proposed Savings Justification

1. The recommended algorithm for the electric attic insulation measure is similar to the algorithm prescribed in the State of Ohio Energy Efficiency Technical Reference Manual[37] (p.36) for the residential market sector.
2. The proposed method provides a calculated approach to savings estimation by utilizing actual field data, which varies significantly from the deemed kWh/sqft approach used in the MA TRM

Proposed Primary Savings Algorithm:

The following discussion presents algorithms to calculate the savings resulting from adding new, or upgrading existing, attic insulation. Savings are calculated based on the nominal pre- and post-retrofit insulation R-values and the area of the attic that is being insulated.

The total annual energy (kWh) savings for the attic insulation measure is the sum of the annual air conditioning, fan/ventilation, and electric space heating kWh savings. However, for this approach, the fan/ventilation savings is ignored as it is usually relatively small.

[37] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010 (p.36)

Air Conditioning Savings:

$$kWh_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times CDH \times DUA \times Area}{1{,}000\ Btu/kBtu \times \eta_{cool}}$$

Electric Heating Savings:

$$kWh_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}} \times 293.1$$

R_{exist}	=	Existing effective R-value (R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
R_{new}	=	New total effective R-value (R-ProposedMeasure + R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
DUA	=	Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F = 0.75[38]
Area	=	Square footage of insulated ceiling area (actual recorded value)
η_{cool}	=	Efficiency of Air Conditioning equipment (SEER or EER[39], actual recorded);
η_{heat}	=	Efficiency of the heating system - COP (actual recorded value);
293.1	=	Conversion constant (1MMBtu = 293.1 kWh)
24	=	Conversion for hours per day
CDH	=	Cooling Degree Hours; dependent on location, see Table 8-3 below.
HDD	=	Heating Degree Days; dependent on location, see Table 8-3 below.
1,000,000	=	Conversion from Btu to MMBtu

Inputs:

The following key parameters are used to calculate energy savings using the primary savings approach:

Area: No additional data collection efforts need to be made since the utilities already gather adequate data for this variable.

- **$R_{ExistingInsulation}$:** The R-value of the existing insulation needs to be recorded by the onsite auditors.

38 Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" (p.31)

39 Whether the SEER or the EER value should be used, depends on the HVAC equipment type and equipment size. Table 8-1 below shows the efficiency rating used by the IECC, based on equipment specifications. These same ratings should be followed, when determining which efficiency rating to use in the algorithm.

- **$R_{NewInsulation}$:** The R-value of the new insulation needs to be recorded by the onsite auditors.
- **$R_{roofassembly}$:** The R-value of the entire assembly needs to be recorded by the surveyor. This includes, but is not limited to, studs, air gaps, air films on surfaces, dry wall, radiant barriers, etc. Currently, National Grid deems a value for their R-ceiling, at 3.36[40], but it is unclear whether R-ceiling includes the entire assembly (minus the insulation). This default value of 3.36 may be used if no additional data is available. Refer to the Future Research section for additional details on $R_{roofassembly}$ value.
- **HVAC System:** The size and type of HVAC system should be recorded by the auditors onsite. This will be used to look up the efficiency if it is not collected onsite.
- **η_{cool}:** The efficiency of air conditioning equipment value needs to be collected on-site.
- **η_{heat}:** The efficiency of the heating unit should be collected on-site.
- **CDH:** Cooling Degree Hours – based on geographical location; see Table 8-3 below.
- **HDD:** Heating Degree Days– based on geographical location; see Table 8-3 below.

Alternative Proposed Savings Algorithm:

We do not recommend an alternative savings methodology, as the primary savings algorithm is deemed to be sufficiently simple and within the scope of the current data collection methods. The only change prescribed herewith is the use of minimum heating and cooling system efficiencies as detailed below.

Inputs:

- **η_{cool}:** Select the appropriate stipulated cooling system efficiency from Table 8-1 below. If adequate data is not able to be collected, a minimum efficiency value of 13 SEER may be used[41].
- **η_{heat}:** Select the appropriate stipulated heating system efficiency from Table 8-2 below. If adequate cannot be collected, a minimum efficiency value of 7.7[42] HSPF may be used[43].

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40 Savings methodology presented in National Grid's gas measure calculations document "EW Gas Measure Calculations_FROM KIM CROSSMAN - USE THIS" (Attic Insulation – p.6)

41 Massachusetts Technical Reference Manual. 2011 Program Year – Plan Version. October 2010. Program: Residential Cooling & Heating Equipment (p.66).

42 2009 International Energy Conservation Code. Table 503.2.3. Unitary Air Conditioners and Condensing Units, Electrically Operated, Minimum Efficiency Requirements.

43 For heat pumps the equipment efficiency used in the prescribed algorithm should be the Coefficient of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).

- **R-Value:** Some Program Administrators do not record the pre- and post- R-values, and instead only record the type of insulation and the depth (inches) of insulation. We provide Table 8-4 below for those Program Administrators who do not record the R-values, to look up an approximate R-value based on the depth and insulation type.

National Grid: National Grid already collects the existing and new R-values to generate the savings based on the proposed primary algorithm. We recommend that National Grid collect the actual heating and cooling system efficiency values (η_{heat} and η_{cool}), and clearly defines the R-Ceiling value. The auditors should also record the zip code to be able to select the closest city for their CDH and HDD value based on Table 8-3 below.

NSTAR: NSTAR's audit spreadsheets show that that they typically do collect most of the necessary data to generate the savings using the recommended algorithms. NSTAR does need to collect the $R_{assembly}$ value, actual cooling and heating system types, and whenever possible, the efficiency values (η_{cool} and η_{heat}). The auditors should also record the zip code to be able to select the closest city for their CDH and HDD value based on Table 8-3 below.

Cape Light Compact: Cape Light Compact currently collects the measure quantity, gross savings, and pertinent measure information, which do not completely satisfy the requirements to estimate savings using the primary savings estimation method. We recommend that Cape Light Compact also collect the following information, at a minimum, to accurately estimate the savings resulting from installing or upgrading the attic insulation.

- **Area:** Square footage of insulated area
- **R_{exist}:** Existing effective R-value
- **R_{new}:** New total effective R-value
- **η_{cool}:** Efficiency of air conditioning equipment (SEER or EER)
- **η_{heat}:** Efficiency of heating equipment (COP)

Future Research

This section covers some topics that should be collected to help inform and validate the savings claims.

1. **$R_{roofassembly}$:** Research on the R-value of the entire assembly (minus insulation) should be explored. At a minimum, information should be collected on the typical roof types (sloped or flat), building materials, and vented or unvented attics. This information will allow derivation of a deemed R-value to use for the assembly, that is relevant to Massachusetts multi-family homes. The US Department of Energy has a website that provides more information on roof assembly construction[44] which may my useful in the calculation of a relevant $R_{roofassembly}$ value.

[44] Building Energy Codes, Online Training. http://www.energycodes.gov/moodle/mod/resource/view.php?id=656.

2. **Annual electric consumption:** This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the DUAs.

Look-Up Tables

Table 8-1: Minimum Efficiency Ratings for Space Cooling Systems[45]

Cooling System	Minimum Efficiency
Air Conditioners, Air Cooled	
<65,000 Btu/h, Split Systems	13.0 SEER
<65,000 Btu/h, Single Package	13.0 SEER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.2 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥240,000 & <760,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	10.0 EER 9.7
≥240,000 & <760,000 Btu/h, All Other Heating Section, Split System and Single Package	9.8 EER 9.7 IPLV
≥760,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	9.7 EER 9.4 IPLV
≥760,000 Btu/h, All Other Heating Section, Split System and Single Package	9.5 EER 9.2 IPLV
≤30,000 Btu/h Through-the-Wall, Split System	12.0 SEER
≤30,000 Btu/h Through-the-Wall, Single Package	12.0 SEER
Air Conditioner, Water and Evaporatively Cooled	
<65,000 Btu/h, Split Systems and Single Package	12.1 EER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.5 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	11.3 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.5 EER
≥240,000 Btu/h, All Other Heating Section, Split System and Single Package	11.3 EER

[45] 2009 International Energy Conservation Code – abridged version of Tables 503.2.3(1) and 503.2.3(2)

Condensing Units, Air Cooled	
≥135,000 Btu/h	10.1 EER 11.2 IPLV
Condensing Units, Water or Evaporatively Cooled	
≥135,000 Btu/h	13.1 EER 13.1 IPLV
Heat Pumps, Electrically Operated, Air Cooled (Cooling Mode)	
<65,000 Btu/h, Split Systems	13.0 SEER
<65,000 Btu/h, Single Package	13.0 SEER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	10.6 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.4 EER
≥240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	9.5 EER 9.2 IPLV
≥240,000 Btu/h, All Other Heating Section, Split System and Single Package	9.3 EER 9.0 IPLV
≤30,000 Btu/h Through-the-Wall, Split System	12.0 SEER
≤30,000 Btu/h Through-the-Wall, Single Package	12.0 SEER
Heat Pumps, Electrically Operated, Water Source, 86ºF Entering Water (Cooling Mode)	
<17,000 Btu/h	11.2 EER
≥17,000 & <65,000 Btu/h	12.0 EER
≥65,000 & <135,000 Btu/h	12.0 EER
Heat Pumps, Electrically Operated, Groundwater Source, 59ºF Entering Water (Cooling Mode)	
<135,000 Btu/h	16.2 EER
Heat Pumps, Electrically Operated, Ground Source, 77ºF Entering Water (Cooling Mode)	
<135,000 Btu/h	13.4 EER

Table 8-2: Minimum Efficiency Ratings for Space Heating Systems[46, 47]

Heating System	Minimum Efficiency
Heat Pumps, Electrically Operated, Air Cooled (Heating Mode)	
<65,000 Btu/h (Cooling Capacity), Split Systems	7.7 HSPF

46 2009 International Energy Conservation Code – abridged version of Table 503.2.3(2)

47 For heat pumps the equipment efficiency used in the prescribed algorithm should be the Coefficient of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).

<65,000 Btu/h (Cooling Capacity), Single Package	7.7 HSPF
≥65,000 & <135,000 Btu/h (Cooling Capacity), 47ºF db/43ºF wb Outdoor Air	3.3 COP
≥65,000 & <135,000 Btu/h (Cooling Capacity), 17ºF db/15ºF wb Outdoor Air	2.25 COP
≥135,000 Btu/h (Cooling Capacity), 47ºF db/43ºF wb Outdoor Air	3.2 COP
≥135,000 Btu/h (Cooling Capacity), 17ºF db/15ºF wb Outdoor Air	2.05 COP
≤30,000 Btu/h Through-the-Wall, Split System	7.4 HSPF
≤30,000 Btu/h Through-the-Wall, Single Package	7.4 HSPF
Heat Pumps, Electrically Operated, Water Source, 68ºF Entering Water (Heating Mode)	
<135,000 Btu/h (Cooling Capacity)	4.2 COP
Heat Pumps, Electrically Operated, Groundwater Source, 50ºF Entering Water (Heating Mode)	
<135,000 Btu/h (Cooling Capacity)	3.6 COP
Heat Pumps, Electrically Operated, Ground Source, 32ºF Entering Water (Heating Mode)	
<135,000 Btu/h	3.1 COP
Electrical Resistance Furnace[48]	
Electrical Resistance Furnace	1.0 COP

[48] This HVAC type is not included in the 2009 IECC table, but is included to show the COP for this measure.

Table 8-3: HDD Values by Weather Station

TMY3 City	HDD[49]	CDH[50]
Barnstable Muni Boa	4379	1349
Beverly Muni	5329	3432
Boston Logan Int'l Arpt	4550	4329
Chicopee Falls Westo	5016	4116
Lawrence Muni	4640	3978
Marthas Vineyard	4312	1345
Nantucket Memorial AP	3988	362
New Bedford Rgnl	4434	4232
North Adams	5234	2524
Norwood Memorial	4872	4763
Otis ANGBb	4718	2588
Plymouth Municipal	4559	2138
Provincetown (AWOS)	4368	2195
Westfield Barnes Muni AP	5301	3784
Worchester Regional Arpt	5816	1753

Table 8-4: Insulation R-Value Lookup[51]

Insulation Type	Insulation Material	Insulation R-Value
Loose Fibers	Fiberglass	=2.5 * Depth (inches)
	Rock Wool	=2.8 * Depth (inches)
	Cellulose	=3.7 * Depth (inches)
Granules	Vermiculite	=2.7 * Depth (inches)
	Perlite	
Batts	Fiberglass	=3.2 * Depth (inches)

[49] These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, will also be provided.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

[50] These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The CDH values were calculated by taking the temperature for each hour, and summing those values over 75ºF.

$$CDH = Sum[Max(0, HourlyTemp - 75ºF)]$$

[51] Oak Ridge National Laboratory. Insulation Fact Sheet. December 22nd, 2008. http://www.ornl.gov/sci/roofs+walls/insulation/ins_06.html

9

Gas: Attic Insulation

Applicable Program Administrators

National Grid and NSTAR

Measure Description

This measure involves adding new or upgrading the existing attic insulation.. Energy savings are the result of reduced HVAC (heating, vent/fan, air conditioning/cooling) use due to reduced roof heat loss. For multifamily units, this measure is only applicable to the units on the uppermost floor.

Proposed Savings Justification

- The proposed primary algorithm is identical to the vendor provided algorithm in the MA TRM for the gas attic insulation measure. No additional data needs to be collected to utilize this algorithm.
- This method is also very similar to the savings algorithm prescribed in the State of Ohio Energy Efficiency Technical Reference Manual[52] (p.36) for the residential market sector.

Proposed Primary Savings Algorithm

The following discussion presents algorithms to calculate the savings resulting from installing new, or upgrading existing, attic access insulation. Savings are calculated based on the nominal pre- and post-retrofit R-values and the area of the attic that is being insulated.

$$MMBtu_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}}$$

R_{exist} = Existing effective R-value (R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh.

[52] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010 (p.36)

R_{new}	=	New total effective R-value (R-ProposedMeasure + R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
Area	=	Square footage of insulated ceiling area (actual recorded value)
η_{heat}	=	Efficiency of the heating system - HSPF (actual recorded value);
24	=	Conversion for hours per day
HDD	=	Heating Degree Days; dependent on location, see Table 9-1 below.
1,000,000	=	Conversion from Btu to MMBtu

Inputs

The following key parameters are used to calculate energy savings using the primary savings approach:

- **Area:** No additional data collection efforts need to be made since the utilities already gather adequate data for this variable.
- **$R_{ExistingInsulation}$:** The R-value of the existing insulation needs to be recorded by the onsite auditors.
- **$R_{NewInsulation}$:** The R-value of the new insulation needs to be recorded by the onsite auditors.
- **$R_{roofassembly:}$** The R-value of the entire assembly needs to be recorded by the surveyor. This includes, but is not limited to, studs, air gaps, air films on surfaces, dry wall, radiant barriers, etc. Currently, National Grid deems a value for their R-ceiling, at 3.36[53], but it is unclear whether R-ceiling is supposed to include the entire assembly (minus the insulation). This default value of 3.36 may be used if no additional data is available. Refer to the Future Research section for additional details on $R_{roofassembly}$ value.
- **η_{heat}:** The efficiency of the heating unit should be collected on-site.
- **HDD:** Heating Degree Days– based on geographical location; see Table 9-1 below.

