NYSERDA EmPower Program and National Fuel Gas Distribution Corporation's Low Income Usage Reduction Program Impact Evaluation (2010–2011)

FINAL Report

Prepared for:

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Energy Research and Development Authority

and

National Fuel Gas Distribution Corporation

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NOTICE

ABSTRACT

This report describes the impact evaluation of the NYSERDA EmPower Program ("EmPower") and NFGDC's Low Income Usage Reduction Program ("LIURP"), collectively ("the Program"). The Program was developed in 2004 to provide electric and natural gas energy efficiency installations at no cost to qualifying low-income homeowners and at minimal cost to qualifying low-income renters. NFGDC's LIURP is part of the Company's Conservation Incentive Program, which was originated in a September 2007 Commission Order in case 07-G-0141.

The objective of the Phase II impact evaluation work was to determine the main drivers of Phase I natural gas realization rates that were lower than expected (0.49 and 0.37 for NYSERDA and NFGDC respectively), and make recommendations that could improve them going forward. Phase II investigation efforts included intensive on-site data collection, project file reviews, and more detailed billing analyses. The on-site work at the 98 participant sites surveyed included: (1) a complete building envelope characterization, (2) the collection of detailed building dimensions, (3) heating system operational details, (4) inspection and verification of installations, and (5) a customer survey. The evaluators compiled a list of recommendations based on an extensive analysis of on-site data and a thorough review of Program practices and calculation methodologies.

The Impact Evaluation Team concluded that current installation contractor practices are satisfactory and are not a direct contributor to low natural gas realization rates. However, it was determined that NYSERDA's EmPCalc tool can be improved by the adjustment of several assumptions and through the application of an empirically derived thermal calibration factor of 0.70 to all insulation and air sealing measures. The Phase II analysis results showed that applying a single thermal calibration factor increases the accuracy of savings estimates without introducing additional work for the installation contractors. Additionally, the Program can benefit by automating the transfer of measure data to the reported savings database and by developing quality assurance/quality control checks into NYSERDA's EmPCalc tool.

ACKNOWLEDGMENTS

This report was prepared by the Impact Evaluation Team led by ERS with Jacque Phelon as the project manager and Susan Haselhorst as the director in charge. ERS is the lead for the on-site engineering measurement and verification (M&V) effort. Kathryn Parlin of West Hill Energy is the sample design lead and Collin Elliot of Itron is the lead for billing analysis. The Impact Team wishes to acknowledge the significant contribution of NYSERDA project manager Jennifer Phelps and other members of the NYSERDA Evaluation group, EmPower Program staff David Friello and Kelvin Keraga, and NFGDC staff Evan Crahen and Eric Meinl. Additionally, the Impact Team acknowledges the valuable suggestions provided by Bill Saxonis of the DPS and its consultants, Ralph Prahl and Rick Ridge of TecMarket Works.

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SECTION 1: EXECUTIVE SUMMARY

This report describes the impact evaluation of the New York State Energy Research and Development Authority (NYSERDA's) EmPower Program and National Fuel Gas Distribution Corporation (NFGDC's) Low Income Usage Reduction Program (LIURP), jointly referred to in this report as the Program. The Program was developed in 2004 to serve the low income residential market by providing both electric and natural gas energy efficiency installations at no cost to qualifying homeowners and at minimal cost to qualifying renters. LIURP began in September 2007 through Commission Order and was designed to be a weatherization program for low income customers. Participants receive a heating system check, an energy audit, weatherization measures, an infiltration reduction, natural gas usage reduction measures and consumer education. LIURP's program design is consistent with, and is jointly administered with NYSERDA, as part of EmPower.

During the time frame of January 2010 through December 2011, the Program completed 12,562 projects with electric service and 4,076 projects with natural gas service, and reported 17,136 MWh of electric savings and 127,765 MMBtu of natural gas savings. In Phase I of the impact evaluation, a billing analysis determined natural gas realization rates (RRs) of 0.49 and 0.37 for NYSERDA and NFGDC respectively. The EmPower electric RR was 0.97. A full report of the Phase I impact evaluation results can be found in Appendix B.

The objective of the Phase II impact evaluation was to determine the main drivers of Phase I natural gas realization rates (RR) that were lower than expected, and make recommendations that could improve them going forward. Phase II investigation efforts included on-site data collection, project file reviews, a thorough examination of NYSERDA's primary savings calculation tool (EmPCalc), and a parametric analysis of installation contractor and evaluator data. Installation contractor data collection and installation practices were found to be satisfactory and do not inflate the estimated savings. However, data entry and transfer processes require improvements. The Program modeling tool, EmPCalc, requires the adjustment of several assumptions and the application of a single thermal calibration factor (CF) of 0.70 to all insulation and air sealing measure savings estimates. The application of an empirically derived calibration factor will increase the accuracy of savings estimates without changing the calculation procedures or introducing additional work for the installation contractors. The single thermal calibration factor accounts for heat load influences that are difficult to model such as variable temperature profiles and exposure to solar radiant heat.

1.1 APPROACH

The objective of Phase II was to identify the reasons why Phase I RRs were lower than expected for natural gas and to recommend steps for improvement going-forward. In the first stage of the Phase II research, analysis of project files, billing results, tracking data, and secondary data were used to posit a variety of hypotheses that might explain the RRs. In the second stage, select hypotheses were tested through intensive on-site data collection and analysis of 98 participant sites, with additional tasks to analyze project files, review the Program QA/QC process, and to conduct further billing analysis. The on-site work included a complete envelope characterization, the collection of detailed building dimensions, an inspection of installation quality, and the implementation of a customer survey. The Program, and therefore the Phase II impact evaluation, primarily concentrated on insulation and air sealing measures due to their large contribution to the reported natural gas savings (84%). As such, the analysis focused on the heat loss through the building envelope. Additional efforts were focused on administrative processes to report savings.

1.2 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This section discusses key findings, and the conclusions and recommendations that follow from those findings.

1.2.1 Finding: Installation Contractors are Accurately Representing Field Conditions

The Program design relies heavily on the installation contractors for implementation and savings reporting. In addition to installing the energy efficiency measures, the installation contractors calculate the projected savings for the vast majority of projects by entering on-site data into NYSERDA’s Excel-based EmPCalc tool. Two proposed hypotheses that could impact RRs were that the installation contractors either: (1) mischaracterize the project being completed (e.g., overstating the size of a wall being insulated or air sealed), or (2) are not completing the work.

The on-site teams collected information to test how well installation contractors represent building dimensions, conduct blower door measurements, and characterize installed measures. Customer surveys were also conducted on-site. The results show that the installation contractors are doing a good job. Generally, the differences between installation contractor and evaluator measurements were within an acceptable margin of error, the paperwork was complete, and installations followed Program practices. The vast majority of customers (89%) was satisfied with the work and was more comfortable (69%) in their homes. However, it is noteworthy that there is a high level of uncertainty surrounding the characterization of wall cavity insulation since all site visits were conducted after project completion. No core samples were collected as part of this evaluation study.

This finding did not result in a recommendation.

1.2.2 Finding: Administrative Errors Reduced the Realization Rate

The Impact Evaluation Team found evidence of two types of administrative errors:

1. EmPCalc savings estimates are manually transcribed from the installation contractor's paper files into the NYSERDA-reported savings database, which introduced typographical errors such as transposed digits and misplaced decimal points. There were also savings version errors which occurred when multiple iterations of EmPCalc were completed and retained for a single project, creating uncertainty about which savings estimates were correct. Fixing the manual transcription errors is expected to improve the Program RR by 4%.
2. Data entry errors were also observed in the formulae for savings calculations within EmPCalc. The sources of these errors were cataloged, but their impact was not estimated.

- **Recommendation: Automate the transfer of EmPCalc savings estimates to the reported savings database.**

  The electronic transfer of savings estimates into the reported savings database would eliminate the potential for manual data entry errors and would make it easier to maintain the latest version of estimates. This recommendation was implemented on January 2, 2015; EmPCalc savings estimates are now automatically uploaded into CRIS, NYSERDA's reported savings database.

- **Recommendation: Implement range checks and techniques to minimize data entry error.**

  The Impact Evaluation Team recommends adding range checks to EmPCalc for select fields to reduce data entry errors. The use of checkboxes to indicate approved measures was particularly error-prone and could be replaced with a pick-list, which would make a mis-key less likely to occur and could also be used to track the reasons measures were not selected for installation.

1.2.3 Finding: Two EmPCalc Factors Are Incorrect

A thorough review of the EmPCalc calculations identified two assumptions that require updating: the window-to-wall ratio and the weather reference conditions. Other factors examined, including insulation characterization and use of thermostat setpoints, do not require updating.

- **Recommendation: Correct the EmPCalc window-to-wall ratio.**

  Detailed building dimensions were collected on site and used in conjunction with standard practice framing techniques to calculate each site's window-to-wall ratio. This ratio accounts for the percentage of the treated area that is either framing, windows, or doors and cannot be insulated. Based on this effort, the Impact Evaluation Team determined that treated homes have an average window-to-wall ratio of 25% and therefore the EmPCalc window-to-wall ratio assumption should be adjusted from 15% to 25%. Implementation of this recommendation was completed in December 2014 following an initial results presentation and is expected to improve the natural gas RR by approximately 2%.

- **Recommendation: Correct the EmPCalc heating degree day (HDD) assumptions.**

  Local weather conditions have been factored into EmPCalc heat load calculation using a 30-year average weather data set. However, this data set does not reflect current warmer conditions. The typical meteorological year version 3 data (TMY3) data with a 60°F base more accurately represents current weather conditions and heating system operation that is characteristic of the participants. Implementation of this recommendation was completed in December 2014 following an initial results presentation and is expected to improve the natural gas RR by approximately 10%.

1.2.4 Finding: Models Overstate Thermal Loading

Each of the 98 sites' annual heating loads were estimated using the EmPCalc thermal calculation, and then were compared to the sites' actual billed usage. Even after model adjustment for the recommendations above, EmPCalc methods consistently overstate the heating energy use by approximately 60%, on average (i.e., modeled heating energy = 1.6 * billed heating energy) which directly leads to overstated savings. This result was not unexpected. Modeling envelope dominated buildings like a residential home is challenging because it is difficult to capture the variability of the internal temperature profile, occupant influences, solar heat load, and the wall cavity composition.

It was hypothesized that savings estimates could be calibrated and improved by multiplying the estimated savings by a site-specific CF (the ratio of the site-specific pre-installation billed usage to the site-specific modeled usage). Analysis showed that site-specific calibration of the model using pre-installation billing data did improve site estimates of post-installation natural gas usage and Program-level savings estimates. However, a single Program-wide thermal CF was found to be as effective at improving savings estimates as site-specific thermal CFs and is less costly to implement. Further details about the thermal CF calculation methodology can be found in Section 4.5.

- **Recommendation: Apply a thermal CF of 0.70 to the savings estimates for all insulation and air sealing measures.**

  The application of a 0.70 CF to the calculated savings of all insulation and air sealing measures will improve the accuracy of savings estimates Program-wide. This CF was derived from models of post-installed usage that account for the implementation of the previous recommendations and therefore, will not 'double-count' the effect of these changes. Implementation of the thermal CF is estimated to improve the Program RR by 26%. The tracking of savings estimates with and without the recommended thermal CF could allow for future analysis, but this practice would need to be decided upon by NYSERDA and NFGDC.

1.2.5 Finding: There is Evidence of Snapback

Further analysis of the billing data for 1,715 natural gas sites included in the Phase I research presented evidence that participants may be increasing thermostat setpoints after the installation of the measures. Evidence of increasing indoor temperatures correlating with a decrease in the savings RR was directionally strong and statistically significant, but it did not provide a direct measure of the potential impact on savings.

- **Recommendation: No additional research is recommended.**

  Further confirmation of this effect would be expensive, is not included in the scope of work for this evaluation study, and would not result in changes to Program algorithms or claimed savings. Therefore, no further research is recommended. As noted above, the CF was derived from the ratio of the post-installation heating usage and the modeled heating usage, not from savings. Therefore, this thermal CF is independent of the snapback or other changes in occupant behavior.

1.2.6 Summary of Recommended Changes

Each of the recommended changes is expected to incrementally improve the Program RR from the initial 0.43 determined in the Phase I billing analysis to a final expected RR of 0.85. The

Impact Evaluation Team concludes the remaining 0.15 is at least partly explained by snapback, but likely incorporates other unknown factors.

Table 1-1 summarizes the magnitude of the recommended Program changes in MMBtus and the expected Program RR after implementation. The Program impacts reflect the methods and population from 2010–2011 and may not fully represent another year, which will have different year-to-year variations in weather and population. That being said, the basic approach of the EmPCalc tool has remained consistent even with ongoing incremental improvements, and the participant population is fairly homogenous. Because of this high level consistency, the impacts calculated for 2010–2011 are expected to be representative of impacts in future years.

Table 1-1. Impact of Recommendations on EmPower Program Savings and RR[1]

	Implementation Status	Program Savings (MMBtu)	Change in RR	RR
Program reported savings	N/A	127,765	–	0.43
Recommendation: Fix administrative errors	Implemented	-10,100	0.04	0.47
Recommendation: Correct EmPCalc factors, including HDD and window-to-wall ratio	Implemented	-24,200	0.12	0.59
Recommendation: Apply a thermal CF of 0.70 to insulation and air sealing measure savings estimates	Recommended	-28,400	0.26	0.85
Total expected reported savings	N/A	65,000	–	0.85
Unknown and behavioral factors	N/A	-10,000	0.15	1.0
Evaluated savings (from Phase I of the impact evaluation)	N/A	55,059	N/A	–

[1] This table presents the expected impact of each recommendation on the Program savings and RR. The overall Program reported natural gas savings are presented at the top, followed by the recommendations and total expected natural gas savings and Program RR after the recommendations have been implemented. The Impact Evaluation Team identified approximately 10,000 MMBtu of overstated savings which are attributed to unknown and behavioral factors that were not evaluated in this study.

While the recommendations are expected to improve the accuracy of the Program savings as a whole, the individual site savings estimates are less certain. Program Staff should consider whether it is appropriate to conduct the screening at the individual site measure level or more programmatically. The implementation method of the single thermal CF is to be determined by Program Staff and NFGDC.

SECTION 2: INTRODUCTION

This section presents a Program description, a summary of previous evaluation efforts, and the Phase II evaluation goals.

2.1 PROGRAM DESCRIPTION

EmPower was developed in 2004 to serve the low-income residential market and provides both electric and natural gas energy efficiency installations at no cost to qualifying homeowners and at minimal cost to qualifying renters. LIURP began in September 2007 through Commission Order and was designed to be a weatherization program for low income customers. Participants receive a heating system check, an energy audit, weatherization measures, an infiltration reduction, natural gas usage reduction measures and consumer education. LIURP's program design is consistent with, and is jointly administered with NYSERDA, as part of EmPower.

With little or no financial contribution from homeowners, project budgets are finite and Program offerings are limited to the most cost-effective measures. As shown in Table 2-1, envelope measures, including wall and attic insulation and air sealing, dominate Program savings.

Table 2-1. EmPower Natural Gas Program-Reported Savings

Measure	Savings (MMBtu)	Percent of Total Savings
Envelope	107,171	84%
Heating system	8,116	6%
Other heating	8,114	6%
Domestic hot water	3,681	3%
Other	683	1%
Total	127,765	100%

A pool of approximately 125 installation contractors[1] is responsible for field implementation of the Program. In addition to identifying and installing the energy efficiency measures, the installation contractors calculate the projected savings for the vast majority of homes by entering on-site data into NYSERDA's Excel-based EmPCalc tool. EmPCalc estimates insulation measure savings with a simple thermal model incorporating the area treated (in square feet), a weather condition factor, and the change in thermal conductance (or, resistance to heat transfer). Unlike in some savings calculation tools, the installation contractor is not required to model the entire home, but only the areas that remain under consideration for treatment. After an installation

[1] The Program uses three different types of contractors, as follows: 1) Installation contractors are responsible for the initial audit, savings calculations, and measure installation; 2) The Implementation Contractor approves or rejects measures received from the installation contractor, reviews each EmPCalc for accuracy, and conducts quality control checks; 3) The Quality Assurance Contractor conducts customer surveys and site-visits at a sample of homes to verify that all measure installations are completed satisfactorily.

contractor completes an initial audit, the Implementation Contractor approves or rejects measures based on their cost-effectiveness and the anticipated total project budget. The Quality Assurance Contractor conducts pre- and post- inspections of a sample of homes randomly.

Each measure offering is described in Appendix C, along with a comparison between the Program's savings calculation methodology and the New York Technical Manual savings calculation methodology.

2.2 PHASE I FINDINGS

The Phase I impact evaluation effort consisted of a Program-wide billing analysis of projects that were installed in 2010 and 2011. The evaluated savings and RR were calculated for both electric and natural gas measures as shown in Table 2-2. A full report of the Phase I impact evaluation results can be found in Appendix B.

Table 2-2. EmPower Reported and Evaluated Electricity and Natural Gas Savings for Projects Installed in 2010 and 2011

	Annual Electric Savings (MWh/Yr)	Annual Natural Gas Savings (MMBtu/Yr)	
Funding	All participants	NFGDC	NYSERDA
NYSERDA Program-reported savings	17,136	62,343	65,422
RR	0.97	0.37	0.49
90% confidence interval	0.92 – 1.02	0.33 – 0.41	0.41 – 0.56
Evaluated gross savings	16,623	22,955	32,104

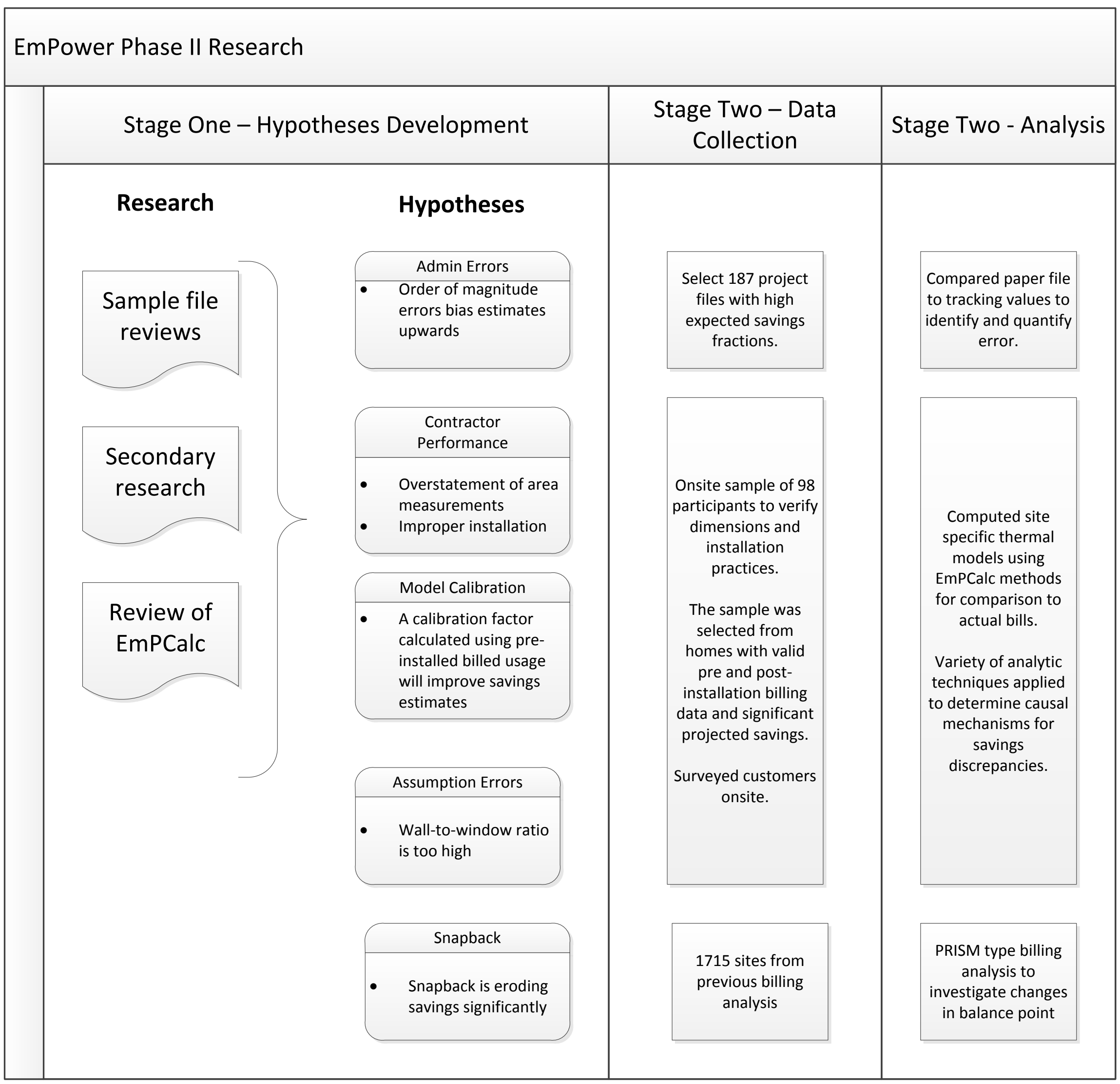
2.3 PHASE II IMPACT EVALUATION OBJECTIVES

The objective of the Phase II impact evaluation was to investigate and identify contributors to the lower than anticipated natural gas RRs and to make recommendations that could improve them going-forward. Electric measures were not targeted in the Phase II effort because the evaluated electric RR was close to 1.0. The Phase II impact evaluation primarily focused on the envelope measures (insulation and air sealing) because they accounted for the vast majority of the reported savings, as shown in Table 2-1 above.

SECTION 3: METHODS

The objective of the Phase II work was to identify the reasons why the Program was overestimating natural gas savings and to recommend steps for the Program to improve those estimates. The approach to the research is illustrated in Figure 3-1. In the first stage, analysis of project files, billing results, tracking data, and secondary data were used to posit a variety of hypotheses that might explain the natural gas RRs. In the second stage, select hypotheses were tested through intensive on-site data collection and analysis of a sample of 98 participant sites, with additional tasks to analyze project files, review Program QA/QC processes, and conduct further billing analysis.

Figure 3-1. EmPower Phase II Research Process



Further details on the methodology are provided in Appendix D.

3.1 STAGE ONE: HYPOTHESES DEVELOPMENT

As a first step, the Impact Evaluation Team conducted initial research, which included an examination of other similar program evaluation results, a review of a sample of 30 project files, and a detailed review of the EmPCalc tool. From this research, a number of possible reasons for the lower than anticipated natural gas RRs were identified. For each major hypothesis, a potential Program impact was estimated as well as a method for testing the hypothesis. The initial research, the hypotheses, and the test plans were reviewed in a stakeholder meeting with Program and Department of Public Service (DPS) Staff. The outcome of the meeting was the research agenda summarized in Table 3-1.

Table 3-1. EmPower Phase II Hypotheses Analysis Parameters and Topics

Program Stage	Hypothesis	Testing Method
Analysis tool	Insulation and air sealing algorithms in the EmPCalc tool are not correct or are inadequate.	▪ Examine EmPCalc tool and associated documents ▪ Review installation contractor data collection documents (project file review)
	Site-specific billing calibration will improve the accuracy of savings estimates.	▪ Calculate whole-home heat load and calibrate the load and estimated savings to pre-installation billing data; compare calibrated savings estimates to realized savings (n=98)
	Inputs into tool are incorrect due to user errors.	▪ Project file review ▪ EmPCalc manual review
	Tool does not account for air leakage.	▪ Assess correlations between heating fuel use and infiltration
Program tracking	Systematic errors are made when entering data into the reported savings database. Random decimal place errors made when manually transposing savings estimates upwardly bias the reported savings.	▪ Quantify the impact of transcription errors by comparing the EmPCalc cover sheet savings to the reported savings (n=187) ▪ Recommend improvements to the Program implementor's data cleaning/QA/QC plan
In-field data collection and measure installation	Field protocols are inadequate.	▪ Review field protocols and training
	Measures are not installed correctly. Measures are not correctly characterized in the savings calculations.	▪ On-site field verification of factors including dimensions, post-installation R-values (n=98), and pre-/post-installation blower door test results (n=16)
Behavioral changes	Snapback refers to changes in use patterns after the installation of an energy-efficient product that reduce the overall measure savings.	▪ Field visits to homes (n=98) ▪ On-site surveys (n=98) ▪ Further analysis of billing consumption changes

3.2 STAGE TWO: DATA COLLECTION

The primary data collection activity consisted of on-site surveys of 98 participant homes (42 NYSERDA sites and 56 NFGDC sites). Site visits were completed throughout New York State.

Teams of two engineers (the on-site team) completed field work between July 10, 2014, and September 12, 2014.

The participant on-site sampling strategy was designed to select homes most likely to provide insights into the natural gas RRs. To that end, the on-site sampling plan (included in Appendix E), targeted homes that had pre- and post- billing data available, had installed envelope measures with reported savings greater than 40 MMBtu, and had either a very high (>30%) or a very low (<15%) evaluated natural gas savings fraction[2].

The on-site data collection plan (provided in Appendix F and Appendix I) was developed so that the heat loss through the building envelope could be calculated for each site. On-site teams collected all exterior building dimensions, defined all materials used in exterior surface assemblies, and noted thermostat setpoints[3] and system efficiency data. As described in Appendix F, the on-site teams also inspected air sealing installation, inventoried air leaks, systematically inspected outlets to assess wall insulation, confirmed the installation of both electric and natural gas measures, and measured attic insulation levels. Additionally, a survey was conducted with each on-site participant. The complete results of this survey effort can be found in Appendix G.

A large sample of project files with suspected data entry errors was drawn (n=190) to examine the frequency of manual transcription data entry errors into the reported savings database. The initial sample frame included all 2010/2011 projects with a reported natural gas savings fraction (reported savings divided by pre-installation consumption) greater than 40% and a pre-installation natural gas consumption greater than 50 MMBtu.

3.3 STAGE TWO: ANALYSIS ACTIVITIES

Extensive quality control was required to ensure that data collected by the Impact Evaluation Team during the site visits were accurately entered and complete. Thermal models were calculated for each visited site, which could then be compared to billing data. The thermal models and billing results were regressed against a variety of factors – such as heated volume, treated area, air changes per hour (ACH), and occupancy changes – to test whether the factors could be contributing to discrepancies between the project savings and the actual savings. Comparisons of installation contractor- and evaluator-collected parameters were examined as part of this work, as well.

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[2] The evaluated site-specific savings fraction is the evaluated savings divided by the pre-installation usage.

[3] The thermostat setpoint is the interior temperature setting selected by a resident and maintained by a thermostat. A functional thermostat will control a home's heating system in order to satisfy the specified temperature setpoint.

Additional billing analysis was conducted using a Princeton Scorekeeping Method (PRISM) type analysis to see if there might be evidence of changes in the home's balance point[4]. Such a change would indicate possible adjustments by household members to internal temperature settings and provide evidence of snapback.

[4] The balance point is the outdoor air temperature at which a home's heating system is required to turn on to satisfy the thermostat setpoint.

SECTION 4: RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

This section presents the results and conclusions from the Phase II evaluation activities. The section concludes with recommendations for the Program. More detailed results are provided in Appendix H.

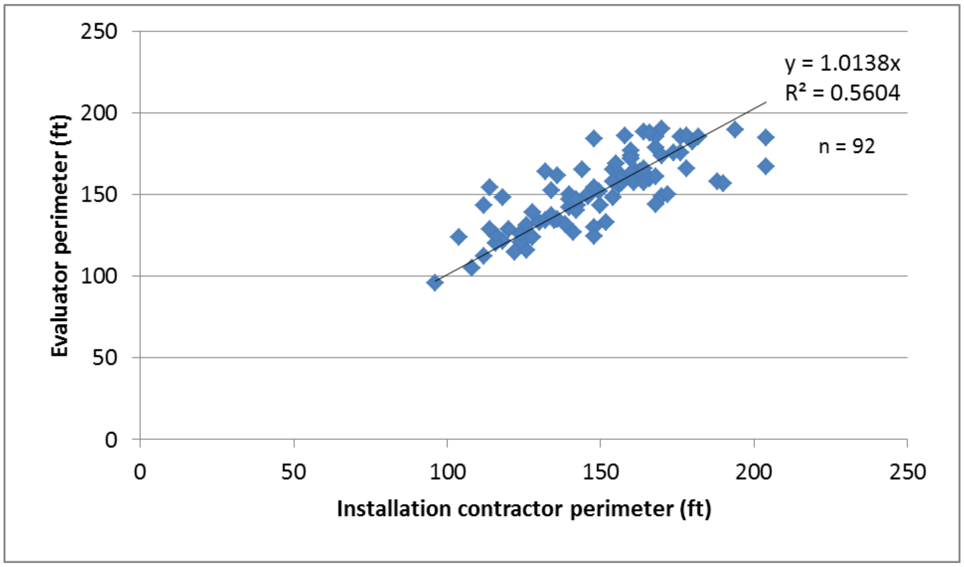
4.1 OBSERVED FIELD CONDITIONS ARE CONSISTENT WITH INSTALLATION CONTRACTOR DATA

The Impact Evaluation Team collected information on-site to test how well installation contractors represented building dimensions, blower door measurements, and installed measures. In every direct comparison, the differences between installation contractor and evaluator measurements were generally within the margin of error.

4.1.1 Dimensions

During 2010 and 2011, installation contractor sketches did not indicate which walls were insulated through the Program. This created uncertainty when the on-site teams attempted to verify areas of wall treated with insulation. However, it was possible to directly compare the building perimeter in most of the projects, which was a simpler and less uncertain comparison. On average, the evaluated perimeter was within 2% of the installation contractor perimeter. Figure 4-1 presents a comparison of the installation contractor and evaluator perimeters.

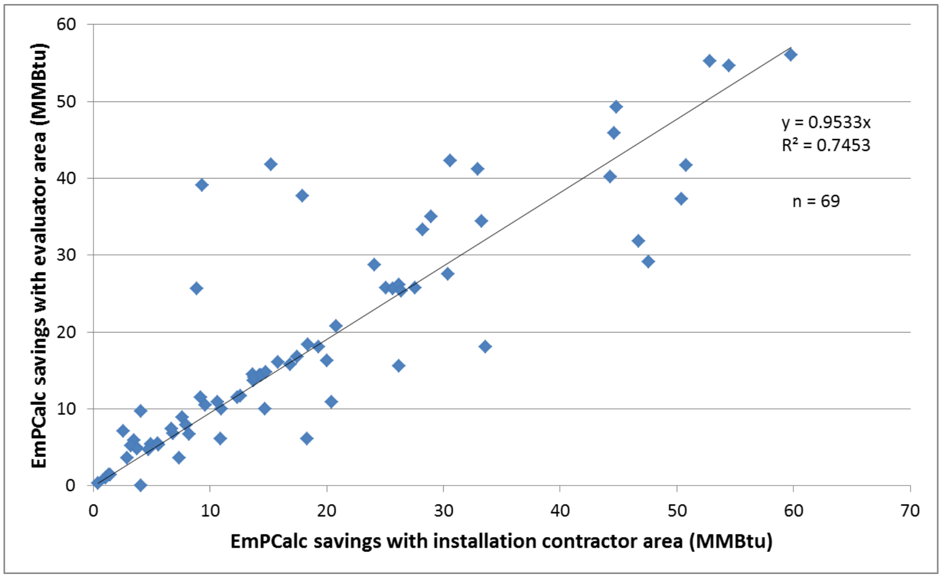
Figure 4-1. EmPower Installation Contractor vs. Evaluated Perimeter



4.1.2 Attic Characterizations

Similarly, the EmPCalc savings estimates generated with installation contractor and evaluator inputs were used to compare installation contractor and evaluator measure characterizations (insulated area, pre-/post- insulation type, and pre-/post- insulation thickness). Attics provided the least amount of uncertainty for this comparison because the on-site teams could most easily match the project file descriptions of the insulated surface with on-site observations. Additionally, many attics were open and the insulation type and thickness could be easily determined through inspection. The total evaluated attic savings estimate (using EmPCalc) was within 1% of the installation contractor attic savings estimate. Figure 4-2 presents a comparison of the installation contractor and evaluator attic savings.

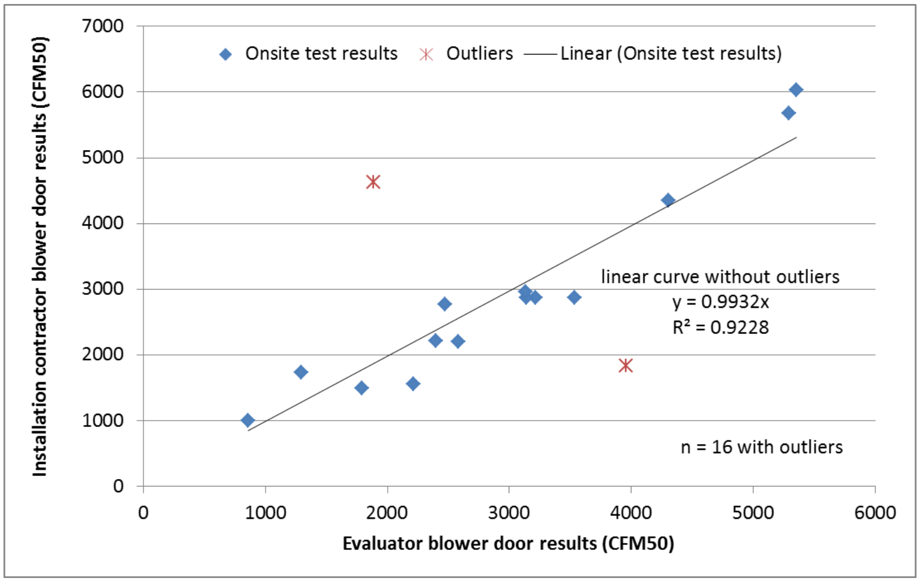
Figure 4-2. EmPower Installation Contractor vs. Evaluator Attic Savings Estimates



4.1.3 Blower Door Measurements

The Impact Evaluation Team completed blower door tests at a small sample of sites to provide another indication of how well contractors were representing home conditions. Program staff indicated early in the Phase II planning stage that the Program's air sealing protocols changed significantly since 2010/2011, therefore, there was little value in determining a statistically significant average ACH for this population. Changes in blower door tests can have a large impact on savings estimates and could be a source of inadvertent or intentional error (i.e., an overstated blower door test result will bias the savings upward); therefore, this is an important indicator of the quality of contractor data collection. Even several years after the project was completed, the evaluated measurements were similar to the installation contractor measurements. Figure 4-3 compares the installation contractor and evaluator blower door test results.

Figure 4-3. EmPower Installation Contractor vs. Evaluator Blower Door Test Results[5]



The outliers above and below the trend line are likely the result of a difference in test procedure for multi-story homes, though this hypothesis is uncertain because no installation contractor notes were provided about the blower door tests.

The Impact Evaluation Team compiled the installation contractor pre-installation and post-installation blower door test results for all homes in the on-site sample at which blower door testing was completed. The data, as presented in Figure 4-4, shows that the claimed air change per hour (ACH[6]) reduction is reasonable because the claimed ACH reduction is a relatively small percentage of the pre-installation ACH, which implies that the pre-installation blower door measurements are not biased. Additionally, the installation contractor distribution of ACH values is similar to those presented in chapter 16 of the 2013 ASHRAE Fundamentals handbook[7], as shown in Figure 4-5.

[5] CFM50 is the airflow needed to create a change in building pressure of 50 Pascals. A CFM50 reading is produced by a blower door apparatus during testing. EmPCalc uses the CFM50 value in air sealing calculations.

[6] ACH is a measure of the air volume added to or removed from a space divided by the volume of the space. The ACH due to air leakage (infiltration) is calculated using blower door test results.

[7] 2013 ASHRAE Handbook: https://www.ashrae.org/resources--publications/handbook/table-of-contents-2013-ashrae-handbook--fundamentals

Figure 4-4. Installation Contractor Pre-/ Post- ACH Values

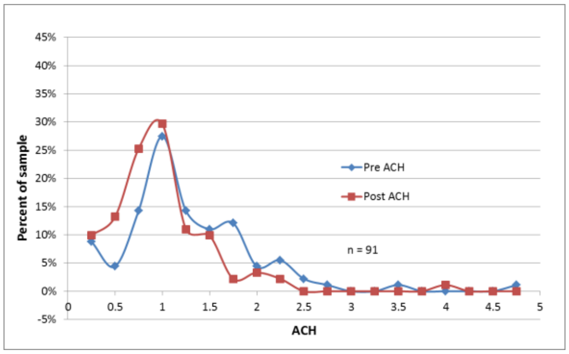
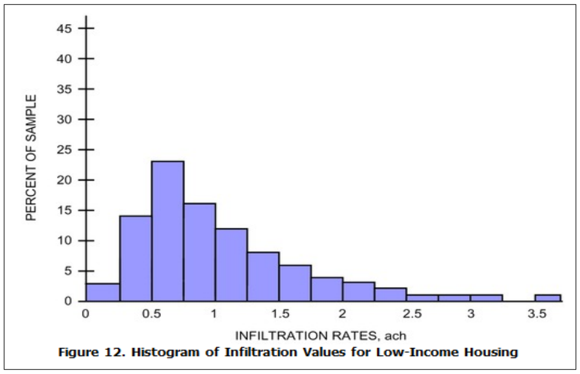


Figure 4-5. ASHRAE 2013 ACH Values



4.1.4 Distribution of Installation Contractors

The sites that were visited represent a diverse cross-section of installation contractors. The work of 24 installation contractors, responsible for 75% of the work completed by the Program in this time period, was observed. Earlier analysis conducted during the first stage of the Phase II research had shown no significant performance differences between installation contractors. Although sites were not selected to statistically represent installation contractors, the on-sites represented a good distribution of installation contractors.

4.2 ADMINISTRATIVE ERRORS ARE PREVALENT AND INFLATE THE REPORTED SAVINGS

Until January 2, 2015, the Implementation Contractor manually typed the EmPCalc cover sheet savings[8] into CRIS, NYSERDA's reported savings database. A selection of 187 project files with very high savings fractions (i.e., savings as a percentage of total use) was examined to determine the frequency of differences between the cover sheet savings and NYSERDA-reported savings values. A net discrepancy of 10,089 MMBtu in natural gas savings was identified in the 187 project files, overstating the total Program-reported savings in 2010 and 2011 by approximately 7.9%. Since all project files were not selected for this analysis, it is likely that the total impact of manual transcription errors is greater than 7.9%. Figure 4-6 presents a comparison of the EmPCalc cover sheet savings and the NYSERDA-reported savings values, while the error distribution is presented in Figure 4-7.

[8] When the Implementation Contractor targets individual measures for installation, their associated measure-level EmPCalc savings are summed in the EmPCalc cover sheet.

Figure 4-6. EmPCalc vs. Reported Natural Gas Savings[1]

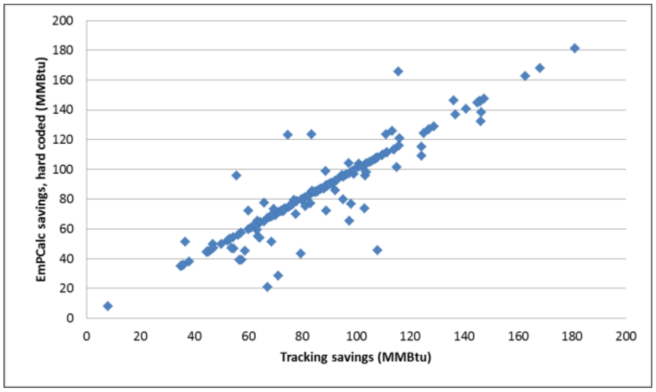
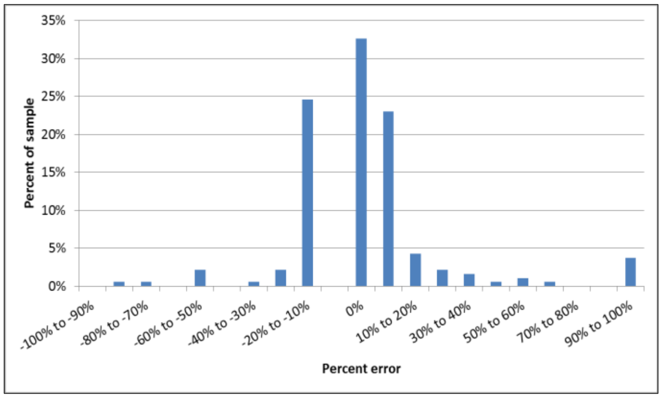


Figure 4-7. Distribution of Transcription Errors



[1]One large outlier was removed from the graph to increase legibility.

The transcription errors are approximately normally distributed, with errors that both overstate and understate the reported savings. However, the sum of all transcription errors inflated the reported savings by 7.9% (10,100 MMBtu)

Aside from the manual transcription errors, data entry errors can occur within the EmPCalc tool itself by either the installation contractor during on-site data entry or by the Implementation Contractor during measure review and approval. For example, EmPCalc features several check boxes that the Implementation Contractor uses to select measures for installation and subsequently approve measures for payment after installation. A data entry error could be made by the Implementation Contractor if he/she fails to check or uncheck a “Targeted Measure” or “Measure Approved” box. Alternatively, a data entry error could be made by the installation contractor if he/she fails to check or uncheck a “Use Default Efficiency” box, or makes typographical errors in any numerical entry (area, blower door cfm, installed quantity, etc.). The evaluation team could not quantify the impact of these types of errors without knowing the intended entries. However, it should be noted that the validity and meaning of checked/unchecked boxes and outlier EmPCalc inputs generated uncertainty during field work and likely had a similar result during the QA/QC process.

4.3 EMPCALC FACTORS ARE INCORRECT AND OVERESTIMATE SAVINGS

The Impact Evaluation Team examined four factors used in EmPCalc and recommended changing three of them. The Program has implemented all three of the recommended changes at this time. The four EmPCalc factors are described and discussed in this section, along with the Impact Evaluation Team’s findings.

4.3.1 Window-to-Wall Ratio

Installation contractors estimate the area to be treated with insulation using rough dimensions (outer edge of the treated area) and do not subtract out untreatable doors, windows, or internal framing from studs or headers. The untreatable area is estimated in EmPCalc by the window-to-wall ratio. On-site teams conducted detailed measurements of each home in the sample, producing fully dimensioned elevation sketches with all windows and doors included. Standard framing practices were researched for estimating stud spacing and header framing. The calculated rough areas, window and door areas, and framing areas were used to estimate each site's actual window-to-wall ratio. The Impact Evaluation Team determined that treated homes have an average window-to-wall ratio of approximately 25% and therefore the EmPCalc window-to-wall ratio assumption should be adjusted from the present value of 15% to 25%. Implementation of this recommendation was completed in December 2014 following an initial results presentation.

4.3.2 Heating Degree Days

Local weather conditions have been factored into EmPCalc heat load calculation using a 30-year average weather data set. However, this data set does not reflect current warmer conditions. The typical meteorological year version 3 data (TMY3) data more accurately represents current weather conditions. The PRISM analysis indicates an average balance point of approximately 60°F, which was used as the reference temperature for calculating an annual HDD value for each of the geographical regions specified by the Program (the recommended HDD values can be found in Appendix D). Implementation of this recommendation was completed in December 2014 following an initial results presentation.

4.3.3 Combustion Efficiency

The Impact Evaluation Team found that EmPCalc versions used in 2010/2011 allowed multiple heating system combustion efficiencies to be used within an individual home's savings calculations (e.g., one efficiency used to calculate insulation savings and another efficiency used to calculate air sealing savings). This EmPCalc inconsistency allowed for oversights when the installation contractor failed to enter the measured combustion efficiency in every measure calculation and instead used an assumed default combustion efficiency for one or multiple savings calculations. Consistently using the measured combustion efficiency will improve the savings estimates. Newer versions of EmPCalc have already corrected the combustion efficiency inconsistencies.

4.3.4 R-value Characterization

EmPCalc assumes a conservative pre-installation R-value of 4.4 for uninsulated surfaces, while calculating the assembly R-value using ASHRAE methods and assuming no insulation is present yields an uninsulated R-value of 1.5 to 2.5. The Impact Evaluation Team does not recommend changing the EmPCalc pre-installation R-value assumption since it is very difficult to confirm that pre-installation surfaces are entirely uninsulated. The elevated Program R-value assumption of 4.4 is likely a better characterization of the thermal resistance of pre-treated surfaces than assuming that there is no insulation present prior to treatment.

4.3.5 EmPCalc Factor Analysis Results

The impact of the EmPCalc factor adjustments on Program savings were estimated using the parametric analysis approach described in Appendix D. In this analysis, savings were estimated for each of the 98 on-sites using first one assumption (e.g. the EmPCalc 30 year average weather based HDD) and then the alternative (e.g. the TMY3 weather based HDD), keeping everything else constant. The results of this analysis led to two important findings. Firstly, the Impact Evaluation Team determined that adjusting the window-to-wall ratio from 15% to 25% will result in a 1% increase in the overall RR. Secondly, changing the EmPCalc HDD values to updated HDD values calculated with a 60°F balance point and TMY3 data will result in a 10% increase in the overall RR. Implementation of these two recommendations was completed in December 2014 following an initial results presentation. Coupled with the already corrected combustion efficiency inconsistencies, the recommended EmPCalc factor adjustments are expected to reduce the Program reported savings by 24,200 MMBtu and increase the overall RR by 12%. A complete tabulation of all recommendations can be found in Table 1-1 above.

The parametric analysis revealed that adjusting the EmPCalc pre-installation R-values to an uninsulated R-value of 1.5 to 2.5 would actually reduce the overall RR by 8%. Therefore, the Impact Evaluation Team does not recommend any changes to the EmPCalc R-value assumptions.

4.4 THERE IS EVIDENCE OF SNAPBACK

In a home with newly installed insulation and air sealing, the outdoor air temperature at which a home's heating system is required to turn on – or balance point – should decrease (e.g., with no changes to the thermostat settings, the heating system in a new treated home is required when the outdoor air temperature is 55°F or lower rather than 60°F or lower). The balance point for a home can be estimated using a billing analysis approach based on the Princeton Scorekeeping Method (PRISM). This method determines the HDD base that is a best fit in a regression analysis with the monthly consumption from billing data. This HDD base is equivalent to the balance point. If the balance point increases, it can indicate that the home's thermostat setpoint is higher, thereby using more heating energy than what it would have if the previous temperatures had been maintained.

The PRISM based billing analysis was completed on 1,715 sites used in the Phase I impact evaluation. The Impact Evaluation Team reviewed the results and found that a large portion of the homes showed an increase in balance point, providing evidence that many thermostat setpoints increased after project completion, indicating snapback. Table 4-1 presents the results of the PRISM type analysis. Additional details can be found in Appendix H.

Table 4-1. The Effect of Balance Point Changes on Realization Rates

Change in Balance Point (Direction)	Number of Sites	Change in Balance Point (°F)	Standard Deviation of the Change in Balance Point	Average Pre-Installed NG Usage (MMBtu)	Average Reported Heating Savings (MMBtu)	Average Billing Heating Savings (MMBtu)	Average Heating Only RR
Decrease	688	-5.7	4.8	144.2	40.2	21.7	54%
No change	134	0.0	0.0	143.7	33.9	13.8	41%
Increase	893	5.9	4.7	143.1	44.9	8.3	18%

The table shows that those homes which showed a decrease in the balance point achieved the highest heating RR, while those homes with the increase in balance point showed the poorest RR. A pair-wise comparison of the three changes-in-balance-point strata (Increase, No Change, Decrease) showed a statistically significant different between the Increase and Decrease groups, indicating a statistically significant change in energy use associated with the balance point change. However, the method is sensitive to weather conditions and is founded on small changes in regression coefficients of determination. Other statistical tests failed to show a correlation between balance point and either total savings or realization rate. While there is evidence of a balance point change related to energy savings, the results are not definitive and it does not provide a direct measure of the potential impact on savings (such an effort would require pre- and post-installation temperature metering in a statistically significant sample of homes, and is outside the scope of this study).

4.5 MODELS OVERSTATE THERMAL SAVINGS

After extensive modeling and analysis of the 98 sites, the Impact Evaluation Team concluded that the overstated natural gas savings were not the result of installation contractor misrepresentations or unsatisfactory measure installation, but rather were due, in part, to NYSERDA's EmPCalc model overstating the thermal load, which in turn overstated the thermal savings. A variety of factors may contribute to the overstatement, including but not limited to: (1) solar heat gains, (2) imperfectly represented internal temperature profiles with lower temperatures at the exterior walls, (3) unpredictable occupancy schedules, and (4) other unidentified reasons. Calibration to billed usage is a typical method for resolving this common outcome of thermal models. As discussed in this section, the Impact Evaluation Team found that a single calibration factor of 0.70 was an effective method for correcting this overstatement. Since this factor was developed from modeled whole building natural gas heating usage and actual bills, it is independent of savings and does not reflect changes in customer behavior, quality of installations, administrative errors, or other Program and measure related concerns that would arise if this factor was an adjustment of modeled savings to match evaluated savings.

4.5.1 Modeling Whole-Home Heating Usage

EmPCalc is not designed to calculate the whole-home heat load, but rather for calculating the incremental changes in heat lost through exterior surfaces targeted for treatment. In addition, the installation contractors do not collect data for the whole building, but only for those areas that are to be treated. To investigate calibration, the Impact Evaluation Team built a whole-home modeling tool using the EmPCalc heat transfer methods and assumptions including the EmPCalc R-values, the recently implemented window-to-wall ratio, and the recently implemented HDD. The whole home building model was tested with the data characterizing the entire building envelope collected by the on-site team for the on-site sample.

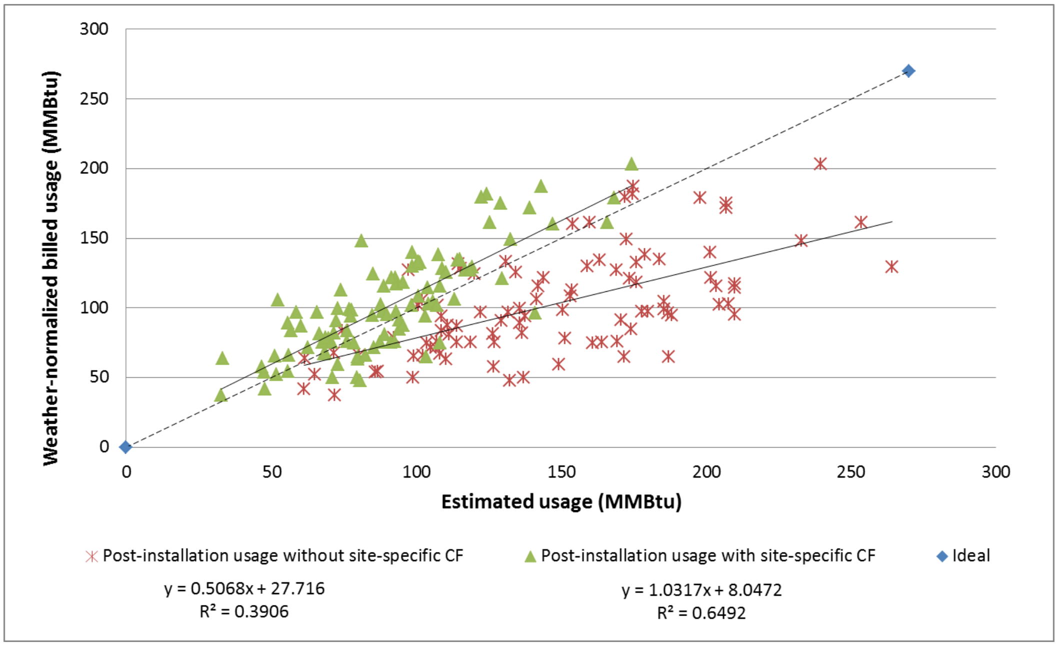
The Impact Evaluation Team estimated each individual home’s pre-installation annual heating natural gas consumption using the data collected by the on-site teams in the EmPCalc-based whole-home heat load model. In every case the billed heating usage was less than the estimated heating usage, where the average ratio of the heating component of the bills to the estimated heating usage was 64% (median = 61%, mode = 54%). It was expected that the application of a site-specific CF would improve post-installation usage estimates (i.e., the usage after the measures were installed).

