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| **Central Air Conditioning**  **Impact and Process Evaluation**  ***DRAFT***  **5/30/2014** |

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| **Submitted to:**  **Connecticut Energy Efficiency Board** |

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| **Submitted by:**  **NMR Group, Inc. and DNV GL** |

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# Executive Summary

The Connecticut Energy Efficiency Board (EEB) requested that the evaluation team of NMR Group, Inc. and DNV GL perform a comprehensive central air conditioning (CAC) impact and process evaluation. This report describes the objectives of the study, the methods and analysis procedures used, and the study findings.

## Findings

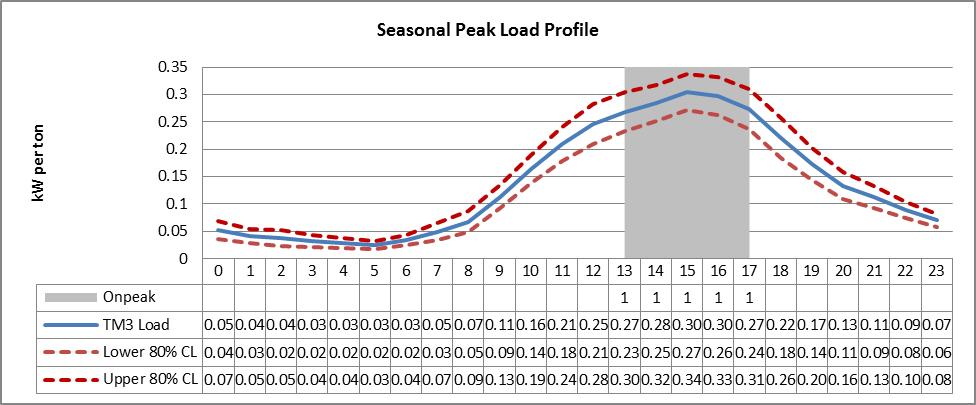
The section below presents the impact and process results. The team begins each section with an overview of the objectives, the methods employed and findings.

### Impact Evaluation

The primary goal of the impact evaluation was to determine the program electric energy and summer on peak and seasonal peak demand savings. In addition, the EEB and Connecticut Light and Power (CL&P) and The United Illuminating Company (UI, collectively the Companies) were also interested in the provision of information on the performance and conditions observed around the installed CAC units, including load shapes, a characterization of CAC units as installed (including size, airflow and rated efficiency) and a determination of whether new replacement units are properly sized for the homes in which they were installed. The CAC units of interest are those installed using rebates provided by the Connecticut Energy Efficiency Fund through the Home Energy Solutions (HES) program or independently of the program.

To achieve these research goals, the evaluation team performed sampling and selection of 92 on-sites visits, including long term post-installation monitoring during the cooling seasons of 2012 and 2013. The visits included data collection on the areas served to support Manual J calculations, when appropriate, as well as true flow diagnostic testing. Regression modeling was applied to the field collected data to project measure savings, determine peak period impacts, and develop measure load shapes.

* The impact portion of this study was designed to provide program savings estimates through the use of a M&V data driven per unit savings estimate. It was also designed to help the Companies and EEB improve on forward looking calculations through recommendations to the Program Savings Document. The bullets below capture our conclusions and recommendations in this regard. The overall statewide Annual Savings factor (ASF) is 368.41 kWh/Ton, with an accompanying precision of ±11% at the 90% confidence interval. This compares to the current Program Savings Document Assumption of 357.6 kWh/Ton.
* The seasonal and On Peak Demand Savings Factor (DSF) is 0.45 and 0.24, respectively, each with precisions of better than ±7% at the 80% confidence interval.
* The overall statewide per unit average annual savings estimate is 208.41 kWh.
* The figure below shows the average daily profile for the Seasonal Peak period. The peak hours are shaded in grey, the mean load is depicted by the solid blue line and the dotted red lines show the lower and upper 80% confidence interval. The Seasonal Peak load occurs between 3:00 and 4:00 PM and the mean value is 0.30 kW/ton.



* Overall, the incentives provided for CAC installations appear to be generating significant levels of savings. This study estimates 1,345 MWh of energy savings associated with 2011 and 2012 CAC installations with a realization rate of 115.2% when compared to the raw tracking data. We estimate 1.405 MW of summer seasonal demand savings with a realization rate of 85.9%.
* There was some inconsistent adherence to the PSD in the tracking systems. When compared to the revised tracking data (tracking that has been corrected to better reflect PSD formulas), the realization rates are 121.9% and 77.1%, respectively. The energy realization rate is moderately high for energy savings, due to a higher annual savings factor than assumed in the PSD. The realization rate around the summer seasonal result is lower primarily due to a reduction in the seasonal demand factor as compared to the PSD.
* The team found 11% of inspected installed CAC systems were either oversized (4%) or undersized (7%) when compared to Manual J. Although the sample of units assessed in this manner was a subset of overall installations visited, we consider these results to be reasonable since there is some contractor judgment in determining the final unit size based on the nature of the ductwork observed, home shading, and home tightness, among other factors. Overall, we conclude that equipment sizing is not causing inefficiencies in the central air conditioning systems replaced under the Connecticut programs.
* Based upon our site work, unit efficiencies appear to be consistently tracked and accurate in the tracking system. Unit sizes, however, were noted to not consistently be accurately tracked.
* The assessment of unit air flow resulted in 49% of units having air flow at or below 350 CFM/ton. However, due to some uncertainty over whether all measurements were taken with blowers at full speed, the team believes that these lower measurements are not likely to be significantly affecting the efficiency of the program installed units.

### Process Evaluation

The main objective of the process evaluation was to identify methods to better induce early replacement of CAC units.[[1]](#footnote-1) Note that the evaluation team was told that the Companies follow a rule of thumb that any CAC more than 10 years old that is still functioning qualifies as an early replacement.

To achieve this objective, the study explored a variety of questions that sought to understand what factors customers consider when deciding to replace their CAC with particular emphasis on the role of standard and early replacement rebates, energy efficiency, information provided by HES vendors, and the advice of installation contractors. The team also included questions about Quality Installation, as this approach provides additional opportunities for rebates among households replacing CAC.

The survey focused on three groups of PY2011 HES participants: those who were recommended CAC replacement as part of the HES audit and

1. Obtained only a standard, $250 CAC rebate (n=70)
2. Obtained a $500 rebate ($250 standard CAC rebate plus $250 “Early Replacement” rebate) (n=70)
3. Were recommended CAC but did not obtain a rebate (n=100, of which 27 replaced CAC without a rebate and 73 did not replace their CAC)

The process evaluation yielded the following key findings:

* Despite the fact that the Companies offer substantial rebates meant to induce early retirement, having a newer, working CAC unit is a substantial barrier to replacement, particularly considering the cost of replacement even with substantial rebates. About one-fifth of participants who replaced their CAC with an early replacement rebate reported that their “old unit broke down.” If these units were truly not functioning, then the HES program did not actually achieve any “early retirement” savings from the replacement.
* The rebate was not one of the primary factors considered in the decision to replace a CAC (only about 5% of respondents volunteered it as factor considered), but rebates were important in the decision to replace an existing CAC system *with a high-efficiency* *ENERGY STAR® qualified model* (76% of rebate users said it was somewhat or very important)*.* The rebates played a more important role in decision-making for early replacement rebate users than for standard rebate users.
* Only 15 respondents used program-supported low-interest financing to replace their CAC, but 13 of them said the loan was somewhat or very important to their decision to replace the CAC unit.
* Participants who obtained an early replacement rebate were much more likely than other participant groups—especially than those who did not replace their CAC—to say that they were aware they could receive a rebate before the audit or before the survey call. However, they were no more likely than those who received a standard rebate to say that they had had plans to replace their CAC equipment before the audit.
* Participants rely more strongly on the advice and opinions of installation contractors over HES vendors when deciding whether to replace the CAC and with which equipment.
* Of those who did not replace their CAC despite the recommendation, one quarter plan to do so within the next five years.
* The data suggest that as much as four-fifths of participants who did not replace their CAC might have qualified for an early replacement rebate had they replaced their CAC.
* Participants who did not use the rebate to replace a CAC suggested that the HES vendors provide more information that explains the benefits of early replacement and perform follow-up calls to encourage following through with audit recommendations.
* There is opportunity to increase participant awareness and use of Quality Installation.

## Recommendations

Based on the impact findings, the Companies or EEB may wish to:

* Consider the use of the seasonal peak DSF from this study (0.45) in lieu of the PSD assumption of 0.59.
* Re-examine the manner in which tracking savings are calculated to ensure adherence to the PSD. Notable items in this regard include ensuring use of the proper baseline when calculating tracking savings and ensuring proper crediting of all savings associated with retrofit events.
* Re-examine the method being used to gather and input CAC unit sizes (tons) in the tracking system.

Based on the process findings, in planning for future program marketing and encouraging early replacement of CAC, the Companies or EEB may wish to:

* Better emphasize, and effectively communicate, the size and types of CAC rebates available to HES participants. As one participant noted, “[They] should say up front about [the] $500 rebate.”
* In program-related communications, emphasize the benefits of replacing systems before they break down, even if the system does not appear to be all that old.
* Consider the means through which the program is marketed and how the program could bring CAC replacement rebates to the attention of participants earlier in the process. Currently, participants are most likely to learn about CAC replacement rebates from the HES vendor, followed by the utility website and a contractor. In order to reach the target audience with rebate information sooner in the program process, improving the likelihood of early CAC replacement, the Companies or EEB may wish to consider exploring other approaches for getting out the word about the availability of substantial rebates for CAC replacement and other residential measures earlier in the participation process. For example, immediately upon receiving an application, prior to approving it, the Companies could automatically send the applicant an eye-catching email or hardcopy mailing with information about the benefits of early CAC replacement and quality installation. There could be a “countdown” of periodic emails or mailings about the program from the point of application to the actual visit.
* While the energy auditor clearly plays an important role in participant decision-making, most participants reported that the installation contractor was even more important. The Companies or EEB may want to help foster closer relationships between HES vendors and CAC installation contractors to increase the likelihood of customers who obtain an audit following through with replacing their CAC with high-efficiency equipment.
* Continue to make financing available for CAC replacement. While only 16% of participants took advantage of financing, its availability mattered a lot to the majority of these customers.
* Although measuring free-ridership was not an objective of this study, the findings suggest that users of the early replacement rebate were more likely to have been aware of the rebate prior to their HES audit—pointing to free-ridership. However, users of the early replacement rebate were no more likely than standard rebate users to report having prior plans to install CAC equipment—suggesting free-ridership is not higher among this group.
* At the same time, a number of early replacement rebate users reported that they used the rebate to replace *a unit that was no longer functioning.* Given these findings, the EEB should consider examining free-ridership and Net-to-Gross for this program in the future. The team also suggests that the Companies have vendors explore how well the unit is functioning, the type and cost of repairs broken units may have needed, and the level of maintenance expenditures over the previous year. Additional data of this type would enable development of an algorithm to better categorize respondents as to early replacement versus replacement on breakdown, and understand the differences in their thinking and decision-making.
* The Companies may wish to consider some of the recommendations made by participants to encourage other customers to replace their CAC equipment. For example, given the customer bias against replacing equipment that still functions, the utilities could find ways to ensure that when HES vendors recommend replacing CAC they always provide information on costs and savings and on the logic of replacing older but still-functioning units with new units of higher efficiency, or could follow up with participants after the audit to encourage them to pursue recommended measures.
* The Quality Installation option could be better supported. HES participant awareness of this option was low. The anecdotal evidence offered by participants in open-ended questions suggests that there are substantial challenges to the implementation of the Quality Installation option, not the least of which is a shortage of qualified technicians. If the Companies wish to garner additional CAC savings by increasing the rate of Quality Installation of CAC in their service territories, they may first need to assess how to increase the number of qualified technicians in their service territories.

# Introduction

The Connecticut Energy Efficiency Board (EEB) requested that the evaluation team of NMR Group, Inc. and DNV GL perform a comprehensive central air conditioning (CAC) impact and process evaluation. The team worked with the EEB evaluation consultant to scope the objectives and methods for this study in 2012 and engaged in data collection and analysis activities in both 2012 (impact) and 2013 (impact and process). This report describes the objectives of the study, the methods and analysis procedures used, and the study findings.

## Research Objectives

### Impact Evaluation

The primary goal of the impact evaluation was to provide the EEB, Connecticut Light and Power (CL&P) and The United Illuminating Company (UI, collectively the Companies) with information necessary to determine energy- and demand-savings for CAC installed using rebates provided by the Connecticut Energy Efficiency Fund. Households may have used these rebates through the Home Energy Solutions (HES) program or independently of the program. The Process Evaluation described below addresses the rebate program.

The impact evaluation had two core objectives:

* To determine the program electric energy savings targeted to achieve ±10 precision at the 90% level of confidence
* To estimate program electric energy demand savings coincident with summer On Peak and Seasonal Peak periods targeted to achieve ±10 precision at the 80% level of confidence.

In addition, the EEB and the Companies were also interested in the provision of information on the performance and conditions observed around the installed CAC units. There were three objectives related to this goal:

* The provision of CAC load shapes
* A characterization of CAC units as installed (including size, airflow and rated efficiency)
* A determination of whether new replacement units are properly sized for the homes in which they were installed.

### Process Evaluation

The main objective of the process evaluation was to identify methods to better induce early replacement of CAC units.[[2]](#footnote-2)

To achieve this objective, the study explored a variety of questions. These included:

* What factors do customers consider when deciding to replace their CAC?
* What role does energy efficiency play in the decision to replace a CAC?
* What role do rebates for energy-efficient CAC play in the decision to replace a CAC?
* Why do some customers decide to use the rebate and others do not?

For these and related questions, the study explores how the responses compare between those recommended early replacement of a CAC and those recommended to exchange one near the end of its useful life. The study also addresses the barriers and the drivers to early replacement of CAC.

# Methods and Analysis

## Impact Methods and Analysis

Table ‎2-1 presents the core impact study objectives and the methods employed to inform each. To achieve these research goals, the evaluation team first developed and deployed a robust sampling methodology based on Model Based Statistical Sampling (MBSS) techniques. Measurement and verification (M&V) activities, including long term post-installation monitoring during the cooling seasons of 2012 and 2013, were next performed on a sample of 92 program-rebated CAC units selected using these MBSS methods. The data collected at these sites included information to characterize CAC installations and perform Manual J calculations, where appropriate. Finally, regression modeling was applied to the field collected data to project measure savings, determine peak period impacts, and develop measure load shapes. These are discussed in more detail following the table.

Table ‎2-1: Relationship of Impact Objectives to Methods

| **Objective** | **Research Questions** | **Methodology** |
| --- | --- | --- |
| To determine the program electric energy savings targeted to achieve ±10 precision at the 90% level of confidence at the state level. | What are the annual electric savings of rebated CAC units? | Addressed through the performance of on-sites with post M&V with one-half performed in the summer of 2012 and the remainder in the summer of 2013. Savings dependent on the development of individual regression equations. |
| To estimate the program electric energy demand savings coincident with summer On Peak[[3]](#footnote-3) and Seasonal Peak[[4]](#footnote-4) periods targeted to achieve ±10 precision at the 80% level of confidence at the state level. | What are the annual seasonal and On Peak demand savings of the program? | Addressed through the performance of on-sites with post M&V with one-half performed in the summer of 2012 and the remainder in the summer of 2013. Coincident demand savings derived from load shapes established from the individual regression equations cited above. |
| To provide CAC load shapes. | How do the load shapes of the installed CAC units behave? What do they look like? | Addressed through the aggregation of the individual load shapes above. |
| To characterize CAC units as installed. | What are the key characteristics of the installed units (airflow, efficiency, size)? | Primarily addressed through the on-site work. As part of our audit of the installed CAC units, the team performed air flow testing and gathered information on the installed unit. |
| To determine whether new replacement units are properly sized for the homes in which they were installed | Are installed CAC units properly sized? | Assessed through site specific Manual J calculations, based on data collected during the field site visits and compared to the sizing of the unit installed at that site. |

### Sampling

The Companies provided data on all households that received program supported CACs installed in 2011 and 2012, including any initiated through HES or independently of that program. Table ‎2-2 presents the final program population data. In total, 6,557 rebates were provided across the two years. Approximately 73% of statewide activity during this time participated through CL&P (4,773) with the remainder having participated through UI (1,784). The vast majority of CAC rebate activity was through non-HES channels.

Table -: Original 2011 and 2012 Program Year Rebates by Utility

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Utility** | **Total** | **HES** | **Non-HES** | **% of Population** |
| Program Year 2011 | | | | |
| CL&P | 2,765 | 111 | 2,654 | 76.0% |
| UI | 873 | 0 | 873 | 24.0% |
| **2011 Total** | 3,638 | 111 | 3,527 | **100.0%** |
| Program Year 2012 | | | | |
| CL&P | 2,008 | 144 | 1,864 | 68.8% |
| UI | 911 | 0 | 911 | 31.2% |
| **2012 Total** | **2,919** | 144 | 2,775 | **100.0%** |
| **Total** | | | | |
| CL&P | 4,773 | 255 | 4,518 | 72.8% |
| UI | 1,784 | 0 | 1,784 | 27.2% |
| **Grand Total** | **6,557** | **255** | **6,302** | **N/A** |

**Sample Design and Selection**

To sample across two summers, the team created a sample design that would achieve the overall objective of ±10% relative precision at the 80% confidence interval for summer peak and seasonal demand impacts and ±10% relative precision at the 90% confidence interval for energy use, each at the state level. In our design, each unit that received a rebate was considered a sample unit (i.e., each CAC condenser unit was a single sample point). The team’s understanding of the Independent Service Operator of New England’s (ISO-NE) Manual for Measurement and Verification of Demand Reduction Value from Demand Resources (M-MVDR) is that both CL&P and UI can use an overall state level peak demand result since Connecticut is a single load zone, and they both implement and calculate program savings in a similar manner.

Central to the sample design was the assumed coefficient of variation (c.v.). In this study, the team assumed a c.v. of 0.75 to estimate the sample size needed for the coincident demand estimate and a c.v. of 0.8 for the energy savings estimate. These assumptions were based upon our past experience with CAC sample design work in California, a 2009 ADM study[[5]](#footnote-5) and the ISO-NE’s M-MVDR.

Table ‎2-3 below presents the estimated sample sizes calculated to achieve ±10% relative precision at the 90% confidence interval for energy and ±10% relative precision at the 80% confidence interval for coincident demand. This table was based on the 2012 population (known at the time of sampling) and also shows the Z value[[6]](#footnote-6) necessary to calculate sample size. As a result of the prohibitively large sample size needed to achieve the energy savings at the desired level of precision and the importance of summer peak and seasonal demand impacts for this measure, the EEB evaluation consultant and team together decided to perform 91 visits overall, which is sufficient to achieve ±10% relative precision at the 80% confidence interval for peak demand savings.

Table -: Sample Design

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coefficient of Variation (c.v.)** | **Population (N)** | **Z-value** | **Relative Precision** | | | **Sample (n)** |
| 80% Confidence (Coincident Demand) | | | | | | |
| 0.75 | 3,638 | 1.282 | | 10% | 91 | |
| 90% Confidence (Energy) | | | | | | |
| 0.8 | 3,638 | 1.645 | | 10% | 166 | |

The team ended up performing 92 sites due to an added site recruited in the 2012 summer sample. They metered 46 randomly selected sites in the summer of 2012 and another 46 in the summer of 2013. Breaking up the metering over two summers helped ensure a full range of weather conditions would be available for the regression analysis work.

Table ‎2-4 presents the final disposition of the recruitment calls made for the 92 on-site visits based on the disposition codes provided in The American Association for Public Opinion Research’s (AAPOR) Standard Definitions.[[7]](#footnote-7) Based on the AAPOR algorithms, the response rate was 20.7% with a 36.4% refusal rate across both program years.

Table -: Final On-site Recruitment Disposition

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Disposition Code** | **Disposition Description** | **2011 PY Participants** | **2012 PY Participants** | **Total** |
| 1.1 | Completion | 46 | 46 | 92 |
| 2.11 | Household-Level Refusal | 65 | 97 | 162 |
| 2.21 | Respondent Never Available | 91 | 60 | 151 |
| 4.32 | Disconnected Number | 13 | 7 | 20 |
| 4.41 | Number Changed | 5 | 14 | 19 |
| 4.54 | Person Not Household Resident | 1 | 0 | 1 |
| Total Customers Called | | 221 | 224 | 445 |
| Response Ratea | | 20.8% | 20.5% | 20.7% |
| Refusal Rateb | | 29.4% | 43.3% | 36.4% |

a Response Rate is the number of completions (1.1) by total customers called.

b Refusal Rate is the number of household-level refusals (2.11) by total customers called.

**Final Sample Characteristics**

The tables below present a comparison of the final primary sample and population characteristics based on utility, program channel, location, and unit efficiency and capacity. During the process of recruitment and site work, we realized that several heat pumps were included in the original sample frame. The tables below reflect the new population with these units removed. While the team did not establish quotas for these dimensions, it did track them during recruitment to ensure the final sample would be representative of the population on these parameters. The final sample is reasonably close in representing the population for all four of these criteria.