Alternative Proposed Savings Algorithm

We do not recommend a alternative savings methodology, as the primary savings algorithm is deemed to be sufficiently simple and within the scope of the current data collection methods. The only change prescribed herewith is the use of minimum AFUE values from Table 9-2.

Inputs

- **η_{heat}:** The AFUE of the heating unit from Table 9-1 below.

[53] Savings methodology presented in National Grid's gas measure calculations document "EW Gas Measure Calculations_FROM KIM CROSSMAN - USE THIS" (Attic Insulation – p.6)

- **R-Value:** Some Program Administrators do not record the pre- and post- R-values, but only record the type of insulation and the depth (inches) of insulation. A table has been provided below, for those Program Administrators who do not record the R-values, to look up an approximate R-value based on the depth and insulation type. See Table 8-4.

National Grid: National Grid already collects the existing and new R-values to generate the savings based on the primary algorithm prescribed herewith. We recommend that National Grid also collect the actual heating system efficiency values (η_{heat}) and clearly define the R-value for ceilings (R-Ceiling). The auditors should also select the closest city for their HDD value based on Table 9-1 below.

NSTAR: NSTAR's audit spreadsheets show that that they do collect adequate data to generate the savings based on the aforementioned algorithms. The other parameters that NSTAR needs to collect here are the R-Ceiling value and the actual heating system efficiency value (η_{heat}). The auditors also need to be able to choose the closest city for their HDD value based on Table 9-1 below.

Future Research

This section covers information that should be collected to help inform and validate the savings claims.

1. **Annual gas consumption:** This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the DUAs.
2. **$R_{roofassembly}$:** Research on the R-value of the entire assembly (minus insulation) should be explored. At a minimum, information should be collected on the typical roof types (sloped or flat), building materials, and vented or unvented attics. This information will allow the derivation of a deemed R-value to use for the assembly, that is relevant to Massachusetts multi-family homes. The US Department of Energy has a website that provides more information on roof assembly construction[54] which may my useful in the calculation of a relevant $R_{roofassembly}$ value.

[54] Building Energy Codes, Online Training. http://www.energycodes.gov/moodle/mod/resource/view.php?id=656.

Look-Up Tables

Table 9-1: HDD Values by Weather Station[55]

TMY3 City	HDD
Barnstable Muni Boa	4379
Beverly Muni	5329
Boston Logan Int'l Arpt	4550
Chicopee Falls Westo	5016
Lawrence Muni	4640
Marthas Vineyard	4312
Nantucket Memorial AP	3988
New Bedford Rgnl	4434
North Adams	5234
Norwood Memorial	4872
Otis ANGBb	4718
Plymouth Municipal	4559
Provincetown (AWOS)	4368
Westfield Barnes Muni AP	5301
Worchester Regional Arpt	5816

Table 9-2: η_{heat} Minimum Efficiency Ratings

Heating System	AFUE
Steam Boiler	0.75[56]
Furnace	0.78[57]
Hydronic Boiler	0.84
Condensing Boiler	0.84

[55] These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, will also be provided.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

[56] IECC 2009. Table 503.2.3(5): Boilers, Gas-and Oil-fired, Minimum Efficiency Requirements.

[57] Current national standards for residential gas furnaces - http://www.appliance-standards.org/product/furnaces.

Table 9-3: Insulation R-Value Lookup[58]

Insulation Type	Insulation Material	Insulation R-Value
Loose Fibers	Fiberglass	=2.5 * Depth (inches)
	Rock Wool	=2.8 * Depth (inches)
	Cellulose	=3.7 * Depth (inches)
Granules	Vermiculite	=2.7 * Depth (inches)
	Perlite	
Batts	Fiberglass	=3.2 * Depth (inches)

58 Oak Ridge National Laboratory. Insulation Fact Sheet. December 22nd, 2008. http://www.ornl.gov/sci/roofs+walls/insulation/ins_06.html

10

Electric: Basement Insulation

Applicable Program Administrators

National Grid

Measure Description

This measure involves adding or upgrading basement and/or floor insulation.

Proposed Savings Justification

- The proposed algorithm for the electric basement insulation measure is similar to the algorithm prescribed in the State of Ohio Energy Efficiency Technical Reference Manual[59] (p.36) for residential market sector and requires most of the same data point inputs that are being collected for the MA Low Income Multi-Family Retrofit program.
- This method, which varies significantly from the MA TRM, provides a calculated approach to savings estimation by utilizing actual field data, unlike the savings estimates that are derived from a deemed kWh/SQFT value, as being prescribed in the current version of the MA TRM.

Proposed Primary Savings Algorithm

The following discussion presents algorithms to calculate the savings resulting from installing new, or upgrading existing, basement insulation. Savings are calculated based on the nominal pre- and post-retrofit R-values and the area of the basement that is being insulated.

The total annual energy (kWh) savings resulting from the basement insulation measure are the sum of the annual air conditioning kWh savings and the annual electric heating kWh savings.

Air Conditioning Savings

$$kWh_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times CDH \times DUA \times Area}{1{,}000\ Btu/kBtu \times \eta_{cool}}$$

[59] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010 (p.36)

Electric Heating Savings

$$kWh_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}} \times 293.1$$

R_{exist}	=	Existing effective R-value (R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh.
R_{new}	=	New total effective R-value (R-ProposedMeasure + R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
DUA	=	Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F = 0.75[60]
Area	=	Square footage of insulated basement area (actual recorded)
η_{cool}	=	Efficiency of Air Conditioning equipment (SEER or EER[61], actual recorded);
η_{heat}	=	Efficiency of the heating system (COP, actual recorded);
293.1	=	Conversion constant (1MMBtu = 293.1 kWh)
24	=	Conversion for hours per day
CDH	=	Cooling Degree Hours; dependent on location, see Table 8-3 below.
HDD	=	Heating Degree Days; dependent on location, see Table 8-3 below.
1,000,000	=	Conversion from Btu to MMBtu

Inputs

The following key parameters are used to calculate energy savings using the primary savings approach:

- **Area:** No additional data collection efforts need to be made since the utilities already gather adequate data for this variable.
- **$R_{ExistingInsulation}$:** The R-value of the existing insulation needs to be recorded by the onsite auditors.
- **$R_{NewInsulation}$:** The R-value of the new insulation needs to be recorded by the onsite auditors.
- **$R_{floorassembly}$:** The R-value of the entire assembly needs to be recorded by the surveyor. This includes (depending on the floor construction), but is not limited to, carpet and pad, wood sub-floor, air film, concrete, etc. Currently, National Grid deems a value for their

[60] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" (p.31).

[61] Whether the SEER or the EER value should be used, depends on the HVAC equipment type and equipment size. Table 8-1 below shows the efficiency rating used by the IECC, based on equipment specifications. These same ratings should be followed, when determining which efficiency rating to use in the algorithm.

R-ceiling, at 6.16[62], but it is unclear whether R-floor is supposed to include the entire assembly (minus the insulation). This default value of 6.16 may be used if no additional data is available. Refer to the Future Research section for additional details on $R_{floorassembly}$ value.

- **HVAC System:** The size and type of HVAC system should be recorded by the auditors onsite. This will be used to look up the efficiency if it is not collected onsite.
- **η_{cool}:** The efficiency of air conditioning equipment value needs to be collected on-site;
- **η_{heat}:** The efficiency of the heating unit should be collected on-site.
- **CDH:** Cooling Degree Hours – based on geographical location and utility; see Table 8-3 below;
- **HDD:** Heating Degree Days– based on geographical location and utility; see Table 8-3 below;

Alternative Proposed Savings Algorithm

We do not recommend a separate alternative savings methodology, as the primary savings algorithm is within the scope of the current data collection methods. The only change is the use of minimum heating and cooling system efficiencies as detailed below.

Inputs

- **η_{cool}:** Select the appropriate stipulated cooling system efficiency from Table 8-1 below. If adequate data is not able to be collected, a minimum efficiency value of 13 SEER may be used[63].
- **η_{heat}:** Select the appropriate stipulated heating system efficiency from Table 8-2 below. If adequate data is not able to be collected, a minimum efficiency value of 7.7[64] HSPF may be used[65].
- **R-Value:** Some Program Administrators do not record the pre- and post- R-values, but only record the type of insulation and the depth (inches) of insulation. A table has been provided below, for those Program Administrators who do not record the R-values, to look up an approximate R-value based on the depth and insulation type. See Table 10-4.

62 Savings methodology presented in National Grid's gas measure calculations document "EW Gas Measure Calculations_FROM KIM CROSSMAN - USE THIS" (Attic Insulation – p.6)

63 Massachusetts Technical Reference Manual. 2011 Program Year – Plan Version. October 2010. Program: Residential Cooling & Heating Equipment (p.66).

64 2009 International Energy Conservation Code. Table 503.2.3. Unitary Air Conditioners and Condensing Units, Electrically Operated, Minimum Efficiency Requirements.

65 For heat pumps the equipment efficiency used in the prescribed algorithm should be the Coefficient of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).

National Grid: National Grid already collects the existing and new efficiency ratings (R-values) to generate the savings based on the proposed primary algorithm. We do recommend that National Grid collect the actual heating and cooling system efficiency values (η_{heat} and η_{cool}) along with clearly defining the R-Floor value. The auditors should select the closest city for their CDH and HDD value based on Table 10-3 below.

Future Research

This section covers some topics that should be collected to help inform and validate the savings claims.

1. **Annual electric consumption:** This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the DUAs;
2. **$R_{floorassembly}$:** Research on the R-value of the entire assembly (minus insulation) should be explored. At a minimum, information should be collected on the typical floor construction types, all wood, concrete over unconditioned space, slab on-grade, or others. This information will help come up with a deemed R-value to use for the assembly, that is relevant to Massachusetts multi-family homes. The US Department of Energy has a website that can provide more information on floor construction assembly types[66].

Look-Up Tables

Table 10-1: Minimum Efficiency Ratings for Space Cooling Systems[67]

Cooling System	Minimum Efficiency
Air Conditioners, Air Cooled	
<65,000 Btu/h, Split Systems	13.0 SEER
<65,000 Btu/h, Single Package	13.0 SEER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.2 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥240,000 & <760,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	10.0 EER 9.7

66 Building Energy Codes, Online Training. http://www.energycodes.gov/moodle/mod/resource/view.php?id=658.

67 2009 International Energy Conservation Code – abridged version of Tables 503.2.3(1) and 503.2.3(2)

≥240,000 & <760,000 Btu/h, All Other Heating Section, Split System and Single Package	9.8 EER 9.7 IPLV
≥760,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	9.7 EER 9.4 IPLV
≥760,000 Btu/h, All Other Heating Section, Split System and Single Package	9.5 EER 9.2 IPLV
≤30,000 Btu/h Through-the-Wall, Split System	12.0 SEER
≤30,000 Btu/h Through-the-Wall, Single Package	12.0 SEER
Air Conditioner, Water and Evaporatively Cooled	
<65,000 Btu/h, Split Systems and Single Package	12.1 EER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.5 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	11.3 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.5 EER
≥240,000 Btu/h, All Other Heating Section, Split System and Single Package	11.3 EER
Condensing Units, Air Cooled	
≥135,000 Btu/h	10.1 EER 11.2 IPLV
Condensing Units, Water or Evaporatively Cooled	
≥135,000 Btu/h	13.1 EER 13.1 IPLV
Heat Pumps, Electrically Operated, Air Cooled (Cooling Mode)	
<65,000 Btu/h, Split Systems	13.0 SEER
<65,000 Btu/h, Single Package	13.0 SEER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	10.6 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.4 EER
≥240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	9.5 EER 9.2 IPLV
≥240,000 Btu/h, All Other Heating Section, Split System and Single Package	9.3 EER 9.0 IPLV

≤30,000 Btu/h Through-the-Wall, Split System	12.0 SEER
≤30,000 Btu/h Through-the-Wall, Single Package	12.0 SEER
Heat Pumps, Electrically Operated, Water Source, 86ºF Entering Water (Cooling Mode)	
<17,000 Btu/h	11.2 EER
≥17,000 & <65,000 Btu/h	12.0 EER
≥65,000 & <135,000 Btu/h	12.0 EER
Heat Pumps, Electrically Operated, Groundwater Source, 59ºF Entering Water (Cooling Mode)	
<135,000 Btu/h	16.2 EER
Heat Pumps, Electrically Operated, Ground Source, 77ºF Entering Water (Cooling Mode)	
<135,000 Btu/h	13.4 EER

Table 10-2: Minimum Efficiency Ratings for Space Heating Systems[68]

Heating System	Minimum Efficiency
Heat Pumps, Electrically Operated, Air Cooled (Heating Mode)	
<65,000 Btu/h (Cooling Capacity), Split Systems	7.7 HSPF
<65,000 Btu/h (Cooling Capacity), Single Package	7.7 HSPF
≥65,000 & <135,000 Btu/h (Cooling Capacity), 47ºF db/43ºF wb Outdoor Air	3.3 COP
≥65,000 & <135,000 Btu/h (Cooling Capacity), 17ºF db/15ºF wb Outdoor Air	2.25 COP
≥135,000 Btu/h (Cooling Capacity), 47ºF db/43ºF wb Outdoor Air	3.2 COP
≥135,000 Btu/h (Cooling Capacity), 17ºF db/15ºF wb Outdoor Air	2.05 COP
≤30,000 Btu/h Through-the-Wall, Split System	7.4 HSPF
≤30,000 Btu/h Through-the-Wall, Single Package	7.4 HSPF
Heat Pumps, Electrically Operated, Water Source, 68ºF Entering Water (Heating Mode)	
<135,000 Btu/h (Cooling Capacity)	4.2 COP
Heat Pumps, Electrically Operated, Groundwater Source, 50ºF Entering Water (Heating Mode)	
<135,000 Btu/h (Cooling Capacity)	3.6 COP
Heat Pumps, Electrically Operated, Ground Source, 32ºF Entering Water (Heating Mode)	
<135,000 Btu/h	3.1 COP
Electrical Resistance Furnace[69]	
Electrical Resistance Furnace	1.0 COP

68 2009 International Energy Conservation Code – abridged version of Table 503.2.3(2)

69 This HVAC type is not included in the 2009 IECC table, but is included to show the COP for this measure.

Table 10-3: HDD Values by Weather Station

TMY3 City	HDD[70]	CDH[71]
Barnstable Muni Boa	4379	1349
Beverly Muni	5329	3432
Boston Logan Int'l Arpt	4550	4329
Chicopee Falls Westo	5016	4116
Lawrence Muni	4640	3978
Marthas Vineyard	4312	1345
Nantucket Memorial AP	3988	362
New Bedford Rgnl	4434	4232
North Adams	5234	2524
Norwood Memorial	4872	4763
Otis ANGBb	4718	2588
Plymouth Municipal	4559	2138
Provincetown (AWOS)	4368	2195
Westfield Barnes Muni AP	5301	3784
Worchester Regional Arpt	5816	1753

70 These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, will also be provided.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

71 These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The CDH values were calculated by taking the temperature for each hour, and summing those values over 75ºF. A look up table, which maps zip code to TMY3 City, will also be provided.

$$CDH = Sum[Max(0, HourlyTemp - 75ºF)]$$

Table 10-4: Insulation R-Value Lookup[72]

Insulation Type	Insulation Material	Insulation R-Value
Loose Fibers	Fiberglass	=2.5 * Depth (inches)
	Rock Wool	=2.8 * Depth (inches)
	Cellulose	=3.7 * Depth (inches)
Granules	Vermiculite	=2.7 * Depth (inches)
	Perlite	
Batts	Fiberglass	=3.2 * Depth (inches)

72 Oak Ridge National Laboratory. Insulation Fact Sheet. December 22nd, 2008. http://www.ornl.gov/sci/roofs+walls/insulation/ins_06.html

11
Gas: Basement Insulation

Applicable Program Administrators

National Grid

Measure Description

This measure involves adding or upgrading basement and/or floor insulation.

