Northeast Energy Efficiency Partnerships

Early Replacement Measures Study: Phase II Research Report

November 2015

About NEEP & the Regional EM&V Forum

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency in the building sector through public policy, program strategies and education. Our vision is that the region will fully embrace energy efficiency as a cornerstone of sustainable energy policy to help achieve a cleaner environment and a more reliable and affordable energy system.

The Regional Evaluation, Measurement and Verification Forum (EM&V Forum or Forum) is a project facilitated by Northeast Energy Efficiency Partnerships, Inc. (NEEP). The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track, and report energy efficiency and other demand resource savings, costs, and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast, New York, and the Mid-Atlantic region.

About Evergreen Economics

Evergreen Economics is an economics research firm founded in 2011 by three principal economists formerly with the consulting firm ECONorthwest. Since then, Evergreen's staff has grown to include 17 members working on diverse energy program evaluation projects throughout the US and Canada. Evergreen specializes in using rigorous economic analysis techniques to evaluate energy efficiency programs, with particular expertise in sophisticated statistical modeling and sampling techniques.

About Michaels Energy

Michaels Energy is nationally recognized in energy efficiency consulting, providing technical, program management, evaluation, and administrative support for utility demand-side management programs. Michaels also provides services to commercial, institutional, and industrial end-users including investment grade feasibility studies, retro-commissioning studies, and LEED® consulting.

About PWP Inc.

PWP Inc.

PWP, Inc. is a small consulting firm located outside Washington DC that has completed numerous assignments in all parts of the country. PWP was incorporated in Maryland in 2004, but the firm's president, Dr. Philippus Willems, has been active in energy program evaluation for decades. PWP is thoroughly experienced in literature review, primary data collection and a variety of analytical techniques for market assessment and evaluation, having conducted hundreds of assessments of utility programs and other interventions in markets for energy-using structures and equipment.

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PWP Inc.

Early Replacement Measures Study

Final Phase II Research Report

A Report to the Regional Evaluation, Measurement and Verification Forum, facilitated by Northeast Energy Efficiency Partnerships

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Table of Contents

Executive Summary

The Regional Evaluation, Measurement and Verification Forum (Forum) facilitated by Northeast Energy Efficiency Partnerships (NEEP) engaged the Evergreen team in November 2014 to conduct this Phase II Early Replacement Measure Research Study.

For this research, an "early replacement" program was defined as any program that promotes the replacement of equipment prior to the assumed time of normal replacement that would occur without the influence of the program. Early replacement (ER) measures are those that replace existing, operational equipment that is not at the end of its useful life or which is not scheduled for replacement for reasons independent of the program.

In contrast, "normal replacement" (NR) measures are installed when equipment has reached the end of its useful life and has become non-operational or is being replaced for some other reason unrelated to program implementation (e.g., the current equipment is functionally obsolete because it can no longer "keep up" with new commercial processes or end user demands).

In the standard dual baseline model for ER savings analysis, two separate equipment lifetime values are used. These are designated as "effective useful life" (EUL) and "remaining useful life" (RUL). The effective useful life of a measure is conventionally defined as the median number of years between the time of installation and the time of expected normal replacement. The remaining useful life is defined as the difference between the current age of a piece of equipment and the time of normal replacement, given that the equipment is in place and still operating.

RUL is used in ER programs because it accounts for the assumption that the equipment being replaced would have been replaced at some future time, independent of the program. Thus, the program does not typically receive credit for energy savings derived from the existing equipment efficiency over the entire EUL of the new equipment, but only for the period of time the existing equipment would have continued operating (i.e., the RUL). After the RUL, the project is treated as a NR project and energy savings calculations typically (under the dual-baseline model) assume a code-compliant baseline instead of the existing equipment's efficiency. RUL prevents over-estimating the energy savings associated with ER projects by incorporating a realistic limit on the life of the existing equipment.

The design of ER programs rests upon two critical baseline assumptions:

1. The RUL of the existing equipment; and
2. The efficiency of the equipment that would have been purchased at the time of normal replacement absent the program.

Program impacts and several key program design elements are informed by these two assumptions, including incentive qualification criteria (e.g., existing equipment efficiency, operating condition, age), incentive amount, incremental measure cost, incremental measure savings and measure cost-effectiveness. The assumptions are therefore important determinants of which measures and existing equipment qualify for incentives as well as the magnitude of the incentive payment and energy savings to be claimed.

The RUL is also an important factor in determining the incremental ER measure cost. While many programs incorrectly assume that ER incremental cost simply equals the total installed cost of the new measure—with no adjustments—other programs incorporate RUL values to reflect that incremental costs must be adjusted to account for a changed cycle of normal replacements. As detailed subsequently in this report, these calculations must accurately reflect the altered pattern of equipment replacements and use accurate values for RUL.

Key objectives for the study included:

1. Producing independent estimates of the age and RUL for three types of residential equipment covered by ER programs: boilers, furnaces, and central air conditioning (AC);
2. Exploring the extent to which some central AC, heat pump, and heat pump water heater projects in residential NR programs may in fact be early replacements;
3. Improving understanding of residential customer equipment replacement decisions;
4. Developing information to help Program Administrators (PAs) qualify projects as early or normal replacements; and
5. Developing guidance on energy efficiency baselines to use for savings calculations.

Research Methods

Early in the study, the Evergreen team conducted interviews with PA staff and/or their implementation contractors to confirm which study measures they offer, and to obtain program design and technical assumptions details. After completing the interviews, we also reviewed relevant Technical Reference Manuals (TRMs) and supporting program documents to get information that could not obtained during the interviews. The combined information from all of the PAs was integrated into a comprehensive study measures database that includes information on participant eligibility requirements, energy savings calculation methods (or deemed values), project cost methods and other relevant information.
After completing the PA interviews and secondary research, we submitted formal data requests to each of the PAs with early or normal replacement measures in our study scope, asking them to provide as much detailed project level, site-specific data as they could for projects completed in 2013 and 2014 (e.g., existing equipment age, existing and new equipment efficiencies, project costs, existing equipment model and serial numbers, etc.). The collected data were integrated into a single comprehensive projects database for various analyses.

Our team completed phone surveys of 373 residential program customers in May and June of 2015, covering key topics such as old equipment condition and characteristics, reasons for replacing old equipment, and customer consideration of repairs versus replacement.

We also completed in-depth interviews with eight of the highest-volume installation contractors distributed across the study PAs and measure types. Key topics covered in the interviews included contractors' distinctions between early and normal replacements, customer decision-making, measures' typical EUL and RUL at time of replacement, and contractor opinions about PA programs.

Lastly, the Evergreen team conducted in-depth interviews with NEEP Buildings and Market Strategies Initiatives staff to document how changes to federal, state, and local energy codes will impact baseline equipment efficiencies used in energy savings calculations.

Key Findings - Program Design and Impacts

1. All of the ER measures in the Connecticut, Massachusetts and New Hampshire programs use the dual baseline method to calculate energy savings.

2. Some PAs try to collect site-specific equipment age information for their ER programs, although none utilize this information to calculate site-specific RULs. PAs typically use a default value for RUL (e.g., 5 years) or use the simple equation, RUL = EUL – AGE, where EUL is for all originally installed equipment, currently surviving or not.

3. Site-specific RULs calculated by the Evergeen team, using survival curve analysis, are generally higher than the values used by the PAs.

4. PA programs typically use default efficiency values for the replaced equipment, or deemed savings values during the RUL, although some PAs attempt to collect site-specific efficiency information.

5. The PAs typically use incremental cost calculation methods for ER projects that do not accurately reflect how the pattern of future normal replacements has shifted into perpetuity. The appropriate method, typically referred to as the Deferred Replacement Credit method, is only used for ER measures by the Massachusetts PAs.[1] Regarding the other methods used by PAs:

    a. Incremental cost is overstated when set to equal the full installed cost of new equipment, with no adjustements.
    b. Incremental cost is understated when set to equal the full installed cost of new equipment, less the discounted costs of the next normal replacement.

[1] However, the Massachusetts calculation appears to incorporate the assumption that RUL=EUL-Age.

6. When the ER Cost Factor method (presented in Section 3, analogous to the Deferred Replacement Credit) is utilized, the incremental cost of ER projects increases as the RUL increases.

7. Older projects with lower RULs may improve cost effectiveness in multiple ways:

    a. Lower RUL is correlated with lower efficiency for the replaced equipment.
    b. Projects with a lower RUL are likely to utilize a lower, current standard efficiency as the baseline after the RUL (i.e., the window for code increases is smaller).
    c. Factors a and b above both increase annual energy savings.
    d. Lower RUL is correlated with lower incremental costs when the ER Cost Factor is used.

Key Findings - Participant Customers

1. Overall, the ER programs are serving households eligible to participate. Fifty-six percent of ER customers said their existing equipment was functioning normally and keeping their home at the desired temperature at the time of their equipment replacement, while an additional 42 percent said their equipment was working improperly or required frequent maintenance calls.

2. Despite having no additional incentive to replace their equipment early, a large majority (73%) of NR customers said their existing equipment was working in some capacity at the time of their replacement. Furthermore, 40 percent of those customers said their equipment was not only working, but working properly and keeping their home at the desired temperature.

3. For ER measures, the most influential factors in customers' decisions to replace their existing equipment included wanting new or current equipment, concern that their equipment might break during heating or cooling seasons, and ER incentives offered by PAs.

4. For NR measures, replacement influences varied between customers with functioning existing equipment and non-functioning existing equipment. For functioning equipment customers, the most influential factors included concern that their equipment might break during heating or cooling seasons and wanting new or current equipment. For customers with non-functioning equipment, the most influential factors leading them to replace and not repair the equipment were concerns that their equipment might break (again) during the heating or cooling season, and a contractor recommendation for the replacement.

5. Seventy-six percent of all customers believe their new equipment will last for fewer years than their existing equipment lasted prior to their replacement.

6. A majority of ER AC (77%) and furnace (65%) customers along with NR air conditioner (75%) and heat pump (84%) customers said they would have bought the same high efficiency equipment had the PA rebate not been available at the time of their purchase. Additionally, 49 percent of ER boiler customers and 39 percent of NR HPWH customers said they would have purchased the same high efficiency unit without an available utility rebate.

Key Findings - Installation Contractor Interviews

1. HVAC contractors have difficulty defining equipment "useful life" beyond functionality. For the most part, projects in ER programs involve equipment that is still functioning at some level (per program requirements).

2. Major repairs start at around 10 to 15 years into the life of the equipment, before the EUL for most HVAC equipment, which may represent an opportunity to encourage ER instead of repair.

3. Customers rarely choose to repair non-functioning equipment, with $1,000 given as a common threshold to determine whether to repair or replace equipment.

4. Standard efficiency units sold by the interviewed contractors are well above code efficiencies, which may have implications for the efficiency baselines used by PAs.

5. Existing unit efficiencies are roughly 70 percent to 80 percent for furnaces and boilers, and 10 SEER AC units, but that is rapidly moving toward 12 or 13 SEER.

6. ER programs are effective at getting customers to replace functioning equipment, and customers often utilize financing and loans to participate.

7. There are concerns about condensing boiler programs stemming from houses that cannot operate below 140°F water temperature, higher maintenance costs associated with condensing boilers, venting requirements in older homes, and customers gaming the system by buying a condensing boiler when they cannot fully utilize one just to get a rebate. Some contractors would like to see non-condensing boilers included.

8. Customers are most motivated by energy cost savings, financing and rebates, and by a significant fear of their existing equipment failing.

9. Contractors said the best ways to get customers to replace equipment early are to develop energy cost savings analyses and bundle other services (e.g., air sealing, insulation, smart home features) with rebates and financing options.

10. Among the contractors surveyed, there is little evidence of ER projects being done outside of the PA programs.

11. Furnaces and AC units are often replaced simultaneously and programs should be aware of this.

Key Findings - Future Efficiency Standards

1. No states in NEEP Forum territory have codes that are above the federal baseline for residential HVAC equipment.

2. Federal efficiency standards for AC units, furnaces, and boilers will not change between 2016 and 2021.

Recommendations

Based upon the research findings, the Evergreen team offers the following recommendations for PAs currently offering or considering ER programs. Notably, the program design and evaluation recommendations are not prioritized and should be considered collectively, since they affect multiple interrelated elements of program cost effectiveness.

Program Design and Evaluation

1. PAs should collect and utilize site-specific equipment ages for their ER savings and cost calculations to the extent possible. The best time to collect site-specific equipment data is during program implementation before equipment has been removed. This practice also allows for accelerated, real-time program evaluation, which is a current goal for many PAs. In Appendix C, we have listed some resources that PAs can utilize to research the ages of HVAC equipment using manufacturer, model, and serial number information.

2. PAs should utilize the survival curve method to estimate site-specific equipment RULs. Importantly, this method reflects the fact that the probability that equipment will reach a given age increases with current age. TRMs developed by NEEP should also recommend this method.

3. PAs should calculate energy savings based on site-specific RULs (using the survival method) and equipment efficiencies. In Appendix D, we have included guidance on how the PAs can adjust or "degrade" the original installed equipment efficiencies to reflect equipment wear and tear over time. In addition, ENERGY STAR has developed tools to estimate efficiency levels for some equipment (furnaces) based on home vintage.

4. The next energy code changes for residential HVAC equipment will occur in 2021 and 2022. PAs utilizing dual baselines should integrate the new efficiency baselines for ER projects with longer RULs.

5. Incremental cost calculations for ER projects should utilize the ER Cost Factor method presented in Section 3 of this report, to accurately reflect that the entire cycle of future normal replacements has been shifted and to be consistent with RUL and EUL

assumptions for energy savings. TRMs developed by NEEP should also recommend this method.

6. "Maximum estimated repair cost" (e.g., $1,000 for HVAC) may be a reasonable criteria for ER program eligibility, since customers are unlikely to incur high repair costs, essentially making their equipment "inoperable."

7. "Maximum replaced efficiency" is also recommended for ER program eligibility to improve energy savings and cost-effectiveness.

8. Equipment age is not a basis to conclusively discriminate between ER and NR projects. In particular, PAs should not implement maximum equipment age requirements—older units are likely to be the most cost-effective to replace.

9. Incremental cost, calculated using the ER Cost Factor, can be used to benchmark ER incentives.

10. Besides equipment age and efficiency, the PAs may want to collect other data during installations that may be useful in program evaluation, but which are difficult to obtain at a later date:

    - Functional status of replaced unit
    - Estimated repair costs
    - Other factors influencing the decision to replace

Future Research

1. PAs should conduct pilot studies to collect complete site-specific age, efficiency, savings, cost, incentive, and customer survey data for a large sample of ER participants at the time of implementation. Analysis of the pilot projects, using the methods we recommend in this study, would give PAs a more accurate picture of the cost-effectiveness of current and potential new programs.

2. PAs should conduct similar pilot studies of NR program participants.

3. PAs should study other measures to see if new or revised ER programs would be cost-effective (e.g., residential appliances, commercial/industrial HVAC, motors, air compressors). These are likely to be measures where federal or state standards have increased relatively rapidly (along with market adoption), and there is high savings potential from removing old inefficient units.

1 Introduction

1.1 Key Issues with Early Replacement Program Design and Analysis

All energy efficiency programs attempt to influence customers' decisions that determine the level of efficiency of energy-consuming equipment. Some programs also try to influence decisions regarding the timing of equipment purchases; these programs are typically described as "early replacement," "early retirement" or "retrofit." In the remainder of this report, we refer to these programs as "early replacement" (ER).

For this research, an "early replacement" program was defined as any program that promotes the replacement of equipment prior to the assumed time of normal replacement that would occur without the influence of the program. Early replacement measures are those that replace existing, operational equipment that is not at the end of its useful life or which is not scheduled for replacement for reasons independent of the program.

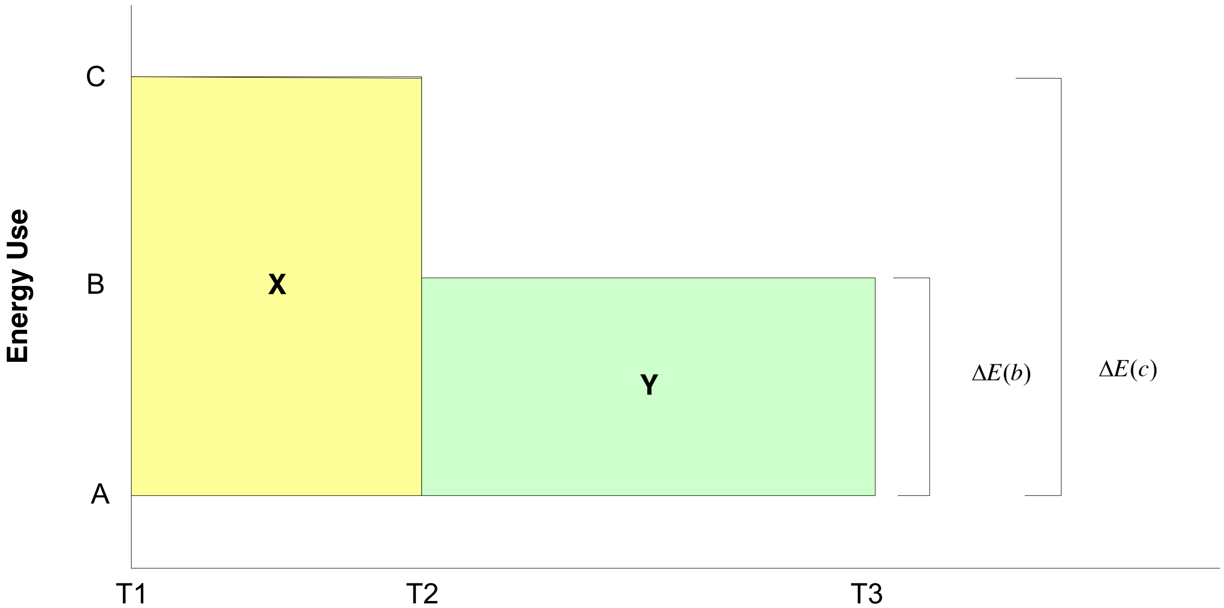
In contrast, "normal replacement" (NR) measures are installed when equipment has reached the end of its useful life and has become non-operational or is being replaced for some other reason unrelated to program implementation (e.g., the current equipment is functionally obsolete because it can no longer "keep up" with new commercial processes or end user demands).

In the standard dual baseline model for early replacement savings analysis, two separate equipment lifetime values are used. These are designated as "effective useful life" (EUL) and "remaining useful life" (RUL). The effective useful life of a measure is conventionally defined as the median number of years between the time of installation and the time of replacement. The remaining useful life is defined as the difference between the current age of a piece of equipment and the time of replacement, given that the equipment is in place and still operating.

EUL is used for new construction and NR measures, while RUL is used for ER measures. RUL is used in ER programs because it accounts for the assumption that the equipment being replaced would have been replaced at some future time, independent of the program. Thus, the program does not typically receive credit for energy savings derived from the existing equipment efficiency over the entire EUL of the new equipment, but only for the period of time the existing equipment would have continued operating (i.e., the RUL). After the RUL, the project is treated as a NR project and energy savings calculations typically (under the dual-baseline model) assume a code-compliant baseline instead of the existing equipment's efficiency. RUL prevents over-estimating the energy savings associated with early replacement projects by incorporating a realistic limit on the life of the existing equipment.

Figure 1 illustrates the concept of RUL and also the dual baseline method of calculating savings for early replacement measures. In the figure, C and B on the Y-axis represent the two distinct energy consumption baselines.

Figure 1: Early Replacement Condition



C = Energy use of pre-existing measure
B = Energy use of code/standard measure
A = Energy use of the new efficient measure
T1 = Date on which new efficient measure is installed
T2 = Date on which existing measure was expected to have failed
T3 = Date on which the new efficient measure is expected to fail
T3 – T1 = Expected effective useful life (EUL) of the new efficient measure
T2 – T1 = Expected remaining useful life (RUL) of the pre-existing measure
T3 – T2 = Expected remaining EUL of the new efficient measure
$\Delta E(c)$ =The full savings defined as C - A
$\Delta E(b)$ = The incremental savings defined as B - A

Source: New York State Technical Reference Manual, Appendix M.

The design of ER programs rests upon two critical baseline assumptions:

1. The RUL of the existing equipment; and
2. The efficiency of the equipment that would have been purchased at the time of NR absent the program.

Program impacts and several key program design elements are informed by these two assumptions, including incentive qualification criteria (e.g., existing equipment efficiency, operating condition, age), incentive amount, incremental measure cost, incremental measure savings and measure cost-effectiveness. The assumptions are therefore important determinants of which measures and existing equipment qualify for incentives as well as the magnitude of the incentive payment and energy savings to be claimed.

The RUL is also an important factor in determining the incremental ER measure cost. While many programs incorrectly assume that ER incremental cost simply equals the total installed cost of the new measure—with no adjustments—other programs incorporate RUL values to reflect that incremental costs must be adjusted to account for a changed cycle of normal replacements. As detailed subsequently in this report, these calculations must accurately reflect the altered pattern of equipment replacements and use accurate values for RUL.

1.2 Study Objectives

The Regional Evaluation, Measurement and Verification Forum (Forum) facilitated by Northeast Energy Efficiency Partnerships (NEEP) engaged the Evergreen team in November 2014 to conduct this Phase II Early Replacement Measure Research Study. Key objectives for the study include:

1. Producing independent estimates of the age and remaining useful life for three types of residential equipment covered by ER programs—boilers, furnaces, and central air conditioning;
2. Exploring the extent to which some central air conditioning, heat pump, and heat pump water heater projects in residential normal replacement programs may in fact be early replacements;
3. Improving understanding of residential customer equipment replacement decisions;
4. Developing information to help Program Administrators (PAs) qualify projects as early or normal replacements; and
5. Developing guidance on energy efficiency baselines to use for savings calculations.

Table 1 shows the PAs that sponsored the study. After the study was initiated, some of these PAs were acquired by Eversource Energy; however, we have used the original PA names in this report. PAs that now operate as Eversouce entities include Connecticut Light & Power (CL&P, now Eversource CT), NSTAR/WMECo (Eversource MA) and Public Service Corporation of New Hampshire (PSNH, now Eversource NH).

Since the Maryland PAs do not have ER programs, the research on NR measures (central air conditioning, heat pumps, heat pump water heaters) was focused on the Maryland PAs.

Table 1: Regional EM&V Forum Sponsors

(* denotes sponsorship of this project)

State	Program Administrator	State	Program Administrator
CT*	CL&P	NY	Central Hudson
	United Illuminating		Consolidated Edison
DE*	DE SEU	*	PSEG-NY
DC*	DC SEU		National Grid
MA*	Cape Light Compact		NYPA
	NSTAR/WMECo		NYSEG/RGE
	National Grid		NYSERDA
	Unitil		ORU
MD*	BGE	RI*	National Grid
	FirstEnergy	VT*	EVT
	PHI/Pepco		
	SMECo		
NH*	Liberty		
	NH Elec Coop		
	PSNH		
	Unitil		

2 Study Methods

In this section, we summarize the tasks that were focused on data collection activities completed for this research. Additional details including discussions of data analysis are included in subsequent sections of this report.

2.1 Program Administrator Staff Interviews

Early in the study, the Evergreen team conducted interviews with PA staff and/or their implementation contractors to confirm which study measures they offer, and to obtain program design and technical assumptions details. While some of this information was available from the Phase 1 research, this step gave us an opportunity to fill in information gaps and confirm information provided previously. The main interview topics included:

- Program eligibility criteria and verification conducted (e.g., equipment functionality, age);
- If/how existing equipment age is determined;
- If/how the PAs use dual baselines (for ER programs);
- If/how remaining useful life is calculated or assigned (for ER programs);
- Baseline efficiencies used;
- If/how avoided repair costs are collected (ER programs);
- How incremental costs are calculated;
- Relevant program participation in 2014 and 2013; and
- Availability and formats of detailed projects/customer information (e.g., customer contact information, replaced and new equipment details, project-level savings estimates, project costs).

During the interviews, we learned that some of the project sponsors (e.g., Efficiency Vermont) do not have early replacement programs for the specific residential study measures, and some PAs indicated that they would not be able to provide detailed project and customer data for analysis and surveys.

After completing the interviews, we also reviewed the following types of documents as needed to get information that could not obtained during the interviews:

- Technical Reference Manuals (TRMs)
- Program descriptions and implementation materials, including rebate forms
- Supporting savings/cost calculation tools

The combined information from all of the PAs was integrated into a comprehensive study measures database that includes information on participant eligibility, energy savings calculation methods (or deemed values), project cost methods, and other relevant information (see Appendices H through M). While PA staff were very helpful in providing information to complete the database, the database still includes gaps. For instance, while program staff could typically list deemed incremental costs for different measures (e.g., $750), they generally could not provide the baseline and new equipment costs that determined this amount.

2.2 Data Request and Projects Data Collection

After completing the PA interviews and secondary research, we submitted formal data requests to each of the PAs with early or normal replacement measures in our study scope, asking them to provide as much detailed project level, site-specific data as they could for projects completed in 2013 and 2014 (e.g., existing equipment age, existing and new equipment efficiencies, project costs, existing equipment model and serial numbers, etc.).

The collected data were integrated into a single comprehensive projects database for various analyses presented in Section 3 of this report, where important data limitations are discussed. While most of the PAs provided data for all program participants, some PAs only provided samples of their completed projects, to limit exposure to data breaches and/or to limit the number of customers that could be recruited for phone surveys.

2.3 Customer Phone Survey

CIC Research Inc. completed surveys of 373 residential customers in May and June of 2015, based on a sample design intended to provide a 90/10 level of confidence/precision for each of the study measures at the regional level (i.e., not for each PA). Key topics covered in the survey include:

- Customer estimates of existing equipment age and remaining useful life;
- Old equipment condition and characteristics;
- Reasons for replacing old equipment;
- Customer consideration of repairs versus replacement;
- Factors causing combination furnace/air conditioning projects;[2] and
- Customer estimates of incremental costs.

The complete survey instrument is included in Appendix A and the survey results are presented in Section 4.

2.4 Installation Contractors Phone Interviews

The Evergreen team completed in-depth interviews with eight of the highest-volume installation contractors distributed across the PAs and study measure types. Key topics covered in the interviews include:

- Customer decision-making and reasons for early replacements;

[2] This is important for PAs to track and evaluate, since some residential customers are inclined to replace additional HVAC equipment if they have concerns about other equipment, and distinct incentives may not be required.

- Measures' typical effective useful life and remaining useful life at time of replacement;
- Contractors' distinctions between early and normal replacements;
- Typical incremental costs;
- Customer consideration of repairs versus replacement; and
- Contractor opinions about PA programs.

The complete interview guide is included in Appendix B and the interview results are presented in Section 5.

2.5 Research on Future Energy Code and Standard Revisions

To determine how changes to federal, state, and local energy codes will impact baseline equipment efficiencies for furnaces, boilers, central air conditioners, and air-source heat pumps, the Evergreen team conducted in-depth interviews with NEEP Buildings and Market Strategies Initiatives staff. The interview results are presented in Section 6 of this report.

3 Findings – Analysis of Project Tracking Data

In this section, we present the results of our analysis of the tracking data for the early replacement (ER) programs operated by each of the PAs. Specifically, we focus on those projects where the contractor or the PA collected information on the age and/or efficiency of the existing equipment. For each equipment type, we examine the distribution of ages and efficiencies, compare the mean and median age of equipment as reported by contractors to what residents reported in the participant survey. Where sufficient data exists, we analyze the relationship between age and efficiency of the existing equipment. Finally, and most importantly for this project, we use the site-specific age information to develop estimates of the remaining useful life (RUL) of each existing piece of equipment based on applying actuarial survival functions. We then compare the distribution of survival-based RULs to the deemed RULs used by the PAs.

The remainder of Section 3 is organized as follows:

3.1 Summary of Tracking Data & Program Characteristics by PA

3.2 Remaining Useful Life Derived From Equipment-Specific Survival Functions

3.3 Incremental Cost of Early Replacement Equipment

For each subsection, we present the results of our analysis separately for each of the three ER measures: furnaces, boilers, and central air conditioners (ACs).