Figure 4-8 shows a scatterplot of each site’s estimated post-installation heating usage compared to actual billed post-installation heating usage with and without a site-specific pre-installation billing CF. The site-specific CFs used to generate the plot below were calculated using estimated and billed pre-installation heating consumptions as follows:

$$CF_{Site-specific} = \frac{Billed\ annual\ heat\ load\ consumption_{pre}}{Modeled\ annual\ heat\ load\ consumption_{pre}}$$

See Appendix D for more details.

Figure 4-8. EmPower Estimated Post-Installation Heating Usage with and without Site-Specific Calibration Factors



It is evident that without the site-specific CFs developed from pre-installation billing data, the post-installation estimated usage is approximately double the billed usage (see regression coefficient 0.5068), while with the CFs the estimated usage is on average approximately equivalent to the billed usage (see regression coefficient 1.0317). Furthermore, the correlation between billed post-installation usage and estimated post-installation usage, as indicated by the coefficient of determination[9] (R^2), is improved from 0.3096 to 0.6492 by site-specific billing calibration. The application of a site-specific CF calculated from pre-installation billing data improves the post-installation usage estimate.

4.5.2 Application of CF to Savings Estimates

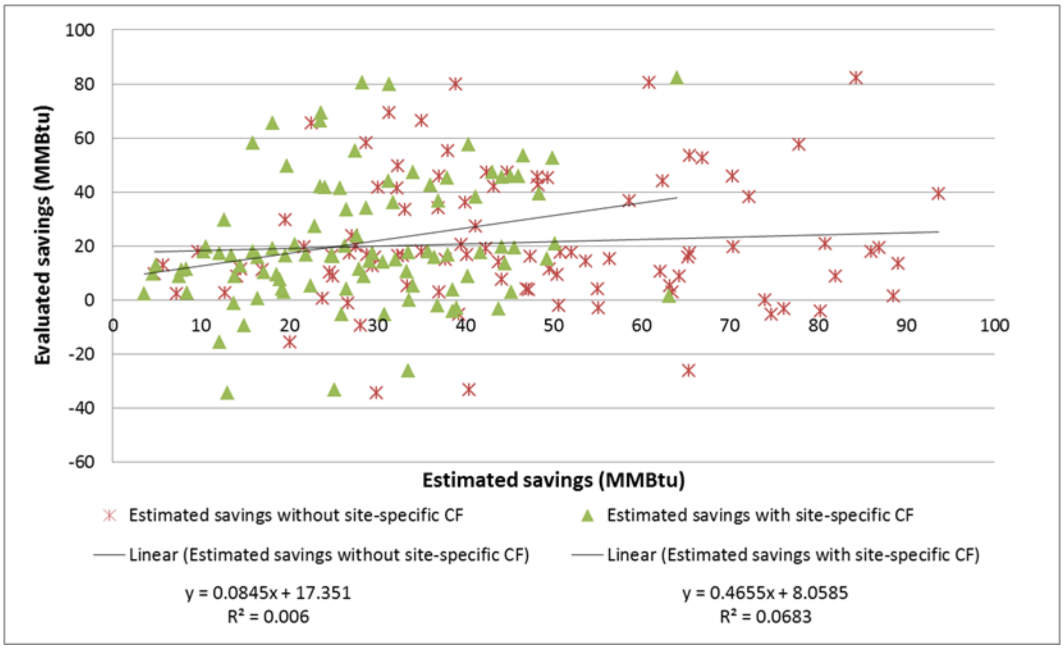
After demonstrating that the application of a site-specific CF was an effective method for improving the whole home thermal model's ability to predict the post-installation heating usage, the next step was to test whether the site-specific CF improved savings estimates.

The Impact Evaluation Team regressed both the calibrated and uncalibrated savings estimates against the evaluated savings for insulation and air sealing measures. The calibrated savings were

[9] The coefficient of determination, or R^2, indicates how well data fit a curve. A high R^2 value indicates a better curve fit than a low R^2 value.

estimated by multiplying the whole home model's estimated thermal savings by the site-specific CF determined from the pre-installation bills. Figure 4-9 shows that site-specific billing calibration did produce more accurate savings estimates, on average. However, unlike what was observed for modeled whole-home usage, the reliability of the savings estimates was not improved by the application of a site-specific CF, as indicated by the R^2.

Figure 4-9. EmPower Insulation and Air Sealing Measure Savings Estimates with and without Site-Specific Billing Calibration



It was concluded that the application of site-specific CFs improves the savings estimation accuracy on average, but does not improve the model's ability to make better site-specific savings estimates. Since the development of a site-specific CF would require installation contractors to create a thermal model of the whole home – a time consuming process – an additional test was performed to see whether a single CF used across the Program might perform as well as site-specific CFs in estimating savings.

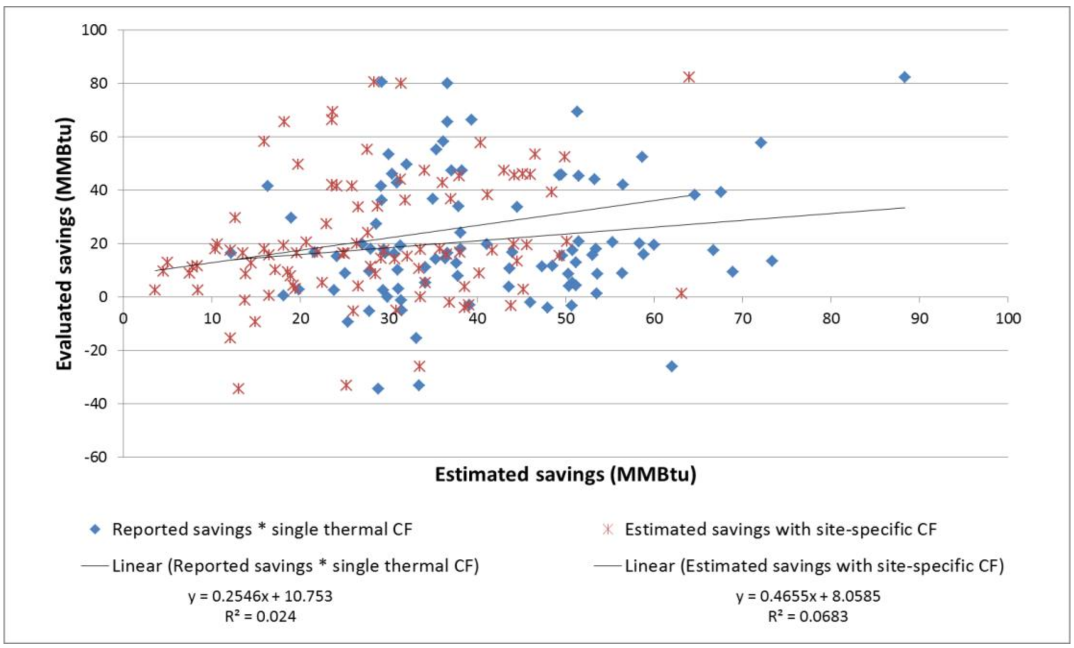
4.5.3 Development of the Single Thermal Calibration Factor

The Impact Evaluation Team used post-installation building characteristics to model the post-installation heating load of every home included in the onsite sample; the heat load model incorporated the recently implemented EmPCalc modifications (window-to-wall ratio and HDD). A single thermal CF was calculated using the estimated post-installation heat loads and billed post-installation heating usage for all 98 sites as follows:

$$CF_{Single\ thermal} = \frac{\sum Billed\ annual\ heat\ load\ consumption_{Post}}{\sum Modeled\ annual\ heat\ load\ consumption_{Post}}$$

The single thermal CF was calculated to be approximately 0.70. The Impact Evaluation Team used post-installation data (instead of pre-installation data) to calculate the single thermal CF because there was less uncertainty about post-installation building conditions and behaviors since they were directly observed by the on-site data collection teams. The Impact Evaluation Team found that applying the 0.70 single thermal CF to all heating savings estimates had an impact similar to the site-specific CF, as shown in Figure 4-10. The single thermal CF performed similarly to the site-specific CFs in terms of the accuracy of the model and its reliability as indicted by the R^2 values. The application of a single thermal 0.70 CF is expected to reduce the Program reported savings by approximately 28,400 MMBtu, as presented in Table 1-1 above.

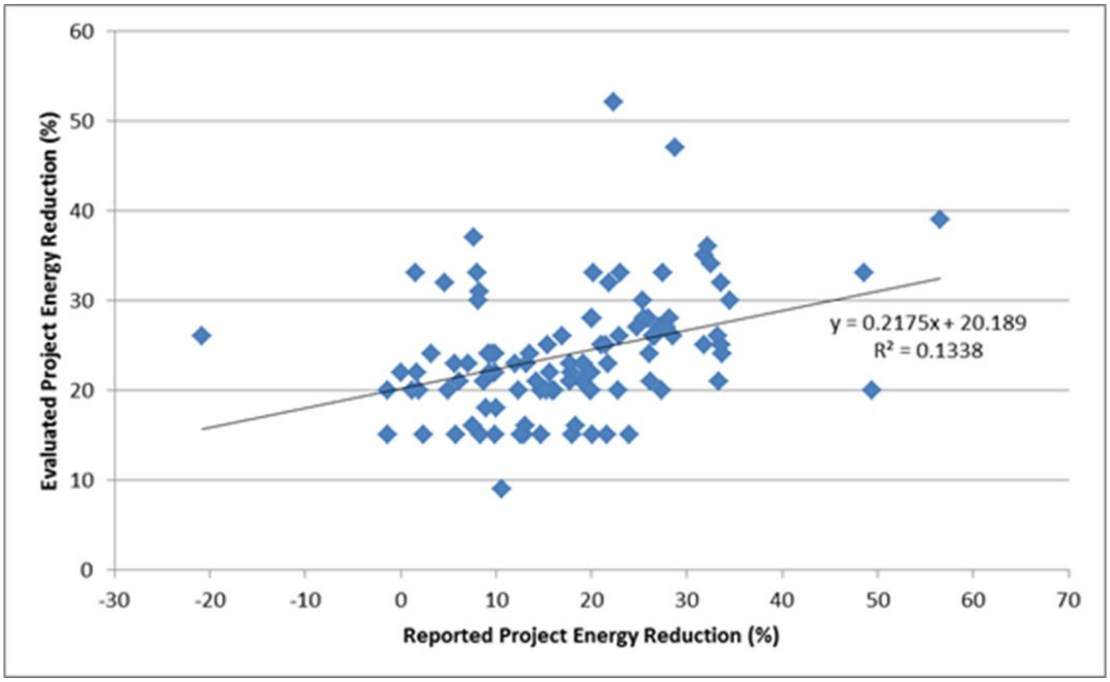
Figure 4-10. EmPower Insulation and Air Sealing Measure Savings Estimates Applying Site-Specific CFs and a Single Thermal CF



4.5.4 Comparison with Other Models

The inaccuracies of thermal models have been noted in other studies including the most recent NYSERDA Multifamily Performance Program (MPP) impact evaluation. The MPP uses TREAT software to model the whole-building loads and measure savings. Even with site-specific model calibration to billing data, the estimated MPP savings were not predicted well, as seen in Figure 4-11.

Figure 4-11. MPP Savings Estimates vs. Reported Savings Estimates with Site-Specific Calibration to Billing Data



4.5.5 Uncertainty of the Factor

The homes were selected at random from a subset of all the homes in the billing analysis. As detailed in the on-site sampling plan (Appendix E and Appendix J), the on-site sample population targeted homes which featured measures that accounted for a large percentage of the Program savings (i.e., envelope measures which account for 84% of the reported natural gas savings) and could be readily inspected in the field. The sampling precision and the coefficient of variation for the variable of interest, the CF, were quite good (+/-5% and 0.28). A more important consideration, given the definition of the sample frame, is whether the results may be biased and not applicable to the larger population. The Impact Evaluation Team examined a number of factors and concluded that the CF is unbiased, as discussed below:

- While the sample frame was designed to capture homes with installed insulation measures and high reported savings, the pre-installation natural gas usage for the general population and the sample population are similar;
- The CF aligns well with the Phase I billing analysis, after accounting for the administrative errors and the other EmPCalc recommendations;

- The CF did not correlate with any other factor – such as square-footage or geographic location – within the sample results that would indicate additional appropriate population differentiation;
- Calculating the single thermal CF using pre- or post-installation data gave similar results (0.621 and 0.696 with R^2 of 0.303 and 0.391, respectively).

The onsite sample was intended to be representative of those homes providing the bulk of the savings. Upon thorough review of the results the Impact Evaluation Team has concluded that the single thermal CF is appropriate for application to thermal modeling of the population.

4.5.6 Thermal Model Conclusions

While EmPCalc is a practical tool for this installation contractor-reliant Program, similar to other modeling tools, it relies on a simplified calculation methodology and idealization of site conditions. The Impact Evaluation Team sees no evidence that more complicated and expensive whole-home modeling with EmPCalc, or an alternate tool, will improve the accuracy of the savings estimates. A single thermal CF applied to all insulation and air sealing measures will true up the Program savings estimates in a simple and effective way. Because the CF was developed using modeled whole home usage and actual billing data, it is independent of savings and does not reflect changes in customer behavior, quality of installations, administrative errors, or other Program and measure related concerns that would arise if this factor was an adjustment of modeled savings to match actual savings.

The analysis indicates the average thermal CF will vary between 0.68 and 0.75 for 90% of the homes, based on the standard error[10] of the sample. The Program Staff will want to consider an appropriate application of the CF for screening individual measures in individual homes and whether individual homes are screened using the recommended CF or, possibly, the upper bound value. While using the upper bound value might ensure that no home is disqualified for a measure that it might have qualified for otherwise, it will overstate Program savings as a whole.

The recommended single thermal CF was determined using the EmPCalc model and assumptions and should be valid with that tool, even assuming the history of regular improvements to the model continues. The CF, however, should be reassessed if the fundamental modeling

[10] The standard error of the sample indicates how far the sample mean is likely to be from the population mean. The standard error of the single thermal CF was calculated using a normal distribution Z-score for a 90% confidence interval.

calculations shift to, for example, hourly simulations or incorporation of solar loading. The application of a single thermal 0.70 CF is expected to reduce the Program reported savings by approximately 28,400 MMBtu, as presented in Table 1-1 above. The tracking of savings estimates with and without the recommended thermal CF could allow for future analysis, but would need to be decided upon my NYSERDA and NFGDC.

4.6 SUMMARY OF RECOMMENDED CHANGES

Each of the recommended changes is expected to incrementally improve the Program RR from the initial 0.43 determined in the Phase I billing analysis to a final expected RR of 0.85. The Impact Evaluation Team concludes the remaining 0.15 is at least partly explained by snapback, but likely incorporates other unknown factors.

Table 4-2 summarizes the magnitude of the recommended Program changes in MMBtus and the expected Program RR after implementation. The Program impacts reflect the methods and population from 2010–2011 and may not fully represent another year, which will have different year-to-year variations in weather and populations. That being said, the basic approach of the EmPCalc tool has remained consistent even with ongoing incremental improvements, and the participant population is fairly homogenous. Because of this high level consistency, the impacts calculated for 2010–2011 are expected to be representative of impacts in future years[11].

[11] Program staff expressed interest in the investigation of a deemed savings approach to calculate estimated savings. While that effort is outside the scope of the Phase II impact evaluation, there is no data indicating that a deemed savings approach would not work for the Program. Additionally, Appendix C contains descriptions of the NYTM savings approach for all measures offered by the Program, and may be a useful resource in any future deemed savings calculation development.

Table 4-2. Impact of Recommendations on EmPower Program Savings and RR[1]

	Implementation Status	Program Savings (MMBtu)	Change in RR	RR
Program reported savings	N/A	127,765	–	0.43
Recommendation: Fix administrative errors	Implemented	-10,100	0.04	0.47
Recommendation: Correct EmPCalc factors, including HDD and window-to-wall ratio	Implemented	-24,200	0.12	0.59
Recommendation: Apply a thermal CF of 0.70 to insulation and air sealing measure savings estimates	Recommended	-28,400	0.26	0.85
Total expected reported savings	N/A	65,000	–	0.85
Unknown and behavioral factors	N/A	-10,000	0.15	1.0
Evaluated savings (from Phase I of the impact evaluation)	N/A	55,059	N/A	–

[1] This table presents the expected impact of each recommendation on the Program savings and RR. The overall Program reported natural gas savings are presented at the top, followed by the recommendations and total expected natural gas savings and Program RR after the recommendations have been implemented. The Impact Evaluation Team identified approximately 10,000 MMBtu of overstated savings which are attributed to unknown and behavioral factors that were not evaluated in this study.

While the recommendations are expected to improve the accuracy of the Program savings as a whole, the individual site savings estimates are less certain. The reduced savings will also reduce the savings-to-investment ratio (SIR)[12] of insulation and air sealing measures. Program Staff should consider whether it is appropriate to conduct screening at the individual site measure level or more programmatically. The single thermal CF could be applied in any one of four points in the process. The choice will impact site or measure screening and the ease with which both adjusted and unadjusted savings values can be tracked. The implications associated with each option are noted in Table 4-3.

[12] According to the *EmPower New York EmPCalc Energy and Cost Savings Calculations* document dated 1/1/2011, "NYSERDA requires that measures have a savings-to-investment (SIR) ratio of 1.1 or greater in order to be considered cost-effective. In calculating SIR, EmPCalc uses a discount rate of 3% for its assessments." The low-income sector was made exempt of a standardized cost-effectiveness regulation in Case 07-M-0548 – Order Approving EEPS Program Changes, issued and effective December 26, 2013 (pages 11 and 12). Even so, the SIR calculation remains in EmPCalc.

Table 4-3. Single Thermal CF Implementation Options

CF Application Location	Practical Implications
CF is applied to the EmPCalc measure-level savings calculations for insulation and air sealing measures	▪ The single thermal CF will reduce the estimated savings to a more accurate value for each proposed component (i.e. wall, attic). A larger number of individual components than is currently observed may have an SIR<1.1. ▪ Additional programming would be required to transfer both calibrated and uncalibrated insulation and air sealing savings estimates into the CRIS database.
CF is applied to insulation and air sealing measures at the site level	▪ The single thermal CF will reduce the estimated savings to a more accurate value for the site. A larger number of site insulation and air sealing projects than is currently observed may have an SIR<1.1. ▪ Additional programming would be required for the automatic transfer of both calibrated and uncalibrated insulation and air sealing savings estimates into the CRIS database.
CF applied to insulation and air sealing measures in CRIS	▪ The calibrated insulation and sir sealing savings estimates would be calculated in the CRIS database. With no other changes in practice, the measure and site screening would not change, however, the Program may have a lower SIR than it would with more measures screened out. ▪ The database would require modification to add this calculation.
CF applied to the Program-wide natural gas savings estimate	▪ The recommended single thermal CF is appropriate for insulation and air sealing measures only. In order to apply a single thermal CF to the Program-wide savings estimate, the CF would need to be adjusted to account for measure mix (i.e, the ratio of insulation and air sealing savings estimates to the esavings estimates for all other natural gas measures). ▪ The calibrated insulation and sir sealing savings estimates would be calculated in the CRIS database. The database would require modification to add this calculation. The factor would have to be adjusted if the measure mix changed over time.

The application methodology of the single thermal CF is to be determined by Program Staff and NFGDC.

4.7 RECOMMENDATIONS

The Impact Evaluation Team has five recommendations, three of which were implemented just prior to publication of this study, as follows:

1. **Automate the transfer of EmPCalc savings estimates into the reported savings database.**

   The electronic transfer of EmPCalc savings estimates into the reported savings database would eliminate the potential for manual data entries, rounding errors, and incorrect decimal placement. This recommendation was implemented on January 2, 2015; EmPCalc savings estimates are now automatically uploaded into CRIS, NYSERDA's reported savings database.

2. **Implement range checks into EmPCalc and provide pick-list descriptors for the status of each measure in EmPCalc.**

The Impact Evaluation Team recommends adding range checks to EmPCalc for select fields to reduce data entry errors. The use of checkboxes to indicate targeted and approved measures was particularly error-prone. It is recommended that the EmPCalc "Targeted Measure" and "Approved Measure" checkboxes be replaced with more descriptive pick-lists for the final measure condition (e.g., measure installed vs. measure rejected). Subsequent training for installation contractors is also recommended to ensure the effectiveness of this recommendation. Although the impact of this recommendation could not be quantified, it is expected to improve the efficiency of QA/QC reviewers.

3. **Correct the EmPCalc window-to-wall ratio.**

   The Impact Evaluation Team collected window, door, and wall dimensions from every home visited. Some additional study of typical framing techniques was conducted and window and door framing dimensions were included in the calculation of each site's window-to-wall ratio. Based on this effort, the Impact Evaluation Team found that treated homes have an average window-to-wall ratio of 25% and therefore recommends adjusting the EmPCalc window-to-wall ratio from 15% to 25%. Implementation of this recommendation was completed in December 2014 following an initial results presentation.

4. **Correct the EmPCalc HDD assumptions.**

   The Impact Evaluation Team used pre-installation and post-installation billing data from all 1,715 sites included in the Phase I billing analysis to determine the most appropriate TMY3 HDD base for the EmPCalc tool. The recommended HDD were added to EmPCalc in December 2014 following an initial results presentation.

5. **Apply a single thermal calibration factor of 70% to all insulation and air sealing measures.**

   While EmPCalc is a practical tool for this installation contractor-reliant Program, the overarching weakness of the tool is its simplified calculation methodology based on ideal conditions. A variety of factors may contribute to the overstatement, included but not limited to: (1) site-specific solar heat gains, (2) imperfectly represented internal temperature profiles, (3) unpredictable occupancy schedules, and (4) other unidentified reasons. The Impact Evaluation Team sees no evidence that a more complicated and expensive whole-home modeling with EmPCalc, or an alternate tool, will improve the accuracy of the savings estimates. Rather, the application of a single thermal 70% calibration factor to the estimated savings for all insulation and air sealing measures would increase the accuracy of savings claims without changing the calculation procedures or introducing additional work for the installation contractors. This CF was derived from models of post-installed usage that account for the implementation of the previous recommendations and therefore, will not ‘double-count’ the effect of these changes.

NYSERDA and NFGDC should be mindful of the impact of all of these recommendations on reported savings and the timing of the implementation. The application methodology of the single thermal CF is to be determined by Program Staff. Furthermore, the tracking of savings estimates with and without the recommended thermal CF could allow for future analysis, but would need to be decided upon my NYSERDA and NFGDC.

APPENDIX A: GLOSSARY OF TERMS[1]

air changes per hour (ACH) – A measure of the air volume added to or removed from a space divided by the volume of the space. The ACH due to air leakage (infiltration) is calculated using blower door test results.

balance point – the outdoor air temperature at which a home's heating system is required to turn on to satisfy the thermostat setpoint.

billing analysis – Estimation of program savings through the analysis of utility consumption records comparing consumption prior to program participation and following program participation. This term encompasses a variety of types of analysis, from simple pre-/post- comparison to complex regressions that involve weather normalization.

blower door test – A test used to determine the air leakage through penetrations in the building envelope.

building envelope – The physical separator between the conditioned and unconditioned environment of a building to include both surfaces and penetrations such as windows and doors. The three basic elements of a building envelope are a weather barrier, air barrier, and thermal barrier.

calibration factor (CF) – A factor applied to a calculated savings estimate to increase the accuracy of the estimate. The Impact Evaluation Team calculated site-specific CFs by calibrating the modeled whole-home heat load to billing data. Upon determining that site-specific billing calibration did not improve the accuracy of individual savings estimates, a single thermal CF was also calculated using modeled thermal loads and billing data.

CFM50 – the airflow needed to create a change in building pressure of 50 Pascals. A CFM50 reading is produced by a blower door apparatus during testing. EmPCalc uses the CFM50 value in air sealing calculations.

EmPCalc – The Excel-based calculation tool used by the Program to estimate the electric and natural gas impacts that will result from the installation of energy efficiency measures. Although some project savings are calculated with other tools (e.g. TREAT or eSIM), the vast majority of savings are calculated using EmPCalc.

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[1] NYSERDA generally follows and uses the terms as defined in the "Northeast Energy Efficiency Partnerships Glossary of Terms," found at http://neep.org/uploads/EMV%20Forum/EMV%20Products/EMV_Glossary_Terms_Acronyms.pdf. This glossary defines those terms absent from the Northeast Energy Efficiency Partnerships (NEEP) report or provides more specific definitions to generalized NEEP terms.

evaluated gross savings – The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an efficiency program, regardless of why they participated, as calculated by program evaluators.

heating degree day (HDD) – The difference between the hourly outdoor air temperature (T_{out}) and the internal temperature (T_{in}), calculated as follows:

$$\text{if } T_{in} > T_{out}, \qquad HDD = \sum_{n=1}^{24} \frac{(T_{in,n} - T_{out,n})}{24}$$

NAC – An acronym for "normalized annual consumption". The annual natural gas usage for each EmPower site was normalized to local weather.

New York Technical Manual (NYTM) – An abbreviation of New York State's 2010 measure savings guidance document, "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs."[2]

participant – The Impact Evaluation Team uses this generic term to describe the homeowners or renters who received services from the Program.

R^2 – Also known as the coefficient of determination, R^2 indicates how well data fit a curve. A high R^2 value indicates a better curve fit than a low R^2 value.

R-value – The measure of a material's resistance to conductive heat transfer.

realization rate (RR) – The ratio of the evaluated gross savings to the Program's reported savings. The RR represents the percentage of program-estimated savings that the evaluator estimates as being actually achieved based on the results of the evaluation M&V analysis. The RR calculation for natural gas energy for a sampled project is shown below:

$$RR = \frac{MMBtukWh_{evaluation}}{MMBtukWh_{program}}$$

where,

RR is the realization rate

$MMBtu_{evaluation}$ is the evaluation M&V kWh savings (by evaluation M&V contractor)

$MMBtukWh_{program}$ is the MMBtu savings claimed by program

[2] http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/766a83dce56eca35852576da006d79a7/$FILE/TechManualNYRevised10-15-10.pdf

setpoint – The interior temperature setting selected by a resident and maintained by a thermostat. A functional thermostat will control a home's heating system in order to satisfy the specified temperature setpoint.

savings-to-investment ratio (SIR) - According to the *EmPower New York EmPCalc Energy and Cost Savings Calculations* document dated 1/1/2011, "NYSERDA requires that measures have a savings-to-investment (SIR) ratio of 1.1 or greater in order to be considered cost-effective. In calculating SIR, EmPCalc uses a discount rate of 3% for its assessments." The low-income sector was made exempt of a standardized cost-effectiveness regulation in Case 07-M-0548 – Order Approving EEPS Program Changes, issued and effective December 26, 2013 (pages 11 and 12). Even so, the SIR calculation remains in EmPCalc.

snapback – A reduction in potential energy savings due to changes in use patterns after the installation of an energy-efficient product.

standard error - The standard error of the sample indicates how far the sample mean is likely to be from the population mean. The standard error of the single thermal CF was calculated using a normal distribution Z-score for a 90% confidence interval.

thermal load – The heating load in a space. The Impact Evaluation Team used thermal load calculations to estimate the natural gas usage during the heating season.

typical meteorological year version 3 (TMY3) weather data – The most recent version of typical hourly weather data derived from a 1991-2005 period of record and published by the National Renewable Energy Laboratory (NREL) in 2008[3].

[3] TMY3 citation: Wilcox, S. and W. Marion, User's Manual for TMY3 Data Sets, NREL/TP-581-43156. April 2008. Golden, Colorado: National Renewable Energy Laboratory.

MEMO

DATE: August 2, 2013; Revised May 15, 2014

TO: NYSERDA

FROM: Jean Shelton and Collin Elliot, Itron, Inc.

RE: EmPower Impact Evaluation (2010–2011) Results from Phase I Billing Analysis

1 EXECUTIVE SUMMARY

This memo presents a report on billing analysis conducted to estimate first-year electricity and natural gas savings for projects installed in program years (PY) 2010 and 2011 of NYSERDA's EmPower Program (EmPower or Program). The analysis relied on a statistical model that combined pre- and post-installation billing records with weather data and program tracking information to determine the extent to which reported savings could be identified in the changes in consumption.

The Program is funded by National Fuel Gas Distribution Corporation (NFGDC) for natural gas measures in its service territory and by NYSERDA through the rest of the state. For electricity savings, the analysis included all EmPower participants with available data, regardless of funding source. For natural gas, the analysis was conducted separately for projects funded by NYSERDA and those funded by NFGDC. The Phase 1 analysis has benefited from the cooperation of NFGDC to incorporate their EmPower participants into the study.

Table 1 presents a summary of the results. Along with the total reported savings from the program tracking data for projects installed in PY 2010–2011, the table shows the realization rates (RRs) from the models and how these translate into overall evaluated gross savings for the program. Additionally, the 90% confidence intervals show the uncertainty associated with the RRs.

Table 1. Summary of Reported and Evaluated Electricity and Natural Gas Savings for EmPower Projects Installed in Program Years 2010 and 2011

	Annual Electric Savings (MWh/Yr)	Annual Natural Gas Savings (MMBtu/Yr)	
Funding	All participants	NFGDC	NYSERDA
NYSERDA program-reported savings	17,136	62,343	65,422
RR	0.97	0.37	0.49
90% confidence interval	0.92 – 1.02	0.33 – 0.41	0.41 – 0.56
Evaluated gross savings	16,623	22,955	32,104

The results of this evaluation are substantially different from the previous EmPower evaluation of PY 2007–2008, as shown in Table 2. For the natural gas results, the more appropriate comparison is between the RR from PY 2007–2008 and RR for NYSERDA from 2010–2011, as the 2007–2008 evaluation did not include any NFGDC projects in the analysis.

Table 2. EmPower Comparison of PY 2007–2008 and PY 2010–2011 RR

Installed Program Year	Electric RR	NYSERDA Natural Gas RR	NFGDC Natural Gas RR
2007–2008	0.54	0.70	N/A
2010–2011	0.97	0.49	0.37

While it is difficult to determine the reasons for the different results with certainty, a reduction in CFL savings assumptions offers a compelling explanation for the change in the electricity savings RR. For natural gas, the underlying population and mix of measures changed between the two periods. The PY 2010–2011 average pre-installed natural gas usage was higher than the previous period and a greater portion of the measures installed were aggressive, high savings measures (e.g., insulation and heating equipment), which in this analysis, were shown to have lower RRs.

2 INTRODUCTION

This memo provides a description of EmPower and outlines the approach, methods, and results of the billing analysis for the Phase 1 impact evaluation of projects installed in program, years 2010 and 2011. It was preceded by an earlier analysis which intended to maximize the precision for natural gas by including all participants in a single model. After a subsequent review of initial results and further examination of data revealed differences between NYSERDA and NFGDC, it became clear that the separate models described in this memo were more appropriate.

Phase I of the PY2010–2011 evaluation cycle was designed to estimate household first-year energy savings using a billing analysis of all PY2010–2011 program participants with sufficient pre- and post-installation consumption data. The purpose of this study is to provide robust and reliable estimates of first-year energy savings, both electric and natural gas, at the household and program level.

The most recent impact evaluation of EmPower was for projects installed in program years 2007 and 2008. It was completed by the Megdal & Associates Impact Team in 2012. This evaluation was the first to utilize the participant consumption data. As a result, that Impact Team experienced some difficulties obtaining and interpreting the data from each of the utilities. Consequently, the billing analysis relied on data provided by only three utilities.

Subsequently, process and data confidentiality protocols were put in place with NYSERDA and each of the utilities. These processes facilitated the delivery of consumption data from all of the electric and natural gas utilities. As a result, the Phase I PY 2010–2011 impact evaluation expanded the scope of the billing analysis to include all of the utilities.[1]

Additional research, conducted as Phase II of this evaluation, will include a measure and site level engineering review and on-site surveys to verify measure installations and collect additional site-specific information that may help explain the drivers of the RRs found in Phase I. Planning for Phase II of the PY 2010–2011 impact evaluation was conducted in the first half of 2013, and a separate work plan has been developed for Phase II.

3 PROGRAM DESCRIPTION AND ACTIVITY

EmPower provides cost-effective electric and natural gas energy reduction measures. In-home energy-use education provides customers with additional strategies for managing their energy costs. NFGDC sponsors and funds EmPower natural gas measures for participants in its natural gas service territory, while NYSERDA funds EmPower through the rest of the state. NYSERDA funds Electric Reduction participants and on rare occasion, participants with natural gas measures, within the NFGDC service territory, as well. NYSERDA administers EmPower on behalf of NFGDC. There is a uniform offering to all EmPower participants and a single implementation contractor as well as a single quality assurance contractor. However, NFGDC aggressively target markets high natural gas use customers, while NYSERDA's outreach is broader.

Electric and natural gas distribution customers who live in one- to four-unit family homes or small multifamily buildings with 100 units or fewer, and either participate in a utility payment assistance program or have a household income below 60% of state median income, are eligible for services. All energy efficiency measures are provided at no cost to the customer. In rental situations, measures that directly benefit the eligible tenant are provided at no cost. Additional measures require a 25% landlord contribution. In addition to energy efficiency measures, all participants receive in-home energy education as part of the initial audit.

EmPower prioritizes cost-effective efficiency measures for low-income households with high energy costs, including payment-troubled customers referred by utilities. The program installs a wide range of measures, focusing on a comprehensive retrofit for low-income households. For natural gas measures, the focus of the program is on insulation, air sealing, and heating system repairs and replacements, as well as other cost-effective home performance measures. For electric measures, the focus of the program is on lighting and refrigerator replacements, as well as other cost-effective home performance measures. In-home energy use education is also provided, educating customers on additional strategies for managing their energy costs. EmPower includes measures that reduce household energy costs by switching from a higher cost per Btu fuel to a lower one. For instance, EmPower funds replacement of electric dryers and water heaters with

[1] The evaluation team, in coordination with NYSERDA, determined that the 2009 program closely resembled the 2007–2008 EmPower program. Given the similarities between the 2009 and the 2007–2008 programs, NYSERDA felt it was advisable to focus this evaluation on PY 2010–2011.

natural gas units. In these instances, the household will experience an increase in natural gas usage along with a decrease in electricity usage.

Program tracking is highly detailed and both savings and extra use are recorded for each fuel type. The following tables show the program-reported electricity savings for PY 2010 and 2011. Table 3 lists the program-reported electric savings for the EmPower Home Performance projects by measure and its contribution to total savings. These savings are dominated by refrigerators (38% of reported savings) and CFLs (27% of reported savings).

Table 3. EmPower Electric Program Reported Savings

Measure	Electric Savings (MWh)	Percent of Total Savings
Refrigerator	6,435	38%
CFLs	4,600	27%
Freezer	1,627	9%
Domestic hot water	1,297	8%
Hardwired lighting	1,159	7%
Envelope	1,102	6%
Other	709	4%
Heating	208	1%

Table 4 lists the natural gas savings for the EmPower Home Performance projects by measure and each measure's contribution to total Program savings. EmPower reported natural gas savings are dominated by envelope savings which account for 86% of the total. Envelope savings are a combination of insulation, air sealing, and programmable thermostat reported savings. The program tracking data also contains many clothes dryers and some water heaters that represent fuel switching measures. These fuel switching measures amounted to 2,200 MMBtu of increased consumption and are not included in this table's totals, since they do not contribute to savings.

Table 4. EmPower Natural Gas Program-Reported Savings

Measure	Savings (MMBtu)	Percent of Total Savings
Envelope	107,171	84%
Heating system	8,116	6%
Other heating	8,114	6%
Domestic hot water	3,681	3%
Other	683	1%

4 METHODS

Several characteristics of the program led to the selection of billing analysis as the method to evaluate the RRs. For one, EmPower is a program with a large number of participants where retrofits are anticipated to save an observable share of energy (conventionally at least 8%–10% of usage). In addition, within the EmPower Program, multiple measures that act on a given end use (i.e., electricity or natural gas) may be installed within a household. Installing multiple measures within a single end use may impact the per-measure savings observed at the household level. The EmPower Program meets the criteria of observable energy savings and the installation of multiple interactive measures, therefore a billing analysis is a good evaluation approach for this Program.

4.1 Data Sources and Issues

The billing analysis relied on three different sources of data:

- Program tracking data with information on the characteristics of each home (e.g., heating fuel and apartment units) and measure-level savings data
- Monthly electric and natural gas utility billing records
- Weather data from National Oceanic and Atmospheric Administration (NOAA) for all major weather stations served by the Program

4.1.1 Attrition in the Billing Models

In large-scale billing analyses like the EmPower evaluation, the primary evaluation concern is the potential for bias. The largest source of potential bias is that participants evaluated within the billing model may differ from participants who were excluded from the model because the billing data was inadequate or suspect. This process of cleaning billing data resulting in participant attrition may introduce bias into the analysis if the households removed from the analysis have specific sets of characteristics that are associated with energy savings. The potential for attrition-related bias is dependent on the methods chosen to remove homes from the model and the methods used to conduct the analysis.

Two aspects of the selected evaluation methods were designed to minimize the impacts of attrition.

Analysis method – RRs were determined by measure group for homes in the model and then applied by measure group to the Program population, which assumes that the RRs are similar between the homes in the model and the total program. The alternative approach of estimating the evaluated gross savings per measure group would assume that the estimated savings per home (which would reflect the size of the homes and the climate zones of the homes in the model) are the same between the model and the total program projects.

Regression model – A fixed effects regression model was used. The fixed effects model compares each home to itself, which means that house-specific differences that are consistent across the analysis period are addressed in the regression analysis.

Thus, in assessing the potential bias associated with attrition, the key issue is whether there is any expectation that specific groups of homes have different RRs rather than whether the homes in the model are a good match to the homes in the population.

The potential for the introduction of bias is discussed for each stage of the billing data cleaning process, which ultimately determined the accounts included in the billing analysis and those that were excluded.

Note that the causes for attrition are not mutually exclusive, and so the five data cleaning stages below simply represent the order in which they were addressed in the analysis.

1. The first stage of cleaning removed accounts without identified savings in the program tracking data. First, for electric bills and the electric model, accounts that did not show any kWh savings were eliminated. For natural gas bills and the natural gas model, the tracking data often indicated the presence of MMBtu savings for homes using fuels other than natural gas. For these projects, savings for heating-related or domestic hot water (DHW) measures were only counted in the model if the tracking data indicated the house used natural gas for the end use in question.
2. The second stage of cleaning involved analyzing the bills for anomalies, such as excessive consumption, missing values for consumption, or large gaps between the end date of one interval and the start date of the next that would make the billing series problematic for purposes of estimating savings. Excess consumption, missing reads, and/or large gaps may indicate infrequent meter reads (where the utilities relied on estimated consumption) or simple clerical errors at the utility. It is likely that this type of error in the billing data is random and would not be expected to introduce bias into the billing analysis RR results because it is not systematic.
3. The third stage of cleaning involved removing any accounts that did not have a sufficient number of bills in the pre- or post-installation periods. While the goal was to have 12 months in each period, the threshold for this study was set to nine bills[2] to allow for the inclusion of a larger number of accounts. Overall, the vast majority of accounts in the final analysis had a full year of pre- and post-installation data. It is not possible to assess the potential impact of this type of attrition on the model's estimated RRs.
4. The fourth stage of cleaning removed accounts based on the presence of excessive estimated reads. Including large numbers of estimated reads in the model reduces the association between energy consumption, weather, and potentially measure savings. Determining the acceptable number of estimated reads was an iterative process in that it took place in conjunction with the actual billing analysis to set a threshold based on when the presence of estimated reads adversely affected the model results. The presence of excessive numbers of estimated reads adversely affected the estimated fit of the model or the R-squared.
5. The fifth and final stage of cleaning removed large multifamily accounts with five or more units. In a billing analysis it is important that the units of analysis are of similar size. Including these in a billing

[2] This criterion was applied to the number of bills, not months' worth of bills (approximately 270 days), so for utilities with bi-monthly bills, an account with five bills accounting for ten months would have been removed. However, the criterion was applied to the total number of bills, not the total within a year, so the number of accounts removed due to this criterion was minimal. Additionally, the allocation of energy from long bill intervals to calendar is often problematic and can result in poor model fit, so there is often good cause to remove these accounts.

analysis dominated by single-family homes could lead to significant heteroskedasticity.[3] The attrition of multifamily complexes from the analysis could introduce bias if there are systematic differences between single-family homes and multifamily complexes and these differences result in lower or higher savings. The large majority of EmPower participants included in the billing models were single-family homes, small apartments (one to four units), and mobile homes. Because the larger apartments represent such a small share of the total projects, they would have to be dramatically different from modeled households to introduce bias into the final results.

Table 5 presents a summary of the data attrition for the current analysis along with a comparison of the figures from the 2007–2008 study. Note that while six utilities provided data for both the electric and natural gas analyses, some utilities only contributed a small share of the total accounts.

Table 5. EmPower Attrition in Billing Models

	2007–2008		2010–2011	
	Participants with Electric Service	Participants with Natural Gas Service	Participants with Electric Service	Participants with Natural Gas Service[1]
Projects	17,051	17,042	12,562	4,076
Participants/households with savings (A)	16,598	7,325	11,723	2,756
Participants/households with billing data (B)	11,482	3,367	9,473	2,061
Total participants in analysis after cleaning[2] (C)	6,138	1,532	3,985	1,775
Percentage of participants/households with billing data included in analysis after cleaning (C/B)	53%	46%	42%	86%
Percentage of participants/households with savings included in analysis after cleaning (C/A)	37%	21%	34%	64%
Total number of utilities included in analysis	3	3	6	6

[1] The 2010–2011 gas participants are based on any project completed in 2010–2011 where the project details database defined the job type as "Home Performance" or "Combined."

[2] The large change from B to C in the electric models for 2010–2011 reflects the fact that billing data from NYSEG and RG&E contained a large number of unidentified estimated reads and reconciliations. The final models were run both with and without data representing these two utilities. The statistical reliability of the analysis dropped dramatically and the estimated savings from the model were substantially lower when these utilities were included in the model; thus, they were ultimately excluded.

4.1.2 Billing Data Calendarization

Billing analyses call for series of consumption on consistent monthly intervals, yet utility billing data invariably have meter read dates distributed throughout the month with interval lengths that are rarely consistent even within a single account. When dealing with a thirty-day bill from the 15th of the month, the

[3] Heteroskedasticity occurs when the variance of the billing analysis error term differs across observations within the model. Including large multifamily complexes in the billing analysis is likely to have these observations with larger errors that those for single-family households. While this would not bias the parameter estimates, it would bias the estimates of the standard errors.

association of that consumption with the current or previous month is ambiguous. As a means of mitigating this ambiguity, a step in the data cleaning and preparation for this study is “calendarization,” which refers to the allocation of the energy in the individual bills to actual annual calendar months using the billing’s read dates and actual weather data for that period. The monthly bills were also normalized to 30.4 days per month to provide each month with the same length for the billing analysis.

4.1.3 Baseline

Since EmPower is a retrofit program, the baseline is the pre-installation conditions. In the billing analysis, the pre-installation conditions are reflected in the pre-installation billing records. An exception to the retrofit scenario occurs when participants replace an aging or nonfunctional heating system. In this case, the decision is to remove a piece of working equipment in order to achieve energy savings and to replace equipment that has failed or is expected to fail in the near future. The baseline for these natural (market opportunity) replacements should be the state or federal standard rather than the consumption of the preexisting equipment. The incidence of replacement of heating equipment, however, is low. The billing analysis was conducted assuming that the pre-existing conditions are the appropriate baseline (i.e., the difference between what their previous equipment was consuming and what the new equipment is consuming).

4.2 Billing Analysis Model

The estimation of gross savings for this study was based on regression models using a cross-section time-series structure. The models employed a home fixed effect to account for differences in participants that are not related to weather or time effects.

The model was a generalized linear model with customer-specific intercept of the form shown in the equation below.

$$C_{it} = \alpha_i + \sum_{j=1}^{p} x_{ijt}\beta_j + \sum_{k=1}^{q} z_{ikt}\gamma_k + \varepsilon_{it} \,, \qquad (1)$$

where

C_{it} = The monthly consumption for the home *i* in period *t*, expressed in kWh or therms

α_i = The “customer-specific” intercept (or error) for home *i*, accounting for unexplained difference in use between homes associated with the number of occupants, appliance holdings, and lifestyle

x_{ijt} = The predictor variables reflecting the installation of energy efficiency measure *j* for household *i* in period *t*

β_j = The slope coefficients that quantify the average influence of modeled efficiency measure *j* on monthly consumption

p = The total number of energy efficiency measures included in the model

z_{it} = The predictor variables reflecting non-program related effect *k* (such as weather impacts) for household *i* in period *t*

γ_k = The slope coefficients that quantify the average influence of modeled nonprogram-related effect *k* on monthly consumption

q = The total number of nonprogram-related effects included in the model

ε_{it} = The error term that accounts for the difference between the model estimate and actual consumption for household *i* in period *t*

The model used dummy variables, in which the *x*'s for the installed measures are one or zero to indicate the installation with coefficients to reflect the savings for the measures.

The Impact Team reviewed the data and assessed the results to ensure that the savings estimates were statistically sound. Testing for violation of statistical assumptions was conducted for all models. The models were tested for autocorrelation[4], multicollinearity[5], and outliers[6], and to assess the impacts of unequal variances across homes (heteroskedasticity).

4.2.1 Nonprogram-Related Impacts on Energy Use

While the fixed effects model controls for the characteristics of the home that are stable over time, it is possible that the estimation of program impacts can be affected by other factors that do change over time. These types of changes can be conceptualized in two broad categories:

1. Individual changes that affect specific homes, such as acquiring new household members, taking a longer vacation, changes in set points, or having a change in one's work schedule
2. Changes in the overall economy that affect the residential market in a global way, such as volatile gasoline prices, unemployment rates, or an increase in home heating costs

Within-home changes may affect energy use on a house-by-house basis, but these impacts do not tend to create a bias in the final results as long as there are enough homes in the model. The Impact Team had

[4]Autocorrelation of errors is most common in time-series due to the intrinsic relationship between the most recent prior period and the present measurement while unspecified variables are missing that would explain the underlying mechanisms for these changes. If the model exhibits autocorrelation, the estimators are unbiased but the variance in the model tends to be artificially low.

[5]Multicollinearity occurs when predictor variables are correlated with one another. This can happen if measures are installed as a group. If multicollinearity is present, the estimators are sometimes of the wrong sign or not statistically significant.

[6]Outliers are observations that differ significantly from the population and may have an undue influence on the results.

intended to account for global factors using trend lines developed from nonparticipant bills.[7] The Impact Team developed nonparticipant average monthly bills using the 2012 participants who had not yet commenced project implementation. The development of these averages, however, was problematic because by the latter half of 2012, very few of the accounts had not yet participated in the EmPower program, so the nonparticipant trend lines were subject to the influence of a very small number of accounts. Given the small number of nonparticipants incorporated into these averages and the fact that the estimated savings did not substantially differ with and without the nonparticipant trends, the trends were dropped from the analysis. Phase II will include additional billing analysis incorporating unemployment trends into the models.

4.2.2 Model Selection Process

Model selection is an iterative process that seeks to find the specification that best fits the data while producing results that are intuitive and reliable. Standard statistics, such as R-square and t-values for specific parameters, were reviewed and the information-theoretic approach to model selection was employed. In conjunction, these two approaches ensured that the selection of the final model is based on objective statistical standards and the final model improves the ability to estimate the parameters of interest.[8]

For this study, the model selection focused on specifying two different types of models for each fuel. The first model was a general whole-home model as a means of estimating overall program savings, irrespective of individual measures. The second model was a measure-specific model to estimate as much of individual measure category savings as possible. For the whole-home model, the model specification was relatively straightforward. In contrast, the disaggregated model presented two challenges. The first is that some individual measures might not have sufficient savings to allow for detection by the regression model. For example, it would be highly unlikely that the savings from a single compact fluorescent lamp (CFL) would stand out in a home that had more substantial retrofits. The second issue is that many measures were installed together in the same home. In particular, lighting and DHW measures were installed together the vast majority of the time. For the natural gas model, most envelope measures were installed at the same time. When this is the case, it becomes very difficult to differentiate the savings associated with the installation of insulation and air sealing measures. As a result, a big component of the

[7] Trend lines incorporating unemployment rates and gas prices have not traditionally shown, in a definitive way, how these variables could increase or decrease residential energy consumption. Studies have found examples indicating both increases in energy consumption and decreases in energy consumption due to these variables.

[8] In billing analysis, the analyst makes many decisions regarding the statistical characteristics of the model and the specific parameters to be included. Thus, there are typically a number of possible models that could be used to estimate savings. The information-theoretic approach provides an objective framework for selecting the best model among a series of competing candidate models. Please refer to *Model Selection and Multimodel Inference* by Kenneth Burnham and David Anderson, Springer-Verlag, NY, 2002.

model selection process was the testing of varying levels of aggregation for the different measure categories to see which resulted is a stable and reliable set of parameter estimates.

After testing dozens of permutations, the final models were based on grouping the measures in a way that balanced good model fit with high RRs and stability in the results.[9] Table 6 shows the mapping of the measure categories in the tracking data to the impact variables used in the model specifications. For the electric models, the measure-specific model breaks out the estimated savings into six different categories, although lighting and DHW measures had to be grouped together due to multicollinearity issues. For the gas models, the difference between the two models is the split of heating into envelope, heating system, and heating repair as well as the separation of the base measures into DHW and other.

Table 6. EmPower Measure Categories Mapped to Modeled Impacts

Tracking Data Measure Category	Electric Whole-Home Model[1]	Electric Measure-Specific Model	Natural Gas Whole-Home Model[1]	Natural Gas Measure-Specific Model
Air sealing	Envelope	Envelope	Heating	Envelope
CFL	Base	Lighting & DHW	N/A	N/A
Clothes dryer replacement	N/A	N/A	Fuel Switch	Fuel switch
DHW improvement	Base	Lighting & DHW	Base	DHW
Freezer replacement	Base	Freezer	N/A	N/A
Hardwired lighting	Base	Lighting & DHW	N/A	N/A
Heating repair	Heating	Envelope	Heating	Heating repair
Heating replacement	Heating	Envelope	Heating	Heating system
Insulation	Envelope	Envelope	Heating	Envelope
Other	Base	Other	Base	Other
Pipe wrapping	Base	Lighting & DHW	Base	DHW
Refrigerator replacement	Base	Refrigerator	N/A	N/A
Shower heads	Base	Lighting & DHW	Base	DHW
Tank wrapping	Base	Lighting & DHW	Base	DHW
Thermostats	Envelope	Envelope	Heating	Envelope
Waterbed-related measures	Base	Other	N/A	N/A

[1]The "base measures" include measures that are not weather dependent, such as water heating conservation and replacement, lighting, and appliances.

5 Electric Results

This section of the memo presents the results of the electric billing analysis, focusing first on the actual output of the regression models and then on how those results translate into gross savings RRs. Two regression models were developed: a whole-home model and a measure-specific model. Due to the tighter confidence bands, more reliable estimates, and the focus of the program on comprehensive whole-house

[9] Stability in the results refers mainly to getting parameter estimates that do not vary dramatically with minor changes in the input data or model specification. For example, in the model selection process, the separation of the two lighting measures resulted in parameter estimates for DHW measures that varied too much to be considered reliable. Only when they were combined did the lighting and DHW measure result in relatively consistent results.

savings, the Impact Team selected the whole-home model as the source of the RR estimates. However, the measure-specific model provides insight into RRs for some of the individual measures, and therefore it is included in this presentation of results. Note that the electric results include households with both NYSERDA and NFGDC funding.