Proposed Savings Justification

- The proposed algorithm is identical to the vendor provided algorithms in the MA TRM to use with the gas basement insulation measure. No additional data collection efforts by the current applicable PAs are required for utilizing this algorithm.
- This method is also very similar to the savings algorithm prescribed in the State of Ohio Energy Efficiency Technical Reference Manual[73] (p.36) for Public Utilities Commission of Ohio for residential market sector and requires most of the same data point inputs that are being collected for the MA Low Income Multifamily Retrofit program.

Proposed Primary Savings Algorithm

The following discussion presents algorithms to calculate the savings resulting from installing new, or upgrading existing, basement insulation. Savings are calculated based on the nominal pre- and post-retrofit R-values and the area of the basement that is being insulated.

The algorithm assumes that an auditor is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and the efficiency of the heating system used in the home.

$$MMBtu_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}}$$

[73] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010 (p.36)

R_{exist}	=	Existing effective R-value (R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh.
R_{new}	=	New total effective R-value (R-ProposedMeasure + R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
Area	=	Square footage of insulated area = actual recorded
η_{heat}	=	Efficiency of the heating system (AFUE) = actual recorded;
HDD	=	Heating Degree Days; dependent on location, see Table 11-1 below.
1,000,000	=	Conversion from Btu to MMBtu

Inputs

The following key parameters are used to calculate energy savings using the primary savings approach:

- **Area:** No additional data collection efforts need to be made since the PAs already gather adequate data for this variable.
- **$R_{ExistingInsulation}$:** The R-value of the existing insulation needs to be recorded by the onsite auditors.
- **$R_{NewInsulation}$:** The R-value of the new insulation needs to be recorded by the onsite auditors.
- **$R_{floorassembly}$:** The R-value of the entire assembly needs to be recorded by the surveyor. This includes (depending on the floor construction), but is not limited to, carpet and pad, wood sub-floor, air film, concrete, etc. Currently, National Grid deems a value for their R-ceiling, at 6.16[74], but it is unclear whether R-floor is supposed to include the entire assembly (minus the insulation). This default value of 6.16 may be used if no additional data is available. Refer to the Future Research section for additional details on $R_{floorassembly}$ value.
- **HVAC System:** The type of HVAC system should be recorded by the auditors onsite. This will be used to look up the efficiency if it is not collected onsite.
- **η_{heat}:** The efficiency of the heating unit should be collected on-site.
- **HDD:** Heating Degree Days– based on geographical location (zip code); see Table 11-1 below[75].

Proposed Alternative Savings Algorithm

We do not find merit in recommending a separate alternative savings methodology, as the primary savings algorithm is within the scope of the current data collection methods. The only

[74] Savings methodology presented in National Grid's gas measure calculations document "EW Gas Measure Calculations_FROM KIM CROSSMAN - USE THIS" (Attic Insulation – p.6)

[75] A spreadsheet will be provided that will the zip code to one of the TMY3 Cities.

change is the use of minimum AFUE values from Table 11-2, for measures where collection of the heating system efficiency is not feasible.

Inputs

- **η_{heat}:** The AFUE of the heating unit from Table 11-1.
- **R-Value:** Some Program Administrators do not record the pre- and post- R-Values, but only record the type of insulation and the depth (inches) of insulation. A table has been provided below, for those Program Administrators who do not record the R-values, to look up an approximate R-value based on the depth and insulation type. See Table 11-3 below.

National Grid Data Points: National Grid already collects the existing and new efficiency ratings (R-values) to generate the savings based on the proposed primary algorithm. We do recommend that National Grid collect the actual heating system efficiency value (η_{heat}) along with clearly defining the R-Floor value. The auditors also select the closest city for their HDD value based on the zip-code lookup spreadsheet provided.

Future Research

This section covers some topics that should be collected to help inform and validate the savings claims.

1. **Annual electric consumption:** This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the DUAs;
2. **$R_{floorassembly}$:** Research on the R-value of the entire assembly (minus insulation) should be explored. At a minimum, information should be collected on the typical floor construction types, all wood, concrete over unconditioned space, slab on-grade, or others. This information will help come up with a deemed R-value to use for the assembly, that is relevant to Massachusetts multi-family homes. The US Department of Energy has a website that can provide more information on floor construction assembly types[76].

[76] Building Energy Codes, Online Training. http://www.energycodes.gov/moodle/mod/resource/view.php?id=658.

Look-Up Tables

Table 11-1: HDD Values by Weather Station[77]

TMY3 City	HDD
Barnstable Muni Boa	4379
Beverly Muni	5329
Boston Logan Int'l Arpt	4550
Chicopee Falls Westo	5016
Lawrence Muni	4640
Marthas Vineyard	4312
Nantucket Memorial AP	3988
New Bedford Rgnl	4434
North Adams	5234
Norwood Memorial	4872
Otis ANGBb	4718
Plymouth Municipal	4559
Provincetown (AWOS)	4368
Westfield Barnes Muni AP	5301
Worchester Regional Arpt	5816

Table 11-2: η_{heat} Minimum Efficiency Ratings

Heating System	AFUE
Steam Boiler	0.75[78]
Furnace	0.78[79]
Hydronic Boiler	0.84
Condensing Boiler	0.84

77 These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, will also be provided.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

78 IECC 2009. Table 503.2.3(5): Boilers, Gas-and Oil-fired, Minimum Efficiency Requirements.

79 Current national standards for residential gas furnaces - http://www.appliance-standards.org/product/furnaces.

Table 11-3: Insulation R-Value Lookup[80]

Insulation Type	Insulation Material	Insulation R-Value
Loose Fibers	Fiberglass	=2.5 * Depth (inches)
	Rock Wool	=2.8 * Depth (inches)
	Cellulose	=3.7 * Depth (inches)
Granules	Vermiculite	=2.7 * Depth (inches)
	Perlite	
Batts	Fiberglass	=3.2 * Depth (inches)

80 Oak Ridge National Laboratory. Insulation Fact Sheet. December 22nd, 2008. http://www.ornl.gov/sci/roofs+walls/insulation/ins_06.html

12

Electric: Wall Insulation

Applicable Program Administrators

National Grid, NSTAR and Cape Light Compact

Measure Description

Measured in square footage, the walls in most houses represent the largest exposure of any area to the outdoors. So making them as resistant to heat flow as possible by adding, or upgrading existing insulation will help reduce the thermal losses and thereby saving energy and costs.

Proposed Savings Justification

- The algorithm we recommend for the electric wall insulation measure is similar to the algorithm prescribed in the State of Ohio Energy Efficiency Technical Reference Manual[81] (p.36) for residential market sector and requires most of the same data point inputs that are being collected for the MA Low Income Multi-Family Retrofit program.
- This method, which varies significantly from the MA TRM, provides a calculated approach to savings estimation by utilizing actual field data, unlike the savings estimates that are derived from a deemed kWh/SQFT value, as being prescribed in the current version of the MA TRM.

Proposed Primary Savings Algorithm

The following discussion presents algorithms to calculate the savings resulting from installing new, or upgrading existing, wall insulation. Savings are calculated based on the nominal pre- and post-retrofit R-values and the area of the wall that is being insulated.

The algorithm assumes that an auditor is on location and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area on which insulation is being added, and the efficiency of the cooling and heating system used in the home.

[81] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010 (p.36)

The total annual energy (kWh) savings resulting from the wall insulation measure are the sum of the annual air conditioning kWh savings and the annual electric heating kWh savings.

Air Conditioning Savings:

$$kWh_{annual}\frac{\left(\frac{1}{R_{exist}}-\frac{1}{R_{new}}\right)\times CDH\times DUA\times Area}{1{,}000\ Btu/kBtu\times\eta_{cool}}$$

Electric Heating Savings:

$$kWh_{annual}\frac{\left(\frac{1}{R_{exist}}-\frac{1}{R_{new}}\right)\times HDD\times 24\times Area}{1{,}000{,}000\times\eta_{heat}}\times 293.1$$

R_{exist}	=	Existing effective R-value (R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh.
R_{new}	=	New total effective R-value (R-ProposedMeasure + R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
DUA	=	Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F = 0.75[82]
Area	=	Square footage of total wall area (actual recorded)
η_{cool}	=	Efficiency of Air Conditioning equipment (SEER or EER[83], actual recorded);
η_{heat}	=	Efficiency of the heating system (COP, actual recorded);
293.1	=	Conversion constant (1MMBtu = 293.1 kWh)
24	=	Conversion for hours per day
CDH	=	Cooling Degree Hours; dependent on location, see Table 12-3 below
HDD	=	Heating Degree Days; dependent on location, see Table 12-3 below
1,000,000	=	Conversion from Btu to MMBtu

Inputs:

The following key parameters are used to calculate energy savings using the primary savings approach:

- **Area:** No additional data collection efforts need to be made since the utilities already gather adequate data for this variable.

[82] Based on Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" (p.31)

[83] Whether the SEER or the EER value should be used, depends on the HVAC equipment type and equipment size. Table 8-1 below shows the efficiency rating used by the IECC, based on equipment specifications. These same ratings should be followed, when determining the which efficiency rating to use in the algorithm.

- **$R_{ExistingInsulation}$:** The R-value of the existing insulation should be recorded by the onsite auditors.
- **$R_{NewInsulation}$:** The R-value of the new insulation should be recorded by the onsite auditors.
- **$R_{wallassembly}$:** The R-value of the entire assembly should be recorded by the surveyor. This includes, but is not limited to, outside air film, stucco, wood/studs, cavity, inside air film, etc. Currently, National Grid deems a value for their R-wall, at 6.65[84], but it is unclear whether R-wall is supposed to include the entire assembly (minus the insulation). This default value of 6.65 may be used if no additional data is available. Refer to the Future Research section for additional details on $R_{wallassembly}$ value.
- **HVAC System:** The size and type of HVAC system should be recorded by the auditors onsite. This will be used to look up the efficiency if it is not collected onsite.
- **η_{cool}:** The efficiency of air conditioning equipment value needs to be collected on-site;
- **η_{heat}:** The efficiency of the heating unit should be collected on-site.

Proposed Alternative Savings Algorithm:

We do not recommend a separate alternative savings methodology, as the primary savings algorithm is within the scope of the current data collection methods. The only recommended change is the use of minimum heating and cooling system efficiencies as detailed below, and the R-value calculations in the case that they are not collected onsite.

Inputs:

- **η_{cool}:** Select the appropriate stipulated cooling system efficiency from Table 8-1 below. If adequate data is not able to be collected, a minimum efficiency value of 13 SEER may be used[85].
- **η_{heat}:** Select the appropriate stipulated heating system efficiency from Table 12-2 below.Table 8-2If adequate data is not able to be collected, a minimum efficiency value of 7.7[86] HSPF may be used[87].
- **R-Value:** Some Program Administrators do not record the pre- and post- R-values, but only record the type of insulation and the depth (inches) of insulation. A table has been provided below, for those Program Administrators who do not record the R-values, to

84 Savings methodology presented in National Grid's gas measure calculations document "EW Gas Measure Calculations_FROM KIM CROSSMAN - USE THIS" (Sidewall Insulation – p.9)

85 Massachusetts Technical Reference Manual. 2011 Program Year – Plan Version. October 2010. Program: Residential Cooling & Heating Equipment (p.66).

86 2009 International Energy Conservation Code. Table 503.2.3. Unitary Air Conditioners and Condensing Units, Electrically Operated, Minimum Efficiency Requirements.

87 For heat pumps the equipment efficiency used in the prescribed algorithm should be the Coefficient of Performance or COP (i.e., divide HSPF by 3.412; e.g., HSPF 7.7 is COP of 2.26).

look up an approximate R-value based on the depth and insulation type. See Table 12-4 below.

National Grid: National Grid already collects the existing and new efficiency ratings (R-values) to generate the savings based on the primary algorithm. We recommend that National Grid collect the actual heating and cooling system efficiency values (η_{heat} and η_{cool}) and clearly defines the R-Wall value. The auditors also need to be able to choose the closest city for their CDH and HDD value based on Table 8-3 below.

NSTAR: NSTAR's audit spreadsheets show that that they do collect adequate data to generate the savings using recommended algorithms. NSTAR does need to collect the R-Wall value, actual cooling and heating system types, and whenever possible, the efficiency values (η_{cool} and η_{heat}). NSTAR also currently collects wall type, which could be used to create new $R_{wallassembly}$ values. The auditors also need to be able to choose the closest city for their CDH and HDD value based on Table 12-3 below.

Cape Light Compact: Cape Light currently collects the measure quantity, the gross savings and pertinent measure information, which does not completely satisfy the requirements to estimate savings using the primary savings estimation method. We recommend that Cape Light collect the following information, at a minimum, to accurately estimate the savings resulting from installing or upgrading the attic insulation.

- **Area:** Square footage of insulated area
- **R_{exist}:** Existing effective whole-assembly R-value
- **R_{new}:** New total effective whole-assembly R-value
- **η_{cool}:** Efficiency of Air Conditioning equipment (SEER)
- **η_{heat}:** Efficiency of Air Conditioning equipment (COP)

Future Research

This section covers some topics that should be collected to help inform and validate the savings claims.

1. **Annual electric consumption:** This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the DUAs;
2. **$R_{wallassembly}$:** Research on the R-value of the entire assembly (minus insulation) should be explored. At a minimum, information should be collected on the typical wall construction types. This information will help come up with a deemed R-value to use for the assembly, that is relevant to Massachusetts multi-family homes. The US Department of Energy has a website that can provide more information on wall assembly types[88].

[88] Building Energy Codes, Online Training. http://www.energycodes.gov/moodle/mod/resource/view.php?id=657.