Table -: Overall Sample versus Population by Utility

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Utility** | **Population** | | **Sample** | |
| **N** | **%** | **n** | **%** |
| CL&P | 4,772 | 77.1% | 71 | 77.2% |
| UI | 1,414 | 22.9% | 21 | 22.8% |
| Total | 6,186 | 100.0% | 92 | 100.0% |

Table -: Overall Sample versus Population by Program Channel

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Channel**[[8]](#footnote-8) | **Population** | | **Sample** | |
| **N** | **%** | **n** | **%** |
| Lost Opportunity[[9]](#footnote-9) | 5,240 | 84.7% | 79 | 85.9% |
| Retrofit | 946 | 15.3% | 13 | 14.1% |
| Total | 6,186 | 100.0% | 92 | 100.0% |

Table -: Overall Sample versus Population by Location

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Location** | **Population** | | **Sample** | |
| **N** | **%** | **n** | **%** |
| Inland | 4,338 | 70.1% | 64 | 69.6% |
| Shoreline | 1,848 | 29.9% | 28 | 30.4% |
| Total | 6,186 | 100.0% | 92 | 100.0% |

Table -: Overall Sample versus Population by Unit Efficiency

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Efficiency (EER)a** | **Population** | | **Sample** | |
| **N** | **%** | **n** | **%** |
| 11.5-12.4 | 1,542 | 24.9% | 19 | 20.7% |
| 12.5-13.4 | 4,192 | 67.8% | 64 | 69.6% |
| 13.5-14.4 | 434 | 7.0% | 9 | 9.8% |
| >14.4 | 18 | 0.3% | 0 | 0.0% |
| Total | 6,186 | 100.0% | 92 | 100.0% |

a Energy Efficiency Ratio

### Data Collection and Metering

Detailed M&V activities were conducted at a sample of 92 program participant sites selected using the aforementioned methods. The research goals of this study aligned themselves with a clearly defined set of on-site activities. Determining demand savings during the coincident peak demand period necessitated equipment monitoring throughout the summer. Savings load shape development required continuous equipment monitoring over a period including both summer and shoulder months. Lastly, characterizing equipment required collection of nameplate information, performance test data, and contextual data. The overlapping requirements of the three primary research goals allowed for the development of a streamlined on-site approach that simultaneously addressed the needs of each study objective. The on-site activities implemented for this project were divided into distinct two components: equipment characteristics data collection and HVAC unit monitoring.

*Equipment Characteristics Data Collection.* Determination of installed equipment characteristics was a goal of the study on its own, but it was also a prerequisite for load shape development and coincident peak demand savings determination. During each initial site visit, the following data were collected off of the newly installed equipment:

Table -: Information gathered from Newly Installed Equipment

|  |  |
| --- | --- |
| **Outdoor Unit** | **Indoor Unit** |
| * Model and Serial Number | * Model and Serial Number |
| * Size (tons) | * Fan HP |
| * Refrigeration type | * Coiling Coil Model Number (if accessible |
| * Compressor HP & RLA |  |
| * Condenser Fan HP |  |
| * Manufacturing Date (Month/Year) |  |

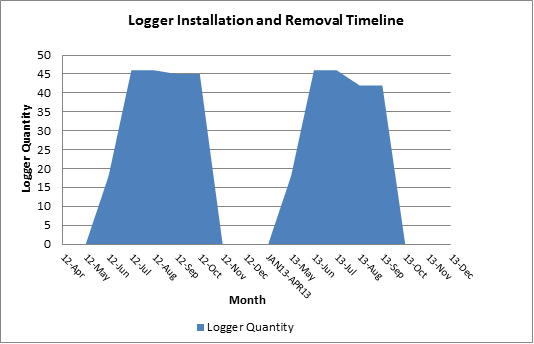
Equipment characteristic data collection also included an airflow testing component. The airflow rates of all sampled units were tested using an Energy Conservatory TrueFlow Grid (a differential pressure air flow meter that temporarily replaces the system’s air filter during testing).

Unit operations data were also collected while on site to increase the number of potential regression model drives in the site-level analysis. Home owners were asked if they operated their CAC system continuously, turned it on and off manually as needed, or followed programmed thermostat schedules. The primary cooling set point was also recorded in all cases. Typical daytime and nighttime home occupancy schedules were also surveyed.

*HVAC Unit Monitoring.* The team metered the same number of units (46) during the 2012 and 2013 cooling seasons. Condensing units were monitored with true power loggers whenever possible, while air handling units (AHU) were monitored with amperage loggers. True power logging was reserved for condensing units because they are more susceptible to power factor fluctuations than AHUs. In instances where it was not safe to install a true power logger because of space constraints, an amperage logger was used instead. Of the 46 units in the 2012 summer sample, seven condenser units were monitored with amperage loggers; five units in the 2013 summer sample were monitored with amperage loggers. More details on the metering equipment used and their specifications are contained in Appendix B.

Figure ‎2‑1 presents an overview of the number of CAC units logged by month during each summer. Nearly all loggers were installed during the summer months of June, July, and August, which is particularly important for purposes of assessing performance during Seasonal Peak periods that might occur at any time during the summer months.

Figure ‎2‑1: Logger Installation Overview



*Off-Site Data Collection.* Hourly temperature readings spanning the entirety of the two summer monitoring periods were collected from two nearby weather stations in Bridgeport and Hartford[[10]](#footnote-10). In the subsequent regression analysis, these data were matched to specific sites and used to model the power/temperature response of each central air conditioner.

### Sample attrition in analysis and data cleaning

As is expected in any data collection exercise, the team witnessed some loss of data. Every effort was made to use the available data without significantly affecting the quality of the analysis. Air Handling Unit (AHU) power data could not be collected for eight out of the total 92 sites that were sampled (three sites from 2013 and five sites from 2012) due to the failure of the logging equipment. The AHU site spot readings were used for these sites as a proxy. Since AHU power is a small contributor to the overall cooling power used by an air conditioner, this approximation did not impact the analysis significantly. Unfortunately, there were four sites (three from 2013 and one from 2012) for which problems with the logging equipment meant that the team had no condenser data or had partial/corrupt condenser data. The team decided to exclude these sites from the final analysis since it had no way to salvage these sites without significantly impacting the quality of the analysis. The analysis was therefore performed on M&V data for 88 out of the total 92 sites (4.4%). We regard this level of data loss/attrition to be reasonable for studies of this nature. In a C&I HVAC load shape study recently performed for the Northeast Energy Efficiency Partnership[[11]](#footnote-11) we experienced a 4% loss of sample due to metering/deployment failure.

### Analysis

Determining CAC measure savings and estimating coincident peak load reductions required development of savings load shapes. CAC unit power regression profiles developed from monitoring data formed the foundation of these load shapes.

Developing regression models for all units in the evaluation sample first required pre-processing and resampling trend data. For each unit, AHU amperage data readings were multiplied by spot measured voltage and power factor values to create an AHU power profile. The team employed a similar process for condensing units subject to amperage logging. The condenser and AHU power profiles were then synchronized and added to develop a total CAC unit power profile. The team only included power data from the AHU profile in the total power profile during periods when the condensing unit was on. As a result, the total power profile for each unit captured only energy use corresponding to cooling operation and ignored ventilation operation. The power profiles for all units were next resampled from their original five-minute format to an hourly format to prepare the data for regression modeling.

The team tested many regression model formulations in SAS to identify the model that best fit the available data. These tests used a variety of terms to account for outdoor temperature, weekday, time of day, consecutive hot days, occupancy patterns, and indoor temperature. Models were compared on the basis of average coefficient of determination (R2) across the entire evaluation sample. The team selected the model that yielded the highest R2 and applied the model to all units. For this study, we decided to use with R-squared because it provides an overall measure of the success of a regression in predicting dependent variable from independent variables. If a model gives an average R-squared value greater than 0.5 across all the sites, generally speaking, it can be said that the model fits well for the majority of the data.

The model that best fit the metered data included a variable base cooling-degree hour (CDH) term, a term specific to each weekday hour, a preceding 48-hour mean temperature term, and two sequential hot day terms.

The final model was specified as,

where for a particular unit,

= CAC power draw for weekday *d* during hour *h*

= Weekday *d* and hour *h* specific constant accounting for time dependent load

variability

= cooling degree-hours, base

= 0/1 dummy indicating that a day is the second hot day in a row

= 0/1 dummy indicating that a day is the third or more hot day in a row

= Mean temperature for the preceding 48 hours

, , , = coefficients determined by the regression

Note that in the above formulation, all coefficients with a subscript of *“dh”* took on different values for each unique combination of weekday *d* and hour *h.*

Each individual term played a key role in modeling unit performance. The CDH variable accounted for the direct impact of current ambient temperature on cooling load. Estimation of unit specific values of the degree day base was particularly important because residential HVAC units experience a wide range of occupant behaviors (set points, tolerance for hot temperatures, etc.). Using a variable degree day base made the model flexible to these behaviors. The sequential hot day and preceding 48-hour mean temperature terms accounted for the impact of thermal inertia, both on cooling load and occupant behavior. Lastly, the weekday and hour specific constant, , accounted for time dependent load drivers such as occupancy. In summation, the model definition recognized the impact of present temperature, thermal inertia, and occupant behavior on CAC energy use.

The team applied many model definitions in an effort to reduce error for problematic sites. After investigating several models, the team selected the one with the tightest distribution of individual R2 values and higher mean R2. The application of this model definition to the population of sites yielded an average R2 value of 0.554 and the distribution of unit-specific R2 values indicated in Figure ‎2‑2 below.

Figure ‎2‑2: Distribution of R-Square for the model using all data

The team also checked the robustness of our model by including only the period when the unit was in the cooling mode. The average R2 turned out to be 0.615. The distribution of unit-specific R2 values is depicted in Figure ‎2‑3 below.

Figure ‎2‑3: Distribution of R-Square for the Model using Values in Cooling Mode

*Normalizing and Extrapolating to a Full Year Shape.* The unit specific regression model results provided a basis for normalizing observed demand to typical weather conditions and extending the logging period data to a full year load shape. The regression models were applied to a single 8,760 hour Typical Meteorological Year (TMY3[[12]](#footnote-12)) weather file in the regression analysis. This blended file was developed by weighting Bridgeport and Hartford weather station data. In this way, the energy use profiles observed during the logging periods were extrapolated to typical year load shapes.

The weather stations used in this analysis, located at Bradley Airport (Hartford) and Bridgeport, were assigned to sites based on their proximity to the coast. Using the same base weather stations for regression modeling and 8,760 hour extrapolation properly normalized the models consistently. This principle is best explained by way of counter-example: imagine that a model was built using weather station logger data gathered locally at a site, and then applied to a weather file developed from a government weather station 20 miles away. If, on average, the temperature at the site were fivedegree Fahrenheit hotter than the temperature at the government weather station at any time, then the model would consistently under-predict cooling load when applied to the weather file.

*Site Level Savings Load Shape Development.* Using the unit specific 8,760 hour load shapes developed from the preceding step, site level savings were determined as follows:

where,

= Energy use in hour *i* predicted from the unit regression model using TMY weather

= Nominal installed equipment EER [kBtu/kWh][[13]](#footnote-13)

= Nominal baseline EER [kBtu/kWh]

This savings calculation approach yielded an estimate of gross annual savings and an hourly savings load shape for each metered unit. Additionally, the savings load shapes provided a basis for determining anticipated average load reductions during the On Peak[[14]](#footnote-14) and Seasonal Peak[[15]](#footnote-15) demand periods of interest. More information on how Seasonal Peak hours were determined for this study is provided in Appendix C.

### Manual J

The team also collected data to perform Manual J calculations to assist in determining whether Connecticut residential HVAC contractors consistently right-size new units. This work was an add-on to the original core project budget, and the analyses proceeded with a limited budget. As such, the team performed Manual J analysis only on houses that had an easily determined zonal boundary for the installed system (i.e., 55 out of 92 sites had a separated and defined zone for the installed CAC unit). Homes not included in the analysis were those with multiple systems in which zonal boundaries were not easily determined and included an interaction of these multiple systems.

To calculate Manual J load requirements, the team used Wrightsoft Right-Suite Universal software. Wrightsoft is the original software program for Manual J calculations approved by the Air Conditioning Contractors of America (ACCA) and has been a technical partner with ACCA since 1986. Wrightsoft is considered the industry leading load calculation program. The analysis relied on the current 8th edition of the ACCA Manual. The program was used to develop Block (whole house) calculations without the assessment of room by room calculations which would be done for actual ductwork installation specifications. Outdoor weather conditions were calculated by the software using historical recorded weather data from either the Hartford Bradley National Weather Station or the Bridgeport Sikorsky National Weather Station depending on the location of the sample site. The mean indoor temperature was set to remain consistent at 68 degrees heating, 72 degrees cooling and 50% indoor relative humidity for all sites. Block appliance calculations were used to estimate average household appliances and their effect of residual heat on cooling loads and bedroom counts were used to estimate the number of occupants for each site calculation.

## Process Methods and Analysis

The evaluation team gathered data for this study via a telephone survey of participants in the Home Energy Solutions (HES) Program. The participants were offered either a standard $250 rebate or a $500 early replacement rebate ($250 standard plus $250 additional for early replacement). Only households that took part in the HES program were eligible for the $500 early replacement rebates. The study focused on participants from PY2011 (chosen to be consistent with the impact evaluation) who were recommended CAC replacement as part of the HES audit.[[16]](#footnote-16) Only customers who already had CAC at the time of the HES audit were eligible for the study (i.e., they had to be in the position of replacing a unit, not installing a system in a home that did not already have one). Participants were randomly selected to be included in the survey. Table ‎2-10 displays the sample design, describing each stratum, sample sizes, and the final sampling errors (calculated at the 90% confidence level with a 50/50 break in responses).

Table -: Participant Survey Sample Design

|  |  |  |
| --- | --- | --- |
| **Strata** | **Sample Size** | **Sampling Error** |
| Obtained $250 rebate | 70 | 9.8% |
| Obtained $500 rebate | 70 | 9.8% |
| Recommended CAC rebate but did not use it | 100 | 8.2% |
| *Did not replace CAC* | *73* | *n/a* |
| *Replaced CAC but did not use rebate* | *27* | *n/a* |

Braun Research conducted the data collection using Computer Assisted Telephone Interviewing (CATI) telephone surveys. Out of a sample of 4,373 HES participants, Braun Research attempted to contact 4,188 randomly selected participants who appeared to meet the study criteria based on the sample data. Of these, 1,592 were usable numbers for households found to be qualified for the study. Braun Research completed telephone interviews with 240 households, for a response rate of 15%.

The evaluation team weighted the survey data proportional to the percentage of 2011 HES participants for each utility.[[17]](#footnote-17) The tables below report all significant differences between subgroups at the 90% confidence level. Significant differences are noted as the letter (in superscript) corresponding with the subgroup with which a significant difference was detected. Subgroup letters are displayed in the table headings.

The team performed the analysis using the Statistical Package for Social Sciences (SPSS), supplemented by Excel. The majority of analyses involved calculating averages and describing the proportions of respondents providing particular answers to survey questions.

# Key Findings

## Impact Findings

To begin our assessment of program impacts, the team reviewed the annual electric energy savings calculation methodology from the Connecticut Program Savings Documentation (PSD, 2012). This review was performed to fully understand the manner in which the PSD requires calculating savings, including all inputs and assumptions. For savings due to retrofit, it is necessary to add the savings from the retrofit gross savings formula and the lost opportunity gross savings formula together to get the full program credit for the early retirement of a working unit where it would have been installed until failure. The equations are shown below.

* Retrofit Gross Energy Savings- Electric
  + )
* Retrofit Gross Peak Demand Savings
* Lost Opportunity Gross Energy Savings
* Lost Opportunity Gross Peak Demand Savings

Where,

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **Description** | **Units** | **Values** |
|  | Annual electric energy savings-cooling | kWh |  |
| ASF | Annual Savings factor | kWh/ton |  |
|  | Installed cooling capacity | Tons | Input |
|  | Seasonal demand savings factor | kW/ton |  |
|  | Summer seasonal demand savings –cooling | kW |  |
|  | Existing EER | Btu/Watt-hr | 8 |
|  | Baseline EER | Btu/Watt-hr | 11 |
|  | Installed EER | Btu/Watt-hr | Input |

\* These values were calculated based on “Residential Central AC Regional Evaluation, study by ADM Associates, Inc., in November 2009.

The tracking systems provided by CL&P and UI for this study contained a lot of information on installed units, including energy and peak summer savings. Table ‎3-4 below presents the raw savings as provided in the tracking databases. Given the importance of the circumstances around the installed unit, the table summarizes these savings according to whether the CAC unit installed was classified as a lost opportunity or a retrofit. CL&P activity represents just over 77% of all energy savings. Statewide, 84.4% of rebates were issued for lost opportunity installations, with an accompanying 82.5% of statewide energy savings. UI has a more equal split of activity between lost opportunity and retrofit events when compared to CL&P. Overall, CL&P and UI tracked savings of 1,168 MWh from CAC program installs in 2011 and 2012.

Table -: 2011 and 2012 CAC Raw Tracking Savings Summary

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sponsor** | **Population** | | | | |
| **N** | **Energy Savings** | | **Summer Seasonal Demand Savings** | |
| **kWh** | **Percent** | **SkW** | **Percent** |
| Lost Opportunitya | | | | | |
| CL&P | 4,518 | 824,987 | 85.6% | 1,004.6 | 78.9% |
| UI | 722 | 139,024 | 14.4% | 269.1 | 21.1% |
| Total | 5,240 | 964,011 | 100.0% | 1,273.7 | 100.0% |
| Retrofit | | | | | |
| CL&P | 254 | 75,555 | 37.1% | 122.8 | 33.9% |
| UI | 692 | 128,095 | 62.9% | 239.4 | 66.1% |
| Total | 946 | 203,650 | 100.0% | 362.2 | 100.0% |
| Overall | | | | | |
| CL&P | 4,772 | 900,542 | 77.1% | 1,127.4 | 68.9% |
| UI | 1,437 | 267,119 | 22.9% | 508.5 | 31.1% |
| Total | 6,209 | 1,167,661 | 100.0% | 1,635.8 | 100.0% |

a For UI, units designated as new installations in the ‘inst\_desc’ field from the tracking system were classified as lost opportunity units. CL&P’s assumption that all units that were rebated are lost opportunity units was followed.

As part of understanding the results from this study, we reviewed the CAC tracking data and the manner in which those savings were being calculated. The following tables summarize the findings from our comparison of the tracking system annual kWh savings estimates for each CAC unit in the population to the savings calculated using the formulas provided in the Program Savings Documentation (PSD) for each year.

Table ‎3-2 below shows a comparison of the per unit UI tracking data to our calculation of savings using PSD formulas. There are two primary discrepancies of interest in this table. The first is the application of the PSD baseline. It is important to note that between 2011 and 2012, the PSD went from an assumed retrofit baseline of “using 8 if existing EER is not known” in 2011 to an assumed EER of 8 for all retrofit units in 2012[[18]](#footnote-18). The majority of the 2012 discrepancy noted in the retrofit “incorrect PSD Baseline application” row is due to the use of the tracking system baseline EER of 11 as opposed to the PSD baseline of 8. The other significant discrepancy also occurred in the 2012 retrofit bin. In these instances, UI appears to have calculated lifetime savings per the PSD then divided those savings by total measure life to estimate annual savings.

Table -: UI Comparison of Tracking to PSD Annual Savings Estimates

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Comparison of tracking kWh savings to PSD | Program Channel/Year | | | | | | Total (N=  1,414) |
| Lost Opportunity | | | Retrofit | | |
| 2011 (N=457) | 2012 (N=265) | Total (N=722) | 2011 (N=416) | 2012 (N=276) | Total (N=692) |
| No Discrepancy\* | 98.5% | 100.0% | 99.1% | 93.3% | 6.9% | 58.9% | 79.4% |
| Discrepancy (detail below) | 1.5% | 0.0% | 0.9% | 6.7% | 93.1% | 41.1% | 20.6% |
| Discrepancy Cause | | | | | | | |
| Incorrect PSD baseline application | 0.7% | 0.0% | 0.4% | 6.3% | 72.5% | 32.7% | 16.2% |
| Calculation inconsistent with PSD | 0.0% | 0.0% | 0.0% | 0.0% | 20.7% | 8.2% | 4.0% |
| Data entry error | 0.7% | 0.0% | 0.4% | 0.5% | 0.0% | 0.3% | 0.4% |
| Tracking claimed no savings | 0.2% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.1% |

\* Includes some very minor (<0.1%) differences in savings, presumably due to rounding.

Table ‎3-3below shows a comparison of the per unit CL&P tracking data to our calculation of savings using PSD formulas. There are two primary discrepancies of interest in this table. The first is the use of incorrect PSD formula in 2011. Essentially, these entries used the older 2010 PSD formula and not the revised 2011 formula. The majority of the 2011 discrepancy noted in the “calculation incorrect with PSD” is due to CL&P not correctly crediting their tracking savings with the retrofit portion of the PSD calculation. We do note that the 2012 PSD more explicitly points out the use of components in the calculation of retrofit CAC savings.

Table -: CL&P Comparison of Tracking to PSD Annual Savings Estimates

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Comparison of tracking kWh savings to PSD | Program Channel/Year | | | | | | Total (N=  4,772) |
| Lost Opportunity | | | Retrofit | | |
| 2011 (N=2,654) | 2012 (N=1,864) | Total (N=4,518) | 2011 (N=110) | 2012 (N=144) | Total (N=254) |
| No discrepancy | 62.8% | 99.9% | 78.2% | 0.9% | 88.9% | 50.8% | 76.7% |
| Discrepancy | 37.2% | 0.1% | 21.8% | 99.1% | 11.1% | 49.2% | 23.3% |
| Discrepancy Cause | | | | | | | |
| Used incorrect PSD formula | 37.0% | 0.0% | 21.8% | 4.5% | 0.0% | 2.0% | 20.7% |
| Calculation inconsistent with PSD | 0.0% | 0.0% | 0.0% | 94.5% | 11.1% | 47.2% | 2.5% |
| Data entry error | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.0% | 0.1% |

Table ‎3-4 shows the revised population savings by event and utility after correcting for the above cited discrepancies. As part of the process of reviewing the application of the PSD, 23 entries originally thought to be CAC units were actually heat pumps and were removed from the population. Overall, after adjusting the tracking savings to be more consistent with the PSD, the overall estimate of annual energy savings decreased by 7% while the summer kW savings increased by 11%. Our overall estimate of impacts after making revision to the tracking savings based on PSD calculations is 1,103 MWh of energy savings and 1.823 MW of summer seasonal peak demand savings.

Table -: 2011 and 2012 CAC Revised Tracking Savings Summary

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sponsor** | **Population** | | | | |
| **N** | **Energy Savings** | | **Summer Seasonal Demand Savings** | |
| **kWh** | **Percent** | **SkW** | **Percent** |
| Lost Opportunitya | | | | | |
| CL&P | 4,518 | 711,620 | 87.0% | 1,176.1 | 87.0% |
| UI | 722 | 106,170 | 12.9% | 175.5 | 12.9% |
| Total | 5,240 | 817,790 | 100.0% | 1,351.6 | 100.0% |
| Retrofit | | | | | |
| CL&P | 254 | 108,738 | 38.1% | 179.7 | 38.1% |
| UI | 692 | 176,694 | 61.9% | 292.0 | 61.9% |
| Total | 946 | 285,432 | 100.0% | 471.7 | 100.0% |
| Overall | | | | | |
| CL&P | 4,772 | 820,358 | 74.3% | 1,356 | 74.4% |
| UI | 1,414 | 282,864 | 25.7% | 467.5 | 25.6% |
| Total | 6,186 | 1,103,222 | 100.0% | 1,823.3 | 100.0% |

a For UI, units designated as new installations in the ‘inst\_desc’ field from the tracking system were classified as lost opportunity units. CL&P’s assumption that all units that were rebated are lost opportunity units was followed.