The primary results of interest from the regression analysis are the parameter and model fit statistics, which are presented in Table 7 for the whole-home model. The whole-home model is the basis for determining the Program RRs presented in Table 1. For the whole-home model, the overall model fit is measured by the R-square of 0.719, which indicates that the model accounted for nearly 72% of the variability in monthly consumption. The individual parameters for both measure impacts and the two weather variables are of the correct sign and statistically significant. For the measure impacts, a negative sign on the estimate means that the variable is associated with a decrease in consumption in the post-installation period, indicating energy savings. For the two degree-day variables, the positive sign shows the expected consumption increases on hotter or cooler days.

Table 7. EmPower Electric Whole-Home Regression Model Parameters

Parameter	Estimate	t Value	Pr > |t|	Units
Base measures	-104.1072	-32.82	<.0001	kWh
Envelope measures – CDD	-1.2159	-7.81	<.0001	kWh/CDD
Envelope measures – HDD	-0.1141	-5.11	<.0001	kWh/HDD
Heating Measures – HDD	-0.7655	-8.73	<.0001	kWh/HDD
CDD – Base 70	0.6640	44.03	<.0001	kWh/CDD
HDD – Base 60	1.4141	151.03	<.0001	kWh/HDD
Model Fit				
R-square	0.7188			

While the direct outputs of the regression models are useful, it is more important to see what the parameter estimates represent in terms of evaluated savings relative to reported savings both overall and per participant. For the base measure, the total evaluated savings are calculated by multiplying the parameter estimate by 12 to get an annual value and then summing for every household that had the measure in question. For the weather sensitive measures, the parameter estimates are multiplied by the eight-year average annual degree day in question (heating or cooling), summing for every household that had the measure.

Table 8 presents a summary of how the regression parameters translate into total MWh savings and then compares those values to the reported savings from the tracking data. The table shows the resulting RR along with the plus or minus 90% confidence interval. Since the analysis was not based on the full set of projects, the RR is then applied to the total reported savings to show the total evaluated savings for the program. The overall RR for the whole-home model is 0.97. The RR for the whole-home model is driven primarily by the base measures, which were present in every home and had an RR of nearly 1.00.

Table 8. EmPower Electric Whole-Home Model Program Savings

Impact Type	Homes in Analysis with Impact	Evaluated Total Savings (MWh)	Reported Savings (MWh) for Households in Analysis	RR	90% +/- Confidence	NYSERDA Program-Reported Savings (MWh)	Total Evaluated Savings (MWh)
Base measures	3,985	4,978	4,985	1.00	N/A	15,826	15,806
Envelope measures	62	63	225	0.28	N/A	1,102	309
Heating measures	10	40	28	1.43	N/A	208	298
Overall	**3,985**	**5,081**	**5,238**	**0.97**	**4.9%**	**17,136**	**16,623**

Table 9 presents the evaluated and reported savings in terms of average per participant and then shows what they represent as a percentage of the average annual pre-installation kWh (savings fraction). The comparison of per participant evaluated and reported savings simply reflects the overall RR.

Table 9. EmPower Electric Whole-Home Model per Participant Savings

Impact Type	Evaluated Savings (kWh) per Modeled Participant	Evaluated Savings as % of Annual Pre-Consumption[1]	Reported Savings (kWh) per Modeled Participant	Reported Savings as % of Annual Pre-Consumption[1]
Base measures	1,249	14.0%	1,251	14.0%
Envelope measures	1,018	6.1%	3,634	21.6%
Heating measures	3,960	28.3%	2,759	19.7%
Overall	**1,275**	**14.3%**	**1,314**	**14.7%**

[1]The annual pre- consumption values used for this table are based on the average annual consumption for households in the model who had the measure installed. The average annual consumption for households installing electric heating measures is substantially higher than the average for all households because they are electrically heated.

In addition to the whole-home model presented above, the Impact Team developed a second measure-specific model to provide additional insight into specific measure performance. The regression model results are presented in Table 10. The overall RR for the measure-specific model drops to 0.89 (relative to 0.97 for the whole-home model) and the 90% confidence band is wider, which demonstrates that the disaggregation of the effects results in less reliable estimates of energy savings.

Table 10. EmPower Electric Measure-Specific Regression Model Parameters

Parameter	Estimate	t Value	Pr > |t|	Units
Lighting and domestic hot water	-62.2466	-18.63	<.0001	kWh
Refrigerator	-49.0307	-15.45	<.0001	kWh
Freezer	-39.5146	-9.17	<.0001	kWh
Envelope measures – CDD	-1.2692	-8.17	<.0001	kWh/CDD
Envelope measures – HDD	-0.1241	-5.57	<.0001	kWh/HDD
Heating measures – HDD	-0.7659	-8.75	<.0001	kWh/HDD
Other measures	-111.9429	-12.69	<.0001	kWh/HDD
CDD – base 70	0.6611	43.92	<.0001	kWh/CDD
HDD – base 60	1.4151	151.38	<.0001	kWh/HDD
Model Fit				
R-square	0.7197			

Table 11 and Table 12 present the program and per participant results similar to Table 8 and Table 9 for the whole-home model. In the measure-specific model, the base measures are broken out into lighting and DHW and the two refrigeration impacts; even with uncertainty, there is evidence that the lighting and DHW package is driving the high RR for base measures. The estimated RRs for the refrigerator and freezer measures indicate that these measures are contributing significant savings, but that their reported savings tracking values may need additional review.

Table 11. EmPower Electric Measure-Specific Model Program Savings

Impact Type	Homes in Analysis with Impact	Evaluated Total Savings (MWh)	Reported Savings (MWh) for Households in Analysis	RR	RR 90% +/- Confidence	NYSERDA Program-Reported Savings (MWh)	Total Evaluated Savings (MWh)
Lighting and domestic hot water	3,819	2,853	2,263	1.26	NA	7,126	8,983
Refrigerator	2,023	1,190	1,918	0.62	NA	6,435	3,993
Freezer	692	328	578	0.57	NA	1,627	924
Envelope measures	62	67	225	0.30	NA	1,102	329
Heating measures	10	40	28	1.44	NA	208	298
Other measures	143	192	226	0.85	NA	639	543
Overall	**3,819**	**4,670**	**5,238**	**0.89**	**6.2%**	**17,136**	**15,278**

Table 12. Empower Electric Measure-Specific Model per Participant Savings

Impact Type	Evaluated Savings (kWh) per Modeled Participant	Evaluated Savings as % of Annual Pre-Consumption	Reported Savings (kWh) per Modeled Participant	Reported Savings as % of Annual Pre-Consumption[1]
Lighting and domestic hot water	747	8.3%	593	6.6%
Refrigerator	588	6.5%	948	10.5%
Freezer	474	4.7%	835	8.4%
Envelope measures	1,084	6.5%	3,634	21.6%
Heating measures	3,962	28.4%	2,759	19.7%
Other measures	1,343	11.7%	1,580	13.7%
Overall	**1,172**	**13.1%**	**1,314**	**14.7%**

[1]The annual pre- consumption values used for this table are based on the average annual consumption for households in the model who had the measure installed. The average annual consumption for households installing electric heating measures is substantially higher than the average for all households because they are electrically heated.

6 NATURAL GAS RESULTS FOR NYSERDA-FUNDED PROJECTS

NYSERDA and NFGDC natural gas results are presented separately, because the populations and results were found to be substantially different. This section describes the NYSERDA results; Section 7 describes the NFGDC results. The section is organized similarly to Section 5.

Two regression models were developed for NSERDA natural gas measures: a whole-home model and a measure-specific model. Due to the tight confidence bands, more reliable estimates, and the focus of the program on comprehensive whole-house savings, the Impact Team selected the whole-home model as the source of the Program RR estimates. However, the measure-specific model provides insight into RRs for some of the individual measures, and therefore it is included in this presentation of results.

The key outputs from the regression model are the parameter and model fit statistics, which are presented in Table 13 for the whole-home model. The whole-home model has very good fit statistics, with an R-square value of 0.921. Relative to the electric model, natural gas models tend to have a better fit due to the preponderance of natural gas consumption related to heating and its strong relationship with weather.[10] Additionally, the high R-square value is also due the natural gas model specification that included separate HDD slopes for each home, which capture the household-specific relationship between consumption and weather. The measure parameters for the energy savings measures are all negative and statistically significant and the parameter associated with fuel switching is positive and statistically significant.

[10] For the natural gas models the tracking data indicate if the home has natural gas heating. For the electric model there is no tracking data to indicate in the home has air conditioning. Information on air conditioning would likely improve the fit of the electric models.

Table 13. EmPower Natural Gas Whole-Home Regression Model Parameters for NYSERDA

Parameter	Estimate	t Value	Pr > |t|	Units
All heating measures	-0.0254	-25.84	<.0001	Therms/HDD
Base measures	-4.2444	-5.19	<.0001	Therms/month
Fuel switching (dryer)	5.7200	3.41	0.0007	Therms/month
Model fit				
R-square	0. 9210			

As shown in Table 14, the whole-home model results lead to an overall NYSERDA RR of 0.49. While the base measures have an RR of more than 2.84, these have little influence on the overall RR because they are associated with a small share of the total program savings. Base measures include DHW improvements, low flow shower heads, and other non-weather sensitive measures. The estimated RR for the All heating measures category (envelope, air sealing, and, to a lesser extent, heating equipment measures) dominates the overall RR because at least one of these measures was installed in most projects and they have substantially higher evaluated and reported savings.

Table 14. EmPower Natural Gas Whole-Home Model Program Savings for NYSERDA

Impact Type	Households in Analysis with Impact	Evaluated Total Savings (MMBtu)	Reported Savings (MMBtu) for Households in Analysis	RR	90% +/- Confidence	NYSERDA Program-Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)
Base measures	249	1,268	446	2.84	11.6%	4,015	11,411
All heating measures	635	8,079	18,655	0.43	5.9%	61,407	26,594
Fuel switching (dryer)	44	-302	-561	0.54	3.1%	-1,180	-635
Overall (non-switching measures)	**680**	**9,347**	**19,102**	**0.49**	**7.0%**	**65,422**	**32,014**

Table 15 presents the per-participant values. The reported savings were projected to save nearly 23% of a household's natural gas consumption. The average evaluated savings, however, confirm consumption savings of just over 11% (see highlighted cells).

Table 15. EmPower Natural Gas Whole-Home Model Per Participant Savings for NYSERDA

Impact Type	Evaluated Savings (Therms) per Modeled Participant	Evaluated Savings as % of Annual Pre-Consumption	Reported Savings (Therms) per Modeled Participant	Reported Savings as % of Annual Pre-Consumption
Base measures	51	4.1%	18	1.5%
All heating measures	127	10.3%	294	23.9%
Fuel switching (dryer)	-69	-5.6%	-127	-10.4%
Overall (non-switching measures)	**137**	**11.2%**	**281**	**22.8%**

As with the electric analysis, the measure-specific results are presented here because they provide insight into measures that could benefit from additional engineering review as part of the Phase II evaluation. Again, the whole-home model is more reliable in terms of confidence and precision of the two models and is what should be used for adjusting the overall program savings. To the extent that the results are reliable, the measure-specific model, which separates envelope from the heating measures, suggests that the envelope measures are not achieving the expected savings.

For the measure-specific model, as shown in Table 16, the estimates are of the correct sign in all cases, though the other measures and heating repair parameters are not statistically significant. Note, envelope measures include insulation, air sealing, and thermostats.

Table 16. EmPower Natural Gas Measure-Specific Regression Model Parameters for NYSERDA

Parameter	Estimate	t Value	Pr > |t|	Units
Envelope measures	-0.0243	-22.30	<.0001	Therms/monthly HDD
Heating system replacement	-0.0399	-11.32	<.0001	Therms/monthly HDD
Heating repair	-0.0012	-0.78	0.4357	Therms/monthly HDD
Domestic hot water measures	-4.6164	-5.61	<.0001	Therms/month
Other measures	1.2189	0.35	0.7231	Therms/month
Fuel switching (dryer)	5.4392	3.26	0.0011	Therms/month
Model Fit				
R-square	0. 9219			

Table 17 and Table 18 present the program and per-participant results similar to the tables presented for the whole-home model. The measure-specific gas model resulted in a nearly identical overall RR compared to the whole-house model, decreasing slightly to 0.48. The heating system replacement had an RR of nearly 0.77. DHW, which was combined with other base measures in the whole-home model, had an RR of more than 428%. The low and negative RRs for other gas measures and heating repair are not statistical significance and are not necessarily indicative of performance. The envelope measures modeled savings represent a savings fraction of 10% compared to a reported savings fraction of 22.2%. Heating system replacement, in contrast, had modeled savings that represent a savings fraction of nearly 17%, which is more similar to the reported savings fraction of 21.6%.

Table 17. EmPower Natural Gas Measure-Specific Model Savings for NYSERDA

Impact Type	Households in Analysis with Impact	Evaluated Total Savings (MMBtu)	Reported Savings (MMBtu) for Households in Analysis	RR	90% +/- Confidence	NYSERDA Program-Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)
Envelope measures	574	7,071	15,704	0.45	6.1%	48,560	21,865
Heating system replacement	32	660	859	0.77	0.7%	7,185	5,514
Heating repair	253	141	2,092	0.07	81.9%	5,662	381
Domestic hot water measures	241	1,335	311	4.29	10.4%	3,393	14,547
Other measures	10	-15	135	(0.11)	6.8%	622	-67
Fuel switching (dryer)	44	-287	-561	0.51	3.3%	-2,994	-1,533
Overall (non-switching measures)	**680**	**9,192**	**19,102**	**0.48**	**7.9%**	**65,422**	**31,481**

Table 18. EmPower Gas Measure-Specific Model per Participant Savings for NYSERDA

Impact Type	Evaluated Savings (Therms) per Modeled Participant	Evaluated Savings as % of Annual Pre-Consumption	Reported Savings (Therms) per Modeled Participant	Reported Savings as % of Annual Pre-Consumption
Envelope measures	123	10.0%	274	22.2%
Heating system replacement	206	16.6%	269	21.6%
Heating repair	6	0.5%	83	6.8%
Domestic hot water measures	55	4.5%	13	1.1%
Other measures	-15	-1.2%	135	11.1%
Fuel switching (dryer)	-65	-5.3%	-127	-10.4%
Overall (non-switching measures)	**135**	**11.0%**	**281**	**22.8%**

6.1 Comparison of NYSERDA Electric and Natural Gas Results with the Previous Evaluation

The comparison of the results from the two evaluation periods raises the important question of why the RRs are so different. For the electricity savings, the new RR is nearly double that from the previous evaluation. For the natural gas savings, the new RR is much lower than that of the previous evaluation. The types of data as well as the methods employed to estimate the savings are fundamentally the same, so how could the two evaluations produce such different results? Table 19 shows a comparison of the results for this analysis from the whole-home models with those from the previous evaluation of 2007–2008 EmPower participants.

Table 19. Overall Comparison of Savings of 2007–2008 and 2010–2011 EmPower Billing Analyses for NYSERDA

	2007–2008		2010–2011	
	Annual Electric Savings (MWh/Yr)	Annual Savings for All Other Fuels (MMBtu/Yr)	Annual Electric Savings (MWh/Yr)	Annual Natural Gas Savings (MMBtu/Yr)
NYSERDA program-reported savings	20,820	91,602	17,136	65,422
RR	0.54	0.70	0.97	0.49
90% confidence interval	0.67–0.71	0.58–0.82	0.92–1.02	0.42–0.56
Evaluated gross savings	11,296	64,095	16,623	32,014

This section presents evidence that differences in the participant populations and changes to program assumptions are likely to account for a substantial share of the differences in the results of the two evaluations.

6.1.1 EmPower Electric Results Comparison with Previous Evaluations

In comparing the evaluation results for PY 2007–2008 and PY 2010–2011 it is important to note that the RR is a fraction where the evaluated savings are the numerator and the reported savings are the denominator. The figures are presented in Table 20. Given the much greater difference in the evaluated savings, this comparison suggests that the major difference between the two evaluations is due to the numerator, but both components need investigation.

Table 20. EmPower Comparison of Electric Realization Rate Components

Installed Program Year	Electric Evaluated Mean Savings (kWh) (Numerator)	Electric Reported Mean Savings (kWh) (Denominator)	Electric RR
2007–2008	685	1,197	0.57
2010–2011	1,275	1,314	0.97

The analysis begins with a comparison of participants with electricity savings for the two evaluation periods. Table 21 presents a summary of the Program tracking data that shows the mean annual kWh consumption and kWh savings and percentage savings for the two Program years by utility. The starkest contrast between the two evaluation periods is the difference in annual consumption for participants (highlighted cells). The average annual consumption for PY 2007–2008 was only 6,246 kWh compared to 9,239 kWh for PY 2010–2011, a 46% increase. The reported savings increased as well, but only by 9%. These numbers translate into reported savings fraction of 19% and 14% for PY 2007–2008 and PY 2010–2011, respectively. From a theoretical perspective, it is likely that households with greater consumption are better candidates to achieve the expected savings. Stated simply, the PY 2010–2011 billing analysis was attempting to find roughly the same level of savings, but in substantially higher-consumption households. At the very least, this comparison shows that participating households were different in fundamental ways.

Table 21. EmPower Mean Annual Electricity Consumption, Reported Savings, and Percent Savings by Evaluation Year

	Evaluation Year								
	2007–2008			2010/2011					
	All Projects			All Projects			Modeled Projects		
	Mean Annual kWh	Mean kWh Savings	Savings as % of Annual	Mean Annual kWh	Mean kWh Savings	Savings as % of Annual	Mean Annual kWh	Mean kWh Savings	Savings as % of Annual
CHGE	3,820	1,133	29.6%	11,601	1,439	12.4%	10,904	1,263	11.6%
Con Edison	3,528	1,198	34.0%	7,235	1,162	16.1%	9,110	1,284	14.1%
NGRID	7,049	1,193	16.9%	8,793	1,239	14.1%	9,041	1,272	14.1%
NYSEG/RGE	6,388	1,148	18.0%	9,713	1,308	13.5%	9,126	1,257	13.8%
ORU	4,088	1,351	33.1%	9,295	1,623	17.5%	9,864	1,654	16.8%
All	6,246	1,182	18.9%	9,170	1,291	14.1%	9,239	1,314	14.2%

To illustrate that the homes included in the PY 2010–2011 billing model are representative of the population of EmPower participants, Table 21 shows consumption and savings for all projects in the tracking data and for the modeled projects. This comparison shows that there are not any marked differences between the modeled projects and the EmPower PY 2010–2011 population of participants. Knowing that the modeled projects are similar to the population of participants affords more confidence that the results of the analysis can be extrapolated to the overall population.

As a supplement to Table 21, Table 22 shows the count of projects and total MWh savings by utility to illustrate how much each utility contributes to the overall total. The values for PY 2007–2008 are based on all EmPower participants during these calendar years.

Table 22. EmPower Program Savings by Evaluation Year

	2007–2008			2010–2011					
	All Projects			All Projects			Modeled Projects		
Utility	Projects	Total MWh	MWh Share	Projects	Total MWh	MWh Share	Projects	Total MWh	MWh Share
CHGE	616	699	3.2%	522	1,293	7.6%	212	268	5.1%
Con Edison	1,427	3,322	15.4%	922	2,280	13.3%	1	1	0.0%
NGRID	7,811	9,319	43.3%	5,153	6,471	37.9%	3,085	3,926	74.9%
NYSEG/RGE	6,162	7,075	32.9%	4,380	5,809	34.0%	234	294	5.6%
ORU	826	1,119	5.2%	691	1,229	7.2%	453	749	14.3%
All	16,842	21,534	100.0 %	11,668	17,083	100.0 %	3,985	5,238	100.0 %

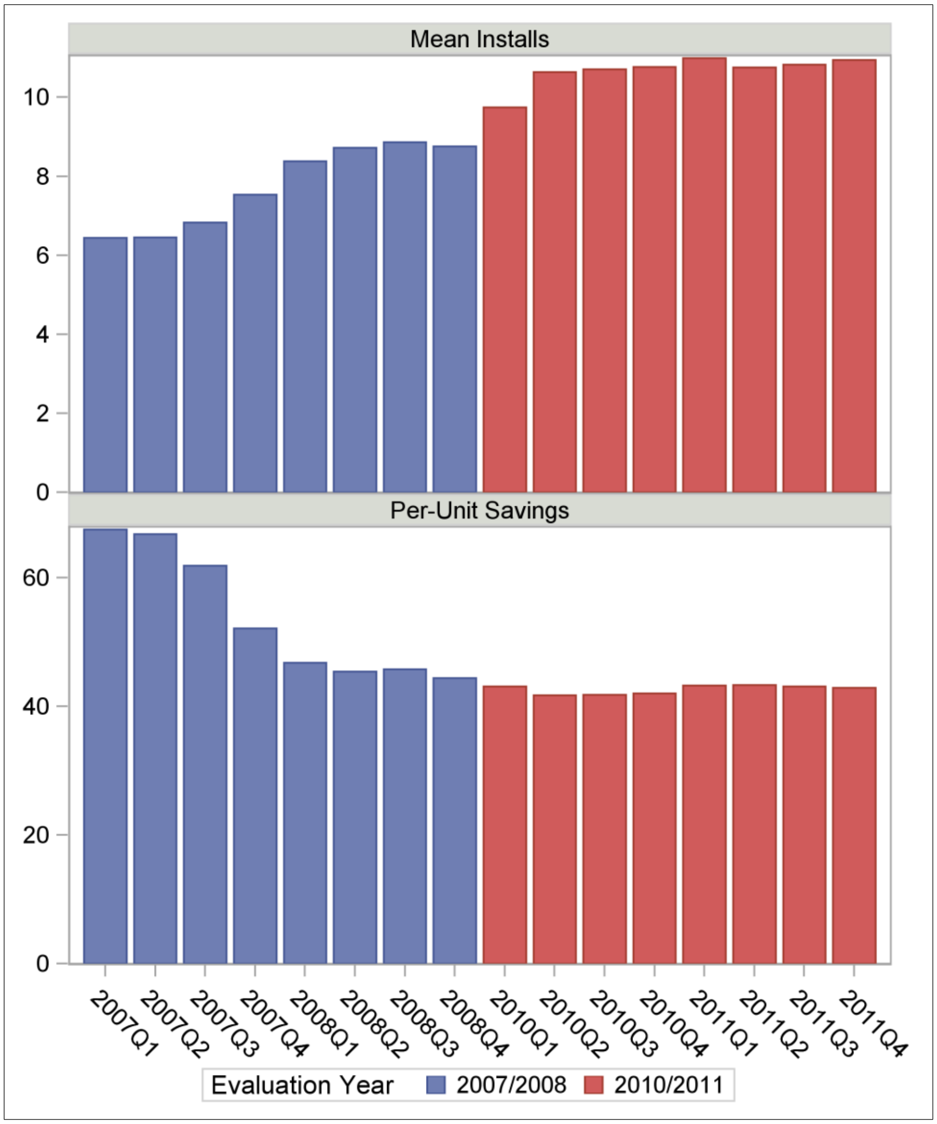
Another valuable comparison is to see whether the per-project savings are different across evaluation periods by measure group and whether there are any differences in the share of total savings associated with different measure groups. To this end, Table 23 shows mean savings per treated unit as well as the total savings for different measure groups for the two evaluation periods. Other than a clear difference in the envelope and other measure groups, the two evaluation periods are quite similar. The share of savings associated with the two measure groups is also similar for the two evaluation periods. Note that this analysis was also done separately for each utility and for the modeled accounts for 2010–2011, but there were no substantive differences.

Table 23. EmPower Mean Electric Savings by Measure Group and Evaluation Year

	Evaluation Year					
	2007–2008			2010–2011		
	Mean kWh Savings	Total MWh Savings	Percent of Total	Mean kWh Savings	Total MWh Savings	Percent of Total
DHW	426	1,181	5.9%	463	1,114	7.5%
Envelope	12,182	1,169	5.9%	3,592	682	4.6%
Freezer	768	2,039	10.2%	876	1,614	10.8%
Refrigerator	857	7,900	39.6%	955	5,844	39.2%
Heating	3,591	43	0.2%	3,246	120	0.8%
Lighting	433	7,100	35.6%	452	5,006	33.6%
Other	578	510	2.6%	1,341	536	3.6%

Table 23 shows that per household lighting savings are expected to be fairly similar in both evaluation periods (433 kWh per household vs. 452 kWh) and they also represent roughly the same share of savings. However, there are underlying details to the lighting measures – CFLs in particular – that help explain why the 2010–2011 evaluation had a higher estimated RR. To illustrate these important details, Figure 1 shows the mean installations per treated unit and mean kWh savings per bulb by year and quarter for the two evaluation periods. What the figure makes clear is that over 2007 and 2008, there was a change to the underlying assumptions about per-bulb savings as well as an increase in the number of bulbs installed. The mean kWh savings per CFL for the 2007–2008 evaluation was 53 kWh, compared to 43 for 2010/2011. The average number of installed CFLs per treated apartment/home was 7.8 in 2007–2008 compared to 10.7 for 2010–2011. While the total savings are similar, the PY 2010–2011 households are more likely to achieve the reported savings because more CFLs were installed and the savings estimate was more conservative. The extent to which higher consumption of participants in PY 2010–2011 is associated with more high-use fixtures would also suggest that the bulbs would result in more savings.

Figure 1. EmPower Mean Installations per Home and Average Savings per Bulb for CFLs by Evaluation Period



In summary, there are two key findings to the comparison of the electric results. The first is that the PY 2010–2011 participant population consisted of higher consumption households that are more likely to realize the relatively same amount of savings. Second, there are changes in underlying savings assumptions for CFLs that would point to higher RRs. While these findings do not necessarily explain all of the differences, they do provide a partial explanation for why the PY 2010–2011 evaluation resulted in a higher RR than the evaluation of the PY 2007–2008 participants.

6.1.2 EmPower Natural Gas Results Comparison with Previous Evaluations

In the case of natural gas, the PY 2007–2008 evaluated mean savings per household was 146 therms with reported savings of 216 therms. In contrast, for NYSERDA the PY 2010–2011 evaluated savings per household was similar at 135 therms, but the reported savings was higher at 276 reported therms savings. One clear indication is that the difference in the RRs is due to higher reported savings in PY 2010–2011. An explanation for this difference can be found in a key difference in the participant populations included in the two evaluation periods.

In the program tracking data there are a substantial number of projects with small amounts of natural gas savings associated with different hot water conservation and "other" measures. In the PY 2010–2011 evaluation, these projects – denoted by a job type designation of "Electric Reduction" – were intentionally excluded from the analysis.[11] The other job type designation is "Home Performance," which consists of those projects involving measures related to envelope and heating systems with more substantial savings. The Electric Reduction projects were a part of the PY 2007–2008 analysis, resulting in modeled accounts with a lower average per-household natural gas reported savings and a different mix of measure groups than were included in the PY 2010–2011 natural gas model.

As a means of assessing what the effect of the "Electric Reduction" projects might be on the billing analysis, Table 24 shows a summary of the program tracking data average annual consumption and average project savings by program year and job type. One issue with the Electric Reduction projects, however, is that they often do not have the annual consumption information, which means that any comparison of averages based on all available data will be based on a nonequivalent set of records. To remedy this, the summary in Table 24 shows the average project savings for all projects as well as for only those projects that had valid annual consumption information.

Table 24. EmPower Mean Reported Savings by Project Type and Program Year for NYSERDA Funded Projects

Program Year	Project Type	Mean Annual Usage (Therms)	Projects with Consumption and Savings			All Projects		
			Projects	Reported Savings (Therms)	Percent Savings	Projects	Reported Savings (Therms)	Percent Savings
2007–2008	Electric Reduction	869	905	36	4.1%	3,706	35	4.0%
	Home Performance	1,101	2,466	279	25.4%	4,285	275	25.0%
	All Projects	1,039	3,371	214	20.6%	7,991	164	15.8%
2010–2011	Electric Reduction	822	1,039	16	1.9%	1,806	15	1.8%
	Home Performance	1,152	1,909	280	24.3%	1,973	276	24.0%
	All Projects	1,036	2,948	187	18.1%	3,779	151	14.6%

[11] For the 2011–2012 evaluation, NYSERDA requested that the natural gas billing model focus on households designated as Home Performance and Combined.

As the summaries in Table 24 show, the "Electric Reduction" projects lower the average project savings by a substantial amount. In PY 2007–2008, the average therms savings for all projects declined from 275 to 164 when "Electric Reduction" projects are included. This explains why the reported savings for PY 2007–2008 were lower, and it should be noted that for just the "Home Performance" projects, the reported savings are similar in both periods.

Perhaps more importantly, the measures installed as part of those "Electric Reduction" projects are those that were shown to have very high RRs, possibly driving up the overall RR in the previous evaluation. To assess the effect of the different study populations accurately would require information on all of the specific projects that were included in the billing analysis for PY 2007–2008, which were not available for this study. In summary, however, it is sufficient to say that the nonequivalent populations underlying the two billing analyses are a substantial factor in the different RRs.

7 Natural Gas Results for NFGDC-Funded Projects

The results of the impact analysis for NFGDC are presented in this section. As noted previously, the populations and results were found to be substantially different from the NYSERDA-funded projects. The same summary tables are provided, though most of the general comments relative to the analysis that were already presented in the results for the NYSERDA have been omitted. The exceptions are primarily those instances where the differences between the two sets of results call for discussion.

Two regression models were also developed for NFGDC: a whole-home model and a measure-specific model. Due to the tight confidence bands, more reliable estimates, and the focus of the program on comprehensive whole-house savings, the Impact Team selected the whole-home model as the source of the RR estimates.

As summarized in Table 25, the whole-home model has very good fit statistics with an R-square value of 0.922. The measure parameters for the energy savings measures are all negative and statistically significant, and the parameter associated with fuel switching is positive and statistically significant.

Table 25. EmPower Natural Gas Whole-Home Regression Model Parameters for NFGDC

Parameter	Estimate	t Value	Pr > |t|	Units
All heating measures	-0.0382	-43.40	<.0001	Therms/HDD
Base measures	-1.1615	-1.27	0.2050	Therms/month
Fuel switching (dryer)	8.1961	2.65	0.0082	Therms/month
Model Fit				
R-square	0. 9218			

As shown in Table 26, the whole-home model results lead to an overall RR of 0.37. As with the results for NYSERDA, the RR of nearly 0.37 for heating measures (primarily envelope measures) is the primary driver of the overall RR. This RR is substantially lower than that of the NYSERDA-funded projects, so it calls for a more detailed examination of the results.

Table 26. EmPower Natural Gas Whole-Home Model Savings for NFGDC

Impact Type	Households in Analysis with Impact	Evaluated Total Savings (MMBtu)	Reported Savings (MMBtu) for Households in Analysis	RR	RR 90% +/- Confidence	NYSERDA Program Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)
Base measures	205	286	277	1.03	N/A	348	359
All heating measures	1,069	21,098	57,796	0.36	N/A	61,994	22,630
Fuel switching (dryer)	16	-157	-227	0.69	N/A	-274	-189
Overall (non-switching measures)	**1,095**	**21,383**	**58,073**	**0.37**	**4.1%**	**62,343**	**22,955**

Table 27 presents the whole-home per participant results. The modeled savings, meaning the annual therms savings based on the regression results, are 42% higher for NFGDC (195 therms for NFGDC, versus the 137 therms for NYSERDA from Table 15). The reported savings for NFGDC-funded projects are nearly 89% higher than NYSERDA, so even though the analysis shows that NFGDC projects result in more therms saved, the reported savings are even higher still, which results in the lower RR.

Table 27. EmPower Natural Gas Whole-Home Model per Participant Savings for NFG

Impact Type	Evaluated Savings (Therms) per Modeled Participant	Evaluated Savings as % of Annual Pre-Consumption	Reported Savings (Therms) per Modeled Participant	Reported Savings as % of Annual Pre- Consumption
Base measures	14	0.9%	14	0.9%
All heating measures	197	13.3%	541	36.4%
Fuel switching (dryer)	-98	-6.6%	-142	-9.6%
Overall (non-switching measures)	**195**	**13.1%**	**530**	**35.7%**

The measure-specific natural gas models shown in Table 28 shows an excellent statistical fit and all parameters except for heating system replacement, DHW, and other measures parameters are of the correct sign and statistically significant.

Table 28. EmPower Natural Gas Measure-Specific Regression Model Parameters for NFGDC

Parameter	Estimate	t Value	Pr > |t|	Units
Envelope measures	-0.0384	-40.95	<.0001	Therms/monthly HDD
Heating system replacement	-0.0307	-8.04	<.0001	Therms/monthly HDD
Heating repair	-0.0015	-0.98	0.3275	Therms/monthly HDD
Domestic hot water measures	-1.2883	-1.39	0.1650	Therms/month
Other measures	-3.7770	-0.98	0.3252	Therms/month
Fuel switching (dryer)	7.4903	2.42	0.0154	Therms/month
Model Fit				
R-square	0. 9223			

The measure-specific NFGDC results have a few differences compared to NYSERDA that are worth discussing. The RR for DHW measures for NFGDC (Table 29) is not nearly as high as that for NYSERDA (Table 17), and though these savings play a small part in the overall RR, the difference is large enough to get one's attention. The reported savings per project are both about 310 therms (Table 29 for NFGDC and Table 18 for NYSERDA), so the difference in RR is clearly something related to the model.

Table 29. EmPower Natural Gas Measure-Specific Model Savings for NFGDC

Impact Type	Households in Analysis with Impact	Evaluated Total Savings (MMBtu)	Reported Savings (MMBtu) for Households in Analysis	RR	RR 90% +/- Confidence	NYSERDA Program Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)
Envelope measures	1,035	20,518	54,708	0.37	N/A	58,611	21,981
Heating system replacement	33	523	878	0.59	N/A	931	554
Other heating measures	244	191	2,210	0.09	N/A	2,452	212
Domestic hot water measures	198	306	218	1.40	N/A	288	404
Other measures	10	45	60	0.76	N/A	61	46
Fuel switching (dryer)	16	-144	-227	0.63	N/A	-274	-173
Overall (non-switching measures)	**1,095**	**21,583**	**58,073**	**0.37**	**4.5%**	**62,343**	**23,169**

Table 30. EmPower Natural Gas Measure-Specific Model per Participant Savings for NFGDC

Impact Type	Evaluated Savings (Therms) per Modeled Participant	Evaluated Savings as % of Annual Pre-Consumption	Reported Savings (Therms) per Modeled Participant	Reported Savings as % of Annual Pre-Consumption
Envelope measures	198	13.3%	529	35.5%
Heating system replacement	158	10.0%	266	16.8%
Other heating measures	8	0.5%	91	6.0%
Domestic hot water measures	15	1.0%	11	0.7%
Other measures	45	2.8%	60	3.7%
Fuel switching (dryer)	-90	-6.0%	-142	-9.6%
Overall (non-switching measures)	**197**	**13.3%**	**530**	**35.7%**

Finally, because NFGDC had limited activity in PY 2007–2008 and contributed no accounts to the billing analysis for those program years, the results of this analysis are not directly comparable to those from the previous study. Consequently, there is no need to include any explanation of the differences in the RRs.

8 CONCLUSIONS AND RECOMMENDATIONS

The billing analysis conducted for this evaluation produced reliable estimates of energy savings for PY 2010–2011 EmPower participants. The regression models generated consistent and statistically significant parameter estimates for program savings for the whole-home models.

As the first recommendation, the Impact Team recommends the application of the whole-home RRs to adjust program savings. The evaluated RR is 0.97 for the electric savings. For natural gas savings, the RR is 0.49 for NYSERDA-funded projects and 0.37 for NFGDC-funded projects. Furthermore, although other fuels were not evaluated, the Impact Team recommends applying the natural gas RR to other fuel reported savings. Other fuel savings are estimated with the same algorithms and tools as natural gas savings and the measures are largely the same (insulation and air sealing), therefore the RR are expected to be similar.

The RRs for both the NYSERDA and NFGDC natural gas models were low, and lower than the previous evaluation. The Phase II evaluation of the EmPower program will undertake an engineering review of the algorithms used to develop the reported savings and examine site conditions at a large number of homes. The engineering review will incorporate all EmPower measures, but it will prioritize those measures with large program importance and/or with low evaluated RRs. The Phase II evaluation will also investigate the tracking data to determine if there are any systematic issues with reported savings that can be easily resolved. Because Phase II is underway, there are no further recommendations for additional analysis to investigate sources of the low realization rates.

One final issue to conclude this report is the selection of an appropriate RR to apply to PY 2009, which was not included in this or the previous billing analysis.

For the electric savings, a straightforward approach is to first compare the program years in terms of customer and project characteristics. To this end, Table 31 shows the average annual kWh consumption and average project savings for the three periods. The averages for 2009 lie roughly in the middle, though they are closer to 2007–2008, which would support using a blended rate of the two evaluations. Rather than attempt some sophisticated weighting that would lend a false sense of rigor, a straight average of 0.76 for 2009 projects is recommended.

Table 31. EmPower Comparison of Average Annual kWh Consumption and Project Reported kWh Savings by Program Year

Program Year	Mean Annual kWh Consumption	Mean kWh Reported Savings	Percent Savings
2007–2008	6,246	1,182	18.9%
2009	7,371	1,215	16.5%
2010–2011	9,170	1,291	14.1%

For NYSERDA natural gas savings, as shown in Table 32, the metrics are more mixed. In PY 2007–2008, the "Electric Reduction" projects represented more than 9% of total therms savings for the NYSERDA utilities. In 2009, this share had fallen to 5.3%, which is much closer to the 4.3% share for PY 2010–2011. These “Electric Reduction” projects were associated with measures that had very high RRs, possibly inflating the overall result and the usage is also more similar to the PY 2010-2011 population. However, the PY 2009 average savings is lower than either, indicating a possible better realization rate. Similar to the logic applied to the PY 2009 electric RR, rather than apply a complicated weighting scheme which might falsely imply a high level of rigor, the Impact Team recommends averaging the RR of the two bookend evaluations.

Table 32. EmPower Comparison of Metrics by Program Year

Program Year	Percentage of ER projects	Mean Consumption (therms)	Mean Reported Savings (therms)	NYSERDA RR
2007–2008	9%	779	282	0.70
2009	5.3%	1106	248	0.60, recommended
2010–2011	4.5%	1159	281	0.49

For the NFGDC natural gas savings, there is no appropriate RR for NFGDC’s PY 2007–2008 projects, as there were no NFGDC projects in the analysis and the projects were clearly distinct from NYSERDA. Consequently, the only option is to use NFGDC’s RR of 0.37 for 2009 projects.

The second recommendation addresses the appropriate RR for the PY 2009 projects. The Impact Evaluation Team recommends apply a rate of 0.76 for electric measures, 0.37 for NFGDC funded natural gas measures, and 0.60 for NYSERDA funded natural gas measures.

APPENDIX C: EMPCALC ALGORITHM REVIEW AND COMPARISON WITH NYTM METHODOLOGY

The following document includes side-by-side comparisons of the savings estimation methodologies and corresponding algorithms found within the following two documents:

- EmPCalc Tool – Version 4.0.5
- New York Technical Manual (NYTM) – Revision Date: 10/15/2010

Each EmPower measure is detailed in its own sub-section. Additionally, review of the EmPCalc Tool version 4.0.5 and the NYTM resulted in the identification of multiple noteworthy observations and differences between the two calculation methodologies as shown in Table C-1.

Table C-1. Summary of Noteworthy EmPCalc Observations

Measure	Observations
Lighting	• EmPower contractors are allowed to install up to 16 CFLs per household, but the EmPCalc Tool allows the user to calculate savings for up to 20 CFLs. • The EmPCalc Tool does not give an error if the user neglects to enter in the post-case wattage, it simply calculates the savings with zero post-case wattage. • 7,500-hour measure life is listed on pg. 22 of EmPCalc Narrative 1/11/11, while 10,000 hours is listed as the measure life on pg. 5 of the same document. • The tool does not give an error if the user neglects to enter in the post-case wattage; rather, it simply calculates the savings with zero post-case wattage.
Insulation	• The EmPCalc Tool does not account for AC energy savings. • The EmPCalc Tool savings do not change when you toggle between “use default efficiency” and “use measured efficiency.” Instead, the actual heating system efficiency must be entered on the cover page in order for the savings to be calculated. • The EmPCalc Tool assumes a post-installation R-value of 16.58 for the wall insulation measure regardless of the proposed insulation type or thickness entered. • Although the proposed wall R-value is held constant, the existing wall R-value is calculated based on the existing insulation parameters entered by the user, thereby making it possible for the wall insulation impact to be negative. • The EmPCalc Tool allows users to select the quality of existing insulation. The EmPCalc Tool defines the three quality options and the corresponding impact on the existing insulation R-value. However, the defined R-value de-rating only applies if fiberglass batts are selected as the existing insulation type.
Air sealing	• The EmPCalc Tool does not calculate demand reduction, even if electric heat is selected. • The EmPCalc Tool does not account for AC energy savings. • Must complete the “Heating Systems” tab in the EmPCalc Tool in order for all formulas to work correctly.
Showerheads and aerators	• The EmPCalc Tool does not adjust energy savings for quantity entered, but it does increase cost accordingly.
DHW heater replacement	• The 2011 EmPower New York EmPCalc Energy and Cost Savings Calculations narrative indicates that this measure includes replacing an existing electric hot water heater with one that uses a different fuel. However, in the EmPCalc Tool the user is able to select multiple fuel types for the existing hot water heater, including a pre- and post-installation unit that both consume the same fuel type (electric, natural gas, oil, etc.). • The NYTM algorithm cannot capture savings associated with fuel switching; it only calculates savings associated with improving the efficiency of the DHW unit (electric or natural gas). • The NYTM algorithm calculates therms savings only for indirect hot water heaters, not kWh savings.
DHW heater tank wrap	• EmPCalc energy savings units dependent upon “existing DHW fuel” selected at top of page (DHW replacement, tank wrap, and pipe wrap are all included on same xls tab). This will return false savings if the heater was replaced and the new tank was wrapped.
Heating systems – programmable thermostats	• In the EmPCalc Tool, the quantity of programmable thermostats installed is entered manually but does not impact energy savings. In the NYTM algorithm, the quantity of programmable thermostats is also entered manually and does impact the energy savings.

APPENDIX CONTENTS

MEASURE 1: LIGHTING

Lighting upgrades are completed at nearly all of the homes that participate in the EmPower program. Table 1-1 summarizes key parameters and assumptions for three lighting savings calculation methods. The calculation methodologies are discussed in this section.

Table 1-1. Lighting Measure Algorithm Comparison

	EmPower – EmPCalc	**NYTM**
Qualifying technologies	Specialty CFLs, hard-wired CFLS, torchieres	CFL screw-in and hard-wired
Method	Deemed value for most estimates. Product of the observed wattage difference and deemed hours of operation for hard-wired.	Product of the observed wattage difference and deemed hours of operation
Wattage reduction	CFL: 46 watt/lamp Hard-wired: pre- to post- wattage	Pre- to post- wattage Where unavailable, use a 2.53 multiplier for an incandescent baseline and a 1.55 multiplier for a halogen baseline
Average hours	CFL: 3.2 hr for 1 lamp to 1 hr for 10+ lamps. Hard-wired: 4	CFL: 3.2 Hard-wired: 2.5
Other	Torchiere: 325 kWh each Candelabra: 42.2 kWh each	N/A
Demand coincidence factors	Not included in estimate	Summer: 0.08 Winter: 0.30
Cooling bonus	Not included in estimate	Varies between 0.068 and 0.101 regionally for fan coil units connected to a chiller
Heating penalty	Not included in estimate	Varies between -0.023 and -0.029 regionally and by steam vs. hot water boiler
Measure life	7,500 hours or about 6 years	Measure life not provided

1.1 MEASURE DESCRIPTION

The EmPower program offers lighting upgrades for both interior and exterior fixtures. The savings that result from EmPower lighting upgrades are divided in the tracking database into two categories, CFLs and hard-wired fixtures. However, the EmPCalc Tool further distinguishes the lighting upgrades into the following four categories: CFL screw-in, candelabra, and torchiere and hard-wired fixtures (which also includes CFLs). According to tracking data spanning from August 2004 to January 2013, 90% of homes received CFL installations and 11% of homes received hard-wired fixtures installations through the Program.

1.2 EMPCALC SAVINGS ESTIMATION APPROACH

The EmPCalc Tool uses a slightly different calculation to determine the energy savings for each of the four lighting categories. These calculations are presented in this section.

1.2.1 Compact Fluorescent Lamps

$$Annual\ kWh\ savings = Qty \times \Delta W \times Hours \times 365\ days \times \frac{1kWh}{1{,}000W}$$

where,

Qty = Quantity of CFLs installed

ΔW = Wattage reduction from lamp replacement = 46 W/lamp

$Hours$ = Daily fixture operating hours, which decrease as the number of upgraded fixtures increases, according to Table 1-2:

Table 1-2. EmPCalc CFL Daily Operating Hours Assumptions

Number of Lamps	Daily Operating Hours
1 – 2	3.2
3 – 5	3.0
6 – 7	2.5
8 – 9	1.5
10 +	1.0

Note that the fixture location is not considered in the CFL daily operating hours assumptions. However, according to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* document, contractors are instructed to install the CLFs in the most frequently used lights. Additionally, EmPower contractors are allowed to install up to 16 CFLs per household, but the EmPCalc Tool allows the user to calculate savings for up to 20 CFLs.

1.2.2 Halogen Torchiere Replacements

$$Annual\ kWh\ savings = Qty \times 325\ \text{kWh}$$

where,

Qty = Quantity of torchieres replaced

It is clear from the equation above that the torchiere location, baseline wattage, or post-case wattage is not used in savings calculations. Torchieres provide about six times the savings as a typical screw-in CFL, according to EmPCalc.

1.2.3 Hard-Wired Fixtures

$$Annual\ kWh\ savings = Qty \times (W_{Baseline} - W_{Post-Case}) \times Hours \times 365\ days \times \frac{1kWh}{1{,}000W}$$

where,

Qty	= Quantity of hard-wired fixtures replaced
$W_{Baseline}$	= Baseline fixture wattage
$W_{Post-case}$	= Post-Case fixture wattage
$Hours$	= Daily fixture operating hours = 4

The NYSERDA tracking database does not contain any of the factors in the equation but it does identify the number of units that were installed and the savings associated with each.

1.2.4 Candelabra Compact Fluorescent Lamps

Although candelabra CFL upgrades are not discussed in the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* document, they are an option in the EmPCalc Tool.

$$Annual\ kWh\ savings = Qty \times 42.2\ \text{kWh}$$

where,

Qty = Quantity of torchieres replaced

Similar to the torchiere replacement calculation, the candelabra CFL calculation does not account for fixture location, baseline wattage, or post-case wattage.

1.2.5 Demand Reduction

The EmPCalc Tool does not account for peak kW savings, only annual kWh savings. The 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* document stipulates an average wattage reduction of 46 W per CFL, but it does not stipulate whether it is assumed that this wattage reduction is coincident with peak, nor does it present assumed wattage reductions for other lamp types.

1.2.6 Heating penalty and Cooling Bonus

The EmPCalc Tool does not calculate the interactive HVAC impacts that result from the lighting upgrades.

1.2.7 Life of Measure

The EmPCalc Tool does not calculate the measure life savings. However, the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* document includes two measure life numbers. The average life of the CFL is listed as 10,000 operating hours in Table 5 on page 5, and 7,500 operating hours is listed on page 22.

1.3 NYTM SAVINGS ESTIMATION APPROACH

The 2013 revision of the 2010 NYTM presents a savings calculation applicable to all residential lighting upgrades excluding outdoor and common-area applications, which tend to have longer run times. This calculation is presented in this section.

1.3.1 Compact Fluorescent Lamps

$$Annual\ kWh\ savings = Qty \times \Delta\, watts \times Hours \times 365\ days \times \frac{1kWh}{1{,}000W} \times (1 + HVAC_C)$$

where,

Qty	= Quantity of CFLs installed
$\Delta\, watts$	= Wattage reduction from lamp replacement
$Hours$	= Daily fixture operating hours = 3.2 for screw-in CFLs and 2.5 for pin-based CFLs
$HVAC_C$	= Cooling bonus coefficient for electric savings, which varies according to location and cooling type as seen in Table 1-4 in Section 1.3.3

Wattage

When the actual pre- and post- wattage is not available, the baseline is calculated assuming a lumen equivalent preexisting lamp. When CFL wattages *are* known, it is permitted to use this data (per the *7-31-13 Record of Revision*).

An incandescent baseline assumes that the wattage is 3.53 times higher than the wattage of the equivalent CFL bulb. For dimmable or three-way CFL bulbs, the highest wattage/setting is selected when calculating the baseline equivalent.

$$Watts_{Incandescent} = 3.53 \times Watts_{CFL}$$

$$\Delta\, watts_{Incandescent\ to\ CFL} = 2.53 \times Watts_{CFL}$$

Similarly, a halogen baseline assumes that the wattage is 2.55 times higher than the wattage of the equivalent CFL bulb. For dimmable or three-way CFL bulbs, the highest wattage/setting is selected when calculating the baseline equivalent.

$$Watts_{Halogen} = 2.55 \times Watts_{CFL}$$

$$\Delta\, watts_{Halogen\ to\ CFL} = 1.55 \times Watts_{CFL}$$

1.3.2 Demand Reduction

The NYTM includes the following algorithm for calculating demand savings associated with residential lighting projects:

$$Demand\ savings = Qty \times \Delta\ watts \times Coincidence\ factor \times (1 + HVAC_d)$$

where,

Qty	= Quantity of CFLs installed
$\Delta\ watts$	= Wattage reduction from lamp replacement
$Coincidence\ factor$	= Percent of time that the upgraded fixture is operating coincident with the peak demand period
$HVAC_d$	= Cooling bonus coefficient for demand savings, which varies according to location and cooling type as seen in Table 1-5 in Section 1.3.3

Coincidence factors for summer and winter on-peak hours are included in the NYTM as shown in Tables 1-3 and 1-4.

Table 1-3. NYTM Summer Peak Coincidence Factors

Lighting Summer On-Peak Hours (1 p.m. – 5 p.m.)	Coincidence Factor
June	0.07
July	0.09
August	0.09
Average summer	**0.08**

Table 1-4. NYTM Winter Peak Coincidence Factors

Lighting Winter On-Peak Hours (5 p.m. – 7 p.m.)	Coincidence Factor
December	0.28
January	0.32
Average winter	**0.30**

1.3.3 Heating Penalty and Cooling Bonus

The NYTM accounts for interactive HVAC impacts that result from lighting upgrades. The details of the interactive calculations are presented in this section.

Cooling Bonus

The cooling bonus is incorporated into the annual energy savings algorithm presented in Section 1.3.1, as well as the demand savings algorithm presented in Section 1.3.2. The NYTM does not account for the penetration of cooling amongst installations, so the user would have to use his/her judgment to determine the applicability of a cooling bonus. The cooling bonus coefficients are presented in Table 1-5.