Look-Up Tables

Table 12-1: Minimum Efficiency Ratings for Space Cooling Systems[89]

Cooling System	Minimum Efficiency
Air Conditioners, Air Cooled	
<65,000 Btu/h, Split Systems	13.0 SEER
<65,000 Btu/h, Single Package	13.0 SEER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.2 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥240,000 & <760,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	10.0 EER 9.7
≥240,000 & <760,000 Btu/h, All Other Heating Section, Split System and Single Package	9.8 EER 9.7 IPLV
≥760,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	9.7 EER 9.4 IPLV
≥760,000 Btu/h, All Other Heating Section, Split System and Single Package	9.5 EER 9.2 IPLV
≤30,000 Btu/h Through-the-Wall, Split System	12.0 SEER
≤30,000 Btu/h Through-the-Wall, Single Package	12.0 SEER
Air Conditioner, Water and Evaporatively Cooled	
<65,000 Btu/h, Split Systems and Single Package	12.1 EER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.5 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	11.3 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.5 EER

89 2009 International Energy Conservation Code – abridged version of Tables 503.2.3(1) and 503.2.3(2)

≥240,000 Btu/h, All Other Heating Section, Split System and Single Package	11.3 EER
Condensing Units, Air Cooled	
≥135,000 Btu/h	10.1 EER 11.2 IPLV
Condensing Units, Water or Evaporatively Cooled	
≥135,000 Btu/h	13.1 EER 13.1 IPLV
Heat Pumps, Electrically Operated, Air Cooled (Cooling Mode)	
<65,000 Btu/h, Split Systems	13.0 SEER
<65,000 Btu/h, Single Package	13.0 SEER
≥65,000 & <135,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	11.0 EER
≥65,000 & <135,000 Btu/h, All Other Heating Section, Split System and Single Package	10.8 EER
≥135,000 & <240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	10.6 EER
≥135,000 & <240,000 Btu/h, All Other Heating Section, Split System and Single Package	10.4 EER
≥240,000 Btu/h, Electric Resistance (or None) Heating Section, Split System and Single Package	9.5 EER 9.2 IPLV
≥240,000 Btu/h, All Other Heating Section, Split System and Single Package	9.3 EER 9.0 IPLV
≤30,000 Btu/h Through-the-Wall, Split System	12.0 SEER
≤30,000 Btu/h Through-the-Wall, Single Package	12.0 SEER
Heat Pumps, Electrically Operated, Water Source, 86ºF Entering Water (Cooling Mode)	
<17,000 Btu/h	11.2 EER
≥17,000 & <65,000 Btu/h	12.0 EER
≥65,000 & <135,000 Btu/h	12.0 EER
Heat Pumps, Electrically Operated, Groundwater Source, 59ºF Entering Water (Cooling Mode)	
<135,000 Btu/h	16.2 EER
Heat Pumps, Electrically Operated, Ground Source, 77ºF Entering Water (Cooling Mode)	
<135,000 Btu/h	13.4 EER

Table 12-2: Minimum Efficiency Ratings for Space Heating Systems[90]

Heating System	Minimum Efficiency
Heat Pumps, Electrically Operated, Air Cooled (Heating Mode)	
<65,000 Btu/h (Cooling Capacity), Split Systems	7.7 HSPF
<65,000 Btu/h (Cooling Capacity), Single Package	7.7 HSPF
≥65,000 & <135,000 Btu/h (Cooling Capacity), 47ºF db/43ºF wb Outdoor Air	3.3 COP
≥65,000 & <135,000 Btu/h (Cooling Capacity), 17ºF db/15ºF wb Outdoor Air	2.25 COP
≥135,000 Btu/h (Cooling Capacity), 47ºF db/43ºF wb Outdoor Air	3.2 COP
≥135,000 Btu/h (Cooling Capacity), 17ºF db/15ºF wb Outdoor Air	2.05 COP
≤30,000 Btu/h Through-the-Wall, Split System	7.4 HSPF
≤30,000 Btu/h Through-the-Wall, Single Package	7.4 HSPF
Heat Pumps, Electrically Operated, Water Source, 68ºF Entering Water (Heating Mode)	
<135,000 Btu/h (Cooling Capacity)	4.2 COP
Heat Pumps, Electrically Operated, Groundwater Source, 50ºF Entering Water (Heating Mode)	
<135,000 Btu/h (Cooling Capacity)	3.6 COP
Heat Pumps, Electrically Operated, Ground Source, 32ºF Entering Water (Heating Mode)	
<135,000 Btu/h	3.1 COP
Electrical Resistance Furnace[91]	
Electrical Resistance Furnace	1.0 COP

90 2009 International Energy Conservation Code – abridged version of Table 503.2.3(2)

91 This HVAC type is not included in the 2009 IECC table, but is included to show the COP for this measure.

Table 12-3: HDD Values by Weather Station

TMY3 City	HDD[92]	CDH[93]
Barnstable Muni Boa	4379	1349
Beverly Muni	5329	3432
Boston Logan Int'l Arpt	4550	4329
Chicopee Falls Westo	5016	4116
Lawrence Muni	4640	3978
Marthas Vineyard	4312	1345
Nantucket Memorial AP	3988	362
New Bedford Rgnl	4434	4232
North Adams	5234	2524
Norwood Memorial	4872	4763
Otis ANGBb	4718	2588
Plymouth Municipal	4559	2138
Provincetown (AWOS)	4368	2195
Westfield Barnes Muni AP	5301	3784
Worchester Regional Arpt	5816	1753

Table 12-4: Insulation R-Value Lookup[94]

Insulation Type	Insulation Material	Insulation R-Value
Loose Fibers	Fiberglass	=2.5 * Depth (inches)
	Rock Wool	=2.8 * Depth (inches)
	Cellulose	=3.7 * Depth (inches)
Granules	Vermiculite	=2.7 * Depth (inches)
	Perlite	
Batts	Fiberglass	=3.2 * Depth (inches)

92 These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, will also be provided.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

93 These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The CDH values were calculated by taking the temperature for each hour, and summing those values over 75ºF.

$$CDH = Sum[Max(0, HourlyTemp - 75ºF)]$$

94 Oak Ridge National Laboratory. Insulation Fact Sheet. December 22nd, 2008. http://www.ornl.gov/sci/roofs+walls/insulation/ins_06.html

13

Gas: Wall Insulation

Applicable Program Administrators

National Grid and NSTAR

Measure Description

Measured in square footage, the walls in most houses represent the largest exposure of any area to the outdoors. So making them as resistant to heat flow as possible by adding, or upgrading existing insulation will help reduce the thermal losses and thereby saving energy and costs.

Proposed Savings Justification

- The proposed algorithm is identical to the vendor provided algorithms in the MA TRM to use for the gas wall insulation measure. No additional data collection efforts by the PAs are required for utilizing this algorithm.
- This method is also very similar to the savings algorithm prescribed in the State of Ohio Energy Efficiency Technical Reference Manual[95] (p.36) for Public Utilities Commission of Ohio for the residential market sector and requires most of the same data point inputs that are being collected for the MA Low Income Multi-Family Retrofit program.

Proposed Primary Savings Algorithm

The following discussion presents algorithms to calculate the savings resulting from installing new, or upgrading existing, wall insulation. Savings are calculated based on the nominal pre- and post-retrofit R-values and the area of the wall that is being insulated.

The algorithm assumes that an auditor will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area on which insulation is being added, and the efficiency of the cooling and heating system used in the home.

[95] Vermont Energy Investment Corporation. State of Ohio Energy Efficiency Technical Reference Manual. August 6th, 2010 (p.36)

$$MMBtu_{annual} = \frac{\left(\frac{1}{R_{exist}} - \frac{1}{R_{new}}\right) \times HDD \times 24 \times Area}{1{,}000{,}000 \times \eta_{heat}}$$

R_{exist}	=	Existing effective R-value (R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh.
R_{new}	=	New total effective R-value (R-ProposedMeasure + R-ExistingInsulation + R-Assembly), ft^2-°F/Btuh
Area	=	Square footage of insulated area = actual recorded
ηheat	=	Efficiency of the heating system (AFUE) = actual recorded;
HDD	=	Heating Degree Days – dependent on location (zip code). See Table 13-2.
1,000,000	=	Conversion from Btu to MMBtu

Inputs

The following key parameters are used to calculate energy savings using the primary savings approach:

- **Area:** No additional data collection efforts need to be made since the current applicable PAs already gather adequate data for this variable.
- **$R_{ExistingInsulation}$:** The R-value of tor mayhe existing insulation should be recorded by the onsite auditors.
- **$R_{NewInsulation}$:** The R-value of the new insulation should be recorded by the onsite auditors.
- **$R_{wallassembly}$:** The R-value of the entire assembly should be recorded by the onsite auditor. This includes, but is not limited to, outside air film, stucco, wood/studs, cavity, inside air film, etc. Currently, National Grid deems a value for their R-wall, at 6.65[96], but it is unclear whether R-wall is supposed to include the entire assembly (minus the insulation). This default value of 6.65 may be used if no additional data is available. Refer to the Future Research section for additional details on $R_{wallassembly}$ value.
- **HVAC System:** The size and type of HVAC system should be recorded by the auditors onsite. This will be used to look up the efficiency if it is not collected onsite.
- **η_{heat}:** The efficiency of the heating unit should be collected on-site.

Proposed Alternative Savings Algorithm

We do not recommend a separate alternative savings methodology, as the primary savings algorithm is within the scope of the current data collection methods. The only recommended change is the use of minimum AFUE values from Table 13-1 below.

96 Savings methodology presented in National Grid's gas measure calculations document "EW Gas Measure Calculations_FROM KIM CROSSMAN - USE THIS" (Sidewall Insulation – p.9)

Inputs

- **η_{heat}:** The AFUE of the heating unit from Table 13-1 below.
- **R-Value:** Some Program Administrators do not record the pre- and post- R-values, but only record the type of insulation and the depth (inches) of insulation. A table has been provided below, for those Program Administrators who do not record the R-values, to look up an approximate R-value based on the depth and insulation type. See Table 13-3 below.

National Grid: National Grid already collects the existing and new efficiency ratings (R-values) to generate the savings based on the proposed primary algorithm. We recommend that National Grid collect the actual heating system efficiency values (η_{heat}), and clearly define the R-Wall value. The auditors should also select the closest city for their HDD value based on Table 13-2 below.

NSTAR: NSTAR's audit spreadsheets show that that they do collect adequate data to estimate savings using the recommended algorithm. To use the recommended approach, NSTAR needs to collect the R-Wall value and actual heating system efficiency value (η_{heat}). NSTAR also currently collects wall type, which could be used to create new $R_{wallassembly}$ values. The auditors should also select the closest city for their HDD value based on Table 13-2 below.

Future Research

This section covers some topics that should be collected to help inform and validate the savings claims.

1. **Annual electric consumption:** This could be used to derive actual weather-sensitive pre-retrofit heating and cooling use, which can then be used to determine the DUAs;
2. **$R_{wallassembly}$:** Research on the R-value of the entire assembly (minus insulation) should be considered. At a minimum, information should be collected on the typical wall construction types. This information will help in estimating a deemed R-value to use for the assembly, that is relevant to Massachusetts multi-family homes. The US Department of Energy has a website that can provide more information on wall assembly types[97].

[97] Building Energy Codes, Online Training. http://www.energycodes.gov/moodle/mod/resource/view.php?id=657.

Look-Up Tables

Table 13-1: η_{heat} Minimum Efficiency Ratings

Heating System	AFUE
Steam Boiler	0.75[98]
Furnace	0.78[99]
Hydronic Boiler	0.8[4]
Condensing Boiler	0.8[4]

Table 13-2: HDD Values by Weather Station[100]

TMY3 City	HDD
Barnstable Muni Boa	4379
Beverly Muni	5329
Boston Logan Int'l Arpt	4550
Chicopee Falls Westo	5016
Lawrence Muni	4640
Marthas Vineyard	4312
Nantucket Memorial AP	3988
New Bedford Rgnl	4434
North Adams	5234
Norwood Memorial	4872
Otis ANGBb	4718
Plymouth Municipal	4559
Provincetown (AWOS)	4368
Westfield Barnes Muni AP	5301
Worchester Regional Arpt	5816

98 IECC 2009. Table 503.2.3(5): Boilers, Gas-and Oil-fired, Minimum Efficiency Requirements.

99 Current national standards for residential gas furnaces - http://www.appliance-standards.org/product/furnaces.

100 These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, will also be provided.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

Table 13-3: Insulation R-Value Lookup[101]

Insulation Type	Insulation Material	Insulation R-Value
Loose Fibers	Fiberglass	=2.5 * Depth (inches)
	Rock Wool	=2.8 * Depth (inches)
	Cellulose	=3.7 * Depth (inches)
Granules	Vermiculite	=2.7 * Depth (inches)
	Perlite	
Batts	Fiberglass	=3.2 * Depth (inches)

[101] Oak Ridge National Laboratory. Insulation Fact Sheet. December 22nd, 2008. http://www.ornl.gov/sci/roofs+walls/insulation/ins_06.html

14

Electric: Insulation – Other

Applicable Program Administrators

Cape Light Compact

Measure Description

This measure involves the installation of an attic hatch or attic stairs cover or insulation. The installation of this measure reduces the movement of air between the attic and the house through the attic hatch.

Proposed Savings Justification

Cape Light Compact currently rebates two different measures – Insulating Stair Cover and Hatch Seal & Insulate, claiming between 307 kWh to 615 kWh. The source for this deemed savings estimate has not been provided but the value seems very high. The heating consumption is estimated to be 4140 kWh for electric resistance units, which puts the deemed savings values from Cape Light Compact between 7% and 15% of the heating consumption.

Our general recommendation is that this measure should not be listed as its own measure, but be rolled up into the air sealing measure, as its savings are a direct result of the reduction of air movement between the attic and the house. This recommendation compliments our recommendations for the gas air sealing measure that the Program Administrators keep records of the specific air sealing measures that are performed on a building, this being one of those possible measures. Until such an approach can be implemented, however, our recommendation is that the savings are calculated as a percent of the total heating consumption[102].

Proposed Primary Savings Method

$$\Delta kWh = (kWh_{cool} + kWh_{heat}) \times \%savings$$

kWh_{cool} = Average kWh consumption of the air conditioning system, based on system type (See Table 14-2).

[102] Correspondence with Cape Light Compact reveals that they are already rolling this measure up into the air sealing measure, and was just broken out in their tracking data. It is unclear how the savings are split out however, as the savings reported in the tracking spreadsheet are much higher than the proposed savings here.

kWh_{heat} = Average kWh consumption of the electric resistance furnace, based on system type (See Table 18-2).

%savings = Energy savings percent from installation of stair cover and hatch insulation deemed at 3%[103].

Table 14-1: Deemed Annual Savings

System Type	Space Heating UEC	Cooling UEC	Annual Savings (3.0%)
No-AC/ER	4140	0	124
AC/ER	4140	397	136
HP	3292	594	117
AC-Only	0	397	12

Inputs

- **HVAC System:** The HVAC system type should be recorded by the auditors onsite.