Discrepancies between equipment specifications reported in the tracking data and that which was recorded during field site visits are summarized in Table ‎3-5. During site visits the condenser unit’s model and serial numbers were recorded from the manufacturer name plate. Referencing the manufacturer’s specifications for the model, the unit’s output capacity in Tons was determined. The name plate also contains the Energy Efficiency Ratio (EER) of the unit.

Of the 88 units in the sample, the EER reported in tracking matched that of the field verification on 77 of the units. In the tracking data there were 10 units in which the EER was not reported. The one EER discrepancy found reported the EER of the unit in the tracking data was as 13.25 EER, while it was verified in the field as 12 EER.

When comparing the tracking data for unit capacity in Tons to field verification, greater discrepancies were found. Of the 88 units in the sample, the tracking data unit capacity and field verifications matched on 46 units. Of the remaining 42, one unit in the tracking data did not report the capacity, 27 units were found to be a higher capacity in Tons than in tracking, and 14 units were found to have a lower capacity in Tons. This level of discrepancy for unit capacity in Tons at 48% results in some question of how this data is being reported into tracking.

When further examining these 42 discrepancies, it was found that 55% were misreported by .5 Tons, 28% were misreported by 1.0 Tons and the remaining 17% reported at > 1.0 Tons. These discrepancies could be the result of a difference between recommended units vs. the actual unit installed by the contractor, where the contractor has adjusted the sizing of the unit based on additional factors determined at the site.

Table -: Discrepancies between Tracking and On-site Summary

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sponsor** | **N** | **EER** | | | | **Capacity (Tons)** | | | |
| **Same** | **Higher** | **Lower** | **Not in Tracking** | **Same** | **Higher** | **Lower** | **Not in Tracking** |
| Lost Opportunity | | | | | | | | | |
| CL&P | 66 | 56 | 0 | 1 | 9 | 31 | 21 | 14 | 0 |
| UI | 11 | 11 | 0 | 0 | 0 | 9 | 2 | 0 | 0 |
| Total | 77 | 67 | 0 | 1 | 9 | 40 | 23 | 14 | 0 |
| Retrofit | | | | | | | | | |
| CL&P | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| UI | 9 | 9 | 0 | 0 | 0 | 6 | 3 | 0 | 0 |
| Total | 11 | 10 | 0 | 0 | 1 | 6 | 4 | 0 | 1 |
| Overall | | | | | | | | | |
| CL&P | 68 | 57 | 0 | 1 | 10 | 31 | 22 | 14 | 1 |
| UI | 20 | 20 | 0 | 0 | 0 | 15 | 5 | 0 | 0 |
| Total | 88 | 77 | 0 | 1 | 10 | 46 | 27 | 14 | 1 |

Table ‎3-6 presents key results for the PSD formula based upon the findings from this M&V- based study. It includes the Annual Savings Factor (ASF, kWh/Ton), Seasonal and On Peak Demand Savings Factor (DSF, kW/ton), and mean savings values. The table provides this information for lost opportunity and retrofit savings events, with the baseline for these being 11 EER and eight or eleven EER (depending on program year), respectively. Precisions associated with each result are also provided, at the 90% confidence interval for the ASF and the 80% confidence interval for the two DSF, with the latter conforming to the requirements of the ISO-NE.

The overall statewide ASF is 368.41 kW/Ton, with an accompanying precision of ±11% at the 90% confidence interval. The ASF is used to reflect usage per ton in the PSD and is used with capacity and delta efficiency to calculate annual energy savings. The seasonal and On Peak DSF is 0.45 and 0.24, respectively, each with precisions of better than ±7% at the 80% confidence interval. The overall statewide per unit average annual savings estimate is 208.41 kWh, with an accompanying precision of ±31% at the 90% confidence interval. The overall statewide per unit seasonal and On Peak savings is 0.22 and 0.12, respectively, each with precisions of better than ±14% at the 80% confidence interval. Poor precisions associated with the retrofit results are largely due to smaller sample sizes among that subset.

**Table ‎3-6: Energy and Summer Demand Results by Savings Event**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Factors** | **Mean** | **Confidence Limit** | | **Precision** |
| **Lower** | **Upper** |
| Lost Opportunity (n=77) | | | | |
| Annual Savings Factor (ASF)(kWh/ton) | 364.64 | 323.31 | 405.98 | 11% |
| Seasonal Demand Savings Factor (DSF)(kW/ton)\* | 0.45 | 0.42 | 0.48 | 6% |
| On Peak Demand Savings Factor (DSF)(kW/ton)\* | 0.24 | 0.22 | 0.26 | 7% |
| Per Unit Annual Energy Savings (A kWh) | 167.89 | 146.50 | 189.28 | 13% |
| Per Unit Summer Seasonal Savings (S kW)\* | 0.21 | 0.19 | 0.22 | 8% |
| Per Unit Summer Onpeak Savings (O kW)\* | 0.11 | 0.10 | 0.12 | 9% |
| Retrofit (n=11) | | | | |
| Annual Savings Factor (ASF)(kWh/ton) | 394.78 | 229.39 | 560.17 | 42% |
| Seasonal Demand Savings Factor (DSF)(kW/ton)\* | 0.43 | 0.33 | 0.53 | 23% |
| On Peak Demand Savings Factor (DSF)(kW/ton)\* | 0.21 | 0.17 | 0.26 | 22% |
| Per Unit Annual Energy Savings (A kWh) | 492.04 | 13.10 | 970.98 | 97% |
| Per Unit Summer Seasonal Savings (S kW)\* | 0.34 | 0.18 | 0.50 | 46% |
| Per Unit Summer Onpeak Savings (O kW)\* | 0.20 | 0.09 | 0.31 | 55% |
| Overall (n=88) | | | | |
| Annual Savings Factor (ASF)(kWh/ton) | 368.41 | 326.71 | 410.11 | 11% |
| Seasonal Demand Savings Factor (DSF)(kW/ton)\* | 0.45 | 0.42 | 0.47 | 6% |
| On Peak Demand Savings Factor (DSF)(kW/ton)\* | 0.24 | 0.22 | 0.25 | 7% |
| Per Unit Annual Energy Savings (A kWh) | 208.41 | 142.84 | 273.98 | 31% |
| Per Unit Summer Seasonal Savings (S kW)\* | 0.22 | 0.20 | 0.25 | 11% |
| Per Unit Summer Onpeak Savings (O kW)\* | 0.12 | 0.11 | 0.14 | 14% |

\*Calculated at the 80% confidence interval

The team also developed daily profile plots for each of the coincident peak definitions. Figure ‎3‑1 shows the average daily profile for the On Peak period—that is, non-holiday weekdays 1:00 to 5:00 PM from June through August. The peak hours are shaded in grey. The mean load is depicted by the solid blue line and the dotted red lines show the lower and upper 80% confidence interval. The peak load occurs around 3:00 PM (i.e., the 15th hour) and the mean value is 0.25 kW/ton.

Figure ‎3‑1: Average Daily Load Profile for On peak Days

Figure ‎3‑2 shows the average daily profile for the Seasonal Peak period. The peak hours are shaded in grey. As before, the mean load is depicted by the solid blue line and the dotted red lines show the lower and upper 80% confidence interval. The Seasonal Peak load occurs between 3:00 and 4:00 PM and the mean value is 0.31 kW/ton.

Figure ‎3‑2: Average Daily Load Profile for Seasonal Peak Days

Figure ‎3‑3 shows the profile for one hot day each in 2012 and 2013 along with the temperature profiles for both years. Hot day is defined as the day for which the mean temperature was greater than 80 Fahrenheit. The peak hours are shaded in grey. The load curves seem to follow the temperature profile fairly closely. Load values for 2013 are higher since the corresponding temperatures were higher than in 2012.[[19]](#footnote-19) The team looked at the mean temperatures for summer 2012 vs 2013 and the trend indicates that the summer of 2013 was hotter than 2012 overall. The peak occurs at 5:00 PM for 2013 with the value of 0.64 kW/ton, aligning well with the corresponding temperature peak which occurs between 4:00 and 5:00 PM. For 2012, the peak occurs between 2:00 and 3:00 PM and the value is 0.51 kW/ton. This aligns well with the temperature peak for that year which occurs at 3pm.

Figure ‎3‑3: Hot day Profile for 2012 and 2013

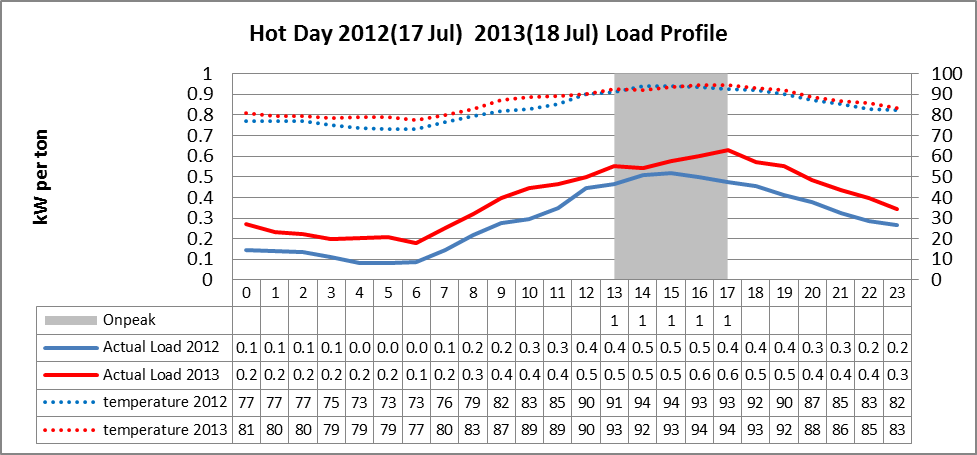


Table ‎3-7 shows the current assumed ASF and DSF values from the PSD along with those calculated from this study. Statistically, the study’s ASF estimate of 371.6 is the same as that currently assumed in the PSD (357.6). The study’s seasonal DSF estimate of 0.45 is statistically lower than the current PSD assumption of 0.591. The estimated On Peak DSF from this study is 0.24; the PSD did not list an On Peak DSF.

Table -: PSD Input Assumptions versus Study Findings

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Symbol** | **Description (units)** | **PSD Value** | **Verified Gross Savings** | **CI Lower** | **CI Upper** |
| ASF | Annual Savings factor (kWh/ton) | 357.6 | 368.41 | 326.71 | 410.11 |
|  | Seasonal demand savings factor (kW/ton)\* | .591 | 0.45 | 0.42 | 0.47 |
| DSF | On Peak demand savings factor (kW/ton)\* | N/A | 0.24 | 0.22 | 0.25 |

\*Calculated at the 80% confidence interval

Table ‎3-8 presents the 2011 and 2012 program verified gross energy and summer seasonal demand savings. This table shows these impacts by lost opportunity versus retrofit savings activity along with realization rates when compared to the *raw* tracking savings estimates. Overall, the study estimates 1,345 MWh of energy savings and 1.405 MW of summer seasonal demand savings. We note that the retrofit sample is small and as such has poor precisions associated with it. Overall, the higher ASF and general increases in capacity between the studies’ on-site work and tracking system are causing energy savings results to go up overall while the decrease in demand savings factors are causing the seasonal demand estimate to go down.

Table -: 2011/2012 CAC Raw Tracking and Verified Savings with Realization Rate

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sponsor** | **Population** | | | | | | |
| **N** | **Energy Savings** | | | **Summer Seasonal Demand Savings** | | |
| **Tracking** | **Verified Gross** | **RR** | **Tracking** | **Verified Gross** | **RR** |
| Lost Opportunity (n=77) | | | | | | | |
| CL&P | 4,518 | 824,987 | 758,528 | 91.9% | 1,004.60 | 930.57 | 92.6% |
| UI | 722 | 139,024 | 121,217 | 87.2% | 269.1 | 148.71 | 55.3% |
| Total | 5,240 | 964,011 | 879,745 | 91.3% | 1,273.70 | 1,079.28 | 84.7% |
| Retrofit (n=11) | | | | | | | |
| CL&P | 254 | 75,555 | 124,979 | 165.4% | 122.8 | 87.44 | 71.2% |
| UI | 692 | 128,095 | 340,493 | 265.8% | 239.4 | 238.21 | 99.5% |
| Total | 946 | 203,650 | 465,472 | 228.6% | 362.20 | 325.64 | 89.9% |
| Overall (n=88) | | | | | | | |
| CL&P | 4,772 | 900,542 | 883,507 | 98.1% | 1,127.40 | 1,018.00 | 90.3% |
| UI | 1,414 | 267,119 | 461,710 | 172.8% | 508.50 | 386.92 | 76.1% |
| Total | 6,186 | 1,167,661 | 1,345,218 | 115.2% | 1,635.90 | 1,404.92 | 85.9% |

Table ‎3-9 presents the 2011 and 2012 program verified gross energy and summer seasonal demand savings. This table shows these impacts by lost opportunity versus retrofit savings activity along with realization rates when compared to the *revised* tracking savings estimates. Since the number of units tracked and the gross savings per unit calculated did not change between the raw and revised tracking estimates, the overall study estimate of impacts is the same between Table ‎3-8 and Table ‎3-9. However, since the revised tracked energy savings decreased from the tracked raw savings, the energy impact realization rate improved to nearly 122% overall. Since the revised tracked summer seasonal demand savings increased from the tracked raw savings, that realization rate went down.

Table -: 2011/2012 CAC Revised Tracking and Verified Savings with Realization Rate

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sponsor** | **Population** | | | | | | |
| **N** | **Energy Savings** | | | **Summer Seasonal Demand Savings** | | |
| **Tracking** | **Verified Gross** | **RR** | **Tracking** | **Verified Gross** | **RR** |
| Lost Opportunity (n=77) | | | | | | | |
| CL&P | 4,518 | 711,620 | 758,528 | 106.6% | 1,176.1 | 930.6 | 79.1% |
| UI | 722 | 106,170 | 121,217 | 114.2% | 175.5 | 148.7 | 84.7% |
| Total | 5,240 | 817,790 | 879,745 | 107.6% | 1,351.6 | 1,079.3 | 79.9% |
| Retrofit (n=11) | | | | | | | |
| CL&P | 254 | 108,738 | 124,979 | 114.9% | 179.7 | 87.44 | 48.7% |
| UI | 692 | 176,694 | 340,493 | 192.7% | 292.0 | 238.21 | 81.6% |
| Total | 946 | 285,432 | 465,472 | 163.1% | 471.7 | 325.64 | 69.0% |
| Overall (n=88) | | | | | | | |
| CL&P | 4,772 | 820,358 | 883,507 | 107.7% | 1,355.8 | 1,018.0 | 75.1% |
| UI | 1,414 | 282,864 | 461,710 | 163.2% | 467.5 | 386.9 | 82.8% |
| Total | 6,186 | 1,103,222 | 1,345,218 | 121.9% | 1,823.3 | 1,404.9 | 77.1% |

### Characterization of Installed Units

A core objective of this study was to characterize program installed CAC units, including size, airflow and rated efficiency. The team gathered the data to perform this as part of our on-site work. During the on-site visits, all units installed under the program were identified by manufacturer and model number to determine appropriate sizing and rated efficiency. Additionally, all installed CAC units and systems were tested during the on-site visit for airflow by performing a TrueFlow diagnostic test.

*Rated Efficiency.* In terms of the EER, all program installed units had efficiencies of 11.5 or greater. Nearly seven in ten participating customers install units in the 12.5-13.4 EER range with another quarter installing units with an EER between 11.5 and 12.4.

Table -: Efficiency of Installed Units Observed On-site

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EER Range** | **11.5-12.4** | **12.5-13.4** | **13.5-14.4** | **>14.4** |
| Population (N=6,186) | 24.9% | 67.8% | 7.0% | 0.3% |
| Sample (n=92) | 20.7% | 69.6% | 9.8% | 0.0% |

*Air-Flow.* Air flow is also a very important aspect of overall CAC efficiency, along with the manufactured EER of the unit and the appropriate sizing of the unit. To characterize system air flow among sampled sites, diagnostic testing was performed using a TrueFlow plate and manometer. During this test, the Cubic Feet per Minute (CFM) of air flow as well as the air pressure within the ductwork are measured as the return air reenters the air exchanger in the air handler system. The plate is installed to replace the air filter during the diagnostic testing and the CFM and TrueFlow operating pressures are recorded with the system in full operation mode. A second reading for air pressure was taken after this test with the filter back in place. This reading is to determine the Normal Standard Operating Pressure (NSOP). The team performed this second reading as a second check on the TrueFlow reading as they should vary slightly but not have an unusually high differential. In this way, the team was able to determine if the system had an acceptable CFM flow and a reasonable difference between TrueFlow operating pressure and NSOP.

Table ‎3-11 reflects percentages of TrueFlow results within ranges of CFM per ton. Sources at both Lawrence Berkeley National Laboratory (LBL)[[20]](#footnote-20) and the Building Performance Institute (BPI)[[21]](#footnote-21) indicate that air handler air flow in CAC systems should be at or above 350 CFM/ton. BPI suggests that CFM rates lower than this can result in lower system efficiency and can suggest improperly installed flexible ducting, undersized ducts, and dirty filters or coils. Note that systems in the study included single speed, multiple speed and variable speed blower motors. The CFM testing was done after trying to get each system into steady state operation for at least ten minutes. However, due to differentials between set temperatures and outside air temperatures, it was often difficult to know whether flow readings were taken on blowers operating at full speed. Since this uncertainty may account for some of the low readings observed, the team regards the 49% of units tested at below 350 CFM/ton not to be impacting the efficiency of the units as much as one might suggest it would. No systems tested at below 250 CFM/ton.

Table -: TrueFlow CFM/Ton Readings

|  |  |  |
| --- | --- | --- |
| **CFM/Ton Range** | **Number** | **Percent** |
| Range 250-300 | 15 | 20.5% |
| Range 300-350 | 20 | 27.4% |
| Range 350-400 | 16 | 21.9% |
| Range 400-450 | 8 | 11.0% |
| Range 450-500 | 6 | 8.2% |
| Range 500-550 | 6 | 8.2% |
| Range >500 | 2 | 2.7% |
| Total | 73 | 100.0% |

Table ‎3-12 presents the air flow results by capacity, which suggests that smaller systems tend to be more prone to surplus airflow than larger systems. This may be the result of larger systems having larger and more complex duct systems, which might be causing lower flow rates.

Table -: CFM/Ton by Capacity

|  |  |  |
| --- | --- | --- |
| **Size (Tons)** | **Number** | **Average CFM/Ton** |
| 2 | 13 | 498.8 |
| 2.5 | 15 | 405.8 |
| 3 | 25 | 367.3 |
| 3.5 | 7 | 325.8 |
| 4+ | 12 | 326.0 |
| Total | 72 | 389.7 |

*System Sizing and Manual J Results*

Determining the appropriate size equipment for the space it serves is crucial to achieving both effective and efficient central air conditioning. Whether the equipment is a replacement unit utilizing preexisting distribution duct work or a newly installed system, system sizing is performed using formulas developed by the ACCA, referred to as Manual J calculations. The sponsors of this study agreed that checking the proper sizing of the installed equipment was such a determining factor for system efficiency that Manual J calculations should be performed on all installed units. The exceptions to this were units that could not be easily distinguished to the space they serve. Large homes with multiple systems and systems that interact with each other were not included in the calculations as the system boundaries could not be accurately determined without ductwork schematics.

The following tables (Table ‎3-13 and Table ‎3-14) indicate the results of the Manual J load calculations for the installed units. For each sample point, we divided the Manual J load calculation by the rated capacity of the installed unit in tons (“Manual J Calculation Per Unit Ton” field). This field represents the BTUh cooling load needed per ton installed. The final field in the table (ratio) captures the relationship between the Manual J calculation per ton and the cooling capacity of a ton (12,000 BTUh). This field is provided to (to simplify the comparison of calculated load vs. installed load. A perfectly sized unit would have a ratio of 1.0 and each ratio less than or greater than that would be under-sized or over-sized, according to the Manual J calculations.