Table 1-5. NYTM HVAC Coefficients

HVAC Interactive Effects Multipliers for Single Family Residential

	AC with gas heat			Heat Pump			AC with electric heat			Electric heat only			Gas heat only		
	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg
Albany	0.043	0.073	-0.026	-0.214	0.119	0.000	-0.575	0.073	0.000	-0.521	0.000	0.000	0.000	0.000	-0.026
Binghamton	0.034	0.182	-0.014	-0.148	0.169	0.000	-0.603	0.182	0.000	-0.313	0.000	0.000	0.000	0.000	-0.014
Buffalo	0.040	0.171	-0.027	-0.230	0.190	0.000	-0.655	0.171	0.000	-0.551	0.000	0.000	0.000	0.000	-0.027
Massena	0.034	0.112	-0.029	-0.298	0.131	0.000	-0.489	0.112	0.000	-0.607	0.000	0.000	0.000	0.000	-0.029
NYC	0.077	0.085	-0.023	-0.105	0.111	0.000	-0.579	0.085	0.000	-0.403	0.000	0.000	0.000	0.000	-0.023
Poughkeepsie	0.060	0.079	-0.025	-0.160	0.115	0.000	-0.577	0.079	0.000	-0.462	0.000	0.000	0.000	0.000	-0.025
Syracuse	0.045	0.095	-0.019	-0.157	0.119	0.000	-0.615	0.095	0.000	-0.382	0.000	0.000	0.000	0.000	-0.019

HVAC Interactive Effects Multipliers for Multifamily Low-rise

	AC with gas heat			Heat Pump			AC with electric heat			Electric heat only			Gas heat only		
City	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg	HVACc	HVACd	HVACg
Albany	0.020	0.128	-0.017	-0.140	0.150	0.000	-0.329	0.128	0.000	-0.363	0.000	0.000	-0.014	0.000	-0.017
Binghamton	0.003	0.137	-0.018	-0.178	0.151	0.000	-0.384	0.137	0.000	-0.407	0.000	0.000	-0.020	0.000	-0.018
Buffalo	0.014	0.142	-0.017	-0.143	0.157	0.000	-0.332	0.142	0.000	-0.359	0.000	0.000	-0.014	0.000	-0.017
Massena	0.015	0.158	-0.018	-0.161	0.181	0.000	-0.349	0.158	0.000	-0.377	0.000	0.000	-0.013	0.000	-0.018
NYC	0.055	0.136	-0.016	-0.064	0.163	0.000	-0.260	0.136	0.000	-0.320	0.000	0.000	-0.005	0.000	-0.016
Poughkeepsie	0.038	0.132	-0.017	-0.102	0.157	0.000	-0.295	0.132	0.000	-0.342	0.000	0.000	-0.010	0.000	-0.017
Syracuse	0.017	0.140	-0.018	-0.160	0.150	0.000	-0.361	0.140	0.000	-0.391	0.000	0.000	-0.013	0.000	-0.018

Heating Penalty

The NYTM includes the following equation for calculating the natural gas impacts that result from the lighting upgrade.

$$Therm\ impacts = Annual\ kWh\ savings \times HVAC_g$$

where,

$HVAC_g$ = Heating penalty coefficient, which varies according to location as seen in Table 1-4 above

1.3.4 Life of Measure

Life cycle energy savings are not addressed in the NYTM.

MEASURE 2: AIR SEALING

The NYTM and EmPCalc Tool each have drastically different methodologies for calculating energy and demand savings that result from air sealing. Table 2-1 summarizes the key parameters and assumptions for three air sealing savings calculation methods. The calculation methodologies are discussed in this section.

Table 2-1. Air Sealing Measure Algorithm Comparison

	EmPower – EmPCalc	**NYTM**
Qualifying technologies	Method of air sealing not specified – field provided in tool to enter description.	Method of air sealing not specified.
Method	Savings are the product of the change in the blower door cfm, deemed savings/cfm, 1/eff. One of 55 deemed savings/cfm selected by number of stories, building exposure, and HDD.	Savings are the product of the change in blower door cfm (corrected to normal conditions via n-factor) and a deemed savings/cfm by region and a deemed efficiency.
Fuel type	Must select one of the following options: Electric, natural gas, fuel oil, propane, kerosene, soft wood, hard wood, wood pellets, coal	Not addressed, though assumed to cover electric and natural gas – electric energy/demand savings calculated for cooling period, therm savings calculated for heating period
HDD/Region	Must select one of the following options: North Country, Central, Finger Lakes, Capital/Saratoga, Mid-Hudson, Western, Southern Tier, NY City	Variables that correspond with each of the following cities are found in the appendix: Albany, Buffalo, Messina, NYC, Syracuse, Binghamton, Poughkeepsie
Number of stories	Must select one of the following options: 1, 1.5, 2, 3	Two-story home is assumed
Exposure	Must select one of the following options: Shielded, normal, exposed	Not addressed
Cooling savings	Cooling savings not calculated in EmPCalc Tool	Summer peak demand and cooling energy savings calculated using default EER and SEER values. Methods provided for calculating with and without site-specific blower door test data.
Heating savings	Peak demand savings not calculated. Must have blower door test data available (cfm @ 50 Pa before and after measure installation) in order to calculate savings.	Methods provided for calculating with and without site-specific blower door test data.
Measure life	15 years	Measure life not provided

2.1 MEASURE DESCRIPTION

This measure includes the sealing of air leaks in the building envelope, which reduces the amount of air that passes between the inside of the building and the outside environment. This results in less air escaping the building, and therefore less heating and cooling energy that is required to condition the interior space. According to tracking data spanning from August 2004 to January 2013, 23% of homes received air sealing through the Program.

2.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

2.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool calculates heating energy savings in units that correspond with the heat source selected by the user. Cooling energy savings are not calculated.

Energy savings are calculated in Btu, which are then converted to the appropriate fuel units depending upon the fuel source selected (therms, gallons, face cords, tons). The heating efficiency entered in the tool is also used in this conversion, although the heating efficiency that should be entered is not defined (AFUE, thermal efficiency, etc.).

Savings calculations require a blower door test, where the infiltration rate at 50 Pa is measured before and after the air sealing measure is completed. These pre- and post-installation infiltration rates are required to calculate energy savings using the EmPCalc Tool. Only heating energy savings are calculated; cooling energy savings are not addressed in the EmPCalc Tool. The annual heating energy savings are calculated as follows:

$$Energy\ savings\ =\ \mathrm{n}_{\,factor} \times \left(\frac{\mathrm{CFM50}_{Pre} - \mathrm{CFM50}_{Post}}{100}\right) \times Conv\ \times Eff$$

where,

$Energy\ savings$	= Heating energy savings resulting from air sealing – units used are dependent upon the fuel source selected by the user
$\mathrm{n}_{\,factor}$	= Therms saved per 100cfm50
$\mathrm{CFM50}_{Pre}$	= Infiltration rate (cfm) at 50 Pa, provided by contractor **before** completion of air sealing measure
$\mathrm{CFM50}_{Post}$	= Infiltration rate (cfm) at 50 Pa, provided by contractor **after** completion of air sealing measure
$C\mathrm{onv}$	= Conversion factor to site-specific heating fuel type
Eff	= Heating system efficiency (entered manually, or 74% used as a default)

The n-factor is dependent upon the following EmPCalc inputs:

- Exposure of the building
- Number of stories of the building
- Geographic location of the building

First, an n-factor is selected based on the exposure of the building and the number of stories found within that building, as is summarized in Table 2-2.

Table 2-2. Therms Saved per 100CFM50 (n-factor)

Exposure Type	Number of Stories			
	1	1.5	2	3
Shielded	22.2	20	17.8	15.5
Normal	18.5	16.7	14.8	13
Exposed	16.7	15	13.3	11.7

The n-factors shown in Table 2-2 are then adjusted based on the heating degree days (HDD) for the location selected (n-factors decrease for areas with fewer HDD). These adjusted n-factors and corresponding HDD are summarized in Table 2-3.

Table 2-3. Adjustments Made to n-factor Based On Geographic Location/Heating Degree Days

	Location							
	North Country	Central	Finger Lakes	Capital/Saratoga	Mid-Hudson	Western	Southern Tier	NY City
Heating Degree Days	8089	6803	6728	6438	7237	6692	6806	4777
Un-adjusted n-factor	Adjusted n-factor							
11.7	10.6	9.4	9.3	9.5	9.7	9.20	9.4	6.5
13	9.6	8.4	8.3	8.5	9	8.20	8.4	6.2
13.3	9.4	8.8	8.7	8.9	8.8	8.60	8.8	5.8
14.8	8.2	7.5	7.4	7.6	7.7	7.30	7.5	5.4
15	8.4	7.3	7.2	7.4	7.6	7.10	7.3	5.1
15.5	8.1	7.1	7	7.2	7.2	6.90	7.1	5
16.7	7.4	6.6	6.5	6.7	6.8	6.40	6.6	4.6
17.8	7.1	6.4	6.3	6.5	6.6	6.20	6.4	4.3
18.5	6.7	5.9	5.8	6	6.1	5.70	5.9	4.2
20	6.3	5.6	5.5	5.7	5.8	5.4	5.6	3.8
22.2	5.5	5	4.9	5.1	5.2	4.8	5	3.4

2.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction, even if electric heat is selected.

2.2.3 Life of Measure

The EmPCalc Tool uses a measure life of 15 years. However, the life cycle energy savings are not calculated in the EmPCalc Tool nor are they addressed in the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative.

2.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section.

2.3.1 Heating and Cooling Energy Savings

The NYTM provides two annual energy savings calculation methodologies for this measure: one that requires a blower door test be performed and a second that is to be used if a blower door test is not possible.

Methodology For Calculating Energy Savings Using A Blower Door Test

The method for calculating both cooling and heating energy savings based on a blower door test is presented below.

Cooling:

$$\Delta kWh = \Delta CFM_{50} \,/\, n_{factor} \times (\Delta kWh/CFM) \times \left(\frac{SEER_{Base}}{SEER_{Part}}\right) \times \left(\frac{\eta_{Dist,base}}{\eta_{Dist,part}}\right)_{Cool}$$

Heating (electric and natural gas only):

$$\Delta therm = \Delta CFM_{50} \,/\, n_{factor} \times (\Delta therm/CFM) \times \left(\frac{AFUE_{Base}}{AFUE_{Part}}\right) \times \left(\frac{\eta_{Dist,base}}{\eta_{Dist,part}}\right)_{Heat}$$

where,

ΔkWh	= Gross annual energy savings
ΔCFM_{50}	= Change in infiltration rate (cfm) at measured 50 Pa
n_{factor}	= Correction from CFM_{50} to natural infiltration rate
$\Delta kWh/CFM$	= Electricity consumption savings per cfm of infiltration reduction
$\Delta therm/CFM$	= Natural gas consumption savings per cfm of infiltration reduction
$SEER_{Base}$	= SEER used in the simulations
$SEER_{Part}$	= SEER of cooling system within participant population
$AFUE_{Base}$	= AFUE used in the simulations
$AFUE_{Part}$	= AFUE of heating system within participant population
$\eta_{Dist,base}$	= Distribution system seasonal efficiency used in simulations
$\eta_{Dist,part}$	= Distribution system seasonal efficiency within participant

Table 2-4, found in the NYTM, includes an explanation of the sources behind the variables used in the NYTM algorithm. In some instances the value to be used is also provided.

Table 2-4. Summary of Variables and Data Sources – from the New York Technical Manual

Summary of Variables and Data Sources

Variable	Value	Notes
Floor area		From application
ΔkWh/CFM		From prototype simulations. HVAC type weighted average by city. Use actual CFM_{50} reduction from blower door test.
ΔkW/CFM		From prototype simulations. HVAC type weighted average by city. Use actual CFM_{50} reduction from blower door test.
Δtherm/CFM		From prototype simulations. HVAC type weighted average by city. Use actual CFM_{50} reduction from blower door test.
n-factor	15	2 story home with normal wind exposure in NY climate
ΔkWh/1000 SF		From prototype simulations. Vintage and HVAC type weighted average by city.
ΔkW/1000 SF		From prototype simulations. Vintage and HVAC type weighted average by city.
Δtherm/1000 SF		From prototype simulations. Vintage and HVAC type weighted average by city.
EER_{base}	11.1	
EER_{part}		Participant population average. Defaults to EER_{base} (no adjustment)
$SEER_{base}$	13	
$SEER_{part}$		Participant population average. Defaults to $SEER_{base}$ (no adjustment)
$AFUE_{base}$	78%	
$AFUE_{part}$		Participant population average. Defaults to $AFUE_{base}$ (no adjustment)
$\overline{\eta}_{dist,base}$	0.956	
$\overline{\eta}_{dist,part}$		Participant population average. Defaults to $\overline{\eta}_{dist,base}$ (no adjustment)
$\eta_{dist,pk,base}$	0.956	
$\eta_{dist,pk,part}$		Participant population average. Defaults to $\eta_{dist,pk,base}$ (no adjustment)
CF_s	0.8	

Table 2-5 includes default energy savings resulting from a reduction in infiltration rates found in Appendix E of the NYTM. These values correspond with the "ΔkWh/cfm" variable.

Table 2-5. Single Family Residential Infiltration Reduction

City	AC and Natural Gas Heat			Heat Pump		AC Electric Heat	
	kWh/cfm	kW/cfm	Therm/cfm	kWh/cfm	kW/cfm	kWh/cfm	kW/cfm
Albany	1.8	0.006	2.2	34.0	0.002	50.8	0.006
Buffalo	1.6	0.004	2.4	38.8	0.005	55.6	0.004
Messina	1.5	0.001	2.7	46.4	0.001	63.0	0.001
NYC	2.3	0.004	1.7	21.0	0.003	39.8	0.004
Syracuse	1.8	0.003	2.4	37.3	0.003	55.1	0.003
Binghamton	1.3	0.004	2.2	35.0	0.002	49.8	0.004
Poughkeepsie	1.9	0.004	1.9	24.8	0.003	43.5	0.004

City	Natural Gas Heat Only			Electric Heat Only	
	kWh/cfm	kW/cfm	Therm/cfm	kWh/cfm	kW/cfm
Albany	1.1	0.000	2.2	50.1	0.000
Buffalo	1.3	0.000	2.4	55.2	0.000
Messina	1.4	0.000	2.7	62.8	0.000
NYC	0.8	0.000	1.7	38.4	0.000
Syracuse	1.2	0.000	2.4	54.6	0.000
Binghamton	1.1	0.000	2.2	49.5	0.000
Poughkeepsie	1.0	0.000	1.9	42.7	0.000

Methodology For Calculating Energy Savings Without Completing Blower Door Test

The method for calculating both cooling and heating energy savings *without* blower door test is presented below.

Cooling:

$$\Delta kWh = Floor\ area\ \times (\Delta kWh/1000\ SF)$$

Heating:

$$\Delta therm = Floor\ area\ \times (\Delta therm/1000\ SF)$$

where,

ΔkWh = Gross annual energy savings

Floor area = Conditioned floor area

$\Delta kWh/1000\ SF$ = Electricity consumption savings per 1000 SF of conditioned floor area

$\Delta therm/1000\ SF$ = Natural gas consumption impact per 1000 square foot of conditioned floor area

Because site-specific infiltration rates are not available using this methodology, assumed savings per square foot are used. These values are dependent upon the geographic location of the site and the age of the building, and are summarized in Table 2-6.

Table 2-6. Assumed Savings per 1,000 Square Feet

City	Vintage	kWh/ 1000 SF	kW/ 1000 SF	Therm/ 1000 SF
Albany	Old	73	0.128	30
Albany	Average	22	0.099	16
Binghamton	Old	64	0.116	33
Binghamton	Average	11	0.085	17
Buffalo	Old	68	0.101	34
Buffalo	Average	20	0.079	19
Massena	Old	66	0.127	30
Massena	Average	20	0.098	17
NYC	Old	118	0.119	29
NYC	Average	56	0.098	17
Syracuse	Old	73	0.195	29
Syracuse	Average	23	0.092	16

2.3.2 Demand Reduction

The NYTM provides two demand savings calculation methodologies based on whether a blower door test can be performed or not. The method for calculating the summer peak demand savings that result from a reduced cooling load based on blower door test is presented below.

$$\Delta kW = CFM_{50} / n_{factor} \times (\Delta kW/CFM) \times CF \times \left(\frac{EER_{Base}}{EER_{Part}}\right) \times \left(\frac{\eta_{Dist,pk,base}}{\eta_{Dist,pk,part}}\right)_{cool}$$

where,

ΔkW = Gross coincident demand savings

CFM_{50} = Change in infiltration rate (cfm) at measured 50 Pa

n_{factor} = Correction from CFM_{50} to natural infiltration rate

$\Delta kW/CFM$ = Electricity demand savings per cfm of infiltration reduction

CF = Coincidence factor = 0.8 (combined with DF)

EER_{Base} = EER used in the simulations

EER_{Part} = EER of cooling systems within participant population

$\eta_{dist,pk,base}$ = Distribution system efficiency under peak conditions used in simulation

$\eta_{dist,pk,part}$ = Distribution system efficiency under peak conditions within participant population

The method for calculating the summer peak demand savings *without* a blower door test is presented below.

$$\Delta kW = Floor\ area\ \times (\Delta kW /\ 1000\ SF)\ \times DF \times\ CF$$

where,

ΔkW = Gross coincident demand savings

$Floor\ area$ = Conditioned floor area

$\Delta kW /\ 1000\ SF$ = Electricity demand savings per 1000 SF of conditioned floor area

DF = Demand diversity factor

CF = Coincidence factor = 0.8

A definition or recommended value for the demand diversity factor (DF) is not provided in the NYTM.

If a blower door test is not completed, the default values for "ΔkW/1000 SF" should be used, which can be found in Table 2-6 above.

2.3.3 Life of Measure

The measure life or life cycle energy savings for this measure are not provided in the NYTM.

MEASURE 3: INSULATION

Table 3-1 summarizes key parameters and assumptions for the insulation savings calculation methodologies found in the EmPCalc Tool and the NYTM. These calculation methodologies are discussed in this section.

Table 3-1. Insulation Measure Algorithm Comparison

	EmPower – EmPCalc	**NYTM**
Area	Must select one of the following options: Attic–floored, attic–open, wall, kneewall, crawlspace, rim joist, slopes Must also enter area of space being insulated, in square feet.	Area, in square feet, must be provided on the application and is used in the NYTM savings algorithm.
Method	U×A×ΔT EmPCalc Tool: U×A×HDD×hrs/day	Deemed savings per sq ft based on building modeling
Qualifying insulation	Must select one of the following options: cellulose, dense pack, fiberglass, foam board, two-part foam Must also enter thickness of insulation (in inches), selecting one of the following options: 1”, 2”, 3.5”, 6”, 8”, 10”, 12” 14”	Table in appendix provides assumed yearly energy savings for baseline/proposed insulation scenarios. Baseline and proposed insulation R-values cannot be the same. Proposed wall insulation R-value options: 11, 13, 17, 19, 21, 25, 27 Proposed roof insulation R-values: 11, 19, 30, 38, 49, 60
Existing insulation	Must select one of the following options: Fiberglass – batts, fiberglass – blown, fiberglass – rigid board, cellulose – loose fill, cellulose – dense pack, cellulose – spray-on, mineral wool – batts, mineral wool – loose fill, mineral wool – rigid board, vermiculite, perlite, polyisocyanurate, polyurethane, polystyrene – expanded, polystyrene – extruded, none Must enter thickness of insulation (in inches), which is entered manually. Must also enter the “insulation rating” for the existing insulation, selecting one of the following options: Good, fair, poor	Table in appendix provides assumed yearly energy savings for baseline/proposed insulation scenarios. Baseline and proposed insulation R-values cannot be the same. Baseline wall insulation R-value options: 11, 13, 17, 19, 21, 25, 27 Baseline roof insulation R-value options: 11, 19, 30, 38, 49, 60
Fuel type	Must select one of the following options: Electric, natural gas, fuel oil, propane, kerosene, soft wood, hard wood, wood pellets, coal	Table in appendix provides assumed yearly energy savings for each of the following heating/cooling systems: AC with natural gas heat, natural gas heat with no AC, AC with electric heat, electric heat with no AC, heat pump
Region	Must select one of the following options: North Country, Central, Finger Lakes, Capital/Saratoga, Mid-Hudson, Western, Southern Tier, NY City	Variables that correspond with each of the following cities are found in the appendix: Albany, Buffalo, Messina, NYC, Syracuse, Binghamton, Poughkeepsie
Cooling savings	Cooling savings not calculated in EmPCalc Tool	Summer peak demand and cooling energy savings calculated using default EER and SEER values.
Heating savings	Peak demand savings not calculated. Must enter heating efficiency on cover tab.	Heating energy savings calculated using default AFUE values.
Measure life	30 years	Measure life not provided

3.1 MEASURE DESCRIPTION

The EmPower program offers an insulation measure, which includes the installation of insulation in attics, walls, and other locations. This results in a reduction of heat loss through the building envelope, therefore reducing the amount of fuel required to heat the building. According to tracking data spanning from August 2004 to January 2013, 22% of homes received insulation through the Program.

3.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

3.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool calculates the baseline heat load for the area being reinsulated based on square footage and the existing insulation type, thickness, and quality, and takes into account the efficiency of the heating system as input by the user. The EmPCalc Tool then calculates the post-case heat load for the area being reinsulated based on the proposed insulation type and thickness, and assumes the same square footage and heating system efficiency. The difference between these two calculations, presented in Btu, is the heating energy savings for this measure.

The exception to this method includes the calculation approach for wall insulation. The tool assumes a post-installation R-value of 16.58 regardless of the proposed insulation type or thickness entered.

Cooling energy savings are not calculated in the EmPCalc Tool, even if AC is present.

The following formula, which defines the EmPCalc heating energy savings algorithm, is derived from the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative:

$$Q = U \times A \times HDD \times \left(\frac{\text{Hours}}{\text{Day}}\right) \times \left(\frac{1}{\text{E}_c}\right)$$

where,

Q	= Heat load due to conductivity (BTU)
U	= U-value of thermal barrier (1/R-value)
HDD	= Heating degree days for geographic location where measure occurs
$\frac{Hours}{Day}$	= 24 hours/day is assumed for all calculations
E_c	= Combustion efficiency of heating system

The u-value of the thermal barrier is based upon inputs entered by the user, as well as look-up values that are chosen based on the inputs (i.e., assumed R-value per inch for the insulation type selected). The assumed R-values for the existing insulation types are listed in Table 3-2.

Table 3-2. R-Value per Inch for Existing Insulation Types

Existing Insulation Type	R/inch
Fiberglass – batts	3
Fiberglass – blown	2.8
Fiberglass – rigid board	4.4
Cellulose – loose fill	3.7
Cellulose – dense pack	3.2
Cellulose – spray on	3.4
Mineral wool – batts	3
Mineral wool – loose fill	3
Mineral wool – rigid board	4
Vermiculite	2.7
Perlite	2.5
Polyisocyanurate	7
Polyurethane	6
Polystyrene – expanded	4
Polystyrene – extruded	5
None	0

The assumed R-values for the proposed insulation types are listed in Table 3-3.

Table 3-3. R-value per inch for proposed insulation types

Proposed Insulation Type	R/inch
Cellulose	3.4
Dense pack	3.4
Fiberglass	2.5
Foam board	3.6
Two-part foam	7

One of the variables in the EmPCalc Tool includes the quality of the existing insulation. Table 3-4 defines the three options available and the corresponding impact on the existing insulation R-value. According to the algorithms in the EmPCalc Tool, this R-value de-rating only applies to fiberglass batts. All other baseline insulation R-values reflect those listed in Table 3-2 above.

Table 3-4. De-Rating of Existing Insulation R-Value Based on Quality

Rating	Description	R-Value De-Rating per Inch
Good	No gaps or imperfections	2.5
Fair	Gaps over 2.5% of insulated area (this equals 3/8" space along a 14.5" batt)	1.8
Poor	Gaps over 5% of insulated area (this equals ¾" space along a 14.5" batt)	1.8

The HDD used by the EmPCalc Tool are dependent upon the region entered by the user. Regions and corresponding HDD used in the EmPCalc Tool are summarized in Table 3-5.

Table 3-5. Heating Degree Days by Region

Region	HDD
North Country	8089
Central	6803
Finger Lakes	6728
Capital/Saratoga	6438
Mid-Hudson	7237
Western	6692
Southern Tier	6806
NY City	4777

It is also worth noting that the EmPCalc Tool adds the proposed insulation thickness to the existing insulation thickness entered (if present) – in the EmPCalc Tool this field is labeled "Proposed Additional Insulation." This might not be clear to the user, who would likely assume the proposed thickness entered into the tool is equal to the thickness of the new insulation only.

3.2.2 Demand reduction

The EmPCalc Tool does not calculate demand reduction, even if electric heat is selected.

3.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 30 years. However, life cycle energy savings are not addressed in either the EmPCalc Tool or the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative. The energy savings calculated in the EmPCalc Tool reflects the yearly heating energy savings only.

3.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section.

3.3.1 Heating and Cooling Energy Savings

The NYTM provides annual energy savings calculation algorithms for calculating heating and cooling savings. The method for calculating both cooling and heating energy savings is presented below.

Cooling:

$$\Delta kWh = Sq\,ft \times \left(\frac{\Delta kWh}{Sq\,ft}\right) \times \left(\frac{SEER_{Base}}{SEER_{Part}}\right) \times \left(\frac{\eta_{Dist,base}}{\eta_{Dist,part}}\right)_{cool}$$

Heating:

$$\Delta therm = Sq\,ft\ \times (\frac{\Delta therm}{Sq\,ft}) \times \left(\frac{AFUE_{Base}}{AFUE_{\text{Part}}}\right) \times \left(\frac{\eta_{Dist,base}}{\eta_{Dist,part}}\right)_{heat}$$

where,

ΔkWh	= Gross annual energy savings (definition not provided in the NYTM)
$Sq\,ft$	= Square footage of area being insulated (definition not provided in the NYTM)
$\frac{\Delta kWh}{Sq\,ft}$	= Electricity consumption savings per square foot of insulated area (definition not provided in the NYTM)
$\Delta therm/Sqft$	= Natural gas consumption impact per square foot of insulated area (definition not provided in the NYTM)
$SEER_{Base}$	= SEER used in the simulations
$SEER_{Part}$	= SEER of cooling system within participant population
$AFUE_{Base}$	= AFUE used in the simulations
$AFUE_{\text{Part}}$	= AFUE of heating system within participant population
$\eta_{Dist,base}$	= Distribution system seasonal efficiency used in simulations
$\eta_{Dist,part}$	= Distribution system seasonal efficiency within participant

The values entered for ΔkWh/Sq ft and Δtherm/Sq ft are found in Appendix E of the NYTM and are dependent on baseline and proposed insulation R-values.

Table 3-6 includes an explanation of the sources behind the variables used in the NYTM algorithm. In some instances, the value to be used is also provided.

Table 3-6. Summary of NYTM Variables and Data Sources

Summary of Variables and Data Sources

Variable	Value	Notes
SF		From application
ΔkWh/SF		HVAC type weighted average by city based on the combination of the existing and installed R-value
ΔkW/SF		HVAC type weighted average by city based on the combination of the existing and installed R-value
Δtherm/SF		HVAC type weighted average by city based on the combination of the existing and installed R-value
EER_{base}	11.1	
EER_{part}		Participant population average. Defaults to EER_{base} (no adjustment)
$SEER_{base}$	13	
$SEER_{part}$		Participant population average. Defaults to $SEER_{base}$ (no adjustment)
$AFUE_{base}$	78%	
$AFUE_{part}$		Participant population average. Defaults to $AFUE_{base}$ (no adjustment)
$\overline{\eta}_{dist,base}$	0.956	
$\overline{\eta}_{dist,part}$		Participant population average. Defaults to $\overline{\eta}_{dist,base}$ (no adjustment)
$\eta_{dist,pk,base}$	0.956	
$\eta_{dist,pk,part}$		Participant population average. Defaults to $\eta_{dist,pk,base}$ (no adjustment)
CF_s	0.8	

3.3.2 Demand Reduction

The NYTM provides the following savings calculation algorithm for calculating peak demand savings associated with the reduction of the cooling load.

$$\Delta kW = Sq\,ft \times (\Delta kW/Sq\,ft) \times CF_S \times \left(\frac{EER_{Base}}{EER_{Part}}\right) \times \left(\frac{\eta_{Dist,pk,base}}{\eta_{Dist,pk,part}}\right)_{Cool}$$

where,

ΔkW = Gross coincident demand savings (definition not provided in the NYTM)

$Sq\,ft$ = Square footage of area being insulated (definition not provided in the NYTM)

$\Delta kW/Sq\,ft$ = Electricity demand savings per square foot of insulated area (definition not provided in the NYTM)

CF = Coincidence factor = 0.8

EER_{Base} = EER used in the simulations

EER_{Part} = EER of cooling systems within participant population

$\eta_{Dist,pk,base}$ = Distribution system efficiency under peak conditions used in simulation

$\eta_{Dist,pk,part}$ = Distribution system efficiency under peak conditions within participant population

The values entered for $\Delta kW/Sq\ ft$ are found in Appendix E of the NYTM and are dependent on the baseline and proposed insulation R-values.

3.3.3 Life of Measure

The measure life or life cycle energy savings for this measure are not provided in the NYTM.

MEASURE 4: SHOWERHEADS & AERATORS

Table 4-1 summarizes key parameters and assumptions for three savings calculation methods associated with the installation of low-flow showerheads and faucet aerators. The calculation methodologies are discussed in this section.

Table 4-1. Showerhead & Aerator Measure Algorithm Comparison

	EmPower – EmPCalc	NYTM
Number of individuals in household	Must select one of the following options: 1, 2, 3, 4, 5, 6	Number of individuals in household is not required
Method	Deemed savings per type	Deemed savings (algorithm primarily uses default values) with some site-specific temperature data used.
Quantity	Must enter the quantity of showerheads and aerators to be installed. When entering the quantity of showerheads, the user must indicate the quantity of either “standard” or “handheld” showerheads to be installed.	Must enter the quantity of showerheads and aerators to be installed.
Water flow	Default values for reduction in water flow are used for both low-flow showerheads and aerators.	Low-flow showerheads: Baseline showerhead flow (3.25 gpm) is used Proposed showerhead flow must be provided on the application Aerators Default values for both baseline (2.2 gpm) and proposed water flow after the installation of the aerator (1.5 gpm) are used
Fuel type	Must select one of the following options: Electric, natural gas, oil, propane, or kerosene	Savings algorithms provided for calculating savings associated with either electric or natural gas domestic hot water (DHW) heaters. Water savings are also calculated for both measures.
Region	Region is not a required input.	Variables that correspond with each of the following cities are found in the appendix: Albany, Buffalo, Messina, NYC, Syracuse, Binghamton, Upstate
Cooling savings	Cooling savings are not calculated in the EmPCalc Tool.	Cooling savings are not calculated in the NYTM.
Heating savings	Heating energy savings associated with reduction in DHW heater load is calculated	Heating energy savings associated with reduction in DHW heater load is calculated
Measure life	Measure life for low-flow showerheads: 8 years Measure life for aerators: 5 years	Measure life not provided

4.1 MEASURE DESCRIPTION

Efficient showerheads and aerators reduce the amount of water that passes through showerheads and faucets, reducing consumption by the end user. Reduced consumption results in less hot water that must be heated, reducing load and generating DHW heater fuel savings. According to tracking data spanning from August 2004 to January 2013, 29% of homes received shower head/aerator installations through the Program.

4.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

4.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool calculates the energy savings associated with the reduction in load on the DHW heater only.

Table 4-2 includes the assumed energy savings for low-flow showerheads, which is dependent upon number of individuals in the household. The EmPCalc Tool does not adjust savings based on the quantity of low-flow showerheads installed.

Table 4-2. Low-Flow Showerhead Energy Savings Assumptions

Number in Household	Electricity (KWh)	Natural Gas (Therms)	Oil (Gallons)	Propane (Gallons)
1	100	3.412	2.455	3.709
2	200	6.824	4.909	7.417
3	300	10.236	7.364	11.126
4	400	13.648	9.819	14.835
5	500	17.060	12.273	18.543
6	600	20.472	14.728	22.252

Table 4-3 includes the assumed energy savings for faucet aerators, which is also dependent upon the number of individuals in the household. The EmPCalc Tool does not adjust savings based on the quantity of faucet aerators installed.

Table 4-3. Faucet Aerator Energy Savings Assumptions

Number in Household	Electricity (KWh)	Natural Gas (Therms)	Oil (Gallons)	Propane (Gallons)
1	42.5	1.450	1.043	1.576
2	85.0	2.900	2.086	3.152
3	127.5	4.350	3.130	4.729
4	170.0	5.800	4.173	6.305
5	212.5	7.250	5.216	7.881
6	255.0	8.700	6.259	9.457

The cooling energy savings are not calculated in the EmPCalc Tool.

4.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction, even if an electric DHW heater is selected.

4.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 8 years for showerheads and 5 years for aerators. However, the life cycle energy savings are not addressed in either the EmPCalc Tool or the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative. The energy savings calculated in the EmPCalc Tool reflect the yearly heating energy savings only.

4.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section.

4.3.1 Heating and Cooling Energy Savings

The NYTM provides savings calculation algorithms for calculating water savings and DHW heater energy savings. Water savings must be calculated first, which is then used to the calculate energy savings associated with a reduction in load on the DHW heater.

<u>Low-flow showerheads:</u>

$$Water\ savings = (GPM_{Base}) - (GPM_{EE})\ \times\ (TF)\ \times \left(\frac{Minutes}{Shower}\right) \times \left(\frac{Showers}{Day}\right) \times \left(\frac{365\ Days}{Year}\right)$$

$$\Delta kWh = (Water\ savings) \times (TS - TH)\ \times \left(\frac{8.3\ Btu}{Gallon}\right) \times \left(\frac{3{,}414\ Btu}{kWh}\right) \times (WHE_{elec})$$

$$\Delta therms = (Water\ savings) \times (TS - TH)\ \times \left(\frac{8.3\ Btu}{Gallon}\right) \times \left(\frac{100{,}000\ Btu}{Therms}\right) \times \left(WHE_{gas}\right)$$

where,

$Water\ savings$	= Yearly water savings as a result of installing a low-flow showerhead
GPM_{Base}	= Flow of existing showerhead
GPM_{EE}	= Flow of low-flow showerhead
TF	= Throttle factor
ΔkWh	= Electric energy savings due to reduction in DHW (electric DHW heater only)

$\Delta therms$	= Natural gas savings due to reduction in DHW (natural gas-fired DHW heater only)
TS	= Water temperature at showerhead
TH	= Water temperature entering heater
WHE_{elec}	= Electric hot water heater efficiency
WHE_{gas}	= Natural gas-fired hot water heater efficiency

Summary of Variables and Data Sources

Variable	Value	Notes
GPM_{ee}		From application
GPM_{base}	3.25	
Throttle factor	0.75	
Min/shower	8	
Shower/day	2	
T_{shower}	105	
T_{mains}		Avg T_{mains} based on upstate or downstate
Water heater effic	0.97	Electric
	0.75	Gas

Faucet aerators:

$$Water\ savings = (GPM_{Base}) - (GPM_{EE}) \times \left(\frac{Duration}{Use}\right) \times \left(\frac{Uses}{Day}\right) \times \left(\frac{Days}{Year}\right)$$

$$\Delta kWh = (Water\ savings) \times (TF - TH) \times \left(\frac{8.3\ Btu}{Gallon}\right) \times \left(\frac{3{,}414\ Btu}{kWh}\right) \times (WHE_{elec})$$

$$\Delta therms = (Water\ savings) \times (TF - TH) \times \left(\frac{8.3\ Btu}{Gallon}\right) \times \left(\frac{100{,}000\ Btu}{therm}\right) \times (WHE_{gas})$$

where,

$Water\ savings$	= Annual water savings as a result of installing an aerator
GPM_{Base}	= Flow of existing faucet
GPM_{EE}	= Flow of faucet with aerator
ΔkWh	= Electric energy savings due to reduction in DHW (electric DHW heater only)

$\Delta therms$ = Natural gas savings due to reduction in DHW (natural gas-fired DHW heater only)

TF = Water temperature at faucet

TH = Water temperature entering heater

WHE_{Elec} = Electric hot water heater efficiency

WHE_{Gas} = Natural gas-fired hot water heater efficiency

Summary of Variables and Data Sources

Variable	Value	Notes
GPM_{ee}	2.2	
GPM_{base}	1.5	
Duration (minutes)	0.5	
Uses/day	30	
Days per year	365	
T_{faucet}	80	
T_{mains}		Avg T_{mains} based on upstate or downstate
Water heater effic	0.97	Electric
	0.75	Gas

There is some inconsistency in the NYTM on definitions related to these measures, but it appears that the water temperature entering the hot water heater (TH in the above algorithms) is also designated as T_{Mains}. This value is derived from a look-up table and is dependent on the geographic location of the site.

City	Annual average outdoor temperature (°F)	T mains (°F)
Albany	48.2	54.2
Binghamton	46.9	52.9
Buffalo	48.3	54.3
Massena	44.7	50.7
Syracuse	48.6	54.6
Upstate average	47.3	53.3
NYC	56.5	62.5

Cooling savings are not calculated and are not applicable to these two measures.

4.3.2 Demand Reduction

Peak demand reduction is not calculated in the NYTM.

4.3.3 Life of Measure

Measure lives for low-flow showerheads and aerators are not provided in the NYTM.

MEASURE 5: REFRIGERATORS & FREEZERS

Table 5-1 summarizes key parameters and assumptions for three savings calculation methods associated with the replacement of old, inefficient freezers and refrigerators with new, high-efficiency units. The calculation methodologies are discussed in this section.

Table 5-1. Refrigerator & Freezer Measure Algorithm Comparison

	EmPower – EmPCalc	NYTM (Refrigerator Only)
Method	Base: Meter existing unit energy consumption/calculate using NYSERDA Refrigerator Calculator software EE: Default proposed unit energy consumption based on type/size	Base: Default yearly kWh from NYTM (retro) or ES website (NC) EE: Yearly kWh for specific model proposed from ES website
Baseline energy usage	Must manually enter yearly kWh consumption for existing refrigerator and/or freezer. Value obtained by metering existing unit, or by using NYSERDA's Refrigerator Calculator software.	3 methods: Metered (early replacement) Deemed (early replacement) Federal Standard (NAECA) maximum, from ES website (end-of-life replacement)
Proposed energy usage	Can either manually enter the yearly kWh consumption for the proposed refrigerator and/or freezer, or refer to a default value. Default values a derived from a look-up table and are dependent upon two factors: Refrigerator or freezer Size of unit, in cubic feet	Available on ENERGY STAR website based on specific make/model installed
Age of existing unit	Entered manually	Used to determine savings calculation method (retro or NC)
Occupant adjustment factor	N/A	Adjusts savings according to number of occupants (1–5)
Market effects factor	N/A	Adjusts savings depending on whether the refrigerator being replaced was recycled or disabled. If not recycled/disabled, savings are decreased to account for the possibility that the unit will be reinstalled at another location.
Measure life	Measure life for both refrigerators and freezers is 12 years.	Measure life not provided

5.1 MEASURE DESCRIPTION

This measure includes replacing old, inefficient refrigerators and freezers with new, high-efficiency units. The EmPCalc Tool calculates savings associated with replacing refrigerators or freezers, where the NYTM calculates savings associated with replacing refrigerators only. According to tracking data spanning from August 2004 to January 2013, 51% of homes received a refrigerator replacement and 15% of homes received a freezer replacement through the Program.

5.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

5.2.1 Electric Energy Savings

The EmPCalc Tool calculates the electric energy savings associated with replacing an old inefficient refrigerator or freezer with a new high-efficiency unit.

Baseline

According to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative, the annual kWh consumption of the existing units can be estimated using one of the following methods:

- Estimated by NYSERDA's Refrigerator Calculator software, which estimates usage based on data from the American Home Appliance Manufacturers (AHAM). The calculator adjusts estimated usage based on the age of the appliance.
- Short-term metering of the actual appliance by the contractor.

Proposed

The EmPCalc Tool allows the user to manually enter the yearly kWh consumption, or a default value can be used. Default values are dependent upon the size (cubic feet) of the refrigerator or freezer.

The default values used in the EmPCalc Tool are included in Tables 5-2 and 5-3. These values differ slightly from those included in the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative, which have also been included in the tables below.

Table 5-2. Proposed Refrigerator Default Yearly kWh Consumption

Refrigerator Size (ft^3)	EmPCalc	2011 Narrative
15	354	372
17	336	391
18	388	412
21	410	443
22 SxS	542	N.D.
25 SxS	577	N.D.

N.D. = Not determined

Table 5-3. Proposed Freezer Default Yearly kWh Consumption

Freezer Size (ft^3)	EmPCalc	2011 Narrative
5	242	242
7	281	281
9	264	294
10	282	282
11.6	409	N.D.
13.7	442	442
14	442	442
15	442	297
21	527	527

N.D. = Not determined

The 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative indicates that measure life savings are reported and provides the methodology for how measure life savings are calculated. However, the EmPCalc Tool does not appear to complete these calculations and instead only reports the first year's energy savings.

Cooling energy savings are not calculated in the EmPCalc Tool.

5.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction.

5.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 12 years for both refrigerators and freezers. However, life cycle energy savings are not addressed in the EmPCalc Tool.

The 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative includes a detailed description for how this measure life was determined.

5.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section.

5.3.1 Heating and Cooling Energy Savings

The NYTM includes two sections related to calculating energy savings associated with refrigerators and freezers:

- Refrigerators Replacement (p. 16)
- Refrigerator and Freezer Recycling (p. 22)

This section will address the Refrigerator Replacement section and corresponding energy savings methodology only, as this more closely resembles the EmPCalc refrigerator measure. Freezer replacements are not addressed in the NYTM.

The NYTM clearly states replacement eligibility and differentiates between early replacements and end-of-life (or "normal") replacements:

- Only replacement of refrigerators that are 10 years old or older are eligible for savings claims.
- Units from 10 to 16 years old will be treated as early replacements and given full savings relative to the existing unit.
- Units built before 1994 will be considered normal replacements and will be given incremental savings. Incremental savings are defined as the difference between the annual kWh consumption of a new unit that is minimally compliant with federal appliance standards (NAECA) and the new ENERGY STAR unit.

Corresponding savings methodologies are then defined for both early and normal replacements, as follows.

Early Replacement Savings Methodology

The NYTM stipulates that to determine baseline energy consumption, metering of the refrigerator to be replaced is required for these scenarios, and it provides a step-by-step methodology for doing so. For buildings that will have multiple refrigerators replaced, the NYTM also provides a minimum sample quantity that must be metered. The sample is based on the total number of units replaced, as shown in Table 5-4.

Table 5-4. Refrigerator Short-Term Metering Minimum Sample Size

Number of Units Expected to Be Replaced per Facility	Minimum Short-Term Metering Sample
10 or fewer	3
11 – 20	4
21 – 50	6
51 – 100	8
101 – 150	10
151 – 200	12
201 – 300	17
300 or more	20

Energy consumption for the new, high-efficiency refrigerator is to be determined by using the DOE rating and ENERGY STAR website data for the make and model of the installed unit.

According to the *7-31-13 Record of Revision*, the following default baseline energy consumption values can be used if metering is not possible:

- 695 kWh/year (Con Edison & O&R territories)
- 595 kWh/year (all other service territories)

Normal Replacement (End-of-Life) Savings Methodology

To determine baseline energy consumption, the “Federal Standard (NAECA) maximum consumption for the type and size of refrigerator purchased” is to be used. This data is available on the ENERGY STAR website.

Similar to the early replacement methodology, yearly energy consumption for the new, high-efficiency unit is also to be determined using the ENERGY STAR website for the specific model installed.

Energy Savings Algorithms

The energy savings algorithms used for both methodologies described above are as follows:

$$\Delta kWh = Units \times (kWh_{Base} - kWh_{EE}) - (1 + HVAC_C) \times F_{Occ} \times F_{Market}$$

$$\Delta therms = \Delta kWh \times HVAC_G$$

where,

ΔkWh	= Gross annual energy savings
$\Delta therms$	= Gross annual heating fuel impacts from heating system interactions
$Units$	= The number of refrigerators installed under the program
kWh_{Base}	= Annual energy consumption for the replaced unit estimated from short-term test
kWh_{EE}	= Annual energy consumption for the new unit from DOE test
$HVAC_C$	= HVAC system interaction factor for annual energy consumption
$HVAC_G$	= HVAC system interaction factor for annual heating fuel consumption
8760	= Conversion factor (hr/yr)
F_{Occ}	= Occupant adjustment factor
F_{Market}	= Market effects factor accounting for replaced refrigerators that enter the used appliance market

The HVAC system interaction factor ($HVAC_c$) takes in to account the reduction of heat rejected into the conditioned space by the high-efficiency refrigerator, thereby reducing the cooling load. Likewise, this results in an increase in the building’s heating load, which is accounted for in the variable $HVAC_G$ above. Both of these variables are found in a look-up table in the NYTM appendix.

Occupant Adjustment Factor (F_{Occ}**)**

From the NYTM: "The occupant adjustment factor is used to adjust the energy savings according to the number of occupants in the apartment." The occupant adjustment factors are shown in Table 5-5.

Table 5-5. Occupant Adjustment Factor (F_{occ}**)**

Number of Occupants	F_{Occ}
0 occupants	1.00
1 occupant	1.05
2 occupants	1.10
3 occupants	1.13
4 occupants	1.15
5 or more	1.16

Market Effects Factor (F_{Market}**)**

From the NYTM: "An adjustment factor must be applied to account for existing refrigerators that enter the used appliance market when programs do not have a recycling or old refrigerator disabling component." The market adjustment factors are shown in Table 5-6.

Table 5-6. Market Adjustment Factor (F_{Market}**)**

Program Component	F_{Market}
No recycling or disabling of existing refrigerators	0.8
Recycling or disabling of existing refrigerators can be demonstrated	1.0

5.3.2 Demand Reduction

$$\Delta kW_s = Units \times \left(\frac{kWh_{Base}}{8{,}760} - \frac{kWh_{EE}}{8{,}760}\right) \times CF_s \times (1 + HVAC_D) \times F_{Market}$$

where,

ΔkW_s = Gross coincident demand savings

CF = Coincidence factor (1.0)

$HVAC_d$ = HVAC system interaction factor at utility peak hour

5.3.3 Life of Measure

Measure lives for refrigerators are not provided in the NYTM.

MEASURE 6: DOMESTIC HOT WATER HEATER REPLACEMENT

Table 6-1 summarizes key parameters and assumptions for three savings calculation methods associated with domestic hot water (DHW) heater improvements. The calculation methodologies are discussed in this section.

Table 6-1. Domestic Hot Water Heater Replacement Measure Algorithm Comparison

	EmPower – EmPCalc	**NYTM**
Method	(Water consumption) x (1/efficiency improvement)	(Water consumption) x (1/efficiency improvement)
Existing DHW fuel	Must select one of the following: • Electric • Natural gas • Oil • Propane • Kerosene	Must select one of the following: • Electric • Natural gas
Proposed DHW fuel	Must select one of the following: • Electric • Natural gas • Oil • Propane • Kerosene	Must select one of the following (algorithm assumes existing and proposed use the same fuel when calculating savings): • Electric • Natural gas
Number of heaters installed	N/A	Must enter quantity
Number in household	Must select one of the following: 1, 2, 3, 4, 5, 6	"Gallons per day" variable in equation is dependent upon number of individuals in household (look-up table)
Energy factor	Energy factor for existing automatically populates, user must enter % for installed	Efficiencies for existing are calculated based on tank volume, proposed efficiency is entered manually
Measure life	12 years	Measure life not provided

6.1 MEASURE DESCRIPTION

This section covers the installation of high-efficiency water heaters that are used for DHW, including showers, faucet end uses, and clothes washers. According to tracking data spanning from August 2004 to January 2013, 7% of homes received DHW improvements through the Program.

6.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

6.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool calculates the energy savings associated with replacing an old inefficient hot water heater with a new high-efficiency unit.

The EmPCalc Tool allows the user to select both the existing and installed fuel type, which may be the same. However, according to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative, the measure includes “the replacement of (an) electrically-heated hot water tank with (a) water heater heated by another fuel.”

$$\Delta kWh = \left(\frac{kWh_{Base}}{EF_{Base}}\right) - \left(\frac{Q}{EF_{Post}}\right)$$

Deemed savings are calculated using the number of individuals in the household (see Table 6-2 below) and the user-specified existing fuel type. If a different fuel source is used for the installed hot water heater, negative energy savings are calculated for that fuel type.

Table 6-2. Estimated Annual Hot Water Fuel Usage

Family Size	Gallons of Hot Water/Day	Annual Fuel Usage			
		kWh (Electric)	Therms (Natural gas)	Gallons (Oil)	Gallons (Propane)
1	29	1861	63.510	45.69	69.032
2	41.6	2670	91.104	65.54	99.026
3	54.8	3517	120.012	86.34	130.447
4	64	4107	140.000	100.83	152.347
5	73.3	4704	160.530	115.48	174.485
6	84.4	5417	184.830	132.97	200.908

“Energy factors” are used for both the existing and installed units, though no explanation is provided (either in the EmPCalc Tool or in the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative). It is assumed that the “energy factor” refers to the efficiency of the water heater. A default energy factor of 0.87 is assumed for the existing tank, where the energy factor for the installed unit must be provided by the contractor.

Cooling energy savings are not calculated in the EmPCalc Tool.

6.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction.

6.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 12 years for both refrigerators and freezers. However, life cycle energy savings are not addressed in the EmPCalc Tool.

6.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section. The NYTM allows for both instantaneous and storage-type (indirect) hot water heaters to be included in this measure. Separate energy savings methodologies are provided for both.

6.3.1 Heating and Cooling Energy Savings

The heating and cooling energy savings formulas for various appliances are detailed in the subsections that follow.

Instantaneous Hot Water Heaters

The algorithms and methodologies found in the NYTM for this measure are as follows:

$$\Delta kWh = Units \times \left(\frac{GPD \times 365 \times 8.33 \times \overline{\Delta T_w}}{3{,}413}\right) \times \left(\frac{1}{EF_{Base}} - \frac{1}{EF_{EE}}\right)$$

$$\Delta therms = Units \times \left(\frac{GPD \times 365 \times 8.33 \times \overline{\Delta T_w}}{100{,}000}\right) \times \left(\frac{1}{EF_{Base}} - \frac{1}{EF_{EE}}\right)$$

where,

ΔkWh	= Gross annual energy savings
$\Delta therms$	= Gross annual natural gas savings
$Units$	= Number of high efficiency water heaters installed under the program
GPD	= Average daily water consumption (gallons/day)
$\overline{\Delta T_w}$	= Average difference between the cold inlet temperature and the hot water delivery temperature (°F)
EF_{Base}	= Baseline water heater energy factor
EF_{EE}	= Efficient water heater energy factor
3,413	= Conversion factor (Btu/kWh)
8.33	= Conversion factor (Btu/gallon-°F)
100,000	= Conversion factor (Btu/therm)
365	= Conversion factor (days/yr)

The hot water delivery temperature is assumed to be 130°F, per the NYTM. Cold water entering temperatures based on the annual average outdoor temperature are shown in Table 6-3 under the "T mains" column. The difference between these values results in the $\overline{\Delta T_w}$ variable used in the equation above.

Table 6-3. Cold Water Inlet Temperature By Location

City	Annual Average Outdoor Temperature (°F)	T mains (°F)
Albany	48.2	54.2
Binghamton	46.9	52.9
Buffalo	48.3	54.3
Massena	44.7	50.7

City	Annual Average Outdoor Temperature (°F)	T mains (°F)
Syracuse	48.6	54.6
Upstate average	47.3	53.3
NYC	56.5	62.5[1]

The gallons of hot water used per day for a given household depend upon the number of individuals who live in the household. The assumed consumption per household is provided in the NYTM and is summarized in Table 6-4.

Table 6-4. NYTM Assumed Hot Water Consumption

Number of People	Gal/Person per Day	Total Gal/Day per Household
1	29.4	29
2	22.8	46
3	20.6	62
4	19.5	78
5	18.9	94
6	18.5	111

The reduction in standby heat losses is considered to have a minimal impact on space heating and cooling systems (HVAC interactivity) and the resulting energy savings and penalties are therefore not calculated for this measure.

Energy factors for the proposed units (EF_{EE}) are derived from the application. NYTM assumptions for baseline energy factors (EF_{Base}), based on the tank volume (V) using the NAECA methodology, are shown in Table 6-5.