Proposed Secondary Savings Method

No secondary savings method has been proposed, as the primary proposed savings method is based off a deemed savings approach which can be used by all PAs in the future programs.

Future Research

1. Future research should be performed to understand the potential of this measure for savings through the reduction of air movement between the attic and the dwelling through the attic hatch.
2. **kWh_{cool} & kWh_{heat}:** Estimate the electric consumption of the heating and cooling units in Massachusetts multi-family buildings. Such estimates were developed for the MF Potential Study using Itron's SitePro, considering local weather data and taking into account saturation and efficiency of different heating systems. These results are currently the best available currently, but future research is recommended to gather more up to date information on saturation, efficiency, and heating/cooling load for the multi-family sector in Massachusetts. A breakdown of energy consumption should also be included by HVAC type to consider the potential for savings based on different heating systems.

[103] The 3% is an engineering estimate. It is recommended that further research is conducted to update this number in the future. See section on future research.

Notes

1. This measure makes up less than 2% of Cape Light Compact's total electric portfolio savings for 2010 and 2011.
2. Relatively few multifamily units are expected to have attic hatches or attic stairs, so this measure accounts for a small portion of overall program savings.

Look-Up Tables

Table 14-2: AC System Saturation and UEC[104]

AC System Type	Population Saturation	UEC	Weight for Avg UEC Calc	Weighted UEC	Final UEC
Whole Bldg AC	10.30%	619	16.90%	105	397
RAC	34.90%	225	57.10%	129	
CAC	15.90%	631	26.00%	164	
HP	7.70%	594	100.00%	594	594

Table 14-3: Heating System Saturation and UEC[104]

Electric Heating System Type	Population Saturation	UEC	Weight for Avg UEC Calc	Weighted UEC	Final UEC
Whole Bldg Htg	14.86%	4226	80.46%	3400	4140
Room Heat	1.54%	4261	8.32%	354	
Central Heat	2.07%	3432	11.22%	385	
Heat Pump	7.70%	3292	100.00%	3292	3292

[104] Values were determined from multiple *SitePro* multi-family building simulations, and used in the Massachusetts Multi-Family Potential Study

15

Gas: Insulation – Other

Applicable Program Administrators

National Grid

Measure Description

This measure involves the installation of an attic hatch or attic stairs cover or insulation. Acceptable models include Therma-dome model 1025A or equivalent. The installation of this measure reduces the movement of air between the attic and the house through the attic hatch.

Proposed Savings Justification

National Grid currently takes a deemed savings approach to estimate the savings for this measure, claiming the measure saves 2,763,158 BTU per installation (2.8 MMBtu). The source for this deemed savings estimate has not been provided and the value seems high. The heating consumption per unit from the Massachusetts Multi-Family Potential Study is estimated to be 36.5 MMBtu[105], which puts the deemed savings from National Grid at 7%.

Our general recommendation is that this measure should not be listed as its own measure, but rather be rolled up into the air sealing measure, as its savings are a direct result of the reduction of air movement between the attic and the house. This recommendation compliments our recommendations for the gas air sealing measure that the Program Administrators record the specific air sealing measures that are performed on a building, this being one of those possible measures. Until such an approach can be implemented, however, our recommendation is that the savings are calculated as a percent of the total heating consumption.

Proposed Primary Savings Method

$$\Delta MMBtu = MMBtu_{heat} \times \%savings$$

$MMBtu_{heat}$ = Average natural gas consumption of the heating system, based on heating type. (See Table 18-2).

[105] This was the average consumption based on the Massachusetts Multi-Family Potential Study. Values were determined from multiple *SitePro* multi-family building simulations.

%savings = Energy savings percent from installation of an attic hatch or attic stairs cover or insulation, deemed at 3%[106].

Table 15-1: Deemed Annual Savings

System Type	Space Heating UEC (MMBtu)	Annual Savings (3.0%) (MMBtu)
Gas Heat	36.5	1.1

Inputs

- **Heating System:** The heating system type should be recorded by the auditors onsite.

Proposed Secondary Savings Method

No secondary savings method has been proposed, as the primary proposed savings method is based on a deemed savings approach which can be used by all utilities in the future.

Future Research

1. Future research should be performed to understand the potential of this measure for savings through the reduction of air movement between the attic and the dwelling through the attic hatch. It is also recommended that National Grid provide justification for their savings estimate of 2.8 MMbtu.
2. **$MMBtu_{heat}$:** Estimate the gas consumption of the heating units in Massachusetts multi-family buildings. Such estimates were developed for the MF Potential Study using Itron's SitePro, considering local weather data and taking into account saturation and efficiency of different heating systems. These results are currently the best available currently, but future research is recommended to gather more up to date information on saturation, efficiency, and heating/cooling load for the multi-family sector in Massachusetts. A breakdown of energy consumption should also be included by HVAC type to consider the potential for savings based on different heating systems.

Notes

1. National Grid currently claims a deemed natural gas savings of 2,763,158 BTU per installation (2.8 MMBtu).
2. This measure makes up less than 1% of National Grid's total gas portfolio savings for 2010 and 2011.

[106] The 3% is an engineering estimate. It is recommended that further research is conducted to update this number in the future. See section on future research.

3. Relatively few multifamily units are expected to have attic hatches or attic stairs, so this measure accounts for a small portion of overall program savings.

Look-Up Tables

Table 15-2: Heating System Saturation and UEC[107]

Gas Heating System Type	Population Saturation	UEC	Weight for Avg UEC Calc	Weighted UEC	Final UEC (MMBtu)
Room Heat	2.18%	38.8	3%	1.0	36.5
Central Heat	15.90%	47.4	20%	9.3	
Whole Bldg Htg	63.06%	33.7	78%	26.2	

[107] Values were determined from multiple *SitePro* multi-family building simulations, and used in the Massachusetts Multi-Family Potential Study

16

Air Sealing: Gas & Electric

The same approach should be used regardless of heating fuel type, therefore, both the electric and gas savings for the air sealing measure are discussed in this single document. In addition, there are several issues that affect both the electric and gas savings estimates discussed in this document. Other than covering multiple fuel types, the format of this document is the same as that for other energy efficiency measures.

Overview

Air sealing savings for single-family homes are typically calculated from pre/post blower door test results, either actual site-specific tests, or a study with a robust sample. As such, TRM savings algorithms are typically based on a CFM_{50} approach, where the actual measured CFM reduction for a space is used, and a reference to the space dimensions (floor area, space volume, ceiling height) is not required. This is the case for single family homes, and algorithms in most TRMs state this assumption[108]. However, blower door testing for multifamily buildings presents many challenges, and there are few studies to draw conclusions from. This is supported by ASHRAE, experts in the field[109], and is confirmed by research, as well as a review of the different approaches used by the Massachusetts PAs to estimate air sealing savings.

As a result, a simple, single, traceable, approach that will allow sanity checking of savings estimates against actual heating consumption, and comparison across utilities is proposed. This proposed approach is similar to the ACH-based approach used by National Grid for estimating gas heating savings, except that the ACH values are set to deemed, traceable/transparent values. The ACH values currently used by National Grid are estimated based on observations made by field auditor's onsite rather than actual testing.

Applicable Program Administrators

National Grid, NSTAR and Cape Light Compact

[108] Mid-Atlantic TRM Version 2.0, July 2011, air sealing measure description: "The measure assumes that a trained auditor, contractor or utility staff member is on location, and will measure and record the existing and post air leakage rate using a blower door in accordance with industry best practices." The algorithm is CFM50 based.

[109] Correspondence with Don Hynek, Multifamily Weatherization Coordinator, Wisconsin Division of Energy Services, January 18, 2012.

Measure Description

Air sealing will decrease the infiltration of outside air through cracks and leaks in the building. Air sealing will also increase the comfort of the occupants by decreasing cold drafts and noise, and will help increase indoor air quality by sealing out dust and airborne pollutants, not only from the outside but from inter-unit air exchange.

Proposed Primary Savings Method

The proposed algorithm is similar to that used for National Grid's gas heating air sealing ACH approach, but is used for both electric and gas. Using a single algorithm will provide a more consistent estimate across fuel types, and make data collection easier for all utilities. It will also help with characterizing the sites and developing metrics for comparing sites/buildings across utilities. The proposed savings algorithm calculates only the *heating* energy savings, based on the reduction in infiltration and associated sensible heating load. Possible cooling and ventilation savings are not addressed by this approach, but these savings are small compared to space heating savings[110]. Only a single algorithm is necessary and the savings can be calculated for therms, MMBtu, and kWh basis:

$$\Delta MMBtu = \frac{Vol \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{1{,}000{,}000}$$

$$\Delta therms = \frac{Vol \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{100{,}000}$$

$$\Delta kWh = \frac{Vol \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{3413}$$

Vol = *[ft3]* This is the air volume of the treated space, calculated from the dimensions of the space, which could include the number of floors, the floor area per floor, and the floor-to-ceiling height, or the dwelling floor area and number of dwellings. The treated space can be the entire building including the common areas, or just the individual dwelling units. (Auditor Input)

ΔACH = *[°F-day]* Infiltration reduction in Air Changes per Hour, natural infiltration basis. This will typically be a default value, but the source of the assumption should be transparent and traceable, or it could come from a blower door test. (Stipulated Value or Blower Door Test)

[110] Neither National Grid nor NSTAR appear to claim fan/ventilation savings, and only NSTAR seems to claim cooling savings, though it is not clear if the algorithm addresses the latent cooling loads correctly.

HDD_{60}	=	Heating degree-days, base 60[111] from TMY3 weather data presented in Table 16-1. A spreadsheet that maps zip codes to these TMY3 weather stations has also been developed. This can be seen in Appendix C.
$\eta_{heating}$	=	*[AFUE, COP, thermal efficiency(%)]* Efficiency of the heating system, as determined on site (Auditor Input)
24	=	Conversion factor: 24 hours per day
0.018	=	[Btu/ft3- ºF] Air heat capacity: The specific heat of air (0.24 Btu/ºF.lb) times the density of air (0.075 lb/ft3)
1,000,000	=	Conversion factor: 1,000,000 Btu per MMBtu
100,000	=	Conversion factor: 100,000 Btu/therm
3413	=	Conversion factor: 3413 Btu/kWh

Inputs

This algorithm requires the PAs to collect or lookup the minimum information described below, only some of which is currently being collected by some Massachusetts PAs:

- **Volume:** The volume of the treated area is calculated from data collected by the on-site auditor. For example, if the treated area is defined as the entire building, then the total building square footage, or square feet per floor and number of stories, and average interior ceiling height would need to be collected. If the treated area is the dwelling unit, then the dwelling square footage, number of dwellings affected, and the interior ceiling height would be needed. All of this detail should be part of the tracking database.
- **ΔACH:** The infiltration reduction in Air Changes per Hour. Ideally, this would come from actual blower door tests for each unit or building, or it could be based on the results of a robust, local study with a robust sample that used blower door testing. However, as neither of these exist, simple default values based on the limited studies and reference sources available are recommended (see the default in the Alternative Proposed Savings approach section). The National Grid approach for gas savings relies upon the auditor's judgment and as such, can be subjective and likely results in artificial variations in ACH.
- **$\eta_{heating}$:** The AFUE (gas heating) or COP (electric heating or heat pump) of the heating unit should be collected on site. If it is not available, then the default values in Table 16-2 should be used, based on the type of heating system found on site.
- **Heating System Type:** In addition to the heating fuel type, the heating system type – gas furnace, electric furnace, or heat pump –should be recorded by the onsite auditor.
- **Heating Degree Days:** The HDD are provided based on a heating base of 60ºF. These values are provided in Table 16-1, but will be looked up by zip code (separate zip code mapping tool available – see Appendix C).

[111] National Grid, the Massachusetts TRM, the Mid-Atlantic TRM Version 2.0, and the Ohio TRM August 6, 2010 all use HDD_{60}, The source of this appears to be a PRISM evaluation of 600,000 Ohio residential single family customers where a 60F balance point was determined. However, an actual citation of the study is not provided in any TRM.

- **Air Sealing Measures Performed:** Although under the ACH approach, the savings will not be dependent on the actual measures installed these should still be tracked to monitor the level of effort for each site, and for possible use to adjust the savings algorithm. Descriptions of the actual work completed are not recorded. A standard list of typical air sealing measures should be developed from which the auditors can make selections.

Additional Inputs and Assumptions

Heating Degree Days: We recommended using HDD_{60} values derived from Typical Meteorological Year (TMY3) data, as show in Table 16-1. HDD values are provided for 15 Massachusetts weather stations throughout the state, along with a separate mapping tool that program administrators can use to map ZIP codes in Massachusetts to the weather stations.

- We chose the TMY3 data instead of the weather source currently being used by National Grid (1971-2000 NOAA) for the following reasons:
  - 1971-2000 NOAA only provides cooling degree days (CDD) for a cooling base of 70ºF. A cooling base of 75ºF is more appropriate, as it is not as likely that people use their cooling below 70ºF. The cooling base of 75ºF is also used by the Ohio TRM[112].
  - The current HDD source used by the PAs (1971-2000 NOAA) lists HDD values for 37 cities that can be selected by the PAs. However, without a mapping tool it is difficult to use this data.
  - By creating weather values based on TMY3 data, a consistent source is provided for both Cooling Degree Hours (CDH) and Heating Degree Days (HDD), and this can also be used for other CDH/HDD dependent measures.
  - HDD values can be looked up by ZIP code. A separate zip code mapping tool is provided in Appendix C).

Additional Contextual Data

In addition to the direct inputs needed for the savings calculations, other general information about the site and the specific savings claim should be collected. Contextual data is information that is not used directly in the calculation, but can be used to validate, categorize, or compare the savings results for a specific site with other sites. For example, the energy savings (and baseline energy use) for dwelling units alone will likely be much different than that for an entire building that has both common areas and dwelling units. In addition, it may be beneficial to incorporate some of these parameters into the algorithm, if these characteristics can be correlated with

[112] State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010. Measure: Attic/Roof/Ceiling Insulation (Retrofit). Page 36.

different energy use and savings levels. The contextual data that should be gathered for the air sealing measures includes the following:

- **Zone Type.** Is the calculation being done for a dwelling, for the entire building, or for the entire complex? National Grid already collects this data and uses "Dwelling Unit" and "Common (Interior)" categories. However, it is not clear if "Common (Interior)" means *only* common areas, or the entire building.
- **For Buildings: The fraction of Common Area.** If the zone type is a building, it would be useful to know the fraction of the building that is common area versus dwelling unit area, as this can make a significant difference in the baseline energy use (and we might want to incorporate it into the algorithm).
- **Year of Construction (or Vintage).** The year of construction or vintage of the building should also be tracked, as newer buildings typically have lower ACH values. In lieu of the actual year, "New" and "Existing" could be used, as long as a date for new construction is defined, for example, anything built in 2004 and later could be considered "New"[113]. Other construction characteristics such as wood-framed, metal framed, or stucco, block, brick, etc. should also be tracked.
- **Ceiling Height.** The floor-to-ceiling height – which could be actual, or could be a weighted average if for an entire building – is needed for the air volume calculation. If tracked, this data can also be used to revise the default assumption for the alternative proposed savings method.
- **Number of floors/stories.** This should be used for the volume calculation, but can also be used to determine if a building is low, mid, or high-rise.
- **Annual Heating Consumption.** This should be derived from the bills via a weather regression analysis, or simple assessment of the monthly energy bills. It could be used as a rough check of the savings calculations, not only for air sealing, but for all the measure savings associated with a site. For its gas savings approach, National Grid mentions an option of using 20% of the actual gas heating to estimate an ACH_{pre} value, however, it is unclear if this method is ever used. It is true though that additional contextual information might be needed to interpret and decompose these bills, and this might be impossible for a master (single) metered site.