Table -: Manual J Results (2012 Sample)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Site ID** | **Conditioned Area (SqFt)** | **Manual J Cooling Load (Btuh)** | **CAC Condenser Size (Tons)** | **Manufacturer** | **Model #** | **Manual J Calculation Per Unit Ton** | **Ratio** |
| 1310 | 1,440 | 26,270 | 2.0 | RUDD | 14AJM24A01 | 13,135 | 0.91 |
| 2223 | 1,668 | 32,721 | 3.0 | GOODMAN | SSX160361BB | 10,907 | 1.10 |
| 1648 | 1,302 | 21,627 | 2.5 | LENNOX | 14ACX-030-230-11 | 8,651 | 1.39 |
| 1267 | 2,038 | 35,740 | 3.0 | GOODMAN | SSX160361BA | 11,913 | 1.01 |
| 1414 | 2,592 | 44,947 | 4.0 | HEIL | HXA648GKA100 | 11,237 | 1.07 |
| 155 | 1,432 | 25,844 | 2.5 | LENNOX | 14ACX030230 | 10,338 | 1.16 |
| 121 | 2,044 | 28,408 | 3.0 | RHEEM | 14AJM36A01 | 9,469 | 1.27 |
| 1687 | 1,728 | 26,034 | 2.0 | FRIGIDAIRE | FS4BF-024KA | 13,017 | 0.92 |
| 695 | 1,674 | 30,895 | 2.5 | BRYANT | 116BNA030-A | 12,358 | 0.97 |
| 2891 | 1,640 | 29,594 | 2.0 | RHEEM | 14AJM24A01 | 14,797 | 0.81 |
| 1296 | 2,114 | 28,762 | 2.5 | AM STD | 4A7A5030E1000AB | 11,505 | 1.04 |
| 2817 | 1,260 | 26,557 | 2.0 | TRANE XR15 | 4TTR5024E | 13,279 | 0.90 |
| g 1237 | 1,816 | 34,208 | 2.5 | LENNOX | XC17-030-230-03 | 13,683 | 0.88 |
| 1317 | 1,185 | 27,363 | 2.5 | LENNOX | 14ACX-030-230-11 | 10,945 | 1.10 |
| 1125 | 1,780 | 38,208 | 3.0 | LENNOX | 14ACX-036-230-11 | 12,736 | 0.94 |
| 564 | 2,167 | 34,728 | 3.0 | TRANE | 4TTX503A1000BA | 11,576 | 1.04 |
| 1099 | 2,287 | 37,841 | 3.0 | LENNOX | 14ACX-041-230-01 | 12,614 | 0.95 |
| 2737 | 1,137 | 26,563 | 2.0 | LENNOX | 14ACX-024-230-1 | 13,282 | 0.90 |
| 885 | 1,170 | 26,364 | 2.5 | AM STD | 4A7A5030E1000AB | 10,546 | 1.14 |
| 2758 | 1,584 | 28,036 | 3.0 | RHEEM | 14AJM36A01 | 9,345 | 1.28 |
| 1389 | 1,546 | 31,185 | 3.0 | HEIL | H4A836GKD200 | 10,395 | 1.15 |
| 3005 | 1,473 | 29,320 | 3.0 | RHEEM | 14AJM36A01 | 9,773 | 1.23 |
| **Total (22)** | | | | | **Average Site** | **11,614** | **1.03** |

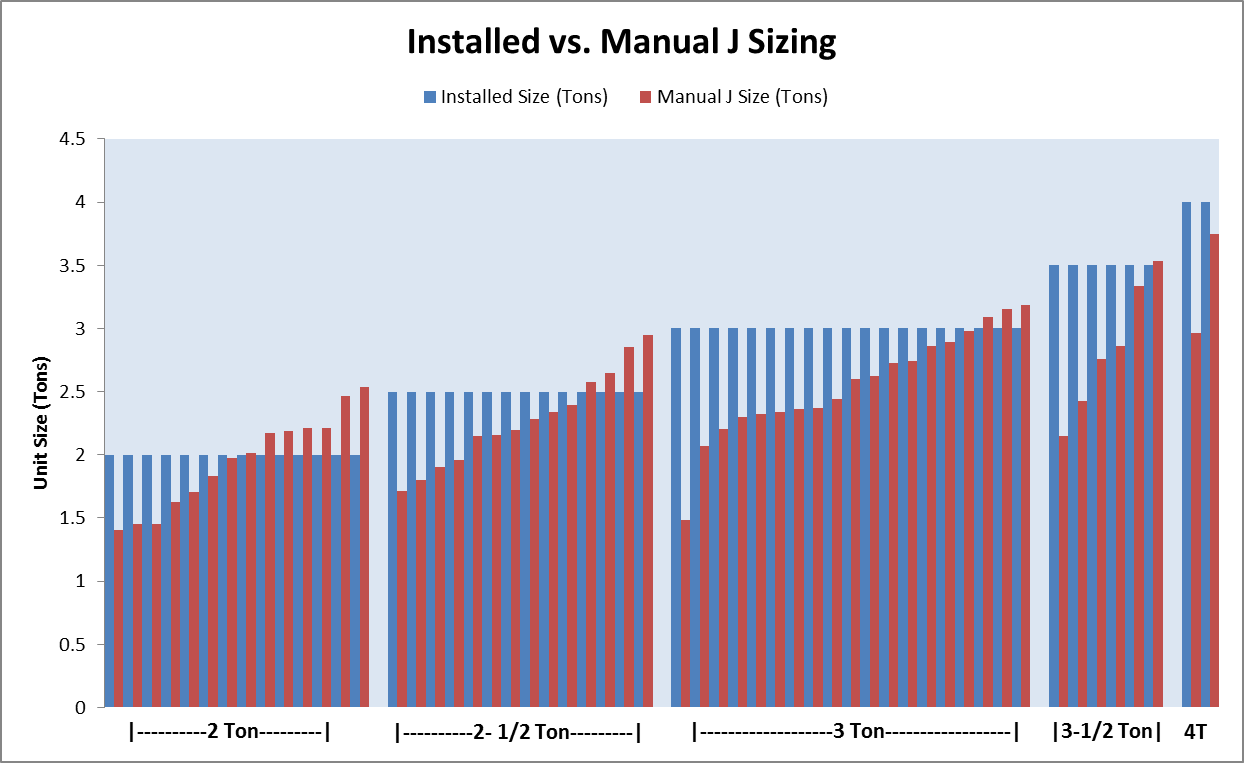
Table -: Manual J Results (2013 Sample)

| **Site ID** | **Conditioned Area (SqFt)** | **Manual J Cooling Load (Btuh)** | **CAC Condenser Size (Tons)** | **Manufacturer** | **Model #** | **Manual J Calculation Per Unit Ton** | **Ratio** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 0009 | 2,660 | 23,512 | 2.5 | AM STD | 4ATA5030E1000AC | 9,405 | 1.28 |
| 0156 | 1,864 | 34,275 | 3.5 | AM STD | 4A7A5042E1000AC | 9,793 | 1.23 |
| 0209 | 2,928 | 35,369 | 2.5 | GOODMAN | SSX160301AA | 14,148 | 0.85 |
| 0220 | 1,968 | 31,753 | 2.5 | LENNOX | 14ACX-030-230-12 | 12,701 | 0.94 |
| 0221 | 1,415 | 19,525 | 2 | RHEEM | 14AJM24A01 | 9,763 | 1.23 |
| 0235 | 1,274 | 20,584 | 2.5 | RHEEM | 14AJM30A01 | 8,234 | 1.46 |
| 0261 | 2,255 | 42,416 | 3.5 | RHEEM | 14AJM42A01 | 12,119 | 0.99 |
| 0470 | 2,057 | 25,743 | 2.5 | LENNOX | 14ACX-30-230-12 | 10,297 | 1.17 |
| 0514 | 2,700 | 32,874 | 3 | DAY & NIGHT | N4A336AKB200 | 10,958 | 1.10 |
| 0538 | 1,512 | 31,454 | 3 | LENNOX | XC14-030-230-05 | 10,485 | 1.14 |
| 0540 | 3,456 | 37,034 | 3 | AM STD | 4A7B4049W1000AA | 12,345 | 0.97 |
| 0597 | 1,896 | 27,842 | 3 | TRANE X15 | 4TTR5036E1000AB | 9,281 | 1.29 |
| 0697 | 1,044 | 16,821 | 2 | CARRIER | 24ABB3 | 8,411 | 1.43 |
| 0816 | 2,266 | 25,758 | 3.5 | HEIL | HXA642GKA100 | 7,359 | 1.63 |
| 0896 | 1,119 | 23,669 | 2 | BRYANT | 187BNA024-A | 11,835 | 1.01 |
| 0914 | 3,028 | 26,420 | 3 | LENNOX | XC17-036-230-05 | 8,807 | 1.36 |
| 0917 | 2,148 | 33,091 | 3.5 | GOODMAN | SSX160421AA | 9,455 | 1.27 |
| 0961 | 802 | 24,147 | 2 | AM STD | 4A7A5024E1000AB | 12,074 | 0.99 |
| 0967 | 2,353 | 34,279 | 3 | TRANE X-15 | TAM7A0B30H21SAA | 11,426 | 1.05 |
| 1081 | 3,431 | 40,005 | 3.5 | AM STD | 4A7A5042E1000AC | 11,430 | 1.05 |
| 1114 | 1,532 | 22,851 | 2.5 | TRANE | 4TTB4030E1000AA | 9,140 | 1.31 |
| 1260 | 1,760 | 29,134 | 3.5 | LENNOX | 14ACX-042-230-12 | 8,324 | 1.44 |
| 1283 | 1,176 | 17,375 | 2 | GOODMAN | SSX160241BB | 8,688 | 1.38 |
| 1334 | 2,748 | 17,835 | 3 | LENNOX | XC14-036-230-05 | 5,945 | 2.02 |
| 1466 | 2,452 | 35,589 | 4 | TEMPSTAR | TXA648GKA100 | 8,897 | 1.35 |
| 1592 | 1,248 | 17,427 | 2 | HEIL | HXA624GKA100 | 8,714 | 1.38 |
| 1643 | 1,976 | 28,083 | 2.5 | HEIL | N4A330GKC200 | 11,233 | 1.07 |
| 1755 | 2,448 | 27,531 | 3 | AM STD | 4A7A5036E1000AC | 9,177 | 1.31 |
| 1871 | 2,618 | 28,375 | 3 | BRYANT | 116BNA036-A | 9,458 | 1.27 |
| 2180 | 2,176 | 30,448 | 2 | AM STD | AAM7AOA24HZ1SAA | 15,224 | 0.79 |
| 2412 | 1,999 | 24,838 | 3 | TRANE | 4TTR5036E1000AC | 8,279 | 1.45 |
| 2431 | 2,060 | 21,991 | 2 | RHEEM | RASL\_024JEC | 10,996 | 1.09 |
| 2549 | 1,440 | 20,480 | 2 | RUDD | 14AJM24A01 | 10,240 | 1.17 |
| **Total ( 33)** | | | | | **Average Site** | **9,856** | **1.19** |

In reality, the HVAC installation contractor typically decides the final sizing of an installed unit. A common industry practice is to reasonably oversize the unit to assure the system is meeting the cooling demand that the customer expects. With models sized to 0.5 ton loads, it is therefore acceptable to have a unit oversized by up to 0.5 tons, as the installing contractor would need to round up to the next available size model. If the contractor felt this amount of oversizing was not needed, a slight undersize of the unit may be acceptable under circumstances such as installations with short, straight and effective ductworks where professional judgment suggests that a slightly undersized unit is sufficient. The 2012 and 2013 average ratios are 1.03 and 1.19, respectively. The results generally suggest that oversizing is not a significant issue for these installations.

Figure ‎3‑4 graphically presents the results of the Manual J load analysis (brown bars) against installed capacity for each unit (blue bars). Looking at the data in this way suggests that the nominal capacity of the majority of installations are within one-half ton of what Manual J suggests is needed.

Figure ‎3‑4: Installed vs. Manual J Sizing



To summarize these results further, the team divided the installed units into five categories, based on their ratio of calculated load to installed Btuh capacity of the unit. These categories are based on a determination of whether a unit is appropriately sized or not. For this purpose, the team considered a unit between the ratios of 1.0 to 1.25 to be appropriately sized and 1.25 to 1.5 and 0.9 to 1.0 to be appropriately over and under sized, respectively. These categories of acceptable sizing allows for some installation contractor discretion. Units that are below the 0.9 ratio and above the 1.5 ratio can be considered undersized or oversized, respectively.[[22]](#footnote-22)

Table ‎3-15 presents these five categories in terms of total number and percent of the 55 units included in the Manual J calculations. The Manual J analysis determined that approximately 38% of the installed units were sized appropriately, that another 51% were acceptably over or undersized and that 11% of the total units installed fell below or above the acceptable range. Considering that some units were retrofit replacements while others were systems new to the home, these percentages indicate a high level of consideration by the installing contractors when sizing the replacement or new units.

Table -: Unit Sizing Summary

|  |  |  |
| --- | --- | --- |
| **Unit Sizing by Ratio** | **Number of Sites** | **Percent of Total** |
| Appropriately Sized units (1.0-1.25) | 23 | 41.82% |
| Acceptable Undersized Units (0.9-1.0) | 9 | 16.36% |
| Acceptable Oversized Units (1.25-1.5) | 17 | 30.9% |
| Oversized Units (>1.5) | 2 | 3.6% |
| Undersized Units (<0.9) | 4 | 7.3% |
| Total | 55 | 100.0% |

Although software tools such as Wrightsoft can make sizing and Manual J calculations far easier in determining capacity of equipment, the fact that equipment is manufactured only in set intervals and the contractor may see something site specific to influence his final decision, still makes HVAC equipment sizing an imperfect science. We do not consider these results to be a strong indicator of installed unit sizing problems. In examining several of these over- and under-sized units, it was apparent that some contractor judgment was used in determining the final unit size needed, based on the nature of the ductwork observed, home shading, and home tightness, among other factors.

## Process Findings

The process evaluation sought especially to understand the factors that households consider when deciding whether to replace their CAC, with particular emphasis on why more households were not using the early replacement rebate. This section seeks to provide some insight into the factors that participants consider regarding CAC replacement. As mentioned in the Methods section, significant differences are noted as the letter (in superscript) corresponding with the subgroup with which a significant difference was detected. Subgroup letters are displayed in the table headings.[[23]](#footnote-23)

### Factors (including Efficiency) Customers Consider for CAC Replacement

*If it ain’t broke, don’t fix it.*When considering whether to replace a still-working CAC, HES participants subscribed to the adage, “If it ain’t broke, don’t fix it.” Specifically, having a newer, working CAC unit was a substantial barrier to replacement, particularly given the cost of replacement.

As Table ‎3-16 shows, about one-third (34%, or 25 total) of the 73 participants who were recommended CAC replacement but did not replace their CAC had considered replacing their unit after the HES vendor[[24]](#footnote-24) recommended it. When asked what kept them from replacing their CAC, the impediment these 25 participants most commonly offered was cost (76%) followed by the fact that the unit was still working (20%).

The 46 participants who did not consider replacing their CAC after the vendor recommended it[[25]](#footnote-25) were asked why not. This group most commonly responded that the unit was still working (59%), followed by cost (39%). As one such participant explained, “The unit worked fine and was still new.” Four respondents to this question added qualitative responses suggesting another reason was that the CAC was not used much, so that the energy savings would be of minor importance. As one noted, “We don’t use the central air that often.” In the words of another, “In the scheme of things the [CAC] is not the worst loss of energy.”

Table -: Why Participants did not Replace CAC

(Base: varies by question)

|  |  |
| --- | --- |
| **What kept you from replacing it?**  **(multiple response\*)** | **Considered Replacing CAC** |
| *Sample Size* | *25* |
| Cost/too expensive | 76% |
| Current unit was still working | 20% |
| Had other financial priorities (refrigerator, roof, etc.) | 8% |
| Just bought the house | 4% |
| Installed geothermal heating | 4% |
| No immediate need for CAC during wintertime | 4% |
| Too busy | 4% |
| **Why didn’t you consider replacing your Central Air Conditioning unit after the recommendation?**  **(multiple response\*)** | **Did Not Consider Replacing CAC** |
| *Sample Size* | *46* |
| Current unit was still working | 59% |
| Cost/too expensive | 39% |
| I don't remember them recommending it | 11% |
| $250 is not enough to replace it | 4% |
| Don't use CAC often | 4% |
| Hassle of installation | 2% |
| Forgot about it and missed rebate deadline | 2% |
| Current unit only 2 years old | 2% |
| Had other efficiency priorities with higher energy savings potential than CAC | 2% |
| No immediate need for CAC during wintertime | 2% |

\*Multiple response results are reported with a percentage sign (%) following each value. Only the first value is followed by a percentage sign for questions that are not multiple response.

The survey asked participants who did not replace their CAC after the audit what else the program could have done that might have made them decide to replace their CAC. It also asked participants who had replaced their CAC what else the program could have done to encourage customers like themselves to replace their CAC. More than one-third (36%) of participants who had not replaced their CAC said that the program could not have done anything else that would have made them decide to replace their CAC. Twelve percent suggested a larger rebate and 10% suggested low or no-interest financing. Note that the Program already offers financing, but these respondents were not aware of it.

About one-fifth (21%) of participants who replaced their CAC suggested providing information on costs and savings or on the efficiency of old versus new units. Presumably auditors are meant to do this already, but this may not be carried out as consistently or thoroughly as it could be. This was followed by more advertising (16%) and continuing to offer the rebate (14%).

*If it is Broke, Replace it.* In contrast, the fact that a CAC was older or even broken served as the major reason for replacing a unit, either with or without a rebate (Table ‎3-17). This open-ended question allowed individuals to name multiple factors they considered when replacing their CAC, and nearly all of the respondents cited the age of a unit and its working (or non-working) condition as one of the reasons to replace it. That is, participants wanted to replace their CAC because the unit was approaching—or had reached—the end of its useful life. The fact that respondents wanted to replace their unit because of its age also likely underlies the fact that three out of five respondents who received a rebate said that they had had plans to replace the CAC equipment prior to having the HES audit (Table ‎3-18).[[26]](#footnote-26)

The results also suggest that more than one-fifth of participants that obtained the early replacement rebate (21%) stated that the old unit having broken down was an important factor in their decision, which seems to violate the concept of an *early* replacement (that is, prior to the end of the unit’s useful life). Nearly the same percentage of participants who replaced their CAC without a rebate (19%) stated that the old unit having broken down was an important factor in their decision to replace it.[[27]](#footnote-27) At the time of this study, the Companies did not have a set definition of “early replacement.” The program should consider setting more stringent criteria for determining early replacement or risk paying greater incentives than needed.[[28]](#footnote-28)

Energy efficiency paled in comparison to the desire to replace an aging unit when considering factors regarding CAC replacement. In fact, only 29% of respondents named energy efficiency or lower energy bills as factors they had considered when deciding to replace a CAC. Interestingly, respondents who received the standard $250 rebate more frequently cited energy efficiency or lowering bills as a factor than did the respondents receiving the early replacement rebate or those who did not use a rebate.

Finally, in a topic explored in more detail below, participants rarely volunteered the rebate as a factor in their decision to replace a CAC in response to this open-ended question. Only five percent of respondents volunteered the rebate as a factor they had considered, while another three percent mentioned the loan. Importantly, however, 11% of respondents who made use of the $500 early replacement rebate cited the rebate as a factor in their decision; although not a large percentage, only two percent of households receiving the standard rebate named it as a factor in deciding to replace their CAC.

Table -: Factors Participants Considered when Replacing CAC

(Base: respondents within group, open-ended, multiple response)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **What factors helped you decide to replace your Central Air Conditioning unit?** | **A. Replaced CAC with CAC**  **Rebate only**  **($250)** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **C. Replaced CAC Without Rebate** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *167* |
| *Unit Getting Old or Not Working Well* | | | | |
| The old unit wasn’t working well | 36%c | 29%c | 56%d | 36% |
| Unit was getting old | 30c | 26c | 59d | 33 |
| The old unit broke down | 8b | 21 | 19 | 15 |
| The old unit required too many repairs | 10 | 7 | 11 | 9 |
| Did not want old unit to break down at a bad time | 12b | 4 | 11 | 9 |
| Contractor convinced me old unit needed to be replaced | 8 | 7 | 11 | 8 |
| Had home inspected and inspector recommended replacing old unit | 0bd | 4c | 0d | 2 |
| *Save Energy, Lower Electric Bill* | | | | |
| Save energy/Energy efficiency concerns | 22 | 15 | 15 | 18 |
| Lowering electric bills | 16b | 7 | 7 | 11 |
| *Rebate or Financing*\* | | | | |
| The rebate | 2b | 11c | 0d | 5 |
| The loan | 4c | 2 | 0d | 3 |
| *Other Factors* | | | | |
| Replaced furnace at same time | 6 | 5 | 4 | 5 |
| We were doing extensive remodeling and needed to replace equipment | 3 | 7c | 0d | 4 |
| Wanted Central Air Conditioning | 4c | 5c | 0d | 4 |
| Comfort | 2 | 1 | 7 | 3 |
| Cost of unit | 1 | 5c | 0d | 2 |
| Other\*\* | 10c | 4c | 0d | 6 |
| Refused | 2 | 0 | 0 | 1 |

\* Respondents answered these questions via “open response” meaning that they volunteered answers and were not asked to select among pre-coded, read responses. In Section ‎3.2.2, the team explores the role of rebates and financing in more detail through a series of questions designed to elicit more specific information on those program offerings.

\*\* Other responses addressed issues such as warranties, indoor air quality, and numerous additional topics.

Table -: Prior Plans to Replace CAC Equipment

(Base: respondents within group)

|  |  |  |  |
| --- | --- | --- | --- |
| **Did you have specific plans to install any of this efficient air conditioning equipment before you talked with anyone about the Home Energy Solutions Program?** | **A. Replaced CAC with CAC**  **Rebate only ($250)** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Total** |
| *Sample Size* | *70* | *70* | *140* |
| Yes | 64% | 60% | 62% |
| No | 33 | 37 | 35 |
| Don’t know/don’t remember | 3 | 3 | 3 |

*Opinions of Installation Contractors Matters.* The team also explored the role that HES vendors and installation contractors played in CAC replacement decisions. The results suggest that respondents tended to rely more on the opinions of installation contractors more than HES vendors when deciding whether to replace the CAC and if so, with which unit (Table ‎3-19).

Of the three groups of participants that replaced their CAC, 77% (54 out of 70) of participants who obtained the early replacement rebate, 88% (24 out of 27) of participants who did not obtain a rebate but did replace their CAC, and 94% (66 out of 70) of participants who obtained the standard rebate, used a firm other than the HES vendor to install the replacement CAC. This is to be expected, given that firms that conduct HES audits would not necessarily qualify to install replacement CAC.

In general, participants who replaced a CAC unit were more likely to rate the firm that did the installation rather than the HES vendor as “very important” to the decision to replace the CAC. The same was true for the decision of which CAC unit to install in its stead. The one exception was the decision to replace the CAC by participants who received an early replacement rebate. These participants were more likely than participants who received a standard rebate to say that the HES vendor’s firm was “very important” to this decision (38% versus 20%), suggesting that the HES vendors are offering convincing reasons for early CAC replacement.