Table 6-5. NYTM Baseline Energy Factors (EF_{base})

Water Heater Type	EF
Electric	0.93 – 0.00132(V)
Natural gas	0.62 – 0.0019(V)

Indirect Hot Water Heaters

The algorithms and methodologies found in the NYTM for this measure are as follows:

$$\Delta therms = Units \times \left(\frac{GPD \times 365 \times 8.33 \times \overline{\Delta T_w}}{100{,}000}\right) \times \left(\frac{1}{E_{C,Base}} - \frac{1}{E_{C,EE}}\right) + \left(\frac{UA_{Base}}{E_{C,Base}} - \frac{UA_{EE}}{E_{C,EE}}\right) \times (\Delta T_S)$$

1 In the above table, the inlet water temperature (“T mains”) for NYC was revised from 62.5°F to 55°F in the 7-31-13 Record of Revision.

$$UA_{Base} = \left(\frac{\frac{1}{EF_{Base}} - \frac{1}{RE_{Base}}}{67.5 \times (0.000584 \times \frac{1}{RE_{Base} \times Cap_{Base}}} \right)$$

$$EF_{Base} = 0.62 - (0.0019 \times V_{Base})$$

where,

$\Delta therms$	= Gross annual natural gas savings
$Units$	= Number of high efficiency water heaters installed under the program
UA_{Base}	= Overall heat loss coefficient of base tank-type water heater (Btu/hr-°F)
UA_{EE}	= Overall heat loss coefficient of efficient water heater storage tank (Btu/hr-°F)
ΔT_S	= Temperature difference between the stored hot water and the surrounding air (°F)
GPD	= Average daily water consumption (gallons/day) - default is 78 GPD for indirect water heaters
$\overline{\Delta T_w}$	= Average difference between the cold inlet temperature and the hot water delivery temperature (°F)
EF_{Base}	= Baseline water heater energy factor
EF_{EE}	= Efficient water heater energy factor
$E_{C,Base}$	= Baseline water heater efficiency (equals RE_{base} if tank type baseline, $E_{c,base}$ if indirect baseline)
$E_{C,EE}$	= Efficient water heater energy factor
RE_{Base}	= Tank type water heater recovery efficiency (NYTM default = 75%)
Cap_{Base}	= Tank type water heater capacity (Btu/hr)
V_{Base}	= Tank type water heater capacity (gallons)
3,413	= Conversion factor (Btu/kWh)
8.33	= Conversion factor (Btu/gallon-°F)
100,000	= Conversion factor (Btu/therm)
365	= Conversion factor (days/yr)

$E_{C,EE}$ is noted in the NYTM as being provided on the application. $E_{C,Base}$ for indirect water heater tanks is derived from Table 6-6.

Table 6-6. NYTM Default Baseline Water Heater Efficiencies ($E_{c,base}$)

Fuel Type	Baseline Water Heater Efficiency
Electric	0.97
Natural gas	0.75

6.3.2 Demand Reduction

The following algorithm applies to instantaneous water heaters only; peak demand reduction is not calculated for indirect water heaters as the algorithm assumes the primary heating source (i.e., the boiler) is natural gas-fired.

$$\Delta kW = Units \times \left(\frac{UA_{Base} - UA_{EE} \times \Delta T_S}{3{,}413}\right) \times DF_s \times CF_s$$

$$UA = \left(\frac{\frac{1}{EF} - \frac{1}{RE}}{67.5 \times (0.000584 \times \frac{1}{RE \times Cap}}\right)$$

where,

ΔkW	= Gross coincident demand savings
ΔkW	= Number of high efficiency water heaters installed under the program
UA_{Base}	= Overall heat loss coefficient of base water heater (Btu/hr-°F)
UA_{EE}	= Overall heat loss coefficient of efficient water heater (Btu/hr-°F)
EF_{Base}	= Baseline water heater energy factor
EF_{EE}	= Efficient water heater energy factor
ΔT_S	= Temperature difference between the stored hot water and the surrounding air (°F)
RE	= Recovery efficiency
Cap	= Water heater capacity (Btu/hr)
DF	= Demand diversity factor
CF	= Coincidence factor
3,413	= Conversion factor (Btu/kWh)

NYTM assumptions for recovery efficiency and input capacity for non-condensing water heaters are shown in Table 6-7.

Table 6-7. NYTM Default Water Heater Recovery Efficiencies and Capacities

Water Heater Type	Recovery Efficiency	Capacity (Btu/hr)
Electric	0.97	15,400
Natural gas	0.75	40,000

NYTM assumptions for baseline energy factors (EF_{Base}) are calculated per Table 6-7 above. Proposed energy factors (EF_{EE}) are provided on the application.

UA_{EE} for indirect water heater tanks are derived from the Table 6-8.

Table 6-8. NYTM Heat Loss Coefficients For Energy Efficient Water Heater Tanks

Volume (gal)	Height of Bare Tank (in.)	Diameter of Bare Tank (in.)	Insulation	UA (Btu/hr-ºF)
40	44	17	1-inch foam	4.1
			2-inch foam	2.1
80	44	24	1-inch foam	6.1
			2-inch foam	3.1
120	65	24	1-inch foam	8.4
			2-inch foam	5.4

According to the *7-31-13 Record Of Revision*, the tank UAs for typical natural gas water heaters are included in Table 6-9; it is not specified whether these values reflect UA_{EE} or UA_{Base}.

Table 6-9. Revised Default NYTM Heat Loss Coefficients

Water Heater Size	Natural Gas Water Heater Tank UA
40	13.6
80	21.6
120	32.8

6.3.3 Life of Measure

The measure life for hot water heaters is not provided in the NYTM.

MEASURE 7: DOMESTIC HOT WATER TANK WRAP

Table 7-1 summarizes key parameters and assumptions for three savings calculation methods associated with the insulation/wrapping of domestic hot water (DHW) tanks. The calculation methodologies are discussed in this section.

Table 7-1. Domestic Hot Water Tank Wrap Measure Algorithm Comparison

	EmPower – EmPCalc	NYTM
Method	U×A×ΔT	U×A×ΔT
Quantity	Must manually enter the number of tanks being insulated – deemed savings per tank	Must enter number of tanks being insulated
Tank volume	N/A	Heat transfer coefficients for the baseline and efficient (wrapped) water heater are determined based on tank volume
Measure life	8 years	Measure life not provided

7.1 MEASURE DESCRIPTION

This section covers the installation of thermal insulation on DHW tanks. This measure reduces heat loss through the tank walls, thereby reducing the frequency of the operation of the DHW heater. According to tracking data spanning from August 2004 to January 2013, 6% of homes received DHW tank wrapping through the Program.

7.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

7.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool calculates the energy savings associated with insulating a hot water tank. The user enters the number of tanks being insulated, and a deemed savings per tank is used to calculate the total energy savings. Energy savings are calculated in kWh.

According to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative the savings algorithm used to calculate savings is as follows:

$$\Delta kWh = \frac{\left(\left(S \times \frac{1}{R_1}\right) \times (T_1 - T_2) \times 8{,}760\right) - \left(\left(S \times \frac{1}{R_2}\right) \times (T_1 - T_2) \times 8{,}760\right)}{3{,}412}$$

where,

ΔkWh = Electric energy savings due to insulation of hot water tank

S = Surface area of water heater; assumed to be 27.2 ft.²

R_1 = R-value of unwrapped water heat; assumed to be R-8

R_2 = R-value of tank + R-value of added insulation; insulation assumed to be R-6.7, therefore R_2 assumed to be R-14.7.

T_1 = Temperature of heated water; assumed to be 120° F

T_2 = Temperature of ambient air; assumed to be 55° F

8,760 = Constant used to calculate yearly energy savings (8,760 hrs per year)

3,412 = Constant used to convert Btu savings to kWh (3,412 Btu per kWh)

After a review of the EmPCalc Tool, it was confirmed that the savings algorithm matches the above. Additionally, it was confirmed that the default values defined in the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* are also the same values used in the EmPCalc Tool.

Cooling energy savings are not calculated in the EmPCalc Tool.

7.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction.

7.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 8 years for both refrigerators and freezers. However, life cycle energy savings are not calculated in the EmPCalc Tool.

7.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section.

7.3.1 Heating and Cooling Energy Savings

The algorithms and methodologies found in the NYTM for this measure are as follows:

$$\Delta kWh = Units \times \left(\frac{(UA_{Base} - UA_{EE}) \times \overline{\Delta T}}{3{,}413 \times \eta_{elec}}\right) \times 8{,}760$$

$$\Delta therms = Units \times \left(\frac{(UA_{Base} - UA_{EE}) \times \overline{\Delta T}}{100{,}000 \times \eta_{Gas}}\right) \times 8{,}760$$

where,

ΔkWh = Gross annual electricity savings

$\Delta therms$	= Gross annual natural gas savings
$Units$	= Number of water heaters installed
UA_{Base}	= Overall heat loss coefficient of base water heater (Btu/hr-°F) (see tables below)
UA_{EE}	= Overall heat loss coefficient of improved efficient water (Btu/hr-°F) (see tables below)
$\overline{\Delta T}$	= Temperature difference between the water inside the tank and the ambient air (°F) (NYTM default = 60°)
3,413	= Conversion factor (Btu/kWh)
8,760	= Conversion factor (hr/yr)
100,000	= Conversion factor (Btu/therm)
η_{elec}	= Electric water heater efficiency (NYTM default = 97%)
η_{gas}	= Natural gas water heater efficiency (NYTM default = 75%)

Heat transfer coefficients used in the energy savings algorithm can be found in Tables 7-2 through 7-4.

Table 7-2. UA Values (Base & EE) for Single-Family Residential Water Heaters

Water Heater Size (Gal)	Height	Diameter	UA_{Base}	UA_{EE}
30	60	16	4.35	1.91
40	61	16.5	4.58	2.00
50	53	18	4.49	1.96
66	58	20	5.51	2.39
80	58	22	6.18	2.67

Table 7-3. UA Values (Base) for Larger Multi-Family Residential Water Heaters

Water Heater Size (Gal)	Height (In)	Diameter (In)	UA_{base} (Btu/hr-ºF)				
			Bare Tank	Fiberglass		Foam	
				1 In	2 In	1 In	2 In
120	61	24	40.6	10.0	5.1	7.9	4.1
140	76	24	47.9	12.0	6.2	9.6	4.9
200	72	30	60.9	14.7	7.6	11.7	6.0
250	84	30	68.1	16.8	8.6	13.3	6.9
350	88	36	88.8	21.5	11.0	17.1	8.7
400	97	36	95.3	23.3	11.9	18.5	9.5
500	74	48	115.9	26.3	13.3	20.9	10.6
750	106	48	146.9	34.9	17.7	27.7	14.1
1000	138	48	177.9	43.5	22.1	34.6	17.6

Table 7-4. UA Values (EE) for Larger Multi-Family Residential Water Heaters

Water Heater Capacity (Gal)	Height (In)	Diameter (In)	UA_{ee} (Btu/hr-ºF)				
			Bare Tank	Fiberglass		Foam	
				1 In	2 In	1 In	2 In
120	61	24	5.1	3.8	2.7	3.4	2.4
140	76	24	6.2	4.6	3.3	4.1	2.9
200	72	30	7.6	5.6	4.0	5.0	3.5
250	84	30	8.6	6.3	4.6	5.7	4.0
350	88	36	11.0	8.1	5.7	7.2	5.0
400	97	36	11.9	8.7	6.2	7.8	5.4
500	74	48	13.3	10.2	6.9	8.9	6.0
750	106	48	17.7	13.2	9.2	11.7	8.0
1000	138	48	22.1	16.1	11.5	14.4	10.0

7.3.2 Demand Reduction

The following algorithm is used to calculate the peak demand savings associated with improvements made to electric hot water heaters only (see Section 7.4.1 for definitions of variables):

$$\Delta kW_s = Units \times \left(\frac{(UA_{Base} - UA_{EE}) \times \overline{\Delta T}}{3{,}413 \times \eta_{Elec}}\right) \times 8{,}760$$

7.3.3 Life of Measure

Measure life for hot water tank insulation is not provided in the NYTM.

MEASURE 8: DOMESTIC HOT WATER PIPE INSULATION

Table 8-1 summarizes key parameters and assumptions for three savings calculation methods associated with the insulation/wrapping of domestic hot water (DHW) piping. The calculation methodologies are discussed in this section.

Table 8-1. Domestic Hot Water Heater Replacement Measure Algorithm Comparison

	EmPower – EmPCalc	NYTM
Method	Deemed savings	U×A×ΔT
Length of pipe insulated	N/A	Must enter length, in feet
Pipe material	N/A	Look-up values based on the following options: • Copper • Steel
Pipe diameter	N/A	Look-up values based on the following options: 0.75”, 1”, 1.25”, 1.5”, 2”, 2.5”, 3”, 4”
Insulation thickness	N/A	Look-up values based on the following options: 0.5”, 1”, 1.5”, 2”
End use	DHW is assumed	Must choose between DHW and space heating
Measure Life	8 years	Measure life not provided

8.1 MEASURE DESCRIPTION

This section covers the installation of insulation on DHW supply piping, which reduces heat loss through those pipes. According to tracking data spanning from August 2004 to January 2013, 16% of homes received DHW pipe wrapping through the Program.

8.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

8.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool assumes 75 kWh savings per year when this DHW pipe insulation is installed. No variables coincide with this measure, and the deemed savings therefore are not impacted by variances such as pipe insulation R-values or the linear feet of insulation installed. While the linear feet of insulation installed is captured in the tool, this is used to calculate cost and payback, but does not impact energy savings.

The 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative includes supporting references and justification for the deemed savings assumed for this measure.

Cooling energy savings are not calculated in the EmPCalc Tool.

8.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction.

8.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 8 years for hot water pipe insulation. However, life cycle energy savings are not addressed in the EmPCalc Tool.

8.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section. The NYTM states that this measure applies to the insulation of pipe serving either DHW or space heating end uses.

8.3.1 Heating and Cooling Energy Savings

The algorithms and methodologies found in the NYTM for this measure are as follows:

$$\Delta kWh = L \times \left(\frac{(UA/L)_{Base} - (UA/L)_{ee}}{3{,}413 \times \eta_{Heater}}\right) \times \overline{\Delta T} \times hrs$$

$$\Delta therms = L \times \left(\frac{(UA/L)_{Base} - (UA/L)_{EE}}{100{,}000 \times \eta_{Heater}}\right) \times \overline{\Delta T} \times hrs$$

where,

ΔkWh	= Gross annual energy savings
$\Delta therms$	= Gross annual natural gas savings
L	= Length of insulation installed
$\overline{\Delta T}$	= Average temperature difference between water within the pipe and air temperature (°F)
UA/L_{Base}	= Uninsulated pipe heat loss coefficient per unit length (Btu/hr-F°-ft.)
UA/L_{EE}	= Insulated pipe heat loss coefficient per unit length (Btu/hr-F°-ft.)
3,412	= Conversion factor (Btu/kWh)
8,760	= Conversion factor (Hrs/year)
100,000	= Conversion factor (Btu/therm)
η_{Heater}	= Water heater or boiler efficiency

The temperature difference between the water inside the pipe and the air temperature is based on the piping end use according to Table 8-2.

Table 8-2. Default ΔT(°F) Between Water Inside Piping and Air

Variable	Value	Notes
$\overline{\Delta T}$	60°F (service hot water) 100°F (hot water heat) 130°F (steam heat)	130°F hot water temp, 70°F room temp 160°F hot water temp, 60°F room temp 190°F steam temp, 60°F room temp

Heat loss coefficients (UA/L) differ depending upon the type of pipe insulated (copper or steel), the diameter of the pipe, and the type/thickness of the insulation installed according to Tables 8-3 through 8-5.

Table 8-3. Baseline Uninsulated Pipe Heat Loss Coefficient (UA/L_{Base}) in Btu/hr-°F-ft

Pipe Size (Nominal; in.)	Bare Copper Piping			Bare Steel Piping	
	Service Hot Water	Hot Water Heat	Steam Heat	Hot Water Heat	Steam Heat
0.75	0.4	0.45	0.49	0.73	0.78
1	0.5	0.56	0.61	0.89	0.95
1.25	0.59	0.67	0.72	1.1	1.18
1.5	0.68	0.78	0.83	1.24	1.33
2	0.86	0.98	1.05	1.52	1.63
2.5	1.04	1.18	1.26	1.81	1.94
3	1.21	1.37	1.47	2.16	2.32
4	1.54	1.75	1.88	2.72	2.92

Table 8-4. Insulated Copper Pipe Heat Loss Coefficient (UA/L_{ee}) in Btu/hr-°F-ft

Pipe Size (Nominal; In.)	Fiberglass				Rigid Foam			
	0.5 In	1.0 In	1.5 In	2.0 In	0.5 In	1.0 In	1.5 In	2.0 In
0.75	0.17	0.11	0.09	0.08	0.12	0.08	0.06	0.05
1	0.21	0.13	0.10	0.09	0.15	0.09	0.07	0.06
1.25	0.24	0.15	0.11	0.10	0.17	0.10	0.08	0.07
1.5	0.27	0.16	0.13	0.11	0.20	0.12	0.09	0.08
2	0.34	0.20	0.15	0.12	0.24	0.14	0.11	0.09
2.5	0.41	0.23	0.17	0.14	0.29	0.17	0.12	0.10
3	0.47	0.26	0.19	0.16	0.34	0.19	0.14	0.11
4	0.60	0.33	0.24	0.19	0.43	0.24	0.17	0.14

Table 8-5. Insulated Steel Pipe Heat Loss Coefficient (UA/Lee) in Btu/hr-°F-ft

Pipe Size (Nominal) (In.)	Fiberglass				Rigid Foam			
	0.5 In	1.0 In	1.5 In	2.0 In	0.5 In	1.0 In	1.5 In	2.0 In
0.75	0.20	0.12	0.10	0.08	0.14	0.09	0.07	0.06
1	0.23	0.14	0.11	0.09	0.17	0.10	0.08	0.07
1.25	0.28	0.17	0.13	0.11	0.20	0.12	0.09	0.08
1.5	0.31	0.18	0.14	0.12	0.22	0.13	0.10	0.08
2	0.37	0.21	0.16	0.13	0.27	0.15	0.12	0.10
2.5	0.44	0.25	0.18	0.15	0.32	0.18	0.13	0.11
3	0.52	0.29	0.21	0.17	0.38	0.21	0.15	0.12
4	0.65	0.36	0.26	0.21	0.47	0.26	0.18	0.15

Cooling savings are not calculated and is not applicable to this measure.

8.3.2 Demand Reduction

$$\Delta kW_s = L \times \left(\frac{(UA/L)_{base} - (UA/L)_{ee}}{3{,}413 \times \eta_{heater}}\right) \times \Delta T_s \times CF_s$$

where,

ΔkW_s = Gross coincident demand savings

ΔT_s = Temperature difference between water within the pipe and air under peak conditions (see Table 8-2 above – same values are used for this variable)

CF_s = Coincidence factor

NYTM coincidence factors are included in Table 8-6. According to the NYTM, boiler systems are assumed to be turned off in the summer, resulting in a coincidence factor of 0, and therefore there are no peak demand savings. As the water heater is assumed to be in-use year-round, a coincidence factor of 1 is assigned to the insulation of piping serving that end use.

Table 8-6. NYTM Coincidence Factors for Hot Water Pipe Insulation

Parameter	Recommended Values
Coincidence factor (water heater)	1.0
Coincidence factor (space heating boiler)	0.0

See Section 8.4.1 for definitions of all other variables.

8.3.3 Life of Measure

Measure life for pipe insulation is not provided in the NYTM.

MEASURE 9: DRYER CONVERSION

Table 9-1 summarizes key parameters and assumptions for two savings calculation methods associated with the conversion of old, inefficient dryers to new, high-efficiency units. The NYTM does not include this measure and corresponding variables are therefore not available. The calculation methodologies are discussed in this section.

Table 9-1. Dryer Conversion Measure Algorithm Comparison

	EmPower – EmPCalc	NYTM
Number in household	Must select one of the following: 1, 2, 3, 4, 5, 6	N/A
Loads per week	Default value populates based on number in household, however this can be overridden and entered manually by the user.	N/A
Measure life	10 years	N/A

9.1 MEASURE DESCRIPTION

The EmPower program offers a measure for converting from an electric dryer to either a natural gas- or propane-fired dryer. According to tracking data spanning from August 2004 to January 2013, 2% of homes received a clothes dryer replacement through the Program.

9.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

9.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool calculates the electric energy savings only resulting from replacing an electric dryer with either a natural gas- or propane-fired dryer. It does not take into account the increase in natural gas or propane consumption that results from installing either of these types of dryers when calculating the energy savings.

The EmPCalc Tool *does* take in to account both the electric energy savings and the increase in natural gas or propane consumption when calculating the financial savings associated with these projects.

To calculate the electric energy savings, the EmPCalc Tool assumes a deemed kWh per load of laundry as shown in Table 9-2.

Table 9-2. Deemed Energy Consumption per Load of Laundry

Fuel	Consumption per Load
Electric	3.76 kWh
Natural gas	0.22 therms
Propane	0.24 gallons

An assumed number of loads of laundry per week is assumed based on the number of individuals in the household, which is selected by the user (see Table 9-3 below). The number of loads per week can be changed manually, but if this number exceeds 10% of the deemed value, the user is prompted to provide an explanation within the EmPCalc Tool.

Table 9-3. Deemed Number of Loads of Laundry per Person

Persons/Household	Loads/Year	Deemed Loads/Week
1	200	4
2	310	6
3-4	454	9
5+	624	12

Cooling energy savings are not calculated in the EmPCalc Tool.

9.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction.

9.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 10 years. However, life cycle energy savings are not addressed in either the EmPCalc Tool or the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative.

9.3 NYTM SAVINGS ESTIMATION APPROACH

The NYTM does not include this measure.

MEASURE 10: WATER BED

Table 10-1 summarizes the key parameters and assumptions for two savings calculation methods associated with replacing water beds with a standard mattress. The NYTM does not include this measure and corresponding variables are therefore not available. The calculation methodologies are discussed in this section.

Table 10-1. Water Bed Measure Algorithm Comparison

	EmPower – EmPCalc	NYTM
Quantity	Deemed savings of 1,250 kWh per year per waterbed replaced	N/A
Measure life	12 years	N/A

10.1 MEASURE DESCRIPTION

EmPower offers a measure for replacing a water bed with a standard mattress.

10.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

10.2.1 Heating and Cooling Energy Savings

The EmPCalc Tool uses a deemed savings of 1,250 kWh per water bed that is replaced with a standard mattress. According to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative, this is derived from the ACEEE "Consumer Guide to Home Energy Savings, 7th Edition." No further explanation as to how this measure generates energy savings is provided.

Cooling energy savings are not calculated in the EmPCalc Tool.

10.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction for this measure.

10.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 30 years. However, life cycle energy savings are not addressed in either the EmPCalc Tool or the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative.

10.3 NYTM SAVINGS ESTIMATION APPROACH

The NYTM does not include this measure.

MEASURE 11: HEATING SYSTEMS

This section includes four measures: installation of setback thermostats, heating system tune-ups, duct repair, and the installation of high efficiency furnaces and boilers. More details regarding each of these measures, including discrepancies between the EmPCalc Tool and the NYTM, are provided below.

Table 11-1 summarizes key parameters and assumptions for three savings calculation methods associated with each of these four measures. The calculation methodologies are discussed in this section.

Table 11-1. Heating Systems Measure Algorithm Comparison

	EmPower – EmPCalc	**NYTM**
Method	Setback thermostat: 6.2% deemed savings factor × (yearly total energy consumption entered by user – yearly DHW consumption) Heating system tune-up: (Yearly total energy consumption entered by user – yearly DHW consumption) × [1 – (Base eff) / (EE eff)] Duct repair: Savings entered manually Heating system replacement: (Yearly total energy consumption entered by user – yearly DHW consumption) × [1 – (Base eff) / (EE eff)]	Setback thermostat: 6.8% deemed savings factor × yearly heating consumption calculated by user Furnace tune-up: 5.0% deemed savings factor × yearly heating consumption calculated by user Duct repair: Yearly heating energy consumption calculated by user × [1 – (Base duct eff) / (EE duct eff)] Heating system replacement: See algorithms below.
Existing heating fuel type	Must select one of the following options: Electric, natural gas, oil, propane, kerosene, soft wood, hard wood, wood pellets, coal	Separate algorithms for calculating electric and natural gas savings
Heating system type	Must select one of the following options: • Forced warm air furnace • Boiler: hot water • Boiler: steam • Electric baseboard • Other	Electric and natural gas savings algorithms available for calculating savings due to reduced operating hours and/or reduced load on electric resistance heaters, electric heat pumps, electric AC units, and natural gas-fired furnaces and boilers
Estimated yearly heating energy consumption	Entered manually by user	Calculated based on EFLH (see below) and heating unit nameplate capacity (from application)
EFLH	N/A	Look-up values (NYTM Appendix G) based on the following options: Building location (Albany, Binghamton, Buffalo, Massena, NYC, Poughkeepsie, Syracuse) Building vintage (Old, Average, New)
Setback thermostats – quantity installed	Entered manually – does <u>not</u> impact savings	Entered manually – <u>does</u> impact savings
Heating system replacement	Must indicate the fuel type the heating system is being converted to: electric, natural gas, oil, propane, kerosene, soft wood, hard wood, wood pellets, coal Must enter the efficiency of the existing and proposed heating system (%). For boiler/furnace tune-ups, the existing and post tune-up efficiency must be entered.	NYTM assumes fuel type remains unchanged and savings are calculated based on the efficiency improvement only.
Measure life	Setback thermostat: 15 years Furnace tune-up: Not provided Duct repair: 15 years Heating system conversion: 15 years	Measure life not provided

11.1 MEASURE DESCRIPTION

This section includes four heating system-related measures.

- Installation of setback thermostat(s)
- Furnace tune-up
- Duct repair
- Heating system conversion/replacement

According to tracking data spanning from August 2004 to January 2013, 12% of homes received a heating system repair and 2% of homes received a heating system replacement through the Program.

There are some inconsistencies between the EmPCalc and NYTM definitions for these measures, which are summarized in Table 11-2.

Table 11-2. Summary of Measure Discrepancies

Measure	Difference
Installation of setback thermostat	None
Heating system tune-up	None
Duct repair	EmPCalc includes furnace repairs in this measure. NYTM includes duct insulation in this measure.
Heating system conversion/replacement	EmPCalc includes heating system fuel conversion and efficiency improvements in this measure. NYTM has two separate measures for high efficiency furnace and high efficiency boiler replacements. NYTM does not account for fuel switching.

The EmPCalc Tool includes duct and furnace repairs under the same measure, and has a separate measure for heating system tune-ups. The NYTM, however, does not include furnace repairs with the duct repair measure, and has a separate measure for furnace tune-ups only.

The NYTM also includes duct insulation in the duct repair measure, where the EmPCalc Tool does not.

Finally, the EmPCalc Tool calculates savings associated with switching fuels (i.e., electric furnace to natural gas), in addition to efficiency improvements to the heating system. The NYTM calculates savings associated with replacing old inefficient furnaces and boilers with new, high efficiency units.

11.2 EMPCALC SAVINGS ESTIMATION APPROACH

The calculation method used in the EmPCalc Tool is presented in this section.

11.2.1 Heating and Cooling Energy Savings

The heating and cooling savings as calculated by EmPCalc Tool for each of the three measures mentioned above will be discussed in this section.

Installation of Setback Thermostat

The EmPCalc Tool assumes a deemed savings of 6.2% of the total yearly heating energy consumption attributable to the installation of setback thermostats. The yearly heating energy consumption is equal to the total yearly energy consumption (entered manually by the user) less the yearly DHW heater consumption (determined as shown in Table 6-2 above). Energy savings are not impacted by the quantity of setback thermostats installed.

According to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative, "average savings (is) based on a study by RLW Analytics, for GasNetworks, as reported in Home Energy Magazine Online."

Heating System Clean & Tune Efficiency Improvement

The pre- and post-installation heating system efficiencies must be entered manually by the user. These efficiencies are used with the yearly heating energy consumption to determine the savings. The yearly heating energy consumption is equal to the total yearly energy consumption (entered manually by the user) less the yearly DHW heater consumption (determined as shown in Table 6-2 above).

Duct and Furnace Repair

Energy savings are not calculated for this measure in the EmPCalc Tool, and instead the estimated savings must be calculated and entered by the user manually.

According to the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative, "in situations where energy savings cannot be reasonably calculated, but the Program Implementer decides to go forward with the measure, no energy savings are estimated on EmPCalc."

Furnace or Boiler Replacement

The EmPCalc Tool calculates the energy savings associated with replacing a furnace or boiler in two ways:

- Energy savings associated with switching fuels (i.e., electric to natural gas)
- Energy savings associated with replacing an old inefficient heating system with a new, high efficiency heating system

Energy savings are provided in both kWh and therms, depending on the existing and proposed heating system type. In cases of fuel switching, negative energy savings are returned for the proposed heating system's fuel type since the baseline consumption for that fuel type is 0.

$$\Delta therms = L - \left(L \times \frac{E_1}{E_2}\right)$$

where,

$\Delta therms$	= The annual therms savings
L	= Estimated existing yearly heating load (therms) = total yearly energy consumption (entered manually by the user) less the yearly DHW heater consumption (determined as shown in Table 6-2 above)
E_1	= Efficiency of existing unit
E_2	= Efficiency of installed unit

The *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative also indicates that this measure may also include tune-ups on existing furnaces, although this is not stated on the EmPCalc Tool. In these cases, a default savings of 2% is noted as being acceptable.

11.2.2 Demand Reduction

The EmPCalc Tool does not calculate demand reduction, even if electric heat is selected.

11.2.3 Life of Measure

The EmPCalc Tool assumes a measure life of 15 years for all three measures in this section. However, life-cycle energy savings are not addressed in either the EmPCalc Tool or the 2011 *EmPower New York EmPCalc Energy and Cost Savings Calculations* narrative. The energy savings calculated in the EmPCalc Tool reflects the yearly heating energy savings only.

11.3 NYTM SAVINGS ESTIMATION APPROACH

The calculation method used in the NYTM is presented in this section.

11.3.1 Heating and Cooling Energy Savings

The NYTM provides annual energy savings calculation algorithms for calculating heating and cooling savings associated with the measures mentioned in Section 11.1. The methods for calculating both cooling and heating energy savings are presented below.

Setback Thermostat

Electric heating & cooling:

$$\Delta kWh = Units \times \left(\left(\frac{Ton}{Unit} \times \frac{12}{SEER} \times EFLH_{Cool} \times ESF_{Cool}\right) + \left(\frac{kBtu/h_{Out}}{Unit} \times \frac{EFLH_{Heat}}{100} \times ESF_{Heat}\right)\right)$$

Natural gas heating:

$$\Delta therms = Units \times \left(\frac{kBtu/h_{In}}{Unit}\right) \times \left(\frac{EFLH_{Heat}}{100}\right) \times (ESF_{Heat})$$

where,

ΔkWh	= The gross annual energy savings
$\Delta therms$	= The gross annual natural gas savings
$Units$	= The number of air conditioning units installed under the program
$\frac{Ton}{Unit}$	= Tons of air conditioning per unit, based on nameplate data (from application, or can use NYTM default of 3)
$SEER$	= The seasonal average energy efficiency ratio (Btu/watt-hour) (NYTM default = 10)
12	= Conversion factor (kBtu/h/ton)
ESF	= The energy savings factor (NYTM defaults: heat = 0.068, cool = 0.09)
$\frac{kBtu/h_{Out}}{Unit}$	= The nominal rating of the heating output capacity of the heat pump in kBtu/hr (including supplemental heaters)
$\frac{kBtu/h_{In}}{Unit}$	= The nominal rating of the heating input capacity of the furnace, boiler or heater in kBtu/hr (from application, or can use NYTM defaults: furnace = 90 kBtu/hr, boiler = 110 kBtu/hr, elec resistance heater = 12 kBtu/hr)
$HSPF$	= The heating seasonal performance factor (Btu/watt-hr), a measure of the seasonal average efficiency of the heat pump in the heating mode
$EFLH_{Heat}$	= The heating equivalent full-load hours (look-up based on location)
$EFLH_{Cool}$	= The cooling equivalent full-load hours (look-up based on location)

Furnace tune-up:

$$\Delta therms = Units \times \left(\frac{kBtu/h_{In}}{Unit}\right) \times \left(\frac{EFLH_{Heat}}{100}\right) \times (ESF_{Heat})$$

where,

$\Delta therms$ = The gross annual natural gas savings

$Units$ = The number of units installed

$\frac{kBtu/h_{In}}{Unit}$ = The nominal heating input capacity in kBtu/hr (from application)

$EFLH_{Heat}$ = The heating equivalent full-load hours (relative to nameplate) (look-up based on location)

ESF = The energy savings factor (NYTM default = 0.05)

Duct insulation and leakage sealing:

$$\Delta kWh = Units \times \left(\frac{Ton}{Unit} \times \frac{12}{SEER} \times EFLH_{Cool} \times \left(1 - \frac{\bar{n}_{Dist,base}}{\bar{n}_{Dist,ee}}\right)_{Cool} \right) + \left(\frac{kBtu/h_{Out}}{Unit} \times \frac{EFLH_{Heat}}{HSPF} \times \left(1 - \frac{\bar{n}_{Dist,base}}{\bar{n}_{Dist,ee}}\right)_{Heat} \right)$$

$$\Delta therms = Units \times \left(\frac{kBtu/h_{In}}{Unit} \right) \times \left(\frac{EFLH_{Heat}}{100} \right) \times \left(1 - \frac{\bar{\eta}_{Dist,base}}{\bar{\eta}_{Dist,ee}}\right)_{Heat}$$

where,

ΔkWh = Gross annual electricity savings

$\Delta therms$ = Gross annual natural gas savings

$Units$ = The number of units treated

$\frac{kBtu/h_{In}}{Unit}$ = The nominal input rating of the heating capacity of the furnace

$\frac{kBtu/h_{Out}}{Unit}$ = The nominal output rating of the heating capacity of the heat pump

$\frac{Ton}{Unit}$ = The nominal rating of the cooling capacity of the air conditioner or heat pump in tons

$SEER$ = The average energy efficiency ratio over the cooling season (Btu/watt-hour) (NYTM default = 10 for existing units, 13 for new construction)

$HSPF$ = The average heating season efficiency of heat pump (Btu/watt-hour) (NYTM default = 6.8 for existing heat pumps, 8.1 for new heat pumps)

$\bar{\eta}_{dist}$ = The duct system average seasonal efficiency

$EFLH_{Cool}$ = The cooling equivalent full load hours (look-up based on location)

$EFLH_{Heat}$ = The heating equivalent full load hours (look-up based on location)

100 = Conversion factor (kBtu/h/therm)

New High-Efficiency Furnace:

$$\Delta therms = Units \times \left(\frac{kBtu/h_{In}}{Unit}\right) \times \left(1 - \frac{AFUE_{Base}}{AFUE_{EE}}\right) \times \left(\frac{EFLH_{Heat}}{100}\right)$$

where,

$\Delta therms$	= Gross annual natural gas savings
$Units$	= The number of units installed
$\frac{kBtu/h_{In}}{Unit}$	= The nominal heating input capacity in kBtu/hr (provided on application)
$AFUE$	= Average fuel utilization efficiency (0-100) (NYTM default base = 78%, efficiency = provided on application)
$EFLH_{Heat}$	= The heating equivalent full-load hours (relative to nameplate) (look-up based on location)

New high-efficiency boiler:

$$\Delta therms = Units \times \left(\frac{kBtu/h_{In}}{Unit}\right) \times \left(1 - \frac{AFUE_{Base}}{AFUE_{EE}}\right) \times \left(\frac{EFLH_{Heat}}{100}\right)$$

where,

$\Delta therms$	= Gross annual natural gas savings
$Units$	= The number of units installed
$\frac{kBtu/h_{In}}{Unit}$	= The nominal heating input capacity in kBtu/hr (provided on application)
$AFUE$	= The average fuel utilization efficiency (0-100) (NYTM default base = 80% for hot water boilers, 75% for steam boilers)
$EFLH_{Heat}$	= The heating equivalent full-load hours (relative to nameplate) (look-up based on location)

11.3.2 Demand Reduction

The NYTM provides peak demand savings calculation algorithms for only one of the five heating measures, duct repair, which is presented below.

Duct repair:

$$\Delta kW = Units \times \left(\frac{Ton}{Unit} \times \frac{12}{SEER} \times \left(1 - \frac{\bar{n}_{Dist,pk,base}}{\bar{n}_{Dist,pk,ee}}\right)\right) \times CF$$

where,

ΔkW	= Gross coincident demand savings (definition not provided in the NYTM)

$\bar{n}_{Dist,pk,base}$ = Duct system baseline efficiency under peak conditions (measured, or NYTM default of 20%)

$\bar{n}_{Dist,pk,EE}$ = Duct distribution system proposed efficiency under peak conditions (see table 11-3 below)

CF = Coincidence factor = 0.8

See Section 11.4.1 for definitions of all other variables.

The NYTM states that the duct distribution system efficiency should be based on the measured duct leakage, or on the default values shown in Table 11-3 when measurements are not available. No detail is provided on how this calculation is completed.

Table 11-3. Default Duct Leakage Rates

Construction Type	Duct Location	Total Leakage (%)
New	Inside thermal envelope	10%
New	Outside thermal envelope	6%
Existing	All	20% or 50% reduction (whichever is greater)

11.3.3 Life of Measure

Measure life or life cycle energy savings for this measure is not provided in the NYTM.

APPENDIX D: METHODS

This appendix details the data collection and analysis methods used by the Impact Evaluation Team to identify the reasons why the Program was overestimating natural gas savings and determine recommendations for the Program to improve those estimates.

1.1 ESTABLISHMENT OF TESTED HYPOTHESES

Following initial analysis of project files, billing results, tracking data and secondary data, the evaluation team worked with Program and Department of Public Service (DPS) staff to select hypotheses to be tested. These hypotheses are summarized in Table D-1.

Table D-1. EmPower Phase II Hypotheses Analysis Parameters and Topics

Program Stage	Hypothesis	Testing Method
Analysis tool	Algorithms in the EmPCalc tool are not correct or are inadequate	▪ Examine EmPCalc tool and associated documents ▪ Review installation contractor data collection documents (project file review)
	Site-specific billing calibration will improve the accuracy of savings estimates	▪ Calculate whole-home heat load and calibrate the load and estimated savings to pre-installation billing data; compare calibrated savings estimates to realized savings (n=98)
	Inputs into tool are incorrect due to user errors	▪ Project file review ▪ EmPCalc manual review
	Tool does not account for air leakage	▪ Assess correlations between heating fuel use and infiltration
Program tracking	System and/or random errors are made when entering data into the reported savings database Data entry errors upwardly bias the reported savings	▪ Quantify the impact of transcription errors by comparing the EmPCalc cover sheet savings to the reported savings (n=187) ▪ Provide input to the program implementor's data cleaning/QA/QC plan
In-field data collection and measure installation	Field protocols are inadequate	▪ Review field protocols and training
	Measures are not installed correctly Measures are not correctly characterized in the savings calculations	▪ On-site field verification of factors including dimensions, post-installation R-values (n=98), and pre-/post- blower door readings (n=16)
Behavioral changes	Snapback refers to changes in use patterns after the installation of an energy-efficient product that reduce the overall measure savings	▪ Field visits to homes (n=98) ▪ On-site surveys (n=98) ▪ Further analysis of billing consumption changes

Each targeted hypothesis was tested as shown in the table above. The data collection and analysis methodology for each testing method is discussed in subsequent sections of this appendix.

1.2 ON-SITE DATA COLLECTION AND ANALYSIS

The primary data collection activity consisted of on-site surveys. Data collected on-site was used to create a thermal model of each site visited, evaluate the accuracy of data collected by installation contractors[1], and complete parametric analysis of EmPCalc variables. The on-site data collection process and successive analysis methods are described in this section.

1.2.1 On-Site Sampling

The on-site sampling strategy was designed to select homes most likely to provide insights into the low realization rates. To that end, the on-site sampling plan targeted single-family homes that had pre- and post-installation billing data available, had installed insulation measures, had a savings estimates greater than 400 therms, and had achieved either a very high (>30%) or a very low (<15%) natural gas savings fraction[2]. The complete on-site sampling plan is included in Appendix E.

1.2.2 On-Site Recruitment

The overarching recruitment plan consisted of a dual outreach approach, which included the distribution of an advance letter to targeted sites and a follow-up outreach call. Initially, sites were grouped into batches by stratum and location for a more targeted approach. However, the inherent challenges of recruiting low-income residential sites led the Impact Evaluation Team to expand the recruitment pool to include all 220 sites.

At the outset of the study, NYSERDA and NFGDC agreed that a one-hundred dollar check incentive would increase site participation. The incentive was to only be offered after a site contact had been verified, and then the check was to be provided to the site contact upon completion of the visit. A check tracking spreadsheet was created, updated, and maintained by the Impact Evaluation Team per NYSERDA's guidelines. Details about the incentive offering and check tracking can be found in Appendix I. To increase site participation, language regarding the incentive was included in the advance letters and recruitment calls.

A week was budgeted between the initial mailing of a site's advance letter and the first recruitment call in order to ensure receipt of the letter prior to the call. Site recruitment was tracked and prioritized using an internal FileMaker database, which was updated in real time to reflect which sites had been contacted,

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[1] The Program uses three different types of contractors, as follows: 1) Installation contractors are responsible for the initial audit, savings calculations, and measure installation; 2) The Implementation Contractor approves or rejects measures received from the installation contractor, reviews each EmPCalc for accuracy, and conducts quality control checks; 3) The Quality Assurance Contractor conducts customer surveys and site-visits at a sample of homes to verify that all measure installations are completed satisfactorily.

[2] The site-specific savings fraction was calculated to be the realized savings divided by the baseline usage.

who was called, and the outcome of each call. If the outcome of a call was neither a successful recruitment nor a refusal, the outreach team made repeated calls to the site as they deemed appropriate, taking into consideration the call result (e.g., dropped call, hang up, etc.), targeted on-site timeline, and time of the previous contact attempts.

The Impact Evaluation Team worked to increase the recruitment yield by emphasizing the availability of the incentive over the phone, calling during and after business hours, and offering flexible site visit dates and times to include weekend and evening appointments as requested. During the last month of on-site work, extra effort was made to recruit non-responsive sites by physically stopping by in-sample homes and either attempting in-person recruitment or leaving an additional copy of the advance letter if the resident was not home.

1.2.3 On-Site Data Collection Activities

The on-site data collection plan, as shown in Appendix F, was developed so that the heat loss through the building envelope[3] could be calculated for each site. As such, on-site teams collected all exterior building dimensions, defined all materials used in exterior surface assemblies, and noted thermostat setpoints[4] and system efficiency data. The on-site teams also inspected air-sealing installation, inventoried air leaks, systematically inspected outlets to assess wall insulation, confirmed the installation of both electric and natural gas measures, and measured attic insulation levels. Blower door tests were conducted at sixteen homes. Additionally, a survey was conducted with each on-site participant. The complete results of this survey effort can be found in Appendix G.

1.2.4 Assessment of Installation Contractor Data

The home characteristics and measure details collected on-site were used to test how well installation contractors represented building dimensions, blower door measurements, and installed measure characteristics. This testing was made possible through the direct comparison of EmPCalc values and evaluated values determined on-site. The EmPCalc values for each site were tabulated by manually recreating each EmPCalc from the PDF version of the project file. Extensive quality control was required to ensure data collected during the site visits and tabulated from the project files was accurately entered and complete.

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[3] The building envelope is the physical separator between the conditioned and unconditioned environment of a building to include both surfaces and penetrations such as windows and doors. The three basic elements of a building envelope are a weather barrier, air barrier, and thermal barrier.

[4] The thermostat setpoint is the interior temperature setting selected by a resident and maintained by a thermostat. A functional thermostat will control a home's heating system in order to satisfy the specified temperature setpoint.

During 2010 and 2011, installation contractor sketches did not include references to which exterior surfaces were treated through the Program. This created uncertainty when the field staff attempted to verify air sealing and insulation installations on-site. Even so, the Impact Evaluation Team identified several points for comparison between the installation contractor values and observed values, including building perimeter, attic insulation characterization, and blower door test results.

1.2.5 Heat Load Analysis

The heating fuel consumption among customers in the residential sector can be quite varied due to an assortment of reasons, including but not limited to: (1) site-specific solar heat gains, (2) imperfectly represented internal temperature profiles with lower temperatures at the exterior walls, (3) unpredictable occupancy schedules, and (4) other unidentified reasons. Calibration to billed usage is a typical method for increasing the accuracy of thermal models like EmPCalc. The Impact Evaluation Team hypothesized that site-specific billing calibration would improve the savings estimates of the highly variable Program population. To test this theory, the Impact Evaluation Team developed a whole-home heat load model that used the same heat loss calculation methodology and assumptions as EmPCalc. As discussed in the report and in Appendix H, the site-specific heat load calibration results ultimately yielded a recommendation to apply a single thermal calibration factor (CF) to savings estimates instead of site-specific CFs. However, it is important to discuss the site-specific calibration methodology because the Impact Evaluation Team used the site-specific results to calculate the recommended single thermal CF. Details about the heat load analysis methodology, including the calculation of site-specific CFs and the single thermal CF, are presented in this section.

Modeling Whole Home Heating Usage

During each of the 98 site visits, the Impact Evaluation Team measured the surface area and characterized the materials used in every surface on the thermal boundary[5] (e.g., exterior walls, knee-walls, attics, ground floors, rim joists, windows, and doors). The Impact Evaluation Team utilized a combination of project file data and customer interviews to characterize the pre-installation building envelope. In contrast, the post-installation building envelope characteristics were determined from observations made on-site. The Impact Evaluation Team relied on project file data and customer interviews to characterize surfaces that could not be visually inspected due to safety concerns, physical obstructions, or lack of permission from the homeowner.

[5] The thermal boundary is defined as the surface between conditioned and unconditioned spaces.

The Impact Evaluation Team used the building envelope characteristics to select the most appropriate pre- and post-installation insulation R-values[6] as defined in EmPCalc. The selected EmPCalc R-values were used in the following equation to calculate the thermal conductivity, or resistance to heat transfer, of each surface on the building envelope.

$$U_{Surface} = \frac{1}{4.44 + R_{Insulation}}$$

where,

$U_{Surface}$ = Surface thermal conductivity[7] (Btu/hr/ft^2/°F)

4.44 = Assumed R-value of uninsulated surfaces, consistent with EmPCalc (hr ft^2 °F/Btu)

$R_{Insulation}$ = Insulation R-value (hr ft^2 °F/Btu)

In addition to calculating the thermal conductivity of the building envelope, the Impact Evaluation Team inspected each home's heating system and conducted interviews to classify each interior space into one of two categories, heated or semi-heated. For modeling purposes, heated spaces were assumed to be 60°F[8] and unheated spaces were assumed to be the average of 60°F and the outdoor air temperature as determined from typical meteorological weather data. Although the surfaces will conduct heat any time there is a difference between the indoor and outdoor temperatures, this heat conduction will only contribute to the space heating load if the heating system is enabled and the temperature differential is significant enough to overcome the internal loads and thermal mass of the home. To account for this, the Impact Evaluation Team assumed that the thermal losses would only contribute to the heating load during non-summer months when the outdoor air temperature is 5°F below the 60°F interior temperature (i.e., 55°F). The Impact Evaluation Team used the following equation to calculate the annual heat loss through the building envelope.

$$Q_{Surface} = \sum_{i=1}^{8760} \begin{cases} 0, & T_{OA\,i} > 55^{\circ} \\ U_{Surface} \times A_{Surface} \times \left(T_{Space} - T_{OA\,i}\right), & T_{OA\,i} \leq 55^{\circ} \end{cases}$$

where,

$Q_{Surface}$ = Annual surface heat loss for an individual surface (Btu)

[6] The R-value is the measure of a material's resistance to conductive heat transfer.

[7] The U-values of windows and doors were not calculated using with the equation above, but were determined from ASHRAE.

[8] The 60°F thermostat setpoint was determined through a PRISM-type analysis of the population. Additional details about this analysis are provided in Section 1.4.1.

$A_{Surface}$ = Surface area (ft^2)

T_{Space} = Heated or semi-heated space temperature (°F)

$T_{OA\,i}$ = Typical outdoor air temperature (TMY3) based on home location at hour i (°F)

i = Hourly index (hr)

Infiltration losses also contribute to a home's energy consumption. The Impact Evaluation Team quantified the infiltration load using the installation contractor's blower door test results (CFM50) to approximate the average natural air changes per hour for each home. This methodology is summarized in the following equation, which sums the energy content of air leaving the conditioned space when the heating system is operating.

$$Q_{infiltration} = \sum_{i=1}^{8760} \begin{cases} 0, & T_{OA\,i} > 55^{\circ} \\ \frac{CFM50}{V \times n\_factor} \times 60\, {}^{min}/_{hr} \times C_p \times \rho \times (60 - T_{OA\,i}), & T_{OA\,i} \leq 55^{\circ} \end{cases}$$

where,

$Q_{infiltration}$ = Annual infiltration heat loss (Btu)

$CFM50$ = Blower door test results (cfm at 50 Pa)

V = Heated volume (ft^3)

n_factor = Correction factor from CFM50 to natural infiltration rate = 14.8

C_p = Specific heat capacity of air (Btu/lb/°F)

ρ = Density of air (lb/ft^3)

$T_{OA\,i}$ = Typical outdoor air temperature (TMY3) based on home location at hour i (°F)

The Impact Evaluation Team modeled the total annual heat load consumption using the following equation, which combines the building's conductive losses, infiltration losses, and the efficiency of the heating system. Similar to EmPCalc, contributions from internal loads and solar heat gain were not included in the modeled annual heat load consumption.

$$Modeled\ annual\ heat\ load\ consumption = \frac{\sum Q_{surface} + Q_{infiltration}}{Eff} \times 10{,}000\, {}^{Btu}/_{therm}$$

where,

Eff = Rated heating system efficiency (%)

Calibrating Whole Home Heating Usage to Billing Data

The Impact Evaluation Team used site-specific, weather-normalized pre-installation billing data to calibrate the modeled annual consumption. Because the insulation and air sealing measures only affect the space heating component of the billed natural gas usage, the Impact Evaluation Team omitted all other base loads from the utility billing data. The Impact Evaluation Team approximated the magnitude of these base loads – which could include domestic hot water, laundry, and cooking – to be the average of the natural gas consumption in June, July, and August. This approximation well represents the non-heating base loads throughout the year because participant surveys revealed that heating systems are not enabled during these summer months, indicating that there are no heating loads. The following equation was used to approximate the weather-normalized annual billed natural gas consumption for space heating.

$$\begin{aligned}&\textit{Billed annual heat load consumption}\\&\quad = \textit{Billed annual consumption}_{Total,normalized}\\&\quad - \left(\textit{Billed monthly consumption}_{Base} \times 12\, {}^{months}/_{yr}\right)\end{aligned}$$

where,

$\textit{Billed annual heat load consumption}$ = Weather-normalized billed annual natural gas consumption for space heating (therms)

$\textit{Billed annual consumption}_{Total,normalized}$ = Weather-normalized billed total annual fuel consumption (therms)

$\textit{Billed monthly consumption}_{Base}$ = Weather-normalized billed monthly fuel consumption for base loads (therms)

The Impact Evaluation Team calculated a site-specific CF for each modeled home using the billed pre-installation heating consumption and the modeled pre-installation heating consumption as shown below.

$$CF_{Site-specific} = \frac{\textit{Billed annual heat load consumption}_{Pre}}{\textit{Modeled annual heat load consumption}_{Pre}}$$

The Impact Evaluation Team then used the site-specific CF to calibrate the modeled post-installation heating usage. The calibrated savings estimate for installed insulation and air sealing measures was calculated to be the difference between the calibrated pre-installation heating usage and the calibrated post-installation heating usage. The Impact Evaluation Team calculated the calibrated insulation and air sealing savings estimate for each site using site-specific CFs as shown in the following equation.

$$
\begin{aligned}
&Estimated\ savings_{Site-specific} \\
&\quad = \left(Modeled\ annual\ heat\ load\ consumption_{Post} \times CF_{Site-specific}\right) \\
&\quad - Billed\ annual\ heat\ load\ consumption_{Pre}
\end{aligned}
$$

The calibrated savings estimates were then compared with the reported and evaluated savings to quantify the impact of site-specific billing calibration on claimed savings. The following equation was used to make this comparison.

$$RR_{Calibrated} = \frac{Evaluated\ savings}{Estimated\ savings_{Site-specific}}$$

where,

$RR_{Calibrated}$ = Realization rate using calibrated heat load estimates

$Evaluated\ savings$ = Actual savings using weather-normalized billing analysis (therms)

The results of the site-specific heat load analysis are presented in Appendix H. Upon reviewing the results the Impact Evaluation Team concluded that the application of site-specific CFs improves the savings estimation accuracy on average, but does not improve the model's ability to make better site-specific savings estimates. Since the development of a site-specific CF would require installation contractors to create a thermal model of the whole home – a time consuming process – an additional test was performed to see whether a single CF used across the Program might perform as well as site-specific CFs in estimating savings.