Proposed Alternative Savings Method

For this approach, only the floor area of the treated space and the city/location (for HDD) are required to estimate savings. The savings approach is similar to that used by the New York

[113] The new construction date would typically be based on whenever a significant change in the new construction Codes & Standards took place.

Multifamily TRM[114], in that it provides savings estimates on a per 1,000 ft^2 basis, as shown in Table 16-1. A 1,000 ft^2 basis is used to make the factors easier to use, that is, they are values greater than 1 rather than decimal numbers. The algorithms are only slightly different from those previously presented, in that a ceiling height is assumed, default heating equipment efficiencies are assumed, and units are converted to per 1,000 ft^2.

$$\frac{\Delta MMBtu}{1{,}000\ ft^2} = \frac{1{,}000 \times Ceiling \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{1{,}000{,}000}$$

$$\frac{\Delta therms}{1{,}000 ft^2} = \frac{1{,}000 \times Ceiling \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{100{,}000}$$

$$\frac{\Delta kWh}{1{,}000 ft^2} = \frac{1{,}000 \times Ceiling \times \Delta ACH \times 0.018 \times HDD \times \frac{24}{\eta_{heating}}}{3{,}413}$$

Ceiling	=	*[ft]* This is the floor-to-ceiling height for the treated space. A value of 8 feet is assumed as typical for multifamily construction[115], as this information was not available from the MA utilities' tracking data.
Δ ACH	=	*[ºF-day]* Infiltration reduction in Air Changes per Hour, natural infiltration basis. This value would be fixed and not vary subjectively by site. A baseline/pre-retrofit ACH =0.5[116] is used, and a 20% reduction[117] in infiltration is assumed, which yields a Δ ACH value of 0.10.
HDD_{60}	=	Heating degree-days, base 60 from TMY3 weather data based on zip code lookup table. See Appendix C.
$\eta_{heating}$	=	*[AFUE, COP, thermal efficiency(%)]* Efficiency of the heating system default values in Table 16-2.
1,000	=	Conversion factors: 1000 ft^2
24	=	Conversion factor: 24 hours per day
0.018	=	[Btu/ft3- ºF] Air heat capacity: The specific heat of air (0.24 Btu/ºF.lb) times the density of air (0.075 lb/ft3)
1,000,000	=	Conversion factor: 1,000,000 Btu per MMBtu

[114] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs: Residential, Multifamily, and Commercial/Industrial Measures, October 15, 2010.

[115] The min. floor-to-ceiling height per MA code is 7 feet. http://www.mass.gov/eohhs/docs/dph/regs/105cmr410.pdf

[116] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs: Residential, Multifamily, and Commercial/Industrial Measures, October 15, 2010. A pre-retrofit value of 0.5 ACH is used for "Average" construction type. The National Grid data pre-retrofit average was 0.4 ACH.

[117] A 20% reduction is consistent with a recent Home Energy article, other studies cited in that article, and communication with the author of that article. A 15% reduction is used by the NY MF TRM, but this was considered to be too conservative. The National Grid gas heating approach uses Δ ACH values from 0.1-0.3.

100,000	=	Conversion factor: 100,000 Btu/therm
3413	=	Conversion factor: 3413 Btu/kWh

The resulting savings using these stipulated values are presented by heating system type – gas furnace, electric resistance, and heat pump - for each TMY3 City/HDD value in Table 16-1.

Recommended Approach by PA

National Grid: Gas Savings. National Grid currently uses alternative methods of estimating reduction in ACH (between 0.1-0.3 reduction), based general "rules of thumb." National Grid does not currently appear to perform blower door tests to calculate ACH. In addition, National Grid does not collect or record the heating type, heating efficiency, or the actual air sealing measures performed.

- The approach that National Grid currently takes may be acceptable, but additional references for and validation of the approach would need to be provided before making such a determination**.**
- Heating efficiency should be looked up based on Table 16-2, however, in the event that the heating type is not being collected, the efficiency should default to a furnace at 78%.
- Air sealing measures performed should be recorded in order to be able to justify or correlate to the ACH and ΔACH values that are selected by the auditors, and to help validate the savings claimed. A standard list of typical air sealing measures should be developed from which the auditors can make selections.

National Grid: Electric Savings. For electric heating savings, National Grid uses a CFM_{50} based algorithm, consistent with a blower door approach, but it does not appear that blower door tests are performed. Electrical savings (kWh) are estimated from the treated floor area, a $\Delta CFM/ft^2$ value, and a kWh/CFM savings constant. A regression-based algorithm is used to *estimate* the pre and post CFM_{50}/ft^2 values from subjective ratings of roof and floor tightness (1 to 5 scale) made by the auditors on site. As such, we recommend the following:

- If National Grid does not perform blower door tests, they could take the same approach that they use for gas savings from air sealing: estimate the baseline ACH reduction based on their current "rules of thumb". This will also require the collection of the volume of the measured area.
- Heating efficiency should be recorded or looked up based on Table 16-2 based on heating technology.
- Air sealing measures performed should be recorded, in order to be able to justify or correlate to the roof and floor tightness rankings that are selected by the auditors, and to

help validate the savings claimed. A standard list of typical air sealing measures should be developed from which the auditors can make selections.

NSTAR: NSTAR has a single approach for both electric and gas savings, which appears to be based on CFM_{50}. The CFM values are only available in site-specific facility audit spreadsheets for individual sites. These spreadsheets currently show a delta CFM being recorded. NSTAR states that they perform blower door tests however, it is not clear what approach is used for the blower door tests, and whether those results are used in their savings approach. Without knowing how the CFM value is determined, it is not possible to confirm the validity of their approach. Heating and cooling savings are calculated, but only in kWh: For gas heating, a simple conversion multiplier of 29.3 kWh per therm is applied, however, the heating system efficiency also should be considered.

- It is recommended that NSTAR collect the minimum information: heating system type, heating efficiency, variables for calculating volume or floor area, and the actual air sealing measures installed for each site.

Cape Light Compact: Cape Light Compact currently does not provide any information on what air sealing information they collect.

- It is recommended that Cape Light Compact collect the minimum information: heating system type, heating efficiency, variables for calculating volume or floor area, and what air sealing measures are currently being performed.

Future Research

1. Future research is required before the current approach taken by National Grid can be approved. Their approach does not show any sources listed that confirm the "general rules of thumb" ACH values that are used to estimate savings.
2. Consider performing blower door tests, as described by Energy Star[118], which performs blower door tests on a sample of dwelling units. Another option is to perform whole building blower door tests as described by Don Hynek in Home Energy Magazine[119]. The optional gas billing analysis proposed by ODC in the evaluation plan should also be considered.
3. Collect contextual data on building characteristics that could help improve the alternative approach values. For example, it makes sense that older buildings with larger and more

[118] www.homenergypros.lbl.gov/group/multifamilybuildings/forum/topics/mid-high-rise-ach-question

[119] Hynek, Don. *Blower Door Testing in Multifamily Buildings.* Home Energy Magazine. August 31st, 2011. http://www.homeenergy.org/show/article/page/1/nav/homeperformance/id/1711/viewFull/.

holes to seal should receive more savings, but the current methods for doing that are not substantiated. If all utilities track more contextual values, and the same values, along with some limited blower door testing, it may be possible to develop a more robust savings estimate.

4. Consider developing kWh savings impacts for HVAC fan energy, as well as cooling savings. Cooling savings would need to consider the latent energy impacts. Fan energy kWh savings could be claimed for gas heating as well as electric heating. However, the savings impacts have been shown to be minimal compared to the heating savings impacts.
5. Through a more detailed multifamily RASS study or a detailed analysis of some participant sites, the savings produced by these algorithms (and for other measures as well) should be compared to actual electric and gas consumption values for multifamily buildings, to make sure that they are reasonable. Any savings determined by an algorithm that is developed independently of actual use and with such uncertainty, should be checked in this manner.
6. Consider the use of a building simulation approach to estimate savings, as was done for the New York TRM. Itron's *SitePro* system was used for the multifamily potential study, and ACH is a parameter that can be changed in that model.

Table 16-1: HDD Values and Alternative Savings Factors by Weather Station[120]

TMY3 City	HDD_{60}	Gas Furnace $\frac{therms}{1{,}000\ ft^2}$	Gas Furnace $\frac{MMBtu}{1{,}000\ ft^2}$	Electric Resistance $\frac{kWh}{1{,}000\ ft^2}$	Heat Pump $\frac{kWh}{1{,}000\ ft^2}$
Barnstable Muni Boa	4379	19.4	1.94	443	196
Beverly Muni	5329	23.6	2.36	540	239
Boston Logan Int'l Arpt	4550	20.2	2.02	461	204
Chicopee Falls Westo	5016	22.2	2.22	508	225
Lawrence Muni	4640	20.6	2.06	470	208
Marthas Vineyard	4312	19.1	1.91	437	193
Nantucket Memorial AP	3988	17.7	1.77	404	179
New Bedford Rgnl	4434	19.6	1.96	449	199
North Adams	5234	23.2	2.32	530	235
Norwood Memorial	4872	21.6	2.16	493	218
Otis ANGBb	4718	20.9	2.09	478	211
Plymouth Municipal	4559	20.2	2.02	462	204
Provincetown (AWOS)	4368	19.4	1.94	442	196
Westfield Barnes Muni AP	5301	23.5	2.35	537	238
Worchester Regional Arpt	5816	25.8	2.58	589	261

[120] These values have been derived from TMY3 data downloaded from the National Solar Radiation Data Base. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html. The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average. A look up table, which maps zip code to TMY3 City, is also provided in Appendix C.

$$HDD = Sum\left[Max\left(0, 60ºF - \frac{dailyMax + dailyMin}{2}\right)\right]$$

Table 16-2: Default Efficiency Values by Heating System Type

Heating System	Default Efficiency
Steam Boiler	0.75 thermal efficiency[121]
Furnace	0.78 AFUE[122]
Hydronic Boiler	0.8 thermal efficiency[121]
Condensing Boiler	0.8 thermal efficiency[121]
Electric Resistance	1.0 thermal efficiency
Heat Pump	7.7 HSPF, 2.26 COP[123]

[121] IECC 2009. Table 503.2.3(5): Boilers, Gas-and Oil-fired, Minimum Efficiency Requirements.

[122] Current national standards for residential gas furnaces. Will be raised to 80%, effective 2015. http://www.appliance-standards.org/product/furnaces.

[123] A seasonal average COP can be approximated by dividing the HSPF (heating seasonal performance factor, unit basis of kBtuh/kWh) by 3.413.

17

Electric: Setback Thermostats

Applicable Program Administrators

National Grid, NSTAR and Cape Light Compact

Measure Description

Programmable Setback Thermostats can save energy through the advanced scheduling of time-of-day and/or day-of week setbacks to control heating and cooling set points. Typical usage reduces the heating set point during times of the day when occupants are usually not at home (work hours) keeping the home at a cooler temperature in the winter reduces heat losses relative to a higher temperature.

Proposed Savings Justification

The US Environmental Protection Agency suspended the ENERGY STAR specification effective December 31, 2009. The MA-TRM[124] currently claims a flat 288 kWh per unit. The PA-TRM[125] describes an equation that takes into account the efficiency of the heating and cooling units, duct efficiency, capacity, and heating and cooling hours. The Mid-Atlantic TRM[126] and Ohio TRM[127] both claim a 6.8% savings factor. There are many different approaches taken to estimate savings of these measures. The proposed savings justification is most similar in approach to that taken by both the Ohio TRM and the Mid-Atlantic TRM, as it takes an annual heating load and applies a percent savings to it.

Proposed Primary Savings Method

$$\Delta kWh = (kWh_{cool} + kWh_{heat}) \times \%savings$$

[124] Massachusetts Technical Reference Manual, 2011 Program Year – Plan Version - October 2010, page 144.

[125] State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards Technical Reference Manual, page 47.

[126] VEIC, *Mid-Atlantic Technical Reference Manual, Version 2.0*, July 2011. Measure: Programmable Thermostat, page 67.

[127] *State of Ohio Energy Efficiency Technical Reference Manual*, August 6th, 2010. Measure: Programmable Thermostats (Time of Sale, Early Replacement), page 125.

kWh_{cool} = Average kWh consumption of the air conditioning system, based on system type (See Table 14-2).

kWh_{heat} = Average kWh consumption of the electric resistance furnace, based on system type (See Table 18-2).

%savings = Energy savings percent from installation of programmable thermostats, deemed at 6.2%.[128]

Table 17-1: Deemed Annual Savings

System Type	Space Heating UEC	Cooling UEC	Annual Savings (6.2%)
No-AC/ER	4140	0	257
AC/ER	4140	397	281
HP	3292	594	241
AC-Only	0	397	25

Inputs

- **HVAC System:** The HVAC system type should be recorded by the auditors onsite.

Proposed Secondary Savings Method

We do not recommend a secondary savings method, as the primary proposed savings method is based off a deemed savings approach which can be used by all Program Administrators.

Future Research

1. **%savings:** The current estimate of 3%, used by National Grid, is a value that has not been sourced anywhere. Regional Technical Forum (RTF)[129] recommends 5%. The Mid-Atlantic TRM and Ohio-TRM both recommend 6.8%[130], based on a residential sector gas billing analysis. Use a combination of onsite M&V and surveys to determine set points and to better estimate percent savings from programmable thermostats. Consider a gas billing analysis to further analyze the actual savings resulting in the multifamily sector.
2. **kWh_{cool} & kWh_{heat}:** Estimate the electric consumption of the heating and cooling units in Massachusetts multi-family buildings. Such estimates were developed for the MF

[128] RLW Analytics. *Validating the Impact of Programmable Thermostats.* 2007. http://www.cee1.org/eval/db_pdf/933.pdf. This study was based on the residential sector.