Table -: Importance of Firms to Decision-making

(Base: all respondents unless otherwise noted)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **A. Replaced CAC with CAC**  **Rebate only ($250)** | **B. Replaced CAC with CAC+Early Replacement Rebate ($500)** | **C. Replaced CAC Without Rebate** | **Total** |
| **How important was advice from the firm that conducted the energy audit to your decision to replace the unit?** | | | | |
| *Sample Size* | *70* | *70* | *27* | *167* |
| Very important | 20%b | 38% | 33% | 30% |
| Somewhat important | 26 | 18 | 30 | 23 |
| Slightly important | 14 | 9 | 19 | 13 |
| Not at all important | 35c | 35c | 19 | 32 |
| Don’t know/don’t remember | 2 | 0 | 0 | 1 |
| Refused | 2 | 0 | 0 | 1 |
| **How important was advice from the firm that installed your replacement Central Air Unit to your decision to replace the unit?** | | | | |
| *Sample Size\** | *66* | *54* | *24* | *144* |
| Very important | 47% | 49% | 38% | 46% |
| Somewhat important | 22 | 14c | 33 | 21 |
| Slightly important | 11 | 9 | 21 | 12 |
| Not at all important | 18 | 21 | 8 | 18 |
| Don’t know/don’t remember | 0 | 4 | 0 | 2 |
| Refused | 0 | 3 | 0 | 2 |
| **How important was advice from the firm that conducted the energy audit to your decision of which Central Air Conditioning unit to install?** | | | | |
| *Sample Size* | *70* | *70* | *27* | *167* |
| Very important | 9%bc | 19% | 26% | 16% |
| Somewhat important | 13 | 17 | 19 | 15 |
| Slightly important | 14 | 12 | 7 | 12 |
| Not at all important | 60 | 48 | 44 | 53 |
| Don’t know | 4 | 4 | 4 | 4 |
| **How important was advice from the firm that installed your replacement Central Air Unit to your decision of which Central Air Unit to install?** | | | | |
| *Sample Size\** | *66* | *54* | *24* | *144* |
| Very important | 58% | 55% | 54% | 56% |
| Somewhat important | 23 | 19 | 29 | 22 |
| Slightly important | 4 | 4 | 8 | 4 |
| Not at all important | 11 | 22c | 8 | 15 |
| Don’t know | 5c | 1 | 0 | 2 |

\*Sixty-six of the 70 respondents who obtained a $250 rebate used a firm other than the audit firm to install the replacement CAC. Fifty-four of the 70 respondents who obtained a $500 rebate used a firm other than the audit firm to install the replacement CAC. Twenty-four of the 27 respondents who replaced their CAC without a rebate used a firm other than the audit firm to install the replacement CAC.

*Plans to Install CAC in the Future.* Of those who did not replace their CAC despite the recommendation, more than two-fifths (44%) said that they will replace the unit when it breaks down (Table ‎3-20). About one-quarter (27%, or 20 participants) reported that they planned to replace it at a future date. Some of the reasons these participants offered for delaying replacement included “I'm not going to replace something when it is working at 100%,” and “That whole Yankee thing—if it is not broke down [sic] do not fix it.”

Of the 20 participants who planned to replace their CAC at a future date (rather than when it breaks down), 90% said they would do so within the next five years. The primary reasons offered for the delay were cost (55%) and that the current unit still worked (30%).

Table -: Expectations about Future CAC Replacement

(Base: varies by question)

|  |  |
| --- | --- |
| **Have you decided to delay the replacement of your Central Air Conditioning unit to a future date, to delay it to when the unit breaks down, or something else?** | **Did Not Replace CAC** |
| *Sample Size* | *73* |
| Replace when unit breaks down | 44% |
| Delay to a future date | 27 |
| No[[29]](#footnote-29) | 14 |
| Something else | 10 |
| Undecided | 3 |
| Don’t know/Refused | 2 |
| **When do you expect to replace the unit?** | |
| *Sample Size* | *20* |
| 1-3 years | 45% |
| 4-5 years | 25 |
| Within 1 year/next spring or summer | 20 |
| Don't know | 10 |
| **Why did you decide to delay replacement of your Central Air Conditioning unit to a future date? (multiple response)** | |
| *Sample Size* | *20* |
| Cannot afford it right now/Costs too much | 55% |
| Current one still works | 30% |
| Don't use CAC often | 10% |
| Not a priority right now | 5% |
| Just installed energy-efficient windows | 5% |
| Current one is under warranty covering all repairs | 5% |
| Other | 5% |

### Role of Rebates in Decision to Replace CAC

The telephone survey explored in some detail the role of rebates in decision-making around CAC replacement. Many of the questions focused on the early replacement rebate, but the team also examined the standard CAC rebate as well as low-interest financing.

*Awareness of Rebates.* The survey asked respondents who used either the standard or early replacement rebates if they knew about the rebates before the HES audit; similarly the survey asked respondents who did not use a rebate if they were aware of CAC rebates before the survey call. Responses to these questions suggest the majority of respondents who replaced CAC systems—whether they used the rebate or not—knew about the availability of rebates prior to the HES audit or to the survey call (Table ‎3-21). Respondents who made use of the early retirement rebate (84%) were significantly more likely to have prior awareness of the rebate than those who used the standard rebate (67%) or did not use a rebate (63%).[[30]](#footnote-30) In contrast, less than one-half (47%) of respondents who did not replace their CAC had prior knowledge of the rebate. Thus, it appears that knowledge of rebates closely correlates with decisions to replace CAC, even when the participant decides not to use the rebate.

Table -: Awareness of CAC Replacement Rebate

(Base: all respondents)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Before the energy audit/this call today, were you aware that you could receive a rebate for replacing your Central Air Conditioning equipment?** | **A. Replaced CAC with CAC Rebate only ($250)** | **B. Replaced CAC with CAC+Early Replacement Rebate ($500)** | **C. Replaced CAC Without Rebate** | **D. Did Not Replace CAC** |
| *Sample Size* | *70* | *70* | *27* | *73* |
| Yes | 67%bd | 84%cd | 63% | 47% |
| No | 19d | 13cd | 33 | 48 |
| Don’t know/don’t remember | 14bcd | 3 | 4 | 5 |

In an open-ended question, the survey asked participants who did not receive a rebate but were aware of it how they had learned about the rebate. Participants most frequently responded the energy auditor (39%), followed by an online source such as their utility website (18%), a contractor who gave them a quote for a replacement (16%), and the contractor who installed their replacement CAC (10%)(Table ‎3-22). That 10% of this group of respondents learned about the rebate from the contractor who installed their replacement CAC, but did not use the rebate, suggests the possibility of spillover.

Table ‎3-22: Sources of Rebate Awareness of Participants Who Did Not Obtain Rebate

(Base: respondents who did not use rebate but were aware of it)

|  |  |
| --- | --- |
| **How did you learn about the rebate?** | **Replaced CAC Without Rebate or Did Not Replace CAC, and Aware of Rebate** |
| *Sample Size* | *51* |
| Energy auditor | 39% |
| Online/Utility website | 18 |
| Contractor who gave them quote | 16 |
| Contractor that installed new CAC | 10 |
| Accountant/Tax research | 6 |
| Rebate application packet | 4 |
| I work in the industry | 4 |
| Newspaper | 2 |
| Other | 6 |
| Refused | 2 |

*Overall Important of Rebates and Financing*. As the findings on prior knowledge of rebates hint, further inquiries confirm that rebates continue to be an important program tool for CAC replacement, especially for encouraging early replacement. Moreover, the results continue to suggest that the rebates were more important to respondents who used early replacement rebates than to those who relied on a standard rebate alone.

The survey asked participants who remembered obtaining a rebate about the importance of the rebate to their decision to replace their CAC with a high-efficiency ENERGY STAR unit. Participants who received an early replacement rebate were significantly more likely than participants who received the standard rebate to say that the rebate was “very important” to their decision to replace their unit (50% versus 35%)(Table ‎3‑23). This finding also points to the possibility of low free-ridership.

Table ‑: Importance of CAC Replacement Rebate in Decision to Replace CAC with High-Efficiency Unit

(Base: respondents who recalled using rebate)

|  |  |  |  |
| --- | --- | --- | --- |
| **How important was the rebate to your decision to replace your Central Air Conditioning with a high-efficiency ENERGY STAR unit?** | **A. Replaced CAC with CAC**  **Rebate only ($250)** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Total** |
| *Sample Size* | *64* | *63* | *127* |
| Very important | 35%b | 50% | 43% |
| Somewhat important | 38 | 27 | 33 |
| Slightly important | 21 | 16 | 19 |
| Not at all important | 5 | 7 | 6 |

Similarly, ten of the 15 respondents who also made use of low-interest financing said that the financing was “very important” to their decision to replace the CAC unit (Table ‎3‑24). Each of the six early replacement respondents who also used financing reported that the financing was “somewhat” or “very important” to their decision to replace the CAC.

Table ‑: Importance of Loan in Decision to Replace CAC

(Base: respondents who used low-interest financing)

|  |  |  |  |
| --- | --- | --- | --- |
| **How important was the loan to your decision to replace your Central Air Conditioning unit?**\* | **A. Replaced CAC with CAC**  **Rebate only ($250)** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Total** |
| *Sample Size* | *9* | *6* | *15* |
| Very important | 6 | 4 | 10 |
| Somewhat important | 1 | 2 | 3 |
| Slightly important | 1 | 0 | 1 |
| Not at all important | 1 | 0 | 1 |

\*Results are reported as unweighted counts where sample size is less than 20.

*Early Replacement Rebate.* When the EEB Evaluation Consultant first approached the team about a process evaluation of the CAC rebate program, the team was asked to focus on the decision-making regarding the early replacement rebate.[[31]](#footnote-31) Therefore, the team asked a number of detailed questions regarding the early replacement rebate. In their efforts to explore this question, the team discovered that there appeared to be no formal criteria for defining “early replacement” for CAC. The evaluation team was informed that the Companies follow a rule of thumb that any CAC more than 10 years old that is *still functioning* qualifies as an early replacement. The team used that definition when discussing early retirement with the respondents.

More than one-third of participants (36%) who did not replace their CAC reported that they were told by the auditor that, because of their unit’s age, they could obtain an additional $250 rebate for replacing their CAC (Table ‎3-25). It is also worth noting that 81% of households not replacing their CAC reported that the units in their home are more than 10 years old, meaning that they met the “rule of thumb” for eligibility for an early replacement rebate. As noted in Table ‎3-16, those households that decided not to replace a CAC most often did so because of the cost or because their unit was still operating.[[32]](#footnote-32)

Table -: Auditor Informed Participant of Additional Early Retirement Rebate

(Base: respondents who did not use rebate)

|  |  |  |  |
| --- | --- | --- | --- |
| **Did the energy auditor tell you that there could be an additional $250 rebate for replacing your Central Air Conditioning unit, because of its age?** | **C. Replaced CAC Without Rebate** | **D. Did Not Replace CAC** | **Total** |
| *Sample Size* | *27* | *73* | *100* |
| No | 37% | 36% | 36% |
| Yes | 26 | 36 | 33 |
| Don’t know/don’t remember | 37 | 29 | 31 |

The survey asked respondents who did use either the standard rebate or the early replacement rebate to rate the importance of the rebate to choosing replace their CAC unit while it was still functioning. The results indicate that the majority respondents in both rebate groups rated the rebates as “somewhat” or “very” important for deciding to replace a still functioning unit. Importantly, respondents who used early replacement rebates were significantly more likely to say the rebate was “very important” to their decision making regarding CAC replacement.

Table -: Importance of CAC Replacement Rebate in Decision to

Replace CAC with High-Efficiency Unit

(Base: respondents who recalled obtaining reports; respondents who recalled replacing a still functioning unit)

|  |  |  |  |
| --- | --- | --- | --- |
| **How important was the rebate to your decision to replace your Central Air Conditioning unit while it was still functioning?** | **A. Replaced CAC with CAC**  **Rebate only ($250)** | **B. Replaced**  **CAC with CAC+Early Replacement Rebate**  **($500)** | **Total** |
| *Sample Size* | *55\** | *63* | *118* |
| Very important | 31%b | 50% | 42% |
| Somewhat important | 31 | 11 | 20 |
| Slightly important | 19 | 16 | 17 |
| Not at all important | 15 | 22 | 19 |
| Don’t know/don’t remember | 3 | 1 | 2 |

\*Fifty-five of the 64 respondents who remembered obtaining a $250 rebate said that their CAC was working at the time of the audit.

The team asked those respondents who recalled receiving rebates to name the factors that were important to them in deciding whether to replace the CAC with a unit that would qualify for a rebate. In contrast to overall factors that led them to replace their CAC (Table ‎3-17), the majority of rebate users (60%) cited energy efficiency as the primary factor of importance when deciding to choose a rebate-qualified CAC unit. Other common factors included the cost to purchase (16%) or operate (14%) the unit, the reliability of the unit (11%), the age or condition of the older unit (10%), and the fact that the rebate existed (10%). Of these top answers, the two types of rebate users only displayed significant differences regarding operating cost (20% for standard rebate users vs. 8% for early replacement users).

Table ‑: Factors Important to Decision to Replace CAC with Rebated Unit

(Base: respondents who recalled obtaining rebate; multiple response)

|  |  |  |  |
| --- | --- | --- | --- |
| **What factors were important to you when deciding whether or not to replace your Central Air Conditioning unit with one that would qualify for a rebate?** | **A. Replaced CAC with CAC**  **Rebate only ($250)** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Total** |
| *Sample Size* | *64* | *63* | *127* |
| Save energy/Energy efficiency concerns | 61% | 58% | 60% |
| Purchase cost of unit | 19 | 14 | 16 |
| Operating cost of unit | 20b | 8 | 14 |
| Reliability | 9 | 13 | 11 |
| Existing CAC was old/damaged | 12 | 8 | 10 |
| The rebate | 5b | 15 | 10 |
| Comfort | 8 | 6 | 7 |
| Installation cost of unit | 9b | 1 | 5 |
| Better for environment | 5 | 4 | 5 |
| The loan | 7 | 2 | 5 |
| Speed of installation | 0 | 3 | 2 |
| Improving health and safety in home | 2 | 2 | 2 |
| Existing CAC wasn't working | 4 | 1 | 2 |
| Lowering Electric Bills | 0 | 1 | 1 |
| Reputation of contractor or brand of equipment | 0 | 1 | <1 |
| Other | 3 | 10 | 7 |
| Don’t know | 2 | 2 | 2 |

The team also asked both early retirement rebate users and households that replaced the CAC without a rebate to discuss the importance of the HES vendor and the installation contractor in their decision to replace a still functioning CAC unit (Table ‎3‑28 and Table ‎3‑29). Unexpectedly, respondents who did not use a rebate when replacing their still working CAC system placed more importance on both the advice from the HES vendor and their installation contractor than did those respondents who made use of the early replacement rebate. Nearly one-half (45%) of early replacement users said the HES vendor’s advice was “not that important” in the decision to replace a still functioning CAC, and 37% of the early replacement rebate users said that the installation contractor’s advice was “not that important” to their decision. In contrast, only 22% of households who replaced CAC without a rebate responded similarly about HES vendors and 17% about installation contractors. Among those respondents who did find the HES vendors and contractors helpful, it seems that the most important pieces of advice included the increased efficiency of a new unit, information about the benefits of the new model, and the existence of the rebate.

Table ‑: Importance of HES Vendor in Decision to Replace Unit Before Failure

(Base: varies by question)

|  |  |  |  |
| --- | --- | --- | --- |
| **How important was advice from the firm that conducted the energy audit in your decision to replace the unit that was still functioning?** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **C. Replaced CAC Without Rebate** | **Total** |
| *Sample Size* | *70* | *27* | *97* |
| Very important | 18% | 26% | 20% |
| Somewhat important | 25 | 30 | 26 |
| Slightly important | 8 | 22 | 12 |
| Not at all important | 45c | 22 | 39 |
| Don’t know/don’t remember | 4c | 0 | 3 |
| **What did the firm do or say that was important to your decision?\*  (multiple response)** | | | |
| *Sample Size* | *31* | *15* | *46* |
| Convinced me a new unit is more efficient | 34% | 4 | 32% |
| Told me it needed to be replaced | 8% | 4 | 14% |
| Demonstrated the cost benefit of replacing old system | 17% | 1 | 14% |
| Performed diagnostic tests on current system | 10% | 2 | 11% |
| Nothing in particular/had already decided to upgrade | 14% | 0 | 9% |
| Told me about the rebate | 12% | 0 | 8% |
| Provided information on new models | 2% | 1 | 3% |
| Reinforced my decision | 2% | 1 | 3% |
| Helped me get the best possible price | 0% | 1 | 2% |
| The firm has done work for me in the past | 0% | 1 | 2% |
| Their professionalism | 2% | 0 | 1% |
| Other | 7% | 0 | 5% |
| Don't remember | 8% | 1 | 8% |

\*Results are reported as unweighted counts where sample size is less than 20.

Table ‑: Importance of Installation Firm in Decision to Replace Unit before Failure

(Base: varies by question)

|  |  |  |  |
| --- | --- | --- | --- |
| **How important was advice from the firm that installed your replacement Central Air Unit in your decision to replace the unit that was still functioning?** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **C. Replaced CAC Without Rebate** | **Total** |
| *Sample Size* | *54* | *24* | *78* |
| Very important | 38% | 38% | 38% |
| Somewhat important | 17 | 29 | 20 |
| Slightly important | 6 | 13 | 8 |
| Not at all important | 37c | 17 | 31 |
| Don’t know/don’t remember | 2 | 0 | 2 |
| Refused | 0 | 4 | 1 |
| **What did the firm do or say that was important to your decision?\***  **(multiple response)** | | | |
| *Sample Size* | *29* | *16* | *45* |
| Convinced me a new unit is more efficient | 21% | 3 | 20% |
| Provided information on new models | 20% | 3 | 20% |
| Demonstrated the cost benefit of replacing old system | 17% | 4 | 19% |
| Told me about the rebate | 17% | 1 | 13% |
| Offered competitive pricing | 7% | 2 | 9% |
| Told me it needed to be replaced | 7% | 2 | 9% |
| Nothing in particular/had already decided to upgrade | 8% | 0 | 5% |
| Firm is trustworthy | 5% | 1 | 5% |
| Reinforced my decision | 2% | 1 | 3% |
| Performed diagnostic tests on current system | 5% | 0 | 3% |
| Offered to service new equipment | 5% | 0 | 3% |
| Told me a new unit would function much better | 0% | 1 | 2% |
| Provided a detailed quote | 2% | 0 | 1% |
| Other | 8% | 2 | 10% |
| Don't remember | 7% | 1 | 6% |

\*Results are reported as unweighted counts where sample size is less than 20.

*Implications for Free Ridership.* Although not directly measured in the study, the findings for recipients of early replacement rebates have mixed implications for free-ridership. On the one hand, higher free-ridership is suggested by some of the possible explanations for the findings that (1) participants who obtained an early replacement rebate were more likely to have been aware of the rebate before the audit than those who replaced their CAC either for the standard rebate or without a rebate, and (2) much more likely to have been aware than those who did not replace their CAC. On the other hand, other possible interpretations of these findings, coupled with (3) the finding that participants who received an early replacement rebate were no more likely than those who received the standard rebate to report having had plans to install efficient air conditioning equipment before talking with anyone about the HES Program, suggest lower free-ridership. Another finding that suggests lower free-ridership for recipients of early replacement rebates is that for participants who retired a system early, the rebate was more important to their decision-making than for those who obtained a standard rebate. Indeed, that 10% of respondents who did not get a rebate for replacing their CAC had heard of the rebate from the contractor who installed the replacement CAC suggests the possibility of spillover.

### Quality Installation

Although not directly related to the main objectives of the process evaluation, the team took the opportunity to ask survey respondents about their experiences with the Quality Installation certification process. This exploration concludes that the opportunity exists to increase participant awareness and use of Quality Installation.

Just three of the survey respondents obtained a rebate for Quality Installation. All three also obtained the early replacement rebate. More than three-quarters (76%) of participants who obtained a rebate for replacing their CAC, but not for Quality Installation, were unaware before the survey that they could have been eligible to receive an additional $500 rebate if the CAC equipment installation had gone through the Quality Installation certification process. (Table ‎3-30)

The survey asked participants who had obtained a rebate but did not go through Quality Installation if the auditor recommended a Quality Installation. Only about 1 in 10 (13%) said they had (Table ‎3-30). The survey also asked these participants why they did not obtain a Quality Installation. Three said that they did not qualify for the rebate (e.g., “I applied for it. They denied me”), and two said that their installation contractor does not offer Quality Installation (e.g., “The installation people were not qualified to fill out the paper work”).

The survey asked what else the HES program could do to encourage customers like themselves to replace their less efficient CAC units with more energy-efficient units. Two participants volunteered that the Quality Installation process should be streamlined. One suggested the following:

*“[To] fix the Quality Installation program. The whole process was a nightmare. No one knew what they were doing. Streamline the process. They need more training. The guy didn't know which papers to fill out. The process took too long. I had to find out all the information on my own [and] it took over a year.”*

Another respondent echoed similar concerns:

*“[The] Quality Installation program is broken. The process does not work well for some customers. I knew I needed a new AC—it wasn't broken but [was] not running efficiently. [I] looked on the CL&P [web]site and learned about the rebates. I had the assessment to get the rebate. [The] installer was not a Quality Installation inspector. I helped him become one so I could qualify for the Quality Installation program. They wanted to me to send the inspector’s workbook. I couldn't do that. [It was] not relevant to the Quality Installation or my house. [I] sent it and was told [the] application was incomplete. I was counting on the Quality Installation rebate. [It was] misleading that I could get a rebate....”*

Table -: Awareness of Quality Installation Rebate – No Quality Installation Certification

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Replaced CAC with CAC**  **Rebate only ($250)** | **Replaced**  **CAC with CAC+Early Replacement Rebate**  **($500)** | **Total** |
| **Before this call today, were you aware that you could have been eligible to receive an additional $500 rebate if the Central Air Conditioning equipment installation went through the “Quality Installation” certification process?** | | | |
| *Sample Size* | *70* | *67* | *137* |
| No | 78% | 73% | 76% |
| Yes | 13 | 27 | 20 |
| Don’t know | 9 | 0 | 5 |
| **Another aspect of the Home Energy Solutions program is known as “Quality Installation and Verification” or QIV. It ensures that your Central Air Conditioning has been installed for best performance and reliability, and carries with it an extra incentive. Did the energy auditor recommend Quality Installation and Verification for the replacement Central Air Conditioning?** | | | |
| *Sample Size* | *70* | *67* | *137* |
| No | 62% | 49% | 56% |
| Yes | 9 | 17 | 13 |
| Don’t know | 29 | 33 | 31 |
| Refused | 0 | 1 | <1 |

# Conclusions and Recommendations

The impact portion of this study was designed to provide program savings estimates through the use of a M&V data driven per unit savings estimate. It was also designed to help the Companies and EEB improve on forward looking calculations through recommendations to the Program Savings Document. The bullets below capture our conclusions and recommendations in this regard.