Development of the Single Thermal CF

The Impact Evaluation Team used post-installation building characteristics to model the post-installation heating load of every home included in the onsite sample. A single thermal CF was calculated using the modeled post-installation heat loads and billed post-installation heating usage for all 98 sites as follows:

$$CF_{Single\ thermal} = \frac{\sum Billed\ annual\ heat\ load\ consumption_{Post}}{\sum Modeled\ annual\ heat\ load\ consumption_{Post}}$$

The Impact Evaluation Team used post-installation data (instead of pre-installation data) to calculate the single thermal CF because there was less uncertainty about post-installation building conditions and behaviors since they were directly observed by the on-site data collection teams.

1.2.6 Evaluation of EmPCalc Assumptions

The Impact Evaluation Team ran a series of parametric analyses to test the validity of various EmPCalc assumptions. In this analysis, savings were estimated for each of the 98 on-sites using first one assumption (e.g. the EmPCalc 30 year average weather based HDD) and then the alternative (e.g. the

TMY3 weather based HDD), keeping everything else constant. The methods used to analyze the assumptions are discussed in this section.

Tested Parameters

After reviewing the EmPCalc savings calculations for each heating measure, the Impact Evaluation Team identified several EmPCalc variables that were hypothesized to overestimate savings claims. Each parameter is discussed in this section.

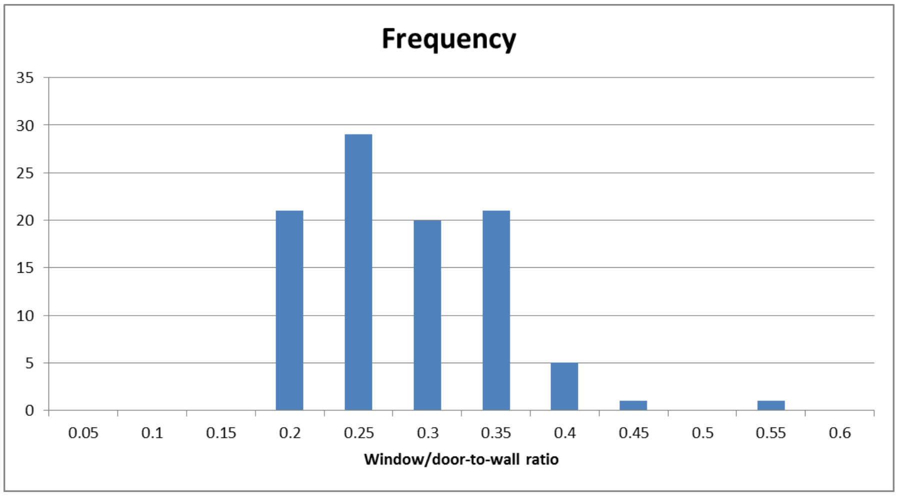
Insulated Area and Thickness

The Impact Evaluation Team tested the insulated area and thickness parameters to determine the accuracy of installation contractor measurements and data entry into the EmPCalc tool. The Impact Evaluation Team completed savings calculations using site-specific area and thickness data gathered from site visits in place of the installation contractor-supplied values.

Window-to-Wall Ratio

The window-to-wall ratio is a number describing the percent of total surface area that is untreatable due to the presence of windows, doors, or internal framing instead of insulatable wall. This factor is applied in EmPCalc to the total insulated area claimed by the installation contractor to account for the non-insulated wall space. EmPCalc version 3.41 uses a 15% window-to-wall ratio. In order to check this factor, the Impact Evaluation Team calculated the site-specific window-to-wall ratio of each home visited. This was accomplished by collecting detailed wall, door, and window measurements while on-site, and accounting for standard construction methods to define the framing dimensions around windows and doors. The Impact Evaluation Team found the average window-to-wall ratio across evaluated sites to be approximately 23%. The window-to-wall distribution is shown in Figure D-1.

Figure D-1. Distribution of Window-to-Wall Ratios



Heating Degree Days

EmPCalc uses heating degree days (HDDs) to calculate heat loads. According to the *EmPower New York EmPCalc Energy and Cost Savings Calculations* document dated 1/1/2011, EmPCalc HDDs are calculated from a 30-year average weather data set; no data is provided about the balance point[9] used in the HDD calculation. In contrast, the Impact Evaluation Team used pre-installation and post-installation billing data from all 5,760 sites included in the Phase I billing analysis to determine the most appropriate balance point to use in HDD calculations (based on PRISM analysis as described in Section 1.4). The Impact Evaluation Team calculated the recommended HDD shown in Table D-2 using TMY3 weather data and the following assumptions, which are based on empirical data collected in the on-site interviews:

- 60°F thermostat setpoint (based on PRISM analysis, see Section 1.4)
- No heating in June, July, and August
- The heating system will not activate until the outdoor air temperature is 5°F below the thermostat setpoint

Table D-2. Recommended EmPCalc HDD

EmPCalc Locations	EmPCalc 3.41 HDD[1]	TMY3 Locations[2]	Recommended HDD
NY City	4,777	New York Central Park	3,827
Mid-Hudson	7,237	Poughkeepsie	4,667
Southern Tier	6,806	Elmira	5,123
Capital/Saratoga	6,438	Albany	5,381
Central	6,803	Syracuse	5,271
Finger Lakes	6,728	Syracuse	5,271
Western	6,692	Buffalo	5,259
North Country	8,089	Massena	6,477

[1] The balance point used in the EmPCalc HDD calculations is unknown.
[2] TMY3 locations were selected by Program staff to be most representative of the current EmPCalc location options.

Combustion Efficiencies

The Impact Evaluation Team found that different heating system combustion efficiencies were used for different measures within the EmPCalc tool (version 3.41), resulting in some calculation discrepancies. Changing the heating system combustion efficiency will have a direct impact on the natural gas savings because it affects the natural gas used per unit of heat required to meet the load. The Impact Evaluation

[9] The balance point is the outdoor air temperature at which a home's heating system is required to turn on to satisfy the thermostat setpoint.

Team used a single combustion efficiency value across all calculations; the evaluated value was selected according to the following logic:

- If the heating system was repaired or replaced, then the efficient case combustion efficiency is used in all other heating measure calculations
- If the heating system was not repaired or replaced, then the measured combustion efficiency is used in all heating measure calculations
- If there is no value for the measured combustion efficiency in the project file, then the EmPCalc defined default combustion efficiency of 74% is used in all heating measure calculations

The combustion efficiency inconsistencies were identified in EmPCalc version 3.41 and other versions used during 2010–2011. However, these inconsistencies have since been fixed and are not found in later EmPCalc versions.

R-Values

EmPCalc assumes a conservative pre-installation R-value of 4.44 for uninsulated surfaces; the R-value of any pre-existing or installed insulation is added to the 4.44 uninsulated surface R-value to yield the total surface R-value. All of the EmPCalc R-values can be found in Section 3 of Appendix C. The Impact Evaluation Team compared the EmPCalc R-values to assembly R-values calculated under the assumption that no pre-existing insulation is present. This involved defining the different layers of the building envelope and then using corresponding ASHRAE R-values for each layer. The R-values used by the Impact Evaluation Team can be found in Table D-3 and Table D-4 below. In this way, site-specific envelope calculations were created for each site the Impact Evaluation Team visited.

Table D-3. Uninsulated Surface Assembly R-values

Surface Type	Assembly Materials	R-Value
Above-grade wall	Brick, 2x4, gypsum interior	1.22
Above-grade wall	Brick, 2x6, gypsum interior	1.40
Above-grade wall	Aluminum, steel, or vinyl siding, 0.75" plywood, 2x4, gypsum interior	2.36
Above-grade wall	Aluminum, steel, or vinyl siding, 0.75" plywood, 2x6, gypsum interior	2.54
Above-grade wall	Wood siding or shakes, 0.75" plywood, 2x4, gypsum interior	2.56
Above-grade wall	Wood siding or shakes, 0.75" plywood, 2x6, gypsum interior	2.74
Knee wall	2x4, gypsum interior	0.76
Knee wall	2x6, gypsum interior	0.94
Roof	Asphalt roof, 2x10, 0.75" plywood, gypsum interior	2.68
Roof	Slate roof, 2x10, 0.75" plywood, gypsum interior	2.33
Roof	Metal roof, 2x10, 0.75" plywood, gypsum interior	2.28
Open attic	2x10, gypsum interior	1.29

Table D-4. ASHRAE Insulation R-Values

Insulation Type	Alternative Material Names	R-Value
None	N/A	0.00
Cellulose	Loose fill, dense pack, spray on	3.42
Fiberglass	Batts, blown, rigid board	3.78
Mineral wool	Batts, loose fill, rigid board	3.42
Perlite	N/A	N/A
Polyisocyanurate	N/A	N/A
Polyurethane	N/A	5.91
Polystyrene	Expanded, extruded	5.00
Spray foam	N/A	5.91
Vermiculite	N/A	2.20

Parameter Testing Methodology

The Impact Evaluation Team tested the impact that each parameter discussed in Section 1.2.6 above has on the EmPCalc savings estimates. The impact of each parameter was assessed by recreating the savings estimate using EmPCalc 3.41 and comparing the result to a parametric run in which a new savings estimate was calculated using the adjusted parameter. The Impact Evaluation Team used EmPCalc version 3.41 because it was used by installation contractors in 2010 and 2011. Additionally, by recreating the savings estimates with a single EmPCalc version, the Impact Evaluation Team was able to eliminate any variability caused by different EmPCalc versions. The list of tested parameters can be found in Table D-5.

Table D-5. EmPCalc Parametric Runs

Run	Parameter Investigated	Description
0	Recreated EmPCalc 3.41	No changes made, this is the baseline for comparison
1	Evaluated areas	Evaluated insulated areas were used in place of installation contractor values
2	Evaluated insulation thicknesses	Evaluated insulation thicknesses were used in place of installation contractor values
3	Evaluated R-values	Evaluated built-up R-values used in place of installation contractor values
4	Evaluated window-to-wall ratio	Evaluated window-to-wall ratio used in place of 15% EmPCalc factor
5	Evaluated combustion efficiencies	Evaluated combustion efficiencies used in place of reported EmPCalc values, errors in logic adjusted
6	Evaluated HDD	Updated HDD based on TMY3 data used in place of EmPCalc HDD
7	Evaluated areas and insulation thicknesses	Combines runs 1 and 2 to quantify the total potential installation contractor error
8	Evaluated window-to-wall ratio, combustion efficiency, and HDD	Combines runs 4, 5, and 6 to quantify the recommended EmPCalc changes

After each parametric run, the natural gas savings calculated within each trial was compared to the natural gas savings of the recreated EmPCalc 3.41, run 0, to determine how the changes affected the reported savings estimates and the overall realization rate. The results of these comparisons can be found in Appendix H.

1.3 ADMINISTRATIVE ERROR ANALYSIS

Project file reviews and analysis of the reported savings database reveled that administrative errors can and do occur. The Impact Evaluation Team tested the hypothesis that these random administrative errors upwardly bias the reported savings, and therefore reduce the achieved RR.

The Impact Evaluation Team determined that the Program's administrative errors can be broken into the following two main categories: 1) Error that occurs during the manual transposition of the EmPCalc savings estimates into the reported savings database, and 2) Error that occurs during the savings calculation in the EmPCalc tool.

The first type of administrative errors, transposition errors, are simple data entry mistakes that could be attributed to typos, rounding errors, incorrect decimal placement, or failure to account for savings estimate updates made after an installation or quality control inspection. This type of administrative error was quantified by comparing the EmPCalc cover sheet[10] savings estimates to the reported savings of a sample of 187 project files with suspected data entry errors. The initial sample frame included all projects installed in 2010/2011 with a reported natural gas savings fraction[11] greater than 40% and a pre-installation natural gas consumption greater than 500 therms. The sample breakdown is presented in Table D-6.

Table D-6. Administrative Error Sample

Stratum	Reported Savings Fraction Range	Number of2010/2011 Projects with Pre-Installation Usage > 500 therms	Number of 2010/2011 Projects Used in Admin Error Analysis	Number of 2010/2011 Project Files without EmPCalc
1	> 100%	33	32	1
2	80% - 100%	52	39	0
3	60% - 80%	142	43	0
4	40% - 60%	444	73	2
Total	**N/A**	**671**	**187**	**3**

[10] When the Implementation Contractor targets individual measures for installation, their associated measure-level EmPCalc savings are summed in the EmPCalc cover sheet.

[11] The site-specific savings fraction was calculated to be the realized savings divided by the baseline usage.

The second type of administrative errors, savings calculation errors, are mistakes made within the EmPCalc tool itself by either the installation contractor during on-site data entry or by the Implementation Contractor during measure review and approval. For example, EmPCalc features several check boxes that the Implementation Contractor uses to select measures for installation and subsequently approve measures for payment after installation. A data entry error could be made by the Implementation Contractor if he/she fails to check or uncheck a "Targeted Measure" or "Measure Approved" box. Alternatively, a data entry error could be made by the installation contractor if he/she fails to check or uncheck a "Use Default Efficiency" box, or makes typographical errors in any numerical entry (area, blower door cfm, installed quantity, etc.). These types of errors could not be quantified without knowing the intended installation contractor and Implementation Contractor entries. However, it should be noted that the validity and meaning of checked/unchecked boxes and outlier EmPCalc inputs generated uncertainty during field work and likely had a similar result during the QA/QC process.

1.4 BILLING ANALYSIS

The impact evaluation team investigated the hypothesis that the low natural gas RRs might be due to either a snapback effect or change in economic status. Two billing analysis tasks were proposed to investigate these phenomena:

- A PRISM-type billing analysis to investigate snapback. PRISM analysis provides an indirect indicator of interior space temperatures which could, in turn, infer temperature setpoint changes associated with snapback.
- A re-analysis of the Phase I billing analysis including economic indicators to potentially tease out the impact of the financial crisis on broader energy use trends.

The re-analysis of the Phase I billing analysis proposed to incorporate economic trends data to determine if some of the changes in energy use could be explained by changes in the broader economy (e.g., shifts in unemployment rates or average weekly wages). The viability of this analysis requires that economic trend data show enough month-to-month to yield a statistically valid result. Unfortunately, the financial crisis had occurred well before most of the installations (where a precipitous drop in economic trends was observed). During the period when most of the participation occurred, neither the unemployment nor weekly wages show much variation. Any analysis of the trends was further compromised because of inherent seasonal economic fluctuations. Further billing analysis incorporating economic trends was abandoned.

Snapback is a reduction in potential energy savings due to changes in use patterns after the installation of an energy-efficient product. It was hypothesized that participants may have increased space temperatures because they could afford more comfort. In a home with newly installed insulation and air sealing, the outdoor temperature at which a home requires heating – or balance point –should go down because less heat is lost through the newly treated exterior surfaces. The balance point for a home can be estimated using a billing analysis approach based on the Princeton Scorekeeping Method (PRISM), which seeks to find the best base temperature for HDD in estimating weather-normalized annual consumption from billing data. If the balance point increases, it can indicate that the home's thermostat setpoint is higher, thereby using more heating energy than what it would if the previous temperatures had been maintained.

Additional billing analysis was conducted using PRISM-type analysis to see if there might be evidence of changes in the home's balance point. Such a change would indicate possible adjustments to internal temperature settings and provide evidence of snapback.

1.4.1 PRISM-Type Method

Given the emphasis on the balance point for heating, this analysis applied an approach based on the Princeton Scorekeeping Method (PRISM), which seeks to find the best base temperature for HDD in estimating weather-normalized annual consumption (NAC) from billing data[12]. This base temperature is equivalent to the balance point in this analysis methodology.

For this analysis, HDD were calculated using base temperatures ranging from 50°F to 75°F. These were combined with gas consumption from the monthly billing data and separate regression models were estimated separately by 1) project, 2) pre- and post-installation periods, and 3) HDD base temperature[13]. The general regression specification for each of these models was as follows:

[12] For more information, see "PRISM: An Introduction, by Margaret Fels, Energy and Buildings 9, #1-2, pp. 5-18 (1986). An essential reference for PRISM users, containing derivation of method and early applications," available at http://www.marean.mycpanel.princeton.edu/~marean/Publications.html.

[13] The post-installation period for this analysis consists of the 12 months after the project completion date. The pre-installation period, however, consists of the 12 months prior to 6 months before the project completion date. The removal of billing data from the 6 months prior to measure installation is intended to eliminate months where the effects of measures is uncertain, since it is not known exactly when they were installed and installations may have been staggered throughout a period of several months prior to the recorded project completion date.

$$ThermsPerDay = \alpha + \beta_{HDDPerDay} \times HDDPerDay + \varepsilon$$

where,

$ThermsPerDay$	= Therms consumed per day for a given billing period
α	= Intercept
$\beta_{HDDPerDay}$	= Slope associated with the heating degree days for the base temperature in question
$HDDPerDay$	= HDD per day for a billing period for the base temperature in question
ε	= Error

For each participant household, the pre- and post- models for the different HDD base temperatures were compared separately for each project based on the coefficient of determination[14] (R^2), which indicates the percentage of variability in consumption that is explained by the HDD. The HDD base temperatures with the highest R^2 were selected to represent the balance points for pre- and post-installation conditions.

There are two areas of emphasis in analyzing the results from the models. The first is the comparison of the selected balance points for the pre- and post- periods. This shows whether there was a change in balance point and its direction. Second, the intercept and slope from the regression models allow for the calculation of NAC for pre- and post- periods. Subtracting the post- NAC from the pre- is NAC provides the normalized savings at a project level, which is something that the Phase I billing analysis did not provide. Additionally, the intercept and slope allow for a breakout of consumption into pre-installation consumption and heating load. Since snapback is associated exclusively with heating, this allows a direct comparison of heating savings from NAC estimates with the expected savings in the program tracking data.

[14] The coefficient of determination, or R^2, indicates how well data fit a curve. A high R^2 value indicates a better curve fit than a low R^2 value.

MEMO

DATE: **April 30, 2014**

TO: Victoria Engel-Fowles, Jennifer Phelps, Evan Crahen and Eric Meinl

FROM: Sue Haselhorst, Jacque Heger Phelon, Kathryn Parlin

RE: **Final EmPower On-Site Sample Selection Protocol**

The purpose of this memo is to present the on-site M&V sample design for NYSERDA's EmPower program and National Fuel Gas Distribution Corporation's ("NFGDC") Low Income Usage Reduction Program ("LIURP"). The purpose of the on-site data collection is to investigate the sources of savings differences between the application estimates of savings and the savings determined through billing analysis. Unlike a typical impact evaluation, the outcome will not be program savings realization rates, but rather an *explanation* of the realization rates.

This memo reflects the discussion with NYSERDA and National Fuel Gas Distribution Corporation (NFGDC) during the meetings on February 26 and March 6.

INITIAL SAMPLE FRAME

In order to maximize the investigative power of this research, the initial sample frame for the M&V sites was defined as follows:

- **Single-family homes only** – Single family homes account for about 95% of all home types treated. Single family homes for this purpose include all dwellings where a single unit was treated in a building with four units or less. This definition is consistent with the Phase I billing analysis definition.
- **Homes included in the billing analysis** – During the secondary research phase, the pre- and post- billing data collected for the billing analysis was weather normalized to TMY3 weather data and used to calculate a site-specific billed savings (the difference between pre- and post- weather-normalized billed usage). Each site could, therefore, be examined for actual billed savings performance and a determination could be made on that basis whether the site had met the predicted savings or not.
- **Homes with insulation measures** – Insulation accounts for 86% of reported program natural gas savings and was installed in 92% of the homes in the billing analysis.

This population includes 1,236 homes. Further analysis of the data set was conducted to investigate trends in billed savings. The homes were sorted from highest to lowest reported savings and grouped into four strata, or quartiles, of equal program savings. This quartile analysis revealed some interesting trends, as shown in Table 1.

Table 1. Reported Savings Quartile Analysis

A - Stratum	B - Number of Homes	C - Reported Savings (therms)	Savings per Home: D - Reported Savings per Home	Savings per Home: E - Billed Savings per Home	F - RR%	Savings Fraction: G - Reported Savings Fraction	Savings Fraction: H - Billed Savings Fraction	I - Avg Cost per Home
Both NYSERDA and NFGDC Homes								
1	127	140,039	1,103	337	31%	64%	21%	$6,729
2	192	139,873	729	268	37%	42%	17%	$5,646
3	279	140,037	502	209	42%	32%	14%	$4,812
4	638	140,220	220	104	47%	15%	7%	$3,413
Grand total	1,236	560,169	453	177	39%	30%	12%	$4,416
NYSERDA - Only								
1	20	20,210	1,010	285	28%	76%	20%	$6,370
2	33	23,300	706	238	34%	44%	15%	$4,923
3	77	38,252	497	185	37%	39%	14%	$4,548
4	278	58,558	211	105	50%	17%	9%	$3,136
Grand total	408	140,319	344	140	41%	27%	11%	$3,705
NFGDC - Only								
1	107	119,829	1,120	346	31%	63%	22%	$6,796
2	159	116,573	733	274	37%	42%	17%	$5,795
3	202	101,786	504	218	43%	30%	14%	$4,913
4	360	81,662	227	103	45%	14%	7%	$3,626
Grand total	828	419,850	507	195	38%	30%	13%	$4,766

Note: Totals are presented at the bottom of columns B and C; these totals were used to create the average values at the bottom of columns D and E. The averages for all of the 1,236 in-sample sites are shown at the bottom of columns F-J.

As can be seen in Column D, stratum 1 has the homes with the highest projected savings per household, while stratum 4 has the lowest. Column E is the actual average savings per home according to the billing savings analysis described above. While the stratum 1 homes do indeed save more energy as demonstrated by the billing savings in column E, the realization rate is the poorest for homes in this stratum. This table demonstrates general tendencies observed in the data:

- Higher reported savings sites have more work done at the home, as demonstrated by the average cost of work done at the home in column I.
- Higher reported savings homes do save more energy, as demonstrated by the billed savings in column E.
- Higher reported savings homes save more of the pre-installation billed usage ("savings fraction"), as shown in column H. The billed savings fraction is calculated as the ratio of the billed savings divided by the weather normalized preinstalled billed usage.
- The realization rate decreases as reported savings increase, as shown by the realization rate in column F.

Another dimension to this data set is the program administrator. NFGDC accounts for a disproportionate share of program savings (approximately 50% of the program-reported natural gas savings), as well as sites in the billing analysis (67% of the sites), in comparison to sites from other utility service territories.

On-Site Site Selection Protocol

The on-site sample selection protocol will randomly select sites within cells defined by four factors:

1. Magnitude of the site reported savings
2. Program administrator
3. Achieved savings, as demonstrated by the billed savings
4. Geography

Magnitude of the Reported Savings

Table 1 clearly shows a relationship between the reported savings, evaluated savings, realization rates, and savings fractions. Stratification by reported savings will help ensure a good representation of those sites contributing most to program savings (those homes with the highest savings per home) and to the low realization rate (they also have, somewhat counterintuitively, lower realization rates). The sample design proposes to exclude sites with the lowest reported savings because these homes have had less work done and therefore there is less to verify and less to learn on-site.

Program Administrator

The program has two administrators: NYSERDA and NFGDC. The original intention was to split the sample with two-thirds of the sites allocated to NYSERDA and the balance to NFGDC. However, factors have conspired to make this simple allocation untenable. As noted previously, NFGDC's program makes up more than half of the total program savings and also the accounts in the billing analysis dataset. NFGDC sites are also concentrated in strata 1 and 2, those sites where we can gather the most information about factors driving savings. Finally, NYSERDA sites are dispersed across the state, making it impractical to include all of them in the site selection frame. Based on a review of all the factors, we propose allocating about one-half of the sites to NYSERDA and one-half to NFGDC.

Achieved Savings

In order to identify those practices and methods that lead to more savings observable in the bills and, hence, better realization rates, the sample protocol proposes classifying homes as follows:

- ❑ High achievers – Billing analysis savings fraction >30%

- Medium achievers – Billing analysis savings fraction 15%–30%
- Low achievers – Billing analysis savings fraction of <15%

As previously discussed, NFGDC sites make up a larger percentage of the initial sample frame (1,236 homes). In an effort to visit an approximately equal number of NFGDC and NYSERDA sites, two approaches will be taken with regard to achieved savings.

NFGDC Sites

NFGDC sites will be selected from the high and low achievers by stratum to provide the highest level of contrast between "good" sites and "bad" sites. This strategy is intended to delineate those factors that drive the better billing performance, whether the sources of those drivers are particular contractors or home types, incidence of snapback or other occupant behavior, or some other factors that we cannot identify *a priori*.

The thresholds for the high achiever vs. low achiever are somewhat arbitrary. The levels identified above provide a robust population within high and low achieving sites while still maintaining a wide spread between their savings. As a reference, the program was expected to achieve an average savings fraction of about 30%, while the actual achieved savings fraction was about 12%.

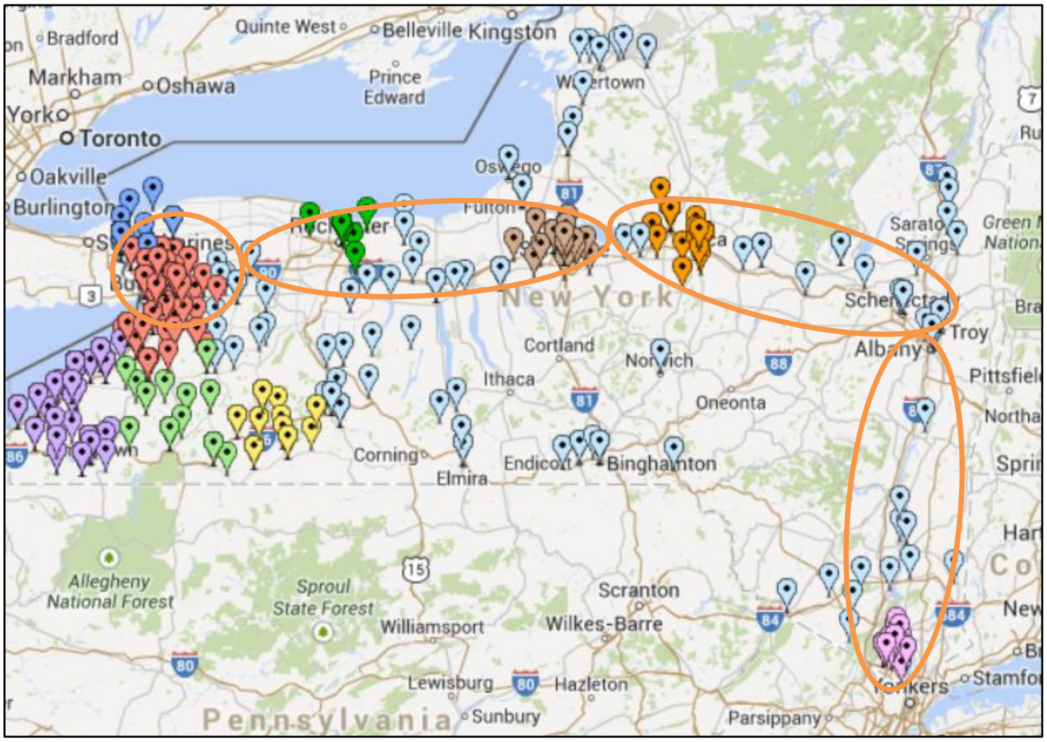
NYSERDA Sites

NYSERDA sites will be selected from the high, medium, and low achievers by stratum. Including the medium achievers increases the population in the NYSERDA sample frame.

Geography

For cost efficiency, the sites must be clustered to minimize driving times between visits. The sample frame will include specific geographic regions. Attention was paid to ensure that sites along the I-87 corridor (between Yonkers and Albany) and I-90 corridor (between Albany and Buffalo) will be included in the sample frame, as these sites provide easy access for field work. Approximately 72% of all sites in the initial sample frame (1,236 homes) are included in in the selected geographic regions. Sites will not be selected from outside these regions. The selected regions are circled in Figure 1.

Figure 1. Selected Geographic Regions for On-Site Selection



Note: The colored markers in Figure 1 above distinguish between counties (the light-blue marker indicates an "other" category which includes several counties with a small number of participating homes).

Other Potential Segmentation Schemes

It is possible that savings achievement and/or savings fractions are correlated with other factors such as contractors, rural vs. urban, renter vs. owner, or measure mix. The Impact Evaluation Team looked in particular at patterns by contractor, but did not see clear indicators that contractors were a driver of savings differences. Rather than speculate on factors that might be driving the model and selecting a sample that represents all possible hypotheses, we used instead the high/low achiever segments to focus on those sites that are achieving savings and those that are not. It is reasoned that if contractors, measure mix, or any other factor is strongly correlated to achieving savings, it should be apparent in the contrast of results between the achiever strata. As such, no contractors were intentionally removed from the sample population and homes served by a wide variety of contractors will be visited.

Final Sample Allocation Table

Table 2 summarizes the proposed sample selection design for the on-site sample.

Table 2. Proposed On-Site Sample Allocation

A - Stratum	Initial Frame: B - Number of Homes	Initial Frame: C - Reported Savings (therms)	Geography: D - Geo Select Number of Homes	Geography: E - Geo Select Reported Savings	PA Distribution: F - NYSERDA Homes	PA Distribution: G - NFG Homes	Final Proposed Sample: H - NYSERDA Allocation	Final Proposed Sample: I - NFG Allocation
1								
Hi	62	60,226	45	42,060	**5**	**40**	3	10
Low	70	67,209	45	43,729	**12**	**33**	8	20
Mid	84	82,614	59	54,839	**5**	**54**	3	
2								
Hi	61	32,376	45	23,687	**19**	**26**	12	10
Low	195	106,517	146	78,882	**41**	**105**	25	20
Mid	126	71,009	85	48,370	**19**	66	9	
4								
Hi	49	12,612	39	9,929	23	16		
Low	445	92,555	311	63,183	145	166		
Mid	144	35,053	117	27,883	58	59		
Grand total	**1,236**	**560,169**	**892**	**392,561**	**327**	**565**	**60**	**60**

The initial sample frame is presented in columns B and C with the number of homes and reported savings shown by stratum. Columns D and E present the final sample frame after selecting for geographical clusters. Columns F and G present the number of homes by program PA within the geographic clusters. The last two columns present the proposed number of completed site visits per stratum accounting for the fact that 100% recruitment rates will not be achieved.

The table reflects the stratification design as follows:

- **Magnitude of savings** – The three highest savings quartiles were collapsed into two segments of equal savings size to simplify the design. The Stratum 4 sites are excluded because they represent the smallest savers.
- **Achieved savings** – Each stratum is sub-segmented into high, medium, and low achieved savings (as indicated by billed savings). NFGDC medium sites will be excluded for on-sites, since these sites may present less clear indicators of factors that are driving savings. Conversely, NYSERDA medium sites will remain in the on-site sample in an attempt to visit an approximately equal number of NFGDC site and NYSERDA sites. The low achievers are disproportionally sampled since this is the group that will tell us what went wrong compared to a high achievers benchmark.

Sites will be randomly selected from each stratum and recruited in order of selection until the cell quota is fulfilled or exhausted.

Conclusions

The final proposed sample is a good balance of competing needs, including representation by PA, per site evaluation costs, distribution of contractors, and a focus on sites likely to reveal the sources of differences in savings. While the allocation between NYSERDA and NFGDC is different from the initial allocation, we believe that the issues found at all sites will inform the entire program and will be consistent between the two PAs. While the billing analysis did find differences between the two populations – both realization rates were lower than anticipated (37% and 49%, for NFGDC and NYSERDA, respectively) – and appeared to be explainable in part as an artifact of NFGDC's aggressive pursuit sites with the highest usage.

The evaluators analyzed any potential differences between sites included in the sample frame and those that were excluded due to geographic location. The result of the effort can be seen in Table 3. The excluded and included sites do not show any alarming differences.

Table 3. Comparison of Excluded and Included Sites in the Sample Frame

A – Stratum	Average Savings Fraction %		Average Reported Savings (therms)	
	B - Excluded Sites	C - Included Sites	D - Excluded Sites	E - Included Sites
1	73%	61%	1036	944
2	39%	38%	556	547
4	17%	16%	229	216
Average, Strata 1 and 2	**52%**	**46%**	**742**	**686**

Note: Table 3 includes both NYSERDA and NFGDC sites.

The Impact Evaluation Team has sent a project file request based on this sample design in conjunction with this memo. The request includes back-up sites as well. Assuming this design is approved, the file requisition can begin immediately.

MEMO

DATE: JUNE 2, 2014

TO: NYSERDA AND NATIONAL FUEL

FROM: ERS

RE: FINAL EMPOWER ON-SITE DATA COLLECTION OVERVIEW

INTRODUCTION

The following document is an overview of the on-site evaluation methodology and objectives to be completed by ERS for the EmPower – Phase 2 effort. The intent is to describe the parameters that the team intends to collect on-site at a high-level and also to present the specific survey instrument for gathering customer responses to key questions.

These efforts will be completed for every site that is visited, and are organized into the following six sections:

- ❑ Contact customer/schedule site visit
- ❑ On-site customer survey instrument
- ❑ Exterior building inspection/data collection
- ❑ Interior EmPower measure-specific inventory/data collection
- ❑ Identification of missed opportunities
- ❑ Site visit conclusion

CONTACT CUSTOMER

An advance letter will be sent to the selected sample of customers. As a percentage of customers will have moved, be unresponsive, or refuse to participate, advance letters will be mailed to more participants than required for the data collection, and some advance letter recipients may not be called for recruitment.

After the advance letters have been mailed, the evaluators will begin calling the site contacts. The phone call will include an introduction by the evaluator, including his/her name, the purpose of the call, a brief overview of the evaluation effort, a description of tasks to be completed on-site, and an expected time commitment for those participating.

The evaluators will make a concerted effort to assure the customer that they are not enforcement officials (such as code enforcement officials) and that customer responses will be confidential. The evaluators will also communicate that their site visit will not impact any previous or future services they have received through NYSERDA or their utility. Additionally, the evaluator will inform the customer that he/she will be given an incentive as compensation for the time required for the site visit. The customer will be asked if he/she agrees to participate in the evaluation and, if so, the site visit will be scheduled at a convenient time for both the customer and the evaluator.

Customer Survey

Site visits will be conducted by a team of two evaluators. Once on-site, the evaluators will reintroduce themselves and again explain the purpose of their visit. The evaluators will explain that an incentive will be presented to the customer at the end of the visit, and that the customer will be asked to sign a form that confirms the receipt of the incentive and the satisfactory condition of their home after the inspection. Again, the evaluators will make a concerted effort to assure the customer that they are not enforcement officials and that all data collected during the site visit will remain confidential. After this introductory conversation, the evaluators will conduct a brief interview with the customer(s) in order to gather information about their home and the measures installed. Questions will be asked to accomplish the following:

- ❑ Confirm building information, including year constructed, exposure, etc. (for the purpose of recording the customer's impressions of the work that was completed).
- ❑ Confirm the owner's understanding of the measures installed per the program files, including the approximate date they were installed.
- ❑ Determine whether other events may have influenced the pre- or post- energy consumption, including added or removed equipment or appliances.
- ❑ Identify changes to the HVAC system(s) after the measures were installed, including changes to thermostat setpoints, remodeling, or changes in occupancy. The customer will also be asked about changes in perceived comfort.

The complete Customer Survey can be found in Appendix F-A.

Exterior Building Inspection and Data Collection

After the customer survey is complete, the evaluators will collect site data and measurements. The exterior data collection is particularly important and will encompass these objectives:

- ❑ Collect information characterizing the building's exterior. This task will include taking measurements of the building's exterior, measuring all window and door dimensions, and detailing the interior and exterior materials and basic construction (e.g., 2×4 wood framing, vinyl siding, asphalt shingle roof, and gypsum interior walls and ceilings). Photos will also be taken of each exterior elevation for record. This task will likely require two individuals.

- ❑ General assessment of the home condition using a rubric. Field staff members will confirm specific EmPCalc assumptions and invoices found in project files and inspect the quality of the work, as site conditions permit.

INTERIOR EMPOWER MEASURE-SPECIFIC DATA COLLECTION

Once the general building info is collected, the evaluators will begin to capture data on the specific EmPower measures installed. Prior to being on-site, the evaluators will review the program files in order to be familiar with the EmPower measures installed so that time is spent efficiently while at the site.

The evaluators will systematically walk through the home, with particular attention paid to the basement and attic. The data gathered will differ from site to site, depending on the measures installed. As previously discussed, the evaluators will primarily focus their efforts on natural gas measures. As such, electric measure installations will be verified, but no data will be collected pertaining to the equipment operation. The following is an overview of the data that will be gathered within each space of the building:

- ❑ Basement:
  - ➢ Rim joist insulation type, thickness, and area (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)
  - ➢ Air sealing measures (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)
- ❑ As located throughout the home:
  - ➢ DHW tank nameplate data, DHW pipe insulation material, DHW tank wrap (DHW improvement measures)
  - ➢ Dryer nameplate data (dryer conversion measure)
  - ➢ Quantity of CFLs installed
  - ➢ Primary and secondary refrigerator/freezer make/model (replacement measure)
  - ➢ Air sealing measures (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)
  - ➢ Inspect and characterize wall insulation where possible using a plastic probe (outside of electric boxes and next to cable and/or pipe penetrations)

- Verify installation of programmable thermostat and record setting
- Characterization of secondary heating systems including heating fuel and approximate operating characteristics
- Quantity and rating of faucet aerators and low-flow showerheads
- Quantity of CFLs
- Verify water bed replacement(s)

❑ Attic:

- Attic and kneewall insulation type, thickness, and area (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)
- Air sealing measures (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)
- When possible, characterize any preexisting insulation by probing underneath/behind new insulation
- Quantity of CFLs installed

❑ Blower door test:

- Conducted on a sample of twenty to thirty homes that had previously received the test as part of EmPower services
- If a blower door test is completed, the evaluators will inspect the home for structural issues (broken basement windows, damaged exterior doors, etc.) and ask the customer when the identified issue(s) occurred

Once all required data is collected from within the building interior, a final inspection of the building exterior may be necessary to inspect and verify air sealing measures, if applicable.

IDENTIFY MISSED OPPORTUNITIES

While collecting site data and measurements inside the building, the evaluators will identify missed ECM opportunities. This will be completed while collecting the EmPower measure information as the evaluators progress through the building.

Some examples of missed opportunities may include the following:

❑ Basement:

- No insulation on basement ceiling or rim joist when needed
- Air sealing opportunities (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)

❑ As located throughout the home:

- Poorly insulated or uninsulated heating ducts
- Poorly insulated or uninsulated DHW tank
- Uninsulated heating hot water or DHW piping
- Standard flow faucets or showerheads
- Eligible dryer
- Presence of incandescent light bulbs
- Old, inefficient boiler or furnace
- Air sealing opportunities (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)
- Poorly insulated or uninsulated walls
- Non-programmable thermostat
- Presence of water bed
- Old, inefficient refrigerator/freezer make/model (replacement measure)

- [ ] Attic:
    - Lack of insulation or poor quality insulation in attic or kneewalls (particularly side attics or dormers)
    - Air sealing opportunities (see Insulation and Air Sealing Best Practices checklist in Appendix F-B)

SITE VISIT CONCLUSION

After the evaluators have collected all relevant data throughout the home, they will convene to review their findings and notes. If any discrepancies are identified between the two evaluators' notes, the evaluators will revisit the item and correct the discrepancy. The evaluators will also ensure that all required data was collected. Once both evaluators are confident that they have collected all data accurately, they will answer any questions the customer may have about the visit, verify with the customer that everything was left as it was found at the beginning of the visit, and thank him/her for his/her time. The incentive will then be presented to the customer and the customer will be asked to sign a form that confirms the receipt of the incentive and the satisfactory condition of the home after the inspection was concluded.

APPENDIX F-A: CUSTOMER SURVEY

OVERVIEW

The following survey is intended to gather specific customer responses during the EmPower – Phase 2 site visits. It will be conducted with the current resident for every site that is visited, and should be completed in conjunction with the building inspection and data collection.

Site Inspector Name ________________________________

Date of Visit ________________________________

Participant Name ________________________________

Address ________________________________

____

CUSTOMER INTERVIEW

Introduction

My name is [NAME] and I work for ERS, an energy efficiency engineering and consulting company. ERS is working on a project on behalf of [NYSERDA/National Fuel] where we are visiting sites that had energy-efficient measures installed as part of the [NYSERDA EmPower Program/National Fuel's Conservation Incentive Program], and your home came up as one of the sites to visit.

The purpose of our visit is to identify the measures installed according to the program documents and provide recommendations to [NYSERDA/NFG] on how they can improve their program. We are offering a courtesy incentive of $100 to you for answering a few questions and allowing us to take site measurements.

Our visit will include a brief survey, and then we will be taking measurements of your home, inspecting equipment in the building, and taking pictures. **We will keep your responses confidential. We are here to check to the quality of the work done on your home. We are not officials or inspectors looking to see if the home meets code, and our visit today will not affect any of the services you have received or will receive in the future. The results of this visit will be confidential.** Is this acceptable?

We appreciate your assistance with this site visit and will be as brief an unobtrusive as possible. This will take us about 2 hours.

We will first take measurements on the outside of the house; this will take us about a half-hour. We would then like to walk through the house with you after that to inspect some of the work completed.

Before we begin do you have any questions I can answer?

INTERVIEW QUESTIONS

Whole-Building Info

1. Do you know what year the building was constructed? ____
2. According to our records, [CONTRACTOR] was here in [APPROXIMATE DATE/SEASON] and did some work in your home. Do you recall the project?

Electric Measures

1. Our records show these measures (below) were installed around [APPROXIMATE DATE/SEASON] to save electricity. Can you confirm if that was the case?

Table of Potential Electric Measures

Measure	Application Quantity	Installed?	
		Yes	No
Lighting – CFLs	[quantity]		
Refrigerator	[specification]		
Freezer	[specification]		
Dryer conversion	[specification]		
Water bed replacement	[specification]		
Showerheads	[quantity]		
Aerators	[quantity]		
DHW tank	[specification]		
DHW tank wrap	[specification]		
DHW pipe insulation	[quantity]		

HVAC Measures

1. Our records indicate that some or all of your walls were insulated on [APPROXIMATE DATE/SEASON]. Do you remember that part of the project?

   1.1. Would you be able to point out to us which walls were insulated?

   [Make notes on elevation sketches]

   1.2. [If applicable] Our records indicate your attic was also insulated. From your knowledge, was there insulation there before?

   1.3. [If applicable] Our records indicate that your home was made less drafty by sealing up the air leaks. Were you aware of this work? The contractor may have used foam to seal the foundation cracks and around windows, for example. Can you describe what you remember being done?

2. [If applicable] Our records indicate your heating system was [REPAIRED/REPLACED]. Were you aware of this work?

   Customer comments:

3. We'd like to better understand how your home was before the work was done compared to how it is now.

   Has any additional work been done at your home since [APPROXIMATE DATE/SEASON]?

   3.1 For example, have you installed additional insulation, done more air sealing, replaced windows, etc.?

   3.2 If so, do you recall when that work occurred (month/date, if known)?

4. Have you purchased and/or installed any new equipment or appliances since [APPROXIMATE DATE/SEASON]?

   4.1. For example, a new TV, gaming system, computer, additional refrigerator, etc.? *If yes, list equipment details, including make/model, below.*

   4.2. If so, do you still use [OLD APPLIANCE]? Can you describe (or point out) [OLD APPLIANCE]?

5. Did you switch from an electric to gas dryer, or vice versa?

6. Can you recall how many people were living here the year before the work was done on [APPROXIMATE DATE/SEASON]?

   6.1. Has this changed since the work was completed?

   6.2. If yes, how many people live here now?

   6.3. Can you recall when the change(s) occurred?

7. Think about your comfort in the home **before** the work was done. In the winter prior to [APPROXIMATE DATE/SEASON], would you say your home was:

   7.1. Very cold

   7.2. Cold

   7.3. Comfortable

   7.4. Hot

   7.5. Very hot

8. During this past winter (or any winter after the project), would you say your home was:

8.1. Very cold

8.2. Cold

8.3. Comfortable

8.4. Hot

8.5. Very hot

Customer comments:

9. Are you satisfied with the work that was done on your home?

10. Did you save energy and money on your electric and/or gas bill?

11. I see your thermostat is set at _____°F. Is that how you usually set it?

11.1. Was it set differently before [APPROXIMATE DATE/SEASON]?

For example, used to set heat to 75° to be comfortable, now can set it to 70°.

11.2. Thermostat type: ☐ Programmable ☐ Non-programmable

11.3. Temperature setpoints:

Weekday	Period 1 (Start time / Temp.)	Period 2 (Start time / Temp.)	Period 3 (Start time / Temp.)	Period 4 (Start time / Temp.)	Period 5 (Start time / Temp.
Monday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F
Tuesday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F
Wednesday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F
Thursday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F
Friday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F

Saturday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F
Sunday	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F	___:_____ $\frac{AM}{PM}$ ________°F

11.4. How often do you change or manually override the settings?

11.5. Have these settings changed as a result of occupancy or employment changes?

12. I see that you have a [PELLET STOVE/FIREPLACE/ETC.]. How much did you use it this past winter?

    12.1. Prior to the work completed on [APPROXIMATE DATE/SEASON], would you say you used it more or less than this past winter?

    12.2. How much fuel do you consume/purchase annually (tons of pellets, cords of wood, etc.) for the [PELLET STOVE/FIREPLACE/ETC.]?

    Customer comments:

13. Did you use electric heaters this past winter?

    13.1. Can you tell me where you used them and about how often you used them?

    13.2. Prior to the work completed on [APPROXIMATE DATE/SEASON], would you say you used electric heaters more or less than this past winter?

14. When do you typically turn your primary heating system on/off?

    Capture month and approximate time of month (i.e., late October – early April)

15. Our records show that [CONTRACTOR] shared some energy savings actions with you, like [EFFICIENCY EDUCATION TOPIC(S)]. I'd like to ask a few questions about those.

    15.1. Do you recall this part of the services? *(Yes/No)*

    15.2. Were you the person who was home when the contractor discussed energy actions? *(Yes/No)*

15.3. Do you remember any of the energy actions that the contractor suggested to you? *(Yes/No)*

If yes, complete table below.

[E1] Strategy – as noted in the application	[E2] Do you recall this recommended action?	[E3] Were you able to use this recommendation
a) [Text 1 -] b) Auditor code:	❒ Yes ❒ No ❒ Don't recall ❒ Maybe other household member	❒ Already did this. ❒ No. Why? ❒ Yes. For how long?
a) [Text 1 -] b) Auditor code:	❒ Yes ❒ No ❒ Don't recall ❒ Maybe other household member	❒ Already did this. ❒ No. Why? ❒ Yes. For how long?

Prompts For E1 (Ask unprompted first)	
Code	Meaning
N	NONE
L	How do you use your lights?
C	How do you cool your home?
H	How do you heat your home?
R	How do you use your refrigerator?
HW	How do you use hot water?

CLOSING REMARKS

Thank you for help with our survey. I know you are busy and we are very appreciative of your time and accommodation. We will now begin our inspection by taking measurements of the outside of your home. If you have any questions during the inspection, please don't hesitate to ask.

APPENDIX F-B: INSULATION AND AIR SEALING BEST PRACTICES

Measure	On-Site Observations
Attic Insulation Bays are filled completely with no gaps or compressed areas; wind baffles or air chutes are present	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Attic Air Sealing Top plates and wall-to-ceiling connections are sealed; all other penetrations (plumbing vent stack, chimneys, wiring, etc.) are sealed; check for air sealing underneath insulation when possible	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Attic Kneewalls Air barrier is installed at the insulated boundary (kneewall transition or roof, as appropriate)	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Attic Access/Pull-Down Stair Attic access panel or drop-down stair cover is in place, insulated, and fully gasketed for an air-tight fit	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Whole-House Fan Penetration at Attic An insulated cover is provided that is gasketed or sealed to the opening from either the attic side or ceiling side of the fan	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Staircase Framing at Exterior Wall/Attic Air barrier is fully aligned with insulation; all gaps are fully sealed	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Duct Insulation and Sealing All ducts are insulated and sealed, especially in attics, vented crawlspaces, and rim areas; insulation is in good condition (no tears)	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Duct Shaft/Piping Shaft and Penetrations Openings from attic to conditioned space are sealed	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Exterior Walls Service penetrations are sealed and air sealing is in place behind or around shower/tub enclosures, electrical boxes, switches, and outlets on exterior walls	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Garage/Living Space Walls Air sealing is completed between garage and living space; pass-through door is weather stripped	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Floor Insulation Insulate between floor joists over unheated spaces	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Cantilevered Floor Cantilevered floors are air sealed and insulated at perimeter or joist transition	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Rim Joists and Sill Plate Rim joists are insulated and include an air barrier.	☐ Not observable ☐ Observed, good installation

Junction of foundation and sill plate is sealed. Penetrations through the bottom plate are sealed.	☐ Observed, inadequate (describe)
Foundation and Floor Floors above unconditioned spaces are insulated. All leaks at foundations, floor joists, and floor penetrations are sealed. Exposed earth in crawlspace is covered with Class I vapor retarder overlapped and taped at seams.	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Pipe Insulation DHW pipes are insulated	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Recessed Lighting Fixtures are provided with air-tight assembly or covering	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)
Flue or Chimney Shaft Opening around flue is closed with flashing, and any remaining gaps are sealed with fire-rated caulk or sealant	☐ Not observable ☐ Observed, good installation ☐ Observed, inadequate (describe)

APPENDIX G: SURVEY DATA COLLECTION RESULTS

ERS field teams conducted customer surveys at each of the 98 homes visited. Each survey was pre-populated with details obtained from the project documents (contractor name, project date, etc.). The survey results are presented in this section.

The instances of no response in the survey results are a consequence of the participant's inability to answer the given survey question for one of the following reasons:

- The participant did not live at the home before or during the project.
- The question did not apply and the surveyor skipped it to reduce the time impact on the customer.
- The participant was not familiar with the subject of the question.

Whole-Building Info

1. Do you know what year the building was constructed?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	1	5	6	6%
Unknown	0	2	2	2%
Before 1900	6	9	15	15%
1901–1925	12	18	30	31%
1926–1950	14	9	23	24%
1951–1975	9	13	22	22%

1.1. Is the home age estimated or certain?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	5	5	5%
Estimated	34	28	62	63%
Certain	8	23	31	32%

2. According to our records, [CONTRACTOR] was here in [APPROXIMATE DATE/SEASON] and did some work in your home. Do you recall the project?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	0	0	0%
Yes	42	56	98	100%
No	0	0	0	0%

HVAC Measures

1. Our records indicate that some or all of your walls were insulated in [APPROXIMATE DATE/SEASON]. Do you remember that part of the project?

Response*	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	1	1	2	2%
No response	0	1	1	1%
Yes	30	42	72	73%
No	11	12	23	24%

* The field team observed a total of 67 homes with wall insulation installed.

1.1. Would you be able to point out to us which walls were insulated?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	2	1	3	3%
No response	1	4	5	5%
Yes	27	39	66	67%
No	12	12	24	25%

1.2. Our records indicate your attic was also insulated. From your knowledge, was there insulation there before?

Response*	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	0	1	1	1%
No response	1	1	2	2%
Yes	21	26	47	48%
No	20	28	48	49%

* The field team observed a total of 84 homes with attic insulation installed.