[129] Northwest Council. Regional Technical Forum. Measure: Heating/Cooling Electronic Thermostats. http://www.nwcouncil.org/energy/rtf/measures/measure.asp?id=132

[130] RLW Analytics. Validating the Impact of Programmable Thermostats. 2007. http://www.cee1.org/eval/db_pdf/933.pdf

Potential Study using Itron's SitePro, considering local weather data and taking into account saturation and efficiency of different heating systems. These results are currently the best available currently, but future research is recommended to gather more up to date information on saturation, efficiency, and heating/cooling load for the multi-family sector in Massachusetts. A breakdown of energy consumption should also be included by HVAC type to consider the potential for savings based on different heating systems.

Notes

1. *National Grid:* Currently National Grid deems a value of 288 kWh reduced per unit. This deemed value of 288 kWh of reduction per unit is referenced to a non-traceable source as of this review. This approach is not recommended, as thermostat savings should not be on a per-unit basis. The savings should not be doubled if two thermostats are placed inside the same household.

2. *NSTAR:* Analysis of the algorithm provided within the NSTAR BCR[131] documentation reveals the usage of an average deemed value of 295 kWh reduced per unit. The actual energy savings for this measure are calculated in the facility audit spreadsheets, by the following equation:

$$kWh = heatLoad \times \%controlled \times \frac{degrees_{setback}}{100}$$

3. *Cape Light Compact:* Cape Light Compact deems a value of 530 kWh reduced per setback thermostat. No source was provided to verify this deemed value.

Look-Up Tables

Table 17-2: AC System Saturation and UEC[132]

AC System Type	Population Saturation	UEC	Weight for Avg UEC Calc	Weighted UEC	Final UEC
Whole Bldg AC	10.30%	619	16.90%	105	397
RAC	34.90%	225	57.10%	129	
CAC	15.90%	631	26.00%	164	
HP	7.70%	594	100.00%	594	594

[131] 2010 Input tab.xls – From the BCR_Model_Inputs – 2010 Production Data.

[132] Values were determined from multiple *SitePro* multi-family building simulations, and used in the Massachusetts Multi-Family Potential Study

Table 17-3: Heating System Saturation and UEC[104]

Electric Heating System Type	Population Saturation	UEC	Weight for Avg UEC Calc	Weighted UEC	Final UEC
Whole Bldg Htg	14.86%	4226	80.46%	3400	4140
Room Heat	1.54%	4261	8.32%	354	
Central Heat	2.07%	3432	11.22%	385	
Heat Pump	7.70%	3292	100.00%	3292	3292

18

Gas: Programmable Setback Thermostats

Applicable Program Administrators

National Grid, NSTAR and Cape Light Compact

Measure Description

Programmable Setback Thermostats can save energy through the advanced scheduling of time-of-day and/or day-of week setbacks to control heating and cooling set points. Typical usage reduces the heating set point during times of the day when occupants are usually not at home (work hours) keeping the home at a cooler temperature in the winter reduces heat losses relative to a higher temperature.

Proposed Savings Justification

The US Environmental Protection Agency suspended the ENERGY STAR specification effective December 31, 2009. The MA-TRM[133] currently claims a flat 7.7 MMBtu per unit. The Mid-Atlantic TRM[134] and Ohio TRM[135] both claim 3.41 MMBtu. There are many different approaches taken to estimate savings of these measures. The proposed savings justification is most similar in approach to that taken by both the Ohio TRM and the Mid-Atlantic TRM, as it takes an annual heating load and applies a percent savings to it.

Proposed Primary Savings Method

$$\Delta MMBtu = MMBtu_{heat} \times \%savings$$

$MMBtu_{heat}$ = Average natural gas consumption of the heating system, based on heating type. (See Table 18-2).

133 Massachusetts Technical Reference Manual, 2011 Program Year – Plan Version - October 2010, page 144.

134 VEIC, *Mid-Atlantic Technical Reference Manual, Version 2.0,* July 2011, Measure: Programmable Thermostat, page 67.

135 VEIC, *State of Ohio Energy Efficiency Technical Reference Manual*, August 6, 2010. Measure: Programmable Thermostats (Time of Sale, Early Replacement), page 125.

%savings = Energy savings percent from installation of programmable thermostats, deemed at 6.2%.[136]

Table 18-1: Deemed Annual Savings

System Type	Space Heating UEC (MMBtu)	Annual Savings (6.2%) (MMBtu)
Gas Heat	36.5	2.3

Inputs

- **Heating System:** The heating system type should be recorded by the auditors onsite.

Proposed Secondary Savings Method

We do not recommend a secondary savings method, as the primary proposed savings method is based upon a deemed savings approach which can be used by all Program Administrators.

Future Research

1. **%savings:** The current estimate of 3%, used by National Grid, is a value that has not been sourced anywhere. Regional Technical Forum (RTF)[137] recommends 5%. The Mid-Atlantic TRM and Ohio-TRM both recommend 6.8%[138], based on a residential sector gas billing analysis. Use a combination of onsite M&V and surveys to determine set points and to better estimate percent savings from programmable thermostats. Consider a gas billing analysis to further analyze the actual savings resulting in the multifamily sector.
2. **$MMBtu_{heat}$:** Estimate the gas consumption of the heating units in Massachusetts multi-family buildings. Such estimates were developed for the MF Potential Study using Itron's SitePro, considering local weather data and taking into account saturation and efficiency of different heating systems. These results are currently the best available currently, but future research is recommended to gather more up to date information on saturation, efficiency, and heating/cooling load for the multi-family sector in Massachusetts. A breakdown of energy consumption should also be included by HVAC type to consider the potential for savings based on different heating systems.

[136] RLW Analytics. *Validating the Impact of Programmable Thermostats.* 2007. http://www.cee1.org/eval/db_pdf/933.pdf. This study was based on the residential sector.

[137] Northwest Council. Regional Technical Forum. Measure: Heating/Cooling Electronic Thermostats. http://www.nwcouncil.org/energy/rtf/measures/measure.asp?id=132

[138] RLW Analytics. Validating the Impact of Programmable Thermostats. 2007. http://www.cee1.org/eval/db_pdf/933.pdf

Look-Up Tables

Table 18-2: Heating System Saturation and UEC[139]

Gas Heating System Type	Population Saturation	UEC	Weight for Avg UEC Calc	Weighted UEC	Final UEC (MMBtu)
Room Heat	2.18%	39	3%	1	36.5
Central Heat	15.90%	47	20%	9	
Whole Bldg Htg	63.06%	34	78%	26	

[139] Values were determined from multiple *SitePro* multi-family building simulations, and used in the Massachusetts Multi-Family Potential Study

19

Electric: Heat Pump Tune-Up

Applicable Program Administrators

National Grid

Measure Description

This measure involves the tune-up of an existing split system air-source Heat Pump for both common area and dwelling units in Multi-family applications.

Proposed Savings Justification

The MA-TRM[140] recommends similar calculation method to estimate savings for residential heat pump tune up measure however they do not specify whether this measure specifically applies to either single family or multi family. The deemed percent savings of 5%, according to the MA-TRM, is a MA common assumption also was verified to be a reasonable estimate based on reported savings range in Wisconsin[141]. Minimum efficiency standards for split system air-source heat pumps are 13 SEER and 7.7 HSPF.

Proposed Primary Savings Method

Two algorithms are provided, as some name plates may display the size of the unit in tons and others display the size in kBtuh.

$$kWh = tons \times 12\frac{kBtuh}{ton} \times \left(\frac{1}{SEER} \times Hours_{cooling} + \frac{1}{HSPF} \times Hours_{heating}\right) \times \%savings$$

$$kWh = kBtuh \times \left(\frac{1}{SEER} \times Hours_{cooling} + \frac{1}{HSPF} \times Hours_{heating}\right) \times \%savings$$

Tons	=	Size of the unit, tons
kBtuh	=	Size of the unit, kBtuh

[140] Massachusetts Technical Reference Manual. 2011 Program Year – Plan Version. October 2010. Program: Residential Cooling & Heating Equipment, Page 81.

[141] Scott Pigg, Energy Center of Wisconsin. *Central Air Conditioning in Wisconsin. A compilation of recent field research.* ECW Report number 241-1. December 15th, 2010. http://www.ecw.org/ecwresults/241-1.pdf.

HSPF	=	Efficiency of the heat pump system, Heating Seasonal Performance Factor, or 7.7[142]
SEER	=	Cooling efficiency, Seasonal Energy Efficiency Ratio, or 13[42]
$Hours_{heating}$	=	The equivalent full load hours are 1200 hours per year for heating[143]
$Hours_{cooling}$	=	The equivalent full load hours are 318 hours per year for cooling[144]
%savings	=	Engineering estimate for tune-up savings, 5%[143]

Inputs

Both algorithms require PAs to collect or lookup the minimum following information:

- **Tons / kBtuh:** The size (tons or kBtuh) of the unit should be collected while onsite.
- **SEER:** The seasonal efficiency of the cooling unit (SEER) should be collected while onsite.
- **HSPF:** The seasonal heat pump efficiency (HSPF) should be collected while onsite.
- **MF Area Type Served:** The multi-family are type served, common area or dwelling unit should be collected.
- **Tune-up Details:** The heat pump tune-ups should specify exactly what is being performed on the heat pump, whether it is a refrigerant charge, airflow adjustment, coil cleaning, filter replacement, or something else.

Proposed Alternative Savings Method

An alternative proposed savings method is to apply deemed savings values based on whether the system treats common areas or dwelling units. The difference between the two deemed values is due to the assumption that the system treating common areas will be larger than those treating dwelling units. However, it is likely that if a tune-up is being performed on the heat pump, the size of the equipment is already being collected.

- Dwelling Unit: System size is assumed to be 1.66 tons[145].
  - $\Delta kWh_{dwelling} = 180$ kWh

142 2009 International Energy Conservation Code. Table 503.2.3. Unitary Air Conditioners and Condensing Units, Electrically Operated, Minimum Efficiency Requirements.

143 Massachusetts Technical Reference Manual. 2011 Program Year – Plan Version. October 2010. Page 81.

144 ADM Associates, Inc. (2009). *Residential Central AC Regional Evaluation – Free-Ridership Analysis.* Prepared for CL&P. Table 4-3. (The MA-TRM estimates 360 based on this same source, but looking at the table shows that an average across the three Massachusetts utilities actually provides an average cooling hours of 318, not 360).

145 Opinion Dynamics Corporation. *Massachusetts Residential Appliance Saturation Survey (RASS). Volume 1: Summary Results and Analysis.* April 2009. This average size was used in the Massachusetts Multifamily Potential Study, extrapolated from this study based on the average square footage and system size for a single family home, and the onsite surveys performed in the Massachusetts Multifamily sector by Cadmus.

- Common Area: System size is assumed to be 3 tons[146].
  - $\Delta kWh_{CommonArea}$ = 325 kWh

National Grid: Currently National Grid deems this measures savings to be 1162 kWh per heat pump. No other information is collected about this measure to be able to use the primary proposed savings approach. However, the location is currently collected by National Grid, which allows them to utilize the alternative savings approach.

Future Research

1. **$Hours_{heating}$:** Conduct M&V to determine the current hours of heating and cooling in multifamily buildings. The values used in the MA-TRM are not adequately documented and secondary sources for multifamily buildings in regions similar to Massachusetts are not available. The Energy Star Calculator[147] assumes a much higher EFLH, at 2,397 and 2,734 for Boston and Worcester respectively. These values, however, are recommended for single family homes, which have a different EFLH than multifamily homes.
2. **%savings:** Conduct M&V on the savings associated with heat pump tune-ups. The percent savings value currently being used by the MA-TRM is a reasonable engineering estimate compared to a recent study in Wisconsin, which took before and after field EER measurements on residential air conditioner tune ups. However, the savings values in Wisconsin ranged from -8% to 32%, and due to that large uncertainty, future field research in MA is recommended to update this value.
3. **Average size:** Collect the average size of units for both common areas and dwelling units.

Notes

1. National Grid's existing method deems savings for all types of unit sizes and efficiencies.
   a. Current deemed savings of 1,167 kWh that National Grid uses for their heat pump tune up is equal to about 17% of the total energy usage for a 3 ton unit using the recommended savings method listed above.
   b. This measure makes up less than 0.5% of National Grid's total electric portfolio savings for 2010 and 2011.

[146] This average size was used in the MA-TRM as the default size for residential systems.

[147] *Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pumps.* http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls?35e1-df47

20

Electric: Aerators

Applicable Program Administrators

National Grid, NSTAR, and Cape Light Compact

Measure Description

The measure involves the replacement of existing aerator being replaced with a low flow aerator having a maximum flow rate of 1.5 GPM.

Proposed Savings Justification

Other TRMs, like the Ohio TRM[148] and the Mid-Atlantic TRM[149] calculate savings based on a complex algorithm involving flow rate, number of people, aerators per home, water temperature, and DHW efficiency. Our recommended approach is simpler and requires fewer inputs. While the complex algorithm likely provides a better savings estimate, given that the savings associated with such measures are relatively low, we do not feel that the extra complexity and associated effort to collect the necessary information, is justified. The proposed approach is consistent with the DEER approach[151].

Primary Proposed Savings Method

The primary proposed savings method has been provided at a deemed savings level due to its status as a low-impact measure. The algorithm is provided, as well as the deemed input variables.

$$\Delta kWh = kWh_{dhw} \times \%savings$$

kWh_{dhw} = Average kWh consumption of electric domestic hot water tank is deemed at 1391 kWh.[150]

148 State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010. Measure: Low Flow Faucet Aerator (Time of Sale or Early Replacement). Page 89.

149 Mid-Atlantic Technical Reference Manual Version 1.2, March 2011. Measure: Faucet Aerator. Page 51.

150 Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average annual Energy Use for Baseline for Water Heaters, for multifamily electric units.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

%savings = Energy savings percent from installation of aerator for DHW end-use, deemed at 3%[151].

Deemed annual kWh savings = **41.7 kWh.**

Inputs

No data collection is required by onsite auditors, as this is a deemed value measure, however, measure quantities should be collected as future research.

Alternative Proposed Savings Method

No alternative savings method has been proposed, as the primary proposed savings method is based off a deemed savings approach which can be used by all PAs looking forward to future programs.

Future Research

1. Consider conducting hot water and total water consumption audits for multi-family DHW units to verify the numbers and provide MA-specific consumption data.

Notes

1. National Grid estimates deemed savings as 80.3 kWh based on the MA-TRM. The specific documentation for the source listed in the MA-TRM is unavailable.
2. This measure makes up less than 0.5% of National Grid's total electric portfolio savings for 2010 and 2011.

[151] Itron. *2004-2005 Database for Energy Efficient Resources (DEER) Update Study. Final Report.* December 2005. Table 2-12: water Heat Measure Energy Savings Fractions from 2004-2005 DEER Update. Page 2-21.

21

Gas: Aerators

Applicable Program Administrators

National Grid and NSTAR

Measure Description

The measure involves the replacement of an existing aerator with a low flow aerator having a maximum flow rate of 1.5 GPM.