* Overall, the incentives provided for CAC installations appear to be generating significant levels of savings. Rebates and incentives provided for CAC units in 2011 and 2012 generated annual energy savings of 1,345 MWh and seasonal peak demand savings of 1.405 MW. This compares to the raw tracking savings estimates of 1,167 MWh of annual energy savings and 1.635 MW of seasonal peak demand savings, which results in realization rates of 115.2% and 85.9%, respectively. The energy realization rate is moderately high for energy savings, due to a higher annual savings factor than assumed in the PSD and generally higher unit sizes observed on-site than captured in the tracking system. The realization rate around the summer seasonal result is lower primarily due to a reduction in the seasonal demand factor as compared to the PSD.
* The current assumed ASF values from the PSD appear very reasonable in light of this study. Statistically, this study’s ASF estimate of 368.41 is the same as that currently assumed in the PSD (357.6).
* The study’s seasonal DSF estimate of 0.45 is statistically lower than the current PSD assumption of 0.591. The estimated On Peak DSF from this study is 0.24; the PSD does not have an On Peak DSF.
* Although the magnitude of savings changes due to discrepancies between the tracking unit savings and the PSD unit savings was minor overall, there were many discrepancies noted.
* Based upon our site work, unit efficiencies appear to be consistently tracked and accurate in the tracking system. Unit sizes, however, were noted to not consistently be accurately tracked.
* In general, although the team found some systems outside the acceptable sizing range, they conclude equipment sizing is not causing inefficiencies in the central air conditioning systems replaced under the Connecticut programs.
* Our assessment of unit air flow resulted in 49% of units having air flow at or below 350 CFM/ton. However, due to not being able to consistently take measurements with blowers at full speed, the team believes that these lower measurements are not likely to be significantly affecting the efficiency of the program installed units.

Based on the impact findings, the Companies or EEB may wish to:

* Consider the performance of some extra M&V site visits to allow for the possibility of sample attribution/data loss in future studies of a similar nature.
* Consider the use of the seasonal peak DSF from this study (0.45) in lieu of the PSD assumption of 0.591.
* Re-examine the manner in which tracking savings are calculated to ensure adherence to the PSD. Notable items in this regard include ensuring use of the proper baseline when calculating tracking savings and ensuring proper crediting of all savings associated with retrofit events.
* Re-examine the method being used to gather and input CAC unit sizes (tons) in the tracking system.

Based on the process findings, in planning for future program marketing and encouraging early replacement of CAC, the Companies or EEB may wish to:

* Better emphasize, and more clearly communicate, the size and types of CAC rebates available to HES participants. As one participant noted, “[They] should say up front about [the] $500 rebate.”
* In program-related communications, emphasize the benefits of replacing systems before they break down, even if the system does not appear to be all that old.
* Consider the means through which the program is marketed and how the program could bring CAC replacement rebates to the attention of participants earlier in the process. Currently, participants are most likely to learn about CAC replacement rebates from the HES vendor, followed by the utility website and a contractor. In order to reach the target audience with rebate information sooner in the program process, improving the likelihood of early CAC replacement, the Companies or EEB may wish to consider exploring other approaches for getting out the word about the availability of substantial rebates for CAC replacement and other residential measures earlier in the participation process. For example, immediately upon receiving an application, prior to approving it, the Companies could automatically send the applicant an eye-catching email or hardcopy mailing with information about the benefits of early CAC replacement and quality installation. There could be a “countdown” of periodic emails or mailings about the program from the point of application to the actual visit.
* While the energy auditor clearly plays an important role in participant decision-making, most participants reported that the installation contractor was even more important. The Companies or EEB may want to help foster closer relationships between HES vendors and CAC installation contractors to increase the likelihood of customers who obtain an audit following through with replacing their CAC with high-efficiency equipment.
* Continue to make financing available for CAC replacement. While only 16% of participants took advantage of financing, its availability mattered a lot to the majority of these customers.
* Although measuring free-ridership was not an objective of this study, the findings regarding prior knowledge of the rebate and prior plans to install new CAC provide contradictory information on this important topic for early replacement rebate users. Specifically, users of the early replacement rebate were more likely to have been aware of the rebate prior to their HES audit—pointing to free-ridership. However, users of the early replacement rebate were no more likely than standard rebate users to report having prior plans to install CAC equipment—suggesting free-ridership is not higher among this group.
* At the same time, a number of early replacement rebate users reported that they used the rebate to replace *a unit that was no longer functioning*, which seems to contradict the purpose of this rebate. Given these findings, the EEB should consider examining free-ridership and Net-to-Gross for this program in the future.
* In future research, it may be worthwhile to probe in more detail about the condition of the unit replaced. This could include questions exploring the degree of functioning of the unit, the type and cost of repairs broken units may have needed, and the level of maintenance expenditures over the previous year. Additional data of this type would enable development of an algorithm to better categorize respondents as to early replacement versus replacement on breakdown, and understand the differences in their thinking and decision-making and avoid free-ridership. This level of examination would be facilitated by collecting somewhat more detailed data from auditors, as described below in the [Appendix E: Research Issues](#AppE).
* The Companies may wish to consider some of the recommendations made by participants to encourage other customers to replace their CAC equipment. In particular, they may wish to make efforts to ensure that when HES vendors recommend replacing CAC that they always provide information on costs and savings and on the logic of replacing older but still-functioning units with new units of higher efficiency. While it is likely that the HES vendors already have such discussion, they may need to find a way to emphasize it or explain it more convincingly, given the customer bias against replacing equipment that still functions. Another promising participant suggestion was follow up with participants after the audit to encourage them to pursue recommended measures.
* The Quality Installation option could be better supported. HES participant awareness of this option was low. The anecdotal evidence offered by participants in open-ended questions suggests that there are substantial challenges to the implementation of the Quality Installation option. However, opportunities appear to be limited by current availability of certified technicians. According to North American Technician Excellence (NATE), NATE certification is a requirement for Quality Installation. The NATE website lists contractors with NATE-certified technicians on staff to facilitate Quality Installation. It appears from this website that as of March 2013, fewer than ten Connecticut-based HVAC contractors have NATE-certified technicians on staff.[[33]](#footnote-33) If the Companies wish to garner additional CAC savings by increasing the rate of Quality Installation of CAC in their service territories, they may first need to assess how to increase the number of qualified technicians in their service territories.

1. Process Evaluation Telephone Survey Instrument

**Central Air Conditioning (CAC) Study**

**Participant Telephone Survey for Process Evaluation**

Sampling Plan

In light of the new definition of “early retirement” (CAC still functioning at time of audit), we propose the new sampling plan below. We may not reach 100 total in the C group, as we plan to stop recruiting once we hit 70 respondents in C who did not replace CAC after the audit. This means that we will get no more than 30 in the other C group—and maybe not even that many. While 30 or less will not be large enough for quantitative generalizations from and comparisons with this group, we'll have to treat the information for this group as qualitative. Given the relatively low importance of this group, this should be OK.



Introduction & Screening

**[ALL]** Hello, my name is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and I am calling from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ on behalf of the Connecticut Energy Efficiency Fund with the cooperation of [READ FULL NAME OF UTILITY FROM PROGRAM RECORDS].

May I please speak to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ [READ “FIRST\_NAME LAST\_NAME” FROM SAMPLE FILE]?

If contact person is not available:

We are conducting a survey to help the Connecticut Energy Efficiency Fund and your electric utility improve the Home Energy Solutions program. Our records show that your household participated in the Home Energy Solutions program in [MONTH, YEAR FROM PROGRAM RECORDS]. I would like to ask a few questions about your household’s experience with the Home Energy Solutions program. Would you be able to answer these questions for us? The survey should take about 15 minutes. I’m not selling anything.]

If contact person is available:

We are conducting a survey to help the Connecticut Energy Efficiency Fund and your electric utility improve the Home Energy Solutions program. Our records show that your household participated in the Home Energy Solutions program in [MONTH, YEAR FROM PROGRAM RECORDS]. I would like to ask you a few questions about your household’s experience with the Home Energy Solutions program. The survey should take about 15 minutes. I’m not selling anything.

**[IF NECESSARY, READ: THE CONNECTICUT ENERGY EFFICIENCY FUND IS SPONSORING THIS PROGRAM AND STUDY. THE CEEF CONTACT PERSON IS TIM COLE. IF YOU HAVE QUESTIONS, YOU CAN REACH HIM AT (860) 874-5813. IF YOU PREFER EMAIL,** [**timothy.cole@ctenergyinfo.com**](mailto:timothy.cole@ctenergyinfo.com)**.]**

1. **[ASK OF ALL]** Our records show that your home is located at [READ STREET ADDRESS, TOWN]. Is this correct?
2. Yes **[IF RESPONDENT VOLUNTEERS THAT THEY ARE THE LANDLORD FOR THE ADDRESS BUT DO NOT LIVE THERE, CHECK YES]**
3. No **[THANK AND TERMINATE]**
4. Don’t know/refused **[THANK AND TERMINATE]**

Are you the best person in your household to talk with about the program? [IF YES GO TO ‎S1. IF NO, ASK FOR THE BEST PERSON AND REPEAT "We are conducting a survey to help the Connecticut Energy Efficiency Fund and your electric utility improve the Home Energy Solutions program. Our records show that your household participated in the Home Energy Solutions program in [MONTH, YEAR FROM PROGRAM RECORDS]. I would like to ask you a few questions about your household’s experience with the Home Energy Solutions program. The survey should take about 15 minutes. I’m not selling anything.”]

1. **[ASK OF ALL]** As part of the program, someone would have come to your home to assess the energy efficiency of your home, given you some free energy-saving devices like light bulbs, and might have recommended additional ways that you could save energy. Do you remember this visit?
   1. Yes **[CONTINUE]**
   2. No or Don’t Know **[ASK IF ANYONE ELSE IN THE HOUSEHOLD MIGHT REMEMBER**
      1. **IF SO, ASK THEM “**"We are conducting a survey to help the Connecticut Energy Efficiency Fund and your electric utility improve the Home Energy Solutions program. Our records show that your household participated in the Home Energy Solutions program in [MONTH, YEAR FROM PROGRAM RECORDS]. As part of the program, someone would have come to your home to assess the energy efficiency of your home, given you some free energy-saving devices like light bulbs, and might have recommended additional ways that you could save energy. Do you remember this visit?**” [IF YES, CONTINUE; IF NO, THANK AND TERMINATE]**
      2. **IF NOT, THANK AND TERMINATE]**
2. Refused **[THANK AND TERMINATE]**
3. **[ASK OF ALL]** Were you directly involved in making decisions about the energy-efficiency assessment of your home, such as deciding whether to purchase and install any of the efficiency measures recommended by the energy auditor?
4. Yes **[CONTINUE]**
5. No **[ASK** “May I please speak to the person in the household who made these decisions?**” IF THIS PERSON COMES TO THE LINE, SAY** "We are conducting a survey to help the Connecticut Energy Efficiency Fund and your electric utility improve the Home Energy Solutions program. Our records show that your household participated in the Home Energy Solutions program in [MONTH, YEAR FROM PROGRAM RECORDS]. I would like to ask you a few questions about your household’s experience with the Home Energy Solutions program. The survey should take about 15 minutes. I’m not selling anything.” **THEN CONTINUE TO S3; OTHERWISE, THANK AND TERMINATE]**
6. Don’t know/refused **[THANK AND TERMINATE]**

**[IF DISPOSITION=1, SKIP TO ‎**S6**. IF DISPOSITION=2, SKIP TO ‎**G5**.]**

1. Did the Home Energy Solutions visit occur at the home you live in, homes or apartments that you rent out, or some other location, such as the home of a family member? [**MARK ALL THAT APPLY**]
2. My own home **[SEE INSTRUCTIONS BELOW. IF CLARIFICATION NEEDED FOR LANDLORDS OR MULTIPLE HOMEOWNERS, THIS IS “THE HOME I LIVE IN MOST OF THE YEAR”**
3. A unit or building that I rent out **[SEE INSTRUCTION BELOW]**
4. Another location **[IF ALSO ‎**S2**=1 OR 2 CONTINUE AS DIRECTED ABOVE, OTHERWISE** **THANK AND TERMINATE]**
5. Don’t know/refused **[THANK AND TERMINATE]**

**[IF S3=BOTH 1 AND 2, READ “FOR THE REST OF MY QUESTIONS, PLEASE ANSWER ONLY FOR THE HOME IN WHICH YOU LIVE” AND CONTINUE. IF S3=2 ONLY, AND RESPONDENT TELLS YOU THEY HAD A VISIT AT OTHER HOMES THEY OWN, OR S3=2 AND S3=3 READ “FOR THE REST OF MY QUESTIONS, PLEASE ANSWER ONLY FOR THE HOME LOCATED AT (READ STREET ADDRESS, TOWN FROM FILE)”]]**

S3a According to our records, at the time of the visit your home had Central Air Conditioning. Is this correct?

1. Yes
2. No **[THANK AND TERMINATE]**
3. Don’t know/don’t remember **[THANK AND TERMINATE]**
4. Refused **[THANK AND TERMINATE]**
5. **[ASK IF DISPOSITION=3]** Our records indicate that the energy auditor who came to your home for the Home Energy Solutions evaluation recommended that you replace your Central Air Conditioning unit; you might also have been offered a rebate or low-interest financing to help with the cost. Do you remember a Central Air Conditioning unit replacement being recommended for your home?
6. Yes [SKIP TO ‎S6]
7. No [USE IF NO OTHER INFO VOLUNTEERED BY RESPONDENT] **[THANK AND TERMINATE]**
8. No/I don’t remember [USE IF RESPONDENT VOLUNTEERS THEY DO NOT REMEMBER] **THANK AND TERMINATE]**
9. No/Recommendation was not made [USE IF RESPONDENT VOLUNTEERS THAT RECOMMENDATION WAS NOT MADE] **THANK AND TERMINATE]**
10. Don’t know **[THANK AND TERMINATE]**
11. Refused **[THANK AND TERMINATE]**
12. **[ASK DISPOSITION=4]** Did the energy auditor who came to your home for the Home Energy Solutions evaluation recommend that you replace your Central Air Conditioning unit?
13. Yes
14. No **[THANK AND TERMINATE]**
15. Don’t know/don’t remember **[THANK AND TERMINATE]**
16. Refused **[THANK AND TERMINATE]**
17. Was your Central Air Conditioning unit working at the time of the audit?
18. Yes
19. No **[IF DISPOSITION=3 OR 4, THANK AND TERMINATE]**
20. Don’t know/don’t remember **[IF DISPOSITION=3 OR 4, THANK AND TERMINATE]**
21. Refused **[IF DISPOSITION=3 OR 4, THANK AND TERMINATE]**

**[IF DISPOSITION= 1 OR 2, SKIP TO ‎**G5**]**

1. Did you replace your Central Air Conditioning unit after the audit?
2. Yes [THIS IS GROUP C1]
3. No [THIS IS GROUP C2]
4. Don’t know/don’t remember **[THANK AND TERMINATE]**
5. Refused **[THANK AND TERMINATE]**

General Questions & Rebate Awareness

1. **[IF ‎S7=2]** To the best of your knowledge, how old is your current Central Air Conditioning unit? Is it . . .
2. Less than 10 years old, or
3. 10 years old or more?
4. Don’t know/don’t remember
5. Refused
6. **[IF ‎S7=1]** To the best of your knowledge, how old was the Central Air Conditioning unit you replaced? Was it . . .
7. Less than 10 years old, or
8. 10 years old or more?
9. Don’t know/don’t remember
10. Refused

1. **[IF C1 OR C2]** Before this call today, were you aware that you could receive a rebate for replacing yourCentral Air Conditioning equipment?
2. Yes
3. No
4. Don’t know/don’t remember
5. Refused
6. **[IF ‎G3=1]** How did you learn about the rebate? [ASK OPEN ENDED. ACCEPT MULTIPLE REPSONSES. BELOW ARE SOME PRECODES FOR LIKELY RESPONSES. FOR ALL OTHERS, RECORD DESCRIPTION OFFERED BY RESPONDENT.]
7. Energy auditor
8. Rebate Application packet
9. Contractor who gave them quote
10. Some other way (RECORD DESCRIPTION)\_\_\_\_\_\_\_\_\_\_\_\_\_\_
11. **[IF DISPOSITION=1 OR 2]** Before the energy audit, were you already aware that you could receive a rebate for replacing yourCentral Air Conditioning equipment?
12. Yes
13. No
14. Don’t know/don’t remember
15. Refused

1. **[IF GROUP C1 OR C2]** Did you get an estimate from the energy auditor’s company or another company to replace your Central Air Conditioning unit?
2. Yes
3. No
4. Don’t know/don’t remember
5. Refused
6. **[IF ‎**G6**=1]** Did any of the companies that gave you estimates recommend a high-efficiency unit that would qualify for a rebate?
7. Yes
8. No
9. Don’t know/don’t remember
10. Refused

Replacement with Rebate

1. **[IF DISPOSITION=1 OR 2]** Our records show that you received a [IF DISPOSITION = 1 **READ** $250, IF DISPOSITION = 2 **READ** $500] rebate for replacing your Central Air Conditioning unit with a more efficient unit. Do you remember the rebate?
2. Yes
3. No
4. Don’t know
5. Refused
6. **[IF DISPOSITION=1 OR 2 AND ‎**R1**=1]** How important was the rebate to your decision to replace your Central Air Conditioning with a high-efficiency ENERGY STAR unit?Would you say it was… (READ RESPONSES ALOUD)
7. Not at all important
8. Slightly important
9. Somewhat important, or
10. Very important?
11. Don’t know/don’t remember
12. Refused
13. [(IF DISPOSITION=2 AND ‎R1=1) OR (IF DISPOSITION=1 AND ‎R1=1 AND ‎S6=1)] How important was the rebate to your decision to replace your Central Air Conditioning unit *while it was still functioning*? Would you say it was… (READ RESPONSES ALOUD)
14. Not at all important
15. Slightly important
16. Somewhat important, or
17. Very important?
18. Don’t know/don’t remember
19. Refused
20. **[IF DISPOSITION=1 OR 2 AND ‎**R1**=1]** What factors were important to you when deciding whether or not to replace your Central Air Conditioning unit with one that would qualify for a rebate? (If respondent asks for clarification – “What kinds of things were important…)”
21. (Speed of installation)
22. (Purchase cost of unit)
23. (Installation cost of unit)
24. (Operating cost of unit)
25. (Reputation of contractor or brand of equipment)
26. (Reliability)
27. (Comfort)
28. (Improving health and safety in home)
29. (Save energy/Energy efficiency concerns)
30. (Better for environment)
31. (Other **[SPECIFY: \_\_\_\_\_\_\_\_\_\_\_]**)
32. (Don't know)
33. **[IF DISPOSITION=1 OR 2]** Did you have specific plans to install any of this efficient air conditioning equipment before you talked with anyone about the Home Energy Solutions Program?
34. Yes
35. No
36. Don’t know/don’t remember
37. Refused
38. **[IF DISPOSITION=1 OR 2 OR C1]** Did the same firm that conducted your energy audit also install your replacement Central Air unit?
39. Yes
40. No
41. Don’t know/don’t remember
42. Refused
43. **[IF DISPOSITION=1 OR 2]** How important was the information provided by the firm that conducted the energy audit to your decision to apply for a rebate for the unit? Was it… **(READ ALOUD)**
44. Not at all important
45. Slightly important
46. Somewhat important, or
47. Very important?
48. Don’t know
49. Refused
50. [**IF DISPOSITION=1 OR 2 AND ‎**R6**=2, 96 OR 97]** How important was the information provided by the firm that installed your replacement Central Air unit to your decision to apply for a rebate for the unit**?** Was it… **(READ ALOUD)**
51. Not at all important
52. Slightly important
53. Somewhat important, or
54. Very important?
55. Don’t know
56. Refused
57. **[IF DISPOSITION=1 OR 2]** Did you consider any drawbacks before using the rebate?
58. Yes
59. No
60. Don’t know
61. Refused
62. **[IF ‎**R9**=1]** What were the drawbacks? **(RECORD VERBATIM)**

Financing

1. **[IF DISPOSITION=1 OR 2 AND IF FINANCING RECEIVED = Y]** Our records show that you obtained a loan through [utility name]to finance the replacement of your Central Air Conditioning. How important was the loan to your decision to replace your Central Air Conditioning unit? Was it . . . (READ RESPONSES ALOUD)
2. Not at all important
3. Slightly important
4. Somewhat important, or
5. Very important?
6. Don’t know/don’t remember
7. Refused

Quality Installation

1. **[IF DISPOSITION=1 OR 2 AND QIV REBATED = N]** Before this call today, were you aware that you could have been eligible to receive an additional $500 rebate if the Central Air Conditioning equipment installation went through the “Quality Installation” certification process?
2. Yes
3. No
4. Don’t know
5. Refused
6. **[IF ‎Q1=1]** How did you learn about it? **[MULTIPLE RESPONSES ALLOWED** ASK OPEN ENDED. BELOW ARE SOME PRECODES FOR LIKELY RESPONSES. FOR ALL OTHERS, RECORD DESCRIPTION OFFERED BY RESPONDENT.]
   * + 1. energy auditor
       2. contractor who gave quote for installation
       3. financing requirement
       4. Other (RECORD VERBATIM)
7. **[IF IF DISPOSITION=1 OR 2 AND QIV REBATED = Y]** According to our records you received an additional $500 rebate because your Central Air Conditioning equipment installation went through the “Quality Installation” certification process. How did you learn about this additional rebate? **[MULTIPLE RESPONSES ALLOWED** ASK OPEN ENDED. BELOW ARE SOME PRECODES FOR LIKELY RESPONSES. FOR ALL OTHERS, RECORD DESCRIPTION OFFERED BY RESPONDENT.]
   * + 1. energy auditor
       2. contractor who gave quote for installation
       3. financing requirement
       4. Other (RECORD VERBATIM)
8. **[IF DISPOSITION=1 OR 2 AND QIV REBATED = N]** Another aspect of the Home Energy Solutions program is known as “Quality Installation and Verification” or QIV. It ensures that your Central Air Conditioning has been installed for best performance and reliability, and carries with it an extra incentive. Did the energy auditor recommend Quality Installation and Verification for the replacement Central Air Conditioning?
9. Yes
10. No
11. Don’t know
12. Refused
13. **[IF DISPOSITION=1 OR 2 AND ‎Q3=1]** What made you decide not to obtain “Quality Installation” certification for your replacement Central Air Conditioning? (MULTIPLE RESPONSE) (RECORD VERBATIM)
14. **[IF DISPOSITION=1 OR 2 AND ‎Q3=1]** Is there anything that would have made you more likely to obtain a certified Quality Installation?
15. Yes
16. No
17. Don’t know/don’t remember
18. Refused
19. **[IF ‎Q5=1]** What would have made you more likely to obtain a certified Quality Installation? [RECORD VERBATIM]