3.1 Summary of Tracking Data & Program Characteristics by PA

In this section, we summarize age and efficiency information of replaced equipment contained in the tracking systems of the PAs. We compare the estimates of age from the tracking systems to those reported by participants in the telephone survey. We also present information on key assumptions of each PA's ER program, including effective useful life (EUL), RUL, and operating efficiency of the replaced equipment.

Throughout this chapter, we present results individually for each of the three measures with little-to-no comparision across equipment type. Before doing so, however, we believe it is instructive to first present an overview of the distribution of ages of replaced equipment in order to show how they vary by equipment type. Table 2 shows the distribution of ages of furnaces, boilers, and air conditioners replaced through the ER programs operated by the PAs. The three equipment types do not differ substantially at the lower end (10th percentile) of the distribution, but do at the upper end, with the 90th percentile replacement age for boilers being nearly double that for AC (49 years versus 26 years) and considerably higher than for furnaces (35 years).

Table 2: Distribution of Ages of Equipment Replaced Through ER Program

Percentile	Furnaces (years)	Boilers (years)	Air Conditioners (years)
10th	14	15	12
25th	18	20	17
50th	20	30	20
75th	25	38	24
90th	35	49	26

3.1.1 ER Furnaces

> **Key Finding:**
>
> **Consistently across the PAs, program participants estimated their furnace to be older than what was determined by the installation contractor or the Evergreen team.**

According to information provided to us from the PAs, there were approximately 1,100 ER furnace projects completed in 2013 and 2014. Of these, there were 214 projects with ages that were either reported by the installation contractor or determined by the Evergreen team based on model and serial numbers provided. As Table 3 shows, there was substantial variability among the PAs with respect to the proportion of projects with reported (or determined) age. Table 3 also shows the minimum age requirement for ER furnaces for each PA and the mean/median age of replaced furnaces based on analysis of the tracking data and surveys of program participants. Consistently across the PAs, program participants estimated their furnace to be older than what was determined by the installation contractor or the Evergreen team.

EVERGREEN ECONOMICS

Table 3: Project Counts, Age Requirements, and Mean/Median Age of ER Furnaces

PA	Universe of Projects (1)	Projects with Reported Age (2)	Old Equipment Minimum Age Requirement (3)	Mean/Median Age Old Furnace (Tracking) (4)	Mean/Median Age Old Furnace (Participant Survey) (5)
CL&P	104	92	No Min Age	23 / 20	28 / 25
MA NGrid	849	10	12	23 / 22	28 / 30
NSTAR	41	12	12	23 / 25	37 / 30
United Illuminating	115	100	No Min Age	22 / 20	35 / 40
Unitil	28	0	10	NA	32 /32

(1) Based on information provided by the PAs. The PAs may have completed additional ER projects; however, these are the counts of projects of which we are aware.
(2) Includes projects with ages that were either reported by contractor or determined by the Evergreen team. Age of replaced equipment is necessary to compute RUL.
(3) Based on interviews with PA staff and review of Connecticut and Massachusetts TRMs.
(4) Based on site-specific age information determined by the contractors or determined by the Evergreen team based on model and/or serial number of old equipment.
(5) Based on self-reported estimates of age of old equipment by program participants.

Table 4 shows the deemed EUL and RUL for each PA, which are based on the respective state's Technical Reference Manual (TRM), and the average and median RUL of the replaced furnaces, computed using survival analysis based on alternative assumptions of the furnace EUL. The "LBNL" estimates of RUL are based on an assumed 22.62-year EUL for furnaces, and in section 4.2 we describe how we used survival curve analysis to calculate these RUL values.[3]

Table 4: Assumed EUL, Deemed RUL, and Estimated RULs of ER Furnaces

PA	Projects with Reported Age (1)	Assumed EUL / Deemed RUL (2)	Mean/Median RUL (LBNL) (3)	Mean/Median RUL (PA-Specific) (4)
CL&P	92	20 / 5	8.7 / 9.2	7.0 / 7.3
MA NGrid	10	18 / 6	8.5 / 8.5	5.5 / 5.5
NSTAR	12	18 / 6	8.3 / 7.7	5.4 / 5.0
United Illuminating	100	20 / 5	9.1 / 9.2	7.3 / 7.3
Unitil	0	18 / 6	NA	NA

(1) Includes projects with ages that were either reported by contractor or determined by the Evergreen team.
(2) Based on interviews with program staff.
(3) Calculated using survival curve approach; based on LBNL 2011 estimated EUL for furnaces of 22.62 years.
(4) Calculated using survival curve approach; based on PA's EUL assumption for furnaces.

[3] Lawrence Berkeley National Laboratory (LBNL). Using National Survey Data to Estimate Lifetime of Residential Appliances. October 2011, page 9.

For the PA-specific estimates of mean and median RUL, we used the deemed EUL contained in the Massachusetts and Connecticut TRMs. On average, the greater EUL reported in the LBNL report results in a two-to-three year greater RUL compared to the EUL in the Massachusetts and Connecticut TRMs.

Table 5 shows the count of ER furnace projects with reported (or determined) efficiencies by PA. In total, there were 194 such projects; however, all but one of these projects are from only two PAs: CL&P and United Illuminating. For National Grid, the PA with the most ER furnace projects, we were able to determine the efficiency of the replaced furnace for only one project. Table 5 also shows efficiency-related information for each PA's program and the mean/median efficiency of the replaced furnaces (approximately 80%).

Key Finding:

For furnaces, the mean and median equipment ages in the tracking systems of the Massachusetts PAs are higher than the EULs assumed by the PAs, and the same or higher than the mean and median for the Conneticut PAs.

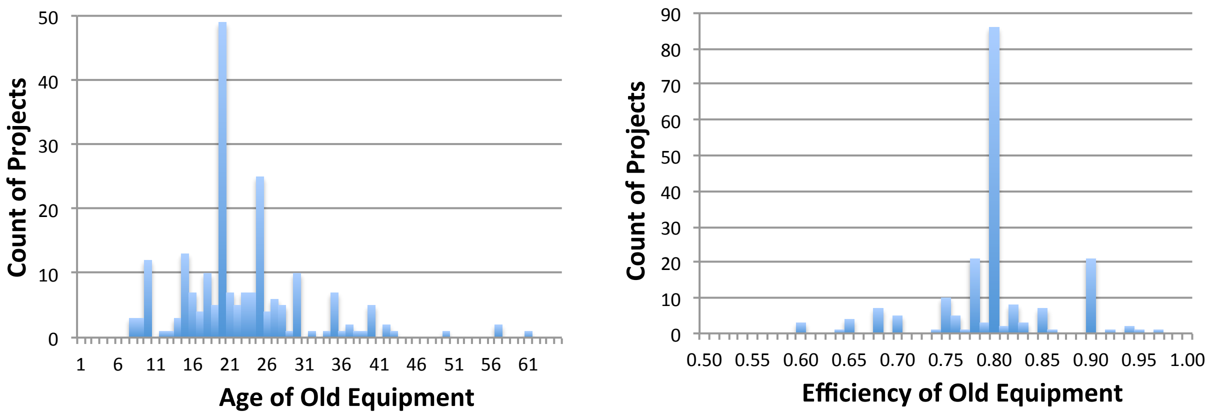
Table 5: Project Counts, Baseline Efficiency for New Furnaces, and Mean/Median Efficiency of ER Furnaces

PA	Projects with Reported Efficiency (1)	Baseline Efficiency for Normal-Replacement Furnace (2)	Efficiency of Existing Furnace (3)	Mean/Median Efficiency Old Furnace (4)
CL&P	92	78% gas/propane, 80% oil	Deemed based on age	79% / 80%
MA NGrid	1	90% (per TRM)	Deemed value*	80% / 80%
NSTAR	0	90% (per TRM)	Deemed value*	NA
UI	101	78% gas/propane; 80% oil	Deemed based on age	80% / 80%
Unitil	0	90% (per TRM)	Deemed value*	NA

(1) Based on site-specific information determined by the contractors or determined by the Evergreen team.
(2) Based on interviews with program staff and review of respective TRM.
(3) Based on interviews with program staff.
(4) Based on site-specific information determined by the contractors or determined by the Evergreen team based on model and/or serial number of old equipment.
* Deemed value could not be determined.

Figure 2 shows the distribution of ER furnace projects by age and efficiency of the replaced equipment. Twenty years was the most frequent age for ER furnaces, and the vast majority of furnaces were less than 30 years old. Most furnaces were determined to have an efficiency rating of 78 to 80 percent, though some furnaces were found to have an efficiency rating of 90 percent or greater.

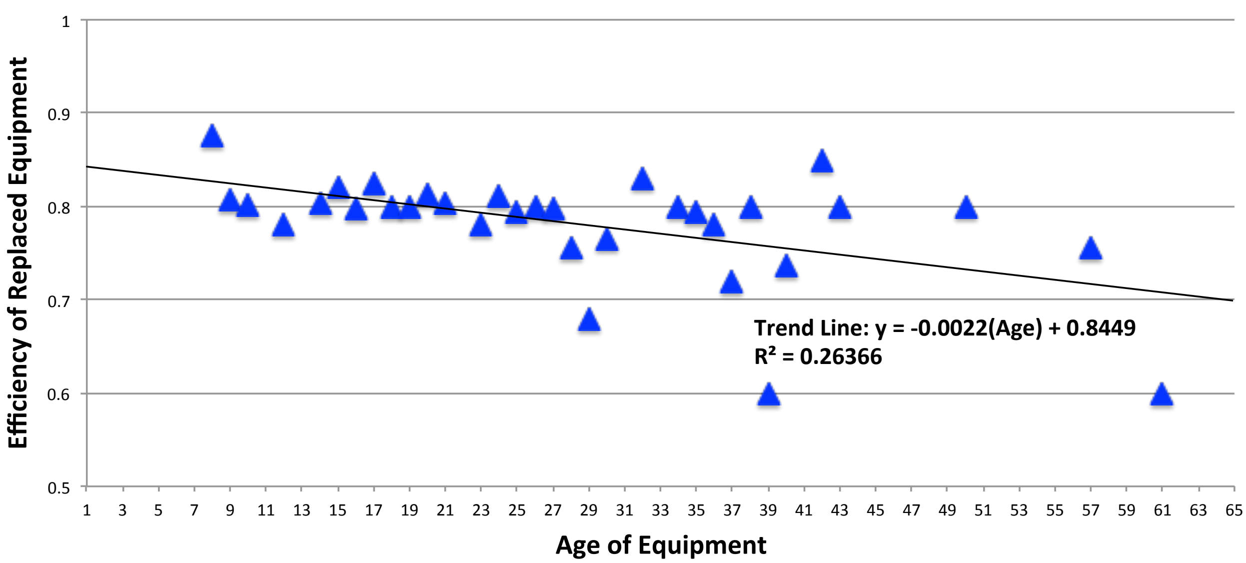
Figure 2: Distribution of ER Furnace Projects by Age and Efficiency



Source: Analysis by Evergreen team of data provided by PAs

Figure 3 shows the relationship between age and efficiency for the approximately 200 ER furnaces for which we had data. While the negative relationship between the two variables is not surprising, it does verify that the older the ER furnace is, the greater the difference is in efficiency between the old and new equipment.[4] Notably, there is more variation in the efficiencies of the oldest furnaces (i.e., older than 40 years,) which may reflect greater variation in historical maintenance practices.

Figure 3: Relationship Between Age and Efficiency of Replaced Furnaces



Source: Analysis by Evergreen team of data provided by PAs

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[4] The estimated slope coefficient of -0.0022 is statistically significant at the 0.01 level (t = -3.332). The interpretation of the coefficient is that for each additional year of age, the efficiency of the installed furnace is 0.22 percentage points lower.

3.1.2 ER Boilers

PAs completed more than 5,700 ER boiler projects in 2013 and 2014, with National Grid responsible for the vast majority of the projects (see Table 6). Of the tracking data made available to us, there were 108 projects for which the contractor determined the age of the replaced boiler or we were able to determine the age based on model and/or serial number. There is substantial variation among the PAs with respect to the minimum age requirement for a boiler early replacement. For Massachusetts PAs, the minimum age is 30 years, while Liberty NH has a minimum age of 10 years and the United Illuminating program does not have a minimum age requirement. Differences in the minimum age requirement appear to have an impact on the age of boilers replaced by the PAs. As the table shows, the average/median age of boilers replaced through the National Grid and NSTAR programs, which have a minimum age for replacement of 30 years, are higher than for Liberty NH and United Illuminating. For the 108 ER boiler projects for which we have age data, the average difference in replacement age between the PAs with a 30-year minimum age and the other two PAs shown in Table 6 is 5.9 years. This difference is statistically significant at the .05 level of significance.[5]

Table 6: Project Counts, Age Requirements, and Mean/Median Age of ER Boilers

PA	Universe of Projects (1)	Projects with Reported Age (2)	Old Equipment Minimum Age Requirement (3)	Mean/Median Age Old Boiler (Tracking) (4)	Mean/Median Age Old Boiler (Participant Survey) (5)
MA NGrid	5,201	24	30	36.3 / 36.5	40 / 38
LIBNH	31	23	10	28.3 / 26.0	21 / 21
NSTAR	320	10	30	32.2 / 32.5	42 /40
United Illuminating	51	51	No Min Age	29.6 / 25.0	33 / 31
Unitil	127	0	30	NA	43 / 38

(1) Based on information provided by the PAs. The PAs may have completed additional ER projects; however, these are the counts of projects of which we are aware.
(2) Includes projects with ages that were either reported by contractor or determined by the Evergreen team. Age of replaced equipment is necessary to compute RUL.
(3) Based on interviews with PA staff and review of Connecticut and Massachusetts TRMs.
(4) Based on site-specific age information determined by the contractors or determined by the Evergreen team based on model and/or serial number of old equipment.
(5) Based on self-reported estimates of age of old equipment by program participants; not part of the PA tracking system.

Table 7 shows the deemed EUL and RUL for each PA based on interviews with PA staff and/or the respective state's TRM. All PAs assume an EUL of 20 years, which is substantially less than the mean/median age of those replaced boilers for which we have data. Table 7 also shows the average and median RUL of the replaced boilers, computed using survival analysis based on alternative assumptions of the EUL for boilers. The "DOE" estimates of RUL are based on an

[5] The t-statistic for a two-independent sample t-test is 2.26 (equal variance not assumed). We are 90 percent confident that the true difference is contained in the interval 1.6 to 10.2 years.

assumed 25.44-year EUL.[6] For the PA-specific estimates of mean and median RUL, we used the deemed EUL contained in the respective state's TRM. On average, the greater EUL reported in the U.S. Department of Energy (DOE) report results in an approximately three year greater RUL compared to the EUL contained in the TRMs.

Table 7: Assumed EUL, Deemed RUL, and Estimated RULs of ER Boilers

PA	Projects with Reported Age (1)	Assumed EUL / Deemed RUL (2)	Mean/Median RUL (DOE) (3)	Mean/Median RUL (PA-Specific) (4)
MA NGrid	24	20 / 10	6.3 /6.1	3.6 / 3.4
LIBNH	23	20 / 10	8.4 / 8.3	5.0 / 4.8
NSTAR	10	20 / 10	8.2 / 6.8	4.9 / 3.8
United Illuminating	51	20 / 5	8.7 / 8.6	5.2 / 5
Unitil	0	20 / 10	NA	NA

(1) Includes projects with ages that were either reported by contractor or determined by the Evergreen team.
(2) Based on interviews with program staff.
(3) Calculated using survival curve approach; Based on DOE 2012 estimated EUL for boilers of 25.44 years. http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0047-0011
(4) Calculated using survival curve approach; based on PA's EUL assumption for boilers.

Table 8 shows the count of ER boiler projects with reported (or determined) efficiencies by PA. In total, there were 87 such projects, with most of these projects from United Illuminating. While the vast majority of ER boiler projects were completed by National Grid, there are only five projects for which we have information on the efficiency of the replaced equipment. Table 8 also shows efficiency-related information for each PA's program and the mean/median efficiency of the replaced boilers, which ranges from 75 percent to 80 percent.

[6] U.S. Department of Energy. Technical Support Document Appendix 8-F Residential Boiler Lifetime Determination for the Notice of Proposed Rulemaking (NOPR) for Energy Conservation Standards for Residential Boilers. Docket Number EERE-2012-BT-STD-0047-0011. Available at: http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0047-0011

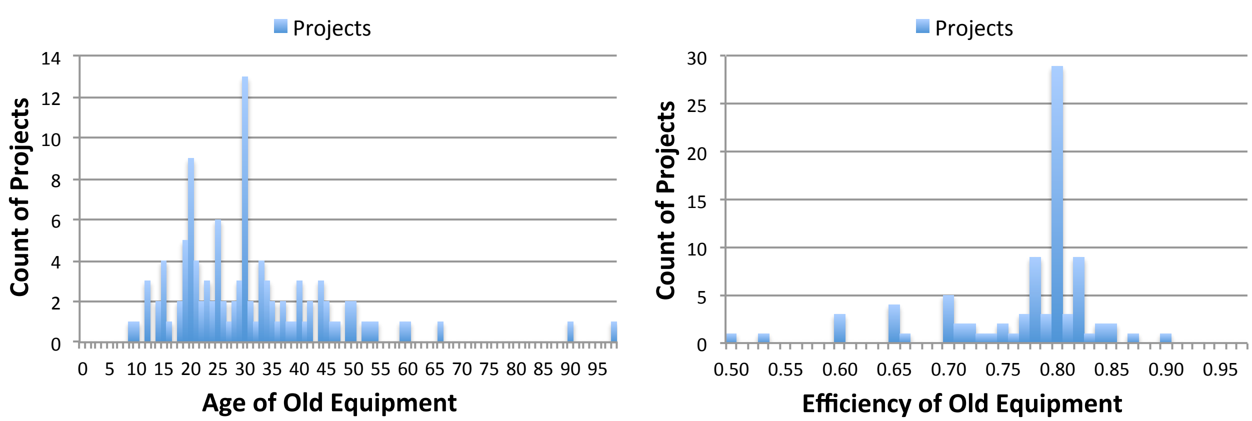
Table 8: Project Counts, Baseline Efficiency for New Boilers, and Mean/Median Efficiency of ER Boiler

PA	Projects with Reported Efficiency (1)	Baseline Efficiency for Normal-Replacement Boiler (2)	Efficiency of Existing Boiler (3)	Mean/Median Efficiency Old Boiler (4)
MA NGrid	5	Gas: Steam 80% / Hot Water 82% Oil/Propane: 80%	Hot Water 65%; Steam 55%	80% / 80%
LIBNH	25	82%	Hot Water 80%; Steam 75%	78% / 80%
NSTAR	2	Gas: Steam 80% / Hot Water 82%; Oil/Propane: 80%	Hot Water 65%; Steam 55%	75% / 75%
United Illuminating	55	80%	Deemed based on Boiler age	76% / 80%
Unitil	0	Gas: Steam 80% / Hot Water 82%; Oil/Propane: 80%	Hot Water 65%; Steam 55%	NA

(1) Based on site-specific information determined by the contractors or determined by the Evergreen team.
(2) Based on interviews with program staff and review of respective TRM.
(3) Based on interviews with program staff.
(4) Based on site-specific information determined by the contractors or determined by the Evergreen team based on model and/or serial number of old equipment.

Figure 4 shows the distribution of ER boiler projects by age and efficiency of the replaced equipment. Thirty years was the most frequent replacement age for ER boilers, though many boilers under 20 and over 40 years of age were replaced through the program. Most boilers were determined to have an efficiency rating of 78 to 82 percent.

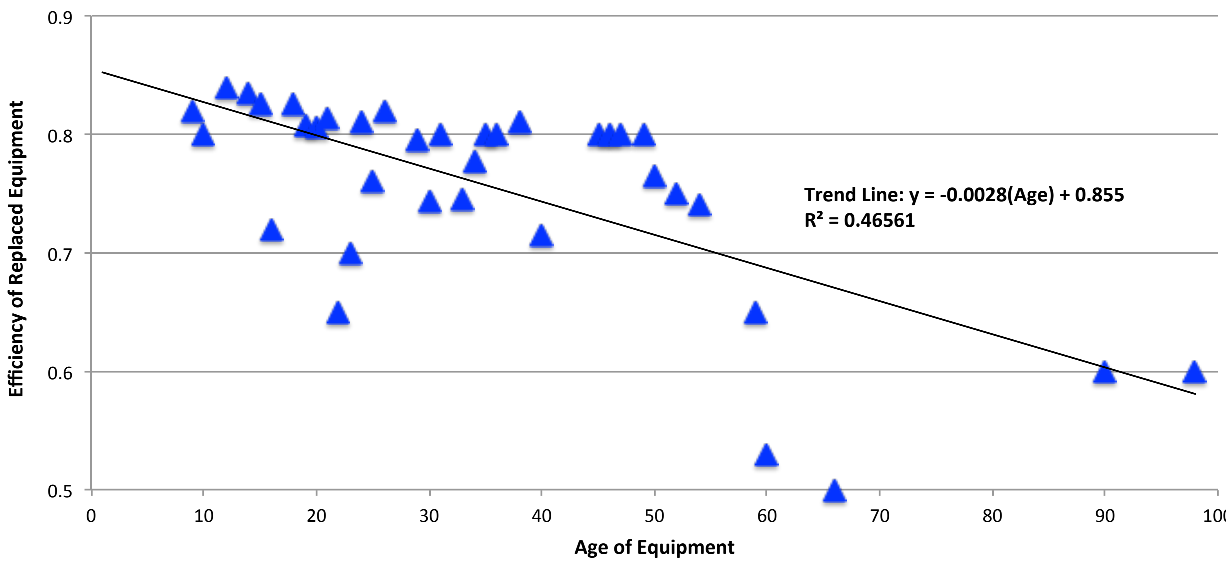
Figure 4: Distribution of ER Boiler Projects by Age and Efficiency



Source: Analysis by Evergreen team of data provided by PAs

Figure 5 shows the relationship between age and efficiency for the approximately 90 ER boilers for which we have data on both variables. As the figure shows, there is a strong negative relationship between the age and efficiency of these boilers, verifying that the older the equipment is, the greater the difference is in efficiency between the replaced and new high-efficiency boiler.

Figure 5: Relationship Between Age and Efficiency of Replaced Boilers



Source: Analysis by Evergreen team of data provided by PAs

3.1.3 ER Air Conditioners

According to information provided to us, only two PAs (Cape Light and United Illuminating) offered an early replacement AC program in 2013 and 2014 (see Table 9). Combined, these PAs completed 162 projects; age was determined by the installation contractor for 52 of these projects.[7] Cape Light does not have a minimum age requirement for early replacement AC, which probably explains why age was not recorded for any of the Cape Light projects. For United Illuminating, the minimum age requirement is 10 years.

Differences in the minimum age requirement appear to have an impact on the age at which early replacement ACs are replaced by the PAs. As the table shows, based on the participant survey, mean estimated age is 11 years greater for United Illuminating than for Cape Light (26 years versus 15 years) and the median estimated age is twice as great (26 years versus 13 years).

Key Finding:

Differences in the minimum age requirement appear to have an impact on the age at which early replacement ACs are replaced by the PAs.

[7] None of the projects included model or serial number; therefore, we were not able to determine age through look-up tables.

Table 9: Project Counts, Age Requirements, and Mean/Median Age of ER AC

PA	Universe of Projects (1)	Projects with Reported Age (2)	Old Equipment Minimum Age Requirement (3)	Mean/Median Age Old AC (Tracking) (4)	Mean/Median Age Old AC (Participant Survey) (5)
Cape Light	73	0	No Min Age	NA	15 / 13
United Illuminating	91	52	10	19.6 / 20	26 / 26

(1) Based on information provided by the PAs. The PAs may have completed additional ER projects; however, these are the counts of projects of which we are aware.
(2) Includes projects with ages reported by contractor.
(3) Based on interviews with PA staff and review of Connecticut and Massachusetts TRMs.
(4) Based on site-specific age information determined by the contractor.
(5) Based on self-reported estimates of age of old equipment by program participants; not part of the PA tracking system.

Table 10 shows the deemed EUL and RUL for Cape Light and United Illuminating. Table 10 also shows the average and median RUL of the replaced ACs for United Illuminating, computed using survival analysis. The "LBNL" estimates of RUL are based on an assumed 18.04-year EUL, which is essentially equal to the EUL assumption used by the PAs (18 years).[8]

Table 10: Assumed EUL, Deemed RUL, and Estimated RULs of ER ACs

PA	Projects with Reported Age (1)	Assumed EUL / Deemed RUL (2)	Mean/Median RUL (LBNL = PA) (3)
Cape Light	0	18 / 7	NA
United Illuminating	52	18 / 5	6.9 / 6.6

(1) Includes projects with ages reported by contractor.
(2) Based on interviews with program staff.
(3) Calculated using survival curve approach; based on LBNL 2011 estimated EUL for ACs of 18.04 years.
(4) Calculated using survival curve approach; based on PA's EUL assumption for ACs.

None of the early replacement AC projects included reported efficiency. Table 11 also shows efficiency-related information for each PA's program and the mean/median efficiency of the replaced boilers, which ranges from 75 percent to 80 percent.

[8] Lawrence Berkeley National Laboratory. Using National Survey Data to Estimate Lifetime of Residential Appliances. October 2011, page 9.

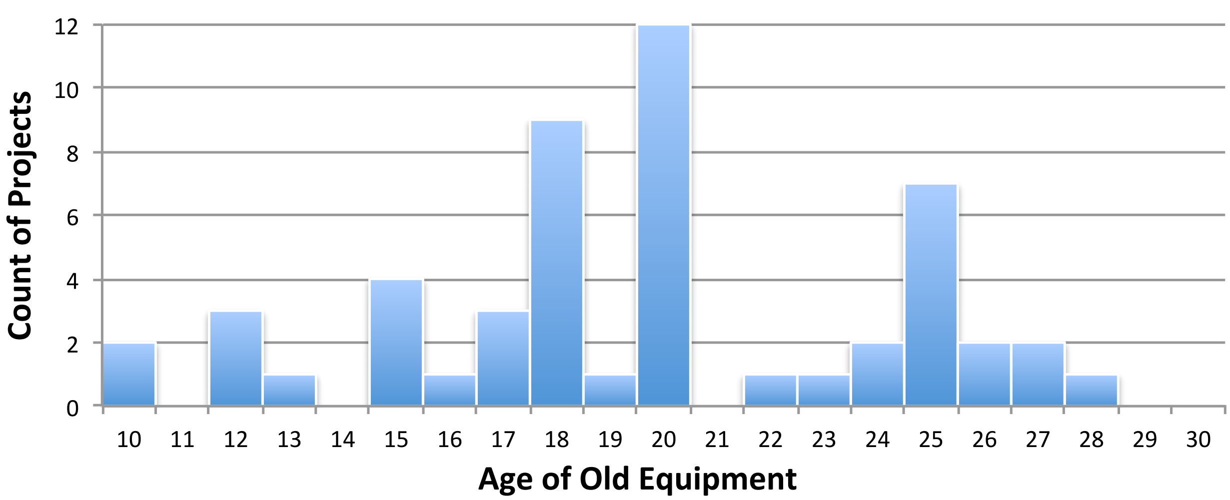
Table 11: Project Counts, Baseline Efficiency for New AC Units, and Mean/Median Efficiency of ER Air Conditioners

PA	Projects with Reported Efficiency (1)	Baseline Efficiency for Normal-Replacement AC (2)	Efficiency of Existing AC (3)	Mean/Median Efficiency Old AC
Cape Light	0	SEER 13, 11 EER, 7.6 HSPF*	None	NA
United Illuminating	0	11 EER**	Site specific / 8.0 default	NA

(1) Based on site-specific information determined by the contractors or determined by the Evergreen team.
(2) Based on interviews with program staff and review of respective TRM.
(3) Based on interviews with program staff.
* Federal standard
**Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009. Page 4-1. "Because there were no instances of early replacement of CAC units in the monitoring sample, the baseline for estimating savings is the min standard for new installs (11 EER)."

Figure 6 shows the distribution of ER AC projects by age of the replaced equipment. Twenty years was the most frequent replacement age for early replacement AC, though many AC units under 20 years of age were replaced through the program. The oldest reported age was 28 years.

Figure 6: Distribution of ER AC Projects by Age



Source: Analysis by Evergreen team of data provided by PAs
Note: There was no information in tracking databases regarding efficiency of replaced equipment.