1.3. Our records indicate that your home was made less drafty by sealing up the air leaks. Were you aware of this work?

Response*	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	0	0	0	0%
No response	2	0	2	2%
Yes	30	50	80	81%
No	10	6	16	17%

* Air sealing savings were claimed for 81 homes.

2. Our records indicate your heating system was repaired. Were you aware of this work?

Response*	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	0	4	4	4%
No response	5	8	13	13%
Yes	18	19	37	38%
No	19	25	44	45%

* Heating repair and/or replacement savings were claimed for 26 homes.

3. We'd like to better understand how your home was before the work was done compared to how it is now. Has any additional work been done at your home since [APPROXIMATE DATE/SEASON]?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	1	1	1%
Yes	21	22	43	44%
No	21	33	54	55%

3.1. What was done? For example, have you installed additional insulation, done more air sealing, replaced windows, etc.?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	20	35	55	56%
No response	0	2	2	2%
Additional insulation	3	1	4	4%
Additional air sealing	3	0	3	3%
Replaced windows	2	5	7	7%
Roof replacement or repair	4	4	8	8%
Heating system replacement	6	2	8	8%
Other, no impact to building envelope or heating systems	4	7	11	12%

3.2. When did the work occur?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	11	23	34	35%
No response	12	16	28	29%
Within one year of project completion	6	5	11	11%
One to two years after project completion	5	3	8	8%
Two to three years after project completion	6	6	12	12%
Three to four years after project completion	2	3	5	5%

4. Have you purchased and/or installed any new equipment or appliances since winter 2010? For example, a new TV, gaming system, computer, additional refrigerator, etc.?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	2	0	2	2%
Yes	24	35	59	60%
No	16	21	37	38%

4.1. If so, do you still use the old appliance(s)?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	1	4	5	5%
No response	7	10	17	17%
Yes	5	1	6	6%
No	29	41	70	72%

5. Did you switch from an electric to gas dryer, or vice versa?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	2	1	3	3%
No change	38	54	92	94%
Electric to gas	1	0	1	1%
Gas to electric	1	1	2	2%

6. Can you recall how many people were living here the year before the work was done in [APPROXIMATE DATE/SEASON]?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	0	0	0%
One person	17	13	30	31%
Two people	9	16	25	26%
Three people	8	6	14	14%
Four people	4	9	13	13%
Five people	2	10	12	12%
Six people	1	1	2	2%
Seven people	1	1	2	2%

6.1. Has this changed since the work was completed?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Yes	15	16	31	32%
No	27	40	67	68%

6.2. If yes, how many people live here now?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	27	40	67	69%
No response	0	1	1	1%
One person	4	2	6	6%
Two people	4	3	7	7%
Three people	2	5	7	7%
Four people	4	2	6	6%
Five people	1	2	3	3%
Six people	0	1	1	1%

Occupancy change tabulation:

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	27	40	67	69%
Three-person decrease	1	1	2	2%
Two-person decrease	2	1	3	3%
One-person decrease	4	4	8	8%
One-person increase	5	7	12	12%
Two-person increase	2	2	4	4%
Three-person increase	1	0	1	1%
Four-person increase	0	1	1	1%

6.3. Can you recall when the change(s) occurred?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	27	40	67	69%
No response	4	2	6	6%
Within one year of project completion	3	4	7	7%
One to two years after project completion	4	4	8	8%
Two to three years after project completion	2	5	7	7%
Three to four years after project completion	1	1	2	2%
Four to five years after project completion	1	0	1	1%

7. Think about your comfort in the home **before** the work was done. In the winter prior to [APPROXIMATE DATE/SEASON], would you say your home was:

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	2	2	2%
Very cold	12	9	21	22%
Cold	21	35	56	57%
Comfortable	9	10	19	19%
Hot	0	0	0	0%
Very hot	0	0	0	0%

8. During this past winter (or any winter after the project), would you say your home was:

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	1	1	1%
Very cold	2	0	2	2%
Cold	7	11	18	18%
Comfortable	32	43	75	77%
Hot	1	1	2	2%
Very hot	0	0	0	0%

Comfort change tabulation:

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No change in comfort	14	16	30	31%
1-step increase in comfort	21	35	56	57%
2-step increase in comfort	7	4	11	11%
3-step increase in comfort	0	1	1	1%

9. Are you satisfied with the work that was done on your home?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	0	1	1	1%
Yes	30	47	77	79%
No	12	8	20	20%

10. Did you save energy and money on your electric and/or gas bill?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	1	2	3	3%
Yes	23	38	61	62%
No	18	16	34	35%

11. I see your thermostat is set at _____°F. Is that how you usually set it?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	15	14	29	30%
Yes	22	31	53	54%
No	5	11	16	16%

11.1. Was it set differently before [APPROXIMATE DATE/SEASON]?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	4	8	12	12%
Yes	12	14	26	27%
No	26	34	60	61%

11.2. Thermostat type:

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Programmable	19	23	42	43%
Non-Programmable	23	33	56	57%

11.3. Temperature set points (weighted average if programmable thermostat):

Response*	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Could not determine	6	5	11	11%
55°F - 59°F	1	1	2	2%
60°F - 64°F	3	3	6	6%
65°F - 69°F	19	20	39	40%
70°F - 74°F	8	20	28	29%
75°F - 79°F	5	7	12	12%

* Observations were made July-September 2014, during the non-heating season.

11.4. How often do you change or manually override the settings?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	2	7	9	9%
Every day	10	9	19	20%
More than once a week, but not every day	6	9	15	15%
Once a week	6	3	9	9%
More than once a month, but not every week	3	2	5	5%
Once a month	15	22	37	38%
Never	0	4	4	4%

11.5. Have these settings changed as a result of occupancy or employment changes?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	1	1	2	2%
Yes	5	3	8	8%
No	36	52	88	90%

12. I see that you have a [PELLET STOVE/FIREPLACE/ETC.]. How much did you use it this past winter?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	30	30	60	61%
Every day	2	1	3	3%
More than once a week, but not every day	0	1	1	1%
Once a week	1	0	1	1%
More than once a month, but not every week	0	0	0	0%
Once a month	9	24	33	34%

12.1. Prior to the work completed on [APPROXIMATE DATE/SEASON], would you say you used it more or less than this past winter?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	30	30	60	61%
More usage	3	1	4	4%
Less usage	0	2	2	2%
No change	9	23	32	33%

12.2. How much fuel do you consume/purchase annually (tons of pellets, cords of wood, etc.) for the [PELLET STOVE/FIREPLACE/ETC.]?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	30	30	60	61%
No response	9	26	35	36%
1 – 1.5 tons of wood	2	0	2	2%
8 Bushells	1	0	1	1%

13. Did you use electric heaters this past winter?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	1	1	2	2%
Yes	16	31	47	48%
No	25	24	49	50%

13.1. Can you tell me about how often you used them?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	18	15	33	34%
No response	3	0	3	3%
Every day	8	12	20	20%
More than once a week, but not every day	3	8	11	11%
Once a week	2	1	3	3%
More than once a month, but not every week	1	5	6	6%
Once a month or less	7	15	22	23%

13.2. Prior to the work completed on [APPROXIMATE DATE/SEASON], would you say you used electric heaters more or less than this past winter?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
Not applicable	14	13	27	28%
No response	1	0	1	1%
More usage	4	11	15	15%
Less usage	7	8	15	15%
No change	16	24	40	41%

14. When do you typically turn your primary heating system on?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	2	4	6	6%
Early September	2	1	3	3%
Mid September	0	1	1	1%
Late September	1	5	6	6%
Early October	2	6	8	8%
Mid October	9	10	19	20%
Late October	12	13	25	26%
Early November	8	8	16	16%
Mid November	3	3	6	6%
Late November	2	5	7	7%
Early December	1	0	1	1%

14.1. When do you typically turn your primary heating system off?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	1	2	3	3%
Early March	0	1	1	1%
Mid March	1	0	1	1%
Late March	5	6	11	11%
Early April	5	16	21	22%
Mid April	9	6	15	15%
Late April	7	11	18	19%
Early May	9	5	14	14%
Mid May	2	5	7	7%
Late May	3	4	7	7%

15. Do you remember any of the energy actions that the contractor suggested to you?

Response	Number of NYSERDA Respondents	Number of NFGDC Respondents	Number of Total Respondents	Percentage of Total Respondents
No response	5	9	14	15%
Remembered 0% – 19% of education items	10	3	13	13%
Remembered 20% – 39% of education items	2	4	6	6%
Remembered 40% – 59% of education items	5	4	9	9%
Remembered 60% – 79% of education items	5	8	13	13%
Remembered 80% – 100% of education items	15	28	43	44%

APPENDIX H: DETAILED RESULTS

This appendix includes the results of the on-site data collection and subsequent analysis efforts.

1.1 ON-SITE DISTRIBUTION

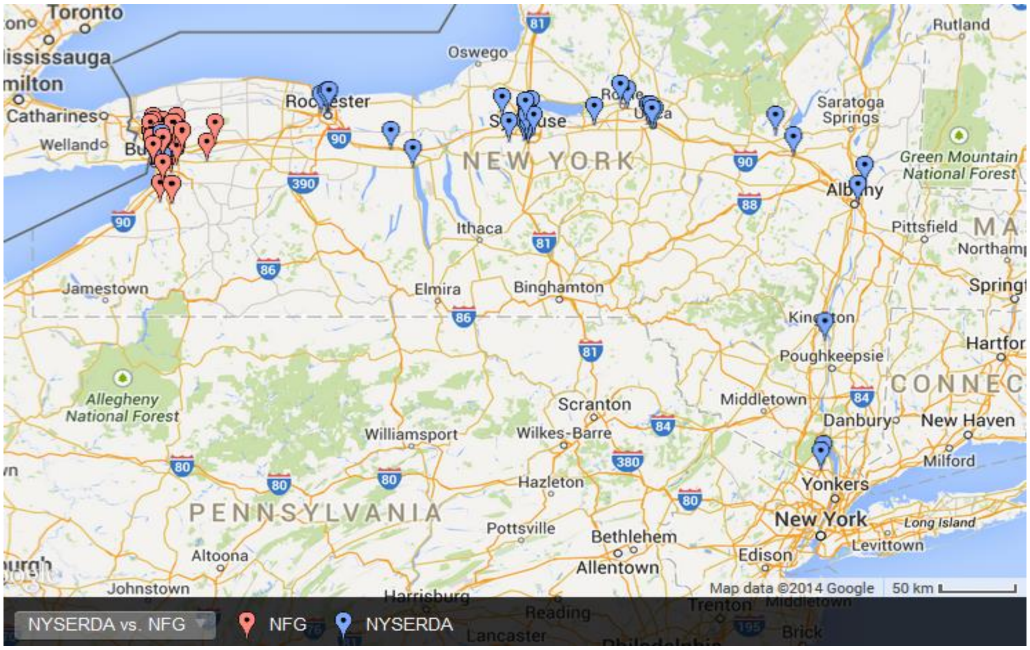
At the start of the study, the goal was to recruit 120 of the 220 sites in the initial sample. Ultimately, 98 sites were recruited and visited between July 10, 2014 and September 12, 2014. Of those 98, 42 were NYSERDA sites and 56 were NFGDC sites. Table H-1 shows the complete breakdown of targeted and visited sites by stratum and funding source.

Table H-1. Recruitment Targets and Results

	High Savers		Mid Savers		Low Savers		Grand Total	
Stratum	**Targeted**	**Visited**	**Targeted**	**Visited**	**Targeted**	**Visited**	**Targeted**	**Visited**
NFGDC	20	18	0	0	40	38	60	56
1 – Largest reported savings per site	10	7	0	0	20	16	30	23
2 – Second largest reported savings per site	10	11	0	0	20	22	30	33
NYSERDA	15	7	12	13	33	22	60	42
1 – Largest reported savings per site	3	1	3	3	8	7	14	11
2 – Second largest reported savings per site	12	6	9	10	25	15	46	31
Total	**35**	**25**	**12**	**13**	**73**	**60**	**120**	**98**

It is important to note that the majority of the NFGDC sites were centered in and around Buffalo, while the NYSERDA sites were spread across the state as shown in Figure H-1. This is to be expected as the NFGDC service territory is concentrated in western New York, while the NYSERDA territory traverses the entire state.

Figure H-1. Geographical Distribution of Visited Sites



1.1.1 Dropped and Un-Recruited Sites

Of the initial sample of 220 sites, 122 sites were not visited; the unvisited sites fall into two main categories: dropped sites and un-recruited sites. Sites were dropped due to lack of usable documentation, customer refusal, and unresponsiveness. A detailed tabulation of dropped and un-recruited sites is shown in Table H-2.

Table H-2. Dropped and Un-Recruited Sites

Category	Quantity	Reason Site Was Not Recruited
Dropped	5	Required EmPCalc documents could not be recovered
Dropped	25	Customer refused participation during recruitment
Dropped	39	Disconnected or incorrect phone number on file
Un-recruited	53	Customer could not be reached within the recruitment timeline
Total	122	N/A

Although there were a variety of reasons given for refusal, a recurring theme was lack of time for participation. Before a site was dropped, the Impact Evaluation Team attempted extensive recruitment tactics. First, the site files were checked for alternate phone numbers. If that was unsuccessful, then web research was performed to look up numbers associated with the participant and the service address. Finally, where feasible, drop-by visits were made to the site as a last resort to establish contact. A site was only dropped when all other contact options were exhausted.

Due to the stringent requirements for dropping a site, outreach efforts were continued to the remaining 53 sites through the date of the final site visit. On average, four contact attempts were made per site for the 53 un-recruited sites; 47% of those outreach calls resulted in voicemails and 25% resulted in un-answered calls (no one answered the call and there was no active voicemail). Ultimately, these sites could not be recruited within the timeline of the study. Further details about the un-recruited sites and the decision to stop recruitment efforts after completing 98 site visits can be found in Appendix J.

1.1.2 On-Site Installation Contractor Distribution

Twenty-four different installation contractors completed installations at the 98 visited project sites. Eight of those installation contractors worked on both NYSERDA and NFG sites. A complete breakdown of recruited sites by installation contractor and funding source can be found in Table H-3.

Table H-3. Count of Recruited Sites by Installation Contractor and Funding Source

Installation Contractor	NYSERDA	NFG
Contractor A	0	6
Contractor B	1	0
Contractor C	1	1
Contractor D	1	0
Contractor E	1	0
Contractor F	1	2
Contractor G	1	0
Contractor H	1	0
Contractor I	1	0
Contractor J	2	0
Contractor K	0	5
Contractor L	1	0
Contractor M	2	0
Contractor N	2	5
Contractor O	6	0
Contractor P	1	8
Contractor Q	0	4
Contractor R	2	0
Contractor S	7	0
Contractor T	5	5
Contractor U	1	8
Contractor V	1	2
Contractor W	0	2
Contractor X	4	8
Total	**42**	**56**

As shown in the table above, the distribution of installation contractors was vast. The 24 installation contractors represented in our on-site work were responsible for 75% of the work completed by the Program in this time period. Earlier analysis conducted during the first stage of the research had shown no significant performance differences between installation contractors. Although sites were not selected to statistically represent installation contractors, the on-sites represented a good distribution of installation contractors based on their contributions to the Program savings.

1.2 ASSESSMENT OF INSTALLATION CONTRACTOR DATA

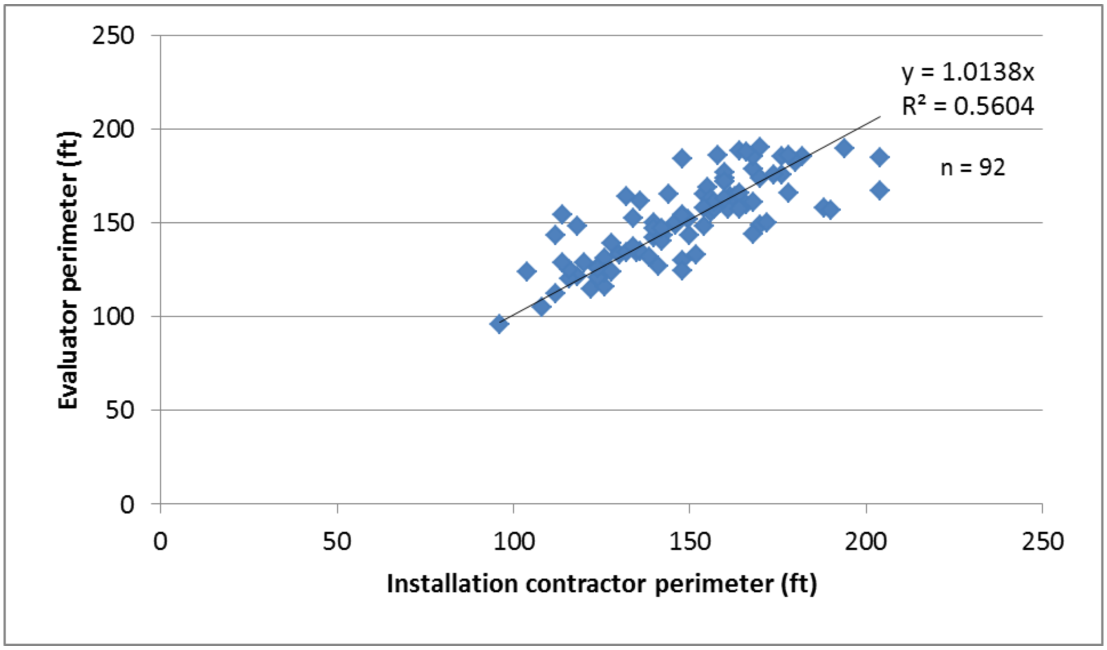
The Impact Evaluation Team collected information on-site to test how well installation contractors represented building dimensions, blower door measurements, and installed measures. Quantifying the accuracy of contractor data allowed the Impact Evaluation Team to determine whether inaccurate efficiency measure characterizations were contributing to the over-estimated savings. In every direct comparison, the differences between the installation contractor and evaluator measurements were generally within a 10% margin of error[1]; however, as discussed in Appendix D, some direct comparisons were less certain than others. As such, the Impact Evaluation Team drew conclusions from the home characterization parameters (e.g., perimeter, attic area and insulation), which could be collected reliably with little uncertainty about matching the inspected surfaces to those identified by the installation contractor. Each of these parameters is discussed in the following subsections.

1.2.1 Dimensions

During 2010 and 2011, installation contractor sketches did not indicate which walls were insulated through the Program. This created uncertainty when the on-site teams attempted to verify areas of wall treated with insulation. However, it was possible to directly compare the building perimeter in most of the projects, which was a simpler and less uncertain comparison. The Impact Evaluation Team used sketches found in the project file to calculate the installation contractor perimeter. Six project files did not contain a usable home sketch, but the remaining 92 project files contained sketches that were detailed enough to calculate the installation contractor perimeter. While on-site, the Impact Evaluation field teams measured each home's perimeter. On average, the evaluated perimeter was within 2% of the installation contractor perimeter. Figure H-2 presents a comparison of the installation contractor and evaluator perimeters.

[1] Small measurement differences are to be expected due to measurement device error and differences in measurement techniques.

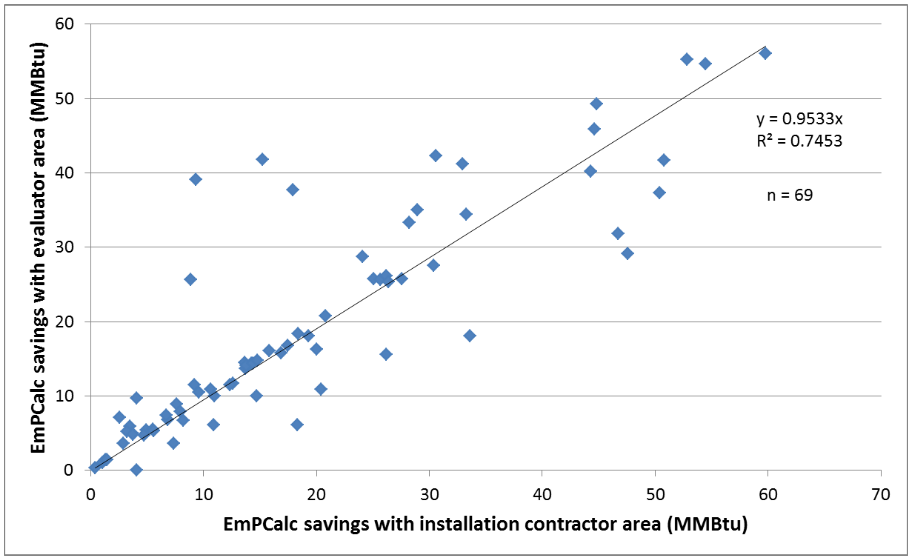
Figure H-2. EmPower Installation Contractor Perimeter vs. Evaluated Perimeter



1.2.2 Attic Characterizations

As discussed in Appendix D, EmPCalc savings were recreated for every home visited by entering installation contractor values from the project files into EmPCalc version 3.41. The EmPCalc savings estimates generated with installation contractor and evaluator inputs could then be directly compared without error related to EmPCalc version differences. The comparison of calculated savings allowed the Impact Evaluation Team to compare all installation contractor and evaluator measure characterizations (pre-/post- insulation type, and pre-/post- insulation thickness). Attics provided the least amount of uncertainty for this comparison because the on-site teams could most easily match the project file descriptions of the insulated surface with on-site observations. Additionally, many attics were open and the insulation type and thickness could be easily determined through inspection. The total evaluated attic savings estimate (using EmPCalc) was within 1% of the installation contractor attic savings estimate. Figure H-3 presents a comparison of the installation contractor and evaluator attic savings.

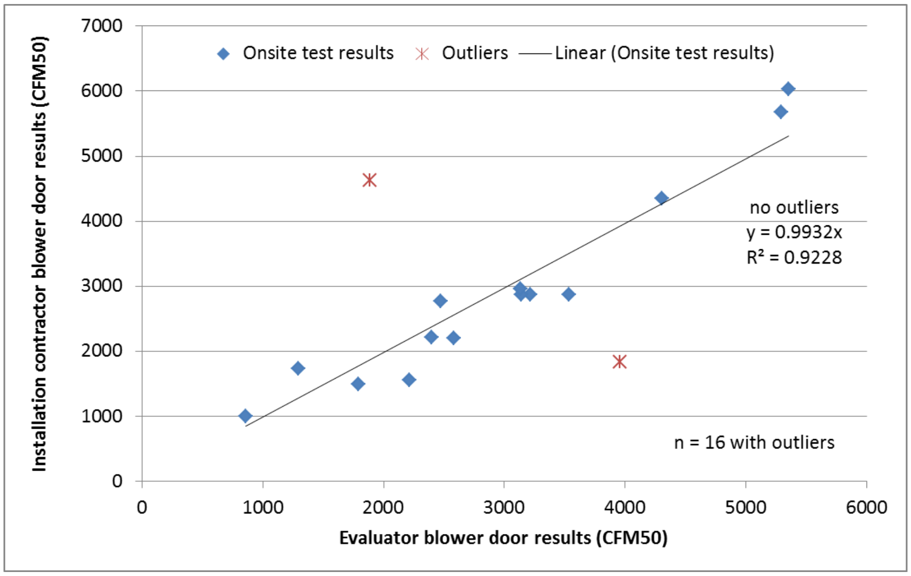
Figure H-3. EmPower Installation Contractor vs. Evaluator Attic Savings Estimates



1.2.3 Blower Door Measurements

The Impact Evaluation Team completed blower door tests at a small sample of 16 sites to provide another indication of how well contractors were representing home conditions. Program staff indicated early in the Phase II planning stage that the Program's air sealing protocols changed significantly since 2010/2011, therefore, there was little value in determining a statistically significant average ACH for this population. Changes in blower door tests can have a large impact on savings estimates and could be a source of an inadvertent or an intentional error (i.e., an overstated blower door test result will bias the savings upward); therefore, this is an important indicator of the quality of contractor data collection. Even several years after the project was completed, the evaluated measurements were similar to the installation contractor measurements. Figure H-4 compares the installation contractor and evaluator blower door test results.

Figure H-4.EmPower Installation Contractor vs. Evaluator Blower Door Test Results[2]



The trend line illustrates the correlation between installation contractor and evaluator blower door test results for the 14 non-outliers. The outliers above and below the trend line are likely the result of a difference in test procedure for multi-story homes, though this hypothesis is uncertain because no installation contractor notes were provided about the blower door tests.

The Impact Evaluation Team compiled the installation contractor baseline and post-case blower door test results for all homes in the on-site sample at which blower door testing was completed. The data, as presented in Figure H-5, shows that the claimed air change per hour (ACH) reduction is reasonable because the claimed ACH reduction is a relatively small percentage of the baseline ACH, which implies that the pre-installation blower door measurements are not biased. Additionally, the installation contractor distribution of ACH values is similar to those presented in chapter 16 of the 2013 ASHRAE Fundamentals handbook[3], as shown in Figure H-6.

[2] CFM50 is the airflow needed to create a change in building pressure of 50 Pascals. A CFM50 reading is produced by a blower door apparatus during testing. EmPCalc uses the CFM50 value in air sealing calculations.

[3] 2013 ASHRAE Handbook: https://www.ashrae.org/resources--publications/handbook/table-of-contents-2013-ashrae-handbook--fundamentals

Figure H-5. Installation Contractor Pre-/Post- ACH Values

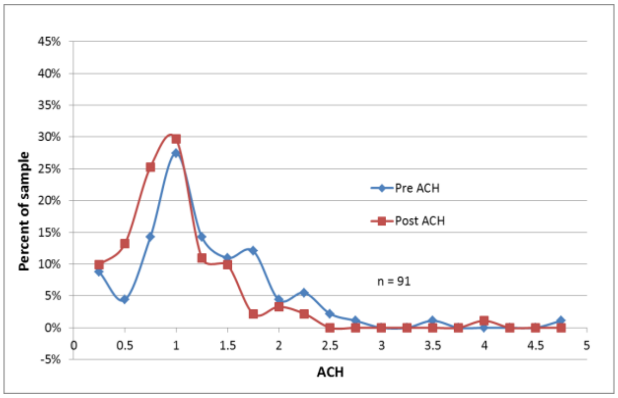
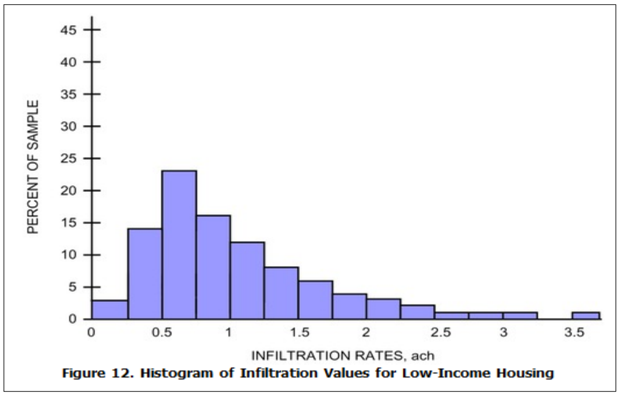


Figure H-6. ASHRAE 2013 ACH Values



1.3 HEAT LOAD ANALYSIS

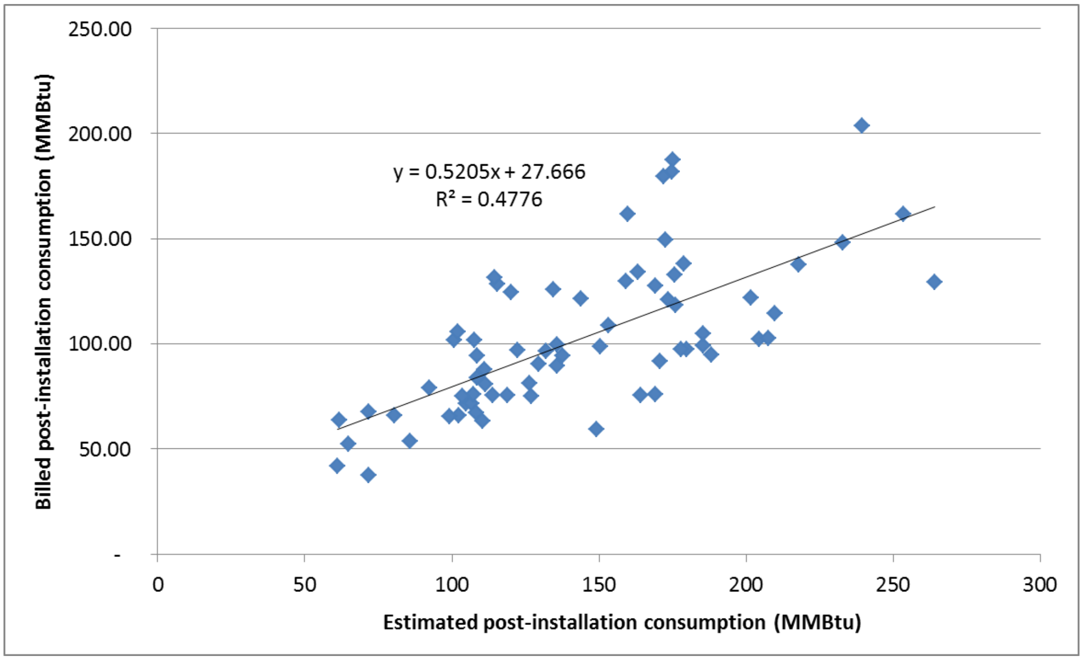
The Impact Evaluation Team used dimensional data collected from each site visit to calculate the total annual heat load for each of the 98 visited homes. The results of the analysis are presented in this section.

1.3.1 Modeled Heat Load Results

As detailed Appendix D, the Impact Evaluation Team developed a whole-home model to calculate the total annual heat load of each of the 98 visited homes. The evaluation model used EmPCalc algorithms to calculate the heat loss through exterior surfaces using the surface area, surface thermal resistance, and temperature difference between the indoor and outdoor air. However, the Impact Evaluation Team's heat load model used characterizations of the complete building envelope to calculate the whole-home heat loss, while EmPCalc is designed to only calculate the incremental changes in heat lost through exterior surfaces targeted for treatment.

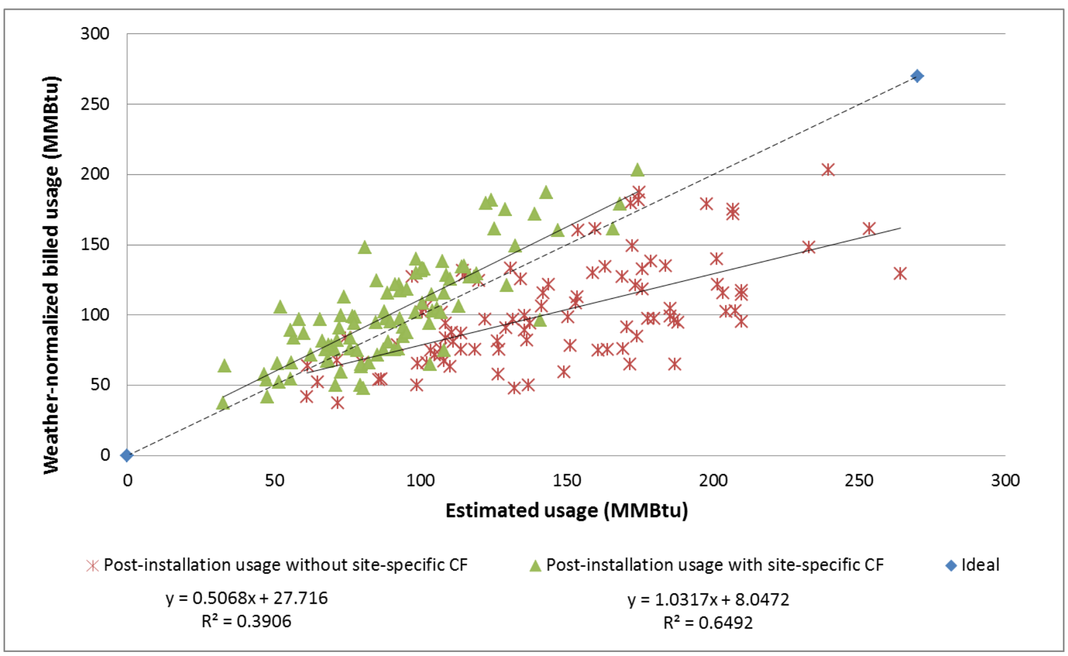
The heat loads calculated from the Impact Evaluation Team's EmPCalc-based whole-home model indicated that the EmPCalc heat loss calculations overestimate the heating fuel usage. In every case the billed heating usage was less than the estimated heating usage, where the average ratio of the heating component of the bills to the estimated heating usage was 64% (median = 61%, mode = 54%). This overestimation of heating fuel usage can be seen in Figure H-7, which shows the comparison between the estimated heating consumption and the billed heating consumption. This plot demonstrates the low precision of the estimated natural gas consumption, although the model was effective at capturing the general consumption trends of each site.

Figure H-7. Estimated Natural Gas Consumption vs. Billed Natural Gas Consumption



It was expected that the application of a site-specific calibration factor (pre-installation billed usage/pre-installation estimated usage or calibration factor [CF]) would improve post-installation usage estimates (i.e., the usage after the measures were installed). Figure H-8 shows a scatterplot of each site's estimated post-installation heating usage compared to actual billed post-installation heating usage with and without a site-specific pre-installation billing CF.

Figure H-8. EmPower Estimated Post-Installation Envelope Heat Loss With and Without Site-Specific CFs



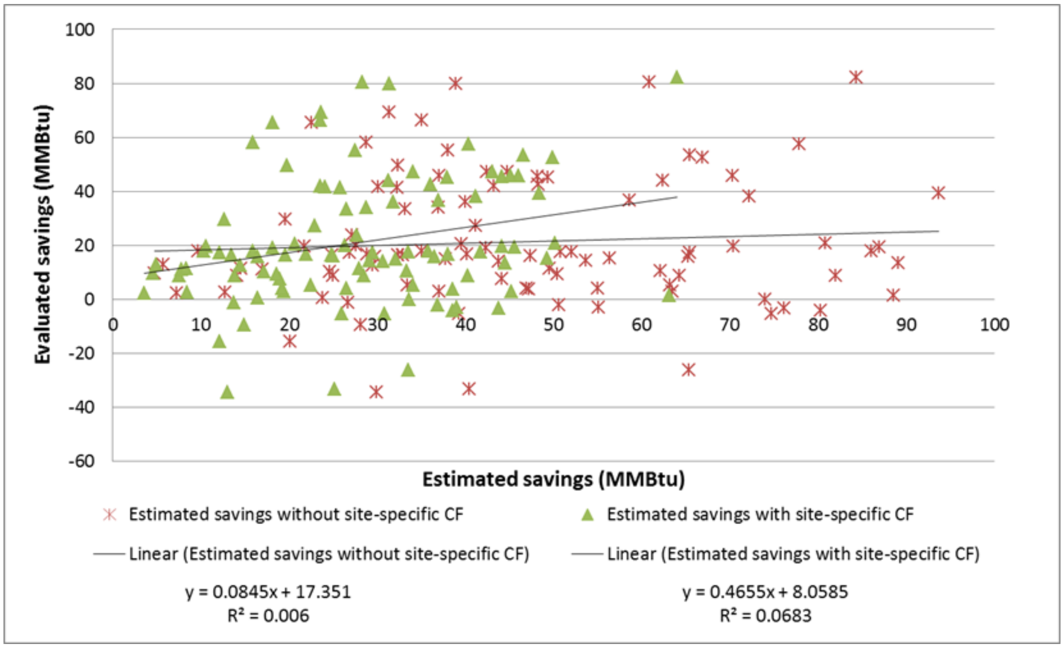
It is evident that without the site-specific CFs developed from pre-installation billing data, the post-installation estimated usage is approximately double the billed usage (see regression coefficient 0.5068), while with the CFs the estimated usage is on average approximately equivalent to the billed usage (see regression coefficient 1.0317). Furthermore, the correlation between billed post-installation usage and estimated post-installation usage, as indicated by the coefficient of determination[4] (R^2), is improved from 0.3096 to 0.6492 by site-specific billing calibration. The Impact Evaluation Team thus concluded that the application of a site-specific CF calculated from pre-installation billing data improves the calculated post-installation usage estimate.

1.3.2 Impact of Site-Specific Billing Calibration

The Impact Evaluation team demonstrated that calibration to site-specific billing data improved post-installation heating usage estimates for the population as a whole. The next step was to test whether the site-specific CF improved the savings estimates for insulation and air sealing measures. This test was completed by regressing both the calibrated and uncalibrated savings estimates against the evaluated savings. As discussed in Appendix D, the calibrated savings estimates were calculated to be the difference between the calibrated pre-installation heating usage and the calibrated post-installation heating usage (pre- and post-installation usage estimates were calibrated with site-specific CFs determined from the pre-installation bills). The savings regressions are shown in Figure H-9.

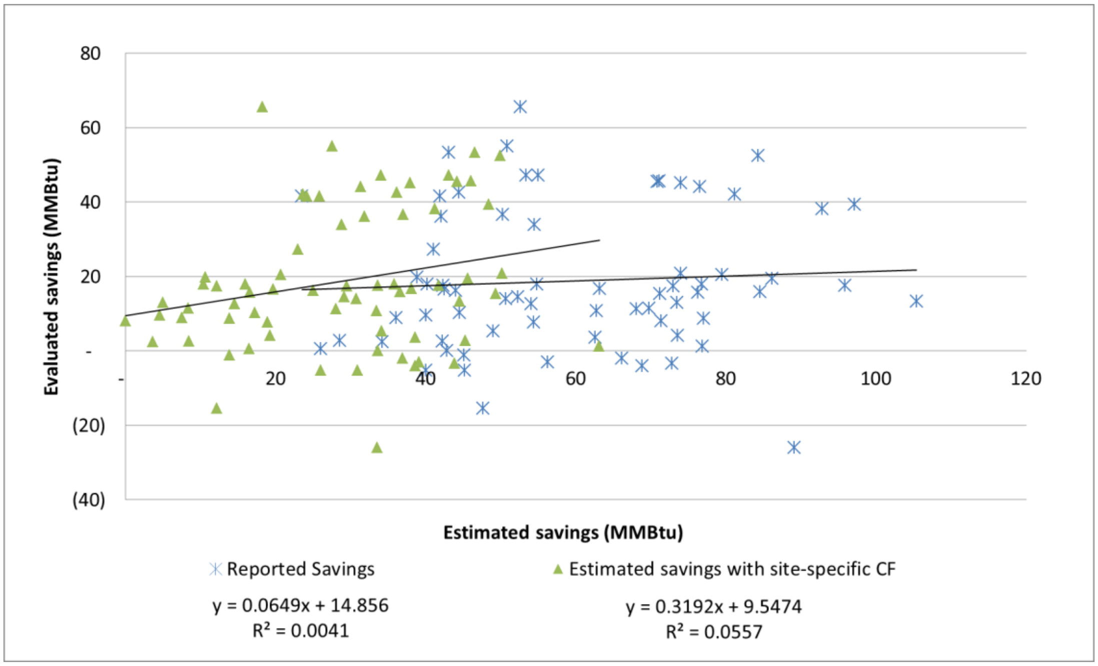
[4] The coefficient of determination, or R^2, indicates how well data fit a curve. A high R^2 value indicates a better curve fit than a low R^2 value.

Figure H-9. EmPower Insulation and Air Sealing Measure Savings Estimates With and Without Site-Specific Billing Calibration



As shown in Figure H-9 above, site-specific billing calibration did produce more accurate savings estimates, on average. However, unlike what was observed for modeled whole-home usage, the reliability of the savings estimates was not improved by the application of a site-specific CF, as indicated by the R^2. Similarly, both the reported savings and the estimated savings with site-specific CFs show a large amount of scatter when regressed against the evaluated savings, as can be seen in Figure H-10.

Figure H-10. EmPower Reported and Estimated Insulation and Air Sealing Measure Savings



The Impact Evaluation Team concluded that the application of site-specific CFs improves the savings estimation accuracy on average, but does not improve the model's ability to make better site-specific savings estimates. Since the development of a site-specific CF would require installation contractors to create a thermal model of the whole home – a time consuming process – an additional test was performed to see whether a single CF used across the Program might perform as well as site-specific CFs in estimating savings.

1.3.3 Impact of Applying a Single Thermal CF to Savings Estimates

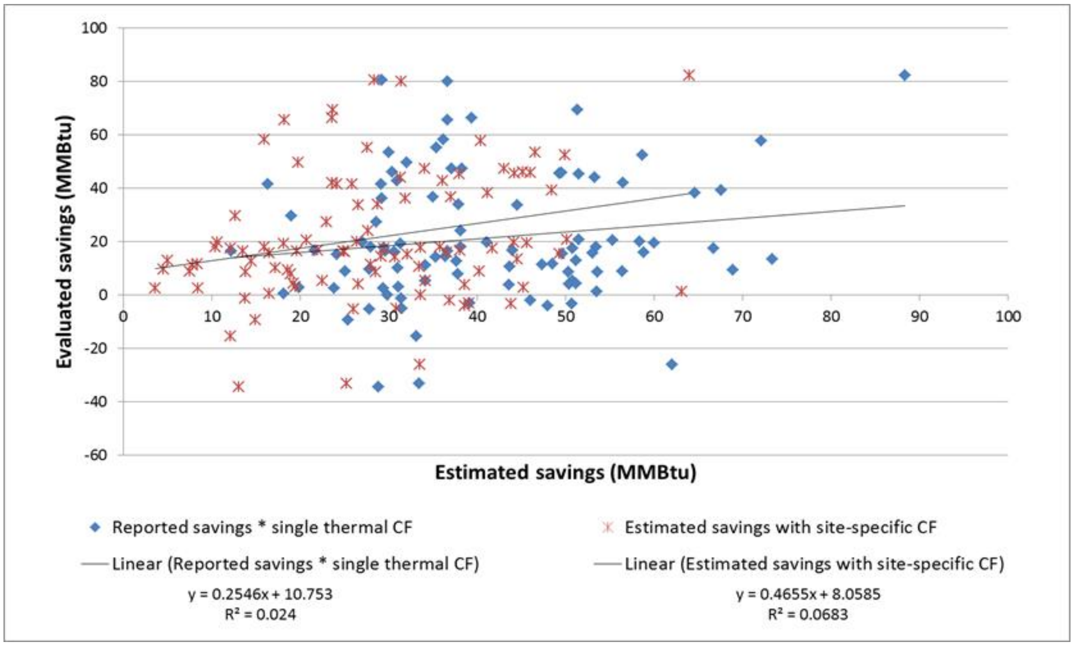
The Impact Evaluation Team calculated a single thermal CF using post-installation heat load estimates and billing data as described in Appendix D. The single thermal CF was calculated to be approximately 0.70. The Impact Evaluation Team found that applying the 0.70 single thermal CF to the heating usage estimated with the whole-home model was an effective method for increasing the accuracy of heat load estimates, on average. The effects of applying site-specific CFs and a single thermal CF can be seen in Table H-4.

Table H-4. Comparison of Post-Installation Heating Usage Estimates With and Without Calibration

Calculation Methodology	Average Usage (MMBtu)	Standard Deviation
Weather-normalized billed heating usage	102.0	36.3
Estimated heating usage with no calibration	146.5	44.8
Estimated heating usage * site-specific CF	91.0	28.4
Estimated heating usage * single thermal CF	102.0	31.2

Similarly, the application of the 0.70 single thermal CF to all heating savings estimates had an impact similar to the site-specific CF, as shown in Figure H-11. Note that the R^2 values are analogous with the single thermal CF and the site-specific CF, which indicates that the accuracy and reliability of both models are comparable.

Figure H-11. EmPower Insulation and Air Sealing Measure Savings Estimates Applying Site-Specific CFs and a Single Thermal CF



1.3.4 Heat Load Correlations

The Impact Evaluation Team sought to identify correlations between site characteristics and heating usage; such correlations could inform heat load calculations and yield more accurate site-specific load calculations. To that end, the Impact Evaluation Team created regressions between fuel usage and home characteristics, including heated volume, insulated area, infiltration ACH, and electric heater use. These home characteristics were determined via on-site inspection, in-person interviews with participants, and information from project documentation. Figures H-12 through H-14 demonstrate some of these comparisons.

Figure H-12. Natural Gas Usage vs. Heated Volume by Site

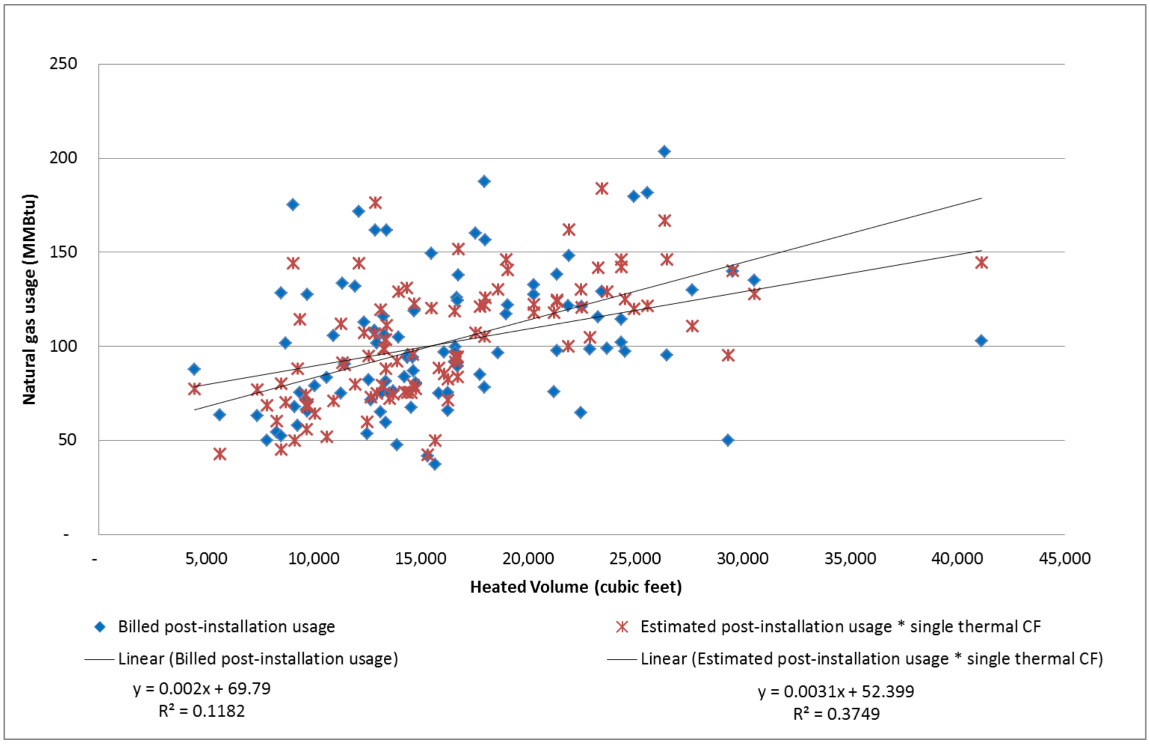


Figure H-13. Natural Gas Usage vs. Post-Installation Air Leakage (ACH) by Site

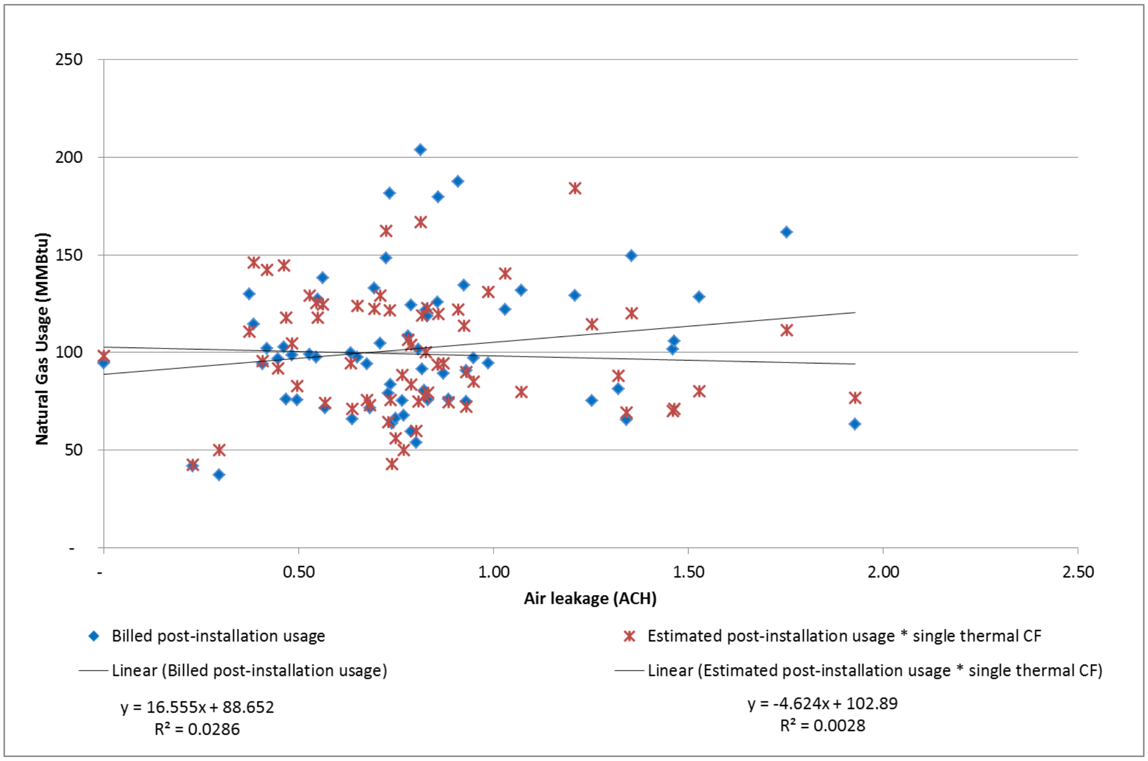
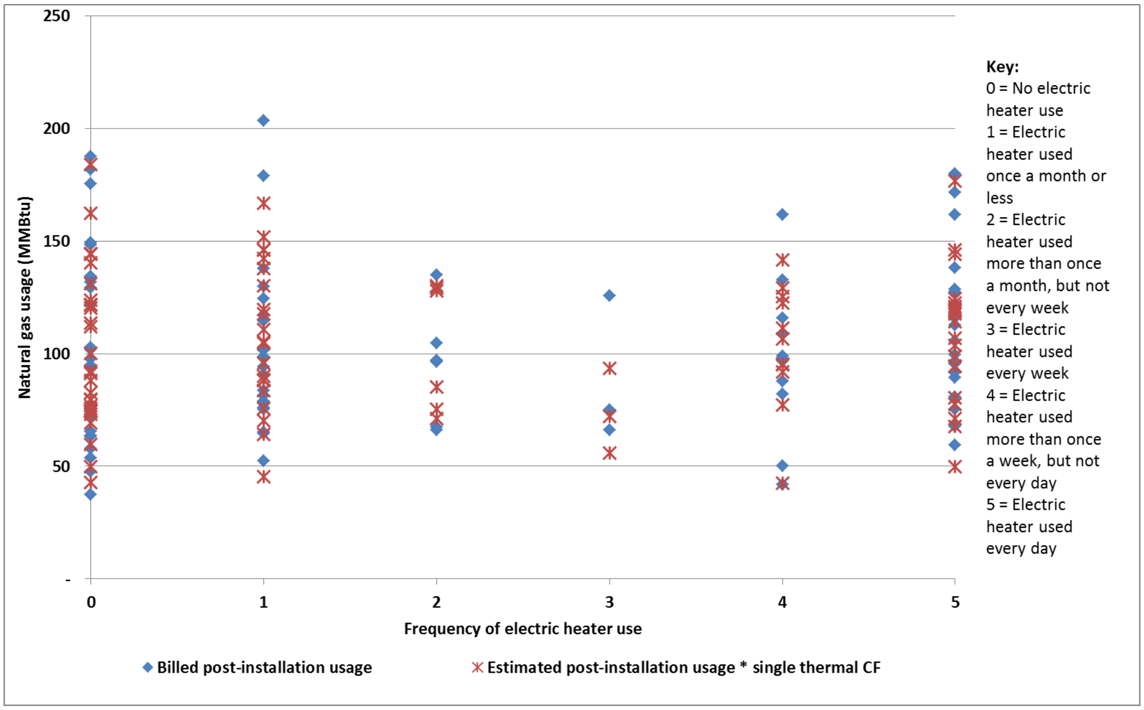


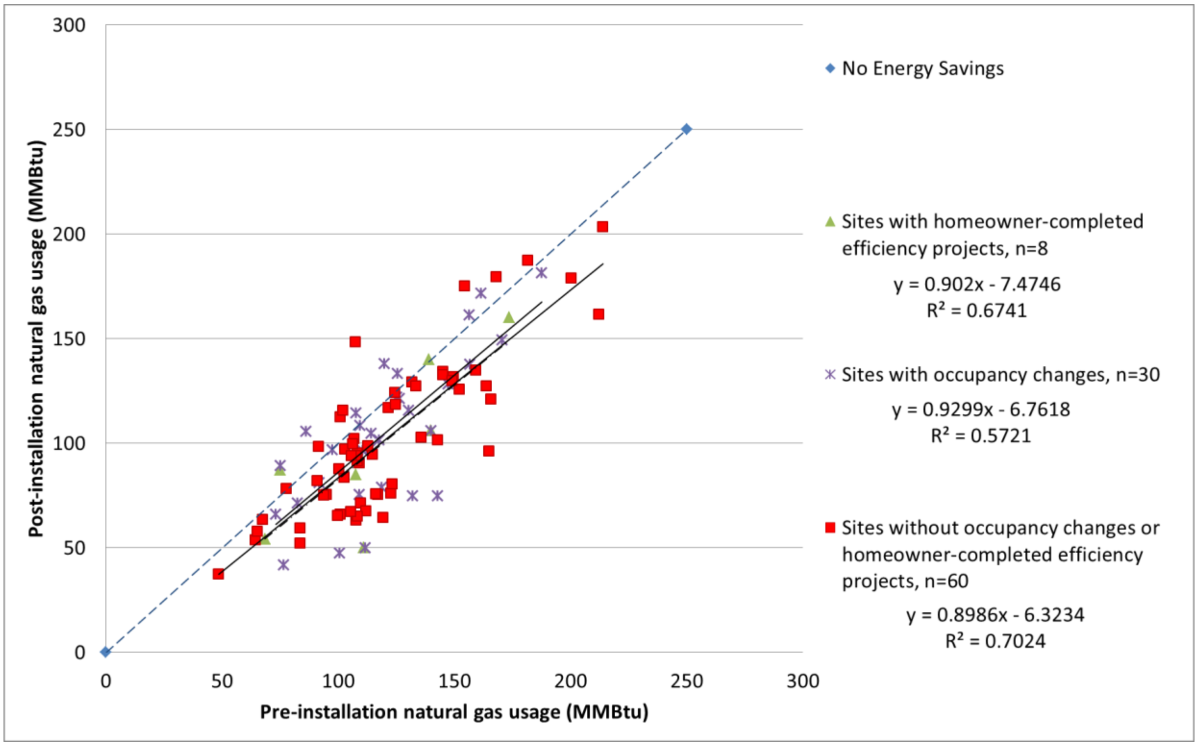
Figure H-14. Natural Gas Consumption vs. Electric Heater Use by Site



As shown in the figures above, no clear correlations were observed for any of the site-specific parameters that were investigated. This somewhat surprising result indicates that the building heat load has a greater than anticipated correlation to parameters which could not be modeled within the scope of this evaluation effort (solar heat gains, differences between core and perimeter interior temperatures, occupancy schedules, etc.).