CAC Replacement (Any Variety)

1. **[ IF DISPOSITION=1 OR 2 OR IF ‎S7=1]** How important was advice from the **[IF ‎**R6**=1 READ “firm that conducted the energy audit and installed your replacement Central Air Unit” IF ‎**R6**=2, 96 OR 97 READ “firm that conducted the energy audit”]** to your decision to replace the unit? **Was it… (READ ALOUD)**
2. Not at all important
3. Slightly important
4. Somewhat important, or
5. Very important?
6. Don’t know/don’t remember
7. Refused
8. **[(IF DISPOSITION=1 OR 2 OR C1 AND IF ‎**R6**=2, 96 OR 97)]** How important was advice from the firm that actually installed your replacement Central Air Unit to your decision to replace the unit?**) Was it… (READ ALOUD)**
9. Not at all important
10. Slightly important
11. Somewhat important, or
12. Very important?
13. Don’t know/don’t remember
14. Refused
15. **[IF DISPOSITION=1 OR 2 OR IF ‎S7=1]** How important was advice from the **[IF ‎**R6**=1 READ “firm that conducted the energy audit and installed your replacement Central Air Unit” IF ‎**R6**=2, 96 OR 97 READ “firm that conducted the energy audit”]** to your decision of *which* Central Air Conditioning unit to install? **Was it… (READ ALOUD)**
16. Not at all important
17. Slightly important
18. Somewhat important, or
19. Very important?
20. Don’t know
21. Refused
22. **[(IF DISPOSITION=1 OR 2 OR C1 AND IF ‎**R6**=2, 96 OR 97)]** How important was advice from the firm that actually installed your replacement Central Air Unit to your decision of *which* Central Air Unit to install? **Was it… (READ ALOUD)**
23. Not at all important
24. Slightly important
25. Somewhat important, or
26. Very important?
27. Don’t know
28. Refused
29. **[IF DISPOSITION=1 OR 2 OR IF ‎S7=1]** What factors helped you decide to replace your Central Air Conditioning unit? (If respondent asks for clarification – “What kinds of things were important to your decision to replace the unit)” [DO NOT READ. ACCEPT MULTIPLE RESPONSES]
    1. (The old unit broke down)
    2. (The old unit wasn’t working well)
    3. (The old unit required too many repairs)
    4. (We were selling home)
30. (Contractor said we should replace the old unit)
31. (Had home inspected and Inspector recommended replacing old unit)
32. (Contractor convinced me old unit needed to be replaced)
33. (Unit was getting old)
34. (Did not want old unit to break down at a bad time)
35. (We were doing extensive remodeling and needed to replace EQUIP)
36. (Other: [SPECIFY] \_\_\_\_\_\_\_\_\_\_\_\_\_)

Early Replacement

1. **[IF GROUP C1 OR C2]** Did the energy auditor tell you that there could be an additional $250 rebate for replacing your Central Air Conditioning unit, because of its age?
2. Yes
3. No
4. Don’t know/ don’t remember
5. Refused

E2 and E3 ask only (if DISPOSITION=2) OR (if ‎S6=1 and ‎S7=1)

1. How important was advice from the **[IF ‎**R6**=1 READ “firm that conducted the energy audit and installed your replacement Central Air Unit”] [IF ‎**R6**=2, 96 OR 97 READ “firm that conducted the energy audit”]** in your decision to replace the *unit that was still functioning*? Were they… (READ ALOUD)
2. Not at all important
3. Slightly important
4. Somewhat important, or
5. Very important?
6. Don’t know/don’t remember
7. Refused
8. [IF E2=3 OR 4] What did the firm do or say that was important to your decision? (RECORD VERBATIM )
9. **[IF ‎**R6**=2, 96 OR 97]** How important was advice from the firm that actually installed your replacement Central Air Unit in your decision to replace the *unit that was still functioning*? Were they… (READ ALOUD)
10. Not at all important
11. Slightly important
12. Somewhat important, or
13. Very important?
14. Don’t know/don’t remember
15. Refused
16. **[IF ‎**E2a**=3 OR 4]** What did the firm do or say that was important to your decision? (RECORD VERBATIM)

Replacement without Rebate

1. **[IF ‎S7=1]** Have you ever seen or heard of the ENERGY STAR label? This is a blue-and-white label that appears on some products and equipment to show that they use less energy than average.
2. Yes
3. No
4. DON’T KNOW
5. REFUSED
6. **[IF ‎**W1**=1]** To the best of your knowledge, does the replacement unit you installed carry the ENERGY STAR label, or is it ENERGY STAR-qualified?
7. Yes
8. No
9. Don’t know/ don’t remember
10. Refused
11. **[IF ‎W2=2]** What factors made the unit you installed preferable to an Energy Star unit? (If respondent asks for clarification – “What kinds of things made the unit you installed preferable)” (RECORD VERBATIM)
12. **[IF ‎W2=2]** What might have convinced you to install an efficient Central Air Conditioning unit that would qualify for a rebate? (RECORD VERBATIM)
13. **[IF ‎S7=1]** To your knowledge, did the unit you installed qualify for a rebate from [UTILITY]?
14. Yes
15. No
16. Don’t know/ don’t remember
17. Refused
18. **[IF ‎W5=1]** Why didn’t you use the rebate when replacing your Central Air Conditioning unit? (RECORD VERBATIM)
19. **[IF ‎**W5**=1]** What factors did you consider when deciding whether or not to apply for the rebate? (MULTIPLE RESPONSE, DO NOT READ ALOUD)
20. (Time limit on use of rebate)
21. (Contractor I used was not associated with Home Energy Solutions program)
22. (I would have installed the unit without the rebate anyway)
23. (Rebate not large enough to be worth the trouble)
24. (Applied but was rejected [for example, model number not qualified]) RECORD VERBATIM
25. Other [RECORD VERBATIM]

No Replacement

1. **[IF ‎**S7**=2]** Did you consider replacing your Central Air Conditioning unit after the energy auditor recommended it?
2. Yes
3. No
4. Don’t know/don’t remember
5. Refused
6. **[IF ‎N1=1]** What kept you from replacing it? (MULTIPLE RESPONSE DO NOT READ ALOUD)
7. Cost/too expensive
8. Current unit was still working
9. Other (RECORD)
10. Don’t know/don’t remember
11. Refused
12. **[IF ‎N1=2]** Why didn’t you consider replacing your Central Air Conditioning unit after the recommendation? (MULTIPLE RESPONSES ALLOWED)
13. Cost/too expensive
14. Current unit was still working
15. Hassle of installation
16. Other (RECORD)
17. Don’t know/don’t remember
18. Refused
19. **[IF ‎S7=2]** Have you decided to delay the replacement of your Central Air Conditioning unit to a *future date*, to delay it to when the unit *breaks down*, or something else?
20. Delay to future date
    1. When do you expect to replace the unit? [RECORD]
    2. Do you plan to replace the unit with a high-efficiency unit that would qualify for a rebate from [UTILITY NAME]?
       1. Yes
       2. No
          1. Why . . .
21. Replace when unit breaks down
    1. When do you expect the unit to break down? [RECORD]
    2. Do you plan to replace the unit with a high-efficiency unit that would qualify for a rebate from [UTILITY NAME]?
       1. Yes
       2. No
          1. Why . . .
22. No
23. Undecided
24. Something else [DESCRIBE]
25. Don’t know
26. Refused
27. **[IF ‎**N4**=1, 2 OR 5] [IF N4=1 READ “**Why did you decide to delay replacement of your Central Air Conditioning unit to a future date?”] [**IF ‎**N4**=2 READ** “Why did you decide to wait until the unit breaks down to replace it?”] [**IF ‎**N4**=5 READ** “Why did you make that decision?”]?
28. (RECORD VERBATIM)
29. Don’t know
30. Refused
31. **[IF ‎S7=2]** How important was the energy auditor or their firm to your decision making about your central air conditioning unit? Were they… (READ ALOUD)
32. Not at all important
33. Slightly important
34. Somewhat important, or
35. Very important
36. Don’t know/ don’t remember
37. Refused
38. [IF ‎N7=3 OR 4] In what way was the energy auditor or their firm important to your decision making? [RECORD VERBATIM]

Recommendations

1. **[IF ‎S7=2]**Other than offering a rebate, what else could the Home Energy Solutions Program have done that might have made you decide to replace your Central Air Conditioning unit? [RECORD VERBATIM]
2. **[IF DISPOSITION=1 OR 2 OR IF ‎S7=1]** In your opinion, what else could the Home Energy Solutions program do to encourage [UTILITY NAME] customers like yourself to replace their less efficient Central Air Conditioning units with more energy efficient units? (RECORD VERBATIM)

Demographic Characteristics [ASK OF ALL RESPONDENTS]

1. Do you or members of your household own this home or do you rent?
2. Own/Buying
3. Rent/Lease
4. Occupied without Payment or Rent
5. OTHER (SPECIFY): \_\_\_\_\_\_\_\_\_\_
6. DON’T KNOW
7. REFUSED
8. Approximately how many square feet is your home?
9. Less than 1,500
10. 1,500 – 1,999
11. 2,000 – 2,999
12. 3,000 – 3,999
13. 4,000 – 4,999
14. 5,000 – 5,999
15. 6,000 or more
16. DON’T KNOW
17. REFUSED
18. How many rooms are in your home, not counting bathrooms?
19. 1
20. 2
21. 3
22. 4
23. 5
24. 6
25. 7
26. 8
27. 9
28. 10 or more
29. (Don’t know/refused)
30. How long have you lived in this home? [DO NOT READ. ASK FOR AN ESTIMATE IF DK]
31. One year or less
32. 1+ to 2 years
33. 2+ to 3 years
34. 3+ to 4 years
35. 4+ to 5 years
36. 5+ to 6 years
37. 6+ to 7 years
38. 7+ to 8 years
39. 8+ to 9 years
40. 9+ to 10 years
41. 10+ to 11 years
42. 11 to 15 years
43. 15+ to 20 years
44. More than 20 years
45. (Don’t know)
46. What is the highest level of education that you have completed? **[READ CATEGORIES]**
47. Less than high school
48. High school graduate
49. Technical or trade school graduate
50. Some college
51. College graduate
52. Some graduate school
53. Graduate degree
54. (Refused)
55. How many people live in your home?
56. 1
57. 2
58. 3
59. 4
60. 5
61. 6 or more
62. (Refused)

DEM7. What is your age?

1. 18 to 24
2. 25 to 34
3. 35 to 44
4. 45 to 54
5. 55 to 64
6. 65 or over
7. (Refused)
8. What category best describes your total household income in 2011, before taxes?
9. Less than $35,000
10. $35,000 to $49,999
11. $50,000 to $74,999
12. $75,000 to $99,999
13. $100,000 or more
14. (Refused)
15. **[RECORD SEX]**

1. Male

2. Female

Recruit For Possible Focus Groups

We may be conducting focus groups in your area about the Home Energy Solutions program within the next few months. We would offer a $75 incentive to focus group participants to compensate them for their time. The focus group would take place during a weekday evening, in North Haven or Farmington. Would you be interested in being part of a focus group?

**[IF NO: GO TO CLOSING]**

**[IF YES]**

1. Is this the best number to reach you at to schedule a focus group? [RECORD BEST NUMBER]
2. Just in case we have trouble reaching you by phone, may we also contact you by email? **[IF YES]** What email address should we use? [RECORD EMAIL]

Closing

Thank you for taking the time to help improve the Home Energy Solutions Program.

1. Metering Equipment, Specifications and On-site Form

Whenever possible, condensing unit powers were monitored using ONSET Hobo Microstation data loggers configured to receive pulse outputs from Continental Control System Wattnode pulse meters. The Wattnode meters were connected to the condensing units via split-core current transducers and voltage taps connected to both split phase legs and the ground terminal. Using the proposed set up, condensing unit energy usage was recorded in five-minute intervals for the duration of the summer monitoring period Figure ‎4‑1 below provides a complete schematic of the condensing unit logging set up.

Figure ‑: Condensing Unit Logging Equipment



Air handler operating data were collected with Onset Microstation data loggers outfit with TRMS modules and CCS split-core current transducers. Current logging was used instead of time of use logging because many residential air handlers have multiple speeds. Multiple speeds can be captured with a single phase current logger, but not with a time of use logger. Current measurements were recorded in five-minute intervals. Figure ‎4‑2 below provides a schematic representation of the air handler logging set up. An identical amperage metering suite was utilized for condenser unit monitoring in instances where it was not possible to install the true power logging suite.

Figure ‑: Air Handler Logging Equipment



In addition to metering, spot power measurements of condensing unit and air handling unit power, power factor, voltage, and amperage were taken whenever possible. Condensing unit spot measurements were taken to QC the magnitude of the logged values and supplement amperage data when true power logging was not possible. Air handler unit spot measurements were taken to determine the voltage and power factor levels corresponding to AHU operation. These data were then used in conjunction with logged amperage to estimate AHU power for each logging interval.

**Meter Compliance-ISO Requirements:**

All metering equipment used to conduct the monitoring in this study on newly installed CAC equipment met or exceeded specifications of the ISO New England Measurement and Verification Equipment Requirements. The relevant requirements include:

**Relevant ISO Requirements:**

* All equipment used for monitoring and data recording shall meet or exceed the relevant standards set by the American National Standard Institute (ANSI) or equivalent standard for the equipment.
* Data recorders that are recording pulses from measurement and monitoring devices must utilize a pulse rate within the resolution capabilities of the recorder.
* All equipment installed on electric circuits with significant harmonics shall meet or exceed the relevant standards provided by the Institute of Electrical and Electronics Engineers (IEEE).
* Any equipment that directly measures electrical demand shall be a true RMS (Root Mean Square) measurement device with an accuracy of no less than ± 2%.
* Any monitoring equipment of current (amps) and nominal voltage used to calculate electrical demand must include the power factor of the end-uses in the demand (kW) calculations.
* The Project Sponsor must maintain documentation on all measurement monitoring and data recording equipment maintenance and calibration activities.
* Interval metering devices shall collect electricity usage data at a frequency of 15 minutes or less.

The table below shows all metering equipment used and their rated accuracy, among other information. We also footnote the specification documents below.

Table -: Primary meters and logging equipment

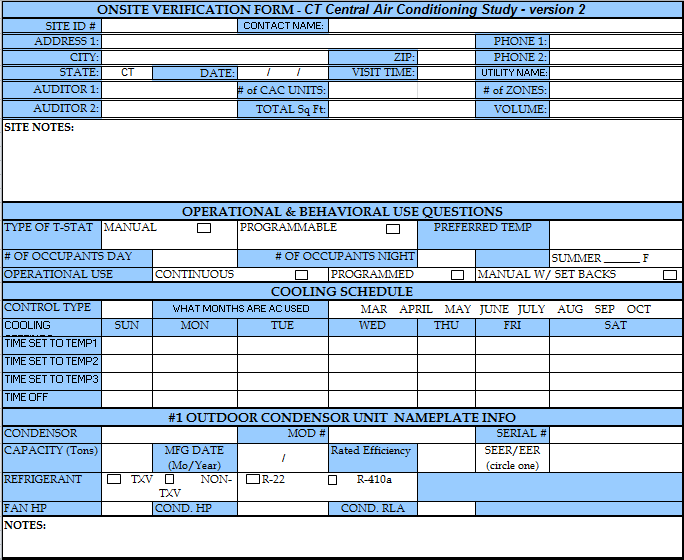
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Equipment Monitored** | **Function/Data Point to Measure** | **Equipment**  **Brand/Model** | **Rated Full Scale Accuracy** | **Duration of Metering** | **Metering Interval** | **Meets Standards** |
| Condenser | Power Meter | Wattnode Power Meter- 240v[[34]](#footnote-34) | ± 0.5% | 10+ Weeks | 5 Min | ANSI 12.20 |
| Condenser | Power Logger | Onset HOBO Micro Station[[35]](#footnote-35) | ± 1.0% | 10+ Weeks | 5 Min | ANSI 12.1 |
| Air-Handler | Power Logger | Onset HOBO H22[[36]](#footnote-36) | ± 1.0% | 10+ Weeks | 5 Min | ANSI 12.1 |
| Condenser and Air Handler | Current Transducer | Magnelab Split-Core AC CT[[37]](#footnote-37) | ± 1.0% | 10+ Weeks | 5 Min | ANSI 12.1 |
| Spot Measurements | Power Measurements | Extech Power Clamp Meter[[38]](#footnote-38) | ± 1.5% | Spot Measurements | Spot Measurements | IEC 1010 Category III |

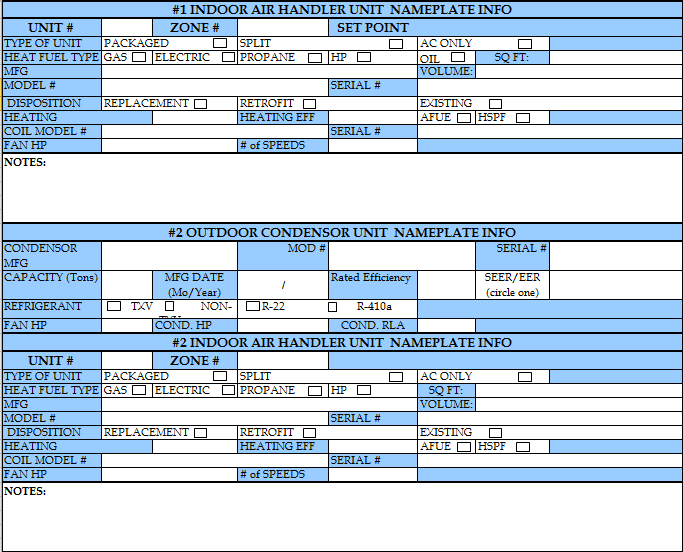
**Meter Calibration and Inventory:**

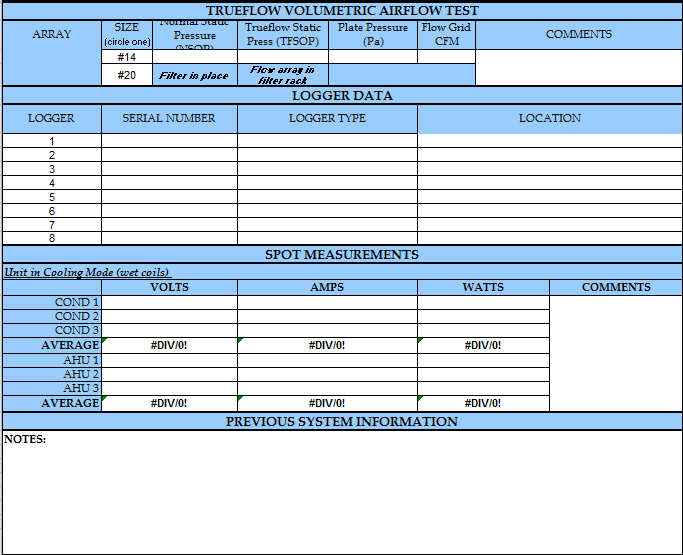
Prior to the commencement of field data collection activities, a comprehensive metering calibration check was performed on all meters to verify accuracy and functionality.

1. All metering equipment was inventoried and serial numbers recorded. All meters received new batteries and visual inspections of wiring and connections.
2. Power Meters: The Continental Control System Wattnode pulse meters were tested for accuracy using a 240 volt circuit with a known power draw and recorded data over a set duration of time. Pulse counts were verified as recorded on the HOBO micro-station logger, and calculated to that of the test load. Any combination of Wattnode and micro-station that was not recording within ± 2.0% of the known test load was eliminated from use.
3. Amp Meters: The HOBO H22s and HOBO micro-stations that were used to record run-time and amp usage by the HVAC equipment were tested using a similar method. Meters were connected to the wiring of a known power draw and recorded data was compared for accuracy with the test load. Any meter that was not recording within ± 2.0% of the known test load was eliminated from use.
4. Meters were preset for launch in the field with recording intervals of 5 minutes. All Wattnode/ micro-stations tested in pairs were kept together as a set for deployment in the field. Meter numbers were recorded on the field data collection forms at each site as the meters were assigned to a particular field site.

The form below was utilized at all sites visited.







1. Seasonal Peak Calculation Approach

The calculation of the summer Seasonal Peak demand reduction was based on the performance hours that were used to evaluate the Demand Reduction Values (DRV). Seasonal demand performance hours for ISO-NE FCM are defined as hours when the real time ISO-NE system load meets or exceeds 90% of the predicted Seasonal Peak from the most recent Capacity, Electricity, Load and Transmission Report (CELT report). The peak load forecast for the summer 2013 season was 27,840 kW, and 90% of which was 25,056 kW. There were 43 hours during the summer 2013 season when the load exceeded 25,056 kW. The evaluation used a blend of both Hartford and Bridgeport real weather data for the summer of 2013 to calculate the weighted average Total Heat Index (THI) of 79.3 for Connecticut during these hours. The Total Heat Index is a forecast variable used by ISO-NE and it is calculated as follows;

THI = 0.5 x DBT + 0.3 x DPT + 15 Where,

THI = Total Heat Index

DBT = Dry Bulb Temperature (°F)

DPT = Dew Point Temperature (°F)

ISO-NE also uses a variable called a Weighted Heat Index (WHI) which is a three day weighted average of the THI and is calculated as follows;

WHI = 0.59 x THIdi hi + 0.29 x THId(i-1) hi + 0.12 x THId(i-2) hi Where,

WHI = Weighted Heat Index

THIdi hi= Total Heat Index for the current day and hour

THId(i-1) hi= Total Heat Index for previous day and same hour

THId(i-2) hi= Total Heat Index for two days prior and same hour

Table ‎4-2 provides the summer 2013 Seasonal Peak hours along with the system load, percent of CELT forecast peak, the THI and the WHI based on Connecticut weather.