3.2 Remaining Useful Life Derived From Equipment-Specific Survival Functions

One of the objectives of this study was to estimate the site-specific RULs of equipment replaced through the ER programs based on survival analysis. Currently, PAs in the states served by NEEP either deem a value for RUL or compute RUL as the difference between the age and the EUL of the equipment. For example, the RUL of a newly installed furnace with a 25-year EUL is 25 years and the RUL of a 10-year old furnace is 15 years (25 – 10 = 15). While on the surface this may appear to be a logical approach, it does not account for the fact that the expected life of a furnace or other equipment changes based on its age.[9]

Using the example of a furnace with a 25-year EUL, when that furnace was installed, its expected life was 25 years. Assume now that 20 years later, the furnace is still operating reliably. The simple approach of assuming that *RUL = EUL – AGE* means that we should expect the furnace to fail within five years. However, this simple approach does not account for the fact that this particular furnace has operated reliably for 20 years and that empirical evidence from studies of mechanical and electronic equipment indicate that the likelihood that an individual furnace (e.g., or boiler, etc.) survives to a particular age increases as the individual piece of equipment successfully ages. Thus, while we would expect only about half of all newly installed furnaces to exceed our assumed EUL of 25 years, we would expect far more than half of all furnaces that reach age 20 to exceed the 25-year EUL.

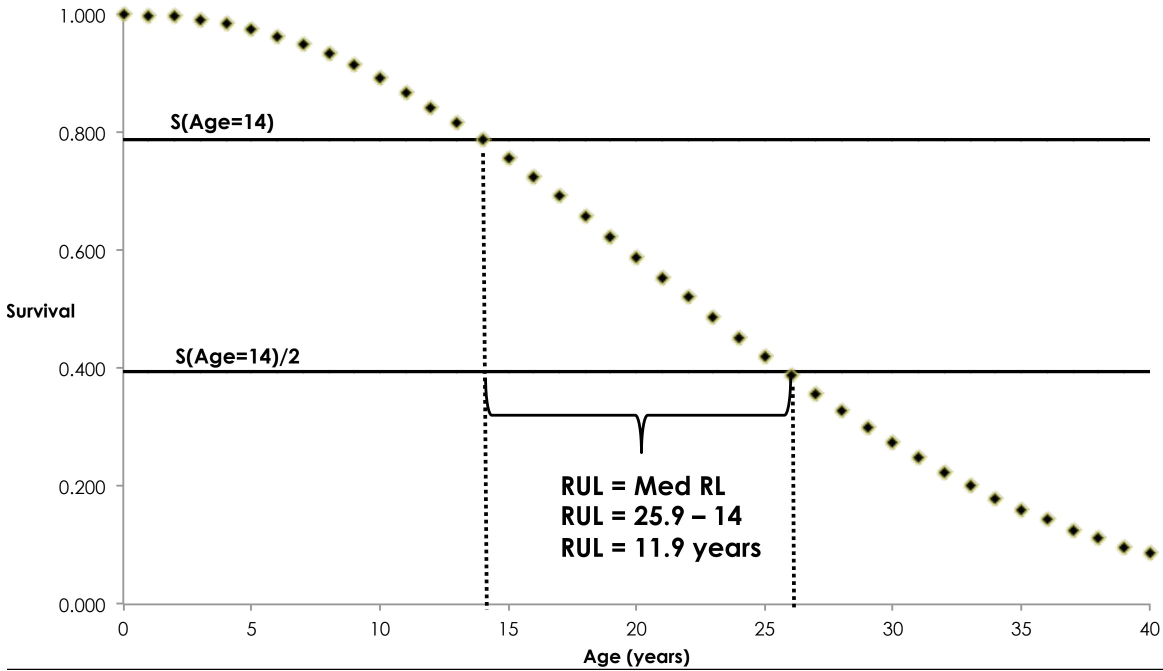
Figure 7 shows how a survival curve is used to estimate RUL based on computing median residual life (MRL) of a piece of equipment.[10] In this example, the existing piece of equipment is 14 years old. Computing the MRL requires four steps:

1. Determine the survival probability associated with a piece of equipment of the given age. *Example: Survival (age = 14) ≈ 0.8*
2. Divide the survival probability from Step 1 in half to obtain the median survival value for only equipment that is still surviving. *Example: 0.8/2 ≈ 0.4*
3. Determine the age on the survival curve that corresponds with a survival probability of the value calculated in Step 2. *Example: approximately 26 years*
4. Subtract the current age of the equipment from the age determined in Step 3. *Example: 26 – 14 ≈ 12 years*

[9] Note also that using the PAs' current approach, for furnaces or other equipment that exceed their EUL, the RUL is zero, which, as Figure 2 shows, is not empirically accurate.

[10] Median residual life is the median (50th percentile) of the *residual* age distribution for all surviving units at some specific age. Median residual life describes a population of equipment with its own unique survival function, and individual pieces of equipment can (randomly) survive more or less than the median value. In contrast, "remaining useful life" is a general concept to reflect that functional equipment can still be used for some period of time.

Figure 7: Computing Median Residual Life Based on a Survival Curve



Appendices E, F, and G provide lookup tables that PAs can use to determine the RUL of existing equipment up to 30 years old. These tables are based on the equipment-specific survival curves computed by LBNL and DOE, and we have provided the formulas that can be used to calculate RULs for equipment of any age.

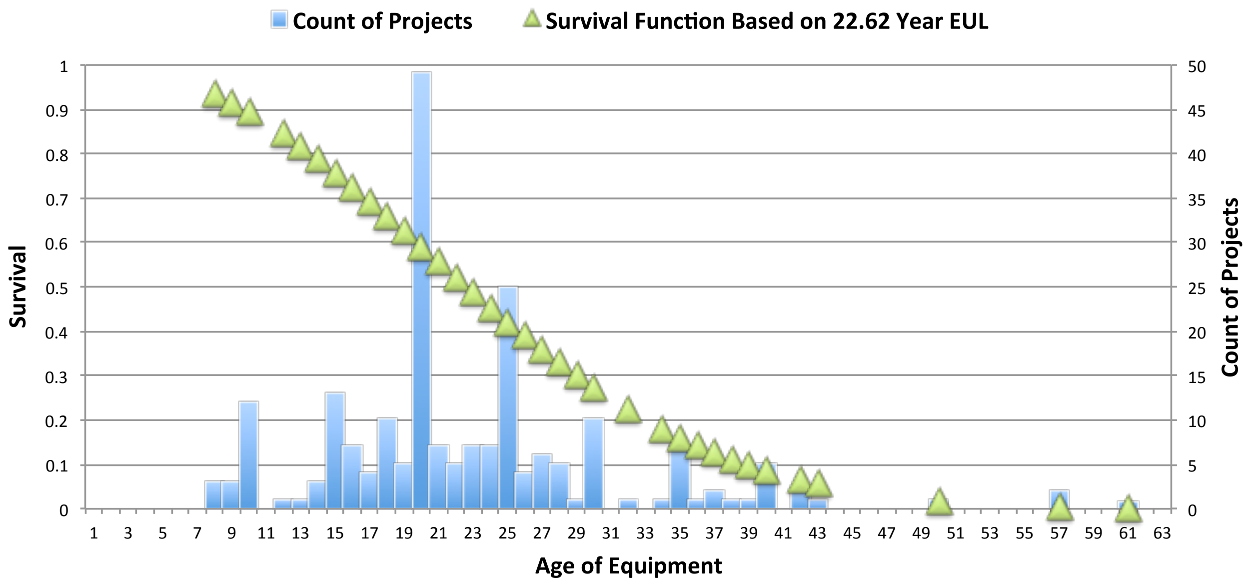
3.2.1 ER Furnaces

Figure 8 shows the survival function for furnaces calculated at the age of each ER furnace project where the age of the replaced furnace was known. The survival curve represents the percentage of furnaces expected to "survive" to each age shown on the horizontal axis, based on an EUL of 22.62 years, as reported in the 2011 LBNL report. For example, we would expect about 90 percent of installed furnaces to survive to age 10, about 60 percent to survive to age 20, and about 27 percent to survive to age 30.[11]

The blue vertical bars in Figure 8 shows the age distribution of furnaces replaced through the ER program and are included in the figure to show the relationship between the expected survival rate by age and the number of furnaces replaced at that age. Most furnaces were replaced at an age of 20 to 30 years.

[11] It is important to note that the curve shown in Figure 8 represents the expected survival function at the time of installation (at age zero). The expected survival age of a furnace continues to increase as the equipment ages.

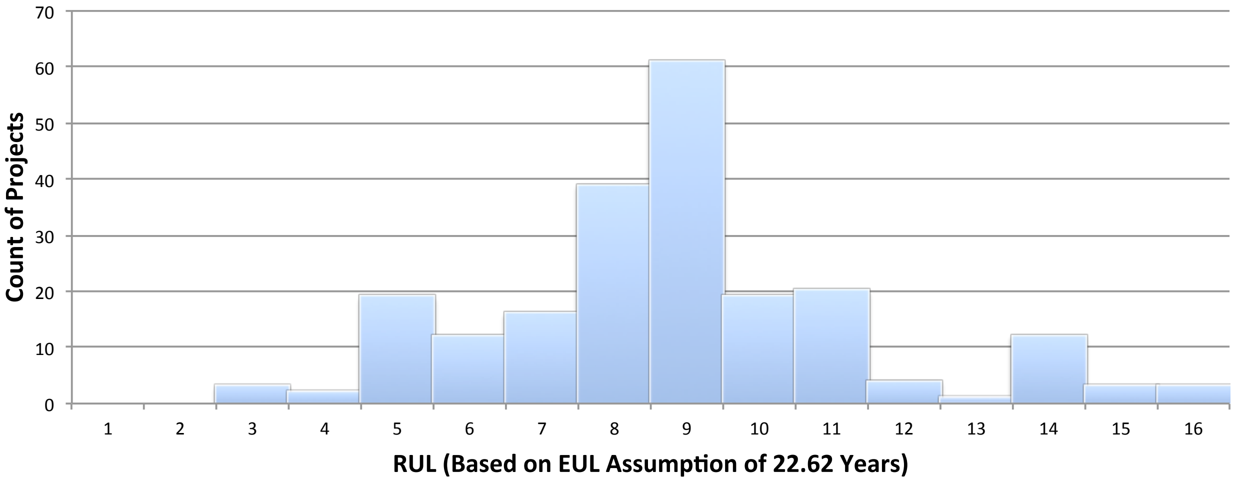
Figure 8: Survival Function Based on EUL of 22.62 Years, Replaced Furnaces



Source: Analysis by Evergreen team of data provided by PAs

Figure 9 shows the distribution (histogram) of RULs computed using the survival analysis approach and assuming an EUL of 22.62 years. The histogram is based on the 214 ER furnace projects for which age of the replaced furnace was determined. Approximately two-thirds of replaced furnaces had an RUL of 8 to 11 years and about one-quarter had an RUL of less than eight years. The remainder of replaced furnaces had RULs of between 12 and 16 years.

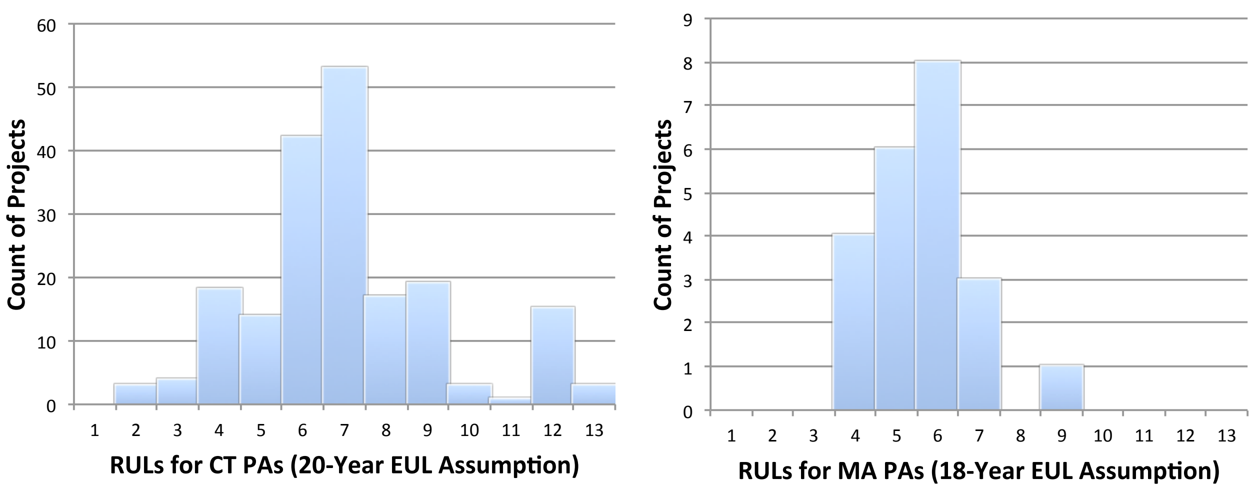
Figure 9: Distribution of RULs Based on Survival Analysis, Assumed EUL of 22.62 Years, Replaced Furnaces



Source: Analysis by Evergreen team of data provided by PAs

We also computed RULs based on alternative assumptions of the EUL for furnaces. Figure 10 shows the distribution of RULs computed using PA-specific EUL assumptions, which are 18 years for Massachusetts PAs and 20 years for Connecticut PAs. Note that the scales of the vertical axis for the two frequency distributions are different. While there were far more ER furnace projects completed by Massachusetts PAs (918 versus 219 based on information provided to us by the PAs), there were far more Connecticut projects with information on the age of the replaced furnace (192 versus 22).

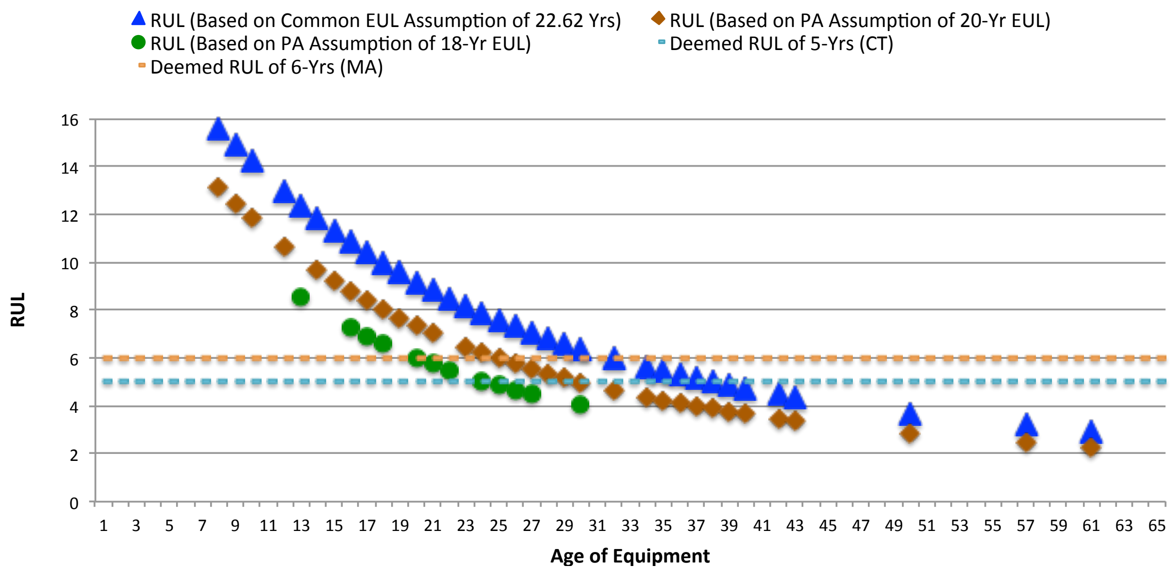
Figure 10: Estimated RULs Based on Survival Analysis, Using PA-specific EUL Assumptions, Replaced Furnaces



Source: Analysis by Evergreen team of data provided by PAs

Figure 11 shows the relationship between age and RUL for ER furnaces. The blue triangle markers represent the calculated RUL based on the LBNL assumption of a 22.62-year EUL, whereas the brown diamond and green circle markers are associated with the 20-year and 18-year EUL for Connecticut and Massachusetts, respectively. The horizontal lines at 5 years and 6 years represent the deemed RULs reported in the Connecticut and Massachusetts TRMs.

Figure 11: Comparison of Computed and Deemed RULs, Replaced Furnaces



Source: Analysis by Evergreen team of data provided by PAs

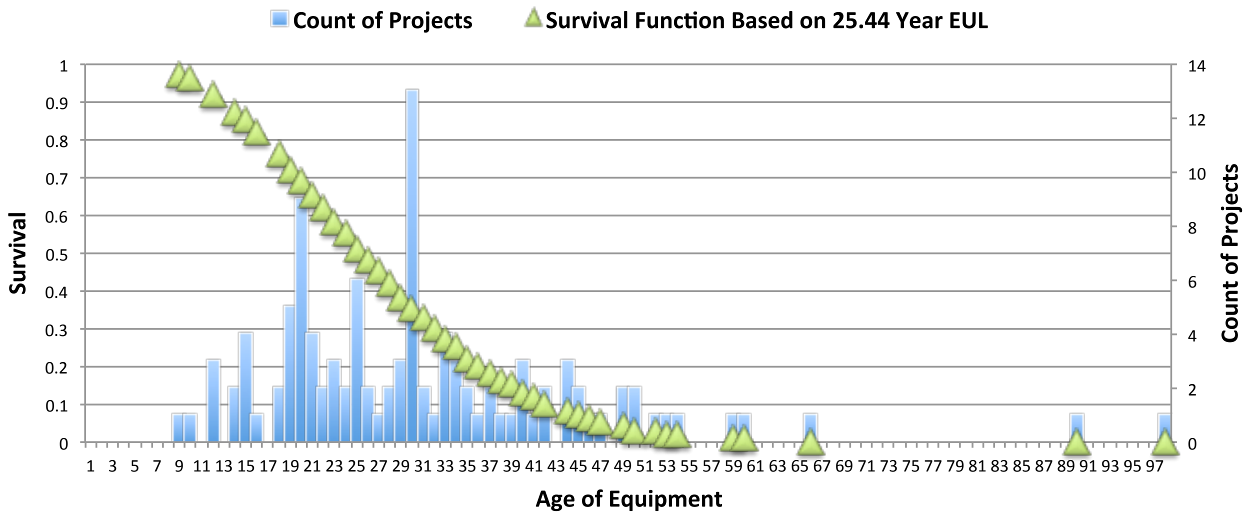
3.2.2 ER Boilers

Figure 12 shows the survival function for boilers calculated at the age of each ER boiler project where age is known. The survival curve represents the percentage of boilers expected to "survive" to each age shown on the horizontal axis, based on an EUL of 25.44 years, as reported by the United States Department of Energy (DOE). Based on this survival function, we would expect about 95 percent of installed boilers to survive to age 10, about 70 percent to survive to age 20, and about 35 percent to survive to age 30.[12]

The blue bars in Figure 12 shows the age distribution of boilers replaced through the ER program. While most boilers were replaced before age 30, nearly 40 percent of boilers were replaced at an age greater than 30 years.

[12] It is important to note that the curve represents the expected survival function at the time of installation (at age zero). The expected survival age of a boiler continues to increase as the equipment ages.

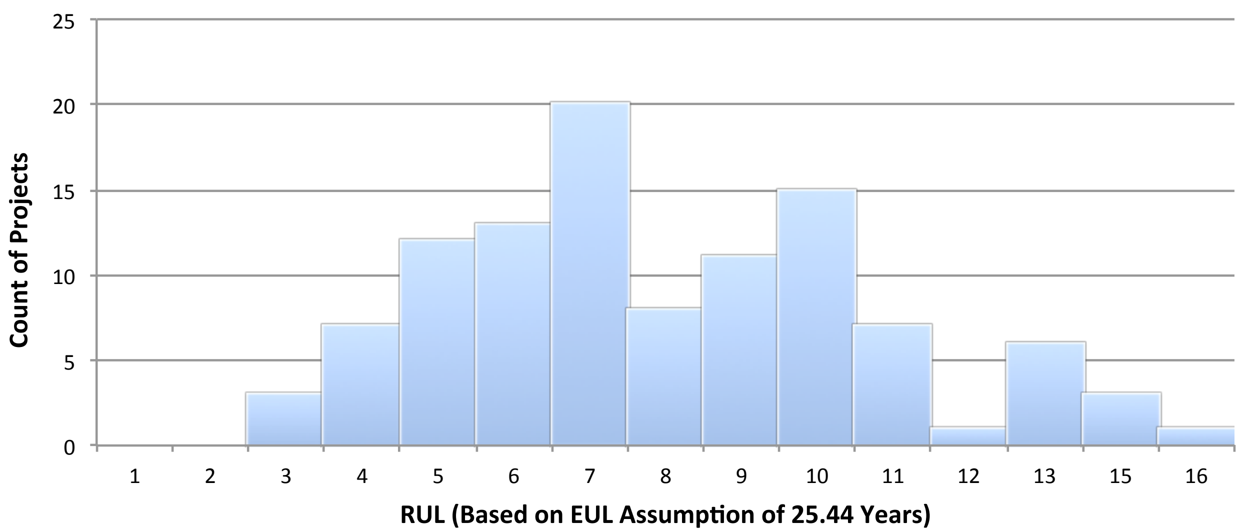
Figure 12: Survival Function Based on EUL of 25.44 Years, Replaced Boilers



Source: Analysis by Evergreen team of data provided by PAs

Figure 13 shows the distribution of RULs of replaced boilers computed using the survival analysis approach and assuming an EUL of 25.44 years. The histogram is based on the 108 ER boiler projects for which age of the replaced equipment was determined. Approximately 75 percent of replaced boilers had an RUL of 5 to 10 years and about 10 percent had an RUL of less than five years. The remainder of replaced boilers had RULs of between 10 and 16 years.

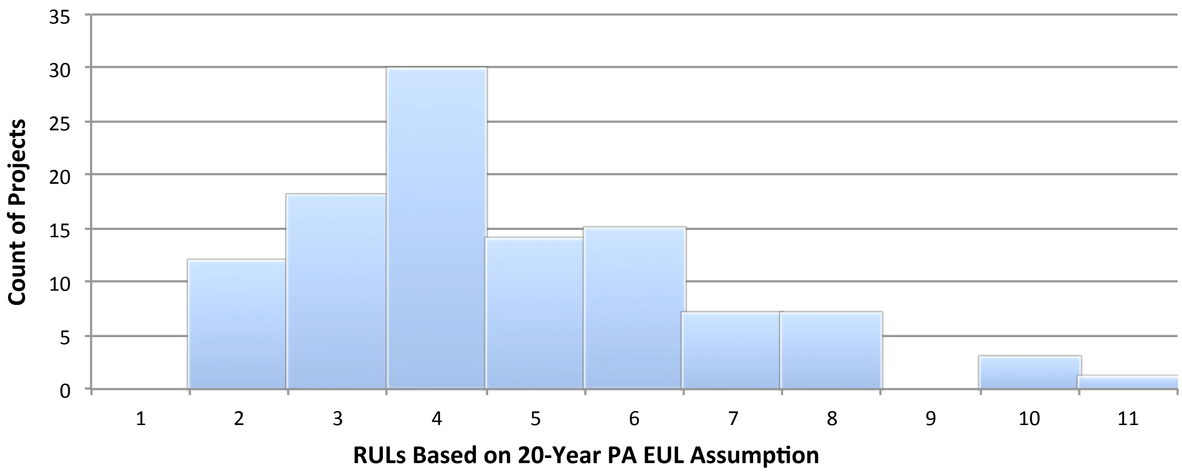
Figure 13: Distribution of RULs Based on Survival Analysis, Assumed EUL of 25.44 Years, Replaced Boilers



Source: Analysis by Evergreen team of data provided by PAs

Figure 14 shows the distribution of RULs computed using the PA-specific EUL assumption of 20 years. With the lower assumed EUL, the distribution of RULs is shifted to the left, resulting in the majority (about 83%) of estimated RULs falling between 2 and 6 years.

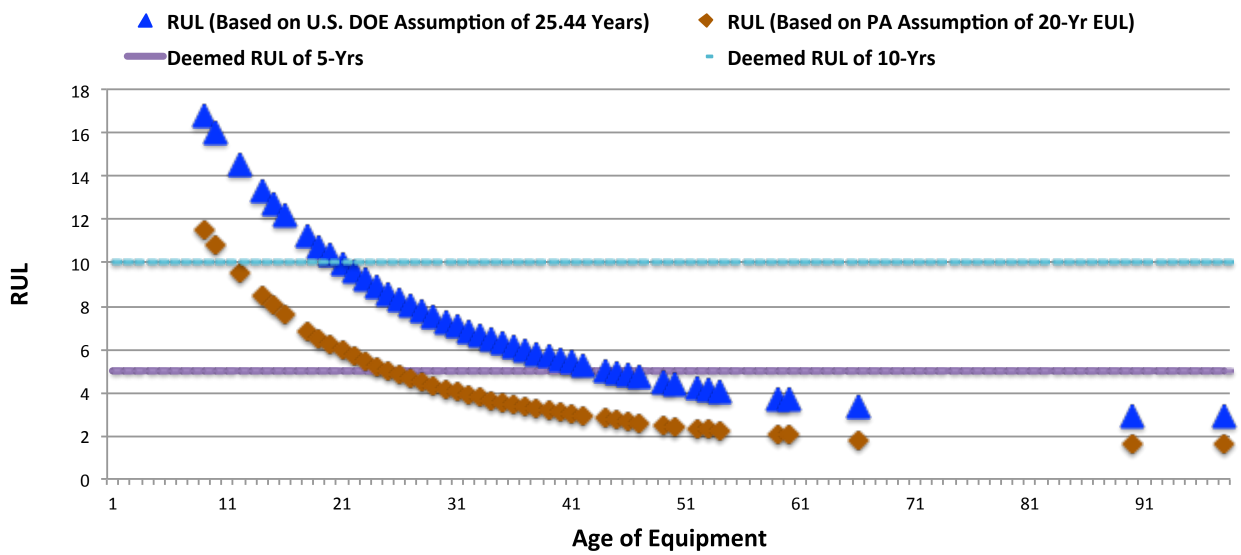
Figure 14: Estimated RULs of Based on Survival Analysis, Using PA-specific EUL Assumptions, Replaced Boilers



Source: Analysis by Evergreen team of data provided by PAs

Figure 15 shows the relationship between age and RUL for ER boilers. The blue triangle markers represent the U.S. DOE assumption of a 25.44-year EUL, whereas the brown diamond markers are associated with the 20-year EUL assumed by the PAs. The horizontal lines at 5 years and 10 years represent the deemed RULs assumed by the PAs.

Figure 15: Comparison of Computed and Deemed RULs, Replaced Boilers



Source: Analysis by Evergreen team of data provided by PAs

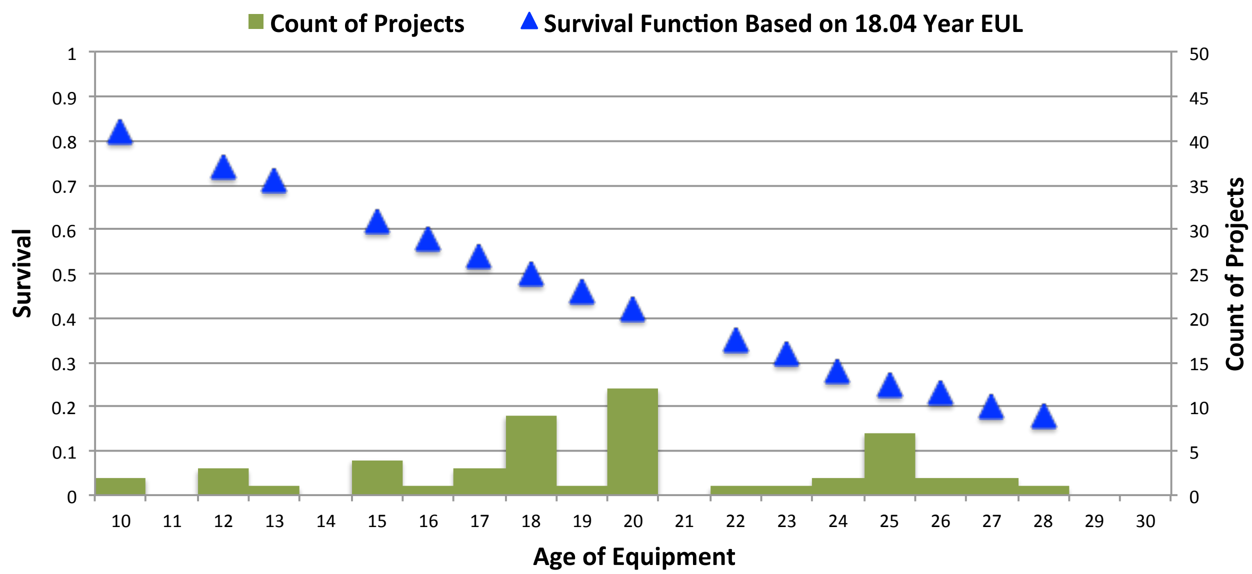
3.2.3 ER Air Conditioners

Figure 16 shows the survival function calculated for central AC at the age of each ER AC project where the age of the replaced unit was known. The survival curve represents the percentage of AC units expected to "survive" to each age shown on the horizontal axis, based on an EUL of 18.04 years, as reported in the 2011 LBNL report. Based on the LBNL report, we would expect about 80 percent of installed AC units to survive to age 10, about 40 percent to survive to age 20, and about 15 percent to survive to age 30.[13]

The green bars in Figure 16 show the age distribution of AC units replaced through the ER program. Approximately 40 percent of units were replaced at an age of 18 to 20 years, with about 30 percent replaced before 18 years and 30 percent replaced after 20 years.