Proposed Savings Justification

Other TRMs, like the Ohio TRM[152] and the Mid-Atlantic TRM[153] calculate savings based on a complex algorithm involving flow rate, number of people, aerators per home, water temperature, and DHW efficiency. Our recommended approach is simpler and requires fewer inputs. While the complex algorithm likely provides a better savings estimate, given that the savings associated with such measures are relatively low, we do not feel that the extra complexity and associated effort to collect the necessary information, is justified. The proposed approach is consistent with the DEER approach[151].

Proposed Primary Savings Method

The primary proposed savings method has been provided at a deemed savings level due to its status as a low-impact measure. The algorithm is provided, as well as the deemed input variables.

$$\Delta MMBtu = MMBtu_{dhw} \times \%savings$$

$MMBtu_{dhw}$ = Average MMBtu consumption of natural-gas fired domestic hot water tank is deemed at 11.9 MMBtu.[154]

152 State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010. Measure: Low Flow Faucet Aerator (Time of Sale or Early Replacement). Page 89.

153 Mid-Atlantic Technical Reference Manual Version 1.2, March 2011. Measure: Faucet Aerator. Page 51.

154 Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average Annual Energy Use for Baseline for Water Heaters, for multifamily natural-gas units. http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

%savings = Energy savings percent from installation of an aerator for DHW end-use, deemed at 3%[155].

Deemed annual MMBtu savings = **0.36 MMBtu.**

Inputs

No data collection is required by onsite auditors, as this is a deemed value measure, however, measure quantities should be collected as future research.

Proposed Alternative Savings Method

We do not recommend a alternative savings method, as the primary proposed savings method is based on a deemed savings approach, which can be used by all PAs.

Future Research

1. Consider conducting hot water and total water consumption audits for multi-family DHW units to verify the numbers and provide MA-specific consumption data.

Notes

1. National Grid estimates deemed savings as 0.944 MMBtu but the documented source for this value is not available.
    a. This measure makes up less than 5% of National Grid's total natural gas portfolio savings for 2010 and 2011.

[155] Itron. *2004-2005 Database for Energy Efficient Resources (DEER) Update Study. Final Report.* December 2005. Table 2-12: Water Heat Measure Energy Savings Fractions from 2004-2005 DEER Update. Page 2-21.

22

Electric: Showerheads

Applicable Program Administrators

National Grid and NSTAR

Measure Description

The measure involves the replacement of existing showerheads with the baseline flow rate between 3.5 and 3.3 GPM, being replaced with a low flow showerhead having a maximum flow rate of 2.5 GPM.

Proposed Savings Justification

Other TRMs, like the Ohio TRM[156] and the Mid-Atlantic TRM[157] calculate savings based on a complex algorithm involving flow rate, number of people, showerheads per home, water temperature, and DHW efficiency. Our recommended approach is simpler and requires fewer inputs. While the complex algorithm likely provides a better savings estimate, given that the savings associated with such measures are relatively low, we do not feel that the extra complexity and associated effort to collect the necessary information, is justified. The proposed approach is consistent with the DEER approach[159].

Proposed Primary Savings Method

The primary proposed savings method has been provided at a deemed savings level due to its status as a low-impact measure. The algorithm is provided, as well as the deemed input variables.

$$\Delta kWh = kWh_{dhw} \times \%savings$$

156 State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010. Measure: Low Flow Showerhead (Time of Sale or Early Replacement) Page 93.

157 Mid-Atlantic Technical Reference Manual Version 1.2, March 2011. Measure: Low Flow Shower head. Page 47.

kWh_{dhw}	=	Average kWh consumption of electric domestic hot water tank is deemed at 1391 kWh.[158]
%savings	=	Energy savings percent from installation of low-flow showerheads for DHW end-use, deemed at 4%[159].

Deemed annual kWh savings = **55.6 kWh.**

Inputs

No data collection is required by onsite auditors, as this is a deemed value measure, however, measure quantities should be collected as future research.

Proposed Alternative Savings Method

No alternative savings method has been proposed, as the primary proposed savings method is based off a deemed savings approach which can be used by all PAs looking forward to future programs.

Future Research

1. Consider conducting hot water and total water consumption audits for multi-family DHW units to verify the numbers and provide MA-specific consumption data.

Notes

1. National Grid estimates deemed savings as 80.3 kWh based on the MA-TRM. The specific documentation for the source listed in the MA-TRM is unavailable.
2. This measure makes up less than 0.5% of National Grid's total electric portfolio savings for 2010 and 2011.

[158] Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average annual Energy Use for Baseline for Water Heaters, for multifamily electric units.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

[159] Itron. *2004-2005 Database for Energy Efficient Resources (DEER) Update Study. Final Report.* December 2005. Table 2-12: water Heat Measure Energy Savings Fractions from 2004-2005 DEER Update. Page 2-21.

23

Gas: Showerheads

Applicable Program Administrators

National Grid, NSTAR, and Columbia Gas

Measure Description

The measure involves the replacement of existing showerheads with the baseline flow rate between 3.5 and 3.3 GPM, being replaced with a low flow showerhead having a maximum flow rate of 2.5 GPM.

Proposed Savings Justification

The Mid-Atlantic TRM[160] calculate savings based on a complex algorithm involving flow rate, number of people, showerheads per home, water temperature, and DHW efficiency. Our recommended approach is simpler and requires fewer inputs. While the complex algorithm likely provides a better savings estimate, given that the savings associated with such measures are relatively low, we do not feel that the extra complexity and associated effort to collect the necessary information, is justified. The proposed approach is consistent with the DEER approach[151].

Proposed Primary Savings Method

The primary proposed savings method has been provided at a deemed savings level due to its status as a low-impact measure. The algorithm is provided, as well as the deemed input variables.

$$\Delta MMBtu = MMBtu_{dhw} \times \%savings$$

$MMBtu_{dhw}$ = Average MMBtu consumption of natural-gas fired domestic hot water tank is deemed at 11.9 MMBtu[161].

160 Mid-Atlantic Technical Reference Manual Version 1.2, March 2011. Measure: Low Flow Shower head. Page 47.

161 Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average Annual Energy Use for Baseline for Water Heaters, for multifamily natural-gas units.
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

%savings = Energy savings percent from installation of a low-flow showerhead for DHW end-use, deemed at 4%[162].

Deemed annual MMBtu savings = **0.48 MMBtu.**

Inputs

No data collection is required by onsite auditors, as this is a deemed value measure, however, measure quantities should be collected as future research.

Proposed Alternative Savings Method

No alternative savings method has been proposed, as the primary proposed savings method is based off a deemed savings approach which can be used by all PAs looking forward to future programs.

Future Research

1. Consider conducting hot water and total water consumption audits for multi-family DHW units to verify the numbers and provide MA-specific consumption data.

Notes

1. National Grid estimates deemed savings as 2.02 MMBtu but the documented source for this value is not available.
    a. This measure makes up less than 7% of National Grid's total natural gas portfolio savings for 2010 and 2011.

[162] Itron. *2004-2005 Database for Energy Efficient Resources (DEER) Update Study. Final Report.* December 2005. Table 2-12: Water Heat Measure Energy Savings Fractions from 2004-2005 DEER Update. Page 2-21.

24

Electric: DHW Pipe Wrap

Applicable Program Administrators

National Grid

Measure Description

This measure describes adding insulation to un-insulated copper electric domestic hot water pipes. The measure assumes the pipe wrap is installed on the exposed hot water pipes and the first 5 feet of the cold water pipes.

Proposed Savings Justification

Other TRMs, like the Ohio TRM[163] and the Mid-Atlantic TRM[164] calculate savings based on a complex algorithm involving pipe characteristics, insulation characteristics, water and air temperatures, and hours of use of the water heater. Our recommended approach is simpler and requires fewer inputs. While the complex algorithm likely provides a better savings estimate, given that the savings associated with such measures are relatively low, we do not feel that the extra complexity and associated effort to collect the necessary information, is justified. The proposed approach is consistent with the DEER approach[166], and in line with what is currently claimed by National Grid.

Proposed Primary Savings Method

The primary proposed savings method has been provided at a deemed savings level due to its status as a low-impact measure. The algorithm is provided below, as well as the deemed input values.

$$\Delta kWh = kWh_{dhw} \times \%savings$$

163 State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010. Measure: Domestic Hot Water Pipe Insulation. Page 97.

164 Mid-Atlantic Technical Reference Manual Version 1.2, March 2011. Measure: DHW Pipe Insulation. Page 86.

kWh_{dhw}	=	Average kWh consumption of electric domestic hot water tank is deemed at 1391 kWh.[165]
%savings	=	Energy savings percent from installation of pipe wrap for DHW, deemed at 4%[166].

Deemed annual kWh savings = **55.6 kWh.**

Inputs

No data collection is required here by onsite auditors, as this is a deemed value measure.

Proposed Alternative Savings Method

No alternative savings method is proposed as the proposed primary savings method is a deemed savings approach which can be used by all utilities both looking forward to future programs, and for reevaluation of 2010 and 2011 programs.

Notes

1. National Grid estimates deemed savings as 55 kWh but the documented source for this value is not available.
    a. This measure makes up less than 1.5% of National Grid's total electric portfolio savings for 2010 and 2011.

[165] Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average annual Energy Use for Baseline for Water Heaters, for multifamily electric units.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

[166] Itron. *2004-2005 Database for Energy Efficient Resources (DEER) Update Study. Final Report.* December 2005. Table 2-12: water Heat Measure Energy Savings Fractions from 2004-2005 DEER Update. Page 2-21.

25

Gas: DHW Pipe Wrap

Applicable Program Administrators

National Grid

Measure Description

This measure describes adding insulation to un-insulated copper natural gas fired domestic hot water pipes. The measure assumes the pipe wrap is installed on the exposed hot water pipes and the first 5 feet of the cold water pipes.

Proposed Savings Justification

Other TRMs, like the Ohio TRM[167] and the Mid-Atlantic TRM[168] calculate savings based on a complex algorithm involving pipe characteristics, insulation characteristics, water and air temperatures, and hours of use of the water heater. Our recommended approach is simpler and requires fewer inputs. While the complex algorithm likely provides a better savings estimate, given that the savings associated with such measures are relatively low, we do not feel that the extra complexity and associated effort to collect the necessary information, is justified. The proposed approach is consistent with the DEER approach[170].

Proposed Primary Savings Method

The primary proposed savings method has been provided at a deemed savings level due to its status as a low-impact measure. The algorithm is provided below, as well as the deemed input values.

$$\Delta MMBtu = MMBtu_{dhw} \times \%savings$$

$MMBtu_{dhw}$ = Average MMBtu consumption of natural-gas fired domestic hot water tank is deemed at 11.9 MMBtu.[169]

[167] State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010. Measure: Domestic Hot Water Pipe Insulation. Page 97.

[168] Mid-Atlantic Technical Reference Manual Version 1.2, March 2011. Measure: DHW Pipe Insulation. Page 86.

[169] Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average Annual Energy Use for Baseline for Water Heaters, for multifamily natural-gas units.

%savings = Energy savings percent from installation of pipe wrap for DHW, deemed at 4%[170].

Deemed annual MMBtu savings = **0.48 MMBtu.**

Inputs

No data collection is required here by onsite auditors, as this is a deemed value measure.

Proposed Alternative Savings Method

No alternative savings method has been proposed, as the primary proposed savings method is based off a deemed savings approach which can be used by all utilities looking forward to future programs.

Notes

1. National Grid estimates deemed savings as 0.016 MMBtu but the documented source for this value is not available.
    a. This measure makes up less than 0.01% of National Grid's total natural gas portfolio savings for 2010 and 2011.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

[170] Itron. *2004-2005 Database for Energy Efficient Resources (DEER) Update Study. Final Report.* December 2005. Table 2-12: Water Heat Measure Energy Savings Fractions from 2004-2005 DEER Update. Page 2-21.

26

Electric: DHW Tank Wrap

Applicable Program Administrators

National Grid

Measure Description[171]

This measure relates to a Tank Wrap or insulation "blanket" that is wrapped around the outside of an electric *storage water heater* to reduce stand-by losses.

Proposed Savings Justification

The algorithm that we are recommending for use is consistent with that used by the Ohio TRM[172] and Mid-Atlantic TRM[173].

Proposed Primary Savings Method

$$\Delta kWh = kWh_{base} \times \left(\frac{EF_{new} - EF_{base}}{EF_{new}}\right)$$

kWh_{base}	=	Average kWh consumption of electric domestic hot water tank is deemed at 1391 kWh.[174]
EF_{new}	=	Assumed efficiency of electric water heater with tank wrap installed (add 0.02 to the EF of the base unit) [175].
EF_{base}	=	Actual efficiency of electric water heater without tank wrap installed.

171 This measure should only be applied if the outside of the tank is warmer than the ambient temperature to the touch, and it will not void the manufacturer's warranty.

172 State of Ohio Energy Efficiency Technical Reference Manual, August 6, 2010

173 Mid-Atlantic Technical Reference Manual Version 1.2, March 2011

174 Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average annual Energy Use for Baseline for Water Heaters, for multifamily electric units.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

175 The Oak Ridge study predicted that wrapping a 40 gal water heater would increase Energy Factor of a 0.86 electric DHW tank by 0.02 (to 0.88) "Meeting the Challenge: The Prospect of Achieving 30 percent Energy Savings Through the Weatherization Assistance Program" by the Oak Ridge National Laboratory - May 2002.

http://www.cee1.org/eval/db_pdf/309.pdf

Inputs

The algorithm requires the PAs to collect or lookup the minimum following information:

- **EF_{base}:** The Energy Factor of the electric water heater should be recorded by the onsite auditor.

Proposed Alternative Savings Method

The alternative savings method for this measure is a deemed savings value due to the measure's relatively low impact. Deemed input values have been applied to the proposed primary method algorithm to provide an overall deemed savings value.

Deemed savings per wrap = **31.5 kWh**

The deemed input values are stated below:

- **kWh_{base}:** Average kWh consumption of electric domestic hot water tank is deemed at 1391 kWh.[176]
- **EF_{new}:** Assumed efficiency of an electric hot water storage tank wrap is 0.88.[177]
- **EF_{base}:** Assumed efficiency of an electric hot water storage tank without tank wrap installed is 0.86[172].

Notes

1. National Grid estimates deemed savings as 55 kWh but the documented source for this value is not available.
    a. This measure makes up less than 0.5% of National Grid's total electric portfolio savings for 2010 and 2011.

[176] Department of Energy. Residential Heating Products Final Rule Technical Support Document. Chapter 11. Life-Cycle Cost Subgroup Analysis. Table 11.3.4: Weighted-Average annual Energy Use for Baseline for Water Heaters, for multifamily electric units.

http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch11.pdf

[177] The Oak Ridge study predicted that wrapping a 40 gal water heater would increase Energy Factor of a 0.86 electric DHW tank by 0.02 (to 0.88) "Meeting the Challenge: The Prospect of Achieving 30 percent Energy Savings Through the Weatherization Assistance Program" by the Oak Ridge National Laboratory - May 2002.

http://www.cee1.org/eval/db_pdf/309.pdf