Table -: 2013 Summer Seasonal Peak Hours and System Load

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Date** | **Hour** | **System Load (kW)** | **Percent of Peak** | **THI** | **WHI** |  | **Date** | **Hour** | **System Load (kW)** | **Percent of Peak** | **THI** | **WHI** |
| 6/24/2013 | 16 | 25,071 | 90% | 78.9 | 77.7 |  | 7/18/2013 | 12 | 25,842 | 93% | 78.4 | 77.6 |
| 6/24/2013 | 17 | 25,129 | 90% | 77.9 | 76.9 |  | 7/18/2013 | 13 | 26,339 | 95% | 79.4 | 78.8 |
| 7/15/2013 | 13 | 25,344 | 91% | 77.9 | 76.4 |  | 7/18/2013 | 14 | 26,747 | 96% | 79.4 | 78.8 |
| 7/15/2013 | 14 | 25,779 | 93% | 77.6 | 76.5 |  | 7/18/2013 | 15 | 26,867 | 97% | 79.6 | 79.0 |
| 7/15/2013 | 15 | 25,972 | 93% | 78.8 | 77.4 |  | 7/18/2013 | 16 | 26,840 | 96% | 80.6 | 79.9 |
| 7/15/2013 | 16 | 26,066 | 94% | 78.1 | 76.8 |  | 7/18/2013 | 17 | 26,680 | 96% | 79.8 | 79.3 |
| 7/15/2013 | 17 | 26,089 | 94% | 78.5 | 77.3 |  | 7/18/2013 | 18 | 26,306 | 94% | 80.7 | 80.0 |
| 7/15/2013 | 18 | 25,917 | 93% | 77.7 | 77.0 |  | 7/18/2013 | 19 | 25,617 | 92% | 80.5 | 79.8 |
| 7/15/2013 | 19 | 25,418 | 91% | 79.1 | 77.7 |  | 7/19/2013 | 11 | 25,436 | 91% | 79.3 | 78.6 |
| 7/16/2013 | 13 | 25,328 | 91% | 77.7 | 77.7 |  | 7/19/2013 | 12 | 26,457 | 95% | 79.8 | 79.0 |
| 7/16/2013 | 14 | 25,900 | 93% | 77.7 | 77.6 |  | 7/19/2013 | 13 | 27,015 | 97% | 80.2 | 79.7 |
| 7/16/2013 | 15 | 26,088 | 94% | 77.9 | 78.1 |  | 7/19/2013 | 14 | 27,347 | 98% | 81.0 | 80.2 |
| 7/16/2013 | 16 | 26,160 | 94% | 78.4 | 78.1 |  | 7/19/2013 | 15 | 27,353 | 98% | 81.4 | 80.5 |
| 7/16/2013 | 17 | 26,226 | 94% | 78.4 | 78.3 |  | 7/19/2013 | 16 | 27,350 | 98% | 81.7 | 81.1 |
| 7/16/2013 | 18 | 26,040 | 94% | 78.2 | 78.0 |  | 7/19/2013 | 17 | 27,360 | 98% | 82.0 | 81.0 |
| 7/16/2013 | 19 | 25,422 | 91% | 78.0 | 78.2 |  | 7/19/2013 | 18 | 27,066 | 97% | 81.3 | 80.9 |
| 7/17/2013 | 13 | 25,487 | 92% | 78.0 | 77.9 |  | 7/19/2013 | 19 | 26,305 | 94% | 81.2 | 80.8 |
| 7/17/2013 | 14 | 26,064 | 94% | 78.2 | 78.0 |  | 7/19/2013 | 20 | 25,483 | 92% | 80.5 | 79.9 |
| 7/17/2013 | 15 | 26,351 | 95% | 78.4 | 78.3 |  | 7/19/2013 | 21 | 25,154 | 90% | 80.3 | 79.1 |
| 7/17/2013 | 16 | 26,522 | 95% | 79.1 | 78.8 |  |  |  |  |  |  |  |
| 7/17/2013 | 17 | 26,622 | 96% | 78.7 | 78.6 |  |  |  |  |  |  |  |
| 7/17/2013 | 18 | 26,494 | 95% | 79.4 | 78.8 |  |  |  |  |  |  |  |
| 7/17/2013 | 19 | 25,890 | 93% | 79.2 | 78.8 |  |  |  |  |  |  |  |
| 7/17/2013 | 20 | 25,089 | 90% | 79.3 | 78.6 |  |  |  |  |  |  |  |

The peak load data and the weighted THI and WHI data for 2013 were used to create linear regressions of peak system load as a function of THI and WHI. The analysis focused on non-holiday weekdays from June through July during hours ending 11 through 21. Evaluators used the time window of hours ending 11 to 21 because of the above observed peaks in the 2013 season that occurred outside of the 1 pm to 5 pm daily peak time period.

The following THI & WHI cutoff points were the result of the regression analyses. These represent the selection points at which both the THI and WHI from a blended Connecticut TMY3 weather file must be greater than in order to trigger a summer seasonal peak hour.

THI Cutoff Point: 79.8

WHI Cutoff Point: 79.1

Table ‎4-3 provides a summary of the THI, WHI and number of summer seasonal hours for the blended Connecticut TMY3 weather file used in the analysis by month and for the summer season. These are the total number of TMY3 hours applied to the evaluation year that meet the above criteria for being selected as a summer seasonal peak hour.

Table -: Summary of Summer Seasonal Hours for Blended TMY3 Weather

|  |  |  |  |
| --- | --- | --- | --- |
| **Month** | **Mean THI** | **Mean WHI** | **# of Hours** |
| June | 80.1 | 79.2 | 6 |
| July | 81.1 | 79.7 | 38 |
| August | 80.9 | 80.4 | 9 |
| **Summer** | **80.9** | **79.7** | **53** |

1. Demographic Characteristics of Survey Respondents

As the primary purpose of the study was to understand participants, the evaluation team compared participants’ responses to demographic characteristics questions with one another rather than with the state population. The tables below show the characteristics across respondent groups and overall.

Table -: Home Ownership

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Do you or members of your household own this home or do you rent?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| Own | 98% | 100% | 100% | 100% | 99% |
| Rent | 2 | 0 | 0 | 0 | 1 |

Table -: Home Square Footage

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Approximately how many square feet is your home?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| Less than 1,500 | 19% | 22% | 11% | 22% | 20% |
| 1,500 to less than 2,000 | 24 | 29 | 11 | 18 | 22 |
| 2,000 to less than 3,000 | 41 | 23 | 52 | 29 | 33 |
| 3,000 to less than 4,000 | 13 | 12 | 11 | 11 | 12 |
| 4,000 to less than 5,000 | 0 | 5 | 7 | 11 | 6 |
| 5,000 to less than 6,000 | 1 | 2 | 4 | 3 | 2 |
| 6,000 or more | 0 | 1 | 0 | 3 | 1 |
| Don’t know | 3 | 4 | 4 | 4 | 4 |

Table -: Number of Rooms in Home

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **How many rooms are in your home, not counting bathrooms?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| 2 | 0% | 0% | 0% | 4% | 1% |
| 3 | 1 | 1 | 0 | 1 | 1 |
| 4 | 4 | 16 | 4 | 7 | 9 |
| 5 | 9 | 9 | 7 | 12 | 10 |
| 6 | 20 | 14 | 11 | 18 | 17 |
| 7 | 14 | 16 | 22 | 11 | 14 |
| 8 | 29 | 15 | 30 | 11 | 19 |
| 9 | 7 | 15 | 4 | 14 | 11 |
| 10 or more | 14 | 10 | 19 | 18 | 14 |
| Don’t know/refused | 3 | 4 | 4 | 4 | 4 |

Table -: How Long Participants Have Lived in Home

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **How long have you lived in this home?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| 1+ to 2 years | 14% | 2% | 0 | 4% | 6% |
| 2+ to 3 years | 5 | 13 | 7 | 14 | 10 |
| 3+ to 4 years | 4 | 4 | 0 | 7 | 5 |
| 4+ to 5 years | 3 | 3 | 4 | 3 | 3 |
| 5+ to 6 years | 1 | 1 | 0 | 1 | 1 |
| 6+ to 7 years | 7 | 8 | 4 | 8 | 7 |
| 7+ to 8 years | 3 | 5 | 4 | 4 | 4 |
| 8+ to 9 years | 4 | 2 | 0 | 10 | 5 |
| 9+ to 10 years | 4 | 5 | 0 | 3 | 3 |
| 10+ to 11 years | 4 | 7 | 15 | 7 | 7 |
| 11 to 15 years | 9 | 12 | 22 | 14 | 13 |
| 15+ to 20 years | 13 | 9 | 15 | 4 | 9 |
| More than 20 years | 25 | 26 | 26 | 21 | 24 |
| Don’t know | 3 | 3 | 4 | 1 | 3 |

Table -: Educational Attainment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **What is the highest level of education that you have completed?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| Less than high school | 0% | % | 4% | 0% | <1% |
| High school graduate | 8 | 7 | 4 | 5 | 7 |
| Technical or trade school graduate | 3 | 0 | 0 | 3 | 2 |
| Some college | 13 | 12 | 19 | 8 | 12 |
| College graduate | 42 | 44 | 41 | 32 | 39 |
| Some graduate school | 0 | 3 | 0 | 3 | 2 |
| Graduate degree | 33 | 33 | 33 | 45 | 37 |
| Refused | 1 | 0 | 0 | 4 | 2 |

Table -: Household Size

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **How many people live in your home?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| 1 | 9% | 14% | 11% | 14% | 12% |
| 2 | 43 | 43 | 44 | 32 | 40 |
| 3 | 25 | 16 | 22 | 14 | 19 |
| 4 | 11 | 18 | 11 | 21 | 16 |
| 5 | 10 | 4 | 7 | 14 | 9 |
| 6 or more | 0 | 4 | 0 | 3 | 2 |
| Refused | 1 | 1 | 4 | 4 | 2 |

Table -: Age

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **What is your age?** | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| 25 to 34 | 8% | 4% | 4% | 8% | 6% |
| 35 to 44 | 14 | 12 | 11 | 22 | 16 |
| 45 to 54 | 24 | 20 | 26 | 23 | 23 |
| 55 to 64 | 30 | 32 | 19 | 21 | 26 |
| 65 or over | 22 | 30 | 33 | 16 | 24 |
| Refused | 2 | 2 | 7 | 10 | 5 |

Table -: Income

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Replaced CAC with CAC**  **Rebate only**  **($250)** | **Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **Replaced CAC Without Rebate** | **Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| Less than $35,000 | 1% | 4% | 7% | 5% | 4% |
| $35,000 to less than $50,000 | 2 | 9 | 4 | 5 | 5 |
| $50,000 to less than $75,000 | 16 | 6 | 0 | 11 | 10 |
| $75,000 to less than $100,000 | 22 | 21 | 15 | 15 | 19 |
| $100,000 or more | 39 | 48 | 48 | 48 | 45 |
| Refused | 21 | 13 | 26 | 15 | 17 |

Table -: Gender

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Gender** | **A. Replaced CAC with CAC**  **Rebate only**  **($250)** | **B. Replaced**  **CAC with CAC+Early Retirement Rebate**  **($500)** | **C. Replaced CAC Without Rebate** | **D. Did not Replace CAC** | **Total** |
| *Sample Size* | *70* | *70* | *27* | *73* | *240* |
| Male | 55% | 71% | 59% | 62% | 62% |
| Female | 45 | 29 | 41 | 38 | 38 |

1. Research Issues
   1. Program Record-keeping

The evaluation team found the participant data supplied for this study by the Companies to be of varying quality.

Mid-year in PY2011, CL&P began collecting data on the measures recommended by auditors as part of the HES program. As a result, data became available for a substantial number of CL&P participants indicating whether an HVAC measure of any kind had been recommended. While this helped in reducing the number of CL&P participants we had to contact to find ones for which CAC replacement was recommended, having data at an even more detailed level—specifically, whether CAC replacement had been recommended—would have been much more effective in reducing the number of calls that had to be made to find participants qualified for the survey. Nonetheless, HVAC recommendation data did help in keeping survey costs down, as participants with this variable responded to the survey at higher rates than participants without it.

The research team found that UI did not collect any data on the recommendations made by auditors as part of the HES program during either PY2011 or PY2012. As a result, the survey data included very few UI participants who did not take advantage of a CAC rebate. In addition, UI does not have a codebook for the program tracking data. The lack of a codebook slowed down the process of developing the sample frame for the study, and the lack of recommendation record-keeping resulted in higher survey research costs than necessary, as the more calls that must be made to reach target quotas, the higher the costs. The lack of information about program recommendations made to participants also presents a substantial barrier to understanding why participants do not follow through with recommendations.

The auditor does not record the year of manufacture of the CAC unit during the audit. Obtaining this information from the auditor would be much more reliable than participants’ retrospective estimates of CAC unit age at the time of the audit and would help in assessing the rate of units eligible for early replacement.

Including the kinds of information described above in program recordkeeping would improve future evaluations of HES CAC efforts.

* 1. Evaluation Design and Planning

Of the 27 respondents in the stratum of participants who reported replacing their CAC without a rebate group, ten later stated during the survey that they did in fact use a rebate. The evaluation team does not know if this is an issue of incorrect data from the Companies, or if the respondents confused the CAC rebate with other rebates they may have obtained through the program, or with federal tax credits.

Evaluating the program closer in time to the audit would yield more reliable results at lower cost. The original plan was to collect the PY2011 data in Summer 2012. This would have allowed participants who were audited late in 2011 time to follow through with CAC replacement while increasing the likelihood that the survey would be fielded during warm weather, when CAC would be a salient topic for the participants. Due to a variety of factors beyond the team’s control, the research was delayed until Fall 2012, and the telephone survey was carried out in mid-winter. In future, a better approach to studying CAC replacement would be to field a survey multiple times over the study period. For example, fielding the survey in two waves over the course of a program year would make it possible to ask questions of all participants within six to 12 months of the audit, at the very latest. By contrast, participants who were audited in winter of 2011 were asked questions nearly two years after their audits. To save on costs with this approach, the evaluation team could report on the results annually or even every other year, reusing the analysis programming and keeping interim reporting brief.

1. The original scope of work for this study included focus groups to explore decision-making regarding early CAC replacement in more detail. However, neither the Companies nor their HES implementation vendors regularly tracked households offered CAC rebates who did not use them. The EEB evaluation consultant and the evaluation team determined that the expense in finding and recruiting HES participants offered early replacement who did not use them would not be a cost effective evaluation strategy. [↑](#footnote-ref-1)
2. The original scope of work for this study included focus groups to explore decision-making regarding early CAC replacement in more detail. However, neither the Companies nor their HES implementation vendors regularly tracked households offered CAC rebates who did not use them. The EEB evaluation consultant and the evaluation team determined that the expense in finding and recruiting HES participants offered early replacement who did not use them would not be a cost effective evaluation strategy. [↑](#footnote-ref-2)
3. Summer On Peak Hours occur weekdays from 1-5 PM throughout June, July, and August. [↑](#footnote-ref-3)
4. Seasonal Peak Hours occur when Real Time load is equal to or greater than 90% of the 50/50 Seasonal Peak load forecast during Summer (June – August). [↑](#footnote-ref-4)
5. Residential Central AC Regional Evaluation, ADM Associates, Inc., November 2009. [↑](#footnote-ref-5)
6. A constant based on the desired level of confidence, e.g., 1.645 for the 90% level of confidence. [↑](#footnote-ref-6)
7. http://www.aapor.org/AM/Template.cfm?Section=Standard\_Definitions2&Template=/CM/ContentDisplay.cfm&ContentID=3156 [↑](#footnote-ref-7)
8. For CL&P, units installed through the HES Program were considered to be retrofit units, while units that were rebated outside of HES were considered to be lost opportunity units. [↑](#footnote-ref-8)
9. Lost Opportunity savings are calculated from a baseline or standard (i.e., they are regarded as replace on burnout and therefore assume a code baseline). Retrofit assumes a baseline based on the existing pre-program unit. [↑](#footnote-ref-9)
10. Unfortunately, there are not very many smaller local weather stations in CT available that have high quality data. [↑](#footnote-ref-10)
11. C&I HVAC C&I Unitary HVAC Load Shape Study, Final Report, June 10, 2011. P 37. [↑](#footnote-ref-11)
12. Typical meteorological year 3 (TMY3) data sets are derived from the 1991-2005 National Solar Radiation Data Base (NSRDB) update. The TMY3 data sets hold hourly values of solar radiation and meteorological elements for a 1-year period. ( http://www.nrel.gov/docs/fy08osti/43156.pdf) [↑](#footnote-ref-12)
13. Corrected from the manufacturer’s provided SEER value using the equation EER = -.02 × SEER2 + 1.12 × SEER according to the method presented in http://apps1.eere.energy.gov/buildings/publications/pdfs/building\_america/house\_simulation\_revised.pdf [↑](#footnote-ref-13)
14. On-Peak: Summer 1-5 pm, non-holiday, weekdays in June, July, and August; [↑](#footnote-ref-14)
15. Seasonal Peak: Non-holiday weekdays when the Real-Time System Hourly Load is equal to or greater than 90% of the most recent “50/50” System Peak Load Forecast for the summer season. [↑](#footnote-ref-15)
16. The survey focused primarily on PY2011 participants. As the evaluation team found it impossible to meet quotas with PY2011 participants, we added PY2012 and a small number of PY2010 participants to the study sample frame. The majority of respondents (87%) were PY2011 participants. The team excluded HES-Income Eligible participants from the study as they did not receive CAC rebates through the program. Because the Newtown, CT school shooting occurred shortly before the survey was fielded, the team excluded from the study customers with the Newtown zip code and adjacent zip codes. [↑](#footnote-ref-16)
17. Per the 2013-15 Electric and Natural Gas Conservation and Load Management Plan, this was 75% CL&P and 25% UI. [↑](#footnote-ref-17)
18. Note that the 2013 PSD returns to the use of a baseline EER of 8 only if the existing EER is not known. [↑](#footnote-ref-18)
19. That is, while each year exhibited similar daily peak temperatures, the overnight and morning temperatures in 2013 exceeded those compared to 2012. [↑](#footnote-ref-19)
20. http://ducts.lbl.gov/hvacretrofitguide.html [↑](#footnote-ref-20)
21. <http://www.bpi.org/Web%20Download/BPI%20Standards/Air%20Conditioning%20and>

    %20Heat%20Pump%20Professional%20Final%202003.pdf [↑](#footnote-ref-21)
22. Although the team notes that in some instances, the contractor may have determined a unique need for a unit to be oversized or undersized. For example, a retrofit into a house with a poor ductwork design may lead to considering additional capacity, and likewise, a house with a conditioned basement that remains relatively cool during the heating season may allow for more under sizing than a Manual J calculation would consider. [↑](#footnote-ref-22)
23. For example, in Table ‎3-19, a superscript “b” next to a result signifies that the result differs significantly from the similar one for the group in the second column with the heading “B. Replaced CAC with CAC+Early Replacement Rebate ($500).” [↑](#footnote-ref-23)
24. The survey instrument used the term “energy auditor” to refer to the vendor staff person who conducted the audit, as participants are more likely to think of auditors than vendors. [↑](#footnote-ref-24)
25. Auditors followed a rule of thumb in recommending CAC for early retirement. In general, auditors were expected to recommend early replacement when they found a functioning CAC that appeared to be more than 10 years old. However, in cases in which customers requested an earlier replacement or the vendor suggested an earlier replacement, the CAC unit would nevertheless qualify as early replacement. [↑](#footnote-ref-25)
26. Note that the survey did not explore how *firm* these plans were. Respondents’ plans likely varied in their specificity and the degree to which households were ready to act on the knowledge that their unit probably should be replaced soon. [↑](#footnote-ref-26)
27. This was asked as an open-ended question and coded by the interviewer. “The old unit broke down” was among the pre-coded answers available. It is possible that some of the broken units may have been repaired and functioning by the time of the audit. [↑](#footnote-ref-27)
28. Assessing free-ridership was not among the goals of this study. The results of this question only point to the possibility, rather than measuring it. [↑](#footnote-ref-28)
29. A response of ‘no’ indicates that the respondent had not consciously made a decision about whether or when to replace the unit. [↑](#footnote-ref-29)
30. At first blush, this finding might suggest a higher level of free ridership among early replacement rebate users, but Table ‎3-18 showed that such rebate users were not significantly more likely than other respondents to have had prior plans to replace CAC. [↑](#footnote-ref-30)
31. Ideally, the HES vendor would record the year of manufacture of the CAC unit during the audit, which would help assess the rate of units eligible for early replacement, but the vendors do not record this information. Moreover, HES vendors do not consistently note which participants receive offers of rebates for CAC, be they standard or early retirement rebates. Without these two pieces of information, the team cannot provide an estimate of the percentage of HES participants who could have used the early retirement rebate that actually did so. The team relied on survey respondents own recollection of the age of their unit and if the HES vendor had recommended they replace their CAC when deciding which questions to ask. [↑](#footnote-ref-31)
32. The team does not present findings on the 27 households that the data tracking systems suggest replaced a CAC without a rebate because ten of these 27 households actually thought they had used a rebate, and another ten did not know the rebate existed. Thus, only seven respondents provided any information on why they had not used the rebate, and this small number of responses cannot be generalized to all participants. [↑](#footnote-ref-32)
33. North American Technician Excellence. “HVAC Contractor Locator” page. Accessed March 11, 2013 from http://www.hvacradvice.com/maps/locator.aspx. [↑](#footnote-ref-33)
34. http://www.ccontrolsys.com/w/Advanced\_Pulse\_WattNode\_-\_Specifications [↑](#footnote-ref-34)
35. http://www.onsetcomp.com/files/manual\_pdfs/7645-K-MAN-H21-002.pdf [↑](#footnote-ref-35)
36. http://www.onsetcomp.com/files/manual\_pdfs/9857-E-MAN-H22.pdf [↑](#footnote-ref-36)
37. http://www.ccontrolsys.com/ww/images/8/8a/Data\_Sheet\_CT\_Splitcore.pdf [↑](#footnote-ref-37)
38. http://www.extech.com/instruments/resources/manuals/380940\_um.pdf [↑](#footnote-ref-38)