[13] It is important to note that the curve represents the expected survival function at the time of installation (at age zero). The expected survival age of an AC unit continues to increase as the equipment ages.

Figure 16: Survival Function Based on EUL of 18.04 Years, Replaced AC

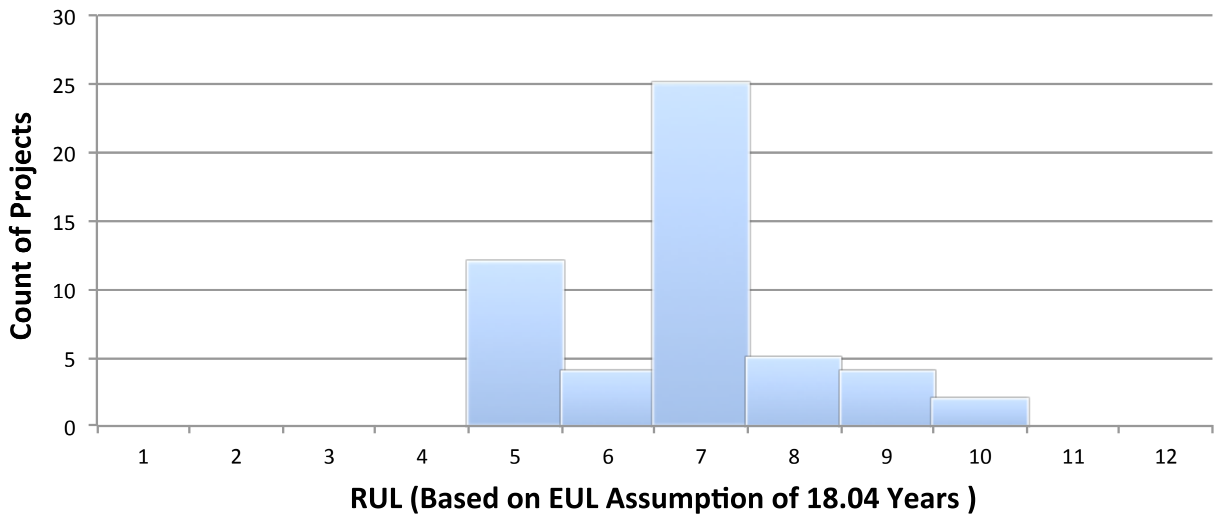


Source: Analysis by Evergreen team of data provided by PAs

Figure 17 shows the distribution (histogram) of RULs computed using the survival analysis approach and assuming an EUL of 18.04 years, which is the EUL reported in the 2011 LBNL report and is nearly the exact EUL value (18 years) assumed by the PAs.[14] The histogram is based on the 52 ER AC projects for which the contractor determined age of the replaced unit. Approximately 80 percent of replaced AC units had an RUL of 5 to 8 years, with the remainder of replaced units having an RUL of between 8 and 10 years.

[14] Because the EUL assumed by the PAs is nearly identical to the value published in the 2011 LBNL report, we do not show a separate figure for RULs based on the PA assumption of the EUL, nor do we include a figure comparing RULs based on alternative EUL assumptions.

Figure 17: Distribution of RULs Based on Survival Analysis, Assumed EUL of 18.04 Years, Replaced ACs



Source: Analysis by Evergreen team of data provided by PAs

3.3 Incremental Cost of Early Replacement Equipment

A secondary objective of this study was to provide insights into the incremental cost of ER projects. To do this, we relied on RULs developed in section 3.2 and on information on the costs of installed equipment gathered from the interviews with contractors (see Section 5). The RUL of the existing equipment is a key parameter for determining incremental cost of early replacement and cost-effectiveness.[15] We learned in the Phase I study that most ER programs employ a default assumption determined by program design, and few programs utilize site-specific information to determine RUL.

The incremental cost of an early replacement project, under the dual-baseline assumption, is comprised of two components: (1) the incremental cost (above normal replacement) of the high efficiency equipment, and (2) the incremental cost of replacing the equipment before the end of its RUL. The first component is determined by technical and market factors, which we estimate based on interviews with installation contractors.

The second component is a function of the EUL of the new equipment, RUL of the replaced equipment, and a real discount rate (RDR). Specifically, it is computed as the product of the ER Cost Factor (defined below) and the installed cost of the baseline efficiency equipment.[16] The ER Cost Factor is the ratio of the present value of the real levelized carrying cost (RLCC)[17] for

[15] Note: It was beyond the scope of this study to assess the cost effectiveness of any specific ER projects or programs.

[16] The incremental cost under the single-baseline assumption is equal to the product of the ER Cost Factor and the installed cost of the new equipment.

[17] The RLCC is the annual amount that returns the installed cost of the existing equipment when discounted at the real discount rate over the EUL of the existing equipment.

the RUL of the existing furnace and the present value of the RLCC for the EUL of the furnace.[18] The ER Cost Factor represents the cost, in percentage terms, of bringing forward to the present the future "normal" replacement of the existing equipment:

$$\text{ER Cost Factor} = \frac{PV(\text{RDR, RUL, RLCC of Existing Equipment})}{PV(\text{RDR, EUL, RLCC of Existing Equipment})}$$

The formulas for the numerator and denominator are as follows:

$$PV(\text{RDR, RUL, RLCC Existing Equipment}) = \frac{RLCC*(1+RDR)^{RUL}-1}{RDR*(1+RDR)^{RUL}}$$

$$PV(\text{RDR, EUL, RLCC Existing Equipment}) = \frac{RLCC*(1+RDR)^{EUL}-1}{RDR*(1+RDR)^{EUL}}$$

The formula is based on the RUL of the existing equipment and the EUL of the new equipment. Assuming the EUL of the new equipment is greater than the RUL of the existing equipment, the ER Cost Factor is bounded by zero and one, with higher values representing greater up-front costs associated with early replacement. Existing equipment with relatively high RULs (i.e., the equipment is not very old) will lead to greater ER Cost Factors and, therefore, higher incremental cost for early replacement.

While computing the incremental cost of an early replacement project is relatively straightforward, it is instructive to demonstrate its computation with an example.

Table 12 shows information on two homes considered for an ER furnace project. For each home, the installed cost of a baseline efficiency furnace is the same ($3,000), as is the incremental cost of a high-efficiency furnace ($500) and the real discount rate assumed for each project (3%). The two homes differ substantially, however, in the age of the existing furnace. For Home 1, the furnace is 40 years and for Home 2, the furnace is only 8 years old. The RUL of the existing furnace in each home is calculated as the median residual life based on survival analysis using the parameters reported in the 2011 LBNL study. For Home 1, the 40-year old furnace is estimated to have an RUL of 4.75 years with a present value of one dollar of RLCC of about $4.40, while the 8-year old furnace in Home 2 has an RUL of 15.6 years and a present value of one dollar of RLCC of $12.30.[19]

[18] Note that this equates to the ratio of the uniform series present value (using the real discount rate) calculated respectively at the RUL and EUL because the RLCC terms in the numerator and denominator cancel each other out.

[19] Computed using formulae shown above; the units of the present value of RLCC are $/RLCC.

Table 12: Computing Incremental Cost of an ER Project, Illustrative Example

Row	Element of Cost Calculation	Home 1	Home 2
A	Installed cost of baseline efficiency furnace	$3,000	$3,000
B	Incremental cost of high efficiency furnace	$500	$500
C	Real Discount Rate	3%	3%
D	Age of Existing Furnace	40	8
E	RUL of Existing Furnace based on Survival Analysis Approach	4.75	15.61
F	Present Value over RUL of $1 RLCC of Existing Furnace	$4.37	$12.32
G	EUL of New Equipment	22.62	22.62
H	Present value over EUL of $1 RLCC of Existing Furnace	$16.25	$16.25
I	ER Cost Factor *(F/H)*	0.27	0.76
J	Incremental Cost of Early Replacement w/ Standard Efficiency *(A*I)*	$806	$2,274
K	Total Incremental Cost of Early Replacement w/ High Efficiency *(B+J)*	$1,306	$2,774

Source: Analysis by Evergreen team

For both homes, we assume the EUL of the new furnace is 22.62 years (from the 2011 LBNL study) and the present value of the RLCC is $16.25/RLCC.[20] The ER Cost Factor, computed using the formula shown on the previous page, is 0.27 for Home 1 and 0.76 for Home 2. Row J shows the incremental cost of early replacement w/standard efficiency, which is the product of the ER Cost Factor and the installed cost of a baseline efficiency furnace (A*I). For Home 1, this cost is $806 and for Home 2, it is $2,774. Finally, row K shows the total incremental cost of ER with a high efficiency furnace, which is simply the incremental costs replacing the furnace today (shown in row J) plus the incremental cost of a high-efficiency furnace (shown in row B).

In this example, the substantial difference in the incremental cost of ER shown in Row J is explained by the substantial difference in the ages and RULs of the existing furnaces. All else equal, older equipment implies a lower RUL, which results in a smaller ER Cost Factor and a lower incremental cost of ER. The net result is that the total incremental cost of ER for the home with the 40-year old furnace is less than half that for the home with the 8-year old furnace.

3.3.1 ER Furnaces

Table 13 shows our estimates of the incremental cost of early replacement furnaces. Columns A and B show our estimates of the cost of installed NR furnaces and the incremental cost of high-efficiency furnaces. These estimates are based on information we obtained in the contractor interviews, but because we interviewed only a small number of contractors (eight)

[20] IBID

across the entire NEEP area, the values in columns A and B should be considered anecdotal.[21] Column C shows three alternative values of the ER Cost Factor for furnaces. The mid-point value (0.49) is the median ER Cost Factor of the 214 ER furnace projects for which we had age information. The lower bound (0.31) is the 10th percentile and the upper bound (0.62) is the 90th percentile value ER Cost Factor. Finally, Column D shows our estimates of the total incremental cost of an ER furnace project and column E shows the age of the replaced furnace. Our mid-point estimate, based on the information in columns A, B, and C, is $3,085, with lower and upper bounds ranging from $2,085 to $4,550. Thus, based on our analysis of "anecdotal" cost information on furnaces and those ER furnace projects with age information (which we cannot say are or are not representative of all ER furnace projects), we find that most ER furnace projects had a total incremental cost of between $2,085 and $4,550, when the ER Cost Factor is applied.

Table 13: Estimated Incremental Cost of Early Replacement Furnaces

	A	B	C	D	E
Cost Estimate	**Installed Cost Normal Efficiency Furnace***	**Incremental Cost of High Efficiency Furnace***	**ER Cost Factor****	**Total Incremental Cost of ER Furnace (A*C + B)**	**Furnace Age**
Mid-Point	$4,000	$1,125	0.49	$3,085	20
Lower Bound	$3,500	$1,000	0.31	$2,085	14
Upper Bound	$5,000	$1,500	0.62	$4,550	35

Source: Analysis by Evergreen team of data provided by PAs and installation contractors.
*Based on information from contractor interviews; not based on statistical sampling and should be considered anecdotal.
**Computed from PA tracking databases: Mid-point = Median; Lower Bound = 10th percentile; Upper Bound = 90th percentile.

3.3.2 ER Boilers

Table 14 shows our estimates of the incremental cost of ER boilers. Columns A and B show our estimates of the cost of installed NR boilers and the incremental cost of high-efficiency boilers based on information we obtained in the contractor interviews.[22] Column C shows three alternative values of the ER Cost Factor for boilers. The mid-point value (0.37) is the median ER Cost Factor of the 108 ER boiler projects for which we had age information. The lower bound (0.24) is the 10th percentile and the upper bound (0.59) is the 90th percentile value ER Cost Factor. Finally, Column D shows our estimates of the total incremental cost of an ER boiler project and column E shows the age of the replaced boiler. Our mid-point estimate,

[21] NEEP's Incremental Cost Study shows that 90 percent AFUE furnaces have installed incremental costs of $1,131 to $1,190 (depending on size), 92 percent AFUE incremental costs are $1,284 to $1,343, and 94 percent AFUE are $1,438 to $1,497.

[22] NEEP's Incremental Cost Study shows that 85 percent AFUE boilers have installed incremental costs of $501 to $1,785 (depending on size) and 90 percent AFUE boilers are $2,142 to $3,427.

based on the information in columns A, B, and C, is $5,655, with lower and upper bounds ranging from $3,960 to $8,720, when the ER Cost Factor is applied.

Table 14: Estimated Incremental Cost of Early Replacement Boilers

	A	B	C	D	E
Cost Estimate	**Installed Cost Normal Efficiency Boiler***	**Incremental Cost of High Efficiency Boiler***	**ER Cost Factor****	**Total Incremental Cost of ER Boiler (A*C + B)**	**Boiler Age**
Mid-Point	$6,500	$3,250	0.37	$5,655	30
Lower Bound	$4,000	$3,000	0.24	$3,960	15
Upper Bound	$8,000	$4,000	0.59	$8,720	49

Source: Analysis by Evergreen team of data provided by PAs and installation contractors.
*Based on information from contractor interviews; not based on statistical sampling and should be considered anecdotal.
**Computed from PA tracking databases: Mid-point = Median; Lower Bound = 10th percentile; Upper Bound = 90th percentile.

3.3.3 ER Air Conditioner

Table 15 shows our estimates of the incremental cost of early replacement ACs. Columns A and B show our estimates of the cost of installed normal replacement ACs and the incremental cost of high-efficiency ACs based on information we obtained in the contractor interviews.[23] Column C shows the three alternative values of the ER Cost Factor for ACs. The mid-point value (0.43) is the median ER Cost Factor of the 52 early replacement AC projects for which we had age information. The lower bound (0.43) is the 10th percentile and the upper bound (0.58) is the 90th percentile value ER Cost Factor. Column D shows our estimates of the total incremental cost of an ER AC project and column E shows the age of the replaced AC units. Our mid-point estimate, based on the information in columns A, B, and C, is $3,359, with lower and upper bounds ranging from $1,952 to $5,400, when the ER Cost Factor is applied.

[23] NEEP's Incremental Cost Study shows that 14.5 SEER ACs have installed incremental costs of $1,100 to $1,466 (depending on size), incremental costs are $1,345 to $1,707 for 15 SEER and $2,548 to $2,910 for 16 SEER.

Table 15: Estimated Incremental Cost of Early Replacement AC

	A	B	C	D	E
Cost Estimate	**Installed Cost Normal Efficiency Central AC***	**Incremental Cost of High Efficiency Central AC***	**ER Cost Factor****	**Total Incremental Cost of ER AC (A*C + B)**	**Central AC Age**
Mid-Point	$3,450	$1,875	0.43	$3,359	20
Lower Bound	$2,800	$1,000	0.34	$1,952	12
Upper Bound	$5,000	$2,500	0.58	$5,400	36

Source: Analysis by Evergreen team of data provided by PAs and installation contractors.
*Based on information from contractor interviews; not based on statistical sampling and should be considered anecdotal.
**Computed from PA tracking databases: Mid-point = Median; Lower Bound = 10th percentile; Upper Bound = 90th percentile.

4 Findings – Customer Phone Survey

In May and June of 2015, CIC Research conducted a phone survey of 373 residential customers that participated in a PA-sponsored normal replacement (NR) or early replacement (ER) program in 2013 or 2014. Equipment available through the ER programs included boilers, furnaces, and central air conditioning (AC), while the NR program measures were air source heat pumps, heat pump water heaters (HPWH), and AC. The Evergreen team analyzed information gathered from the participant survey to understand the process residential customers go through when replacing major household equipment. In addition, we asked the participants to describe the age and functionality of replaced equipment, and to evaluate various influences that may have affected their installation decisions. Appendix A includes the detailed survey instrument.

Table 16 shows the total number of completed surveys by PA, program, and equipment type and Table 17 shows a breakdown of completed surveys by initial targets. For ER projects, the key measures were ACs, boilers, and furnaces. For NR projects, the key measures were ACs, heat pumps, and HPWHs.

Table 16: Completed Surveys by PA and Equipment

	Early Replacement			Normal Replacement		
PA	**AC**	**Boiler**	**Furnace**	**AC**	**Heat Pump**	**HPWH**
MA Cape Light	8	-	-	-	-	-
CL&P	-	-	15	-	-	-
MA NGrid	-	47	28	-	-	-
Liberty NH	-	1	-	-	-	-
MA NSTAR	-	23	13	-	-	-
United Illuminating	9	4	4	-	-	-
MA Unitil	-	14	6	-	-	-
BGE	-	-	-	2	3	7
DPL	-	-	-	4		6
FirstEnergy	-	-	-	43	41	20
Pepco	-	-	-	8	4	19
PSNH	-	-	-	7	6	15
DE SEU	-	-	-	-	-	-
SMECO	-	-	-	1	1	14
Total Completes	**17**	**89**	**66**	**65**	**55**	**81**

Table 17: Completed Surveys with Initial Targets

Measure	Early Replacement (Completes/Targets)	Normal Replacement (Completes/Targets)	Total Completes
AC	17/46	65/65	82
Boiler	89/89	-	89
Furnace	66/66	-	66
Air Source Heat Pump	-	55/54	55
HPWH	-	81/52	81
Total	**172/201**	**201/171**	**373**

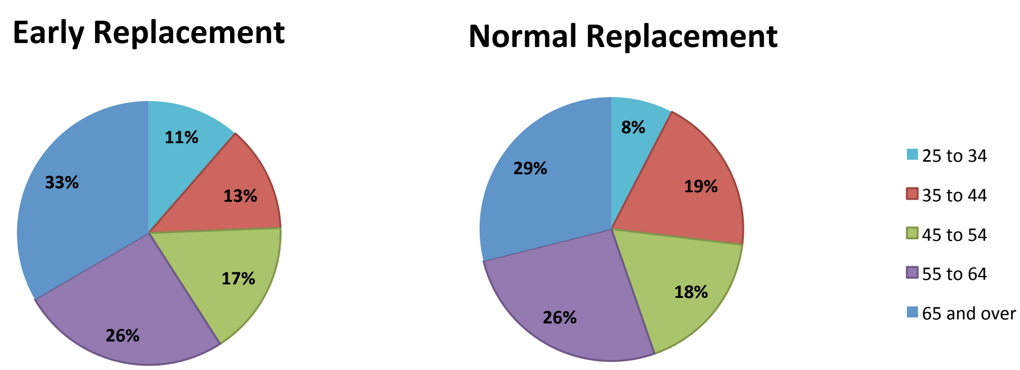
As Table 17 shows, we were able to meet all of our target quotas with the exception of ER ACs, a target which we knew would be difficult to meet because of the relatively small number of participants in the ER AC programs (164 participants with contact information for only 140).

4.1 Customer Demographics

We asked participating customers that purchased an ER or NR measure a series of demographic questions regarding their age, education level, and income level.

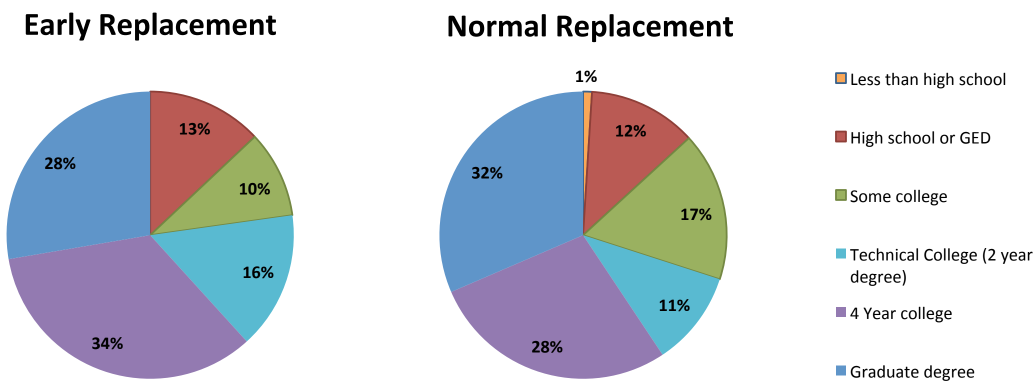
As shown in Figure 18, the age distribution of participants was relatively similar between ER and NR. Thirty-three percent of ER participants and 29 percent of NR participants were 65 or older, with an additional 26 percent of all participants aged 55 to 64. Only 11 percent of ER customers and 8 percent of NR customers were aged 25 to 34.

Figure 18: Participant Age Distribution



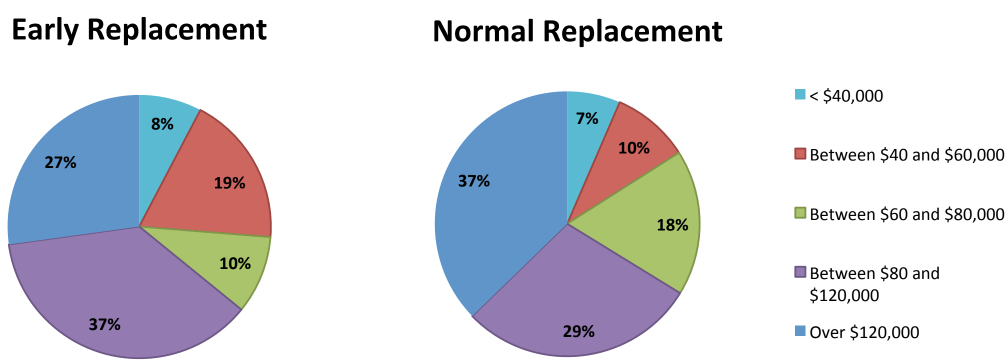
Additionally, ER and NR customers had similar distributions of education as well (see Figure 19). Sixty-two percent of ER customers and 60 percent of NR customers had a college or graduate degree. Only 13 percent of customers in both groups had a high school education or less. Comparatively, 40 percent of Massachusetts residents ages 25 or older have at least a college degree, along with 37 percent of Connecticut and Maryland residents.[24]

Figure 19: Participant Education Distribution



As Figure 20 below shows, a majority of customers reported household incomes greater than $80,000, including 64 percent of ER participants and 66 percent of NR participants. Twenty-nine percent of ER participants and 28 percent of NR participants reported incomes between $40,000 and $80,000, with only 8 percent of ER participants and 7 percent of NR participants reporting incomes less than $40,000. For the general population in the participating Northeast states, approximately 38 percent of households have incomes greater than $75,000, while approximately 39 percent of households have incomes below $50,000.[25]

Figure 20: Participant Income Distribution



[24] Massachusetts ranked as the most educated state in the U.S. while Connecticut and Maryland were the 3rd and 4th most educated states respectively (Based on 2013 U.S. Census Bureau American Community Survey).
[25] Based on 2012 U.S. Census Bureau Statistical Abstract of the United States: Household Income – Distribution by Income level and State.

4.2 Existing Equipment Condition and Replacement Decision Factors

We asked participants a series of questions regarding the condition of their replaced equipment and their decision making process in selecting their new equipment.

Among ER participants that installed a new central AC, 83 percent replaced an existing central AC unit and 17 percent replaced a room AC unit. Comparatively, 95 percent of NR participants that installed central AC replaced an existing central AC unit and 5 percent replaced a room AC unit.

As shown in Table 18, 41 percent of ER boiler customers replaced an existing gas boiler, while 31 percent replaced a heating oil boiler and 19 percent replaced a heating oil furnace. The majority of ER furnace customers replaced an existing gas furnace (83%).

Table 18: Replaced Equipment Type (Boilers and Furnaces)

Replaced Equipment Type	ER Boilers (n=89)	ER Furnaces (n=65)
Gas furnace	8%	83%
Gas boiler	41%	3%
Heating oil furnace	19%	13%
Heating oil boiler	31%	1%
Electric furnace	0%	1%
Coal furnace	2%	0%
Total	**100%**	**100%**

Additionally, as shown in Table 19 and Table 20, 53 percent of NR heat pump customers replaced an existing heat pump, while 11 percent replaced an existing gas furnace plus central AC and 9 percent replaced an existing electric furnace plus central AC. For NR HPWH replacements, 79 percent of customers replaced a conventional tank electric water heater, 12 percent replaced a tank oil water heater, and 4 percent replaced a conventional tank gas water heater.

Table 19: Replaced Equipment Type (Heat Pumps)

Replaced Equipment Type	Heat Pumps (n=55)
Heat pump	53%
Gas furnace plus central air	11%
Electric furnace plus central air	9%
Propane forced air	7%
Air conditioner	6%
Other	14%
Total	**100%**

Table 20: Replaced Equipment Type (HPWH)

Replaced Equipment Type	HPWH (n=81)
Conventional tank electric water heater	79%
Tank oil water hater	12%
Conventional tank gas water heater	4%
None	2%
Other	3%
Total	**100%**

> **Key Finding:**
>
> **Customers doing normal replacement air conditioning and heat pump projects were most likely to increase the capacity of their new equipment. A large percentage of early replacement air conditioning projects (41%) also installed higher cooling capacity.**

The Evergreen team also asked participants about the size or capacity of their replaced equipment in comparison to their new ER or NR equipment. As shown in Table 21, for ER AC and NR HPWHs, a majority of customers said their new equipment was about the same size or capacity as the replaced unit (53% and 59%, respectively). A majority of NR AC and heat pump customers said their new equipment was larger or had a higher capacity than their existing unit, while approximately a third said the equipment was about the same size or capacity as their existing unit.

Participants that installed an ER boiler responded more evenly to the size/capacity question. Just under 40 percent of ER boiler participants said their new equipment is about the same size, while 28 percent said the new equipment is larger or has a higher capacity and 26 percent said the new equipment is smaller or has a lower capacity than the existing unit. ER furnace customers had a similar distribution, as 37 percent said the new equipment is about the same size, 26 percent said the new equipment is larger or has a higher capacity, and 34 percent said the new equipment is smaller or has a lower capacity than the existing unit.

Table 21: Size or Capacity of Replaced Equipment

	Early Replacement			Normal Replacement		
Size or capacity of the old unit compared to the new unit	**AC (n=17)**	**Boiler (n=89)**	**Furnace (n=66)**	**AC (n=65)**	**Heat Pump (n=55)**	**HPWH (n=81)**
The new equipment is about the same size or capacity as the old unit	53.1%	39.2%	36.5%	32.3%	36.4%	58.5%
The new equipment is larger or higher capacity than the old unit	41.4%	27.6%	25.8%	66.2%	52.7%	19.2%
The new equipment is smaller or lower capacity than the old unit	0.0%	26.4%	34.1%	0.0%	1.8%	18.2%
Don't Know	5.6%	6.7%	3.6%	1.5%	9.1%	4.1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

We then asked program participants about the working condition of their replaced equipment (Table 22). A majority of boiler and furnace ER customers (55% and 61%, respectively) said their replaced equipment was working normally and keeping their home at the desired temperature. Less than 1 percent of ER boiler customers and about 5 percent of ER furnace customers said that their replaced equipment was broken or not functioning. Comparatively, while 47 percent of ER AC customers also indicated that their equipment was working normally, 35 percent said the equipment was broken or not functioning.