In addition to identifying the correlations between natural gas usage and site-specific modeled parameters, the Impact Evaluation Team also investigated the relationship between natural gas usage and other parameters that could affect billed natural gas usage, including changes in occupancy and energy efficiency projects completed by homeowners without Program involvement. These correlations can be seen in Figure H-15.

Figure H-15. Gas Consumption for Homes with Non-Program Energy Projects or Changes in Occupancy



As demonstrated in Figure H-15 above, neither homeowner-completed efficiency projects nor changes in occupancy had a significant impact on natural gas savings.

1.3.5 Uncertainty of the Single Thermal CF

The Impact Evaluation Team has attempted to narrow down the factors that influence the single thermal CF by examining how well the model estimates home heating usage compared to the billed heating usage. The analyzed homes were selected at random from a subset of all the homes in the billing analysis. As detailed in the Sample Design Memo (Appendix E), the on-site sample population targeted homes which featured measures that accounted for a large percentage of the Program savings (i.e., envelope measures which account for 84% of the reported natural gas savings) and could be readily inspected in the field. Table H-5 summarizes the population attrition and its impact on home usage and savings. While the savings of the on-site population is over 50% greater than that of the general population, the annual usage is almost identical.

Table H-5. Population Attrition and Annual Usage

	Population	Total Reported Savings (Therms)	Average Reported Savings Per Household	Annual Usage (Therms)
Included in Phase I billing analysis	1,775	771,750	435	1,506
With insulation measures	1,236	560,169	436	1,465
Reported savings >400 therms	319	279,910	877	1,598
Final sample population randomly selected for recruitment	220	148,958	677	1,510
Final sample	98	67,719	691	1,513

It is clear in the table that the subset of homes from which the sample was selected has higher average savings than the Program-wide population, which is to be expected because it would not be fruitful to conduct an on-site investigation for a couple of square-feet of insulation. Sites with small estimated savings and no insulation measures were screened out. The sample was selected to be representative of those homes providing the bulk of the savings to ensure our findings broadly applied and that our observations about contractor practices was representative of their work.

The Impact Evaluation Team calculated the sampling statistics for the subset of homes from which the sample was selected, as shown in Table H-6.

Table H-6. On-Site Sampling Statistics

Subset population	319
Sample size	98
Mean site-specific CF	0.715
Standard deviation	0.203
Coefficient of variation	0.284
Standard error	+/- 0.034
Precision (90% confidence)	+/- 0.047
Single thermal CF, CF = sum(billed heating load) / sum(estimated heating load)	0.696

As shown above, the sampling precision and the coefficient of variation for the variable of interest, the CF, were quite good. A more important consideration, given the definition of the sample frame, is whether the results may be biased and not applicable to the larger population. The Impact Evaluation Team examined a number of factors and concluded that the CF is unbiased, as discussed below:

- While the sample frame was designed to capture homes with installed insulation measures and high reported savings, the pre-installation natural gas usage for the general population and the sample population are similar;
- The CF aligns well with the Phase I billing analysis, after accounting for the administrative errors and the other EmPCalc recommendations;
- The CF did not correlate with any other factor – such as square-footage or geographic location – within the sample results that would indicate additional appropriate population differentiation;
- Calculating the single thermal CF using pre- or post-installation data gave similar results (0.621 and 0.696 with R^2 of 0.303 and 0.391, respectively).

Upon thorough review of the results the Impact Evaluation Team has concluded that the single thermal CF is appropriate for application to thermal modeling of the population.

1.3.6 Thermal Model Conclusions

While the EmPCalc is a practical tool for the installation contractor-reliant Program, the overarching weakness of the tool is its idealized calculation methodology. A variety of factors may contribute to the overstatement: site-specific solar heat gains, imperfectly represented temperature profiles, unpredictable occupancy schedules, and snapback, as well as other unidentified reasons. The Impact Evaluation Team sees no evidence that a more complicated and expensive whole-home modeling with EmPCalc or an alternate tool will improve the accuracy of the savings estimates. A single thermal CF applied to all heating measures will true up the savings estimates in a simple and effective way. Because the single thermal CF was developed using modeled whole home usage and actual billing data, it is independent of savings and does not reflect changes in customer behavior, quality of installations, administrative errors, or other Program and measure related concerns that would arise if this factor was an adjustment of modeled savings to match actual savings.

The analysis indicates the average thermal CF will vary between 0.68 and 0.75 for 90% of the homes, based on the standard error[5] of the sample. The Program Staff will want to consider an appropriate application of the CF for screening individual measures in individual homes and whether individual homes are screened using the recommended CF or, possibly, the upper bound value. While using the upper bound value might ensure that no home is disqualified for a measure that it might have qualified for otherwise, it will overstate Program savings as a whole.

The recommended single thermal CF was determined using the EmPCalc model and assumptions and should be valid with that tool, even assuming the history of regular improvements to the model continues. The CF, however, should be reassessed if the fundamental modeling calculations shift to, for example, hourly simulations or incorporation of solar loading.

1.4 EVALUATION OF EMPCALC ASSUMPTIONS

The Impact Evaluation Team completed a parametric analysis[6] to evaluate various EmPCalc assumptions. As described in Appendix D, the Impact Evaluation Team completed the analysis with EmPCalc version 3.41 because it was used by installation contractors in 2010 and 2011. The impact of each analyzed parameter on the estimated savings was quantified by comparing the natural gas savings calculated in each parametric run to the natural gas savings calculated with EmPCalc 3.41. The distribution of these results can be found in Figure H-16 and Table H-7. Note that a negative percentage of deviation means that the parametric run yielded a smaller savings estimate than EmPCalc 3.41.

[5] The standard error of the sample indicates how far the sample mean is likely to be from the population mean. The standard error of the single thermal CF was calculated using a normal distribution Z-score for a 90% confidence interval.

[6] In the parametric analysis, savings were estimated for each of the 98 on-sites using first one assumption (e.g. the EmPCalc 30 year average weather based HDD) and then the alternative (e.g. the TMY3 weather based HDD), keeping everything else constant.

Figure H-16. Parametric Run Savings Estimates vs. EmPCalc Savings Estimates

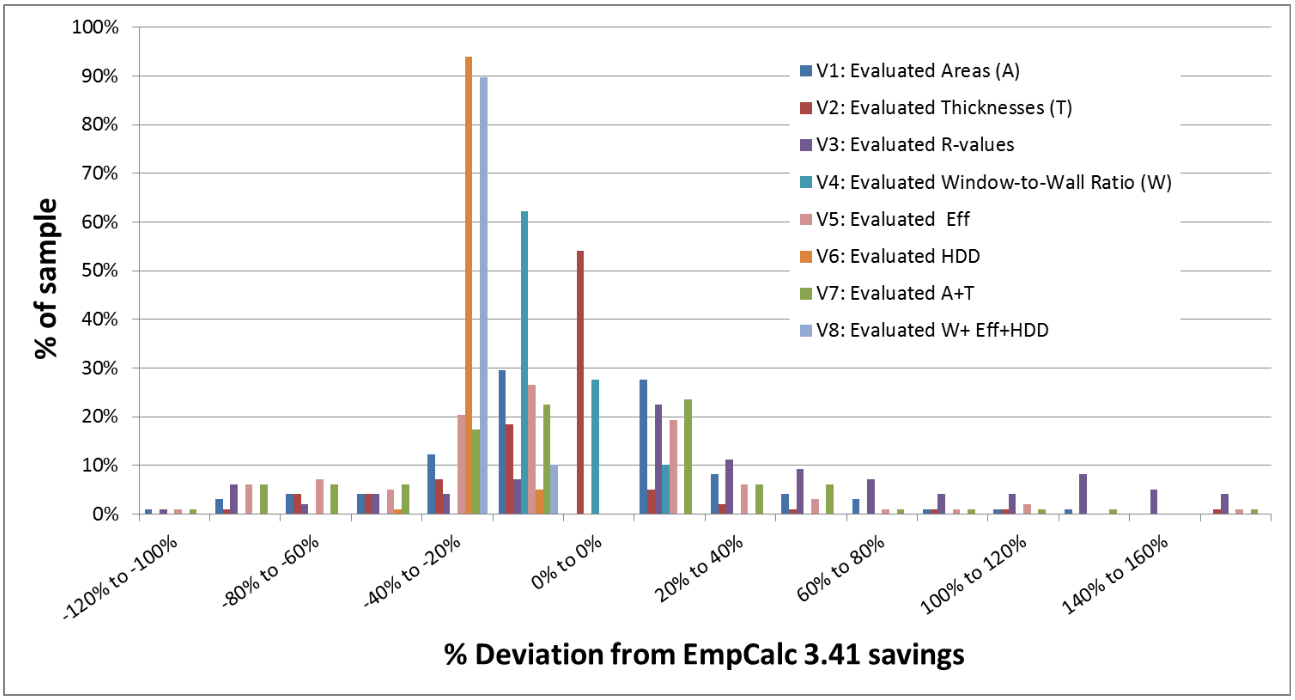


Table H-7. EmPCalc Parametric Run Results

Run	Parameter Investigated	Percentage of Change in Total Claimed Savings[1]
1	Evaluated areas	-2.1%
2	Evaluated insulation thicknesses	-3.8%
3	Evaluated R-values	30.8%
4	Evaluated window-to-wall ratio	-2.9%
5	Evaluated combustion efficiencies	-1.2%
6	Evaluated HDD	-17.1%
7	Evaluated areas and insulation thicknesses	-5.6%
8	Evaluated window-to-wall ratio, combustion efficiency, and HDD	-20.5%

[1] The negative % change in claimed savings means a lower expected savings, yielding a higher RR.

The results of the parametric analysis show that measurement differences between the installation contractor dimensions and the Impact Evaluation Team dimensions (runs 1, 2, and 7) have a small impact on the estimated savings. As discussed in Section 1.2, the differences between the installation contractor dimensions and the Impact Evaluation Team dimensions were generally within the margin of measurement error. However, completing heating savings calculations with the correct combustion efficiency value throughout EmPCalc will more precisely represent the pre- and post-installation onsite conditions. Likewise, changing the window-to-wall ratio to a more accurate value (25% instead of 15%) will result in more correct savings estimates. Finally, adjusting the EmPCalc HDD values to updated

HDD values calculated with a 60°F balance point and TMY3 data will result in savings estimates which are more accurate. When the combustion efficiency, window-to-wall ratio, and HDD are adjusted interactively (run 8), the estimated savings are reduced by approximately 21%, which will boost the RR by approximately 12%.

The parametric analysis revealed that assuming the pre-installation walls are completely uninsulated (run 3) would increase the already over-inflated savings estimates. This is because EmPCalc conservatively assumes that the pre-installation walls have an R-value of 4.44, while completely uninsulated walls have an R-value of 1.5 to 2.5. The Impact Evaluation Team determined that the elevated Program R-value assumption of 4.44 is likely a better characterization of the thermal resistance of pre-treated surfaces than assuming that there is no insulation present prior to treatment. Therefore, changing the EmPCalc R-value assumptions is not recommended.

Based on the results of the parametric analysis, the Impact Evaluation Team recommends the following actions:

- Change the window-to-wall ratio from 15% to 25%[7].
- Use a consistent combustion efficiency for all heating measures throughout EmPCalc (already implemented in later EmPCalc versions).
- Adjust the EmPCalc HDDs for each location as specified in Appendix D.

The Program has implemented all three of the recommended changes at this time.

1.5 ADMINISTRATIVE ERROR

Until January 2, 2015, the Implementation Contractor manually typed the EmPCalc cover sheet savings[8] into CRIS, NYSERDA's reported savings. As detailed in Appendix D, a selection of 187 project files with very high savings fractions (i.e., savings as a percentage of total use) was examined to determine the magnitude of differences between the cover sheet savings and NYSERDA-reported savings values. This analysis was not intended to evaluate the accuracy of the EmPCalc entries and assumptions, but rather, to evaluate the accuracy of the savings reporting methodology. Because this sample of 187 projects was different from the onsite sample of 98 projects, the Impact Evaluation Team could not field verify the EmPCalc entries and therefore assumed that the EmPCalc values retained in the project file were correct.

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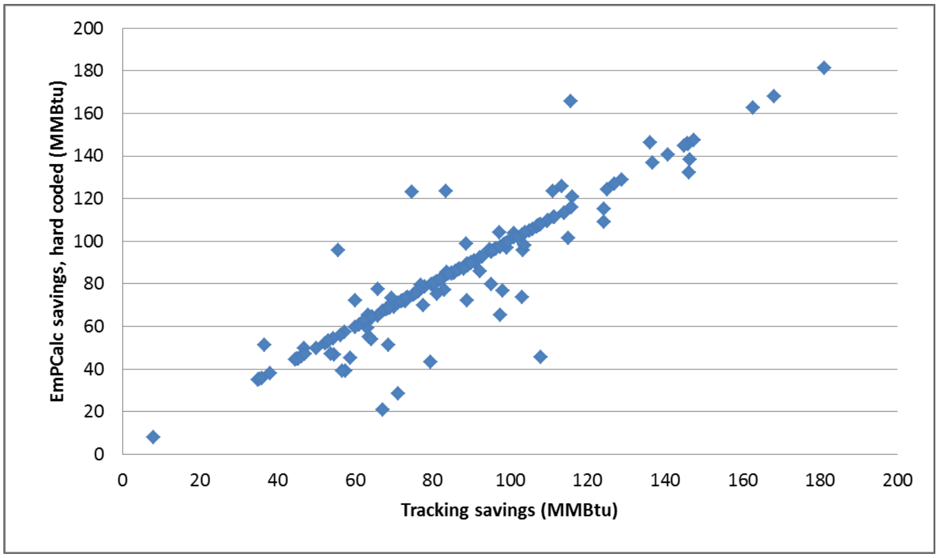
[7] The evaluated sample returned an average window-to-wall ratio of 23%, but the sample design was not intended to evaluate this individual parameter. Therefore, the Impact Evaluation Team recommends using a slightly more conservative 25% window-to-wall ratio.

[8] When the Implementation Contractor targets individual measures for installation, their associated measure-level EmPCalc savings are summed in the EmPCalc cover sheet.

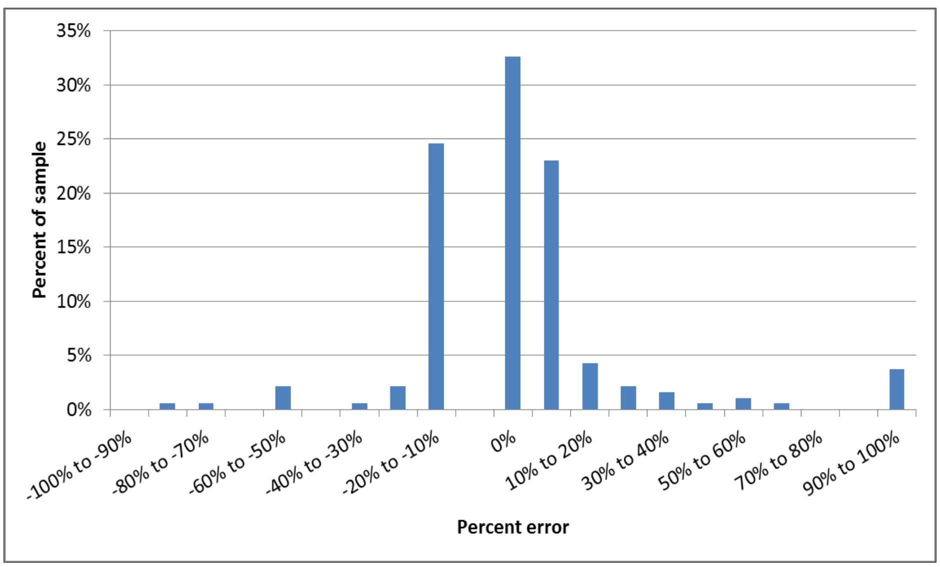
A net discrepancy of 10,089 MMBtu in natural gas savings was identified in the 187 project files, overstating the total Program-reported savings in 2010 and 2011 by approximately 7.9%. Because not all of files were selected for this analysis, it is likely that the total impact of manual transcription errors is greater than 7.9%. Figure H-17 presents a comparison of the EmPCalc cover sheet savings and the reported savings for the 187 project files, while the error distribution is presented in Figure H-18.

Figure H-17. EmPCalc vs. Reported Natural Gas Savings[1]



[1]One large outlier (reported savings = 5,523 MMBtu, evaluated savings = 105 MMBtu) was removed from the graph to increase legibility.

Figure H-18. EmPower Distribution of Transcription Error



As shown in Figure H-18 above, random data entry errors can result in reported savings that are either greater than or less than the EmPCalc savings. However, the overstated reported savings have a larger impact on the Program savings than the understated reported savings, thereby inflating the Program savings and reducing the evaluated RR.

1.6 PRISM ANALYSIS

The Impact Evaluation Team used a PRISM-type billing analysis to investigate the hypothesis that the low natural gas RRs might be due to a snapback effect. The methodology for this analysis effort is presented in Appendix D, while the results are presented in this section.

1.6.1 Comparison with Phase 1 Results

Table H-8 compares the Phase 1 billing results with the PRISM-type analysis of this billing analysis. This comparison is important because if the two methods produce different results, it makes it difficult to associate the findings from this snapback analysis back to the original RRs.

Overall, the Phase 1 billing analysis resulted in slightly higher savings and, consequently, a higher RR. This is likely due to the exclusion of 60 projects with fuel switching with a gas dryer installation. The results using each of the two approaches are, however, very similar.

Table H-8. Comparison of Results for Pseudo PRISM with Phase 1 Billing Analysis

	PRISM-Type / Snapback Analysis			Phase 1 Billing Analysis		
Utility	Annual Savings	Percent of Consumption	RR	Annual Savings	Percent of Consumption	RR
NFG	194	12.6%	36.4%	195	13.1%	36.8%
NYSERDA	132	10.5%	46.4%	137	11.2%	48.9%
Overall	171	11.9%	38.8%	173	12.4%	41.4%

1.6.2 Site Results

It was hypothesized that the expected result of weatherization would be a decline in the outdoor temperature at which homes begin to need heating. This effect should be seen as a decrease in the balance point[9] temperature selected and/or the slope associated with heating consumption[10] in a billing analysis. To illustrate this expected effect, Figure H-19 juxtaposes scatter plots of the best base temperatures selected for the pre- and post- periods for a household that showed a decrease in the balance point. Each base temperature is plotted for both pre- and post- periods with their respective regression lines overlaying the data. Insets in the plots are the R^2, intercept, and slope associated with the data.

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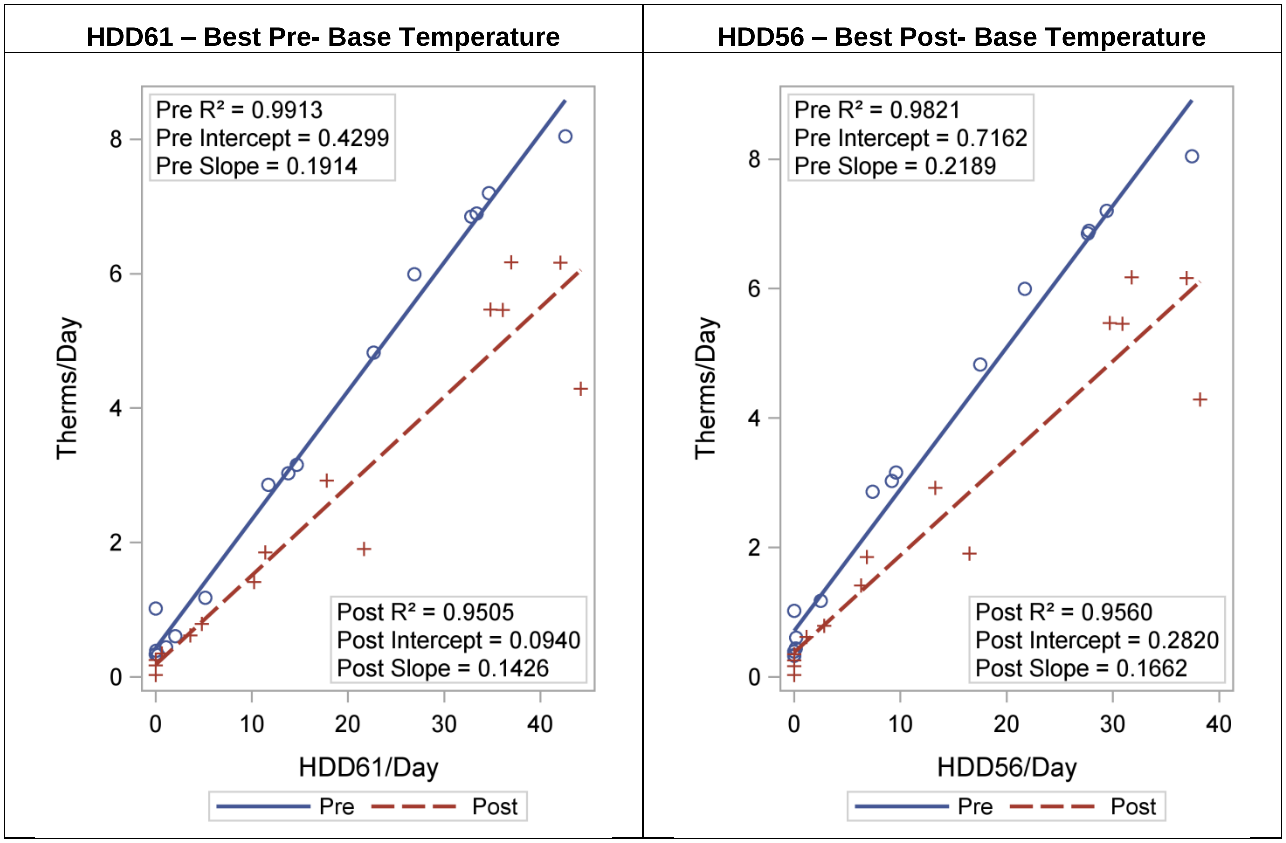
[9] The balance point is the outdoor air temperature at which a home's heating system is required to turn on to satisfy the thermostat setpoint.

[10] Note that the slopes from models with different HDD base temperatures are unit dependent, so they cannot be compared directly to each other. They can, however, be used to calculate the normalized annual consumption (NAC) for heating, and these values are directly comparable.

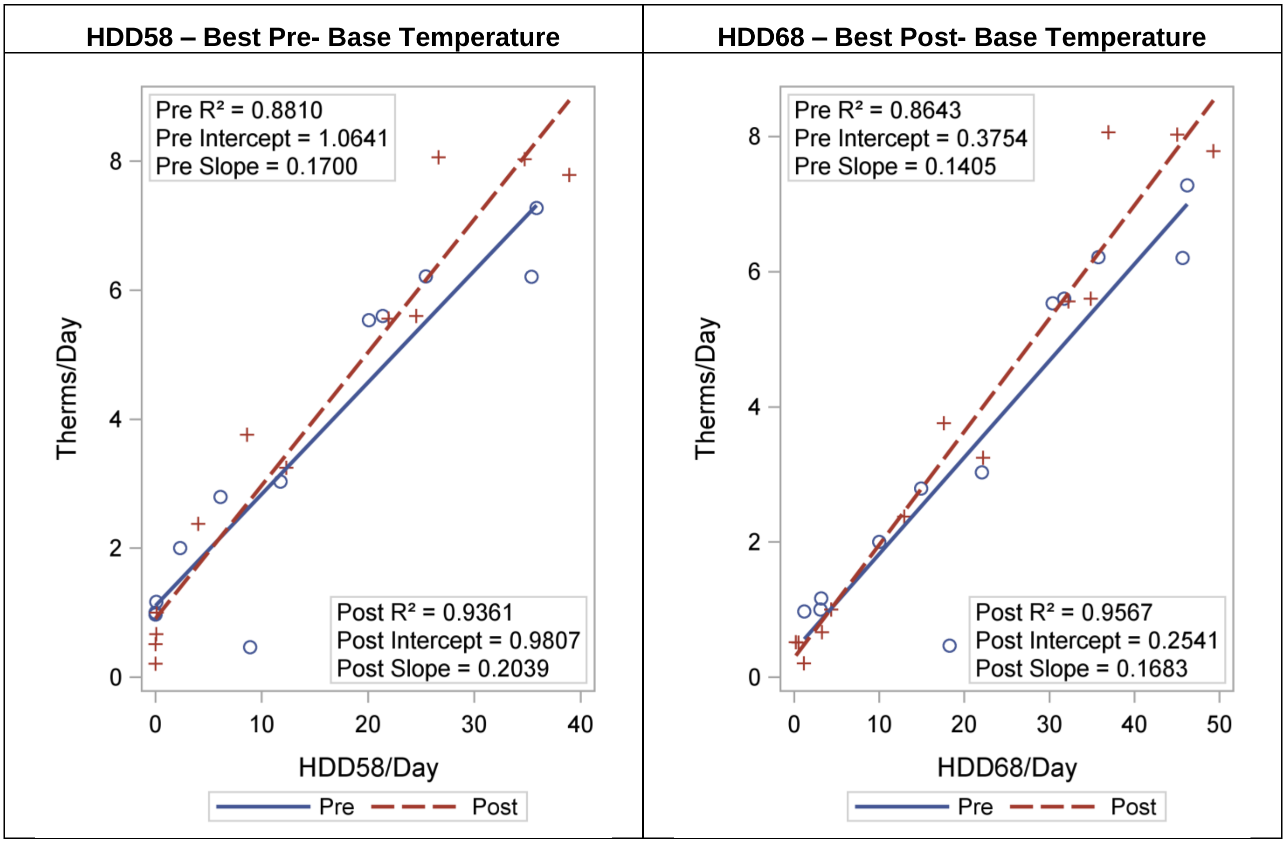
Figure H-19. Sample of Pre- and Post- Comparisons of Best Pre- and Post- Base Temperatures for Decrease in Balance Point for a Single Site



While there is a lot of information in these plots, one of the key attributes to note is the markedly lower slope (the dashed red line) associated with the post- period for both base temperatures. This lower slope reflects a decrease in heating consumption per degree day, consistent with expectations for a weatherized home. Although the balance point decreased from 61°F to 56°F degrees, the difference in the R^2 values are small. For example, the R^2 for the best pre- base temperature in the post- period was 0.9505, which was only slightly lower than the R^2 of 0.9560 for the best post- base temperature. This illustrates that in some cases the changes in balance point might be driven by small differences in goodness of fit.

In contrast, Figure H-20 presents an illustration of a household with an increase in the balance point following weatherization. In this case, the balance point increased from 58°F to 68°F and the slope indicates that this was accompanied by an increase in consumption per degree day. The difference in the R^2 value that determined the change in balance point in the previous example (0.9361 vs. 0.9567 for the post- balance point) might still seem small, but it means that the 68°F degree balance point actually explained nearly 3% more of the variability in consumption.

Figure H-20. Sample of Pre- and Post- Comparisons of Best Pre- and Post- Base Temperatures for Increase in Balance Point for a Single Site

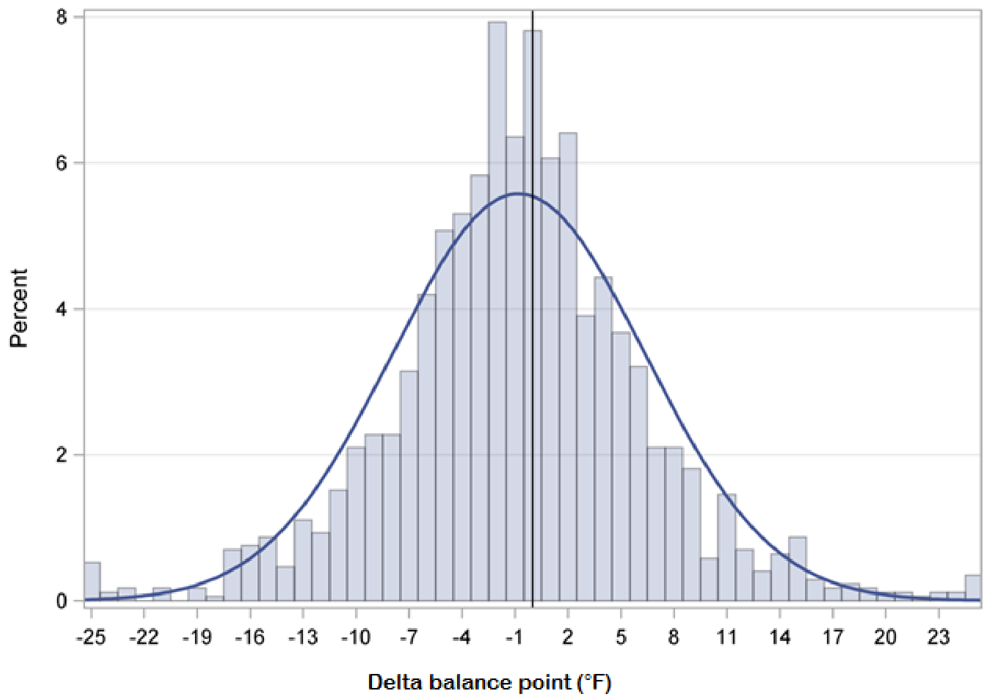


The examples in Figure H-19 and Figure H-20 above, however, represent just two of 1,715 projects that were included in the analysis.

1.6.3 Program Level Results

Across all of the projects, the average change in balance point represented an **increase** of 0.8°F. And while it is not surprising that some balance points increased, the expectation was that on average the balance points would go down. As shown in Figure H-21, the distribution of changes in balance point was normally distributed and highly variable, covering the full possible range of changes (-25°F to 25°F). Negative values indicate an increase in the balance point (outside temperature that triggers the home heating to be turned on), and the shift to the negative side of the distribution is slight but still perceptible.

Figure H-21. Histogram of Delta Balance Point



As shown in Table H-9, which presents the RRs for heating measures and change to the balance point, the data generally support the expectations about how the change in balance points will be related to RRs. For example, the RR for heating measures is nearly 54% for households that had a decrease in balance point, compared to less than 19% for those with an increase.

Table H-9. The Effect of Balance Point Changes on Realization Rates

			Balance Points (outside temperature at which heat is turned on in home)			Heating Savings		
Utility	Change in Balance Point	Projects	Pre-	Post-	Difference	NAC[1] Heating Savings (MMBtu)	Tracking Heating Savings (MMBtu)	Heating RR
Overall	Decrease	688	64	58	-5.7	21.7	40.2	54%
	No change	134	61	61	0.0	13.8	33.9	41%
	Increase	893	59	65	5.9	8.3	44.9	18%
	All	**1,715**	**61**	**62**	**0.8**	**14.1**	**42.2**	**33%**

[1] Normalized annual consumption

This data provides evidence of snapback, as indicated by an increase in space temperatures correlated with a decrease in savings. It is worth noting that there are a substantial number of inconsistencies that undermine drawing any clear conclusions. For example, there are many instances where a decrease in balance point did not coincide with a reduction in the NAC, either overall or just for heating. As seen in

Table H-10, 23% of the households with a decrease in balance point actually had an increase in NAC, a share that was not greatly different from the households with an increase in balance point.

Table H-10. Percent of Households Increasing NAC and Heating NAC

Change in Balance Point	Percentage Increasing NAC	Percentage Increasing NAC Heating
Decrease	22.8%	17.2%
No change	26.9%	24.6%
Increase	25.8%	37.3%
All	**24.7%**	**28.2%**

The results of this analysis show that not every household exhibited the types of hypothetical changes in consumption that are expected from a weatherization program. The PRISM-type analysis looked at changes in balance point (i.e., the outside temperature at which households turn on heating systems) and revealed that the balance point temperatures went both up and down with high variability and a net increase of less than one.

However, comparisons of the average heating savings using the Tukey test, as summarized in Table H-11, showed statistically significant differences at the 0.05 level between projects with a decrease in the balance point and both other groups indicating the balance point change partly explains the change in heating savings.

Table H-11. Results of the Pairwise Comparison of the Balance Point Stratum

Change in Balance Point	Projects	Mean Difference (MMBtu)	Confidence Limits (95%)		Statistically Different
			Lower Bound	Upper Bound	
Decrease vs. no change	688	78.94	13.22	144.66	Yes
Decrease vs. increase	134	133.96	98.65	169.27	Yes
No change vs. increase	893	55.02	-9.46	119.50	No

Based on a definition of snapback as any increase in the balance point, the delineation of the households into groups and a comparison of their attributes provided evidence to support this definition, including substantially lower RRs and increases in heating consumption. There is some evidence that households are exhibiting behavior that could be indicative of a snapback effect. But given the variability in the results and the presence of substantial inconsistencies there is no way to say for certain what the possible underlying causes or what the program impact might be.

MEMO

DATE: JUNE 19, 2014

TO: NYSERDA, NFGDC

FROM: ERS

RE: Final Empower and Home Performance with ENERGY STAR Site Participation Incentive Overview

The following document is an overview of the survey participation incentives proposed for the EmPower Phase 2 on-site M&V effort. An incentive is proposed for every site visited.

The first section explains why an incentive is justified and the balance of the memo describes the protocols that we will use for incentive invoicing, payout, and tracking, organized as follows:

- Incentive discussion
  - Incentive level
- Incentive protocol
  - Incentive invoicing
  - Customer contact/recruitment
  - Incentive payment
  - Incentive tracking
- Appendix I-A – receipt of incentive form

INCENTIVE DISCUSSION

Incentives are frequently offered to residential nonparticipating customers and sometimes to participants as a means of ensuring a high response rate and to acknowledge the time and inconvenience of providing responses or hosting a site visit. Table 1 presents examples of incentives offered in other programs or situations to gather information after program services were complete.

Table 1. Examples of Post-Service Incentives

Data Gathering Effort	Incentive Level	Recruitment Rate
ConEdison CAC impact study. This study measured the performance of central air conditioners in 30 participant homes. The initial site visit took approximately 2 hours and required a separate equipment pickup. Study completed in 2013.	$100	50%*
Massachusetts LI lighting socket inventory and hours of operation and HVAC measurement at both participant and non-participant households. This study determined the number, use and hours of sockets in 240 low-income households. The initial site visit took about 1hour and required a separate equipment pickup. Study completed in 2013.	$150	35%–50%*
Vermont Home Performance with ENERGY STAR billing analysis. About 200 participants completed a telephone survey and returned a signed billing release authorization. Study completed in 2012.	$25	50%
Proposed EmPower on-site M&V. This study will inventory installed equipment, conduct a customer survey, inspect the home top-to-bottom, record elevation dimensions, and conduct blower door tests for a subset. The site visit will take about two hours. The goal is to complete 60 NYSERDA and 60 NFGDC site visits in 2014.	Proposed $100	50%+ is required to meet NYSERDA quotas
NYSERDA EmPower QC follow-up visit. The QC contractor inspects a sample of participant sites within 60 days of the completion of services. The site QC visit takes approximately 1 hour and includes a blower door test. Ongoing.	$0	25%–30%

*As recalled by project manager, actual figures were not available.

With a $100 incentive, the Impact Evaluation Team (IET) is projecting an aggressive 50%–60% recruitment rate. With no incentive, we would plan for a 25% recruitment rate, which will put the NYSERDA results at risk, increase evaluation costs, and push out the final report date by about 2 months.

NYSERDA Sample at Risk

The on-site sample has been designed to focus on sites with a projected high level of savings, further segmented into High Savers (sites that demonstrate a high level of actual savings per a billing analysis) and Low Savers (sites that demonstrate a low level of actual savings per a billing analysis). The NYSERDA sample frame population is quite small (only 101 sites are in the sample frame) because there was limited billing data available for the NYSERDA sites and about half the NYSERDA sites were small savers that did not have enough measures installed to warrant a site visit.

To meet the sample design, we must recruit **60**% of the NYSERDA sample frame population (n=60, N=101), which in our judgment, can only be done with a substantial incentive. Without an incentive, we expect that we would only be able to recruit about half of the desired sample and would have to replace NYSERDA sites with NFGDC sites to meet the overall quota of 120 sites.

Increased Evaluation Costs

While the elimination of incentives does reduce the budget by $100 per site, that reduction is offset by other increases in cost. Without an incentive, the IET will make a request for another 240 project files to provide a larger replacement pool. Each project file requires data entry in order to be usable (about one half-hour per file). Additionally, since we expect that the recruitment rate would be halved without an incentive (25% based on EmPower QC recruitment), the actual recruitment hours are doubled. Finally, the efficiency of the number of on-sites per day is reduced, because cancellation rates will increase. This is expected to produce a net increase of 630 labor hours at a net cost of about $64,000.

Delay Final Report

We foresee a 6- to 10-week delay in the production of the final report if incentives are not offered. Before the evaluators go on-site, all the project files must be acquired and data entered so that we can efficiently schedule sites geographically. The previous file request took about a month for delivery. Each file must be data entered, which is expected to take about 2 weeks. Additional time will be required for a decision on the incentive, formulation of a project file request, and to re-engage the site teams, which will have to be allocated to other work while the files are processed. Training is currently planned for July 1, with the first audits during the week of July 7.

It should be noted that it is very important that we schedule site visits geographically so that we can minimize travel times. In order to do this, all of the project files for a region need to be acquired, data entered, and processed into pre-populated data collection forms. This means that work cannot begin until we have a complete set of files for a region.

Incentive Level

We believe that a $100 incentive level is appropriate based on the information in Table 1 and a judgment that $100 reaches a psychological threshold that will be compelling for about half of those that we call. We understand that we must offer the same incentive to any of the residential customers that we may visit in these evaluations. We believe that a relatively high incentive level is required for non-low income households. We therefore recommend a $100 incentive for each site visit.

Incentive Protocol

The remaining sections describe the protocol for administering the incentives, should NYSERDA authorize them.

All survey respondents will be offered the same incentive. Telephone surveys are not being conducted; incentives will only be offered for site visits. One hundred-twenty site visits will be conducted; each site will be offered $100 for complete participation, with a total possible program cost of $12,000. Each site visit is expected to take around 2 hours, and will be conducted on non-holiday weekdays, including evenings, with Saturday customer-convenience appointments.

Incentive Invoicing

ERS will pay out the survey participation incentives and bill NYSERDA for the incentive reimbursement within the normal monthly invoice. Any unused incentives, such as unused, expired, or refused checks, will be credited to NYSERDA.

For every check disbursed to a respondent, ERS will track necessary information for accounting and auditing purposes, including but not limited to check number, check date, name, and address. This information will be available for a NYSERDA or NFGDC audit, if requested. For further information on what incentive information will be tracked, please refer to the "Incentive Tracking" section of this memo.

Customer Contact/Recruitment

An advance letter will be sent to the selected sample of customers (or current residents); however, this letter does not mention an incentive, only that the customer may be contacted for an on-site appointment. After the mailing of the advance letters, ERS will begin calling the site contacts to confirm the correct contact person, recruit for and schedule on-site visits and first introduce the incentive. During this call the evaluators will inform the customer that the visit will take up to 2 hours, that the on-site participant must be available to accompany the interviewer during the entire on-site visit, and at the end of the visit, ERS will give the on-site participant a $100 survey participation incentive check for their participation, after the participant signs a receipt. The evaluators will also explain that incentives will only be paid for site visits completed at that time and will be made out in the on-site participant's name.

If the site contact agrees to an on-site visit, the evaluator will confirm and record the name and address of the on-site participant. ERS will only complete site visits at homes in which the site contact resided in the home both before and after project completion. ERS will request that the person most familiar with the project work be present for the site visit; we anticipate that this will be the site contact on file. The incentive check will be made out to the site contact that is present for the site visit, which will be determined during the recruitment call.

Incentive Payment

Once an on-site visit is scheduled and confirmed, ERS will make a check out to the on-site participant and give it to the on-site evaluators to be distributed at the end of the completed site visit. ERS will maintain tracking of the check number and the contact information for each on-site participant. Checks will be issued from an ERS account and will be on an ERS check.

At the start of the on-site visit, the evaluators will explain that the incentive will be presented to the customer at the end of the visit, and that the customer will be asked to sign a form that confirms the receipt of the incentive.

At the end of the completed visit, the interviewer will hand the survey participation incentive to the on-site participant and require the on-site participant's signature to confirm that the check was received. The interviewer will also make it clear that the on-site participant will have 90 days to cash the check.

Any incentives not distributed will be noted by on-site evaluators and tracked by ERS. If an on-site visit is not completed, the incentive will not be distributed, the reason for the incomplete visit will be recorded, and NYSERDA will be credited for the check. If the on-site visit is completed, but the incentive is refused, the on-site participant will be thanked for their time and the refusal will be recorded by ERS. If the on-site participant refuses the survey participation incentive, but requests that the amount be donated to charity, the on-site participant may take the incentive and make the donation themselves. Alternatively, the on-site participant can refuse the incentive and it will remain in the pool of public goods funds that are used to evaluate and help better the program.

ERS will collect and retain a form signed by the customer (Appendix I-A) that confirms that the customer either received or refused the incentive.

ERS will stop payment on all uncashed checks 90 days after their payout date, and credit NYSERDA for the amount in the next monthly invoice. A record of uncashed checks along with the stop payment date will be kept in a tracking spreadsheet. If the customer requests a stop payment and reissuance check, the new check will be issued with a new date. If payment is stopped on any checks for any other reason, NYSERDA will be notified and reimbursed.

The *Receipt of Incentive Form* can be found in Appendix I-A.

Incentive Tracking

All survey participation incentives will be tracked by ERS to assist in monthly invoicing, bill reconciliation, and other needs if requested or required. The checks and their associated information will be tracked in an Excel spreadsheet that will be updated as needed. The following information will be recorded for each check disbursed:

- ❑ Check information: Check number, check date, name and address of recipient
- ❑ Payment date: If cashed within 90 days, if payment was stopped, reason for stop payment (if applicable), if a check was reissued
- ❑ Receipt of signed Receipt of Incentive Form: If form was signed, record that ERS has the signed form
- ❑ Non-payment (if applicable): Why the check was not paid out (i.e., refusal or incomplete on-site visit), reason for refusal of check (if applicable)

- Relevant site information: Site I.D. number, site address, evaluator name(s), whether the on-site participant received an advance letter

APPENDIX I-A: RECEIPT OF INCENTIVE FORM

Overview

This form is intended to confirm payment of the $100 incentive to the on-site participant following a completed on-site visit for EmPower Phase 2 site visits. It should be filled out by the evaluator and signed by the on-site participant at the end of the completed site visit when they receive their incentive check.

Receipt of Incentive

This is a required form. If the site visit was not completed, an incentive may not be paid out.

For the Evaluator

Date of visit	
Name of evaluator	
Site ID	
Customer name	
Customer address	
Check number	

- ❑ Site visit is complete – OK to payout incentive
- ❑ Site visit was not completed – no incentive paid out

If not complete, please give reason: ________________________________

Example: on-site participant was not available

For the Customer

Thank you for your participation in today's on-site visit. Please choose an option and sign and date the form. Note that you will have 90 days from today to cash your incentive check. After 90 days, payment will be stopped on any uncashed checks.

- ❑ Check for $100 received
- ❑ Check refused – my refused incentive amount will be returned to NYSERDA's public benefits fund

On-site participant name: ____

On-site participant signature: ____

Date: _____________________

For Office Use Only:
Date received:
Entered:

MEMO

DATE: **September 18, 2014**

TO: Jennifer Phelps, Jennifer Meissner, Judeen Byrne, Evan Crahen, Eric Meinl

FROM: Jacque Phelon, Sue Haselhorst, Kathryn Parlin

RE: **Revised On-Site Data Collection Sample**

The purpose of this memo is to present revisions to the on-site data collection sample plan for the phase II evaluation of NYSERDA's EmPower program and National Fuel Gas Distribution Corporation's ("NFGDC") Low Income Usage Reduction Program ("LIURP"). As previously discussed, the purpose of the on-site data collection is to investigate the sources of savings differences between the application estimates of savings and the savings determined through billing analysis. Unlike a typical impact evaluation, the outcome will not be program savings realization rates, but rather an *explanation* of the realization rates.

This memo reflects discussions with NYSERDA and NFGDC during the week of August 25, 2014.

ORIGINAL ON-SITE SAMPLE

As described in the final sample memo dated 4/30/2014, the original sample was designed to balance competing needs for representation by PA, per site evaluation costs, and a focus on sites likely to reveal the sources of differences in savings.

The sample frame was somewhat constrained, particularly for NYSERDA sites. Sites were included in the initial sample frame if they met these criteria:

- Single-family homes – these constituted 95% of EmPower participants
- Valid pre- and post- billing data – used to determine actual savings at the meter
- High reported savings – the high saver participants (those sites with reported savings greater than 400 therms) represented a disproportionate share of the savings and provide more opportunities for discerning reasons for differences since substantially more work was done at these homes
- Achieved either high or low savings – extremes in performance as demonstrated by the billing savings to highlight differences driving savings (mid-savings sites were included in the NYSERDA selection because of the limited number of NYSERDA sites available)

- Geography – for cost efficiency, sites were clustered to minimize driving between visits

Ultimately, 220 sites were selected as primary and back-up sites from a sample frame of 305 sites meeting the criteria listed above. It was recognized that the sample quotas would require an aggressive recruitment rate of about 55% to achieve 120 completed on-sites.

STATUS OF SITE RECRUITING

Recruitment efforts through the past 12 weeks have included mailed introductory recruitment letters noting the incentive, repeated phone calls during the day and in the evening, and in a few cases, drop-in visits with a leave-behind letter. The team also scheduled weekend and evening site visits at the convenience of the participants. While the recruiters were very successful when calls were answered, about a quarter of the phone numbers were disconnected.

At this time, the initial sample (primary and back-up sites) has been exhausted and at least two contact attempts have been made to all customers to include the advance letter mailing and one or more call attempts (based on the connection status of the phone number on file). Table 1 illustrates the current sample disposition as was initially described in the 4/30/2014 final sample memo. The highlighted cells indicate that the primary and back-up sites constitute the entire population in that stratum and there are no further sites in the sample frame to draw upon.

Table 1. Sample Disposition as of September 18, 2014

Stratum[1]	Site Quota		Completed and Scheduled	
	NYSERDA	NFG	NYSERDA	NFG
1				
High savers	3	10	1	7
Medium savers	3	N/A	3	N/A
Low savers	8	20	7	16
2				
High savers	12	10	6	11
Medium savers	9	N/A	10	N/A
Low savers	25	20	15	22
Total	**60**	**60**	42	56

[1] The three highest savings strata were collapsed into two segments of equal savings size to simplify the design.

After the final recruitment efforts, the team completed visits at ninety-eight sites, short of the goal of completing 120 site visits.

DISCUSSION OF OPTIONS

At this juncture, the team has two options:

1. Extend the sample selection to include additional sites. This approach will add about 6 weeks to the schedule for the additional data collection cycle.
2. Cease further data collection and commence with analysis with the sites in-hand, maintaining the current schedule with a final report delivered in December 2014.

The first option seeks to meet the original sample target of 120 sites by expanding the recruitment pool by about 90 sites in order to secure 22 additional completes. About 70 of the new recruits would come from the original sample frame; the 20 remaining would require expansion of the original sample frame to include more remote sites. While it may be possible to expand the recruitment pool to meet the overall quota of 120 sites, not all the quotas for individual cells (i.e., NYSERDA stratum 1, high savers) can be met because the population has been exhausted for some cells as shown by the highlights in Table 1.

Adding the 90 sites adds an additional data collection cycle (acquire project files, recruit, complete site visit), which will extend delivery of the draft final report to February 2015, about 6 weeks after the current schedule's due date.

In the second option, the Impact Evaluation Team will complete the recruitment of the current sample and commence analysis with no further expansion of the sample. At the conclusion of recruitment, the team completed 98 site visits. This approach allows the team to maintain the current schedule which projects a draft report in November, 2014.

CONCLUSIONS

After considering the options, NYSERDA, NFGDC, and the Impact Evaluation Team concluded that 98 sites should be sufficient for identifying factors that would substantially explain the realization rates determined in the last impact evaluation. While the sample quota will not be reached, the 98 sites represent a substantial data collection effort and a very rich dataset. Furthermore, there are no big gaps, as the sites are relatively well distributed across the proposed segments with reasonable representation of both administrators and of the high and low saver sites. Thus, there is no reason to expect that the added effort and time to attempt to meet the original sample quotas will be worth the effort.

As a course of action, the Impact Evaluation Team will complete the recruitment of the current sample and proceed immediately to the analysis phase of the plan with the intent of maintaining the current reporting schedule.