Nearly 60 percent of NR customers that installed a HPWH said their replaced equipment was working normally. Comparatively, only 29 percent of NR customers that installed a heat pump and 19 percent of NR customers that installed central AC indicated their replaced

Key Finding:

A majority of all normal replacement customers (73%) said their existing equipment was working in some capacity at the time of replacement.

equipment was working properly. Slightly more than half of all NR customers that received central AC or a heat pump indicated their equipment was broken or not functioning properly at the time of their replacement.

Table 22: Condition of Old Equipment at Time of Replacement

Old Equipment Condition	Early Replacement			Normal Replacement		
	AC (n=17)	Boiler (n=89)	Furnace (n=66)	AC (n=65)	Heat Pump (n=55)	HPWH (n=81)
It was working normally and keeping home/water at the desired temperature	46.9%	55.2%	61.3%	18.5%	29.1%	64.2%
It was working, but not keeping water/home at the desired temperature	11.7%	18.4%	18.1%	29.2%	18.2%	2.2%
It was working, but required frequent service calls	6.2%	26.1%	15.4%	35.4%	12.7%	8.2%
It was broken or not functioning	35.2%	0.2%	5.2%	16.9%	40.0%	25.4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Overall, ER customers reported that their existing equipment had to be repaired more frequently than NR customers reported, as 89 percent of ER customers that reported service calls in the past year said they required two or more repairs compared to 71 percent of NR customers.

4.2.1 Functioning Replaced Equipment

As shown in Table 23, for customers that said their existing equipment was still functioning (including those that stated their equipment required frequent service calls), a majority expected their existing equipment to continue operating for less than two more years had they not replaced it. An additional 32 percent of boiler customers, 22 percent of furnace customers, and 27 percent of HPWH customers expected that their replaced equipment would have continued to operate at least five more years.

Table 23: Expected Remaining Life For Functioning Equipment*

Expected Remaining Life Without Replacement	Early Replacement			Normal Replacement		
	AC (n=9)	Boiler (n=79)	Furnace (n=52)	AC (n=53)	Heat Pump (n=31)	HPWH (n=53)
Less than a year	0.0%	35.6%	22.0%	24.5%	29.0%	19.6%
1 - 2 years	57.4%	26.5%	38.5%	54.7%	35.5%	33.1%
3 - 4 years	21.8%	5.6%	17.7%	13.2%	22.6%	20.2%
5 - 10 years	20.7%	23.0%	21.1%	7.5%	6.5%	19.6%
More than 10 years	0.0%	9.4%	0.7%	0.0%	6.5%	7.5%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

*Includes participants that stated their replaced equipment was working, but excludes those who stated "I don't know" to the question "*How much longer do you think that your old equipment would have operated if it hadn't been replaced?*"

We asked customers with functioning equipment about the factors that influenced their decision to replace the equipment rather than wait until the equipment stopped functioning. For ER measures, the most influential factors included PA rebates, wanting new and current equipment, and concern that their existing equipment might break during the heating or cooling season.[26]

Key Finding:

For early replacement measures, the most influential decision factors were a desire for new or current equipment, concerns that existing equipment would break during the heating/cooling season and/or early replacement incentives offered by the PAs.

For ER ACs, 83 percent of customers said wanting new and current equipment was very influential in their decision making process, while 72 percent said that concern their unit might break during the cooling season was very influential, and 55 percent said wanting to have time to make a careful purchase was very influential.

For ER boilers, 75 percent of customers said a utility incentive for early replacements was very influential, while 68 percent were concerned their equipment might break during heating season and 56 percent wanted new or current equipment. The most influential factor for furnace customers was the concern of their equipment breaking during the heating season (59%), while less than half of furnace customers indicated any of the other factors were very influential.

[26] The survey did not ask customers if they desired new "energy efficient" equipment specifically.

Across all early replacement measures, the least influential factors were preparing a home for sale or rent and the availability of federal or other tax credits. Figure 21 shows a detailed breakdown of ER customer influences for each equipment type.

Figure 21: ER Customer Influences

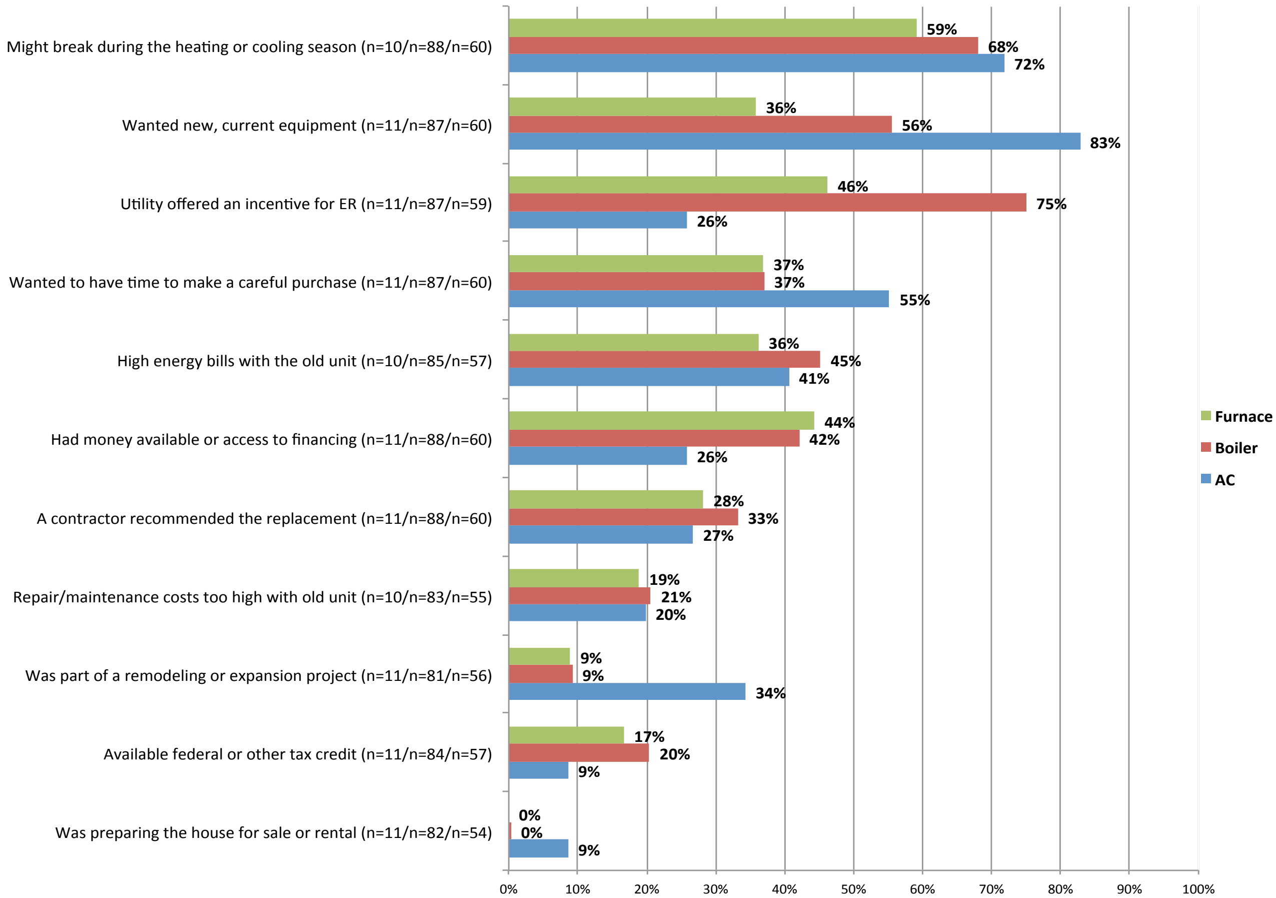
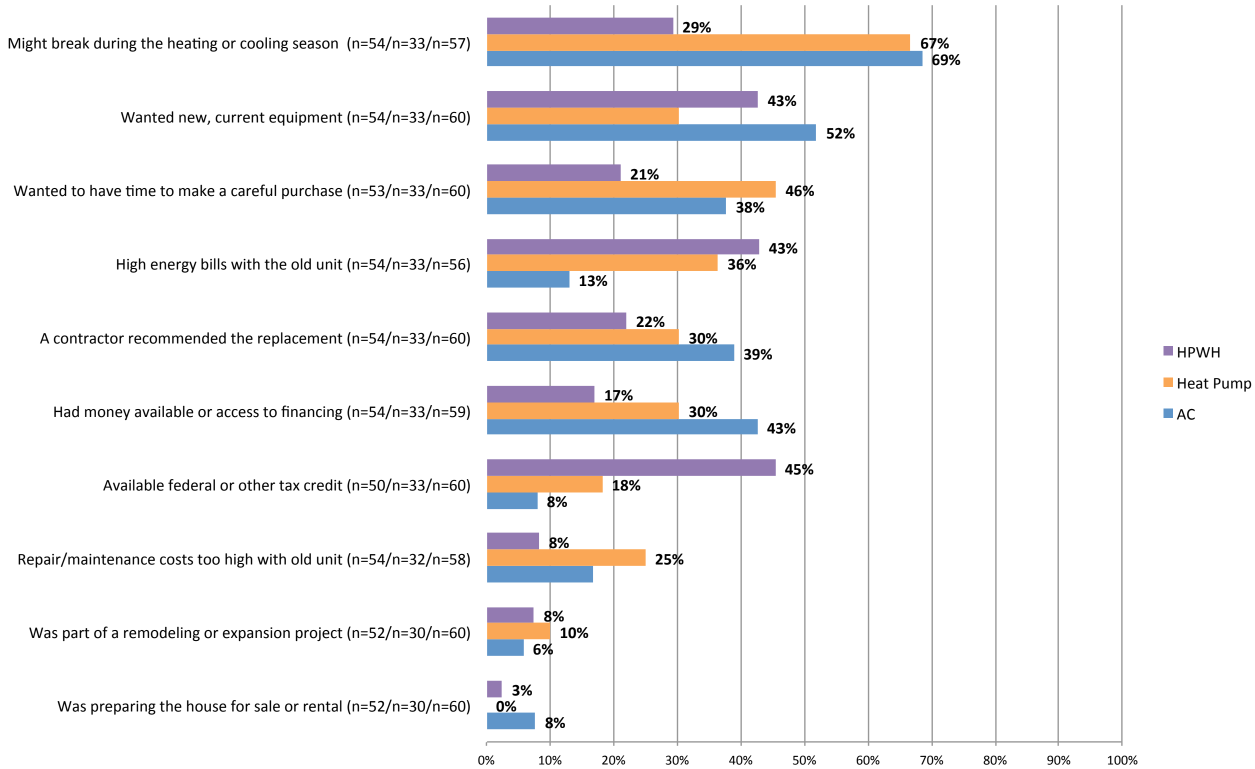


Figure 22 shows the degree to which these factors influenced NR customers' purchasing decisions. For AC and heat pump customers, the most influential factor was the concern that their existing equipment might break during the heating or cooling season (69% and 67%, respectively). For HPWHs, the most influential factors included wanting new or current equipment and high energy bills from the previous equipment (43%).

Figure 22: NR Customer Influences - Working Equipment



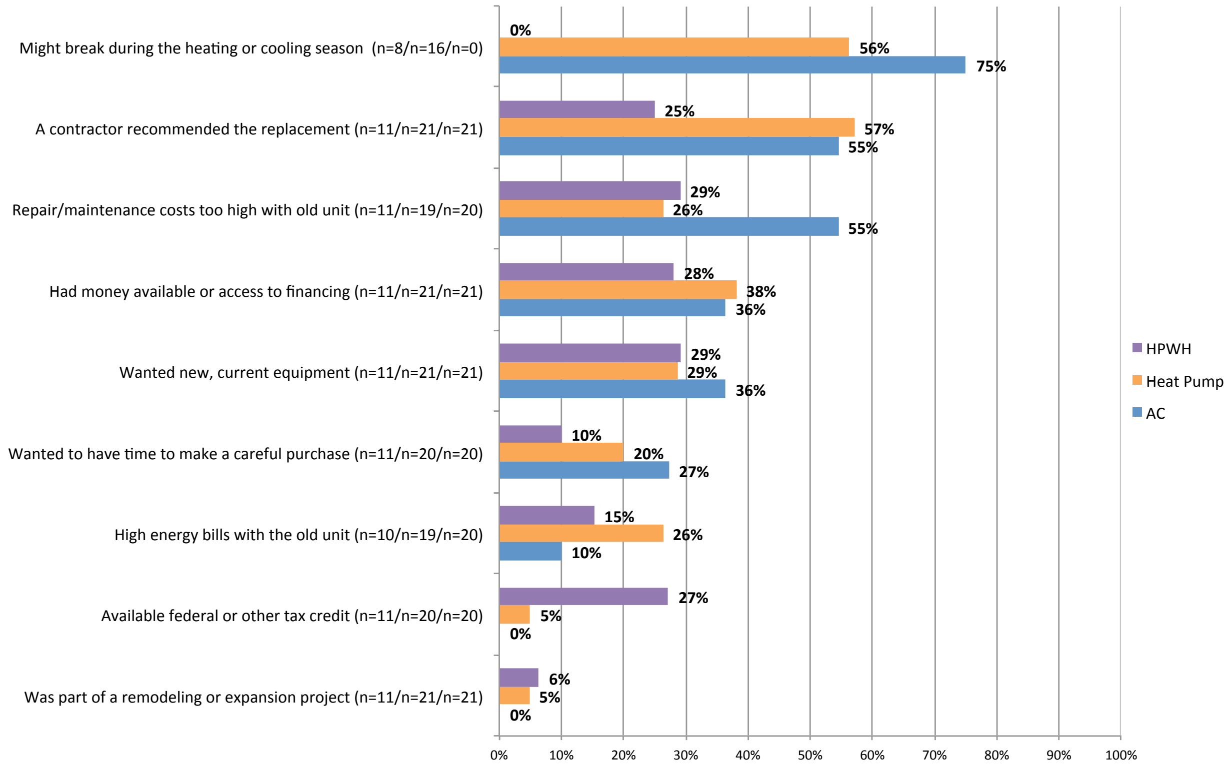
4.2.2 Non-Functioning Replaced Equipment

For NR customers with non-functioning AC or heat pumps, 55 percent said they received an estimate of how much it would cost to fix the old equipment before they decided to install a new unit, compared to only 17 percent of HPWH customers.[27]

As shown in Figure 23, NR AC and heat pump customers stated that concerns their equipment might break during the heating or cooling season and replacement recommendations from contractors were the two most influential factors in their decision to replace their existing equipment (rather than have it repaired). HPWH customers said that high repair costs for their existing unit (29%) and wanting new and current equipment (29%) were the most influential factors in their decision process.

[27] There were also 13 total early replacement customers that reported their replaced equipment was not functioning; however, because of the low sample sizes and the expectation that ER measures should theoretically be functioning, they were not included in the analysis.

Figure 23: NR Customer Influences - Non-working Equipment



4.3 Replaced Equipment Age and Efficiency

Both ER and NR customers estimated the age of their existing equipment at the time of the replacement. The age estimates were based on when the customer moved into their current house (if the house and equipment were new when they moved in), on when their current home was built (if the equipment was installed when the house was built under a previous owner), or on when they installed the equipment themselves. Table 24 shows the summary statistics on equipment age for each of the measures.

Table 24: Replaced Equipment Age (Years)

Summary Statistics	Early Replacement			Normal Replacement		
	AC (n=14)	Boiler (n=87)	Furnace (n=62)	AC (n=62)	Heat Pump (n=49)	HPWH (n=69)
Mean	22	40	29	18	20	15
Median	22	38	30	19	18	15
Min	3	12	7	3	5	1
Max	40	85	70	40	45	47
25th Percentile	13	30	22	13	14	10
75th Percentile	30	46	35	22	25	20

We asked participants to estimate the number of years they expected their new equipment to last (see Table 25). Central AC was the only equipment type available in both the ER and NR programs. ER participants estimated their AC would last longer than NR participants estimated theirs would last (median = 20 years versus median = 15 years).

Table 25: New Equipment Age Estimate (Years)

Summary Statistics	Early Replacement			Normal Replacement		
	AC (n=16)	Boiler (n=80)	Furnace (n=64)	AC (n=63)	Heat Pump (n=51)	HPWH (n=73)
Mean	18	24	21	16	15	13
Median	20	20	20	15	15	10
Min	10	10	10	5	10	2
Max	25	50	50	27	30	25
25th Percentile	15	20	20	15	10	10
75th Percentile	20	30	24	20	20	15

In comparing Table 24 and Table 25, on average, customers expect their new equipment to last fewer years than their replaced equipment lasted. For example, on average, boiler customers estimate their new equipment will last 24 years compared to the average age for replaced boilers of 40 years.

When asked how they arrived at the estimate of life expectancy of their new equipment, 32 percent of participants based it on their experience with similar units, 28 percent said it was just a guess, and 21 percent based the estimate on information from the manufacturer or contractor.

For those customers responsible for the installation decision of the old equipment, we asked if the replaced unit was standard or high efficiency. Table 26 shows the percentage of customers for each measure that previously installed high efficiency equipment versus normal efficiency equipment. For ER and NR AC customers and heat pump customers, most customers said they installed a high efficiency unit previously. Conversely, a majority of boiler, furnace, and HPWH customers installed a standard efficiency unit previously. Overall, a large percentage of participants either did not install the previous equipment or did not know the equipment efficiency.

Table 26: Efficiency of Replaced Equipment

Replaced Equipment Efficiency at Time of Initial Installation	Early Replacement			Normal Replacement		
	AC (n=5)	Boiler (n=7)	Furnace (n=14)	AC (n=12)	Heat Pump (n=9)	HPWH (n=25)
High efficiency	61.2%	4.9%	42.4%	58.3%	66.7%	28.0%
Standard efficiency	38.8%	95.1%	57.6%	41.7%	33.3%	72.0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

4.4 Complete System Replacements – Furnace and Central Air Conditioners

A majority of the participating PAs offered incentives for multiple early or normal replacement measures. Additionally, certain measures such as air conditioners and furnaces are commonly replaced together as part of a comprehensive HVAC system project. Thus, we asked air conditioner and furnace customers whether their equipment purchase was part of a larger, complete system replacement that included a new furnace and air conditioner.

Overall, 63 percent of ER air conditioner and furnace customers said they replaced both equipment types in a complete system upgrade. The vast majority (85 percent) of these customers said their replaced air conditioner and furnace were about the same age at the time of replacement;13 percent of customers said their air conditioner was newer than their furnace.

Key Finding:

Overall, 63 percent of ER air conditioner and furnace customers said they replaced both equipment types in a complete system upgrade. The vast majority (85%) of these customers said their replaced air conditioner and furnace were about the same age at the time of replacement.

As Table 27 shows, 31 percent of customers that replaced both a furnace and an air conditioner said both pieces of equipment were working normally at the time of replacement, while 17 percent said both pieces of equipment were working improperly and three percent said both pieces of equipment were broken. An additional 28 percent of complete system replacement customers indicated at least one measure was broken or not functioning at the time of replacement.

Table 27: Equipment Functionality At Time of Replacement - Furnace and AC (n=73)

	Air Conditioner		
Furnace	**It was working normally and keeping home at the desired temperature**	**It was working, but not keeping home at the desired temperature or required frequent service calls**	**It was broken or not functioning**
It was working normally and keeping home at the desired temperature	30.6%	9.1%	7.0%
It was working, but not keeping home at the desired temperature or required frequent service calls	12.2%	17.4%	9.6%
It was broken or not functioning	9.6%	1.9%	2.6%

4.5 Replacement Actions Without PA Programs

To better understand the impact of utility rebate programs in ER and NR purchases, we asked participants what their purchasing behavior would have been had a utility rebate program not been available. As shown in Table 28, the most common response among all customers was that they would have bought the same new high efficiency unit without the utility rebate program. With the exception of HPWH customers (31%), less than 15 percent of customers said they would have purchased a standard efficiency unit had the utility rebate not been available. For all ER measures, as well as NR HPWHs, between 20 and 30 percent of customers said they would have continued using their old unit, compared to less than 10 percent of NR ACs and heat pumps. Overall, less than 2 percent of customers across all measures said they would have repaired the old unit, done more research, or bought a smaller capacity high efficiency unit.

It is important to note that potential free ridership was not a focus of this study. The survey asked only one question about customers' likely actions and did not use any comprehensive free ridership question batteries that are often used in impact evaluations. Replacement timing was not considered at all.

Table 28: Self-Reported Action If No Utility Rebate Offered

Replacement Actions	Early Replacement			Normal Replacement		
	AC (n=17)	Boiler (n=87)	Furnace (n=63)	AC (n=65)	Heat Pump (n=55)	HPWH (n=81)
Continued using the old unit	22.9%	37.0%	25.0%	9.2%	5.5%	27.8%
Repaired the old unit[28]	0.0%	0.0%	0.0%	1.5%	0.0%	0.8%
Bought a standard efficiency unit	0.0%	13.9%	10.2%	13.8%	9.1%	30.9%
Bought the same high efficiency unit	77.1%	49.0%	64.8%	75.4%	83.6%	39.1%
Done more research	0.0%	0.0%	0.0%	0.0%	1.8%	1.3%
Bought smaller capacity high efficiency unit	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%

[28] Prompted only to customers that previously said their old equipment was broken or not functioning.

5 Findings – Installation Contractor Interviews

To improve our understanding of both early replacements (ERs) and normal replacements (NRs) and how partner contractors and their customers view these programs, we conducted interviews with eight contractors. The contractors were selected based on three primary factors: the number of projects they completed in 2014 with the PA in their area, the equipment types they most frequently replace, and availability for an interview.

We made every effort to conduct interviews with at least one contractor associated with each PA that provided us with contact information and to cover all of the primary study measures. If repeated attempts at scheduling an interview were unsuccessful, we moved to the next largest contractor company on the list provided by the PA.[29]

In total, we interviewed eight contractors representing seven PAs: Liberty NH, Eversource CT, Unitil (MA), Eversource NH, Cape Light Compact (MA), First Energy (MD), and National Grid (MA). We focused each interview on one specific measure type to simplify and shorten the process. Furnaces and air conditioners (ACs) accounted for two interviews each, while there were three boiler interviews and one heat pump water heater (HPWH) interview. Significant effort was made to schedule a second water heater interview, especially with a Maryland-based contractor, but no correspondence was returned.

The PAs in Massachusetts, Connecticut, and New Hampshire serve ER programs that are home audit-driven, where customers receive a home energy audit first and then are steered toward an HVAC contractor if their equipment is deemed in need of replacement. They may be presented with a report detailing potential energy savings from equipment replacement. This could have impacted the results of these interviews. The Connecticut furnace contractor interviewed works for a home audit company and does not perform the furnace installs themselves.

The Evergreen team conducted these interviews during June of 2015. The first interview was completed on June 1st and the last on June 24th. The summer months are a very busy time for HVAC contractors, due to AC repair and replacement projects, so as the weather warmed up, it became increasingly difficult to reach any of the contractor contacts. In all, 21 phone calls were made and three emails were sent. We received vendor contact information from eight PAs, and we were only unable to reach one PA's (United Illuminating Company) contractors.

Appendix B details the questions we reviewed with the installation contractors. The questions were reviewed and approved by NEEP's project management team, and covered customer decision-making, measure EULs and RULs, costs, repairs, and opinions about PA programs. Each interview took about 30 minutes to complete.

[29] Evergreen intended to complete more interviews; however, contractor information was not available for most of the Maryland PAs participating in the study.

Some respondents had trouble answering certain questions, so there were not eight complete responses to every question in the survey. For example, the question "Can you tell if existing equipment is being replaced before it has passed its useful life?" was hard for some contractors to address. We learned that some contractors do not have a ready definition for "useful life" and instead simply designate equipment as functioning or non-functioning. Similarly, the question "Besides operational status, do you consider anything else when distinguishing between early and normal replacement?" was difficult to answer. It seems that most contractors do not make this distinction and are not aware of the program repercussions of the two options, besides the fact that one gets a larger rebate. The next question, "How could early and normal replacement be better distinguished?" had similar problems. They do not seem to consider this often, so it was hard for them to answer.

Finally, contractors interpreted the following question differently: "What is the average frequency of major repairs on HVAC equipment?". Some respondents viewed the question as asking how many years typically exist between major repairs, while others viewed it as how many units out of, say, 100 need major repairs. Thus, there is some "noise" in the responses to this question.

5.1 Functionality, Age, Useful Life, and Repairs

Most of the respondents indicated that the majority of equipment (all measure types) is still functioning when replaced in the ER programs—seven out of eight responses were in the 80 to 100 percent range. The anticipated exception was the Maryland AC contractor, who said 30 to 40 percent of AC units in the program are functioning when replaced overall, with only 20 to 30 percent in summer and 40 percent in spring and fall. This is not surprising given that their program is not an ER program.

According to the contractors, the average age range for equipment failure is 15 to 30 years, with a mean of about 20 years. This general age range was consistent across equipment types, with boilers, AC, and furnaces all reporting ages in the same age range. One boiler contractor in Massachusetts reported a failure age of 10 to 60 years, which is consistent with project data that shows that older cast iron boilers can continue to function for over 50 years. The age of *functioning*, replaced equipment was cited as being about five years younger than failed equipment, on average. That range was approximately 10 to 25 years.

One Massachusetts boiler contractor reported a failure age of 25 to 30 years for functioning equipment and only 15 to 20 years for failed equipment. His reasoning was that newer boilers are not built as robustly as older models and simply do not last as long. Another Massachusetts boiler contractor listed 20 to 50 years for functioning equipment, far above the other responses. However, this same contractor reported 10 to 60 years for non-functioning equipment, which was internally consistent.

When asked about the percentage of replaced functioning equipment that falls within three age ranges—less than 10 years old, 11 to 20 years old, more than 20 years old—respondents generally supported their previous age assertions. The most common response among the contractors was the 11 to 20 year range.

As noted earlier, the question asking if the replaced equipment was past its "useful life" was challenging for some respondents. Four of the respondents did cite specific traits to look for to indicate equipment has passed its useful life. For instance, contractors can perform an efficiency test on a furnace burner after a cleaning to see if the cleaning was enough to improve the efficiency. If not, the furnace is beyond its useful life. Leaks and burning marks on the front of boilers are also indicators of the end of useful life. For AC units, corrosion on the outdoor unit (fan blades, motor, coil) can be used. Finally, one contractor noted that most of their AC replacements occur after a service call, so the contractor is already familiar with the condition of the unit before replacement.

Most of the contractors estimated the remaining useful life (RUL) of replaced equipment to be in the 2 to 5 year range. One contractor used 5 to 10 years for furnaces and another used 15 to 20 years for boilers, but they were the exceptions. This indicates that most of the respondents believe the RUL should be 5 years or less for most equipment.

Most respondents said that the RUL for non-program ERs is the same. The two AC contractors indicated that ERs that are not high-efficiency and do not qualify for a program rebate have remaining lives of 0 to 1 year because they are usually already non-functioning or "in bad shape" and the customer cannot wait for a rebate, so they request the fastest option, which is installing a code-compliant unit. One contractor indicated this occurs in 25 to 30 percent of installations. We note here that non-functioning units would typically be classified as NRs, further highlighting the difficulties contractors have in distinguishing ER and NR projects.

When asked about the average useful life (i.e., EUL) of equipment when operated normally, the contractors gave answers that were in general agreement with published sources for their assigned measure. Boilers and furnaces were reported to have an average useful life of around 20 years, air conditioners around 18 years, and the water heater contractor assumed 11 years. While the furnace and boiler responses were very consistent from contractor to contractor, the two AC contractors produced very different values, with one at 18 to 25 years and the other at 12 to 15 years.

Respondents indicated that major repairs start to occur in the range of 10 to 15 years for all of the equipment types. Many provided qualifiers because this time period depends on how well maintained and installed the equipment is. Poor installations and neglected maintenance lead to shorter times before repairs are needed. The general consensus was that 15 to 20 years was a good range for properly maintained equipment. The water heater contractor and, surprisingly, one boiler contractor only listed 10 years, with no maintenance qualifiers.

Responses to a question about the most common repairs needed yielded expectedly technology-specific answers. For the most part, however, each contractor provided a completely unique set of common repairs/failures. The three boiler contractors mentioned some similar components failing like gas valves and chambers, but that was the extent of their agreement.

We asked the contractors two questions about customer decision-making regarding major repairs on equipment. The first question focused on defining the proportion of customers that choose to repair non-functioning equipment rather than replace it. The furnace and AC contractors indicated that about 20 percent of customers choose to make repairs. Two of the three boiler contractors said that a high percentage will repair instead of replace their boiler. However, one of these contractors clarified that the majority of repairs are for boilers under 10 years old. The other boiler contractor said that only 5 percent opt for repairs. The water heater contractor said that very few choose repairs.

The second question asked if there is a cost threshold that determines whether a customer will choose to repair. Answers ranged from “half of replacement cost” and “a couple thousand,” and the most common answer was $1,000. Four contractors used that latter value as a decision threshold. The water heater contractor said that “half of replacement cost” is a rule of thumb he uses for these decisions.

None of the contractors reported that customers are replacing equipment with larger equipment. Three contractors stated that customers typically install a unit of the same size, and four stated that customers typically install smaller units. One respondent noted that they do a heat loss calculation to re-size the furnace. It is likely that this calculation results in a reduction in equipment size. Only two of the contractors mentioned performing sizing/loading calculations. One boiler contractor said he reduces the size by 40 percent for new units.

The respondents were also asked to provide the standard efficiency option that they sell along with the average efficiency of equipment that they replace. The standard efficiency options they offer were all above code baselines, despite the question including the words “code-compliant.” Minimum efficiencies for boilers and furnaces ranged from 80 to 94 percent, with two citing 80 percent, two citing 84 percent, and the other using 87 percent for oil boilers and 94 percent for gas boilers. AC minimum efficiencies ranged from 14 to 15 SEER.

As for the replaced equipment efficiencies, the boilers and furnaces ranged from 60 to 84 percent with most falling in the 70 to 80 percent range, while the AC units were in the range of 8 to 12 SEER, with 10 SEER being the most common. One AC contractor mentioned that as 1990s-era units become the most replaced units, the replaced efficiency has moved up to 12 or 13 SEER in recent years for many installs.

5.2 Costs and Financial Factors

Although costs can vary by region and equipment type, we asked respondents a number of questions about costs to get a better idea of how costs influence decision making. As expected, boilers had the highest baseline and high-efficiency costs and the highest incremental cost. The incremental costs for high-efficiency condensing boilers ranged from $3,000 to $5,000. On the opposite end of the spectrum, water heaters were the cheapest, but had the same incremental costs as the furnaces, $1,000 to $1,500. AC incremental costs ranged from $1,500 to $2,000.

Repair costs varied significantly from contractor to contractor. They ranged from $200 for a water heater to $3,000 for an AC unit or furnace burner. The most common repair cost was about $1,000 to $2,000 for boilers, AC units, and furnaces. One contractor commented that most customers with non-functioning water heaters just replace them instead of repair them. Similarly, two other contractors (one for furnaces, one for boilers) noted that repairs are often not possible due to a lack of available parts or the fact that boiler leaks cannot be safely repaired.

5.3 Impacts of PA Early Replacement Programs

When asked about how utility ER programs affect customer decision-making, all of the contractors indicated that the programs are effective in motivating customers to replace equipment early. Two Massachusetts contractors also noted that equipment financing assistance was especially helpful to customers.

Two of the boiler contractors from Massachusetts voiced concerns about condensing boilers. Condensing boilers, they contend, require special venting and can be difficult to install in older homes. According to the contractors, many customers purchase a condensing boiler to get the incentive but cannot fully utilize it since their home radiators require a 180°F water temperature, so the customer would achieve the same efficiency with a non-condensing boiler. Condensing boilers apparently also require more maintenance, and without the efficiency gain “do not make sense” to promote.

Respondents were asked if ER and NR projects could be better distinguished in the field. As mentioned earlier, this question was interpreted in a number of ways, and the responses covered a wide range. Some said they could not think of a better way, a few others mentioned equipment age or serial number, and the remaining two were technology-specific. One of these mentioned using refrigerant type and variable speed control of the fan or compressor for AC units. The other suggested that a furnace that is not producing sufficient heat and needs a new heat exchanger would be a normal replacement.

When asked how contractors can distinguish between NRs and ERs, besides functional status, the contractors gave a variety of replies, including equipment age, efficiency/operating cost, visible (boiler) failure points, and cracking boiler tanks. Other contractors, however, replied with “(there is) no other method” and “all our projects are early replacement.” All of this seems to indicate that the contractors do not often make the determination between project types and appear to consider most of their projects “early replacement.”

Key Finding:

Early replacement program installation contractors in our survey indicated that they consider most of their projects to be "early replacement." They also said they do not often make a determination between early and normal replacements.

To get customers to replace equipment early, the contractors discuss a range of topics. Many cited energy cost savings calculations, simple payback, financing options, bundling other equipment or services such as air sealing and insulation with a furnace replacement or AC replacement with a furnace replacement, and rebates. One contractor mentions the risk of heat exchanger failure "sooting" the entire house. Another asks customers how long they plan to live in their home and bundles home automation and smart home products with AC replacements. That same contractor goes to every customer and develops a replacement plan. About one-third of the time, the customer decides to replace the equipment early when presented with a customized plan.

The contractors were all asked what they like about their PA's ER programs and what could be improved. All but one of the contractors provided very positive reviews of their programs, noting that the incentives and financing options were popular. One even specifically cited increased sales for their company from the program. Regarding recommended improvements, a common one was to improve program consistency and continuity. Several mentioned programs "coming and going suddenly," changing rebate amounts, and poor communication from utilities to contractors about program changes.

Two Massachusetts boiler contractors said incentivizing non-condensing boilers would be an improvement, and not giving incentives to condensing boiler installations that could not operate in the condensing range (below 140°F). A New Hampshire boiler contractor appreciated the fast response on rebates (one week turnaround instead of six to eight weeks for other utilities). A furnace contractor in Massachusetts had the opposite opinion, saying the process (three to four weeks) took too long and that there was too much post-project follow-up and qualification debating after project completion.

Finally, the Maryland AC contractor described issues involving program drop dead dates and honesty. He said that companies are incentivized to lie on applications about installation dates so that they can back date the projects to before the drop dead date for the program. He said his company does not lie about dates and can lose work to contractors that are willing to do so. His company has a three to four week lead time for work and so drop dead dates leave them with a month's worth of customers that are ineligible for incentives. They would prefer a longer install period after the time of sale (three to four weeks) to allow them time to complete the installations before the drop dead date. Also, they would like more advanced notice of the next year's incentive amounts because they do not know in December what the new January rates will be.

Customers' most common reasons for replacing their equipment, according to the contractors, revolve mainly around two issues: fear of the equipment failing (and being without heat or cooling) and the cost of operation. Appearance, size, avoided repair cost, taking care of it now instead of later, no longer having to use their boiler for hot water, and wi-fi connectivity were less common reasons cited for replacement.

When asked to estimate the percentage of high-efficiency ERs that do not receive utility incentives, respondents perceived that very few projects (about 5%) probably fall into this category. Cities with municipal utilities are the largest exception to this trend, since municipal utilities may not participate in statewide programs. That said, the contractors surveyed for this project are inherently a biased sample, since they participated in ER programs more than any other contractors in their areas. Thus, it is not a surprise that they utilize programs so heavily.

Finally, the contractors were asked to estimate the percentage of furnace or AC installations where both were replaced at the same time, even if only one required repair. This yielded a range of responses including 20 percent, 50 to 60 percent, 60 percent, 97 percent, 8 to 10 percent, 10 percent, and 0 percent. It is not clear why there is such a large range of answers. One respondent clarified his answer of 50 to 60 percent, noting that the old central AC unit is often not compatible with their new air handler, especially when they are the same age, forcing both to be replaced simultaneously. Overall, it appears that a significant number of ER projects are done because other equipment needs to be replaced and customers decide to do both at the same time.

6 Findings – Future Efficiency Standards

To determine how changes to federal, state, and local energy codes will impact baseline equipment efficiencies for furnaces, boilers, central AC units, and air-source heat pumps, the Evergreen team interviewed Darren Port and David Lis from the NEEP Buildings and Market Strategies Initiatives. Mr. Lis monitors and tracks federal rulings on equipment efficiencies and uses a spreadsheet to record the current standards, unpublished finalized standards, future standard revision finalization dates, and future standard revision effective dates.

The next tables show the current state of NEEP's tracking information for the measures relevant to this study. Key findings include:

- Gas furnace baseline efficiencies will increase from 78 percent to 80 percent in 2015;
- Central AC units and heat pumps' latest changes took effect in January 2015; and
- The effective dates for future changes for all these measures are in 2021 and 2022. Thus, for that six or seven-year window between now and then, there will be no changes to the federal baselines.

All federal energy codes use a six-year review cycle implemented by the U.S. Department of Energy. Mr. Lis also directed us to the Appliance Standards Awareness Project website,[30] which tracks all of the Department of Energy's standards and changes.

Key Finding:

Federal efficiency standards for air conditioners, furnaces, and boilers will not change between 2016 and 2021. Changes occurring in 2015 for furnaces, air condtioners, and heat pumps will need to be accounted for, however.

[30] http://www.appliance-standards.org/

Table 29: Space Heating - Current and Future Efficiency Standards

	Current Standards		On Deck	Standards Revision Process		
Equipment Type	Efficiency Metric	Current Federal Standard (Effective Date)	Finalized Revisions not yet Effective (Effective Date)	Status of Ongoing Standard Revision Process	Final Rule Due Date for Next Revision	Effect. Date of Next Standard Revision
Gas Furnaces (non-weatherized)	AFUE	78% AFUE (1992)	80% (Month TBD, 2015)	"Rulemaking data" published in September, 2014. NOPR expected in February, 2015. 92% AFUE proposed.	2016	2021
Gas Boilers (Hot Water)	AFUE	82% AFUE/No constant burning pilot- set by EISA 2007, codified in 2008 Tech Amend (September, 2012) Some NE states adopted 84% standards, not implemented		NODA in February, 2014, NOPR expected in early 2015. 85% AFUE proposed.	2016	2021
Gas Boilers (Steam)	AFUE	80% AFUE/No constant burning pilot- Set by EISA 2007, codified in 2008 Tech Amend (September, 2012)		NODA in February, 2014, NOPR expected in early 2016. 85% AFUE proposed.	2016	2021

Table 30: Space Cooling - Current and Future Efficiency Standards

	Current Standards		On Deck	Standards Revision Process		
Equipment Type	Efficiency Metric	Current Federal Standard (Effective Date)	Finalized Revisions not yet Effective (Effective Date)	Status of Ongoing Standard Revision Process	Final Rule Due Date for Next Revision	Effect. Date of Next Standard Revision
Central Air Conditioners (Split and Packaged)	SEER	North Region- split systems-remains @ 13 SEER, packaged 14 SEER South Region split- SEER 14 SW Region split- SEER 14, EER 12.2 (Jan, 2015)		RFI (Nov , 2014)	2017	2022
Heat Pumps (Split and Packaged)	SEER, HSPF	All Regions- Split systems- 14 SEER, 8.2 HSPF Packaged systems- 14 SEER, HSPF 8.0 (Jan, 2015)		RFI (Nov , 2014)	2017	2022

The interview also covered changes to local, state, and/or regional codes that might supersede federal baselines. Mr. Port assured us that no states in NEEP Forum territory have codes that are above the federal baseline for HVAC equipment and in fact, local and state codes often lag behind federal guidelines.

It is apparent that the federal standards set the baselines for these HVAC equipment types and should be used in early and normal replacement energy savings calculations. These calculations should therefore be adjusted periodically to account for the planned changes to the federal code prior to their effective dates.

7 Key Findings and Recommendations for Program Administrators

In this section, we present some of the key findings from the research, followed by recommendations that the PAs can consider for program updates or future programs.

7.1 Key Findings

7.1.1 Program Design and Impacts

1. All of the early replacement (ER) measures in the Connecticut, Massachusetts, and New Hampshire programs use the dual baseline method to calculate energy savings.

2. Some PAs try to collect site-specific equipment age information for their ER programs, although none utilize this information to calculate site-specific remaining useful life (RUL). PAs typically use a default value for RUL (e.g., 5 years) or use the simple equation, RUL = EUL – AGE, where effective useful life (EUL) is for all originally installed equipment, currently surviving or not.

3. The site-specific RULs calculated by the Evergeen team, using survival curve analysis, are generally higher than the values used by the PAs.

4. PA programs typically use default efficiency values for the replaced equipment, or deemed savings values during the RUL, although some PAs attempt to collect site-specific efficiency information.

5. The PAs typically use incremental cost calculation methods for ER projects that do not accurately reflect how the pattern of future normal replacements (NRs) has shifted into perpetuity. The appropriate method, typically referred to as the Deferred Replacement Credit method, is only used for ER measures by the Massachusetts PAs.[31] Regarding the other methods used by PAs:

    a. Incremental cost is overstated when set to equal the full installed cost of new equipment, with no adjustements.
    b. Incremental cost is understated when set to equal the full installed cost of new equipment, less the discounted costs of the next normal replacement.[32]

6. When the ER Cost Factor method (presented in Section 3, analogous to the Deferred Replacement Credit) is utilized, the incremental cost of ER projects increases as the RUL increases.

[31] However, the Massachusetts calculation appears to incorporate the assumption that RUL=EUL-Age.
[32] For example, the ER Cost Factors in Table 12, Row J would be understated by approximately 50 percent.

7. Older projects with lower RUL may improve cost effectiveness in multiple ways:

    a. Lower RUL is correlated with lower efficiency for the replaced equipment.
    b. Projects with a lower RUL are likely to utilize a lower, current standard efficiency as the baseline after the RUL (i.e., the window for code increases is smaller).
    c. Factors a and b above both increase annual energy savings.
    d. Lower RUL is correlated with lower incremental costs when the ER Cost Factor is used.

7.1.2 Participant Customers

1. Overall, the ER programs are serving households eligible to participate. Fifty-six percent of ER customers said their existing equipment was functioning normally and keeping their home at the desired temperature at the time of their equipment replacement, while an additional 42 percent said their equipment was working improperly or required frequent maintenance calls.

2. Despite having no additional incentive to replace their equipment early, a large majority (73%) of NR customers said their existing equipment was working in some capacity at the time of their replacement. Furthermore, 40 percent of those customers said their equipment was not only working, but working properly and keeping their home at the desired temperature.

3. For ER measures, the most influential factors in customers' decisions to replace their existing equipment included wanting new or current equipment, concern that their equipment might break during heating or cooling seasons, and ER incentives offered by PAs.

4. For NR measures, replacement influences varied between customers with functioning existing equipment and non-functioning existing equipment. For functioning equipment customers, the most influential factors included concern that their equipment might break during heating or cooling seasons and wanting new or current equipment. For customers with non-functioning equipment, the most influential factors leading them to replace and not repair the equipment were concerns that their equipment might break (again) during the heating or cooling season and a contractor recommendation for the replacement.

5. Seventy-six percent of all customers believe their new equipment will last for fewer years than their existing equipment lasted prior to their replacement.

6. A majority of ER AC (77%) and furnace (65%) customers along with NR AC (75%) and heat pump (84%) customers said they would have bought the same high efficiency equipment had the PA rebate not been available at the time of their purchase. Additionally, 49 percent of ER boiler customers and 39 percent of NR HPWH customers

said they would have purchased the same high efficiency unit without an available utility rebate.

7.1.3 Installation Contractor Interviews

1. HVAC contractors have difficulty defining equipment "useful life" beyond functionality. For the most part, projects in ER programs involve equipment that is still functioning at some level (per program requirements).

2. Major repairs start at around 10 to 15 years into the life of the equipment, before the EUL for most HVAC equipment, which may represent an opportunity to encourage ER instead of repair.

3. Customers rarely choose to repair non-functioning equipment, with $1,000 given as a common threshold to determine whether to repair or replace equipment.

4. Standard efficiency units sold by the interviewed contractors are well above code efficiencies, which may have implications for the efficiency baselines used by PAs.

5. Existing unit efficiencies are roughly 70 percent to 80 percent for furnaces and boilers, and 10 SEER for AC units, but that is rapidly moving toward 12 or 13 SEER.

6. ER programs are effective at getting customers to replace functioning equipment, and customers often utilize financing and loans to participate.

7. There are concerns about condensing boiler programs stemming from houses that cannot operate below 140°F water temperature, higher maintenance costs associated with condensing boilers, venting requirements in older homes, and customers gaming the system by buying a condensing boiler when they cannot fully utilize one just to get a rebate. Some contractors would like to see non-condensing boilers included.

8. Customers are most motivated by energy cost savings, financing and rebates, and by a significant fear of their existing equipment failing.

9. Contractors said the best ways to get customers to replace equipment early are to develop energy cost savings analyses and bundle other services (e.g., air sealing, insulation, smart home features) with rebates and financing options.

10. Among the contractors surveyed, there is little evidence of ER projects being done outside of the PA programs.

11. Furnaces and AC units are often replaced simultaneously and programs should be aware of this.

7.1.4 Future Efficiency Standards

1. No states in NEEP Forum territory have codes that are above the federal baseline for residential HVAC equipment.

2. Federal efficiency standards for AC units, furnaces, and boilers will not change between 2016 and 2021.

7.2 Recommendations for Program Administrators

Based upon the research findings, the Evergreen team offers the following recommendations for PAs currently offering or considering ER programs. Notably, the program design and evaluation recommendations are not prioritized and should be considered collectively, since they affect multiple interrelated elements of program cost effectiveness.

7.2.1 Program Design and Evaluation

1. PAs should collect and utilize site-specific equipment ages for their ER savings and cost calculations to the extent possible. The best time to collect site-specific equipment data is during program implementation before equipment has been removed. This practice also allows for accelerated, real-time program evaluation, which is a current goal for many PAs. In Appendix C, we have listed some resources that PAs can utilize to research the ages of HVAC equipment using manufacturer, model, and serial number information.

2. PAs should utilize the survival curve method to estimate site-specific equipment RULs. Importantly, this method reflects the fact that the probability that equipment will reach a given age increases with current age. TRMs developed by NEEP should also recommend this method.

3. PAs should calculate energy savings based on site-specific RULs (using the survival method) and equipment efficiencies. In Appendix D, we have included guidance on how the PAs can adjust or "degrade" the original installed equipment efficiencies to reflect equipment wear and tear over time. In addition, ENERGY STAR has developed tools to estimate efficiency levels for some equipment (furnaces) based on home vintage.

4. The next energy code changes for residential HVAC equipment will occur in 2021 and 2022. PAs utilizing dual baselines should integrate the new efficiency baselines for ER projects with longer RULs.

5. Incremental cost calculations for ER projects should utilize the ER Cost Factor method presented in Section 3 of this report, to accurately reflect that the entire cycle of future NRs has been shifted and to be consistent with RUL and EUL assumptions for energy savings. TRMs developed by NEEP should also recommend this method.

6. "Maximum estimated repair cost" (e.g., $1,000 for HVAC) may be a reasonable criteria for ER program eligibility, since customers are unlikely to incur high repair costs, essentially making their equipment "inoperable."

7. "Maximum replaced efficiency" is also recommended for ER program eligibility to improve energy savings and cost-effectiveness.

8. Equipment age is not a basis to conclusively discriminate between ER and NR projects. In particular, PAs should not implement maximum equipment age requirements—older units are likely to be the most cost-effective to replace.

9. Incremental cost, calculated using the ER Cost Factor, can be used to benchmark ER incentives.

10. Besides equipment age and efficiency, the PAs may want to collect other data during installations that may be useful in program evaluation, but which are difficult to obtain at a later date:

    - Functional status of replaced unit
    - Estimated repair costs
    - Other factors influencing the decision to replace

7.2.2 Future Research

1. PAs should conduct pilot studies to collect complete site-specific age, efficiency, savings, cost, incentive, and customer survey data for a large sample of ER participants at the time of implementation. Analysis of the pilot projects, using the methods we recommend in this study, would give PAs a more accurate picture of the cost-effectiveness of current and potential new programs.

2. PAs should conduct similar pilot studies of NR program participants.

3. PAs should study other measures to see if new or revised ER programs would be cost-effective (e.g., residential appliances, commercial/industrial HVAC, motors, air compressors). These are likely to be measures where federal or state standards have increased relatively rapidly (along with market adoption), and there is high savings potential from removing old inefficient units.

Appendix A: PA Customer Phone Survey Instrument

GENERAL INTRODUCTION

Hi. May I please speak to [RESPONDENT]? This is <INTERVIEWER NAME> calling on behalf of [UTILITY] and Northeast Energy Efficiency Partnerships. This is not a sales call. I'm calling because our records show that you recently installed a new [NEW EQUIPMENT TYPE] and I'd like to do a follow-up survey. In return for your participation we'll send you a $15 gift card for Amazon, Starbucks, Petco or Home Depot.

Are you the best person to talk to about equipment replacement decisions and energy use at your home?

1. Yes (CONTINUE)
2. No (ASK:) Who would be the best person to talk to about the new [NEW EQUIPMENT TYPE] and energy use at your house? (REPEAT INTRO WHEN CORRECT PERSON COMES ON LINE; ARRANGE CALL BACK IF NECESSARY & PUT NAME IN CAPS IN NOTES AREA)

NEEP and its utility members would like to better understand how households like yours think about and make equipment replacement decisions. Your input is very important to help NEEP and [UTILITY] manage energy use and improve its energy programs and rebates.

IF NEEDED: We are collecting data for a study on the new equipment you installed and the equipment it replaced. All your responses will be treated as confidential, and will only be reported as part of combined results.

CONFIRM PARTICIPATION AND ESTIMATE NEW EQUIPMENT LIFE

A1. We understand that you installed a [NEW EQUIPMENT TYPE] in [INSTALLMONTH – if not blank/INSTALLYEAR] and received an incentive from [UTILITY]. Is this correct?
   1. Yes (SKIP TO A3)
   2. No, information is wrong – Thank and Terminate

INTERVIEWER – Some respondents may say that got the incentive from another utility where UTILITY = "Eversource". That is OK, since Eversource recently acquired some utilities.

INTERVIEWER – If they say they also installed something else at the same time, say "That's OK, for this call we'll focus on the NEW EQUIPMENT TYPE you installed."

A2. NOT USED

A3. Was your [NEW EQUIPMENT TYPE] installation for a newly constructed home?

1. Yes (THANK & TERMINATE)
2. No

We are collecting data for a study on the new equipment that households install and the equipment it replaced. All your responses will be treated as confidential, and will only be reported as part of combined results.

To begin, I'd like to ask you about the new [NEW EQUIPMENT TYPE] that you installed in [INSTALLMONTH – if not blank/INSTALLYEAR].

A4. First, about how many years do you expect the new [NEW EQUIPMENT TYPE] to last?

____enter number of years

99. Dk (SKIP TO A6/7/8/11 AS APPROPRIATE)

A5. Which of the following would you say is your MAIN basis for estimating that life expectancy for the new equipment? Was it:

1. Manufacturer or contractor information
2. Your own experience with similar units
3. Others' experience with similar units
4. The warranty length
5. Just a guess
6. Something else (specify)__________________________________

(NOW GO TO A6/7/8/11 AS APPROPRIATE)

OLD EQUIPMENT CONDITION AND REPLACEMENT DECISION

A6. (IF NEW EQUIPMENT TYPE = CENTRAL AIR CONDITIONER:) What equipment did your new [NEW EQUIPMENT TYPE] replace? Was the old equipment a…? (READ CHOICES)

1. Central A/C
2. Room A/C
3. Something else (specify)
4. Had no previous A/C (THANK AND TERMINATE)

A7. (IF NEW EQUIPMENT TYPE = HEAT PUMP:) What equipment did your new [NEW EQUIPMENT TYPE] replace? Was the old equipment a… (READ CHOIES)

1. Heat Pump
2. Electric furnace only – with no Central Air
3. Electric furnace plus Central Air

4. Baseboard electric heat plus Central Air
5. Gas furnace plus Central Air
6. Heating oil furnace plus Central Air
7. Gas boiler plus Central Air
8. Heating oil boiler plus Central Air
9. Something else (SPECIFY)_______________________________________

A8. (IF NEW EQUIPMENT TYPE = FURNACE or BOILER) What equipment did your new [NEW EQUIPMENT TYPE] replace? Was the old equipment a… (READ CHOICES)

1. Gas furnace
2. Gas boiler
3. Heating oil furnace
4. Heating oil boiler
5. Heat pump
6. Baseboard electric heat
7. Electric furnace
8. Other (specify)________________________

A9.(IF NEW EQUIPMENT TYPE = FURNACE or BOILER:) Just to confirm, the fuel source for your new [NEW EQUIPMENT TYPE] is natural gas, correct?

1. Yes (SKIP TO A11)
2. No

A10. What is the fuel source for your new unit? ______

A11. (IF NEW EQUIPMENT TYPE = HEAT PUMP WATER HEATER:) What equipment did your new [NEW EQUIPMENT TYPE] replace? Was it a… (READ CHOICES)

1. Conventional tank electric water heater
2. Conventional tank gas water heater
3. Instantaneous or tankless electric water heater
4. Instantaneous or tankless gas water heater
5. Other (SPECIFY) ____

A12. ALL: And what about the size or capacity of the old unit compared to the new unit? Would you say. . . (READ CHOICES)

1. The new equipment is about the same size or capacity as the old unit
2. The new equipment is larger or higher capacity than the old unit
3. The new equipment is smaller or lower capacity than the old unit
9. (DON'T KNOW)

A13. Now I'd like you to think about the old equipment that you replaced. Which of the following statements best describes the condition of the old equipment at the time it was replaced? (READ CHOICES; ONE ANSWER ONLY)

1. It was working normally and keeping your [If NEW EQUIPMENT TYPE = HEAT PUMP WATER HEATER – “water”, ELSE “home”] at the desired temperature - (SKIP TO A15)
2. It was working, but not keeping your [If NEW EQUIPMENT TYPE = HEAT PUMP WATER HEATER – “water”, ELSE “home”] at the desired temperature (SKIP TOA15)
3. It was working, but required frequent service calls (ASK A14)
4. It was broken or not functioning (GO TO A18)
5. Other (specify)____

A14. About how many times did you have to repair the old system in the year prior to replacement?

Number of times:___________

IF WORKING (A13 = 1-3)

A15. How much longer do you think that your old equipment would have operated if it hadn't been replaced? Would you say: (READ CHOICES)

1. Less than a year
2. 1 -2 years
3. 3 – 4 years
4. 5 – 10 years
5. More than 10 years

A16. I'm going to list a number of factors that might have influenced your decision to replace the old equipment when you did rather than wait until it broke down. For each factor, please tell me if it was not at all influential, somewhat influential, or very influential. (READ - ROTATE ITEMS)

1. Concerned that it might break unexpectedly (if NEW MEASURE TYPE = BOILER, FURNACE, CENTRAL AIR CONDITIONER, HEAT PUMP ADD:) during the heating or cooling season.
2. Energy bills were too high with the old unit
3. Wanted to switch fuel sources
4. Repair and maintenance costs were too high with the old unit
5. Wanted to have time to make a careful purchase
6. Had money available or access to financing at that time
7. A contractor recommended the replacement
8. Was part of a remodeling or expansion project
9. Was preparing the house for sale or rental
10. (If PROGRAM TYPE = ER:) [UTILITY] offered an incentive to replace the old unit early
11. Available federal or other tax credit
12. Wanted new, current equipment

13. Other (specify)____

(IF TIE FOR HIGHEST RATING:)

A17. Between these, which would you say was MOST influential in your decision? (*PROGRAMMER SHOW ITEMS IN HIGHEST CATEGORY*) (READ CHOICES)

Item________________________

[NOW SKIP TO OLD EQUIPMENT AGE AND EFFICIENCY SECTION (A25)]

IF NOT FUNCTIONING (A13 = 4)

A18. Did you get an estimate of how much it would cost to fix the old equipment before you decided to install a new unit instead?

1. Yes (CONTINUE)
2. No (SKIP TO A23)

A19. IF YES: About how much would it have cost to have the unit repaired?

$____(ENTER AMOUNT)

99. DK (GO TO A20 OR A21 AS APPROPRIATE)

A20. (IF DK AND NEW EQUIPMENT TYPE = FURNACE/BOILER/CENTRAL AIR CONDITIONER/HEAT PUMP) Would it have been:

1. $1,000 - $2,000
2. 2,000 - $3,000
3. More than $3,000
9. DK

A21. (IF DK AND NEW EQUIPMENT TYPE = HEAT PUMP WATER HEATER) Would it have been:

1. $100 - $200
2. $200- $300
3. More than $300
9. DK

A22. If you had had the unit repaired, how much longer do you think that equipment would have operated? Do you think it would have been… (READ CHOICES?)

1. Less than a year

2. 1 -2 years
3. 3 – 4 years
4. 5 – 10 years
5. More than 10 years
9. DK

A23. I'm going to list a number of factors that might have influenced your decision to replace the old equipment rather than have it repaired. For each one, please tell me if it was not at all influential, somewhat influential, or very influential? Some of them may not apply to your situation and, if so, you can just tell me that. (READ AND ROTATE ITEMS)

1. Concerned that it might break unexpectedly after the repair (if NEW MEASURE TYPE = BOILER, FURNACE CENTRAL AIR CONDITIONER, HEAT PUMP – during the heating or cooling season).
2. Energy bills were too high with the old unit
3. Wanted to switch fuel sources
4. Repair and maintenance costs were too high with the old unit
5. Wanted time to make a careful purchase
6. Had money available or access to financing at that time
7. A contractor recommended the replacement
8. Was part of a remodeling or expansion project
9. Was preparing the house for sale or rental
10. If PROGRAM TYPE = ER: [UTILITY] offered an incentive to replace the old unit early
11. Available federal or other tax credit
12. Wanted new, current equipment
13. Other (specify)____

(IF TIE FOR HIGHEST RATING, ASK:)

A24. Between these, which would you say was MOST influential in your decision? (*PROGRAMMER: SHOW ITEMS IN HIGHEST CATEGORY)* (READ CHOICES)

Item #________

OLD EQUIPMENT AGE AND EFFICIENCY

ALL:

A25. About how many years have lived in your house?

______ years

A.26. Thinking about the old equipment you replaced, which of the following best describes when and how it was originally installed. (READ CHOICES)

1. You bought the house new and the unit was original equipment when you bought it.
2. It was original equipment in a newly constructed home when the previous owner bought it.
3. It was there when you bought the house from a previous owner (SKIP TO A29)
4. You or your family installed the old unit (SKIP TO A33)
5. Other (specify)

A27. (IF A26 = 1 OR 2.) About what year was your home built?

Enter year _____ (SKIP TO B1)

99. DK (ASK A28)

A28. Would you estimate that your house was built:

1. Before 1990
2. 1990-2000
3. 2001-2005
4. After 2005
9. DK

(NOW SKIP TO B1)

A29. (IF A26=3:) Do you know the approximate age of the equipment that was replaced?

1. Yes (CONTINUE)
2. No (SKIP TO A32)

A30. How old was it?

enter age in years _____

A31. How were you able to determine the age of the old equipment? (DO NOT READ)

1. Documentation included with the unit
2. Contractor knew or estimated it
3. Age of units was included in description of home when we bought it
4. Previous owner told us
5. Other (specify) ____

(NOW SKIP TO B1)

A32. (IF A.29 = NO) Which of the following do you think is the most likely age of the old equipment:

1. More than 20 years old
2. 15 – 20 years old
3. 10 – 15 years old
4. Less than 10 years old

(NOW SKIP TO B1)

A.33. (IF A26=4) About what year did you install the old unit?

Year__________

A34. (IF A26=4) And would you say the old unit was a high efficiency model when you installed it, or was it standard efficiency?

1. High Efficiency (ASK A35)
2. Standard Efficiency (SKIP TO B1)
9. DK (SKIP TO B1)

A35. At the time you purchased the old equipment, did you receive a utility rebate or tax credit for installing a high efficiency model?

1. Yes
2. No
9. DK

SECTION B. COMPLETE SYSTEM REPLACEMENT QUESTIONS – CENTRAL AIR REPLACED ALONG WITH FURNACE

ASK SECTION B IF NEW EQUIPMENT TYPE = FURNACE; ALL OTHERS SKIP TO SECTION C

B1. (IF NEW EQUIPMENT TYPE = FURNACE) When you installed your new FURNACE, did you also replace your central air conditioning system at the same time?

1. Yes (CONTINUE)
2. No (SKIP TO C1)
3. Got a new central AC but didn't have an AC previously (SKIP TO B7)
9. DK (GO TO C1)

B2. Compared to the FURNACE that you replaced, was the old central air conditioning system: (READ CHOICES)

1. Older (CONTINUE)
2. About the same age as the old FURNACE (SKIP TO B5)
3. Newer (SKIP TO B4)
4. DK (SKIP TO B5)

B3. About how many years older?

_______ Years

99. DK

(NOW SKIP TO B5)

B4. About how many years newer?

_______ Years

99. DK

B5. Which of the following statements best describes the condition of the old central air conditioning system at the time it was replaced? Was it:

1. Working normally and keeping your home at the desired temperature (SKIP TO B7)
2. Working but not keeping your home at the desired temperature (SKIP TO B7)
3. Working, but requiring frequent service calls (CONTINUE)
4. Broken, not functioning (SKIP TO B7)
5. Other (specify)___________________________________ (SKIP TO B7)

B6. (If B5=3) About how many times did you have to repair the old system in the year prior to replacement?

_______ Times

99. DK

B7. Did you get a rebate for the new central air conditioning?

1. Yes
2. No
9. DK

SECTION C. COMPLETE SYSTEM REPLACEMENT QUESTIONS – FURNACE REPLACED ALONG WITH CENTRAL AIR

ASK SECTION IF NEW EQUIPMENT TYPE = CENTRAL AIR CONDITIONER and A6 = CENTRAL A/C; ALL OTHERS SKIP TO SECTION D

C1. (IF NEW EQUIPMENT TYPE = CENTRAL AIR CONDITIONER) When you installed your new central air conditioner, did you also replace your furnace at the same time?

1. Yes (CONTINUE)
2. No (SKIP TO D1)
9. DK (SKIP TOD1)

C2. Compared to the central air conditioner that you replaced, was the old furnace system:

1. Older (CONTINUE)
2. About the same age as the old central air conditioner (SKIP TO C5)
3. Newer (SKIP TO C4)
4. DK (SKIP TO C5)

C3. About how many years older?

_______ Years

99. DK

(NOW SKIP TO C5)

C4. About how many years newer?

________ Years

99. DK

C5. Which of the following statements best describes the condition of the old furnace at the time it was replaced? Was it:

1. Working normally and keeping your home at the desired temperature (SKIP TO C7)
2. Working but not keeping your home at the desired temperature (SKIP TO C7)
3. Working, but requiring frequent service calls (CONTINUE)
4. Broken, not functioning (SKIP TO C7)
5. Other (specify)_________________________________ (SKIP TO C7)

C6. About how many times did you have to repair the old system in the year prior to replacement?

_______ times

C7. Did you get a rebate for the new furnace?

1. Yes
2. No
9. DK

D. REPLACEMENT ACTION WITHOUT PROGRAM

D1. Now, thinking again about your recent equipment purchase, which of the following actions would you have been MOST LIKELY to take if the [UTILITY] rebate had not been available at that time? Would you have: (READ CHOICES; ONE ANSWER ONLY)

1. (READ IF A13 = 1-3) Continued using the old unit
2. (READ IF A13 = 4) Repaired the old unit
3. Bought a standard efficiency new unit
4. Bought the same high efficiency unit
5. Something else (specify) ____________

D2. [IF NEW EQUIPMENT TYPE = FURNACE, BOILER, CENTRAL AIR CONDITIONER, or HEAT PUMP] To the best of your knowledge, how much more did your new high efficiency [NEW EQUIPMENT TYPE] cost than a new standard efficiency unit of the same size or capacity?

$_____________ more (SKIP TO D4)

99. DK (CONTINUE)

D3. Would you say it was:

1. Less than $500
2. $500 - $1000
3. $1,000 - $1500
4. $1,000 - $2,000
5. Over $2,000 more than a standard efficiency unit

D4. [IF NEW EQUIPMENT TYPE = HEAT PUMP WATER HEATER] To the best of your knowledge, how much more did your new heat pump water heater cost than a new conventional water heater of the same size or capacity?

$____________ more (SKIP TOD6)

999. DK (CONTINUE)

D5. (If D4 = DK) Would you say it was: (READ CHOICES)

1. Less than $100
2. $100 - $250
3. $251-500
4. $501-750
5. $751-1,000 or
6. Over $1,000 more than a standard unit?

D6. Approximately how much was the installed cost of your new [NEW EQUIPMENT TYPE], including labor costs?

$____________________ 9999 DK (SKIP TO E1)

D7. Is that before or after the [UTILITY] rebate?

1. Before
2.After

E. DEMOGRAPHICS

We're almost done. The following questions are only for classification purposes only, and your answers will be kept confidential.

E1. First, what is your birth year?

RECORD [RESPOND AGE]________________

8888) Refused
9999) Don't know

E2. (IF E1 = REFUSED) Could you please tell me which of the following categories includes your age? (READ LIST)

1) 18 to 24
2) 25 to 34
3) 35 to 44
4) 45 to 54
5) 55 to 64
6) 65 and over
88) Refused
99) Don't know

E3. Which of the following best describes your educational background?

1) Less than high school,
2) High school or GED
3) Some college
4) Technical College (2 year degree)
5) 4 Year college
6) Graduate degree
88) Refused

99) Don't know

E4. Which of the following categories best represents your approximate annual household income from all sources in 2014, before taxes?

1) < 40,000
2) Between 40 and 60,000
3) Between 60 and 80,000
4) Between 80 and 120,000
5) Over 120,000

88) Refused
99) Don't know

Those are all of my questions. Thank you for sharing your time and information.

Can you please tell us the type of gift card you would prefer – Amazon, Petco, Home Depot, or Starbucks - the name of the person we should send it to, and their email address?

Record: CardType
Record: CardName
Record:EmailAddy

Appendix B: Installation Contractor Interview Guide

GENERAL INTRODUCTION

NOTE: We will try to interview highly active companies that are doing installs primarily for a single PA, based on the project counts we received. If we know they are doing projects for multiple utilities, we will ask them to distinguish differences throughout the interview.

This is <INTERVIEWER NAME> calling from _______on behalf of [Utility] and Northeast Energy Efficiency Partnerships (NEEP). This is not a sales call. I'm calling because our records show that you have installed many [furnaces, boilers, air conditioners, heat pumps and/or water heaters] for [Utility]'s residential programs and I'd like to ask you a few questions about your experiences with programs that replace equipment early, before failure. Are you the best person to discuss these installations and programs at a high level?

1. Yes (CONTINUE)

2. No: Who would be the best person to talk to about the programs and your company's experience with them? (REPEAT INTRO WHEN CORRECT PERSON COMES ON LINE; ARRANGE CALL BACK IF NECESSARY)

NEEP and its utility members would like to better understand what you and your coworkers think about the programs, how customers are responding to them, and how well the programs are working. Your input is very important to help NEEP and [UTILITY] manage energy use and improve its energy programs and rebates.

We are collecting data for a study on the characteristics of existing residential heating or cooling [heat pump hot water for HPHW participants only] equipment at the time it was replaced. All your responses will be treated as confidential, and will only be reported as part of combined results.

ESTIMATES OF EXISTING AGE, FUNCTIONALITY, USEFUL LIFE

Before we start, please know that we are just asking you to answer the questions to the best of your knowledge. We don't need you to dig through project records and get specific details - your best estimates will be fine.

NOTE: To be respectful of respondents' time we will ask them about one specific measure throughout the interview for which they have done many installs. In some cases where we only know they install "heating equipment" we may need them to confirm their most popular measure and we'll discuss that.

1. Using your best guess from projects you have worked on, what percentage of (water heaters, furnaces, boilers, central air, and heat pumps) is still functioning when it is

replaced through (utility's) program? (**If necessary**, would you say less than 25%, 25-50%, or more than 50%?)

2. Based on your experience, what is the typical age of (furnaces, boilers, central air, water heaters, and heat pumps) that have already failed when you replace them?

3. And what is the average age of (furnaces, boilers, central air, water heaters, and heat pumps) that are still working when you replace them through (utility's) program?

4. About what percentage of the replaced functioning equipment is less than 10 years old? 11-20 years old? More than 20 years old?

5. During installations, do you usually know or can you tell if the existing equipment is being replaced before it has passed its useful life (Useful life is defined using studies of failure rates of equipment and is an average value representing a typical unit's functional life. Typical values: 20 years for furnaces and boilers, 15 years for air conditioners and water heaters)? If so, how?

6. How many years would you say most functioning (furnaces, boilers, central air, water heaters, and heat pumps) have left in them when they are replaced through (utility's) program, assuming no major repairs?

7. How does this remaining useful life compare to early replacements that do not go through utility rebate programs?

8. What do you estimate to be the average useful life of a [furnace, boiler, central air conditioner, heat pump, water heater] when operated normally in homes?

9. Again, using your experience, what is the average cost required to get the replaced failed equipment functioning again?

10. At what equipment age do major repairs start to occur?

11. What are the most common major repairs needed?

12. Roughly what percentage of customers with non-functioning equipment will choose to have it repaired instead of replacing it?

13. Is there a repair cost threshold that seems to determine whether a customer will choose the repair or a replacement? (Get details on threshold amount or reasons for no specific threshold.)
14. Would you say that the new units are usually the same size (heating or cooling capacity) as the existing unit they replace? Larger? Smaller?

15. What are the lowest-efficiency, code-compliant options that you sell for [furnaces, boilers, central air conditioners, heat pumps, and water heaters] and what are their efficiencies?

16. And what is the average efficiency of the units that you replace?

PROGRAM QUESTIONS

Now, we have a few questions about [utility's] program(s).

17. FOR EARLY REPLACEMENT PROGRAMS: How do [utility]'s early replacement HVAC programs help or hinder customer participation?

18. Besides operational status, do you consider anything else to distinguish early versus replace-on-failure replacement projects? (They may say an auditor makes the determination – that's OK).

19. How could early (replaced with functional life remaining without major repairs) and normal equipment replacements (replaced after failure or needing major repair) be better distinguished?

20. What seem to be the most effective ways to get customers to replace equipment early?

21. FOR EARLY REPLACEMENT PROGRAMS: What do you like about [utility]'s early replacement programs? What would you like to see improved?

22. What are the most common reasons customers give for wanting to replace their equipment?

23. What percentage of high-efficiency early replacements do not receive any utility incentives? That is - the equipment is replaced early but the utility is unaware of it.

24. Do you see customers replacing both their furnace and their air conditioning system (indoor coil + outdoor condensing unit) at the same time, even if only one needs repair -

especially if the functioning system is within 5 years of its pre-defined effective useful life anyway? What percentage of installs?

COSTS

Just a few more questions on project costs and then we'll be done.

25. On average, how much does a standard efficiency, code-compliant [furnace, boiler, air conditioner, heat pump, water heater] typically cost (including installation)? The costs for typical sizes are fine (3-ton A/C, 60 kBTU/h furnace, 90 kBTU/h boiler, 40 gallon water heater)

26. On average, how much does a high-efficiency [furnace, boiler, air conditioner, heat pump, water heater] that qualifies for [utility]'s incentives cost, including install labor?

27. What is the average frequency of major repairs on HVAC equipment?

Those are all of our questions – thanks for your time and good information!

Appendix C: Resources to Identify Equipment Age

Because an accurate estimate of existing equipment age is so important to early replacement programs, it is useful to have tools that aid in identifying equipment ages. A comprehensive and useful tool is the Building Intelligence Center's equipment age database. This website (www.buildingcenter.org/content/hvac-production-dateage) contains serial number keys for dozens of HVAC and water heater manufacturers. These serial number keys are breakdowns of how each manufacturer hides the year of manufacture in their serial numbers. Each manufacturer has a unique way of doing this, and the same manufacturer may change their serial number key as often as every five years.

To determine the age of equipment using this database, simply go to the site and select the manufacturer of the equipment in question. Then, using the serial number recorded off the equipment and the serial number keys on the site, one can determine which type of serial number it is (from which era in that manufacturer's history), and then what the year of manufacture was.

Importantly, the manufacturer, model number and serial number are necessary information that should be collected from every piece of existing equipment being replaced. This information is crucial to age identification. If one of these three values is missing, it can be very difficult to find the equipment's age.

The Building Intelligence Center's database should be the first place one accesses to cross-reference a serial number. If either the manufacturer of the equipment is not listed or the serial number does not match any of the available keys for that manufacturer, other sources can be utilized. Two other sources of information are: www.inspectorsjournal.com/forum and www.nachi.org/forum. These are home inspector forums where home inspectors post questions about equipment they find while performing home inspections. Using the search feature of these sites is an effective method to comb through the forums looking for specific manufacturer and model number data. These forums can also provide information about equipment that pre-dates the Building Information Center database and can sometimes provide efficiency values as well.

For air conditioners, another resource is www.localinspectioncompany.com/articles/acdata.pdf. This site has serial number keys for a number of air conditioner manufacturers. Furthermore, many manufacturers have serial or model number lookups on their websites. Finally, www.inspectapedia.com has a section devoted to HVAC product manuals. These can be useful for age identification and sometimes efficiency determination.

If the above resources do not produce an age estimate, the final—and most time-consuming—option is to contact the manufacturer directly, usually through a sales representative, as they can often look up the serial numbers. For some manufacturers that do not use a serial number key at all, this is unfortunately the only way to get accurate age information. Units that cannot be found using the above methods are likely older than 40 years of age or are from an obscure manufacturer that no longer exists. For example, American Standard Arcoliner boilers are very common in New England, but are 40 to 70 years old, and there is no way to identify their specific age. Only after all of the above methods have been attempted should the age be estimated using a best guess.

Appendix D: Energy Efficiency Degradation Factors

HVAC and water heating equipment naturally loses efficiency over time due to a variety of factors: wear on moving parts, airway obstructions, gas line deposits, corrosion, and other factors. To consider these effects, we propose the introduction of a degradation factor for furnaces, boilers, water heaters, heat pumps, and air conditioners to better account for the actual operating efficiency of existing equipment.

We propose using the degradation factor model used by the National Renewable Energy Laboratory's "Building America House Simulation Protocols" report (p. 38).[33] This method is also used by the Arkansas statewide Technical Reference Manual (2015).[34] The basic formula for this method is: Current eff = (Eff when new) x $(1 - M)^{age}$. In this equation, "Current eff" is the existing equipment efficiency as it is operating at the time of removal, "Eff when new" is the estimated efficiency of the existing equipment when it was new, "M" is the degradation (maintenance) factor, and "age" is the estimated age of the equipment.

The degradation factor, M, should be selected from Table 31 for furnaces and boilers, Table 32 for air conditioners and heat pumps, and Table 33 for water heaters. It is dependent on the fuel source and frequency of system maintenance. Note that the formula above is non-linear. When graphed, it does appear linear, but it will not decrease the efficiency by an equal amount each year. In order to use this method, one only needs the estimated equipment age and an estimate of the efficiency of the equipment when it was new. A reasonable assumption for most heating equipment can be selected from the same tables used for degradation factors, given the type and fuel source for the equipment.

The equations for each type of equipment are shown below:

Furnaces and Boilers: AFUE = (Base AFUE) x $(1 - M)^{age}$

In this equation, "AFUE" is the existing furnace or boiler efficiency as it is operating at the time of removal, "Base AFUE" is the estimated efficiency of the existing equipment when it was new, "M" is the degradation (maintenance) factor, and "age" is the estimated age of the equipment.

Air Conditioners and Heat Pumps: EFF = (Base EFF) x $(1 - M)^{age}$

In this equation, "EFF" is the existing air conditioner or heat pump efficiency as it is operating at the time of removal, "Base EFF" is the estimated efficiency of the existing equipment when

[33] Hendron, Robert and Engebrecht, Cheryn. National Renewable Energy Laboratory. "Building America House Simulation Protocols". October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf
[34] Frontier Associates, LLC. Deemed Savings, Installation & Efficiency Standards. Arkansas TRM Version 5.0 Volume 2: Deemed Savings. August 2015.

it was new, and "M" and "age" are as before. "EFF" and "Base EFF" can be in units of SEER, EER, or HSPF, provided they are both in the same units.

Water Heaters: EF = (Base EF) x $(1 - M)^{age}$

In this equation, "EF" is the existing water heater's energy factor at the time of removal, "Base EF" is the estimated energy factor when the water heater was new, and the other variables are the same.

For all of these equations, there is a maximum age limit of 20 years to prevent values that are unreasonably low for very old equipment. If the equipment in question is over 20 years old, simply use 20 years in the equations.

Table 31 - Heating Equipment M Factors And Base Efficiencies

Type of Space Heating Equipment	Base AFUE*	Maintenance Factor (M)	
		Annual Professional Maintenance	Seldom or Never Maintained
Condensing gas furnace	90	0.005	0.015
Gas furnace, direct vent or forced draft combustion, electronic ignition, in conditioned space	80	0.005	0.015
Gas furnace, natural draft combustion, vent damper, electronic ignition, in conditioned space	78	0.005	0.015
Gas furnace, natural draft combustion, standing pilot light, in conditioned space	75	0.005	0.015
Gas furnace, natural draft combustion, standing pilot light, no vent damper, in unconditioned space	64	0.005	0.015
Gas hot water boiler, natural draft combustion, standing pilot light	80	0.005	0.015
Gas steam boiler	81	0.005	0.015
Condensing gas boiler	90	0.005	0.015
Gas hot water/fan coil combo system	80	0.005	0.015
Gas boiler/tankless coil combo system	80	0.005	0.015
Gas space heater, fan type	73	0.005	0.015
Gas space heater, gravity type	60	0.005	0.015
Oil furnace, flame retention burner, vent dampers, in conditioned space	81	0.01	0.025
Oil furnace, conventional burner, no vent dampers, in conditioned space	71	0.01	0.025
Oil hot water boiler, forced draft combustion	80	0.01	0.025
Oil steam boiler	82	0.01	0.025
Electric resistance furnace or boiler, conditioned space	100	0	0
Electric resistance furnace or boiler, unconditioned space	98	0.001	0.001
Electric resistance baseboard heating	100	0	0
Electric space heater	100	0	0

* Combined Appliance AFUE or combo systems

Table 32 - Cooling Equipment M Factors And Base Efficiencies

Type of Air Conditioning or Heat Pump Equipment	Base SEER	Base EER	Base HSPF	Maintenance Factor (M)	
				Annual Professional Maintenance	Seldom or Never Maintained
Split central air conditioner, two-speed reciprocating compressor, electronically commutated air handler motor (BPM), thermostatic expansion valve, fan coil	14	10.5		0.01	0.02
Split central air conditioner, single-speed scroll compressor, BPM air handler motor, cased coil	12	10.8		0.01	0.03
Split central air conditioner, single-speed reciprocating compressor, PSC air handler motor, cased coil (after 1991)	10	9.3		0.01	0.03
Split central air conditioner, single-speed reciprocating compressor, PSC air handler motor, cased coil (1981–1991)	8	7.7		0.01	0.03
Split central air conditioner, single-speed reciprocating compressor, PSC air handler motor, cased coil (before 1981)	6.5	6.4		0.01	0.03
Split heat pump, single-speed scroll compressor, BPM air handler motor, thermostatic expansion valve	14	10.5	8.0	0.01	0.03
Split heat pump, single-speed reciprocating compressor, PSC air handler motor (after 1991)	10	9.3	7.1	0.01	0.03
Split heat pump, single-speed reciprocating compressor, PSC air handler motor (1981–1991)	8	7.7	6.6	0.01	0.03
Split heat pump, single-speed reciprocating compressor, PSC air handler motor (before 1981)	6.5	6.4	6.0	0.01	0.03
Packaged central air conditioner, single-speed reciprocating compressor, PSC air handler motor	10	9.1		0.01	0.03
Packaged heat pump, single-speed reciprocating compressor, PSC air handler motor	10	9.1	6.8	0.01	0.03
Room air conditioner, louvered sides, cooling only, single-speed compressor, PSC fan motor, < 20,000 Btu/h (after 1991)		9.75		0.01	0.03
Room air conditioner, louvered sides, cooling only, single-speed compressor, PSC fan motor, ≥ 20,000 Btu/h (after 1991)		8.5		0.01	0.03
Room air conditioner, louvered sides, cooling only, single-speed compressor, PSC fan motor (1981–1991)		7.5		0.01	0.03
Room air conditioner, louvered sides, cooling only, single-speed compressor, PSC fan motor (before 1981)		6.5		0.01	0.03
Room electric heat pump, louvered sides, single-speed compressor, PSC fan motor, < 20,000 Btu/h		9		0.01	0.03
Room electric heat pump, louvered sides, single-speed compressor, PSC fan motor, ≥ 20,000 Btu/h		8.5		0.01	0.03
Direct evaporative cooling		25		0.02	0.05

Table 33 - Water Heater M Factors And Base Efficiencies

Type of Water Heating Equipment	Base EF	Maintenance Factor (M)	
		Annual Professional Maintenance	Seldom or Never Maintained
Gas water heater, 40 gallon tank, pilot light, natural draft combustion, poorly insulated, no heat traps, poor heat recovery from flue.	0.45	0.005	0.01
Gas water heater, 40 gallon tank, pilot light, natural draft combustion, 1" insulation, no heat traps, standard flue baffling.	0.54	0.005	0.01
Gas water heater, 40 gallon tank, intermittent ignition, forced draft combustion, 3" insulation, heat traps, enhanced flue baffling, flue/vent dampers	0.64	0.005	0.01
Gas instantaneous water heater*	0.76	0.005	0.01
Oil water heater, 32 gallon tank, intermittent ignition, forced draft combustion, poorly insulated, no heat traps, poor heat recovery from flue.	0.53	0.005	0.01
Oil water heater, 32 gallon tank, interrupted ignition, forced draft combustion, 3-in. insulation, heat traps, enhanced flue baffling.	0.61	0.005	0.01
Electric water heater, 50 gallon tank, poorly insulated, no heat traps.	0.79	0.001	0.002
Electric water heater, 50 gallon tank, 1.5-in. insulation, heat traps.	0.87	0.001	0.002
Electric water heater, 50 gallon tank, 3-in. insulation, heat traps.	0.90	0.001	0.002
Electric instantaneous water heater*	0.91	0	0

* Tankless water heaters are derated by 8% due to thermal losses that aren't reflected in the standard DOE rating procedure.

Appendix E: Survival and RUL Values – Furnaces

a	b	c	d
Age	**Survival Probability**	**Median Replacement Age**	**RUL**
0	1.000	22.6	22.6
1	0.999	22.6	21.6
2	0.997	22.7	20.7
3	0.992	22.7	19.7
4	0.985	22.8	18.8
5	0.976	23.0	18.0
6	0.964	23.1	17.1
7	0.950	23.4	16.4
8	0.933	23.6	15.6
9	0.914	23.9	14.9
10	0.893	24.2	14.2
11	0.869	24.6	13.6
12	0.844	25.0	13.0
13	0.816	25.4	12.4
14	0.787	25.9	11.9
15	0.757	26.3	11.3
16	0.725	26.9	10.9
17	0.692	27.4	10.4
18	0.659	28.0	10.0
19	0.624	28.6	9.6
20	0.590	29.2	9.2
21	0.555	29.8	8.8
22	0.521	30.5	8.5
23	0.487	31.2	8.2
24	0.454	31.9	7.9
25	0.421	32.6	7.6
26	0.389	33.3	7.3
27	0.358	34.1	7.1
28	0.329	34.8	6.8
29	0.300	35.6	6.6
30	0.273	36.4	6.4

Formulas for Furnaces

$$Row\ b = e^{-\left(Age/26.68\right)^{2.218}}$$

$$Row\ c = -\ln\left(Row\ b \times 0.5\right)^{1/2.218} \times 26.68$$

$$Row\ d = Row\ c - Age\ of\ Unit$$

Appendix F: Survival and RUL Values – Boilers

a	b	c	d
Age	**Survival Probability**	**Median Replacement Age**	**RUL**
0	1.000	25.4	25.4
1	1.000	25.4	24.4
2	1.000	25.4	23.4
3	1.000	25.4	22.4
4	1.000	25.4	21.4
5	1.000	25.4	20.4
6	1.000	25.4	19.4
7	0.990	25.6	18.6
8	0.990	25.6	17.6
9	0.970	25.9	16.9
10	0.960	26.0	16.0
11	0.940	26.3	15.3
12	0.920	26.6	14.6
13	0.900	26.9	13.9
14	0.870	27.4	13.4
15	0.850	27.7	12.7
16	0.820	28.2	12.2
17	0.790	28.7	11.7
18	0.760	29.1	11.1
19	0.720	29.8	10.8
20	0.690	30.3	10.3
21	0.650	31.0	10.0
22	0.620	31.6	9.6
23	0.580	32.3	9.3
24	0.550	32.9	8.9
25	0.510	33.7	8.7
26	0.480	34.3	8.3
27	0.450	35.0	8.0
28	0.420	35.7	7.7
29	0.380	36.6	7.6
30	0.350	37.4	7.4

Formulas for Boilers

$$Row\ b:\ if\,Age \le 5\ Row\ b = 1.0;\ \ if\,Age > 5\ Row\ b = e^{-\left(\left(Age-5\right)/24.55\right)^{2.0}}$$

$$Row\ c = -\ln\left(Row\ b \times 0.5\right)^{1/2.0} \times 24.55 + 5$$

$$Row\ d = Row\ c - Age\ of\ Unit$$

Appendix G: Survival and RUL Values – Central Air Conditioners

a	b	c	d
Age	**Survival Probability**	**Median Replacement Age**	**RUL**
0	1.000	18.0	18.0
1	0.998	18.1	17.1
2	0.993	18.1	16.1
3	0.984	18.2	15.2
4	0.971	18.4	14.4
5	0.954	18.6	13.6
6	0.933	18.9	12.9
7	0.909	19.2	12.2
8	0.881	19.5	11.5
9	0.851	19.9	10.9
10	0.817	20.4	10.4
11	0.782	20.9	9.9
12	0.744	21.4	9.4
13	0.705	21.9	8.9
14	0.665	22.5	8.5
15	0.624	23.1	8.1
16	0.583	23.7	7.7
17	0.542	24.4	7.4
18	0.502	25.1	7.1
19	0.462	25.8	6.8
20	0.423	26.5	6.5
21	0.386	27.3	6.3
22	0.350	28.0	6.0
23	0.316	28.8	5.8
24	0.284	29.6	5.6
25	0.253	30.4	5.4
26	0.225	31.2	5.2
27	0.199	32.0	5.0
28	0.175	32.9	4.9
29	0.154	33.7	4.7
30	0.134	34.6	4.6

Formulas for Central Air Conditioners

$$Row\ b = e^{-\left(Age/21.49\right)^{2.094}}$$

$$Row\ c = -\ln\left(Row\ b \times 0.5\right)^{1/2.094} \times 21.49$$

$$Row\ d = Row\ c - Age\ of\ Unit$$

Appendix H: Study Measures – Descriptive Information

State - Program Administrator	Efficient Measure Description	End Use Category	Fuel Source	Eligible Customer Segments
CT - CL&P, UI	Boiler	HVAC	Gas, Oil	Residential
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	HVAC	Natural Gas	Residential
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	HVAC	Oil, Propane	Residential
NH - Liberty	Boiler	HVAC	Natural Gas	Residential
CT - CL&P, UI	Central AC	HVAC	Electric	Residential
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Central AC or HP Early Replacement	HVAC	Electric	Residential
CT - CL&P, UI	Furnace	HVAC	Gas, Oil, Propane	Residential
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Furnace	HVAC	Gas, Oil, Propane	Residential
MD - First Energy	Heat Pump Water Heater (HWPH)	Water Heating	Electric	Residential
MD - SMECo, Pepco, BGE	Heat Pump Water Heater (HWPH)	Water Heating	Electric	Residential
NH - PSNH	Heat Pump Water Heater (HWPH)	Water Heating	Electric	Residential
MD - First Energy	Air Source Heat Pump	HVAC	Electric	Residential
MD - SMECo, Pepco, BGE	Air Source Heat Pump	HVAC	Electric	Residential
NH - PSNH	Air Source Heat Pumps	HVAC	Electric	Residential
MD - First Energy	Central AC	HVAC	Electric	Residential
MD - SMECo, Pepco, BGE	Central AC	HVAC	Electric	Residential
NH - PSNH	Central AC	HVAC	Electric	Residential

Appendix I: Study Measures – Normal Replacements Information

State - Program Administrator	Efficient Measure Description	EUL for Normal Replacements	Baseline Efficiency for Normal Replacements (often Code or Market Standard)	Energy Savings for Normal Replacements	Baseline Cost for Normal Replacements	Incremental Cost for Normal Replacements	Rebates and Incentives for Normal Replacements
CT - CL&P, UI	Boiler	20 years, from Appliance Magazine. U.S. Appliance Industry: Market Share, Life Expectancy & Replacement Market, and Saturation Levels. January 2010. Page 10.	80%	Calculated, based on area being heated, AFUE of new unit, and heating factor, which is based on the age of the home and has units of BTU/SF/Year			$750
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	20 yrs, from EPA study of Life Cycle Cost Estimate for ENERGY STAR Qualified Boilers	AFUE of 80% for steam, 82% for forced hot water, based on code	Deemed at 10.4 MMBTU for forced hot water, 3.5 MMBTU for steam. Values come from these two sources: The Cadmus Group, Inc. (2012) Memo to HEHE Program Administrators Re: Impacts of Upcoming Federal Standards on HEHE Gas Space and Water Heating Measures; June 8, 2012, GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks		2883 forced hot water incremental cost, 400 for steam, don't offer anymore for steam normal replacement	$1,000-$1,500
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	20 yrs, from EPA study of Life Cycle Cost Estimate for ENERGY STAR Qualified Boilers	AFUE of 80%, based on code	Deemed at 8.5, 3.5, 16, and 3.5 MMBtu for oil forced hot water, oil steam, propane forced hot water, and propane steam boilers, respectively		500 incremental for oil, 2833 for propane	$1,000-$1,500, depending on efficiency, Cape Light Compact: $200 for steam, $500 for hot water
NH - Liberty	Boiler	20 yrs	82% AFUE boiler	Deemed at 12.0 or 13.9 MMBtu for 90% AFUE and 95% AFUE, respectively	NO DETAILS AVAILABLE	$1500 for 90% AFUE, $2400 for 95% AFUE	$1,007 for 90% AFUE, $1,507 for 95% AFUE

State - Program Administrator	Efficient Measure Description	EUL for Normal Replacements	Baseline Efficiency for Normal Replacements (often Code or Market Standard)	Energy Savings for Normal Replacements	Baseline Cost for Normal Replacements	Incremental Cost for Normal Replacements	Rebates and Incentives for Normal Replacements
CT - CL&P, UI	Central AC	25 years, from GDS Associates Inc. Measure Life Report, Residential and Commercial Industrial Lighting and HVAC Measures, June 2007, Table 1.	11 EER, from Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009. page 4-1. "Because there were no instances of early replacement of CAC units in the monitoring sample, the baseline for estimating savings is the minimum standard for new installations, namely 11 EER."	Calculated, based on capacity and EER of the proposed unit and a value of 357.6 kWh/year/ton, from an evaluation study. Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009. page 4-1.			$250
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Central AC or HP Early Replacement	18 yrs, from GDS Associates 2007 Measure Life Report for NE State Program Working Group	SEER 13, 11 EER, 7.6 HSPF, which is federal standard	Deemed at 103 kWh, 0.273 kW for AC, 519 kWh, 0.273 kW summer, 0.347 kW winter for heat pumps			$150-$500, depending on efficiency
CT - CL&P, UI	Furnace	20 years, no source	78% for gas or propane, 80% for oil	Calculated, based on area being heated, AFUE of new unit, and heating factor, which is based on the age of the home and has units of BTU/SF/Year			$600 for gas furnace ($390 outside of CL&P and UI territory), $200 for propane or oil
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Furnace	18 years	Current code efficiency (86% for oil, 95% for propane)	Deemed at 4.5 MMBTU for 95% AFUE, 5.9 MMBTU for 97% AFUE	NO DETAILS AVAILABLE	NO DETAILS AVAILABLE	$300 for 95%, $600 for 97%, Cape Light Compact: $100 w/o ECM, $400 with ECM
MD - First Energy	HWPH	10 years	Standard electric water heater (TRM); (min req. for program EF >= 2.0)	Deemed at 1436 kWh	NO DETAILS AVAILABLE	$925 (From TRM)	
MD - SMECo, Pepco, BGE	HWPH	10 years	Federal code	Deemed at 1604.143 kWh	NO DETAILS AVAILABLE	Estimated by Navigant for cost effectiveness, is "in between Navigant and TRM"	$350 for Electric Heat Pump Water Heater, EF >= 2.0
NH - PSNH	HPWH	10 years	Current code efficiency	Deemed at 1775 kWh for 50 gal and 2672 for 80 gal	NO DETAILS AVAILABLE	NO DETAILS AVAILABLE	$500 for 50 gal, $600 for 80 gal

State - Program Administrator	Efficient Measure Description	EUL for Normal Replacements	Baseline Efficiency for Normal Replacements (often Code or Market Standard)	Energy Savings for Normal Replacements	Baseline Cost for Normal Replacements	Incremental Cost for Normal Replacements	Rebates and Incentives for Normal Replacements
MD - First Energy	Air Source Heat Pump	18 years	Federal code; (min req. for program EER >=13, SEER >=16 (Geothermal EER >=17.1))	Savings between 390 kWh and 1332 kWh based on SEER	NO DETAILS AVAILABLE	From Mid-Atlantic TRM: Ranges from $208/ton of capacity for SEER 14 to $918/ton of capacity for SEER 18	$750 for SEER >=16, EER >=13, and HSPF >=9 $1250 for SEER >=18 and EER >=13, HSPF >=9.5 ($1800 for Geothermal HP)
MD - SMECo, Pepco, BGE	Air Source Heat Pump	18 years	Federal code	Calculated using the Mid-Atlantic TRM. Cooling and heating hours vary across utilties based off of evaluations. Peak demand savings are set at a savings/ton per the evaluation, rather than calculating	NO DETAILS AVAILABLE	From Mid-Atlantic TRM: Ranges from $208/ton of capacity for SEER 14 to $918/ton of capacity for SEER 18	$300 for Air Source Heat Pump 2012 Tier 2: >=15 SEER and >=12.5 EER and >=8.5 HSPF $500 for Air Source Heat Pump 2014 Tier 1: >=16 SEER and >=13.0 EER and >=9.0 HSPF
NH - PSNH	Air Source Heat Pumps	12 years	Current code efficiency	Deemed at 176.59 kWh for HSPF>=8.2 and 855.94 kWh for HSPF>=10	NO DETAILS AVAILABLE	NO DETAILS AVAILABLE	$300 for HSPF>=8.2, $500 for HPSPF>=10
MD - First Energy	Central AC	18 years	Federal code; (min req. for program EER >=13, SEER >=16)	Savings between 145 kWh and 396 kWh based on SEER (From TRM)	NO DETAILS AVAILABLE	From Mid-Atlantic TRM: Ranges from $95/ton for SEER 14 to $734 for SEER 21	$500 for SEER >=16 and EER >=13 $1000 for SEER >=18 and EER >=13
MD - SMECo, Pepco, BGE	Central AC	18 years	Federal code	Calculated using the Mid-Atlantic TRM. Cooling and heating hours vary across utilties based off of evaluations. Peak demand savings are set at a savings/ton per the evaluation, rather than calculating	NO DETAILS AVAILABLE	From Mid-Atlantic TRM: Ranges from $95/ton for SEER 14 to $734 for SEER 21	$150 for Central AC 2012 Tier 1: >=14.5 SEER and >=12 EER $500 for Central AC 2014 Tier 1: >=16 SEER and >=13.0 EER
NH - PSNH	Central AC	14 years	Current code efficiency	Deemed at 110.29 kWh	NO DETAILS AVAILABLE	NO DETAILS AVAILABLE	$200

Appendix J: Study Measures – Eligibility Requirements for Early Replacement

State - Program Administrator	Efficient Measure Description	Old Equipment - Efficiency Requirement	Old Equipment - Age Requirement	Old Equipment - Other Requirements	Verification Done, Data Collected (e,g., how AGE determined, functional status)
CT - CL&P, UI	Boiler	NONE	NONE	Must be working, if found not to be working, it becomes a lost opportunity project	Age estimated by home auditor who uses model number or estimated age of unit.
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	NONE	>=30 years	Must be functioning	Age determined by auditor using model number or best guess (they have a lookup table of model numbers)
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	NONE	>= 30 years	Must be functioning	Age determined by auditor using model number or best guess (they have a lookup table of model numbers)
NH - Liberty	Boiler	NONE	10 years	Functioning and non-condensing	HPwES contractors test the combustion efficiency of the working boiler and take a photo of the name plate with date of manufacture. Sometimes they cannot find a name plate.
CT - CL&P, UI	Central AC	NONE	NONE	Must be working, if found not to be working, it becomes a lost opportunity project	Age estimated by home auditor who uses model number or estimated age of unit.
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Central AC or HP Early Replacement	NONE, NGRID assumes 10 SEER, 7 HSPF, 8.5 EER	NONE, 12 years old (NGRID)	Must be functioning, Must have home audit first to determine eligibility.	Age determined by auditor using model number or best guess (they have a lookup table of model numbers)
CT - CL&P, UI	Furnace	NONE	NONE	Must be working, if found not to be working, it becomes a lost opportunity project	Age estimated by home auditor who uses model number or estimated age of unit.
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Furnace	None	12 years old (NGRID) 10 years old (Unitil)	Must be functioning. Unitil: Must be installed by 10/31.	Age determined by auditor using model number or best guess (they have a lookup table of model numbers)

Appendix K: Study Measures – Early Replacement Savings Methods

State - Program Administrator	Efficient Measure Description	Early Replacement Savings	Early Replacement Rebates and Incentives	Dual Baselines Used?	Savings Calculations - Method Description	RUL USED?	RUL Value and Source	Old Equipment - Efficiency for Savings Calcs	Assumed Efficiency after RUL (if Dual Baselines)
CT - CL&P, UI	Boiler	Calculated, based on heated area, heating load factor (based on home age), and the deemed value of the AFUE of the existing boiler (based on boiler age). They compare the existing to NC Baseline for RUL, then Baseline to Efficient for EUL.	$1,000	Yes	The same algorithm is used for normal and early replacement. Only the AFUE values are changed. The existing boiler AFUE is determined from the boiler's age and deemed values from the PSD. These efficiency values come from: ENERGY STAR Microsoft Excel tool, "Life Cycle Cost Estimate for an ENERGY STAR Residential Furnace," http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Furnaces.xls, last updated July, 2009, last accessed August 6, 2012. The fossil fuel savings for this measure are calculated using the same methodology as the ENERGY STAR Boiler calculator, which is located on the ENERGY STAR Website. The calculator uses the home's year of construction, location, and area to determine the home's annual heating load. The age of the boiler is used to determine the efficiency.	Y	5 years, no source	Deemed, based on boiler age	Federal Energy Efficiency Standard
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	Deemed at 23.6 + 10.4 = 34 MMBTU for forced hot water, 43.9 + 3.5 = 47.4 MMBTU for steam. The first number for each is the savings for the RUL of the existing boiler. The second value is the savings for the efficient new boiler over baseline for the EUL-RUL (10 years) of the new boiler.	$1,900.00	Yes	Deemed values based on two different sources of information: #1: The Cadmus Group, Inc. (2012) Memo to HEHE Program Administrators Re: Impacts of Upcoming Federal Standards on HEHE Gas Space and Water Heating Measures; June 8, 2012 #2: GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks Savings are based on old equipment efficiency and code baseline for RUL of existing boiler and code baseline and AFUE values of 93% for forced hot water and 82% for steam for the new boiler's EUL	Y	10 yrs, based on agreed-upon value with EEAC consultants for the purpose of counting savings and adjusting costs.	Assumed at 65% AFUE for forced hot water boilers, 55% for steam boilers, based on estimated efficiency of a 30 year old boiler	AFUE of 80% for steam, 82% for forced hot water, based on code

State - Program Administrator	Efficient Measure Description	Early Replacement Savings	Early Replacement Rebates and Incentives	Dual Baselines Used?	Savings Calculations - Method Description	RUL USED?	RUL Value and Source	Old Equipment - Efficiency for Savings Calcs	Assumed Efficiency after RUL (if Dual Baselines)
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	Deemed at 25.4, 26.3, 24, 26.3 MMBtu for Oil Forced Hot Water, Oil Steam, Propane Forced Hot Water, and Propane Steam boilers for the early retirement portion of the measure and 8.5, 3.5, 16, 3.5 MMBtu for the rest of the life of the new unit after the RUL of the existing unit. The total savings is the sum of the two corresponding values for each boiler type. (RUL (10 years) for new unit versus existing unit, then EUL-RUL (10 years) for new unit vs. baseline unit)	$1,750 for oil forced hot water, $3,500 for propane	Yes	Savings calculated using information from *Natural Gas Energy Efficiency Potential in Massachusetts* by GDS Associates in 2009. For the first 10 years (RUL), the baseline is 65% efficiency and the efficient case is 80% efficiency. After RUL, the baseline efficiency is 80% and the efficient case is 82% for steam boilers, 85% for forced hot water oil boilers, and 90% for forced hot water propane boilers	Y	10 yrs, from agreed-upon value from EEAC consultants	Assumed to be 65% AFUE	Code-compliant AFUE 80% boiler
NH - Liberty	Boiler	Forced hot water: Deemed at 23.6 MMBtu during RUL and 10.4 thereafter. Steam: deemed at 43.9 MMBtu during RUL and 3.5 thereafter.	Forced hot water: 50% of cost, up to $3,000. Steam: 50% of cost, up to $1,900.	Yes	Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.	Y	RUL = 10 years - no source. Measure life of new equipment = 20 years.	80% AFUE forced hot water; 75% for steam	93% AFUE forced hot water; 82% for steam
CT - CL&P, UI	Central AC	Calculated, based on capacity and EER of the new unit, EER of the existing unit (if available), and the 357.6 kWh/year/ton savings factor used for normal replacements. They compare the existing to NC Baseline for RUL, then Baseline to Efficient for EUL.	$500	Yes	If the existing unit efficiency is unknown, it is assumed to be 8 EER and the EER portion of the calculation can be combined with the savings factor to 97.53 kWh/ton. The same algorithm is used for both normal replacement and early retirement, but the baseline EER changes from the existing unit EER to the federal baseline EER after the RUL of the existing unit.	Y	5 years, no source	Observed on-site. If unknown, assumed to be 8 EER, based on average installed efficiency for an approximately 15 year old unit. ASHRAE/IESNA Standard 90.1-1999 Table 6.2.1A has a minimum requirement of 10 SEER for 2011. Note: Units of that vintage were only rated on SEER. EER is approximately 80% of SEER (Ref [1], page ES-1 gives the ratio 11 EER / 14 SEER). 8 EER is used as the estimated existing efficiency.	11 EER, same as normal replacement

State - Program Administrator	Efficient Measure Description	Early Replacement Savings	Early Replacement Rebates and Incentives	Dual Baselines Used?	Savings Calculations - Method Description	RUL USED?	RUL Value and Source	Old Equipment - Efficiency for Savings Calcs	Assumed Efficiency after RUL (if Dual Baselines)
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Central AC or HP Early Replacement	Deemed at 299 kWh and 0.963 kW for AC for the RUL of the existing unit with 103 kWh and 0.273 kW for the next 11 years, 786 kWh and 0.963 kW summer, 0.406 kW winter for heat pumps for RUL, 519 kWh, 0.273 kW summer, 0.347 kW winter for the next 11 years.	$850. Rebate for ER paid as a rebate for the ER part (850) and a rebate for the normal replacement part	Yes	Savings based on SEER 10, EER 8.5, HSPF 7 baseline for RUL of existing unit and then baseline becomes SEER 13, EER 11, HSPF 7.6 for EUL of new AC or heat pump unit (with efficient case being SEER 14.5, EER 12, 8.2 HSPF). 1200 heating EFLH and 360 cooling EFLH are used for all calculations	Y	7 yrs, found by subtracting the assumed age of the existing equipment (10-12 years) from the EUL of new AC units (18 years) to get 18-11=7 years.	SEER 10, EER 8.5, HSPF 7	SEER 13, EER 11, HSPF 7.6
CT - CL&P, UI	Furnace	Calculated, based on heated area, heating load factor (based on home age), and the deemed value of the AFUE of the existing boiler (based on furnace age). They compare the existing to NC Baseline for RUL, then Baseline to Efficient for EUL.	$1,000	Yes	The same algorithm is used for normal replacement and early retirement. Only the AFUE values are changed. The existing furnace AFUE is determined from the furnace's age and deemed values from the PSD. These efficiency values come from: ENERGY STAR Microsoft Excel tool, "Life Cycle Cost Estimate for an ENERGY STAR Residential Furnace," http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Furnaces.xls, last updated July, 2009, last accessed August 6, 2012. The fossil fuel savings for this measure are calculated using the same methodology as the ENERGY STAR Furnace calculator, which is located on the ENERGY STAR Website. The calculator uses the home's year of construction, location, and area to determine the home's annual heating load. The age of the furnace is used to determine the efficiency.	Y	5 years, no source	Deemed, based on furnace age	Same as normal replacement (80%)
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Furnace	No Details Available	$1,000 for natural gas and propane, $750 for oil	Yes	NO DETAILS AVAILABLE	Y	6 years, based on EUL - 12 year old min age	Deemed value, but that value could not be determined.	Current code (but looking at increasing it based on actually installed equipment (common practice)

Appendix L: Study Measures – Early Replacement Costs Methods

State - Program Administrator	Efficient Measure Description	Early Replacement - Fully Installed Cost Amount, UNADJUSTED (equipment + labor)	Early Replacement - Cost Calculation METHOD for Cost Effectiveness (e.g., Full UNADJUSTED Cost, Avoided Replacement Cost Adjustment, Deferred Replacement Cost Adjustment w/ real levelized costs)	Early Replacement Cost AMOUNT Recorded (may be different than Full Unadjusted Cost)
CT - CL&P, UI	Boiler	Varies	Installation costs are estimated and only used to set incentive levels (what level of incentive will drive the customer to choose to replace the existing equipment? Installed costs are estimated to determine payback for equipment replacement and what incentive level will induce customers to pursue early retirement.). After the project, the installed cost is recorded in the database.	Unadjusted Full Install Cost
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler		Uses method described in "Correcting Common Errors in Demand-Side Management Cost-Benefit Analysis". It is determined using a discount rate, the existing boiler age, the new boiler lifetime, the high efficiency boiler cost, the baseline boiler cost, and the remaining useful life of the existing boiler and putting them into an alogrithm that takes into account the time value of money.	$4,127 for forced hot water, $2046 for steam
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler		Uses Deferred Replacement Credit method described in "Correcting Common Errors in Demand-Side Management Cost-Benefit Analysis". It is determined using a discount rate, the existing boiler age, the new boiler lifetime, the high efficiency boiler cost, the baseline boiler cost, and the remaining useful life of the existing boiler and putting them into an alogrithm that takes into account the time value of money.	$1,766 for oil, $4,127 for propane
NH - Liberty	Boiler	NO DETAILS AVAILABLE	NO DETAILS AVAILABLE	Steam = $2,406. Forced Hot Water = $4,127

State - Program Administrator	Efficient Measure Description	Early Replacement - Fully Installed Cost Amount, UNADJUSTED (equipment + labor)	Early Replacement - Cost Calculation METHOD for Cost Effectiveness (e.g., Full UNADJUSTED Cost, Avoided Replacement Cost Adjustment, Deferred Replacement Cost Adjustment w/ real levelized costs)	Early Replacement Cost AMOUNT Recorded (may be different than Full Unadjusted Cost)
CT - CL&P, UI	Central AC	After the project, the unadjusted installed cost is recorded in the database.	Installation costs are estimated and only used to set incentive levels (what level of incentive will drive the customer to choose to replace the existing equipment? Installed costs are estimated to determine payback for equipment replacement and what incentive level will induce customers to pursue early retirement.). After the project, the installed cost is recorded in the database.	Unadjusted Full Install Cost
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Central AC or HP Early Replacement		Unknown	$1,000 cost adjusted for deferred replacement
CT - CL&P, UI	Furnace	After the project, the unadjusted installed cost is recorded in the database.	Installation costs are estimated and only used to set incentive levels (what level of incentive will drive the customer to choose to replace the existing equipment? Installed costs are estimated to determine payback for equipment replacement and what incentive level will induce customers to pursue early retirement.). After the project, the installed cost is recorded in the database.	Unadjusted Full Install Cost
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Furnace	Recorded for each project, but includes total cost of everything installed at the time (may include A/C, insulation, etc.)	Uses method described in "Correcting Common Errors in Demand-Side Management Cost-Benefit Analysis". It is determined using a discount rate, the existing boiler age, the new boiler lifetime, the high efficiency boiler cost, the baseline boiler cost, and the remaining useful life of the existing boiler and putting them into an alogrithm that takes into account the time value of money.	Both incremental measure cost and full unadjusted cost are recorded. Unitil: uses deemed incremental costs

Appendix M: Study Measures – Other Information

State - Program Administrator	Efficient Measure Description	Other Information	Info Sources Used
CT - CL&P, UI	Boiler	Early Retirement savings are shown as the sum of the lost opportunity savings (normal replacement) and the retrofit savings (RUL of existing unit against existing unit efficiency). When a boiler is also used for domestic hot water, those savings are also included and are estimated using the hot water load from the water heater program	Connecticut Program Savings Documentation 2013, Energize Connecticut website, Star Supply website
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	This program was designed to remove very old boilers from homes. To qualify for the extra incentive, the existing boiler needs to be at least 30 years old. This is not a new program but a new way of counting savings. They are now claiming some additional savings (and lower lifetime) in the HEHE program to account for the % of equipment that was early retirement based on a recent evaluation study.	Massachusetts TRM, Rhode Island 2014 TRM
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Boiler	"Correcting common errors in cost benefit analysis" paper was used in this analysis	Massachusetts TRM, GasNetworks.com, "Incentive Programs for Residential Energy Efficiency & Renewable Energy Projects In Massachusetts, August 2013"
NH - Liberty	Boiler		MA TRM 2013-2015; Rebate form, and "Early Retirement" excel forms. Communications with Liberty program manager.
CT - CL&P, UI	Central AC	Early Retirement savings are shown as the sum of the lost opportunity savings (normal replacement) and the retrofit savings (RUL of existing unit against existing unit efficiency)	Connecticut Program Savings Documentation 2013, Energize Connecticut website

State - Program Administrator	Efficient Measure Description	Other Information	Info Sources Used
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Central AC or HP Early Replacement	Installation of new equipment is verified. Age of existing equipment is not verified and is assumed to be 10-12 years.	Massachusetts TRM, Mass. Statewide Three-year plan
CT - CL&P, UI	Furnace	Early Retirement savings are shown as the sum of the lost opportunity savings (normal replacement) and the retrofit savings (RUL of existing unit against existing unit efficiency)	Connecticut Program Savings Documentation 2013, Energize Connecticut website, Star Supply website
MA - National Grid, NSTAR, Cape Light Compact, Unitil	Furnace	Functionality and age are verified by auditor. New furnace must have ECM fan	Massachusetts TRM, interview with program managers, masssave.com
MD - First Energy	HWPH		MA TRM; interview with program managers; provided customer data
MD - SMECo, Pepco, BGE	HWPH		MA TRM; interview with program managers; provided customer data
NH - PSNH	HPWH		interview with program managers; provided customer data
MD - First Energy	Air Source Heat Pump		MA TRM; interview with program managers; provided customer data
MD - SMECo, Pepco, BGE	Air Source Heat Pump		MA TRM; interview with program managers; provided customer data
NH - PSNH	Air Source Heat Pumps		interview with program managers; provided customer data
MD - First Energy	Central AC		MA TRM; interview with program managers; provided customer data
MD - SMECo, Pepco, BGE	Central AC		MA TRM; interview with program managers; provided customer data
NH - PSNH	Central AC		